Education in a Technological Society

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# Table of Contents

Cover Page .................................................................................. 1  
Table of Contents ......................................................................... 2  
Chapter 1: Pre-Practicum ......................................................... 3-20  
Chapter 2: The Curriculum ....................................................... 21-23  
Chapter 3: Accumulation of Materials and Logistics ............... 24-145  
  3.1 AP Physics ............................................................................ 25-105  
    3.1.1 Exams ................................................................. 25-66  
    3.1.2 Homework .......................................................... 67-70  
    3.1.3 Quizzes ............................................................... 71-76  
    3.1.4 Reading .............................................................. 77-79  
    3.1.5 Practice Multiple Choice ................................. 80-87  
    3.1.6 Practice Open Response .................................. 88-98  
    3.1.7 Extra Credit ......................................................... 99-101  
    3.1.8 Labs ................................................................. 102-105  
  3.2 College Prep ......................................................................... 106-156  
    3.2.1 Exams ................................................................. 106-112  
    3.2.2 Homework .......................................................... 113-129  
    3.2.3 Quizzes ............................................................... 130-140  
    3.2.4 Reading .............................................................. 141-156  
Chapter 4: Course Material and Class Analysis ...................... 157-162  
Chapter 5: Assessments ........................................................... 163-167  
Chapter 6: Conclusion .............................................................. 168-170  
Chapter 7: Appendix ............................................................... 171  
    A1 MA State Frameworks ............................................. 172-179  
    A2 Additional Exams .................................................. 180-226  
    A3 Additional Homework ......................................... 227-274  
    A4 Additional Quizzes ............................................... 275-297  
    A5 Additional Reading ................................................ 298-415  
    A6 Additional Practice Multiple Choice .................... 416-427  
    A7 Additional Practice Open Response ...................... 428-456
Chapter 1: Technical Considerations

I: The Teaching Reform Act of 1993

On June 18th, 1993, the Massachusetts Education Reform Act was signed into law. The act, which consists of 105 sub-sections, created a generalized framework to be considered by all teachers as the standards of teaching, and the generalized cultural values that the United States wished to convey from generation to generation. It created a standardized testing system by which to judge the progress of students across the country, and set goals, expectations, and purposes for teachers and students alike. In addition, it set professional standards that teachers would be held to; ethical codes, laws of interaction, and improved the contemporary system of school management, and equity of funding. Until the MERA was set in place, the country had neither a distinct method of progressing the country’s education as a whole, nor any specific goals in education other than the basics of reading, writing, and communication.

The First Year, by means of the Act, 54 activities were undertaken by the Department of Elementary and Secondary Education and Executive Office of Education in order to begin the initiation of the Act. In addition, 59 advisory groups, task forces, and commissions were created in order to manage the considerable task set forth. The Massachusetts Common Core of Learning organized the participation of over 15,000 citizens in order to create a rubric and outline for what was felt necessary for all students to know and be able to accomplish upon graduation. The Common Core was also involved in the heightened standards for student performance that become graduation requirements in 1999.
The Act distributed over $360 million in new aid to schools by means of the Foundation Budget Program, and 282 schools received over $27 million in grants from the Health Protection Fund to support new comprehensive health programs. To this degree, a unified grant process was created to provide a means by which schools could access state and federal grants for a variety of purposes, under a number of circumstances. Most importantly, a new certification statute was enacted which created a framework for improved professional standards for instructors, in addition to the formation of school councils in every district to increase authority on the school-based level. By the end of the first year, the committees had formed an Implementation Plan and laid the 54 distinct activities originally decided upon out as a group of five Strategic Goals:

- Establish new standards and programs for students that ensure high achievement.
- Administer a fair and equitable system of school finance.
- Work with school districts to create a governance structure that encourages innovation and accountability.
- Enhance the quality and accountability of all educational personnel.
- Improve the Department of Elementary and Secondary Education’s capacity and effectiveness in implementing Education Reform.

As things progressed it became apparent that there simply weren’t enough resources or funding to provide equal attention to each of the 54 activities outlined originally, and thus the primary focus was directed towards the activities that would best suit the development of the standards which were then in question. The remaining activities would be placed aside for the time being, and returned to attention when the standards had been better formed.
During the second year of the Act’s instatement, the task forces set out to enforce the new learning standards encountered several difficulties. The challenge still remained to make the Common Core of Learning a more public figure, which was eventually resolved by translating the C.C.o.L into the curriculum frameworks that are more familiar today, with the content standards laid on for each subject area in accordance to grade levels. Still to be distributed for 1995-1996 was the new system of student assessment and accountability, as well as the new professional standards and guidelines for teaching and administration that would allow districts to lay a guideline for their teachers. Additionally, a plan had been formed to develop interim indicators of school performance so that the parents, local communities, and state could begin to determine how well schools were incorporating the objective standards. One of the major goals of the Act was to allow the community to become more involved in the educational development of their children by checking in with progress reports.

There were obviously still many complications while the Act was being enforced, as were to be expected by the instatement of such a large, unifying document. In the second year, the five Strategic Goals set forth by the Implementation Plan were beginning to be addressed, as the focus of the implementation was being directed towards an outreach program that would encompass any demographic of students that had been overlooked. In the First Annual Implementation Report, the five goals were analyzed one by one.

II: The First Annual Implementation Report:

Goal I.

Establish new standards and programs for students that ensure high achievement.
While the entire purpose of the Act was to improve the efficiency of education by means of certain standards, it was important to keep a close eye on the degree to which the program had managed to focus directly on the students, and less on the technical aspects of the program. One of the most important features of the Act is the implementation of statewide student standards, which recognize the Common Core, curriculum frameworks and student standards, statewide student assessments, and performance standards and graduation requirements, as the key components. During the 1993 meeting in April, the Board of Education defined the Common Core by the declaration that,

“…the Common Core of Learning refers to the broad set of educational goals which indicate what students should know and be able to do at the end of schooling; in essence they reflect what citizens highly value and see as essential for success in our democratic society."

The Board felt that there could be no method more efficient in determining the cultural values of education than by means of direct solicitation of comments, suggestions, and concerns from the citizens themselves. Thus, through televised advertisements, open forums, tens of thousands of brochures handed out statewide and across all districts, letters sent in, and direct meetings with the Commonwealth, common themes began to emerge. While many concerns were vague and open to interpretation, the communities seemed concerned that their children would be adequately prepared for the challenges that they would face later in life, that the educational system was not adapting to consider recent changes in the workplace and at home for the state. However, above all, it seemed that the Commonwealth wished to encompass these concerns, and many others, in the pursuit of higher educational standards.
After culminating their research, and after countless interactions with Commonwealth and general community, a first draft of the Common Core was released, and after a second round of interviews, letters, forums and meetings, a second draft which more clearly stated the academic expectations. On July 14th, a third and final draft was presented to the Board of Education, and finally approved.

The Common Core had now set the stage for what was needed in education, and the curriculum frameworks could now categorize this for convenience, as it was, into seven categories: mathematics, science and technology, history and social sciences, English, the arts, foreign languages, and health. The same process as the Common Core convened committees to address the development of each of the seven areas, this time calling upon the expertise of the instructors, the Commonwealth, and other professional educational practitioners. Final drafts of the frameworks were presented to the Board of Education the following spring.

Since 1988, the Massachusetts Educational Assessment Program had been the standard for testing student progress, and it was done so bi-annually. Where the MEAP would provide results on a school and district-wide level, the Act called for results to be presented on an individual basis to better analyze students based on their demographics. The Act also called for a more comprehensive approach to analyzing student education, doing away with the primarily multiple-choice MEAP and incorporating portfolio evaluations and performance tasks as additional means of assessment. In a drastic contrast to the MEAP, the Act designed the standardized testing to be more inclusive for students with special needs or limited English, a quality that was previously absent in the MEAP. One additional quality of the testing suggested by the Act was that of cumulative understanding, ensuring that students would take the tests in the seven areas of interest for education only after they had encountered them, and never before.
The final way that the new assessment system varied from the MEAP involved the previously discussed goal of accountability for all students. By the rules set down by the Act, no student could receive a high school diploma certifying their graduation unless they had received a passing (satisfactory) score on their 10th grade assessment. This new consideration of high stakes in the school system placed a certain pressure on teachers to adhere to the curriculum frameworks, while pushing students into a new realm of accountability in their work.

Special education, bilingual education, and early childhood education, adult basic education and other programs that would reach out to previously excluded segments of the learning population were beginning to take shape as well, allowing those that had been left behind to now rise to meet the expectations and goals of the Common Core. In addition, vocational educators and employers alike were convened to focus on the need for statewide job training, while doing away with the general track that had placed students in a difficult system that was neither college-bound nor vocationally based. Lastly, with an entirely new set of expectations placed on the educational system, more time was deemed necessary in order to address all of it. The duration of the school year was increased, as were the length of the school days, in order to accommodate the new considerations.

Goal II.

Administer a fair and equitable system of school finance.

The concept of the second goal was simple: without books, the students cannot read. Without pencils, they cannot write. While the provision of materials and resources by no means guarantees the success of a school, the lack thereof will certainly guarantee its failure. By means of stable, equitable, and adequate financial support, the Board of Education sought to aid schools
in their pursuit of excellence with this promise. On June 18th, 1993, when the Governor signed the Act into law, he promised on behalf of himself and the Legislature that schools would receive adequate financial support. Just days before, the Supreme Court had ruled that the state was constitutionally bound to “cherish its school” in the *McDuffy vs. Robertson* case, thus bringing the Commonwealth into a great position to create the desired system of support, which was accomplished by means of two sets of standards.

The first set of standards sought to define what constituted an adequate budget. The original formula was based primarily on assumptions that placed a need for a certain number of faculty per certain number of students, as well as additional requirements for special needs students. In the first year, 248 schools met what was called the *foundation gap*, the difference between what the schools were spending and the newly defined standards of adequacy. In order to address this issue, the Legislature set a standard of equity that would prevent unfair taxing of property owners in order to fund the school, promising to make up the difference. A funding schedule, and five year financial projection for most schools was developed, allowing school ample foresight into their projected budget, and time to adjust for the necessary provisions, thus addressing the issue of stability.

Unfortunately this large financial change carried its own set of burdens in its initial implementations. Many issues of interpretation regarding the districts budgets in the summer and fall were compounded by conflicting understandings of how the budgets would be implemented. The Department of Elementary and Secondary Education, along with the Board of Education, did their best to help clear up these misinterpretations, and by December many of the issues had been resolved.
As the Supreme Court had already ruled (prior to the Act) that equal education was a burden of the state, and not local communities, the Act had no bearing on the parent’s choice to send their students to schools outside of the district they lived in; that right was already in place. However, the Act expanded on this topic. Where the 1991 school choice statute required poorer districts to pay the full tuition charged by the receiving district, the Act capped the amount that could be charged, and even reimbursed schools that spent below the foundation budget level. Secondarily, by means of the Act, all schools were now assumed to take part in this program unless the explicitly voted to opt out, making the options to students much more wide-reaching.

The final consideration of the second Strategic Goal deals with Early Childhood Education and Adult Education. The contemporary statute of education in these areas only covers those students above the age of five and below the age of twenty-one, which limits a certain demographic. The Act considers the costs of expanding these age limits in both directions, and the fact that the National Adult Literacy Survey determined that, “…over 50% of our adult population lacks the basic skills they need to be partners in their children's education and successful contributors to the economy.”

The Act continues to make a case for the expansion, citing that a mere 2% of the adult population in need would be covered by the contemporary standards, and thus suggests that the expansions be made in order to consider the greater goals of the Act, which is to reach the smaller, more neglected segments of student groups.

**Goal III.**
Work with schools districts to create a governance structure that encourages innovation and accountability.

The purpose of the third goal was simply to draw accountability from a state-based model, to a more school-based system in which the principals and superintendents could have more authority over their facilities. By means of the Act, principals were now effectively the employers of their own individual schools, with the power to hire, evaluate, and dismiss faculty. They were also granted the power to make purchasing and curriculum decisions, buffered by a mandatory school council of which they were considered co-chair with the parental community, teacher’s union, and secondarily, students. The councils found themselves to be paper-tigers, only being allows to make advisory decisions, but with the aid and training resources for principals provided by the Department of Elementary and Secondary Education, principals were at least well equipped to hear what the councils had to say.

Charter schools were also initialized by Act, giving the Secretary of Education authority to charter twenty-five schools to operate independently in the pursuit of experimental or alternative forms of learning, free from the state constraints. Additionally, during this time of transfers of accountability, factors like drop-out rates and attendance became issues that were granted attention in the considerations for school’s success rate with students. The Board of Education felt this a necessary factor to keep track of for the state, who was paying the school, and the parents, who placed their children there.

The considerations of accountability were far more wide reaching in the Act than in previous systems, reaching even as far as the principal. The Act placed both state and local responsibility on the educational system, permitting the Commissioner to take necessary steps in
school systems deemed “chronically underperforming”, including the replacement of the principal. In order to allow the responsibility of the quality of their student’s education to be transferred to parents and students as well, frequent statistics on school performances were published in order to make the community well-aware of how the schools were holding up against the new standards.

Goal IV.

Enhance the quality and accountability of all educational personnel.

In order to do what is necessary to best teach the student, schools much make sure that their professional staff are up to the task. Just as the Act placed expectations on the students and parents, it would also place expectations on the administrative and educational personnel. By means of the Act, faculty would have to demonstrate both their knowledge of the content they intended to teach, as well as their ability to communicate it effectively. This was accomplished by requiring that all new teachers or administrators to first receive provisional certification before they went on to acquire full certification. The provisional certification would primarily test the educator’s knowledge of the content, and they would then have five years following this certification to complete their professional training and obtain full certification. Since content knowledge would be assumed at this stage, this final piece tests administrative skills.

Additionally, following certification and all interim stages to keep close tabs on the educators, instructors would also be required to undergo recertification in order to demonstrate consistent skill in their field. Every five years an instructor must submit to their supervisor appropriate documentation showing that they have successfully completed an individual development plan, consisting of at least 120 point/hours of professional development activities.
for the educator’s primary area of certification, and an additional 30 point/hours for each additional certification. In this way the faculty is kept fresh, consistent, and skilled in their respective fields, ensuring that students are learning from educators who are familiar with what they are teaching.

One of the primary focuses of the fourth Strategic Goal is to provide appropriate authority to the district in employment decisions regarding its personnel, in accordance with one of the basic assumptions of the Act, which is the enhancement of professional standards and performance. Like the student standards under the Act, professional standards are an additional provision to ensure that the faculty of any given school is kept at a certain level of excellence and performance in terms of serving the students’ best interests. The standards set forward by the Act bear this in mind when addressing the need for elevated professional performance.

The final consideration of the fourth Strategic Goal is that of Professional Development, and this undertaking is a large one. To students, the Act is a new system of learning to best suit their needs, whereas to administrators, the Act is a new way of running their school. To educators, the Act presents the unique challenge of teaching to a certain set of necessities, under the ever-changing definition of the word “necessary”. Thus, instructors were instructed to begin ongoing Individual Professional Development Plans, focusing on the discovery, development and evolution of school-based activities aimed primarily on the improvement and efficiency of the way students learn and approach material. This, of course, is a terribly vague description of how to go about things, and thus school councils were encouraged to develop guidelines along which teachers should develop their plans, a total development plan, to build into their School Improvement Plan. This plan would then be built into a District Improvement Plan, which would then be built into a District Improvement Plan to determine how the state can best serve every
school. Of course, the Act emphasizes that regardless of the support provided, the major financial responsibility still lies on the district level.

**Goal V.**

**Improve the Department of Elementary and Secondary Education's capacity and effectiveness in implementing Education Reform.**

The fifth Strategic Goal can almost be looked at as the culmination of all the adaptations the Act must make to itself, as it stresses self-improvement once the first four are in effect. In the Acts initial instatement, the Department of Elementary and Secondary Education had to learn the Act even as districts were looking to them to explain it. As such, the Department took a bottom-up approach, developing their Implementation Plan from scratch using the census material gathered during their research and forums. Once the plan was in effect, schools, Legislature, the Governor, and the public could safely hold the Department accountable for their end of the deal. Due to the large involvement of education reform being accomplished in the classroom and building level, the Department had to make sure that the state-wide standards were being enforced. Thus, a conscious effort was made to involve the teachers, parents, community leaders, and students in the process, and as time went on the effort was made to include more of each per year. The Department felt that the act of participation was of the utmost importance in developing the standards that all would learn by.

In dealing with the new influx of teachers, administration, and other concerned individuals during this time of change, the Department adopted a customer-service orientation of response, doing their best to ensure timely responses for all questions and concerns, and took the necessary measures of increasing their own personnel in order to handle it. In developing relationships with
other state agencies and key stakeholders, the Department sought to better the accuracy of the common themes suggested for standardized education, while looking for opportunities for cooperation between agencies that could benefit the Act’s enforcement and development.

In final consideration of the introduction of technology into the educational system, the Mass Ed Online oversaw a yearlong research project that looked to link together all the schools together by means of a wide area network, on a statewide level. At the time of its consideration, funding was still being pursued to continue this research, and has since been successful in connecting all the schools to a common network.

**Conclusion of the Education Reform Act of 1993**

With the Act in place, and its Strategic Goals analyzed under the considerations of its first year of implementation, it is now worth considering a specific case, which will be the focus of this project. From a distance, the Act and its Implementation Plan seem to offer a vague outline of how to pursue education, and it is thus instructive to examine its true implementation in a real life case. It is also of interest to examine how the Education Reform Act has held up in the seventeen years that have passed since its enactment. We now look to a local public high school as our focus group.
III: Doherty Memorial High School

Doherty At A Glance

Doherty Memorial High School is a public high school located at 299 Highland St., in Worcester, Massachusetts. It is one of four public high schools in the area and serves the largest district, the west area. It first opened its doors in the fall of 1966, replacing two closing schools in the process: Worcester Classical High School and Worcester Commerce High School. The high school has remained public for the entirety of its existence, and for the past 20 years has averaged approximately 1600 students per year, primarily due to its location near the downtown Worcester area.

2010 Statistical Breakdown

Students

In the 2009-2010 year, Doherty Memorial High School has a total attendance of 1,398, with 376 in grade 9, 321 in grade 10, 333 in grade 11, and 368 in grade 12. The student demographic is predominantly White and Hispanic, with the student population being comprised of 47.4% White, 26.3% Hispanic, 14.7% African American, 9.5% Asian, 1.6% Multi-racial/Non-Hispanic, 0.6% Native American, and 0.0% Native Hawaiian. Of these racial statistics, it may be considered noteworthy that the White student population is approximately 20% lower than the state average for White students in public high schools (but 10% higher than the district average), as well as the Hispanic student population being just under twice the state average.
The African American student population is only slightly higher than the state average, at approximately 6% above the norm, and a mere 1% above the district average. The male to female ratio is almost 1:1.

Doherty has a 4.2% dropout rate, comparable to 5.1% for the district but worrisome compared to the 2.9% state average. Their attendance rate is also below the averages, at 91%, below approximately 94% for both state and district averages. Of the additional Indicators, Doherty also has In- and Out-of-School suspension rates well above both the district and state averages (between 7% and 10% above the norm), and a Truancy rate of a disturbing 36%, 6% above the district average and 34% above the state average.

In the field of technology (as promised by the Strategic Goals of the Implementation Plan), there are about 3.8 students per modern (functioning) computer, and 100% of the classrooms have access to the Internet. An impressive 89% of students enrolled have plans to attend some form of higher education following graduation, comparable to the 81% district average and the 90% state average. In the 2008-2009 academic year, of the 372 grade 12 students (324 in the Cohort), the 4-year Adjusted Cohort Graduation rate was 84.9%, with a 9% dropout rate. Of this number, 82.1% of the male student population graduated, and 87.2% of the female population graduated.

Of the racial and special considerations breakdown for graduation rates, the lowest graduated rates were with the Special Education and Hispanic groups, with 63% and 66%, respectively, and drop-out rates of 24.7% and 21.5%, respectively. The remaining statistics can be examined by means of the attached charts, provided by the website for the Massachusetts Department of Elementary and Secondary Education.
Teachers

Of the 90 instructors who teach within Doherty’s walls, 98% of them are licensed in Teaching Assignment, and 95% of the 423 total core classes taught in the primary academics areas are taught by teachings who are highly qualified. While the number of licensed teachers falls within the district average (both of which are above the stage average), the number of highly qualified teachers in the core academic areas is slightly under the district average of 98%. The student to teacher ratio is approximately 13.6:1, which is just about the average for the state and district.

In consideration of a racial breakdown, the entire staff is considered, not just instructors. Of the 51 male teachers and 72 female teachers, 101 are White, 11 are Hispanic, 7 African America, 1 Asian (of the 32 in the district), 1 Native American (of the 2 in the district), and 2 Non-Hispanic/Multi-racial. While the staff is predominantly (incredibly so) White, the diversity of the school is considerable when examining the number of teachers of each race as a percentage of the total number of their race in the district.

The teachers cover all ranges of ages, from the 5 under 26, to the 4 over 64, with the most common age group being between 41-48, with 32 staff in this age range. Of the 90 teachers, 4 of them teach multiple grades, 2 teach all grades (the gym teachers), and the rest teach in respective grade levels. The school also houses 1 English Language Learner instructor, 2 for vocational instruction, and 11 for special education, with the rest teaching in the field of general education.

Assessment

DMHS takes part each year in the Massachusetts Comprehensive Assessment System, set forth by the Education Reform Act of 1993. For the 2009 MCAS grade 10 assessment, in the
field of English and Language Arts, 20% of the student population scored in the Advanced range, a full 9% below the state average, while 55% scored Proficient, 20% received “Needs Improvement” marks, and 5% were in the Failure range, all within 3%-5% of the state average. In Mathematics an impressive 43% scored Advanced, only 4% below the state average, where 23% scored Proficient, 20% NI, and a 14% failure rate, 6% above the state average in this range.

Science and Technology (which includes Biology, Chemistry, Physics, and Technology/Engineering) received the lowest marks of the three subject areas tested, with only 8% scoring Advanced, where the state average was 16%. From there, 37% received Proficient marks (45% state average), 45% Needs Improvement (29% state average), and 10% Failure (9% state average). It is noteworthy, in light of these disappointing figures, to see that since 2006, the percentage of students scoring in the Advanced and Proficient range in English and Language Arts has increased 19%, 16% in Mathematics, and 12% in Science and Technology, with a definite upward trend in average scores. The Student Growth Report (attached) also shows an upward trend towards higher growth and higher achievement, which suggests that the improvement rate is accelerating.

If we examine the Science and Technology MCAS results more closely (as my focus is in this field), there are some interesting trends to be considered. Of those that scored Advanced in Biology, there were no racial distributions other than White (7%) and Asian(11%), although it is worth mentioning that 2% of that group was in the Low-Income demographic. Chemistry data was unavailable for the Doherty district in 2009, but on the state level, the highest scoring percentage of racial groups in the Advanced and Proficient range were again White (48%, cumulatively) and Asian (68% cumulatively), with the Low-Income group making up a mere 14% of this range of scores. I feel it necessary to mention that I am including a focus specifically
on the Low-Income range of scores simply because it is a noticeable, well-documented and interested trend that has frequent repercussions in how educators address certain demographic groups.

The same trends follow through in the Introductory Physics and Technology/Engineering results, but with explicit focus on Introductory Physics, the numbers are considerably lower in the Advanced range. Of those students in Low-Income homes, a full one-third of them received failing marks on the Physics MCAS, with a racial breakdown showing that 35% of African Americans, 36% of Hispanic/Latinos, and 18% of Native Americans received Failure marks, compared to the 8% of Asians and 8% of Whites. There seems to be no major trend in gender performance, but 23% of those in homes considered Non-Low-Income scored Advanced, compared to 4% of those in Low-Income homes.

There are definitive trends in the racial breakdown of the MCAS performance which may be attributable to either being in low-income homes or some other socio-economic phenomenon, although the number of White students in the higher levels (ranked AP, Honors, College 1, College 2) greatly outweigh those in lower levels, and the opposite prevails for African Americans and Hispanics. In educational theory, all students can learn given the opportunity and motivation, which thus suggests that at some point a falling out in the execution of this mantra has occurred. It is with these statistics, and a better understanding of what the Reform Act of 1993 sought to accomplish, that I step inside Doherty Memorial High School to begin observation, to better my understanding of the ethics, technical aspects, and general execution of teaching.
Chapter 2: Curriculum

The physics curriculum taught at Doherty Memorial High School closely follows the MA State Frameworks, with little variation. The Frameworks are a demanding guideline, with a large number of standards to cover in a relatively short time, so I carefully approached the class with a tentative schedule. By splitting the full school year into sections reflecting the percentage of the AP exam that each subject would span, an accurate picture of a class pace could be obtained, and was thus structured. The AP class in particular follows it as closely as possible, as is necessary to ensure that the students are prepared for the exam that follows the class in May. I was fortunate enough to be handed control of the two classes that I taught, which were AP and College level, respectively, at the very start of the year, so we began with Significant Figures and worked our way up.

The expectations from the Massachusetts State Frameworks are vast (see Appendix A1, pages 128-133), and expect nothing from students in terms of pre-requisites, other than a basic knowledge of mathematics no greater than trigonometry and simultaneous equation solving. Thus, students in every class, of every level, are taught Significant Figures (the degree to which a scientist’s level of accuracy is relevant and practical), Scientific Notation (using powers of ten to represent large and small numbers), and the Metric System (International Units) before moving on to actual physical principles.

2.1 Kinematics
Once the groundwork was laid to begin studies in physics, we started with One-Dimensional Kinematics: the three big equations of motion:

\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]  
(Equation 1)

\[ v = v_0 + at \]  
(Equation 2)

\[ v^2 = v_0^2 + 2ad \]  
(Equation 3)

These stress the importance of the relationships and differences between scalars and vectors, displacement and position, speed and velocity, and acceleration. The AP students then moved on to Two-Dimensional Motion, resolving vectors into components using basic trig functions, summation over singular directions, and combining “net” variables into a resolved, single vector with one direction and magnitude using Pythagorean Theorem. In the College level class, it was more judicious to skip two-dimensional motion to keep the correct pace of the class for the year, and they moved on to Forces. This entailed Newton’s Three Laws of Motion, the mathematical formula for a force, and a tutorial on breaking forces down into components. The AP class followed suit with this after 2D motion, delving a bit more into 2D Forces as they had with kinematics. Both classes were introduced to the concept of friction, but it was much more prominent in the higher-level class.

2.2 Energy

Energy was the natural progression from forces, offering an alternative method of solving kinematics problems without worrying about the paths the objects took. Both classes were introduced to Kinetic, Gravitational Potential, and Spring Potential Energy and a variety of
problems in which they could be intertwined. Concepts of Conservation of Energy and the Work Energy Theorem were introduced, as well as their immediate implications in solving problems. From here, both classes were introduced to momentum, one more than the other. Both classes were shown the three types of collisions: elastic, inelastic, and perfectly inelastic, and of course the Conservation of Momentum equation, but the AP class was given work that tested knowledge of the energy implications of each collision. Any collision other than elastic would never conserve kinetic energy in the collision, so students in the AP class were asked to identify what type of collision had occurred based on whether energy was conserved or not.

2.3 Heat and Fluid Flow [Respectively]

Beyond Kinematics, which entails motion, forces, energy and momentum, the AP class then began working with fluid-flow, while the college class moved onto heat. Please keep in mind that these two classes were moving at drastically different speeds, and by the time the College level class reached heat, I had finished my time teaching. Thus, the remainder of the curriculum mentioned here is solely for the AP class. The students were shown concepts of “conservation” within an ideal fluid system using Bernoulli’s equations, and fluid rate flow conservation. In reality there were only two major equations in this section, but it presented a great challenge for the students, as each element of the equations could be obtained from a variety of places within the system they were looking at; the responsibility fell on the student to choose a convenient reference frame to help them solve the problem.
Chapter 3: Accumulation of Materials
AP Physics Exams
Part 1: Multiple Choice – Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box in the table labeled “Part 1 Answers” at the end of this section.

Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

An object is thrown with a horizontal velocity of 20 m/s from a cliff that is 125 m above level ground. If air resistance is negligible, the time that it takes the object to fall to the ground from the cliff is most nearly

- a. 3 sec
- b. 5 sec
- c. 6 sec
- d. 12 sec
- e. 25 sec

Questions 2 – 5 refer to the following diagram and caption:

A ball is thrown straight up by a student at rest on the surface of the Earth. A graph of the position $y$ as a function of time $t$, in seconds, is shown to the left. Air resistance is negligible.

Questions 2 – 5:

At which of the following times is the ball farthest from the student?

- a. 1 sec
- b. 2 sec
- c. 3 sec
- d. 4 sec
- e. 5 sec

At which of the following times is the speed of the ball the least?

- a. 1 sec
- b. 2 sec
- c. 3 sec
- d. 4 sec
- e. 5 sec

Which of the following best describes the acceleration of the ball?

- a. It is downward and constant from 0 to 6 s.
- b. It is downward and increases in magnitude from 0 to 3 s, then decreases.
- c. It is downward and decreased in magnitude from 0 to 3 s, then increases.
- d. It is upward and increases in magnitude from 0 to 3 s, then decreases.
- e. It is upward and decreased in magnitude from 0 to 3 s, then increases.

What is the initial speed of the ball?

- a. 30 m/s
- b. 45 m/s
- c. 60 m/s
- d. 90 m/s
- e. 180 m/s
A displacement vector is a
Change in position.
Velocity.
Scalar.
Distance without direction.
Dimensionless quantity.

Three stones of different masses (1m, 2m, and 3m) are thrown vertically upward with different velocities (1v, 2v, and 3v respectively). Rank from high to low the maximum height of each stone. Assume air resistance is negligible.
(high) 1, 2, 3 (low)
(high) 2, 1, 3 (low)
(high) 3, 2, 1 (low)
(high) 1, 3, 2 (low)

All stones reach the same height

An object is released from rest on a newly discovered planet. After 2 seconds, the object has moved 4 meters. What is the acceleration due to gravity on this planet?
a. 16 m/s²  
b. 10 m/s²  
c. 8 m/s²  
d. 4 m/s²  
e. 2 m/s²

When an object falls freely in a vacuum near the surface of the Earth
the velocity cannot exceed 10 m/s²
the terminal velocity will be greater than when dropped in air
the velocity will increase but the acceleration will be zero
the acceleration will constantly increase
the acceleration will remain constant

A ball is rolled off the edge of a horizontal table. The ball has an initial speed \( v_0 \) and lands on the floor some distance from the base of the table. Which of the following statements concerning the fall of the ball is FALSE?
The time of flight depends on the height of the table.
One of the components of the final speed will be \( v_0 \).
The ball will accelerate.
The ball will have a longer flight time if \( v_0 \) is increased.
The ball will fall due to the force due to gravity.

Two objects are launched off a cliff. The first object, a large car, has an initial horizontal velocity of 20 m/s. The second object, a tennis ball, rolls horizontally off the cliff at 5 m/s. Which of the following statements is TRUE?
a. The car will travel through the air for a longer period of time than the ball.
b. The ball will travel through the air for a longer period of time than the car.
c. The car will have a larger acceleration due to its larger mass.
d. The ball will hit the ground with the same vertical speed as the car.
e. The ball has a greater net velocity than the car when it collides with the ground.

The motion of a particle along a straight line is represented by the position versus time graph above. At which of the labeled points on the graph is the magnitude of the acceleration of the particle greatest?

The maximum resultant of a 20 m displacement and a 4 m displacement is
5 m                 b. 16 m                c. 20 m                  d. 24 m            e. 80 m

The following variables are listed with their units.

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<td>a</td>
<td>meters/second²</td>
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Which of the following equations is NOT dimensionally correct?
a. $x = vt + \frac{1}{2}at^2$                  b. $F/t = mav$                     c. $a = F/m$                    d. $v^2 = ax$               e. $t = x/v$

A person of mass $m$ falls from a bridge spanning a rushing river, falling a distance $h$ before hitting the water. Neglecting air resistance, what would be the person’s speed at the moment of impact?
a. $v = \sqrt{2gh}$                             b. $v = \sqrt{mgh}$                 c. $v = \sqrt{gh/2}$                  d. $v = \sqrt{mgh/2}$                  e. $v = \sqrt{2mgh}$
Part 1 Answers: Be sure to write clearly and in the correct, corresponding box. (3 points each = 45 points)

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Part 2: Open Response Questions – Answer all three questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for each question. The parts within a question may not have equal weight. Show all of your work in the area provided after each part. Use \( g = 9.8 \text{ m/s}^2 \) in all parts.

An arrow is shot from a castle wall 10 m high. It leaves the bow with a speed of 40 m/s directed 37° above the horizontal.

Find the initial velocity components.

Find the maximum height of the arrow.
If the ground is level, what is the range of the arrow?

How fast is the arrow moving just before impact?

(20 points)
A football is thrown to a moving football player. The football leaves the quarterback’s hands 1.5 m above the ground with a speed of 15 m/s at an angle of 25 degrees above the horizontal. If the receiver starts 10 m away from the quarterback along the line of flight of the ball when it is thrown, what constant velocity must he have to get to the ball at the instant it is 1.5 m above the ground?
A person is stuck inside a falling elevator, whose cable broke 10 meters above the ground. Let’s say the person wanted to cancel out their final velocity by jumping exactly when the elevator hits bottom. Assume the elevator started from rest. How long after the cable breaks would the person need to jump?

In order to completely cancel the accumulated velocity, at which velocity (relative to the elevator) would he need to jump?
If they were to jump at this velocity on stable ground, how high would they go? Is this reasonable?

Sketch a graph of the elevator’s position vs. time, velocity vs. time, and acceleration vs. time. Your graphs should reflect your choice of reference frame. Label the starting value of each dependent variable on each graph. Assume time to begin when the cable breaks and ends when the elevator just reaches the floor.

Sketches can go on the back.

(20 points)
Chapter 5-6: Test

Part 1: Multiple Choice Questions: Listed below are multiple choice questions from Chapters 1-6. For each, assume there is only one answer unless otherwise noted. List all answers in the section marked "Part 1 Answers." You do not need to show any work for this section. Good Luck!

A particle travels in a circular path of radius 0.2 m with a constant kinetic energy of 4 J. What is the net force on the particle?
   a. 4 N  b. 16 N  c. 20 N  d. 40 N  e. Cannot be determined from the information given.

Two satellites are in circular orbit around the earth. The distance from satellite 1 to the earth's center is \( r_1 \), and the distance from Satellite 2 to the earth's center is \( r_2 \). If the speed of Satellite 1 is \( v_1 \), what is the speed of Satellite 2? (hint – both have the same period of motion)
   a. \( v_1 \sqrt{\frac{r_1}{r_2}} \)  b. \( v_1 \sqrt{\frac{r_2}{r_1}} \)  c. \( v_1 \frac{r_2}{r_1} \)  d. \( v_1 \left( \frac{r_2}{r_1} \right)^2 \)  e. \( v_1 \frac{r_1}{r_2} \)

A spring of force (spring) constant 800 N/m is hung from a ceiling. A block of mass 4.0 kg is hung from its lower end and allowed to come to rest. How far will the block stretch the spring?
   a. 0.49 cm  b. 0.98 cm  c. 3.2 cm  d. 4.9 cm  e. 9.8 cm

A crane lifts a shipping crate that weighs 5000 N at a constant speed of 4 m/s. At what rate is this crane doing work on the crate?
   a. 1250 W  b. 2000 W  c. 4000 W  d. 10,000 W  e. 20,000 W

An astronaut lands on a planet whose mass and radius are each twice that of Earth. If the astronaut weighs 800 N on earth, how much will he weigh on this planet?
   a. 200 N  b. 400 N  c. 800 N  d. 1600 N  e. 3200 N

Questions 6-8 refer to this information:
A confused pigeon is flying in a circle with a radius of 5 meters, at a constant speed of 10 m/s. What is the equation for centripetal acceleration?
   a. \( v^2 r \)  b. \( r^2 \frac{v}{v} \)  c. \( r^2 v \)  d. \( \frac{v^2}{r} \)  e. \( \frac{v^2}{r^2} \)

What is the centripetal acceleration of the pigeon?
   a. 2 m/s\(^2\)  b. 15 m/s\(^2\)  c. 25 m/s\(^2\)  d. 20 m/s\(^2\)  e. Cannot be solved with the information given

What is the period of the pigeon's orbit?
   a. 3.14 s  b. 2 s  c. 12.56 s  d. 6.24 s  e. 6.28 s

A block is pushed along a frictionless surface for a distance of 2.5 meters. How much work has been done if a force of 10 Newtons applied to the block makes an angle of 60° with the horizontal?
   a. 10.5 J  b. 8.5 J  c. 6.5 J  d. 12.5 J  e. 25 J
A spring with a (force) spring constant $k$ is stretched a distance $x$. By what factor must the spring's elongation be changed so that the elastic potential energy in the spring is doubled?

a. $1/4$  
   b. $1/2$  
   c. $2$  
   d. $4$  
   e. $\sqrt{2}$

Which of the following is an expression for power?

a. $Ft/m$  
   b. $Fm/t$  
   c. $F^2m/t$  
   d. $Fm^2/t$  
   e. $F^2t/m$

Which of the following is an equivalent expression for the units of the spring constant $k$?

a. $kg \cdot m^2/s^2$  
   b. $kg \cdot m/s$  
   c. $kg \cdot s^2$  
   d. $kg/s^2$  
   e. $kg \cdot s/m$

A student weighing 700 N climbs at constant speed to the top of an 8 m vertical rope in 10 s. The average power expended by the student to overcome gravity is most nearly

a. $1.1$ W  
   b. $87.5$ W  
   c. $560$ W  
   d. $875$ W  
   e. $5,600$ W

A box with a 500 N mass inside goes over a hill that has a radius of 60 meters, as shown below. The velocity of the car is 20 m/s. what are the force and the direction that the car exerts on the driver?

- a. $840$ N, up
- b. $160$ N, up
- c. $160$ N, down
- d. $840$ N, down
- e. $500$ N, up

Questions 14-15 apply to the following diagram.

How much work was done to displace the mass 10 meters?

a. $40$ J  
   b. $38$ J  
   c. $32$ J  
   d. $30$ J  
   e. $26$ J

What was the average force supplied to the mass for the entire 10 meter displacement?

a. $3.2$ N  
   b. $1.2$ N  
   c. $4.4$ N  
   d. $4$ N  
   e. $2.6$ N
A child pushes horizontally on a box of mass \( m \), which moves with constant speed \( v \) across a horizontal floor. The coefficient of friction between the box and the floor is \( \mu \). At what rate does the child do work on the box?

a. \( \mu mgv \)  
b. \( mgv \)  
c. \( v/\mu mg \)  
d. \( \mu mg/\nu \)  
e. \( \mu mv^2 \)

Questions 20-21 apply to the following diagram.

A rock of mass \( m \) is thrown horizontally off a building from a height \( h \), as shown above. The speed of the rock as it leaves the throwers hand at the edge of the building is \( V \).

How much time does it take the rock to travel from the edge of the building to the ground?

a. \( \sqrt{hV} \)  
b. \( h/V \)  
c. \( hV/g \)  
d. \( 2h/g \)  
e. \( \sqrt{(2h/g)} \)

What is the kinetic energy of the rock just before it hits the ground?

a. \( mgh \)  
b. \( 0.5 mV^2 \)  
c. \( 0.5 mV^2 - mgh \)  
d. \( 0.5 mV^2 + mgh \)  
e. \( mgh - 0.5 mV^2 \)

Part 2: Open Response: Listed below are 4 questions. Answer all five. Each part within a question may not have equal weight. Show all your work, printing clearly and legibly. Include all units. Perform all calculations using 2-3 decimal places. Place a box around your final answer(s).

Consider the simple pendulum in the figure below. The ball is released from rest at point A.

What will the speed of the ball be as it passes through point B?
What will be the ball's speed at point C?

A 250 gram ball is suspended from a 75 cm cord from a fixed point. The ball swings in a horizontal circle at an angle of 40° between the cord and the vertical. (a) What is the tension in the cord. (b) What is the period of the ball's motion?
A block is initially at rest on an inclined plane at the equilibrium position that it would have if there were no friction between the block and the plane. How much work is required to move the block 10 cm down the plane (a) if the frictional coefficient is $\mu = 0$ and (b) if the frictional coefficient is $\mu = 0.17$?

A stone thrown downward with a speed of 15.7 m/s from a height of 12.7 m above the ground has a kinetic energy of 293 J when it is 1.29 m above the ground. What is the mass of the stone?
Circular Motion and Energy: Exam

Part 1: Multiple Choice. Listed below are several multiple choice questions covering the physical concepts of kinematics, forces, circular motion, and energy. Complete all problems. Put all answers to the multiple-choice questions in the section labeled “Part 1 Answers.” You do not need to show any work for this section. For the multiple-choice questions, you may assume \( g = 10 \text{ m/s}^2 \). Work hard!

The gravitational constant \( G \) is
- equal to \( g \) at the surface of the Earth
- different on the Moon than on Earth
- obtained by measuring the speed of falling objects having different masses
- none of the above

Two satellites A and B of the same mass are going around Earth in concentric orbits (circular orbits). The distance of satellite B from Earth’s center is twice that of satellite A. What is the ratio of the centripetal force acting on B to that acting on A?
- a. \( 1/8 \)
- b. \( 1/4 \)
- c. \( 1/2 \)
- d. \( \sqrt{(1/2)} \)
- e. 1

Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has
- As much kinetic energy as the lighter one.
- Twice as much kinetic energy as the lighter one.
- Half as much kinetic energy as the lighter one.
- Four times as much kinetic energy as the lighter one.
- Impossible to determine

A block initially at rest is allowed to slide down a frictionless ramp and attains a speed \( v \) at the bottom. To achieve a speed \( 2v \) at the bottom, how many times as high must a new ramp be?
- a. 1
- b. 2
- c. 3
- d. 4
- e. 5
- f. 6

A mass is hung vertically from a spring and allowed to come to rest. If the spring stretches 0.05 m, the value of the spring constant is most nearly
- a. 2.5 N/m
- b. 5 N/m
- c. 25 N/m
- d. 50 N/m
- e. 0.5 N/m

A ball is thrown with a kinetic energy of 200 Joules. If the ball’s mass is doubled with the same speed, then the new kinetic energy of the ball is
800 J because the factor of 2 will be squared in the kinetic energy formula.
400 J because the mass is doubled.
200 J because mass is irrelevant when calculating kinetic energy.
100 J because if the mass is doubled, it is harder for it to move through the air.

A 4 kg mass initially moving at 10 m/s at the bottom of a 5 m long 37° incline barely makes it to the top before coming to rest. The magnitude of the work done by friction is most nearly
a. 320 J    b. 200 J    c. 120 J    d. 80 J    e. 0 J

Which of the following statements is true?
As a car travels along a highway, its kinetic energy must increase.
When a ball falls through the air, its kinetic energy will increase only if friction is not acting on the ball.
As a box slides down a hill, its mechanical energy will decrease because its height is decreasing.
When a ball is kicked from the ground, its kinetic energy is conserved as it rises to a maximum height.

If friction acts on an object, which of the following is true?
The total mechanical energy will remain constant because heat is a type of energy.
If the object were falling, the object would have to stop shortly before hitting the ground because some energy is lost.
Friction cannot act, because total energy is always conserved.
The total mechanical energy would decrease as the object moved from one point to another.

Questions 10 – 12 refer to a ball of mass m on a string of length R, swinging around in circular motion, with an instantaneous velocity v and centripetal acceleration a.

What is the centripetal acceleration of the ball if the length of the string is doubled?
a. a/4    b. a/2    c. a    d. 2a    e. 4a

What is the centripetal acceleration of the ball if the instantaneous velocity of the ball is doubled?
a. a/4    b. a/2    c. a    d. 2a    e. 4a

What is the centripetal acceleration of the ball if its mass is doubled?
a. a/4    b. a/2    c. a    d. 2a    e. 4a

If we consider the gravitational force F between two objects of masses m₁ and m₂ respectively, separated by a distance R, and we double the distance between the masses, what is the magnitude of the resulting gravitational force between them?
a. F/4    b. F/2    c. F    d. 2F    e. 4F

A ball of mass m drops off a tower of height h. The force of air resistance if F. What is the ball’s kinetic energy when it hits the ground?
Questions 15 – 16 refer to the following diagram, to the right, of a 1 kg mass suspended from a spring whose spring constant is $k = 4$ N/m. The system is in equilibrium when the center of mass is at point A.

If the mass is pulled from point A to point B, a distance of $x$ meters from A, what is the energy stored in the spring?

a. $-kx$  
b. $kx$  
c. $-\frac{1}{2}kx^2$  
d. $\frac{1}{2} kx^2$  
e. 0

At point B, what is the force exerted on the mass by the string, if we now assume that $x = 0.25$ m?

1 N, pointing down
1 N, pointing up
0.25 N, pointing down
0.25 N, pointing up
zero

A mass on a frictionless surface is attached to a spring, as shown to the right. The spring is compressed from its equilibrium position, B, to point A, a distance $x$ from B. Point C is also a distance $x$ from B, but in the opposite direction. When the mass is released and allowed to oscillate freely, at what point or points is its velocity maximized?
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Part 2: Open Response Question
Name __________

Each part within the question may not have the same weight. Be sure to show all relevant work. Use \( g = 9.8 \text{ m/s}^2 \). Be sure to circle your final answer(s). Work hard!

A 18 kg mass is hung from an ideal 1.5 m long string. The mass is spun in a horizontal circle at a constant speed. The string makes an angle of 25° with the vertical.
What is the speed of the mass?

What is the period of motion for the mass?

What would the new period be if the mass was doubled to 36 kg? Justify your answer.
If the angle is increased, does the tension in the string increase, decrease or stay the same? Justify your answer.

(15 points)
Part 2: Open Response Question

Each part within the question may not have the same weight. Be sure to show all relevant work. Use $g = 9.8 \text{ m/s}^2$. Be sure to circle your final answer(s). Work hard!

One end of a spring of spring constant $k$ is attached to a wall, and the other end of attached to a block of mass $M$, as shown above. The block is pulled to the right, stretching the spring from its equilibrium position, and is then held in place by a taut cord, the other end of which is attached to the opposite wall. The spring and cord have negligible mass, and the tension in the cord is $F_T$. Friction between the block and the surface is negligible. Express all algebraic answers in terms of $M$, $k$, $F_T$, and fundamental constants.

On the dot below that represents the block, draw and label a free-body diagram for the block.

Calculate the distance that the spring has been stretched from its equilibrium position.
The cord suddenly breaks so that the block initially moves to the left and then oscillates back and forth. Calculate the speed of the block when it has moved half the distance from its release point to its equilibrium position.

Suppose instead that friction is not negligible and that the coefficient of friction between the block and the surface is $\mu_k$. After the cord breaks, the block again initially moves to the left. Calculate the initial acceleration of the block just after the cord breaks.

(14 points)
Part 2: Open Response Question
Name

Each part within the question may not have the same weight. Be sure to show all relevant work. Use $g = 9.8$ m/s$^2$. Be sure to circle your final answer(s). Work hard!

A 0.8 kg ball hangs on the end of a 3.0 m cord. It is kicked by a child and rises, from its resting height, vertically 2.1 m, as shown below.

What is the maximum change in gravitational potential energy of the ball?
What was the ball’s velocity immediately after being hit?

What was the ball’s kinetic energy immediately after being hit?

If air resistance removes 20% of the mechanical energy of the system, what will be the new maximum height of the ball?

(11.5 points)
At 2 atmospheres of pressure, 100 cubic meters of an ideal gas at 50 degrees Celsius is heated until its pressure and absolute temperature are doubled. What is the new volume of the gas?

- a. 62 m$^3$
- b. 100 m$^3$
- c. 58 m$^3$
- d. 50 m$^3$
- e. 112 m$^3$

A metal rod is bent into the following shape shown above. If the metal is uniformly heated, the space between the ends will

- a. Increase
- b. Decrease
- c. Stay the same
- d. There is not enough information

Consider $n$ moles of an ideal gas. Which of the following properties of the gas is solely dependent on its temperature?

- I. pressure
- II. volume
- III. internal energy

- a. I only
- b. II only
- c. III only
- d. I, II and III
- e. None

The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?

- Pressure: Remains the same
- Density: Remains the same
- Pressure: Remains the same
- Density: Doubles
- Pressure: Doubles
- Density: Is multiplied by a factor of 4
- Pressure: Is multiplied by a factor of 4
- Density: Doubles

On a new world where $R = 0.25 \text{ L} \cdot \text{atm/mol} \cdot \text{K}$, an ideal monatomic gas at a temperature of 400 K occupies a volume of 2.5 liters at sea level. How many moles of the gas are there?

- a. 0.00625
- b. 0.025
- c. 2.5
- d. 6.25
- e. 12.5

When the Kelvin temperature of a gas is quadrupled, what will happen to the $v_{rms}$?

- The $v_{rms}$ is halved.
- The $v_{rms}$ is doubled.
- The $v_{rms}$ is quadrupled.
- The $v_{rms}$ is unchanged.

What is the absolute temperature of -73°C?

- a. 346 K
- b. 273 K
- c. 200 K
- d. 127 K
- e. 0 K
An ice cube is floating in water in thermal equilibrium. Heat is gradually added to the water without disturbing thermal equilibrium. Which of the following instantly occurs initially?

The ice temperature rises.
The water temperature rises.
Some of the ice melts.
Both (a) and (b) occur.
Options (a), (b), and (c) occur.

A cube at rest in a fluid floats so that ¾ of it is submerged. If \( \rho \) is the density of the fluid, then the density of the cube is

a. \( \rho \)   
b. \( 4\rho/3 \)   
c. \( 3\rho/4 \)   
d. \( \rho/4 \)   
e. \( \rho/3 \)

What will be the ratio \( (\Delta L_1/\Delta L_2) \) of thermal expansion between two identical objects whose temperature increases by 50°C (object 1) and decreases by 50°C (object 2)?

a. 1   
b. 0.5   
c. 0   
d. -0.5   
e. -1

A cylindrical pipe has a radius of 12 cm in one region where the fluid speed is 0.2 m/s. In another region, the pipe is narrower with a radius of 4 cm. The fluid speed in this region is most nearly

a. 9 m/s   
b. 1.8 m/s   
c. 0.6 m/s   
d. 0.011 m/s   
e. 0.067 m/s

An ideal fluid flows through a pipe that runs up an incline and gradually rises to a height \( H \). The cross sectional area of the pipe is uniform. Compared with the flow at the bottom of the incline, the flow at the top is

moving slower at lower pressure
moving slower at higher pressure
moving at the same speed at lower pressure
moving at the same speed at higher pressure
moving faster at lower pressure

For an ideal gas in a container with fixed volume and constant temperature, which of the following is true?

Pressure results from molecular collisions with the walls.
The molecules all have the same speed.
The average kinetic energy is directly proportional to the temperature.

a. I, II and III   
b. I and II only   
c. II and III only   
d. II only   
e. I and III only

Two identical containers contain 1 mole each of two different monatomic ideal gases, gas A and gas B, with the mass of gas B 4 times that of the mass of gas A. Both gases are at the same temperature. 10 J of heat is added to gas A, resulting in a temperature change of \( \Delta T \). How much heat must be added to gas B to cause the same \( \Delta T \)?

a. 2.5 J   
b. 10 J   
c. 40 J   
d. 100 J   
e. 1,600 J

Which of the following is equivalent to 1 Pascal of gas pressure?

a. 1 kg⋅m/s²   
b. 1 kg⋅m/s²   
c. 1 kg⋅m²/s²   
d. 1 kg⋅m/s²   
e. 1 kg⋅m²/s³

A change in temperature of 75°C is equivalent to a change in absolute temperature of_____.

a. 348 K   
b. 75 K   
c. 273 K   
d. 198 K   
e. 175 K
An ideal monatomic gas at a temperature of 400 K occupies a volume of 2.5 liters at sea level. How many moles of the gas are there?

a. 160  
b. 0.076  
c. 2.5  
d. 12.2  
e. 0.68

The temperature of a substance is a relative measure of the___.
average kinetic energy of its molecules.
arrangement of its molecules.
bonding between the molecules.
chemical identity of its molecules.

A change of phase takes place at a constant______.

a. pressure  
b. volume  
c. temperature  
d. heat  
e. none of these

The Sun's energy is transmitted to Earth by means of______.

a. conduction           
b. convection           
c. radiation           
d. all of these             
e. none of these

Which of the following statements is true concerning phase changes?
When a liquid freezes, it releases thermal energy into its immediate environment.  
When a solid melts, it releases thermal energy into its immediate environment.  
For most substances, the latent heat of fusion is greater than the latent heat of vaporization.  
As a solid melts, its temperature increases.  
As a liquid freezes, its temperature decreases.

When the Kelvin temperature of a gas is quadrupled, what will happen to the \( v_{\text{rms}} \)?

The \( v_{\text{rms}} \) is halved.
The \( v_{\text{rms}} \) is doubled.
The \( v_{\text{rms}} \) is quadrupled.
The \( v_{\text{rms}} \) is unchanged.

If a certain mass of a gas occupies a volume \( V \) at standard temperature and pressure, what will be the final volume if the temperature is halved and the pressure is doubled?

a. 0.5\( V \)  
b. 2\( V \)  
c. 0.25\( V \)  
d. 4\( V \)  
e. \( V \)

If a certain mass of a gas occupies a volume \( V \) at standard temperature and pressure, what will be the final volume if the temperature is halved and the pressure remains constant?

a. 0.5\( V \)  
b. 2\( V \)  
c. \( V \)  
d. we are not given enough information to calculate the final volume.

The experimental diving bell shown below is lowered from rest at the ocean’s surface and reaches a maximum depth of 80 m. Initially, it accelerates downward at a rate of 0.10 m/s\(^2\) until it reaches a speed of 2.0 m/s, which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross sectional area \( A = 9.0 \text{ m}^2 \). The density of seawater is 1025 kg/m\(^3\).
Calculate the total time it takes the bell to reach the maximum depth of 80 m.
Calculate the weight of the water on the top of the bell when it is at the maximum depth.
Calculate the absolute pressure on the top of the bell at the maximum depth.

On the top of the bell there is a circular hatch or door or radius \( r = 0.25 \) m.
Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.
What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

The cylinder below contains an ideal gas and has a movable, frictionless piston of diameter \( D \) and mass \( M \). the cylinder is in a room with atmospheric pressure \( P_{\text{atm}} \). Express all algebraic answers in terms of the given quantities and fundamental constants.

Initially, the piston is free to move, but remains at equilibrium. Determine each of the following.
the force that the confined gas exerts on the piston
the absolute pressure of the confined gas

If a net amount of heat is transferred to the confined gas when the piston is fixed in place, what happens to the pressure of the gas? I.e. does the pressure of the gas increase, decrease, or stay the same. Explain your reasoning.
In a certain process the absolute pressure of the confined gas remains constant as the piston moves up a distance \( x_0 \). Calculate the work done by the confined gas during the process.
Fluids, Thermal Physics and Gas Laws: Test

Part 1: Multiple Choice Questions: Listed below are multiple choice questions. For each, assume there is only one answer unless otherwise noted. List all answers in the section marked “Part 1 Answers.” You do not need to show any work for this section. Work hard!

An ideal gas is enclosed in a container which has a fixed volume. If the temperature of the gas is increased, which of the following will also increase?

- The pressure against the walls of the container.
- The average kinetic energy of the gas molecules.
- The number of moles of gas in the container.

I only
I and II only
II and III only
II only
III only

An ideal gas in a closed container initially has volume V, pressure P, and Kelvin temperature T. If the temperature is changed to 4T, which of the following pairs of pressure and volume is possible?

- P and V
- P and \( \frac{1}{2} V \)
- 4P and 4V
- 4P and V
- \( \frac{1}{4} P \) and V

In general, when a solid is heated, it
Expands proportionally to the change in temperature.
Contracts proportionally to the change in temperature.
Expands inversely proportionally to the change in temperature.
Contracts inversely proportionally to the change in temperature.
Does not expand nor contract.

A sphere is mass m and diameter d is immersed in a liquid of density \( \rho \). The buoyant force on the sphere is

\[ \rho \pi d^3 g/6 \]
\[ \rho \pi d^3 g/4 \]
\[ \rho \pi d^3 g/3 \]

The conversion of molecules to liquid from the vapor state is
Vaporization.
Melting.
Freezing.
Condensation.

An ideal fluid flows through a pipe that runs up an incline and gradually rises to a height H. The cross
sectional area of the pipe is uniform. Compared with the flow at the bottom of the incline, the flow at the top is
Moving slower at lower pressure.
Moving slower at higher pressure.
Moving at the same speed at lower pressure.
Moving at the same speed at higher pressure.
Moving faster at lower pressure.

The floor of a building is made from a square, solid piece of concrete. When the temperature of the floor increases from 20°C to 28°C, each side of the square expands by 0.4 cm. If the temperature of the floor were to decrease from 20°C to 8°C, by how much would each side of the square contract?

0.2 cm
0.4 cm
0.6 cm
1.0 cm
It cannot be determined without knowing the coefficient of linear expansion of the concrete.

Two identical containers hold different ideal gases, X and Y, at the same temperature. The number of moles of each gas is the same. The molecular mass of gas X is twice that of gas Y. The ratio of the pressure of X to that of Y is

\( \frac{1}{2} \)
1
\( \sqrt{2} \)
2
4

A body having a density of 300 kg/m\(^3\) is floating in a container of liquid of unknown density. If one-third of the volume of the body remains above the surface of the liquid, what is the density of the liquid?

200 kg/m\(^3\)
100 kg/m\(^3\)
400 kg/m\(^3\)
900 kg/m\(^3\)
450 kg/m\(^3\)

A balloon is filled with a gas having a density that is half that of the surrounding air. When the balloon is released from rest, what will be its acceleration? (Ignore the mass of the balloon material.)
g/2 upward
g/2 downward
2g upward
2g downward
g upward

The temperature of absolute zero is equal to

0°C
100°C
273°C
-273°C
-100°C

Heat is added to a block of ice initially at 0°C until the ice changes completely into water. The same amount of heat continues to be added to the liquid water for 15 minutes. Which of the following statements is true?
The temperature of the ice and water remains constant until the end of the 15 minute time period.
The temperature of the ice rises steadily until all of the ice has melted into water.
The temperature of the ice remains constant until all of the ice has melted into water, then the temperature of the water steadily rises for 15 minutes.
The temperature of the ice rises from 0°C to 32°C, then the temperature of the water rises from 32°C to 100°C.
The temperature of the ice remains at 0°C until the ice has melted, then the temperature of the water remains constant at 32°C.

Which of the following graphs best represents the relationship between the average kinetic energy of the molecules of a gas and its temperature?

\[ K \]
\[ T \]

\[ K \]
\[ T \]
Questions 16 and 17 refer to a candle burning inside a metal container, as shown above. Three types of heat transfer are listed below.
Radiation
Conduction
Convection

Heat can be transferred to the inside surface of the walls of the container by which of the above?
I only
I and II only
I and III only
II only
I, II, and III only

If you touch the outside surface of the metal container, your hand will become warmer directly by which of the above choices?
I only
I and II only
I and III only
II only
III only

Part 2: Open Response Question
Name ___________

Each part within the question may not have the same weight. Be sure to show all relevant work. Use $g = 9.8 \text{ m/s}^2$. Be sure to circle your final answer(s). Work hard!

A 20 m high dam is used to create a large lake. The lake is filled to a depth of 16 m as shown above. The density of the water is 1000 kg/m$^3$. Calculate the absolute pressure at the bottom of the lake next to the dam.
A release valve is opened 5.0 m above the base of the dam, and water exits horizontally from the valve. Use Bernoulli’s equation to calculate the initial speed of the water as it exits the hole.

Suppose that the atmospheric pressure in the vicinity of the dam increased. How would this affect the initial speed of the water as it exits the valve?

_____ It would increase  _____ It would decrease  _____ It would remain the same

Justify your answer.

Part 2: Open Response Question

Name___________
Two moles of an ideal monatomic gas is enclosed in a cylindrical container with a moveable lid. The sealed container is placed in a large ice/water bath and allowed to come to thermal equilibrium. If the contents of the container are found to have a pressure of $1.45 \times 10^5$ Pa, determine the volume of the gas.

The container is removed from the ice/water bath. The temperature of the container increases by 15°C. Calculate the new pressure of the gas.

Calculate the change in internal energy of the gas.

As the container continues to warm an additional 25°C, it develops a leak. The leak is sealed after the gas reaches atmospheric pressure. Determine the change in the number of moles of the gas during this leak. Did the amount of the gas inside the container increase, decrease, or stay the same?
A large rectangular raft (density 650 kg/m$^3$) is floating on a lake. The surface area of the top of the raft is 8.2 m$^2$ and the volume of the raft above the surface the water is 1.80 m$^3$. The density of the lake water is 1000 kg/m$^3$.

Calculate the height $h$ of the portion of the raft that is above the surrounding water.

Calculate the magnitude of the buoyant force on the raft and state its direction.
If the average mass of a person is 75 kg, calculate the maximum number of people that can be on the raft without the top of the raft sinking below the surface of the water. (Assume that the people are evenly distributed on the raft.)
Part 1 Answers: Write the answers to the multiple choice questions in the space below. Be sure to write clearly. Do not leave any answers blank. Work hard!

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>16</td>
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<td>17</td>
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</tbody>
</table>
Part 1: Multiple Choice – Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box in the table labeled “Part 1 Answers” at the end of this section. Note: To simplify calculations, you may use \( g = 10 \text{ m/s}^2 \) in all problems.

An ideal gas undergoes an isochoric change. Which of the following remains constant?
- a. Phase
- b. Temperature
- c. Internal Energy
- d. Pressure
- e. Volume

Which of the following graphs represents an isothermal expansion of an ideal gas?

Which of the following is not involved in an ideal Carnot cycle?
- Isothermal expansion
- Isobaric expansion
- Adiabatic expansion
- Adiabatic compression
- Isothermal compression

An ideal gas is initially in a state that corresponds to point 1 on the graph shown, where it has pressure \( P_1 \), volume \( V_1 \), and temperature \( T_1 \). The gas undergoes an isothermal process represented by the curve shown, which takes it to a final state 3 at temperature \( T_3 \). If \( T_2 \) and \( T_4 \) are the temperatures the gas would have at points 2 and 4, respectively, which of the following relationships is true?
- a. \( T_1 < T_3 \)
- b. \( T_1 < T_2 \)
- c. \( T_1 < T_4 \)
- d. \( T_1 = T_2 \)
- e. \( T_1 = T_4 \)

In a certain process, 400 J of heat is added to a system and the system simultaneously does 100 J of work. The change in internal energy of the system is
- a. 500 J
- b. 400 J
- c. 300 J
- d. \(-100\) J
- e. \(-300\) J
A gas expands at a constant pressure of \(2.0 \times 10^5\) Pa, and the volume changes by 0.040 m\(^3\). The heat added to the gas is 12x10\(^3\) J and the internal energy of the state is 26x10\(^3\) J. The internal energy of the initial state is

a. 12x10\(^3\) J           b. 6x10\(^3\) J            c. 0 J           d. 22x10\(^3\) J             e. 26x10\(^3\) J

Questions 7-8 are based on the following information and diagram.
Which of the following is true of the mechanical work done on the gas?
It is greatest for process 1.
It is greatest for process 3.
It is the same for processes 1 and 2 and less for process 3.
It is the same for processes 2 and 3 and less for process 1.
It is the same for all three processes.

Which of the following is true of the final temperature of this gas?
It is greatest for process 1.
It is greatest for process 2.
It is greatest for process 3.
It is the same for processes 1 and 2.
It is the same for processes 1 and 3.

The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Remains the same</td>
<td>Remains the same</td>
</tr>
<tr>
<td>b. Remains the same</td>
<td>Doubles</td>
</tr>
<tr>
<td>c. Doubles</td>
<td>Remains the same</td>
</tr>
<tr>
<td>d. Doubles</td>
<td>Is multiplied by a factor of 4</td>
</tr>
<tr>
<td>e. Is multiplied by a factor of 4</td>
<td>Doubles</td>
</tr>
</tbody>
</table>

An ideal gas is enclosed in a container which has a fixed volume. If the temperature of the gas is increased, which of the following will also increase?
The pressure against the walls of the container.
The average kinetic energy of the gas molecules.
The number of moles of gas in the container.
I only  
I and II only  
II and III only  
II only  
III only

A heat pump warms a house by absorbing 90 J of heat and doing 60 J of work on the pump. The heat then delivered to the house is
5,400 J  
150 J  
30 J  
1.5 J  
0.67 J

If a gas in a container absorbs 300 J or heat, then has 100 joules of work done on it, then does 50 J of work, the increase in the internal energy of the gas is
450 J  
400 J  
350 J  
200 J  
100 J

A system has 60 J of heat added to it, resulting in 15 J of work being done by the system, and exhausting the remaining 45 J of heat. What is the efficiency of this process?
100 %  
60 %  
45 %  
25 %  
15 %

An amount of an ideal gas is introduced into a container of unchanging volume. Thermal energy is added to the gas, which increases its temperature from 200 K to 400 K. Before heating, the average speed of the gas molecules was $v_o$, and after heating, the speed is $v_f$. The ratio of $v_f$ to $v_o$ is
$1/\sqrt{2}$  
$\frac{1}{2}$  
1  
$\sqrt{2}$  
4

A heat engine operates in a cycle between temperatures 700 K and 400 K. The heat input to the engine during each cycle is 2800 J. What is the maximum possible work done by the engine in each cycle?
1200 J  
1600 J  
2100 J  
2800 J  
4400 J
An ideal monatomic gas is compressed while its temperature is held constant. That happens to the internal energy of the gas during this process, and why?

- It decreases because the gas does work on its surroundings.
- It decreases because the molecules of the ideal gas collide.
- It does not change because the internal energy of an ideal gas depends only on its temperature.
- It increases because work is done on the gas.
- It increases because the molecules travel a shorter path between collisions.

The figure above shows three isothermal processes for an ideal gas. Which one takes place at the higher temperature?

- Process A
- Process B
- Process C
- They all take place at the same temperature.
- The answer cannot be determined from the information given.

A monatomic ideal gas undergoes an adiabatic expansion. During this process, the temperature of the gas

- Remains constant
- Increases
- Decreases
- Increases, then decreases
- Decreases, then increases

In terms of the principles of thermodynamics, which of the following statements best describes the reason that a person will feel warm after exercising?

- According to the third law of thermodynamics, work generates heat.
- Because of the second law of thermodynamics, entropy is decreasing, which increases the temperature.
- The temperature increases as the speed increases and the exercise moves the muscles, giving them a higher temperature.
- Working muscles must absorb more heat according to the first law of thermodynamics
- Muscles are not 100% efficient and must therefore generate waste heat according to the second law of thermodynamics

Questions 20 and 21 refer to the following diagram:
What is true for the process D→A?
ΔU = 0  Q > 0
ΔU = 0  Q < 0
ΔU > 0  W = 0
ΔU < 0  Q = 0
W = 0  Q = 0

What is true for the two step process A→B→C?
ΔU = 0  Q = 0
ΔU = 0  Q > 0
W = 0  Q > 0
W = 0  Q < 0
W > 0  Q < 0

The slope of the line in a PV diagram representing an isochoric process would be
a. 0          b. positive                c. negative            d. a function of volume           e. infinite

If the pressure of an ideal gas in a vessel is halved while its volume is quadrupled, the temperature will be
half of its original volume.
The same as its original volume.
Twice its original volume
One quarter of its original volume
Four times its original volume

Part 2: Open Response Questions – Answer all four questions, which are weighted according to the points indicated. The parts within a question may not have equal weight. Show all of your work in the area provided after each part.

An engine takes in 9220 J and does 1750 J of work each cycle while operating between 689°C and 397°C.
(a) What is its actual efficiency? (b) What is its maximum theoretical efficiency?
Initially, 70 liters of an ideal gas has a temperature of -80°C and pressure 4 atm. the gas is first heated at constant volume to twice its original pressure. Then the volume is expanded isothermically to its original pressure. Finally, keeping pressure and temperature constant, it is isobarically returned to its original volume by letting gas escape. Find the final number of moles of this gas.
The diagram below of pressure $P$ versus volume $V$ can be used to show the expansion of 2.0 moles of a monatomic ideal gas from State A to State B. In this transition, $P_A = P_B = 600 \text{ N/m}^2$, $V_A = 3.0 \text{ m}^3$, and $V_B = 9.0 \text{ m}^3$.

On the diagram above, draw the process AB. Be sure to label the points A and B.
Determine the following:
Calculate the work done by the gas as it expands.
Calculate the change in internal energy of the gas as it expands.
Calculate the heat added to or removed from the gas during this expansion.
The pressure is then reduced to 200 N/m$^2$ without changing the volume as the gas is taken from State B to State C. Label State C on the diagram and draw a line or curve to represent the process from State B to State C.
The gas is then compressed isothermally back to state A.
Draw a line or curve on the diagram to represent this process.
Is heat added to or removed from the gas during this isothermal compression? You must justify your answer.
The cylinder represented above contains 2.2 kg of water vapor initially at a volume of 2.0 m³ and an absolute pressure of 3.0x10⁵ Pa. This state is represented by point A in the PV diagram below. The molar mass of water is 18 g, and the water vapor can be treated as an ideal gas.

Calculate the temperature of the water vapor at point A.

The absolute pressure of the water vapor is increased at constant volume to 4.0x10⁵ Pa at point B, and then the volume of the water vapor is increased at constant pressure to 2.5 m³ at point C, as shown in the PV diagram.

Calculate the temperature of the water vapor at point C.

Does the internal energy of the water vapor for the process A→B→C increase, decrease, or remain the same?

______ Increase  _______ Decrease  _______ Remain the same.

Justify your answer.

Calculate the work done on the water vapor for the process A→B→C.
AP Physics Homework
For each problem, show all the work (no pun intended) you did to arrive at your answer. Be thorough and clear, not just so that we understand your work, but so that you can look back on it and understand it as well!

A man climbing a flight of stairs goes from the ground floor to the 25th floor of his apartment building, 70m above the ground. Find the work he has done at

25m
50m
70m
The total work done climbing the stairs and descending to the ground floor again.

A 5kg box is pulled by a 200N tension force on an incline that makes an angle of 65º with the horizontal. After the box has been pulled 15m up the incline:

Find the work done in the x-direction
Find the work done in the y-direction
If the box is stopped after moving 15m up the incline, write the formula for its total energy.
Suppose the box is now released and allowed to slide down the incline. In the absence of friction, what is the box’s speed at the bottom of the incline?

On a wonderful day at Six Flags with Mr. Staley and Mr. Hopkins, you decide to brave the Mind Eraser with your friends. The 100kg cart climbs slowly up the track and reaches its maximum height of 35m above the ground, at which point it stops for a moment before propelling you down the track. At 5m above the ground you start a loop-de-loop that has a radius of 10m, and afterwards the track goes straight at 5m above the ground until coming to a stop.

What is the cart’s potential energy at its maximum height? What is its kinetic energy?
At what point on the track do you reach your maximum velocity? Minimum velocity?
Calculate the minimum and maximum velocities for the cart, excluding your weight.

Chapter 3: Vector Worksheet
Complete each of the following. Use trigonometry rules to determine the required values. Do not assume anything! (i.e. right angles, equal lengths, etc)
For each of the following, find the resultant vector.

A vector has a magnitude of 23 units and is directed 25º East of South. Find the eastward and southward components.
A vector $\mathbf{A} = 44 \text{ N at } 130^\circ$. A vector $\mathbf{B} = 13 \text{ N at } 205^\circ$. A vector $\mathbf{C} = 17 \text{ N at } 90^\circ \text{ North of East.}$

$\mathbf{A} = 20 \text{ N at } 45^\circ$. $\mathbf{B} = 20 \text{ N at } 0^\circ$. $\mathbf{C} = 20 \text{ N South.}$

Swimming at an angle of 27° from the horizontal, an angelfish has a velocity vector $\mathbf{v}$ with a magnitude of 25 m/s. Find the x and y components of $\mathbf{v}$.

Vector $\mathbf{A}$ has a length of 14 cm at 60° with respect to the x-axis, and vector $\mathbf{B}$ has a length of 20 cm at 20° with respect to the x-axis.

Vector $\mathbf{A}$ is 9.0 m/s North. Vector $\mathbf{B}$ is 10 m/s at 10°. Vector $\mathbf{C}$ is 15 m/s at 225°. Vector $\mathbf{D}$ is 12 m/s at 335°.

A box is placed on a 30° inclined plane. There are forces acting on the block. One force acts perpendicular to the surface of the plane and has a magnitude of 10N. Another force acts due South and has a magnitude of 15N. Another force acts parallel to the surface, is directed up the plane, and has a magnitude of 1.1N. What is the resultant, and where is it directed?

A man pushes a lawnmower across his yard. The handle of the mower makes an angle of 50° with the level ground. The man pushes with a force of 150 N directed along the handle. The mower has an additional force of 45 N acting at 270° and a force of 30 N acting at 90°. What are the resultant, and its direction?

Locusts have been observed to jump horizontal distances up to 80 cm on a level floor. Photographs of their jump show that they usually take off at an angle of about 55° from the horizontal. Calculate the initial velocity of a locust making a jump of 80 cm with a takeoff angle of 55°.

Which of the following statements is/are false?

I. The centripetal force on a mass on a string can never be greater than the weight of the object.

II. An object with a net force of zero cannot have a nonzero net torque.

III. A mass on a frictionless incline ($0^\circ < \theta < 90^\circ$) must have some net acceleration.

I only          b. III only          c. I and II only          d. II and III only          e. I, II, and III

Multiple Choice – Scenario A: Scenario B situation

Hint – There are 2 situations explained in these types of problems. There is one concept being tested (here it is gravitational forces and centripetal motion). Technique – there is 1 formula that relates the quantities identified in the problem.
Write out the formula twice: one time with info and labels for scenario A, and the other identical formula, but with info and labels for scenario B. In the problem, they will relate a quantity from A in terms of B. Substitute and combine the equations until you get your answer.

A spring with a (force) spring constant \( k \) is stretched a distance \( x \). By what factor must the spring’s elongation be changed so that the elastic potential energy in the spring is doubled?

a. 4  b. 2  c. ½  d. ¼  e. \( \sqrt{2} \)

Two satellites A and B of the same mass are going around Earth in concentric orbits (circular orbits). The distance of satellite B from Earth’s center is twice that of satellite A. What is the ratio of the tangential speed of B to that of A?

a. \( \frac{1}{2} \)  b. \( \sqrt{1/2} \)  c. 1  d. \( \sqrt{2} \)  e. 2

Circular Motion:

A coin C of mass 0.0050 kg is placed on a horizontal disk 0.14 m away from the center, as shown above. The disk rotates at a constant rate in the counterclockwise direction as seen from above. The coin does not slip, and the time it takes for the coin to complete one revolution is 1.5 s.

The figure below shows the disk and the coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.

Determine the linear speed of the coin.

The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

If the experiment is part (c) were repeated with an identical coin glued on top of the first coin, how would this affect the answer to part (c)? Explain your reasoning.
AP Physics Quizzes
Circular Motion and Energy Quiz

If asked to draw an FBD, should one include the centripetal force? Explain why or why not.

Two masses separated by a distance R exert a gravitational force F on each other. To quadruple the force, what must the new separation distance be to achieve this new force? Justify your answer.

A mass m moves clockwise in a vertical circle of diameter d, as shown below. A massless string connects the mass to the center of the circle. The speed of the mass at each point is \( v_P \), \( v_Q \), and \( v_R \) respectively. Express all answers using the quantities given and fundamental constants.

For each of the labeled points P, Q, and R, write an expression for the tension in the string.

Which point has the greatest tension? Justify your answer.
If the string breaks at point Q, qualitatively describe the motion of the mass immediately after.

Two friends stand on top of a building. They each throw an identical ball off the building with the same speed. If person A throws the ball straight down and person B throws the ball directly up, compare the final speed of the balls when they hit the ground (I.e. does one ball have a greater speed than the other, or are they equal?). Explain your answer.

Rank the following objects based on their total mechanical energy.

(highest) _____ > _____ > _____ > _____ > _____ (lowest)

Ball of mass 4 kg is at rest on top of a 40 m tall building.
Plane of mass 1000 kg is moving at 1.5 m/s along the runway at the airport
Car of mass 1200 kg cruising at 12.5 m/s along a level road
Ball of mass 8 kg moving at 7 m/s while 5.5 m off the ground
Truck of mass 1400 kg moving at 9.9 m/s along a level road

A rocket blasts off from the ground with a kinetic energy of 17.5x10^6 J. The mass of the rocket is 1450 kg. After a few seconds, a scientist observed the speed of the rocket to be 28.0 m/s. How high had the rocket risen?
Shown below is a sample test multiple choice question. Identify the correct choice by circling the answer. For the other 3 choices, make one comment explaining why that choice is incorrect. If there are several incorrect statements in the choice, identify only one.

A father and daughter are throwing a ball back and forth to each other. The ball has a mass of 0.22 kg, and each person is equally strong and can throw the ball with a maximum speed of 4.5 m/s. The father and daughter are facing each other as they throw the ball back and forth. Which of the following is true?

The kinetic energy of the ball is positive as the ball moves right, then it is negative as it moves left. The values of the kinetic energies are equal however.

The kinetic energy of the ball is positive as the ball moves right, then it is negative as it moves left. The values of the kinetic energies are not equal because the father has a greater mass than the daughter.

Both kinetic energies are positive. The values of the kinetic energies are equal however.

Both kinetic energies are positive. The values of the kinetic energies are not equal because the father has a greater mass than the daughter.
Quiz: Chapters 12 – 13

Part 1: Short answer questions. Answer the following. Include all relevant information.
Define and/or explain the following terms. Include formulae where appropriate.
First Law of Thermodynamics, Internal energy, State Variable

Demonstrate a conceptual understanding of the following terms by creating a short paragraph linking them together. Be sure to demonstrate the relationships between the terms, how they depend on one another, whether they are proportional, etc. Do NOT create an example problem.
Terms: root mean square speed, internal energy, temperature, gas molecule

Write the ideal gas equation. For each quantity, what does it stand for and what are the SI units (UNITS only, no numbers)?

Part 2: Open response problems. Complete all problems below and on the back of the page. Show as much work as needed to demonstrate mastery. For each, show which formula you are using before you insert values. Label all values, and include units.

A small container of gas undergoes a thermodynamic cycle. The gas begins at room temperature. First the gas expands isobarically until its volume has doubled. Second, the gas expands adiabatically. Third, the gas is cooled isobarically. Finally, the gas is compressed adiabatically until it returns to its original state. The initial state of the gas is indicated on the PV diagram below. Sketch the process explained above on the PV diagram.
Is the temperature of the gas greater right before or right after the adiabatic expansion? Justify your answer.

Is heat added to or removed from the gas in one cycle?

Does this gas act as a heat pump or a heat engine? Justify your answer. (Extra credit, but only if the justification is valid)

You are given a PV diagram below with 5 processes (labeled I, II, III, IV, and V). Be sure to note the direction of the arrow. Each process is distinct from the others. Choose any three (3) and complete the following:

What happens to the temperature of the gas throughout this process? Justify your answer.

What happens to the number of moles of the gas throughout this process? Justify your answer.

Does this process provide any specific information relating to the first law of thermodynamics? If so, explain how the first law of thermodynamics is affected.

Is there work done on or by the gas? If so, which is it and briefly explain?

Is heat added to or removed from the gas? Justify your answer.

Process _______    Process _______        Process _______

Process II is isothermal
Process III is adiabatic
AP Physics Reading
As you read this chapter, answer the following questions and consider the following prompts. All questions and prompts are presented chronologically with the sequence of the chapter. As you read through the notes, make a list of all formulas introduced that you feel are important. Space for this list is provided at the end of this guide.

***Ignore the sections that discuss ANGULAR (velocity, displacement, acceleration). Focus your efforts around the questions below.

Radians are a unit of angular measure. They are sometimes called a dimensionless unit. Explain. (p. 190-192)

(Questions 2 – 5 refer to Section 7.4)
Define uniform circular motion. Also, explain why velocity is not constant.

What is the centripetal acceleration? What is its direction?

Describe the centripetal force in detail. (p. 202)

Define the terms centripetal and centrifugal.

Describe the Cavendish Experiment. Briefly describe what was done and the result.

What is the period of an object? Can any object travel with a period? Justify your answer. (p. 216)

Summary – Reflect on your reading.
1. What is the centripetal force? From your understanding of the reading, would the centripetal force be labeled on an FBD and if so, where would it act?

What factors or quantities are involved when determining the gravitational force between two objects?

What is G, what is its value and what are its units?

Formula List:

79
AP Physics Practice Multiple Choice
A mass hangs from two ropes at unequal angles, as shown below. Which of the following makes correct comparisons of the horizontal and vertical components of the tension in each rope?

- Horizontal Tension  
  - Greater in Rope B  
  - Equal in both Ropes  
  - Greater in Rope A  
  - Greater in Rope B

- Vertical Tension  
  - Greater in Rope B  
  - Greater in Rope A  
  - Equal in both Ropes

An object rolls along level ground to the right at constant speed. Must there be any forces pushing the object to the right?
- Yes: the only forces that act must be to the right.
- Yes: but there could also be a friction force acting to the left.
- No: no forces can act to the right.
- No: while there can be forces acting, no force must act.
- The answer depends on the speed of the object.

Which of the following must be true of an object in uniform circular motion?
- Its velocity must be constant.
- Its acceleration and its velocity must be in opposite directions.
- Its acceleration and its velocity must be perpendicular to each other.
- It must experience a force away from the center of the circle.
- Its acceleration must be negative.

A planet of mass \( m \) orbits in a circle around a sun. The speed of the planet in its orbit is \( v \); the distance from the planet to the sun is \( d \). What is the magnitude and direction of the net force experienced by the planet?
- \( v^2/d \) toward the sun
- \( mv^2/d \) toward the sun
- \( mv^2/d \) away from the sun
- \( mv^2/d \) along the orbital path
- \( v^2/d \) along the orbital path

A satellite orbits the moon in a circle of radius \( R \). If the satellite must double its speed but maintain a circular orbit, what must the new radius of its orbit be?
- a. 2R
- b. 4R
- c. \( 1/2 \) R
- d. \( 1/4 \) R
- e. R
The space shuttle orbits 300 km above the Earth’s surface. The Earth’s radius is 6400 km. What is the gravitational acceleration experienced by the space shuttle?

a. 4.9 m/s²  

b. 8.9 m/s²  

c. 9.8 m/s²  

d. 10.8 m/s²  

e. Zero

A satellite orbits the moon far from its surface in a circle of radius r. If a second satellite has a greater speed, yet still needs to maintain a circular orbit around the moon, how should the second satellite orbit?

- with a radius greater than r
- with a radius less than r
- only an eccentric elliptical orbit can be maintained with a larger speed
- no orbit at all can be maintained with a larger speed

Questions 8 and 9 refer to the following information:

Ancient warriors used a crude device known as a slingshot. Examples include David in the biblical story of David v. Goliath and the Ewoks in Return of the Jedi. The warrior throws rocks using a circular motion device. A rock is attached to a string. A warrior whirls the rock in a horizontal circle above his/her head, then lets go, sending the rock toward the head of the enemy.

What force provides the rock’s centripetal acceleration?

- The vertical component of the string’s tension.
- The horizontal component of the string’s tension.
- The entire tension of the string.
- The gravitational force on the rock.
- The horizontal component of the gravitational force on the rock.

The warrior whirls the rock and releases it from a point above his/her head and to the right. The rock initially goes straight forward. Which of the following describes the subsequent motion of the rock?

- It will continue in a straight line forward, while falling due to gravity.
- It will continue forward but curve to the right, while falling due to gravity.
- It will continue forward but curve to the left, while falling due to gravity.
- It will fall straight down to the ground.
- It will curve back toward the warrior and hit him/her in the head.

A car with a 500 N mass inside goes over a hill that has a radius of 60 meters, as shown below. The velocity of the car is 20 m/s. what are the force and the direction that the car exerts on the driver?

a. 840 N, up  

b. 160 N, up  

c. 160 N, down  

d. 840 N, down  

e. 500 N, up

A space shuttle orbits Earth 300 km above the surface. Why can’t the Shuttle orbit 10 km above Earth? The Space Shuttle cannot go fast enough to maintain such an orbit.
Kepler’s laws forbid an orbit so close to the surface of the Earth. Because \( r \) appears in the denominator of Newton’s Law of Gravitation, the force of gravity is much larger closer to the Earth; this force is too strong to allow such an orbit. The closer orbit would likely crash into a large mountain such as Everest because of its elliptical nature. Much of the Shuttle’s kinetic energy would be dissipated as heat in the atmosphere, degrading the orbit.

Open Response Questions – Answer these as you would a traditional exam problem. Show all work on attached paper.
Consider two points on a rotating turntable: Point A is very close to the center of rotation, while Point B is on the outer rim of the turntable.
In which case would the speed of the penny be greater, if it were placed at point A or if it were placed at point B? Explain.

For parts (b) and (c), a penny could be placed on a rotating turntable without moving at either point A or point B.
At which point would the penny require the larger centripetal force to remain in place? Justify your answer.

Point B is 0.25 m from the center of rotation. If the coefficient of friction between the penny and the turntable is \( \mu = 0.30 \), calculate the maximum linear speed the penny can have there and still remain in circular motion.

Forces
Multiple Choice Problem Set

Vectors A, B, and C have magnitudes 6, 11, and 20. When these vectors are added, what is the least possible magnitude of their resultant?

- a. 25
- b. 15
- c. 2
- d. 3

When we subtract a velocity vector from another velocity vector, the result is:

- a. another velocity
- b. an acceleration
- c. a displacement
- d. a scalar

The first displacement is 6 m and the second displacement is 3 m. They cannot add together to give a total displacement of:

- a. 2 m
- b. 3 m
- c. 6 m
- d. 9 m

A taxicab moves five blocks due north, five blocks due east, and another two blocks due north. Assume all blocks are of equal size. What is the magnitude of the taxi’s displacement, start to finish?

- a. 12 blocks
- b. 9.8 blocks
- c. 9.2 blocks
- d. 8.6 blocks
An automobile of mass 2,000 kg moving at 30 m/s is braked suddenly with a constant braking force of 10,000 N. How far does the car travel before stopping?

a. 45 m  b. 90 m  c. 135 m  d. 180 m

In the terminology *a 500-N block*, the 500-N refers to the block’s:

a. mass  b. force  c. weight  d. none of the above

A thrown stone hits a window, but doesn’t break it. Instead it reverses direction and ends up on the ground below the window. In this case, we know:

the force of the stone on the glass > the force of the glass on the stone  
the force of the stone on the glass = the force of the glass on the stone  
the force of the stone on the glass < the force of the glass on the stone  
the stone didn’t slow down as it broke the glass

As a basketball player starts to jump for a rebound, he begins to move upward faster and faster until he leaves the floor. During the time that he is in contact with the floor, the force of the floor on his shoes is:

bigger than his weight  
equal in magnitude and opposite in direction to his weight  
less than his weight  
zero

A 500-N tightrope walker stands at the center of a rope, such that each half of the rope makes an angle of 10° with the horizontal. What is the tension in the rope?

a. 1,440 N  b. 1,000 N  c. 500 N  d. 2,900 N

A 100 kg box is placed on a ramp. As one end of the ramp is raised, the box begins to move downward just as the angle of inclination reaches 15°. What is the coefficient of static friction between box and ramp?

a. 0.15  b. 0.27  c. 0.77  d. 0.95

Three identical 6.0 kg cubes are placed on a horizontal surface in contact with one another. The cubes are lined up from left to right and a 36-N force is applied to the left side of the left cube causing all three cubes to accelerate to the right. If the cubes are each subject to a frictional force of 6.0 N, what is the magnitude of the force exerted on the middle cube by the left cube in this case?

a. 12 N  b. 24 N  c. 36 N  d. None of the above

Three identical 6.0 kg cubes are placed on a horizontal surface in contact with one another. The cubes are lined up from left to right and a 36-N force is applied to the left side of the left cube causing all three cubes to accelerate to the right. If the cubes are each subject to a frictional force of 6.0 N, what is the magnitude of the force exerted on the right cube by the middle cube in this case?

a. 12 N  b. 24 N  c. 36 N  d. None of the above

Two objects, A and B, are placed on an inclined plane that can be rotated to different angles of elevation. A starts to slide at twice the angle of elevation that B starts sliding. The respective coefficients for static friction for A and B are \( \mu_A \) and \( \mu_B \). Choose the answer that is correct.
A block is launched up an incline plane. After going up the plane, it slides back down to its starting position. The coefficient of friction between the block and the plane is 0.3. The time for the trip up the plane:
is the same as the time for the trip down.
Is more than the time for the trip down.
Is less than the time for the trip down.
Cannot be compared without knowing the angle of inclination.

A block is launched up an incline plane. After going up the plane, it slides back down to its starting position. The coefficient of friction between the block and the plane is 0.3. The speed of the block when it reaches the starting position on the trip down:
is the same as the launching speed.
Is less than the launching speed.
Is more than the launching speed.
Cannot be compared to the launch speed with the information given.

The coefficient of friction between a racecar’s wheels and the track is 1.0. The car starts from rest and accelerates at a constant rate for 400 m. Find the maximum speed at the end of the race.
a. 44 m/s  b. 66 m/s  c. 89 m/s  d. 99 m/s
Momentum and Collisions

If the acceleration of an object is not zero, then all of the following could be constant EXCEPT the object’s
speed
linear momentum
kinetic energy
   a. I only  b. I and II only  c. I and III only  d. II only  e. II and III only

Which of the following is not a vector quantity?
a. displacement  b. velocity  c. acceleration  d. linear momentum  e. potential energy

Two people, one of mass 100 kg and the other of mass 50-kg, stand facing each other on an ice-covered (essentially frictionless) pond. If the heavier person pushes on the lighter one with a force F, then the force felt by the heavier person is -F/2.
the force felt by the heavier person is -2F.
the magnitude of the acceleration of the lighter person will be 1/2 of the magnitude of the acceleration of the heavier person.
the magnitude of the acceleration of the lighter person will be twice of the magnitude of the acceleration of the heavier person.
none of the above.

What braking force is applied to a 2500-kilogram car having a velocity of 30 meters per second if the car is brought to a stop in 15 seconds?
a. 5000 N  b. 6000 N  c. 8000 N  d. 10,000 N  e. 12,000 N

A 1-kilogram object is moving to the right with a velocity of 6 meters per second. It collides with, and sticks to, a 2-kilogram mass, also moving to the right, with a velocity of 3 meters per second. How much kinetic energy was lost in this interaction?
a. 1.5 J  b. 2 J  c. 3 J  d. 3.5 J  e. 0 J

A ball with a mass of 0.2 kilogram strikes a wall with a velocity of 3 meters per second. It bounces straight back with a velocity of 1 meter per second. What was the magnitude of the change in momentum for this ball?
a. 0.1 kg·m/s  b. 0.8 kg·m/s  c. 0.4 kg·m/s  d. 0.6 kg·m/s  e. 0.7 kg·m/s

A railroad car of mass \( m \) is moving at speed \( v \) when it collides with a second railroad car of mass \( M \), which is at rest. The two cars lock together instantaneously and move along the track. What is the speed of the cars immediately after the collision?
a. \( v/2 \)  b. \( mv/M \)  c. \( Mv/m \)  d. \( (m + M)v/m \)  e. \( mv/(m+M) \)
The picture above shows two motorized dynamics carts, A and B, that have been placed on a lab table, with cart A to the left of cart B. The motors of each cart are turned on simultaneously and the two carts begin to race towards the right end of the table with constant accelerations. Both the front end of cart A and the front end of cart B reach the right edge of the table at exactly the same time. Which line in the chart below makes the correct comparison of the average velocity and the acceleration of cart B with the average velocity and the acceleration of cart A?

The average velocity of cart B is:  
- a. less than that of cart A  
- b. greater than that of cart A  
- c. less than that of cart A  
- d. same as that of cart A  
- e. greater than that of cart A

The average acceleration of cart B is:  
- same as that of cart A  
- greater than that of cart A  
- less than that of cart A  
- greater than that of cart A  
- same as that of cart A

If the momentum of an object doubles, its kinetic energy
- a. doubles  
- b. is half  
- c. quadrupled  
- d. is quartered  
- e. is eighthed

Questions 10-11 apply to the following information and diagrams.
Three objects can only move along a straight, level path. The graphs below show the position d of each object plotted as a function of time t.

The magnitude of the momentum of the object is increasing in which of the cases?
- a. I only  
- b. III only  
- c. I and II only  
- d. I and III only  
- e. I, II, and III

The sum of the forces on the object is zero in which of the cases?
- a. II only  
- b. III only  
- c. I and II only  
- d. I and III only  
- e. I, II, and III

A railroad car with a mass of 40,000 kg is going east at 3 m/s when it collides with a second car whose mass is 25,000 kg and is going east at 1 m/s on the same track. If the two cars couple together, how much kinetic energy was lost in the collision?
- a. 940 J  
- b. 3.1 \times 10^4 \text{ J}  
- c. 7.3 \times 10^4 \text{ J}  
- d. 1.8 \times 10^5 \text{ J}
AP Physics Practice Open Response
A heavy ball swings at the end of a string as shown above, with negligible air resistance. Point P is the lowest point reached by the ball in its motion, and point Q is one of the two highest points.

a. On the following diagrams draw and label vectors that could represent the velocity and acceleration of the ball at points P and Q. If a vector is zero, explicitly state this fact. The dashed lines indicate horizontal and vertical directions.

i. Point P

ii. Point Q

b. On the following diagrams, draw and label vectors that represent the forces on the ball at points P and Q. For each m point, create an expression for the centripetal force. If there is no centripetal force, explicitly state this fact. The dashed lines indicate horizontal and vertical directions.

i. Point P

ii. Point Q

c. After several swings, the string breaks. The mass of the string and air resistance are negligible. On the following diagrams, sketch the path of the ball if the break occurs when the ball is at point P or point Q. In each case, briefly describe the motion of the ball after the break.

i. Point P

ii. Point Q
From the top of a cliff 80 meters high, a ball of mass 0.4 kilogram is launched horizontally with a velocity of 30 meters per second at time t = 0 as shown above. The potential energy of the ball is zero at the bottom of the cliff. Use g = 10 meters per second squared.

Calculate the potential, kinetic, and total energies of the ball at time t = 0.

On the axes below, sketch and label graphs of the potential, kinetic, and total energies of the ball as functions of the distance fallen from the top of the cliff.
(c) On the axes below, sketch and label the kinetic and potential energies of the ball as functions of time until the ball hits.
Forces
Practice Open Response Question

A mass \( m \) is attached via a massless string and pulley to another mass \( M \), sitting on a table, as shown below. The coefficient of kinetic friction between the block of mass \( M \) and the table is \( \mu_k \). The entire system is initially at rest. The block of mass \( m \) starts at a height of 0.5 m and descends to the floor, dragging mass \( M \) along the tabletop. Mass \( M \) slides to a stop 1 m from its initial position. Express answers to parts (a) and (b) in terms of \( M \), \( m \), and \( g \).

Find an expression for the acceleration of mass \( m \) before it hits the floor.

Determine the coefficient of kinetic friction, \( \mu_k \), between mass \( M \) and the table.

Sketch a graph of the velocity of mass \( M \) versus time. Explain the graph in words and label and maxima or minima appropriately.

If \( \mu_k = 0.2 \), determine the mass \( M \) in terms of \( m \).
Forces
Practice Open Response Question

The hanging block (m) causes the entire system to accelerate. The hanging block moves downward and hits the ground in time \( t_o \). The mass on the incline (m) is attached to the hanging mass with a light string around a frictionless pulley. The incline is also frictionless. The angle of inclination is 37°. Using sin 37 = 0.6 and cos 37 = 0.8, determine the distance \( h \) in terms of m, g, and \( t_o \).

1. A stone (stone A) is thrown downward at 5.0 m/s from a height of 30 meters. At the same time, from a height of 50 meters, another stone (stone B) is thrown downward with a speed of 20 m/s.
   a. Do the stones meet at some height before hitting the ground? If so, find this height.
   b. From the time it was released to the time it hits the ground, how long was stone B in the air?
   c. If this activity were performed on the moon, would the stones take longer, shorter or the same amount of time before colliding than on Earth? Use logic or a quantitative (numerical) analysis to briefly justify your answer.

2. Two planetary explorers land on an uncharted planet and decide to test the range of a cannon they brought along. When they fire a cannonball with a speed of 100 m/s at an angle of 25° from the horizontal
ground, they find that the cannonball follows a parabolic path and takes 10 seconds to return to the ground. Determine the acceleration due to gravity on this uncharted planet. Determine the maximum height above the level ground the cannonball reaches. One of the explorers exclaims that the cannonball “must have landed over a mile away!” Is the explorer correct? Justify your answer (1 mile ≈ 1600 m). The explorers then fire another cannonball at 100 m/s at an angle of 75° to the horizontal ground. Will the cannonball travel a horizontal range x’ which is less than, greater than, or equal to the horizontal range for a 25° launch angle?

_____ less than  _____ greater than  _____ equal to

Justify your answer.

1. A stone (stone A) is thrown downward at 5.0 m/s from a height of 30 meters. At the same time, from a height of 50 meters, another stone (stone B) is thrown downward with a speed of 20 m/s.
   a. Do the stones meet at some height before hitting the ground? If so, find this height.
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2. Two planetary explorers land on an uncharted planet and decide to test the range of a cannon they brought along. When they fire a cannonball with a speed of 100 m/s at an angle of 25° from the horizontal ground, they find that the cannonball follows a parabolic path and takes 10 seconds to return to the ground. Determine the acceleration due to gravity on this uncharted planet. Determine the maximum height above the level ground the cannonball reaches. One of the explorers exclaims that the cannonball “must have landed over a mile away!” Is the explorer correct? Justify your answer (1 mile ≈ 1600 m). The explorers then fire another cannonball at 100 m/s at an angle of 75° to the horizontal ground. Will the cannonball travel a horizontal range x’ which is less than, greater than, or equal to the horizontal range for a 25° launch angle?

_____ less than  _____ greater than  _____ equal to

Justify your answer.
A 0.5-kilogram object rotates freely in a vertical circle at the end of a string of length 2 meters as shown above. As the object passes through point P at the top of the circular path, the tension in the string is 20 newtons. Assume $g = 10$ meters per second squared.

On the above diagram of the object, draw and clearly label all significant forces on the object when it is at point P.

Calculate the speed of the object at point P.
Calculate the increase in Kinetic energy of the object as it moves from point P to point Q.

Calculate the tension in the string as the object passes through point Q.

An 0.10-kilogram solid rubber ball is attached to the end of an 0.80-meter length of light thread. The ball is swung in a vertical circle, as shown in the diagram above. Point P, the lowest point of the circle, is 0.20 meter above the floor. The speed of the ball at the top of the circle is 6.0 meters per second, and the total energy of the ball is kept constant.
a. Determine the total energy of the ball, using the floor as the zero point for gravitational potential energy.

b. Determine the speed of the ball at point P, the lowest point of the circle.

c. Determine the tension in the thread at
   i. the top of the circle;
   ii. the bottom of the circle.

The ball only reaches the top of the circle once before the thread breaks when the ball is at the lowest point of the circle.

d. Determine the horizontal distance that the ball travels before hitting the floor.
A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown below. When the ball is at point P, the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q, respectively.

Derive an expression for $v_{\text{min}}$, the minimum speed the ball can have at point Z without leaving the circular path.

The maximum tension the string can have without breaking is $T_{\text{max}}$. Derive an expression for $v_{\text{max}}$, the maximum speed the ball can have at point Q without breaking the string.

Suppose that the string breaks at the instant the ball is at point P. Describe the motion of the ball immediately after the string breaks.
AP Physics Extra Credit
AP Physics

Extra Credit Question – due Wednesday 12/8 by the beginning of class. Question is worth 4 test points if completely correct, work is thoroughly and neatly presented, and handed in on time.

Suppose a ball bearing (a small metal ball) is thrown vertically upwards from a point X, and it takes a time T to reach its maximum point. Will the ball bearing take the same time T to drop back to point X when:

It is rising and falling without air resistance?
It is rising and falling with air resistance?

If the time(s) are not the same, explain why part of the motion (upward or downward) takes longer.

Justify your answers. A qualitative response would be sufficient (i.e. you can use formulas and words, but do not make up numbers).

Blocks of mass m and 2m are positioned on a semicircular frictionless track at a height of R/4 above the lowest point. The blocks are released simultaneously and collide elastically. How high does each block rise after the collision?

Extra Credit (5 test points) will be awarded to each person who submits a completed, thorough and completely correct answer. No partial credit will be given. The extra credit assignment is due Wednesday November 17th. If you bring your work to Mr. Staley before the due date, he will tell you if the answers are correct.
Blocks of mass $m$ and $2m$ are positioned on a semicircular frictionless track at a height of $R/4$ above the lowest point. The blocks are released simultaneously and collide elastically. How high does each block rise after the collision?

![Diagram of blocks on a semicircular track]

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AP Physics Labs
AP Physics
Force Analysis Laboratory Exercise – Pendulum Motion

**Introduction:** When an object is in motion, there are many factors that can affect this motion. Qualitative and quantitative analysis of an object’s motion can help explain the conceptual basis of why an object moves, and make predictions as to how a specific variable can affect the motion of an object. In this exercise, your group will investigate the relationship between the tension in a string, the weight of a suspended object, the angle at which it is spun, the velocity or speed at which the object moves and the length of the string attached to the object.

**Materials:** Your group should acquire the following materials:
- String (yarn – approximately 6 feet long)
- Masses (3 different sizes)
- Tape measure or ruler (metric)
- Stopwatch or timing device
- Protractor or Contractor’s Angle
- Calculator
- Paper
- Pencil, Pen
**Practice:** You will need to extend a rod over the edge of the table. You will cut strings of various lengths and create a pendulum. You will need to secure one end of the string to the rod. Connect masses to the other end of the string and measure the length of the pendulum. By lifting the mass while keeping the string taught, you can initiate circular motion. Practice measuring the time (period) of the object. One technique is to measure 3 – 5 oscillations, then dividing to find the time for 1 oscillation. Determine a method that works well for you.

**Procedure:** You are attempting to determine qualitative and quantitative relationships between the angle, tension, weight, length and velocity. In order to accomplish this, you will need to evaluate the affect one variable has on another. Complete the following tasks:
- Get all necessary materials
- Discuss as a group the procedure for this activity. Assign roles as needed. Discuss possible, reliable ways to measuring the angle. When creating a scientific experiment, how many variables should you be evaluating at a time?
- You will need to set up the apparatus as shown on the board in the classroom.
- You will conduct trials in which you are changing one variable while keeping the others constant. The data table provided should help guide you through all the necessary trials you need to run.

**Analysis:** In your data analysis and conclusion sections, be sure to investigate the following:
- When determining the period of an object in pendulum motion, what is the affect of changing the angle?
- When determining the period of an object in pendulum motion, what is the affect of changing the length of the string?
- When determining the period of an object in pendulum motion, what is the affect of changing the mass of the object?
- Analyze the motion of the mass at 3 points: the maximum height on the right, the minimum height, and the maximum height on the left. Compare the tension, velocity, acceleration, and weight of the mass at each of these points. Justify your answers.
- What is the importance of holding all variables except one constant during an experiment? Explain.
- Name one change to the set-up that would increase the speed of the mass at the bottom of its circular motion. Explain.
- Name one change to the set-up that would NOT increase the speed of the mass at the bottom of its circular motion. Explain.

**Data Table:** On attached paper, create your own data table to run the 9 trials. A possible example is shown below, though several key data points are missing.

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Weight (N)</th>
<th>String Length (m)</th>
<th>Angle (°)</th>
<th>Radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 trials</td>
<td>3 trials</td>
<td>3 trials</td>
<td>3 trials</td>
<td></td>
</tr>
</tbody>
</table>

Data Table: Create the headings and fill as much data as possible before running the trials. There may be extra columns and/or rows, depending on the data you wish to collect.
Analysis – Jot down some of your ideas, reflections, and initial conclusions. You will write up the analysis and results in a more formal format for next week.
College Prep Exams
Exam: Energy and Momentum

Part 1: Multiple Choice – For each of the questions below, choose the most appropriate answer.

In any collision
kinetic energy is always conserved.
Momentum is always conserved.
Both kinetic energy and momentum are always conserved.
Neither kinetic energy nor momentum are always conserved.

Momentum is a
a. vector b. scalar c. unitless quantity d. constant for all objects

In a perfectly inelastic collision,
total kinetic energy is constant
the velocity of separation equals the velocity of approach
the final momentum is always zero
the colliding objects stick together

Part 2: Vocabulary Review – Match the following terms with the correct definition. There may be extra definitions.

____ 4. Joule
b. energy of position
c. energy can never be created or destroyed, only changed from one form to another
d. energy of motion
e. total measure of all forms of energy
f. occurs when object separate without deformation
g. proportional to mass and velocity
h. objects have same final velocity after collision
i. equal to velocity squared
j. deformation causes a loss of kinetic energy

a. measure of kinetic or potential energy
Clayon, being an avid skydiver, is doing a jump from his private G6 jet 3500m above the ground. At the instant he jumps, his jet is traveling at 150 m/s.

At the instant he jumps, what is his kinetic energy?

At the instant he jumps, what is his gravitational potential energy?

At the instant he jumps, what is his total energy?

Find Clayon’s velocity:

When he is at 1750m (halfway down)
Right before he hits the ground (where a trampoline will break his fall 😊 )
Chelsea is cruising around town in her 2000 kg Mercedes at 45 m/s. Some thoughtless jerk rear-ends her with his 2300 kg Lexus doing 55 m/s. After they collide, Chelsea’s car has a velocity of 50 m/s.

What is Chelsea’s initial momentum?

What is the thoughtless jerk’s initial momentum?

What is Chelsea’s final momentum?

d) Using all of that, what is the thoughtless jerk’s final velocity?
1. What is the speed of an object at rest?
   a. 0.0 m/s  
   b. 1.0 m/s  
   c. 9.8 m/s  
   d. 9.81 m/s

2. Which of the following situations represents a negative displacement? (Assume positive position is measured vertically upward along a $y$-axis.)
   a. A cat stands on a tree limb.
   b. A cat jumps from the ground onto a tree limb.
   c. A cat jumps from a lower tree limb to a higher one.
   d. A cat jumps from a tree limb to the ground.

3. Which of the following units is the SI unit of velocity?
   a. meter  
   b. meter \cdot second  
   c. meter per second  
   d. second per meter

4. In the graph above, a toy car rolls from +3 m to +5 m. Which of the following statements is true?
   a. $x_f = +3$ m  
   b. $x_i = +3$ m  
   c. $\Delta x = +3$ m  
   d. $v_{avg} = 3$ m/s

5. Acceleration is defined as
   a. rate of displacement.  
   b. the rate of change of displacement.  
   c. the change in velocity.  
   d. the rate of change of velocity.

6. What is the SI unit of acceleration?
   a. m/s  
   b. m$^2$/s  
   c. m/s$^2$  
   d. m$\cdot$s$^2$

7. When a car’s velocity is positive and its acceleration is negative, what is happening to the car’s motion?
   a. The car slows down.  
   b. The car speeds up.  
   c. The car travels at constant speed.  
   d. The car remains at rest.
8. Explain how a dog that has moved can have a displacement of zero.

______________________________________________________________
______________________________________________________________

PROBLEM

9. A biker travels at a constant speed of 18 km/hr along a 200 m straight segment of a bike path. How much time does the biker take to travel this segment?

10. A car traveling south at 17 m/s coasts to a stop in 8 seconds.
   (a) What is the acceleration of this car?

   (b) How far did this car travel during these 8 seconds?
\[ v_f = v_i + at \]
\[ v_f^2 = v_i^2 + 2a\Delta x \]
\[ \Delta x = v_it + \frac{1}{2} at^2 \]

\[ G = 10^9 \]
\[ M = 10^6 \quad k = 10^3 \]
\[ c = 10^{-2} \quad m = 10^{-3} \]
\[ \mu = 10^{-6} \quad n = 10^{-9} \]
College Prep Homework
An elevator is at rest on the ground floor. A 75 kg man enters the elevator.

Draw and label the FBD for the man in the elevator.

The elevator accelerates upward at 1.5 m/s². Draw and label the FBD for the man in the accelerating elevator.

Determine the apparent weight of the man in the elevator as it accelerates upward.

Upon nearing the intended destination, the elevator accelerates to a stop. If the magnitude of the acceleration is 3.5 m/s², determine the apparent weight of the man.

The elevator then moves down, traveling at a speed of 5.5 m/s. If it slows to a stop, explain the direction of the man’s acceleration and the relative magnitude of the apparent weight.

As the elevator moves upward in dynamic equilibrium, draw and label an FBD for the elevator.

As the elevator slows to a stop, draw and label the FBD for the elevator. Explain any changes in the forces in the FBD.
Conceptual Questions:

What does it mean for an object to accelerate?
Can an object’s velocity vector and acceleration vector point in the same direction? If so, describe the object’s motion.
Can an object’s velocity vector and acceleration vector point in the opposite direction? If so, describe the object’s motion.
Can an object be moving and have an acceleration of zero?
Can an object be stationary and have a nonzero acceleration?
What does it mean for a graph to have positive area and negative area (for a velocity vs. time graph specifically)?
What does it mean for an object to have a nonzero acceleration?

Graphical Questions:

For the following graph, draw the velocity vs. time and the acceleration vs. time graphs.

For the following graph, draw the position vs. time and acceleration vs. time graphs.
A car with an initial positive velocity slows to a stop with a constant acceleration. Which graph best represents its position vs. time graph?


Which graph best represents the velocity vs. time graph?


Vocabulary: What is a practical, useful, definition for the following terms?
Acceleration
Acceleration due to gravity
Acceleration-time graph
Apparatus
Average velocity
Comes to a stop
Constant
Displacement
Distance
Final velocity
Free fall
From rest
Inertia
Initial
Initial velocity
Instantaneous
Is launched
Is dropped

Kinematics
Linear
Parabolic
Position-time graph
Rate
Rate of change
Reference frame
Scalar
Slope
Speed
Uniform motion
Velocity
Velocity-time graph
Vector
KWL Chart: This exercise is designed to help you identify the things that are most familiar to you about the upcoming material, while also revealing some of the things you may not have seen before. Please lease 3 things you already knew about the material after you have completed the reading, followed by 2 things you want to know, and 1 thing that you learned in the process. Work hard!

Know:

Want to Know:
Learned:
AP Physics – Momentum and Collisions

Which of the following is/are true? Justify your answers. Conservation of the total momentum of a system …
Holds only when mechanical energy is conserved.

Holds for any system

Follows from Newton’s second law

Is equivalent to Newton’s third law

A rocket is propelled forward by ejecting gas at high speed. The forward motion is a consequence of
conservation of energy
conservation of momentum
both of the above
neither of the above

The impulse delivered to a body by a force is
defined only for interactions of short duration
equal to the change in momentum of the body
equal to the area under an F vs. x graph
defined only for elastic collisions

In an elastic collision,
energy is conserved
momentum is conserved
the magnitude of the relative velocity is conserved
all of the above

In an inelastic collision
both energy and momentum are conserved
energy is conserved
momentum is conserved
neither is conserved

In two dimensional elastic collisions, the conservation laws allow us to determine the final motion
place restrictions on possible final motions
do not allow us to say anything about the final motion
are not covered in this chapter
A steel ball is dropped from a height of 2.37 m onto a flat stone table. On rebounding, the speed of the ball is 3.94 m/s when it is 1.52 m above the stone slab. Is the collision elastic? Justify your answer.

A 0.145-kg baseball is thrown by a pitcher, and travels in the direction as indicated below. The ball is traveling 35.2 m/s and is stopped in 0.163 seconds by a catcher’s mitt. (a) What is the average acceleration of the ball? (b) What is the average force on the catcher’s mitt?

Due to a sleeping technician, two trains are approaching each other on the same linear track. The first train, mass of 110,000 kg, is traveling at 45 km/hr. The second train has a mass of 75,000 kg and is moving at 70 km/hr.

Which train has the larger initial momentum (magnitude only)?
If the trains collide and stick together, what is their final velocity?
If the trains collide and stick together, how much kinetic energy was LOST in the collision?

Physics – Chapter 4 FBD Exercise
Directions – On an attached paper, draw and label an FBD for the following scenarios. Draw the forces on the object in **bold** only. Unless otherwise stated, assume friction to be present. Then create the \( \Sigma F_x \) and \( \Sigma F_y \) formulas.

- A **book** is at rest on a horizontal table.
- A **book** is pushed across a horizontal, frictionless table.
- A **person** is standing in a stationary elevator.
- A **person** is standing in an elevator that is slowly rising.
- A **person** is standing in an elevator that is slowly falling.

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A person is standing in an elevator that is slowly falling.

Physi...
A person is standing in a stationary elevator.
A person is standing in an elevator that is slowly rising.
A person is standing in an elevator that is slowly falling.
A box is pulled across a horizontal, frictionless table by a rope that is 45° above the surface of the table. The box has a mass of 75 kg. Determine the tension in the rope if the box accelerates at 1.2 m/s² across the table.

(These directions are very specific to this problem. Follow these steps to get the final answer.)

Draw and label the FBD for the box.
Establish your reference frame.
Resolve any force not lying on your reference frame.
Create the two force formulas (ΣFₓ and ΣFᵧ).
Write the other force formulas you have available (Friction and Weight formulas). Now you have 4 formulas to choose from.
You are looking for the tension. Choose one of the formulas that have tension and rearrange the formula so tension is by itself. Do not plug in numbers yet.
Are you missing any information from this tension formula? If so, go to one of the other 3 formulas to find this missing information.
Once you have found all missing information, plug the values into the tension formula and solve.
A car broke down in the Doherty parking lot. A group of students work together to push the car back across the flat parking lot. The car has a mass of 1500 kg, and the coefficient of friction between the tires and the parking lot is 0.45. Determine the applied force created by the students if the car has an acceleration of 0.75 \text{ m/s}^2.

(These are general directions – good problem solving strategy for any problem)

1. Establish your reference frame.
2. Resolve any force not lying on your reference frame.
3. Create the two force formulas ($\Sigma F_x$ and $\Sigma F_y$).
4. Write the other force formulas you have available (Friction and Weight formulas). Now you have 4 formulas to choose from.
5. Identify the unknown (what are you looking for in this problem?). Choose one of the formulas that have this unknown and rearrange the formula so this quantity is by itself. Do not plug in numbers yet.
6. Are you missing any information from this formula? If so, go to one of the other 3 formulas to find this missing information.
7. Once you have found all missing information, plug the values into the first formula and solve.
Directions – Shown below are several physics situations. For each situation, create the list of physics quantities. Identify the unknown quantity. Finally, write the formula that is the best choice for solving the problem. Rearrange the formula to get the unknown quantity by itself. Do NOT substitute the values, except for any term that is zero. You do NOT have to solve the problem.

Example: A car accelerates from rest to a speed of 18 m/s. It travels 38 m. What is the car’s acceleration?

\[ \Delta x = 38 \text{ m} \quad \text{No conversions necessary.} \]
\[ v_i = 0 \text{ m/s} \]
\[ v_f = 18 \text{ m/s} \]
\[ a = ? \]

\[ v_f^2 = v_i^2 + 2a\Delta x \]
\[ v_f^2 = 2a\Delta x \]
\[ a = \frac{v_f^2}{2\Delta x} \]

A ball is thrown off the roof of the school. You throw the ball down at 5 m/s, and 1.2 s later, it hits Mr. Staley on the head. He was 3.75 m below you. Determine the acceleration of the ball.

\[ \Delta x = \]
\[ v_i = \]
\[ v_f = \]
\[ t = \]
\[ a = \]

You are riding your bike down the street. You see a large puddle 150 m ahead of you and apply your brakes. If your brakes cause you to decelerate at -3.75 m/s² until you come to a stop, how fast were you initially going?

\[ \Delta x = \]
\[ v_i = \]
\[ v_f = \]
\[ t = \]
\[ a = \]

At the beginning of a race, a runner is perfectly still. As the race begins, she accelerates at 2.1 m/s² for 3 seconds. How far does she travel in this time?
How much time is needed for a plane to accelerate at 10.5 m/s² from rest to a final speed of 120 m/s?

A boat travels 7.5x10² m across a large lake, moving with no acceleration. If the boat needed 3 hours to move this distance, how fast was it going?

Mathematics Review:
There are three formulas we have used so far. Sometimes you will have to rearrange the formula to isolate the unknown. In general, there are a few rules to do this:

- Get the unknown variable into the numerator. Usually this is done by cross multiplying.
- Once the unknown is in the numerator, leave it alone.
- Any term that is being added or subtracted to the unknown, move this term to the other side of the equation by using the opposite operation.
- Any term that is being multiplied to or divided by the unknown, move this term to the other side of the equation by using the opposite operation.
- Solve for the unknown.

Example: \( x = x_i + v_i t + \frac{1}{2} a t^2 \)     Solve this formula for \( v_i \)
Practice:

\[ v_f = v_i + at \] (solve for a) \hspace{1cm} v_f^2 = v_i^2 + 2a\Delta x \] (solve for a)

\[ x = x_i + v_i t + \frac{1}{2} at^2 \] (solve for a) \hspace{1cm} v_f^2 = v_i^2 + 2a\Delta x \] (solve for \( v_i \))

Directions: Listed below are several questions using the rules of 1 dimensional motion (kinematics). For each, complete the following:

- Make a list (x, x_i, v_i, v_f, a, t)
- Indicate your reference frame
- Write the formula you will use
- Rearrange the formula to isolate the unknown variable
- Plug in the values from your list and solve
- Check your work. Is the answer reasonable?

A car accelerates at 1.3 m/s^2 for 5 seconds. The car traveled 45 meters. How fast was the car initially moving?
A ball is thrown down from the top of 120 m tall building. It acceleration due to gravity, 9.8 m/s², causes the velocity to increase. When it hits the ground, its velocity is 50 m/s. How fast was the ball thrown?
College Prep Quizzes
Quiz: Chapter 4
Part 1: Short Answer Response – Using complete sentences, answer the following. Include all relevant information.
Briefly describe Newton’s three (3) Laws of Motion. Include any equations, properly labeled, that might aid in the description.

For each of the following situation, draw an FBD on all objects identified in *italics*. Then create the standard starting formulas for the system.
A book slides down a steep incline at constant velocity
A child swings from a rope and is at the maximum height of its trajectory
Two masses are connected via strings and are at rest on the frictionless incline.

a. b. c.
Provide 3 characteristics or properties for each force identified below.

**WEIGHT**
- 
- 

**FRICTION**
- 
- 

**TENSION**
- 
- 

**NORMAL**
- 
- 

Part 2: Open Response Problems – Listed below are two problems either from or similar to the homework and classwork problems. Complete both problems. For each, show all necessary work. Include formulas, FBD’s, diagrams, reference frame, etc. Be sure your work is neat, legible and organized.

A 52-kg box is sliding up a frictionless incline of 58°. This box is connected to a large mass (80 kg) that is suspended over a pulley at the top of the incline.

Draw and label an FBD of the situation described above. Be sure to clearly indicate your reference frame.

Create the net force equations (both x and y) for each mass.

A 52-kg man is standing in a hot-air balloon that is resting on the ground. What force does the man exert on the balloon under the following conditions?

The balloon accelerates up off the ground with an acceleration of 2.10 m/s².

The balloon accelerates up off the ground with an acceleration of 2.10 m/s².
The balloon rises with a constant velocity of 4.35 m/s.

The balloon decelerates at a rate of 1.45 m/s² until it comes to a stop floating in the air.
Physics Quiz: Forces

Part 1 – Multiple Choice. Identify the choice that best completes the statement or answers the question.

Which of the following is the cause of an acceleration?

a. speed  b. inertia  c. force  d. velocity

A free body diagram represents all of the following except

a. the object  b. forces exerted by the object
 c. forces as vectors  d. forces exerted on the object

A free body diagram of a ball falling in the presence of air friction would show

only a downward arrow to represent the force of air friction.

Only a downward arrow to represent the weight force

A downward arrow to represent the weight force and an upward arrow to represent the force of air friction

An upward arrow to represent the weight force and a downward arrow to represent the force of air friction

The magnitude of the gravitational force acting on an object is

a. frictional force  b. weight  c. inertia  d. mass

Friction

acts parallel to the surfaces in contact

is independent of the nature of the materials in contact

acts in the direction of motion of the object

depends on the area of contact

Part 2: Free Body Diagrams. Written below are 4 situations. For each, draw and label the FBD.

<table>
<thead>
<tr>
<th>A skier is pulled by a level rope along a flat, frictionless field</th>
<th>A man stands in an elevator that is rising at a constant speed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A child pulls a toy across a rough floor by a string that makes an angle of</td>
<td>A man stands in an elevator that is rising with a constant acceleration</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 3: In part 2, you created an FBD for each situation. There was one question in the box above that was italicized. For this ONE problem only, create the starting equations. If you need to resolve any of the forces, please do so.

\[ \Sigma F_x \quad \Sigma F_y \]
List all common prefixes discussed in class, their symbol, and their value.

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fill in the remaining two representations of each given quantity. For problems (b) and (c), be sure to use the metric prefix indicated.

<table>
<thead>
<tr>
<th>Standard Form</th>
<th>Scientific Notation</th>
<th>Metric Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td></td>
<td>5.88 mg</td>
</tr>
<tr>
<td>b 90100000 meters</td>
<td>6.74x10^9 g</td>
<td>Mm</td>
</tr>
<tr>
<td>c</td>
<td>6.74x10^9 g</td>
<td>cg</td>
</tr>
<tr>
<td>d</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Below is the velocity-time graph of an object moving along a straight path. Use the information in the graph to fill in the table below.

![Velocity-time graph](image)

For each of the lettered intervals below, indicate the motion of the object (whether it is speeding up, slowing down, or at rest), the direction of the velocity (±, −, or 0), and the direction of the acceleration (±, −, or 0).

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Motion</th>
<th>v</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
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The graph below shows the motion of a dog pacing along a fence. Refer to the graph to answer questions 4-7.

4. For the five time intervals shown, during how many intervals does the dog have the same average velocity?
   a. 0  
   b. 1  
   c. 2  
   d. 3  

5. For the five time intervals shown, during how many intervals does the dog pace at the same average speed?
   a. 0  
   b. 1  
   c. 2  
   d. 3  

6. Describe the dog's motion when it is at 1.0 m.

   ____________________________________________________________

   ____________________________________________________________

9. The graph at right describes the motion of a ball. At what point does the ball have an instantaneous velocity of zero?
   a. A  
   b. B  
   c. C  
   d. D  

   ____________________________________________________________

   ____________________________________________________________
Use the graph below to answer questions 10–12.

**Motion of a Cat**

**10.** During which interval is the cat at rest?
   - a. 0.0–5.0 s
   - b. 5.0–10.0 s
   - c. 10.0–15.0 s
   - d. 15.0–20.0 s

**11.** The cat has the fastest speed during which interval?
   - a. 0.0–5.0 s
   - b. 5.0–10.0 s
   - c. 10.0–15.0 s
   - d. 15.0–20.0 s

**12.** During which interval does the cat have the greatest positive velocity?
   - a. 0.0–5.0 s
   - b. 5.0–10.0 s
   - c. 10.0–15.0 s
   - d. 15.0–20.0 s

**13.** Which of the following line segments on a velocity versus time graph is physically impossible?
   - a. horizontal line
   - b. straight line with positive slope
   - c. straight line with negative slope
   - d. vertical line
College Prep Reading
AP Physics
Chapter 4 Study Guide

As you read through chapter 4, consider the following questions. Answer these to the best of your ability.
Is a force a vector quantity or a scalar quantity? What are the units for force? Write this force unit in SI units (meters, seconds, kilograms, etc).

Compare and contrast between field forces and contact forces.

List 5 properties that can describe any force.

Define Newton’s First Law. Provide any alternate names for this law. What does this law imply with respect to any physics concept? What are the mathematical or formulaic applications?

What is mass? Does the size of a force affect the mass of an object? Why or why not?

Define Newton’s Second Law. Provide any alternate names for this law. What does this law imply with respect to any physics concept? What are the mathematical or formulaic applications?

Define equilibrium. Be sure to identify and differentiate between the two types of equilibrium.
The relationship between a force between two objects and the distance between these objects is sometimes called an inverse square force. Briefly describe the mathematical relationship between \( r \) and \( F \).

Compare and contrast gravitational forces and weight.

Define Newton’s Third Law. Provide any alternate names for this law. What does this law imply with respect to any physics concept? What are the mathematical or formulaic applications?

Define the Normal force. What can be determined about the normal force with respect to direction, cause, acceleration, etc?

Define the tension force. What can be determined about the tension force with respect to direction, cause, acceleration, etc?

What is an FBD? Why is it necessary when working with forces? What forces are drawn on an FBD? What forces are NOT drawn on an FBD.
Draw and briefly explain the function of an Atwood machine. Try to determine the role tension, weight, reference frame, acceleration and mass have in the function of an Atwood machine. (See Example 4.10 on p. 100)

Define friction. What properties can be applied to frictional forces? Be sure to consider the direction, acceleration, cause and affect friction has in a situation.

Having read the chapter, what questions or confusions do you have? Try to clearly identify areas of confusion in the space below.

Chapter 5 Reading Guide

As you read this chapter, answer the following questions and consider the following prompts. All questions and prompts are presented chronologically with the sequence of the chapter.

List three facts explained about work W. (5.1)
Is work a vector or a scalar? Explain. (5.1)

List some forms that energy can take. Can you think of any that are not in the chapter? (5.2)

Explain the Work Energy Theorem in general terms. (5.2)

For those kinds of energy mentioned in the chapter, list each of them and the formula that goes along with it. (5.2)
What is the formula for elastic potential energy of a spring? What is the formula for work to compress a spring the same? Do you notice anything interesting about the two? (5.2)

What is the law of conservation of mechanical energy? What is the formula? What forms of energy can be used in this formula? (5.3)

What happens to the law of conservation of mechanical energy if you include non-conservative (or dissipative) forces? Write the updated formula in the case where friction acts. What is another name for a non-conservative force? (5.3, right at the end)

What are the units for power? Where have you heard of these units before? (5.4)

From pages 179-180, there are several formulas introduced. List all formulas provided for power P. Do you understand how these were developed? (5.4)
Summary: Define the following terms:
Energy
Chapter 5 Reading Guide

As you read this chapter, answer the following questions and consider the following prompts. All questions and prompts are presented chronologically with the sequence of the chapter.

Section 5.1:

List some forms that energy can take. Can you think of any that are not in the chapter?

List five facts explained about work W. One fact should be the formula [Refer to formula 5.2 (not 5.1)] and another should describe the units of work.

Is work a vector or a scalar? Explain.

Frictional forces can do work. The text refers to this as dissipative work. Explain this term.

Complete Quick Quiz 5.1 (p. 121). Explain your answer.

Section 5.2:

Explain the Work Energy Theorem in general terms.

Define Kinetic Energy.

Compare and contrast conservative and non-conservative forces.
Section 5.3:
Describe Potential Energy and its relationship to gravitational work and an object’s weight.

We said energy and work are scalar quantities, though a reference frame is still needed (p. 129). Explain.

What is the law of conservation of mechanical energy? What is the formula? What forms of energy can be used in this formula?

If work on an object and a change in the object’s energy are equivalent expressions, how can you account for frictional forces in the Work-Energy Theorem?

Section 5.4:
What is Hooke’s Law? Write down the two formulas provided. (Hint: one formula is for force, the other is for work)

Why is there a $\frac{1}{2}$ in the work formula for Hooke’s Law?
Why is the formula for elastic potential energy of a spring and the formula for work to compress a spring the same?

Section 5.5: (read, but no questions)
Section 5.6:
What are the units for power? Where have you heard of these units before?

Equation 5.23 (p. 143) depicts several alternative formulas for Power. List all formulas provided for power P. Do you understand how these were developed?

Section 5.7: (read, but no questions)

Summary: Can you define the following terms?
As you read this chapter, answer the following questions and consider the following prompts. All questions and prompts are presented chronologically with the sequence of the chapter.

List three facts explained about work W. (5.1)

Is work a vector or a scalar? Explain. (5.1)

List some forms that energy can take. Can you think of any that are not in the chapter? (5.2)

Explain the Work Energy Theorem in general terms. (5.2)

For those kinds of energy mentioned in the chapter, list each of them and the formula that goes along with it. (5.2)
What is the formula for elastic potential energy of a spring? What is the formula for work to compress a spring the same? Do you notice anything interesting about the two? (5.2)

What is the law of conservation of mechanical energy? What is the formula? What forms of energy can be used in this formula? (5.3)

What happens to the law of conservation of mechanical energy if you include non-conservative (or dissipative) forces? Write the updated formula in the case where friction acts. What is another name for a non-conservative force? (5.3, right at the end)

What are the units for power? Where have you heard of these units before? (5.4)

From pages 179-180, there are several formulas introduced. List all formulas provided for power P. Do you understand how these were developed? (5.4)
Summary: Define the following terms:
Momentum and Collisions
Reading guide
As you read Chapter 6, answer the following. The answers appear in sequence with the reading of these chapters.

Section 6.1
Define linear momentum. What is the formula? Units? Is momentum a scalar or vector? Explain.

What are the two formulas for impulse? (Note – look on the equation sheet for the symbol for impulse) Explain why the formula uses the average force.

Explain why impulse is a vector quantity. How could you determine the direction of this vector?

Section 6.2
What is the law of conservation of linear momentum? Explain what a net external force (or isolated) of zero really means. (Do not state that the sum of the external forces add to zero. I got that.)

What is the formula for the law of conservation of linear momentum? How would this change if a third object were added to the situation?
Section 6.3
What are the three types of collisions? Identify them by name, kinetic energy conservation status (is K conserved or not) and by description of what occurs during the collision.

How does the formula for the law of conservation of linear momentum change when a collision occurs in 2 dimensions? Why is this change necessary? (Remember chapter 3) What will be needed when starting a momentum problem? (Hint: R__ F__)

For what situations is the law of conservation of linear momentum valid? For what situations is the law of conservation of mechanical energy valid? (Hint – think of examples where these laws are not true)

Section 6.4
Read the glancing collisions section. This section introduces conservation of momentum in a 2 dimensional situation. Explain how to account for x- and y-dimensions in momentum.
Review the problem solving strategies on page 174 and page 177. Reflect on our problem solving strategies of the past. How are these strategies similar?

Section 6.5 – you can read this, but will not be a focus in this class.

Vocabulary: In order to become proficient at working at Physics, there is a certain amount of base information that must be learned. This basic information includes formulas and definitions. With this information memorized, you can then work to analyze complex motions, draw qualitative conclusions about the mechanics of interactions and have success at solving unique problems. Therefore, on Wednesday November 17th, everyone will be checked on their ability to provide the following functional definitions and recite the following formulas.

Momentum (definition and formula(s))
Impulse (definition and formula(s))
Law of Conservation of Linear Momentum (definition and formula(s))
Elastic Collision
Inelastic Collision
Perfectly Inelastic Collision
Reference Frame
Law of Conservation of Mechanical Energy (definition and formula(s))
Vector
Scalar
Conserved
Interact
Collision
Chapter 4: Course Material Developed and Class Analysis

Over the course of the 150 hours spent teaching, my perspective and approach to alternative methods of educating students changed and expanded daily. What worked for one student was not only not guaranteed to work on the next, it wasn’t even likely. As such, I, in collaboration with John Staley, developed a large variety of material to approach the subjects from. I feel that in some sense I was spoiled by the lack of major behavioral disorders in both of my classes, and thus was not greatly challenged to find new ways of interesting the students, which is not to say that there was no challenge. That is also not to say that there were no behavioral disorders; at times the students needed to be reminded of their focus for the day’s work, or perhaps that I was not one of their peers, but rather their instructor. Indeed, I found that, while students in both classes were content to subscribe to whatever method of teaching I had on hand, in some cases they were simply nodding and smiling, but weren’t actually absorbing anything. Determining which methods worked best for each group of students was difficult for this reason, as there was very little feedback to work with.

The development of course material and the subsequent reflection of its effect on the classroom addressed the primary educational standards (a)1,2,3,4.5.6, (b)1c,1d, and 2, all of which address the need to recognize the student’s individual wants and needs in terms of understanding material. At no point during the teaching process was the curriculum a static item; it was constantly changed and shifted to reflect the progress of the students, and adjusted to make careful note of the patterns emerging in terms of understanding and misconceptions.
Various teaching methods were used to convey daily objectives, the most prominent of which was a daily agenda placed on the side of the board so that all students would have a clear idea of what the daily process would be. This frequently resulted, in situations where time was short, in students asking what to do about the remaining topics on the board, or perhaps the homework, which involved material not yet covered. In these situations, the homework was either postponed or adjusted, but it was encouraging to know that students were paying attention to the daily roster.

Of course, I had/have no illusions of grandeur that I could accomplish this task on my own, it being my very first try. John Staley, my mentor, was my primary source of assistance in enhancing my own teaching abilities, and in situations where I was uncertain of how to progress or deal with a situation, he was present to help me through it. In my own right, however, I did my best to utilize my connections at WPI to acquire more interesting lab materials for students, and to keep the schedule planned but open to readjustment.

4.1 College Level Methods

In the college level group, it was found that, aside from outright lecturing, group problem solving was absolutely the most effective, not only because it generated the most discussion that remained on topic, but also because there was a greater potential to be there at the moment that the student(s) started having difficulties. By engaging the students with each other, they effectively became their own mentors, but they also had the resources (i.e. John and myself) in the moments when they felt their confidence waver. What was peculiar about the experience was the noticeable fact that, if given a problem set, students in the college level group were likely to
slack off and bounce from topic to topic in conversation and on paper. However, when handed one *single* problem, with many parts, the problem held the group’s attention. I hypothesized that students on this level felt overwhelmed by the idea of multiple problems, and gave up quickly; having only one problem (regardless of how many parts) was just a puzzle they could jump on and hopefully solve. This method of group dynamics, using one large board problem and having them piece it together, was interesting and useful, and definitively something I would try again.

I am both fortunate and unfortunate enough to have not have had any major behavioral issues in this class, as it allowed me to progress through the material unhindered. I feel, however, that I now lack experience in dealing with such matters, although every teacher ideally hopes that they will never have to. Without such naivety, I am concerned, although mentally prepared, to face such challenges. My only real experience with what could hardly be called a behavioral disorder was a student who refused to stop speaking while I was teaching. I use the term “refused” in the sense that I would warn him and he would continue anyway; there was never an actual confrontation on the matter. To deal with this, although I am not normally an advocator of negative attention, I would cease my lesson, which all of the other students were paying attention to, and wait quietly for him to notice. As a result, because he was the only one left speaking, the students suddenly turned their attention to him, which eventually brought his attention to me, and I could continue the lesson with little more than an annoyed glance in his direction.

There were no major absence issues to speak of in this class, although the majority of the students would arrive two or three minutes after the bell. This seemed to be a non-issue, and something that could be worked around, although in future classrooms I believe a brief experiment with score deductions or tardy lists would be a fast remedy. Before each class, worksheets and homework assignments were printed out with extra copies for those that would inevitably be lost, and for those that were absent. These were kept in the classroom, in a drawer
at the front end, for anyone that needed them. When absent students arrived (hopefully) the next day, the previous night’s work would be handed to them with the expectation that it be completed along with any other assignments, within the same amount of time given to the other students.

4.2 AP Level Methods

The AP was generally more receptive to a wide variety of material, and thus, while it wasn’t always necessary to change up the style we were teaching in, we tried to make a regular habit of doing so anyway. For the first two weeks of kinematics, the equations were taught from memory, lecture style, and individual assessments were given. When the class had finally warmed up to me somewhat, we switched the teaching style to reflect the weaknesses of the class and attempt to strengthen them, using PowerPoints, demonstrations, and group projects to spur discussion and interest. In one particular case, we gave students of booklets containing ranking tasks, which present one problem that the student must do several times to obtain a number of results and order the answers in a certain way. In contrast to the lecture style, this lets the student see what the equations actually do if you adjust the variables yourself. These “Scenario A, Scenario B” type problems, as they were dubbed, were important substitution problems that students found easiest to learn by experimentation rather than lecture.

A few days out of the month were kept aside as lab experimentation days, in which a variety of demonstrations could be performed for the students, and then a set task for them to accomplish, such as determining which variables of a swinging pendulum effect the period of oscillation. In one case, we reserved the computer labs for a couple days, in order to introduce the AP students to a website from NASA that houses a number of educational physics games
with highly interactive features. The result was bittersweet, in that the students found the material interesting, but only after several warnings to stay off of other games, websites, or generally other material not related to the topic on hand.

With this in mind, behavioral issues are a key point of interest in this class, as there seems to be a unique kind of discipline necessary in this environment. Unlike the lower levels, which seemed to require more individual, one-on-one attention to address singular issues, the AP level was actually much difficult to manage as a class. From what I can only seem to describe as a sense of superiority in their class ranks, a genuine air of control and authority was necessary to keep the class under control and aware of the task on hand. My age, which for all intent and purpose is not greatly apart from theirs, was decidedly a factor in their level of respect for me, as they felt (correctly) that they could relate to me, and misguidedly judged me as a peer with only slightly more authority. I am of the distinct impression that the class would have been significantly harder to manage had it not been for John Staley’s presence in the room at most times.

My sense of authority with these students, or others, is not fully developed, and I felt myself flip flop on issues I had not generated sincere opinions on yet, such as phones being used as calculators, or doing work from other classes once the work from my class was complete. I feel that this demonstrates a need on my part to reflect on these issues a bit more, or at the very least to take an opinion on each matter and never waver in that class’ year, or else risk losing their perception of my authority. Although no formal confrontations occurred due to behavioral disorders, the AP class had a number of students with special considerations, such as extra (or in one case, unlimited) time on exams, backpacks and/or food being permitted to class for functional purposes, and psychological observations for counselor purposes, to name a few. As a result, discussion with the students on the matter also allowed time for me to ask them questions
as to what I could do better to improve their educational experience. The one on one discussions were a great help in identifying problems that students were actively aware of, but unwilling or afraid to point out in class among their peers.

4.3 Overall Thoughts On Developed Methods and Classes

While the appendix will display the variety of methods used to convey material to the students, my general thought on these methods is that, while diverse in nature, they reveal a singular pattern throughout. Lecturing is a very necessary method of teaching, and indeed it is difficult for me to think of alternative ways of introducing equations without this method at some points. Interactive material, however, whether it be experimentation, group problems, group discussions, or demonstration days, keep the students’ attention far better than methods that do not engage the students directly.

My general approach to lecturing was to keep the subcategories of the lecture as interesting as possible, varying my approach to days when new material was introduced using the board, the overhead, or PowerPoint presentations, each of which have their own merits.
Chapter 5: Assessments

By the same token of logic that not all students learn the same way, it is also fair to assume that not all students can successfully demonstrate their skills in the same way. It is a frequent fall back, which is sometimes very true, that some students are simply “bad test takers”; they panic without reason, even if they know the material very well, they over study, under study, study the wrong material, or simply don’t have the confidence to follow through with what they believe is the correct approach to a problem. As a result, relying purely on exams is a poor choice for any teacher who wishes to accurately gauge a student’s abilities. For this reason, multiple means of assessment were employed during my stay at Doherty High, which I will further discuss in pieces in order to dissect their purpose and intention.

Assessments cover the entirety of the 5 Standards of Education, as they not only reflect the student’s progress, but also the instructors ability to convey the material prior to each check. Maintaining class cohesion and individual attention, keeping pace with the intended schedule, carefully selecting homework assignments to test the day’s lectures or material covered, and identifying naïve schemas for the student’s model of the topic are all prerequisites to an assessment of any kind. As such, a successful assessment is a positive indicator of all of these standards; my time at Doherty saw a great deal of successful exams in both levels, which I feel is a positive reflection on my teaching abilities.

5.1 Homework
Students in every class, of every level, were regularly assigned homework (See Chapter 3.1.2, 3.2.2, and Appendix A3); if not every night, then at least 3-5 times per week, weekend homework included. Problem solving would only be assigned if the work would reflect the day’s topics, and would never be assigned ahead of the material we were working on. Reading, however, would be assigned as a way of preparing students for the coming lecture or activity, so as to streamline the process of introducing the material. In the case of reading assignments, since I have no ideas of grandeur that they would all truly read it without some consequence or incentive, a KWL chart (Know, Want to know, want to Learn, Chapter 3.2.2) would be required for the section assigned, so that I could get a good idea of where the pitfalls were in their understanding of the initial material.

The success rate of these small but important assignments was encouraging, and frequently resulted in an increased class participation rate the next day. Problems would often be collected and discussed (in that order) the next day. In situations where I discovered a common mistake or misconception, I found it useful to clear up the issue and allow an extension on the assignment, allowing for the possibility that the misconception could simply have been a poor explanation on my part.

5.2 Group Work

Once initial material had been covered to the extent that students would presumably have a working knowledge of it, a common method of assessing the class’ understanding was to break them off into groups, chosen at random, and have them work together on various assignments. In some cases the students would be solving problems together, which resulted in students having to explain their methods to each other in order to understand what was going on. Admittedly, in
some cases the students would revert back to working individually or simply ask for my help; in the latter case I would try my best to question their methods until they lead themselves to the answer, rather than simply explaining it. The use of Socratic Dialogue in the classroom proved to be an extremely effective tool in allowing the students to make their own conclusions by subtle guiding questions which made the physical concept, and thus the answer, more clear.

In order to work more conceptually students in groups would construct description charts (3.2.2) of the topic we were working on, with each group writing one thing down on a large piece of paper relevant to our studies, and moving on to the next group’s sheet. In the end each group had contributed something to each other’s sheets and produced 4 or 5 comprehensive lists describing our topic. Overall, group work was more difficult to manage, since there was frequently no score or consequence of not accomplishing the task at hand. Near the end of my teaching, I began holding the expectation that students in groups would turn in a single completed sheet with all of their names on it, to be graded and counted as a homework assignment (in terms of value). The result of this, a more stringent approach to homework collection, was a full awareness of the students that their homework should be completed each night, which placed full accountability on them.

Students, at times, appeared to be exploiting the potential ambiguity of whether an assignment was going to be turned in or not, and pleaded ignorance when it was time to come around for it. As such, the open class announcement that all homework assigned will be collected, even if only for a “completed” mark and not a specific grade, without exception, raised a red flag in many students’ minds, and thus the final result was a better influx of assigned work the following day.

5.3 Individual Class Work
Individual work was often the method of assessment that closely followed group work, since students had had a chance to be exposed to the problems and methods of solution, and now needed to try it on their own in an environment in which they were free to ask questions. Students were not forbidden from consulting their peers or their instructors, but the former choice was discouraged under the pretense that they now needed to formulate their own idea of how to solve problems, and where their unique difficulties lay. The individual work could range from problem sets, conceptual questions, or peer evaluation, which entailed students completing a problem set, then swapping papers with someone and grading it according to a specific rubric. The last assignment allows them to have their hand at the problems, and then see the correct solution while identifying common mistakes that they, or someone else, may have made. Individual work was most successful in identifying the students’ unique problems, allowing me to clear them up before a formal evaluation.

5.4 Quizzes and Exams

Once class and homework had been sufficiently evaluated, formal exams were administered for a slightly larger portion of credit, testing students on their ability to not only remember, but also apply the material discussed in class. Quizzes, depending on the material, were often very conceptual (3.1.3, 3.2.3, and A4), or simply involved blatant memorization, which I must concede is a necessary part of laying the foundations of basic physics. In short, they were not the means by which we would test their ability to fully grasp and apply the concepts, but rather the means by which we could intermittently check their progress in an environment more certain to provide incentive for them to study than homework.
Regrettably, assignment which hold greater weight in terms of grades usually provide the greatest incentive to study, thus more accurately reflecting their full potential. In an idealistic situation, they would study for every assignment simply because they found the material fascinating, but I have to do the best with what I have, and thus, for the time being, quizzes and exams are necessary.

Exams, which usually marked the halfway point or the completion of an entire section, were comprehensive in that they tested the students’ ability to grasp the situation, understand the problem, evaluate the best approach, and follow what usually amounted to a simple pattern to reach the solution. Problems on exams were often just slightly harder than those seen in class, with the notion that, with a proper conceptual understanding of the material, a more difficult problem shouldn’t add many more mathematical steps to the situation, but should instead take a slightly longer time considering the approach (3.1.1, 3.2.1, A2). The exam scores were often slightly below the homework scores and other assessments, which is, on some level, to be expected by a test that pushes the boundaries of the students’ abilities to conceptually understand a problem before tackling it mathematically.

The ability to regurgitate information is not a useful skill anywhere except in high school, and thus the exams were designed, after many class discussions and Critical Thinking Questions, group assignments and individual assignments, to help the students apply their conceptual knowledge in a practical setting, with questions that reflect real-life situations and bring the work to life.
Chapter 6: Conclusion

The time that I have spent teaching has certainly brought me a long way in terms of my idealistic expectations against my new, more realistic expectations. The public school system is every bit as I remember it, the initial difficulty was that I had forgotten much of what a high school student’s life is like, and thus had a faulty grasp of how to approach the material. At the start, I was told that I spoke too quickly, and hadn’t considered their level of understanding of the material, especially after four years of rigorous work at WPI. As time progressed I became more aware and in tune with their needs as students, both inside the classroom and out; many students not only have other homework to do, but sports, jobs, and other extracurricular activities. Gauging the happy balance of the proper amount of work to test their skills, while also respecting their other duties at this time in their lives was a difficult task, one that I feel I eventually accomplished.

John Staley, in some of the spare time before and after class, explained that he had spent time comparing and contrasting the results of assigning his students more and less homework each year, in combination with the knowledge the abundance of classes and other activities students were engaged in. Ultimately he found that his expectations of assigning homework almost every night were not unreasonable, as long as he varied the type of assignment. Students did not respond well in situations where night after night of problem worksheets were assigned, but could manage their time well enough if he staggered this type with other assignments, such as reading, lab preparation, or studying. During my time in the classroom I did my best to get a feel for this “optimal response level” by gauging homework and quiz scores by the level of effort put in. Eventually it became apparent that the problem worksheets did indeed need to be staggered
and varied in order to ease the tension of the workload, while also encouraging them to continue their studies. Time before quizzes and exams was also given in order to make sure that students could receive all of their work back in time to study, and also give them time to study as well.

Additionally, the classroom dynamic (in each class) had its own starting friction, as my students were unfamiliar with me, but related to me as a peer, which made it difficult to establish the comfortable but respectful environment I wanted. In the end, humor seems to be the most effective method of developing a comfortable environment, while more subtle mannerisms, such as upholding previously mentioned class rules, develop the sense of authority and respect that keeps the classroom cohesive and well-managed. The experience of creating an atmosphere of understanding and acceptance among students that, at this time in their lives, are vying for recognition more among their peers than their elders (although I can hardly be called one), was a challenging but necessary task as well, as it allowed students the ability to ask questions in class without fear of heckling or rejection from their classmates. I found that the class sizes were also a key factor in managing the overall environment, as the college class was only 12 students, but the AP class was 24. As a result, the small discussions were easy to identify in one class, but not the other. These, however, was easily remedied in the moments when I was not at the board, as I could simply walk out into the class and speak to them from the center, which usually resulted in the side discussions ceasing by my sheer proximity.

Overall, I feel that teaching is a bittersweet process of learning for ourselves, but very scientific in nature. Each year, after having spent our time and energy learning the individual needs of our students, having found efficient methods of education among them, and having developed the proper means of dealing with behavioral disorders, we must start fresh with a new class and begin the process again. As time passes, I will certainly see trends, common distributions if you will, of methods that are most efficient and well accepted in each class, along
with the constant challenge of improving or creating new methods of edifying students that do not respond to my current ways. The experience at Doherty Memorial High School has given me much to reflect on for myself, but has also provided me valuable experience and insight into how to prepare for my career as an educator.
Chapter 7: Appendix
Appendix A1: MA State Frameworks
## 1. Content Standards

### 1. Motion and Forces

*Central Concept:* Newton’s laws of motion and gravitation describe and predict the motion of most objects.

1. Compare and contrast vector quantities (e.g., displacement, velocity, acceleration force, linear momentum) and scalar quantities (e.g., distance, speed, energy, mass, work).
2. Distinguish between displacement, distance, velocity, speed, and acceleration. Solve problems involving displacement, distance, velocity, speed, and constant acceleration.
3. Create and interpret graphs of 1-dimensional motion, such as position vs. time, distance vs. time, speed vs. time, velocity vs. time, and acceleration vs. time where acceleration is constant.
4. Interpret and apply Newton’s three laws of motion.
5. Use a free-body force diagram to show forces acting on a system consisting of a pair of interacting objects. For a diagram with only co-linear forces, determine the net force acting on a system and between the objects.
6. Distinguish qualitatively between static and kinetic friction, and describe their effects on the motion of objects.
7. Describe Newton’s law of universal gravitation in terms of the attraction between two objects, their masses, and the distance between them.
8. Describe conceptually the forces involved in circular motion.

### 2. Conservation of Energy and Momentum

*Central Concept:* The laws of conservation of energy and momentum provide alternate approaches to predict and describe the movement of objects.

1. Interpret and provide examples that illustrate the law of conservation of energy.
2. Interpret and provide examples of how energy can be converted from gravitational potential energy to kinetic energy and vice versa.
3. Describe both qualitatively and quantitatively how work can be expressed as a change in mechanical energy.
2.4 Describe both qualitatively and quantitatively the concept of power as work done per unit time.
2.5 Provide and interpret examples showing that linear momentum is the product of mass and velocity, and is always conserved (law of conservation of momentum). Calculate the momentum of an object.

3. Heat and Heat Transfer

*Central Concept:* Heat is energy that is transferred by the processes of convection, conduction, and radiation between objects or regions that are at different temperatures.

3.1 Explain how heat energy is transferred by convection, conduction, and radiation.
3.2 Explain how heat energy will move from a higher temperature to a lower temperature until equilibrium is reached.
3.3 Describe the relationship between average molecular kinetic energy and temperature. Recognize that energy is absorbed when a substance changes from a solid to a liquid to a gas, and that energy is released when a substance changes from a gas to a liquid to a solid. Explain the relationships among evaporation, condensation, cooling, and warming.

3. Heat and Heat Transfer (cont.)

3.4 Explain the relationships among temperature changes in a substance, the amount of heat transferred, the amount (mass) of the substance, and the specific heat of the substance.

4. Waves

*Central Concept:* Waves carry energy from place to place without the transfer of matter.

4.1 Describe the measurable properties of waves (velocity, frequency, wavelength, amplitude, period) and explain the relationships among them. Recognize examples of simple harmonic motion.
4.2 Distinguish between mechanical and electromagnetic waves.
4.3 Distinguish between the two types of mechanical waves, transverse and longitudinal.
4.4 Describe qualitatively the basic principles of reflection and refraction of waves.
4.5 Recognize that mechanical waves generally move faster through a solid than through a liquid and faster through a liquid than through a gas.
4.6 Describe the apparent change in frequency of waves due to the motion of a source or a receiver (the Doppler effect).

5. Electromagnetism

*Central Concept:* Stationary and moving charged particles result in the phenomena known as electricity and magnetism.

5.1 Recognize that an electric charge tends to be static on insulators and can move on and in conductors. Explain that energy can produce a separation of charges.
5.2 Develop qualitative and quantitative understandings of current, voltage, resistance, and the connections among them (Ohm’s law).
5.3 Analyze simple arrangements of electrical components in both series and parallel circuits. Recognize symbols and understand the functions of common circuit elements (battery, connecting wire, switch, fuse, resistance) in a schematic diagram.
5.4 Describe conceptually the attractive or repulsive forces between objects relative to their charges and the distance between them (Coulomb’s law).
5.5 Explain how electric current is a flow of charge caused by a potential difference (voltage), and how power is equal to current multiplied by voltage.

5.6 Recognize that moving electric charges produce magnetic forces and moving magnets produce electric forces. Recognize that the interplay of electric and magnetic forces is the basis for electric motors, generators, and other technologies.

6. Electromagnetic Radiation

**Central Concept:** Oscillating electric or magnetic fields can generate electromagnetic waves over a wide spectrum.

6.1 Recognize that electromagnetic waves are transverse waves and travel at the speed of light through a vacuum.

6.2 Describe the electromagnetic spectrum in terms of frequency and wavelength, and identify the locations of radio waves, microwaves, infrared radiation, visible light (red, orange, yellow, green, blue, indigo, and violet), ultraviolet rays, x-rays, and gamma rays on the spectrum.

Scientific literacy can be achieved as students inquire about the physical world. The curriculum should include substantial hands-on laboratory and field experiences, as appropriate, for students to develop and use scientific skills in introductory physics, along with the inquiry skills listed below.

**SIS1. Make observations, raise questions, and formulate hypotheses.**

- Observe the world from a scientific perspective.
- Pose questions and form hypotheses based on personal observations, scientific articles, experiments, and knowledge.
- Read, interpret, and examine the credibility and validity of scientific claims in different sources of information, such as scientific articles, advertisements, or media stories.

**SIS2. Design and conduct scientific investigations.**

- Articulate and explain the major concepts being investigated and the purpose of an investigation.
- Select required materials, equipment, and conditions for conducting an experiment.
- Identify independent and dependent variables.
- Write procedures that are clear and replicable.
- Employ appropriate methods for accurately and consistently
  - making observations
  - making and recording measurements at appropriate levels of precision
  - collecting data or evidence in an organized way
- Properly use instruments, equipment, and materials (e.g., scales, probeware, meter sticks, microscopes, computers) including set-up, calibration (if required), technique, maintenance, and storage.
- Follow safety guidelines.

**SIS3. Analyze and interpret results of scientific investigations.**
• Present relationships between and among variables in appropriate forms.
  o Represent data and relationships between and among variables in charts and graphs.
  o Use appropriate technology (e.g., graphing software) and other tools.
• Use mathematical operations to analyze and interpret data results.
• Assess the reliability of data and identify reasons for inconsistent results, such as sources of error or uncontrolled conditions.
• Use results of an experiment to develop a conclusion to an investigation that addresses the initial questions and supports or refutes the stated hypothesis.
• State questions raised by an experiment that may require further investigation.

SIS4. Communicate and apply the results of scientific investigations.

• Develop descriptions of and explanations for scientific concepts that were a focus of one or more investigations.
• Review information, explain statistical analysis, and summarize data collected and analyzed as the result of an investigation.
• Explain diagrams and charts that represent relationships of variables.
• Construct a reasoned argument and respond appropriately to critical comments and questions.
• Use language and vocabulary appropriately, speak clearly and logically, and use appropriate technology (e.g., presentation software) and other tools to present findings.
• Use and refine scientific models that simulate physical processes or phenomena.

III. MATHEMATICAL SKILLS

Students are expected to know the content of the Massachusetts Mathematics Curriculum Framework, through grade 8. Below are some specific skills from the Mathematics Framework that students in this course should have the opportunity to apply:

✔ Construct and use tables and graphs to interpret data sets.
✔ Solve simple algebraic expressions.
✔ Perform basic statistical procedures to analyze the center and spread of data.
✔ Measure with accuracy and precision (e.g., length, volume, mass, temperature, time)
✔ Convert within a unit (e.g., centimeters to meters).
✔ Use common prefixes such as milli-, centi-, and kilo-.
✔ Use scientific notation, where appropriate.
✔ Use ratio and proportion to solve problems.

The following skills are not detailed in the Mathematics Framework, but are necessary for a solid understanding in this course:
- Determine the correct number of significant figures.
- Determine percent error from experimental and accepted values.
- Use appropriate metric/standard international (SI) units of measurement for mass (kg); length (m); time (s); force (N); speed (m/s); acceleration (m/s²); frequency (Hz); work and energy (J); power (W); momentum (kg•m/s); electric current (A); electric potential difference/voltage (V); and electric resistance (Ω).
- Use the Celsius and Kelvin scales.
Accelerating Cars

Introductory Physics, High School

Acceleration is a concept Ms. Luke chooses to teach students early in her introductory physics class. Many students are aware that acceleration means that an object moves faster, but Ms. Luke has found that students often have difficulty articulating how to measure acceleration and graphically relating acceleration to changes in speed. She decides to teach these concepts by using something with which all her students are familiar: cars.

In an opening dialog, Ms. Luke and her students together define speed and velocity, and how they are calculated. They then move on to the more challenging concept of acceleration, including deceleration, no acceleration, and constant acceleration. Ms. Luke asks, “How can you tell something is accelerating?” One student quickly mentions using a speedometer. Another student mentions “that thing that measures how fast you walk,” which Ms. Luke identifies as a pedometer. “How can you use a speedometer, for example, to measure acceleration?” she asks. “Or, if you didn’t have an speedometer or pedometer, how would you know that the object is accelerating?”

After listening to student responses, without accepting or dismissing any of them, Ms. Luke proposes that the class go outside to observe whether cars that drive by the front of the school build up speed, slow down, or maintain a constant speed over a given distance. With the data students collect, they will relate what they see and hear to a graph of each car’s speed and an analysis of its acceleration.

The students are organized into small groups. Each group stands on the sidewalk along a stretch of road identified by Ms. Luke, separated from the next group by twenty meters. Ms. Luke has already marked off 20-meter increments. She has chosen to use a strip of road that begins at the stop sign in front of the school and includes the downward sloping hill beyond. Here she knows her students will have a good opportunity to observe different rates of speed and acceleration. The students are equipped with stopwatches and their lab notebooks. Each group knows to measure and record the time it takes a car to travel from the stop sign to their position. They are also instructed to record observations of each car while it is in their assigned zone, including the sound of its engine and whether the brake lights are on. The groups record data for five cars identified by Ms. Luke before going back into class to work through their calculations, graph their data, and answer the key questions of the activity.

Upon reentering the classroom, the students record their data on the board. Ms. Luke asks one student to demonstrate how to calculate the speed of one car, within that student’s assigned zone, using the data from the student’s group plus the data of the group positioned just uphill of them. Each group then records the speed of each car in their zone on a class chart for everyone to see. Ms. Luke also asks students to relate these calculations to their observations of the cars. Ms. Luke then asks her students to consider, “What does the graph of the speed of each car over the entire stretch of road look like?” She has each student make a position vs. time graph and a velocity vs. time graph for each car. Ms. Luke has the students annotate each graph with their observations of that car. From these graphs the class compares change in speed for the cars relative to each other.

Ms. Luke then asks the class to focus on the speed vs. time graph of the first car, which she projects for everyone to see. They notice that the points on the graph do not form a continuous straight line across the grid, but instead go up, straight across, and then down slightly in the last segment. “What does this mean?” she asks. “It means that the car sped up and slowed down,” offers one student. “It means that the
car accelerated from here to here,” another student points out on the graph, “but then it stopped speeding up from here to here.” She asks the students to confirm this against their observations of the car.

Ms. Luke then says to the class, “Determine if each car accelerated, decelerated, or showed no acceleration over any period of time. If a car did accelerate or decelerate at some time, did it keep doing so at the same rate?”

Finally, Ms. Luke instructs the students to circle and notate the places on each graph where that car possibly accelerated, decelerated, or showed no acceleration. To quantify the areas circled, she has the students calculate the acceleration from one zone to the next, pointing out that a negative result means that the car slowed down or decelerated, and a zero result means that the car maintained its speed. Ms. Luke also instructs her students to look for instances where the acceleration is the same for two or more adjacent places on the graph, and to label those instances as constant acceleration.

Assessment Strategies
- Students should pay particular attention to the construction and labeling of graphs. They should use units appropriately throughout their work.
- Students can write out a scenario that aligns with the changes in speeds on the graphs they have created themselves. Students should properly use the terms “speed,” “velocity,” “acceleration,” “deceleration,” “no acceleration,” and “constant acceleration” in their scenarios.
- As a follow-up assignment, the students can create a data chart that includes distance, time, and speed of a fictitious vehicle. With this data, they create a speed vs. time graph. Their data must show acceleration, deceleration, no acceleration, and constant acceleration on their graph. They should also calculate acceleration.

Introductory Physics Learning Standards
High School
1.1 Compare and contrast vector quantities (e.g., displacement, velocity, acceleration, force, linear momentum) and scalar quantities (e.g., distance, speed, energy, mass, work).
1.2 Distinguish between displacement, distance, velocity, speed, and acceleration. Solve problems involving displacement, distance, velocity, speed and constant acceleration.
1.3 Create and interpret graphs of 1-dimensional motion, such as position vs. time, distance vs. time, speed vs. time, velocity vs. time, and acceleration vs. time where acceleration is constant.

Scientific Inquiry Skills Standards that apply
High School
SIS2. Design and conduct scientific investigations.
- Employ appropriate methods for accurately and consistently
  o making observations
  o making and recording measurements at appropriate levels of precision
  o collecting data or evidence in an organized way
SIS3. Analyze and interpret results of scientific investigations.
- Use mathematical operations to analyze and interpret data results.
SIS4. Communicate and apply the results of scientific investigations.
- Explain diagrams and charts that represent relationships of variables.
Appendix A2: Additional Exams
Part 1: Multiple Choice – Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box in the table labeled “Part 1 Answers” at the end of this section.

Note: To simplify calculations, you may use \( g = 10 \text{ m/s}^2 \) in all problems.

1. An object is thrown with a horizontal velocity of 20 m/s from a cliff that is 125 m above level ground. If air resistance is negligible, the time that it takes the object to fall to the ground from the cliff is most nearly
   a. 3 sec                    b. 5 sec                   c. 6 sec                      d. 12 sec                   e. 25 sec

Questions 2 – 5 refer to the following diagram and caption:

2. At which of the following times is the ball farthest from the student?
   a. 1 sec                       b. 2 sec                         c. 3 sec                       d. 4 sec                      e. 5 sec

3. At which of the following times is the speed of the ball the least?
   a. 1 sec                       b. 2 sec                         c. 3 sec                       d. 4 sec                      e. 5 sec

4. Which of the following best describes the acceleration of the ball?
   a. It is downward and constant from 0 to 6 s.
   b. It is downward and increases in magnitude from 0 to 3 s, then decreases.
   c. It is downward and decreased in magnitude from 0 to 3 s, then increases.
   d. It is upward and increases in magnitude from 0 to 3 s, then decreases.
   e. It is upward and decreased in magnitude from 0 to 3 s, then increases.

5. What is the initial speed of the ball?
   a. 30 m/s                b. 45 m/s                      c. 60 m/s                      d. 90 m/s                     e. 180 m/s

6. A displacement vector is a
   a. Change in position.
   b. Velocity.
   c. Scalar.
   d. Distance without direction.
   e. Dimensionless quantity.

7. Three stones of different masses (1m, 2m, and 3m) are thrown vertically upward with different velocities (1v, 2v, and 3v respectively). Rank from high to low the maximum height of each stone. Assume air resistance is negligible.
   a. (high) I, II, III (low)
b. (high) II, I, III (low)
c. (high) III, II, I (low)
d. (high) I, III, II (low)
e. All stones reach the same height

8. An object is released from rest on a newly discovered planet. After 2 seconds, the object has moved 4 meters. What is the acceleration due to gravity on this planet?
   a. 16 m/s²  
   b. 10 m/s²  
   c. 8 m/s²  
   d. 4 m/s²  
   e. 2 m/s²

9. When an object falls freely in a vacuum near the surface of the Earth
   a. the velocity cannot exceed 10 m/s²
   b. the terminal velocity will be greater than when dropped in air
   c. the velocity will increase but the acceleration will be zero
   d. the acceleration will constantly increase
   e. the acceleration will remain constant

10. A ball is rolled off the edge of a horizontal table. The ball has an initial speed \( v_0 \) and lands on the floor some distance from the base of the table. Which of the following statements concerning the fall of the ball is FALSE?
   a. The time of flight depends on the height of the table.
   b. One of the components of the final speed will be \( v_0 \).
   c. The ball will accelerate.
   d. The ball will have a longer flight time if \( v_0 \) is increased.
   e. The ball will fall due to the force due to gravity.

11. Two objects are launched off a cliff. The first object, a large car, has an initial horizontal velocity of 20 m/s. The second object, a tennis ball, rolls horizontally off the cliff at 5 m/s. Which of the following statements is TRUE?
   a. The car will travel through the air for a longer period of time than the ball.
   b. The ball will travel through the air for a longer period of time than the car.
   c. The car will have a larger acceleration due to its larger mass.
   d. The ball will hit the ground with the same vertical speed as the car.
   e. The ball has a greater net velocity than the car when it collides with the ground.

12. The motion of a particle along a straight line is represented by the position versus time graph above. At which of the labeled points on the graph is the magnitude of the acceleration of the particle greatest?
   a. A  
   b. B  
   c. C  
   d. D  
   e. E

13. The maximum resultant of a 20 m displacement and a 4 m displacement is
   a. 5 m  
   b. 16 m  
   c. 20 m  
   d. 24 m  
   e. 80 m

14. The following variables are listed with their units.

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   Which of the following equations is NOT dimensionally correct?
   a. \( x = vt + \frac{1}{2} at^2 \)  
   b. \( F/t = mav \)  
   c. \( a = F/m \)  
   d. \( v^2 = ax \)  
   e. \( t = x/v \)
15. A person falls from a bridge spanning a rushing river, falling a distance \( h \) before hitting the water. Neglecting air resistance, what would be the person’s speed at the moment of impact?

a. \( v = \sqrt{2gh} \)  

b. \( v = \sqrt{mgh} \)  

c. \( v = \sqrt{gh/2} \)  

d. \( v = \sqrt{mgh/2} \)  

e. \( v = \sqrt{2mgh} \)

Part 1 Answers: Be sure to write clearly and in the correct, corresponding box. (3 points each = 45 points)

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Part 2: Open Response Questions – Answer all three questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for each question. The parts within a question may not have equal weight. Show all of your work in the area provided after each part. Use \( g = 9.8 \text{ m/s}^2 \) in all parts.

16. An arrow is shot from a castle wall 10 m high. It leaves the bow with a speed of 40 m/s directed 37° above the horizontal.

a. Find the initial velocity components.

b. Find the maximum height of the arrow.

c. If the ground is level, where does the arrow land?
d. How fast is the arrow moving just before impact?

17. A football is thrown to a moving football player. The football leaves the quarterback’s hands 1.5 m above the ground with a speed of 15 m/s at an angle of 25 degrees above the horizontal. If the receiver starts 10 m away from the quarterback along the line of flight of the ball when it is thrown, what constant velocity must he have to get to the ball at the instant it is 1.5 m above the ground?
18. A person is stuck inside a falling elevator, whose cable broke 10 meters above the ground. Let’s say the person wanted to cancel out their final velocity by jumping exactly when the elevator hits bottom. Assume the elevator started from rest.
   a. How long after the cable breaks would the person need to jump?

   b. In order to completely cancel their accumulated velocity, at which velocity (relative to the elevator) would they need to jump?

   c. If they were to jump at this velocity on stable ground, how high would they go? Is this reasonable?
d. Sketch a graph of the elevator’s position vs. time, velocity vs. time, and acceleration vs. time. Your graphs should reflect your choice of reference frame. Label the starting value of each dependent variable on each graph.
Chapters 4, 5, and 9: Test
Part 1: Multiple Choice. Listed below are several multiple choice questions from chapters 1, 2, 3, 4, 5, and 9. Complete all problems. Put all answers to the multiple-choice questions in the section labeled “Part 1 Answers.” You do not need to show any work for this section. For the multiple-choice questions, you may assume \( g = 10 \text{ m/s}^2 \). Work hard!

1. In the diagram below, a picture frame held by two ropes is at rest. Find the value of the tension in rope 1.

   ![Diagram of a picture frame held by two ropes](image)

   \( \sin 45 = \frac{\sqrt{2}}{2} \)

   a. 50 N    b. 70 N    c. 100 N    d. 140 N    e. 200 N

2. An object is held in uniform circular motion in a vertical circle by a length of taut rope. Which of the following best describes the forces acting on the object at the top of the circle?
   a. The tension in the rope upward and gravity downward
   b. The tension in the rope and gravity both downward
   c. The tension in the rope and gravity downward and the centripetal force upward
   d. The tension in the rope and gravity downward and the centripetal force downward
   e. The tension in the rope and the centrifugal force upward and gravity downward

3. An object is moving at some velocity, when a force is applied perpendicular to the velocity. Which of the following best describes what will happen?
   a. The velocity will not change
   b. The speed will increase but the direction will not change
   c. The speed will decrease but the direction will not change
   d. The speed will not change but the direction will change
   e. Both the speed and direction will change

4. Several distinct, massless strings connect three blocks as shown below. A force of 12 N acts on the system. What is the acceleration of the blocks and the tension in the rope attached to the 1-kg block?

   ![Diagram of three blocks connected by strings](image)

   a. \( \frac{4 \text{ m/s}^2}{6 \text{ N}} \)    b. \( \frac{2 \text{ m/s}^2}{2 \text{ N}} \)    c. \( \frac{2 \text{ m/s}^2}{12 \text{ N}} \)
d. 12 m/s² 6 N
e. 4 m/s² 3 N

5. In the apparatus shown below, what is the tension in the rope, if we assume constant velocity?

![Diagram of pulley system]

a. 39 N  b. 1.9 N  c. 50 N  d. 78 N  e. 100 N

6. A force F acts on object 1 of mass m₁. An identical force acts on object 2 of mass m₂. Object 1 experiences acceleration a₁ and object 2 experiences an acceleration a₂. If a₂ = 2a₁, what is m₂ in terms of m₁?
   a. ¼ m₁  b. ½ m₁  c. m₁  d. 2m₁  e. 4m₁

7. The figure below shows a pulley system in equilibrium.

![Diagram of pulley system with weights]

What is the weight read by the scale?
   a. 0 N  b. 10 N  c. 30 N  d. 40 N  e. 50 N

8. A person normally weighing 500 newtons steps on a bathroom scale in an elevator. If later, the scale reads 450 newtons, this indicates that the elevator is
   a. moving downward with a constant velocity
   b. accelerating downward
   c. moving upward with a constant velocity
   d. accelerating upward
   e. none of the above

9. Two masses, M and m, are hung over a massless, frictionless pulley as shown below. If M > m, what is the downward acceleration of mass M?

![Diagram of pulley system with masses]
10. Which of the following statements is/are false?
   I. The centripetal force on a mass on a string can never be greater than the weight of the object.
   II. An object with a net force of zero cannot have a nonzero net torque.
   III. A mass on a frictionless incline \((0^\circ < \theta < 90^\circ)\) must have some net acceleration.
   a. I only  b. III only  c. I and II only  d. II and III only  e. I, II, and III

11. A box of mass 10 kg slides on a surface at 30 m/s. The coefficient of friction between the box and the surface is 0.5. The amount of force needed to maintain a constant velocity for the box is most nearly
   a. 0.05 N  b. 0.5 N  c. 5 N  d. 25 N  e. 50 N

12. A 15 kilogram ball is suspended by a rope from the ceiling. The magnitude of the force exerted on the ball by the rope is most nearly
   a. zero  b. 1.5 N  c. 15 N  d. 150 N  e. 200 N

13. A ball is dropped from the top of a building. Ignoring air resistance, which of the following remains constant for the ball?
   a. velocity  b. acceleration  c. speed  d. displacement  e. distance

14. Two satellites A and B of the same mass are going around Earth in concentric orbits (circular orbits). The distance of satellite B from Earth’s center is twice that of satellite A. What is the ratio of the centripetal force acting on B to that acting on A?
   a. 1/8  b. ¼  c. ½  d. \(\sqrt{1/2}\)  e. 1

15. If the rod in the figure above is uniform and has mass m, what is the tension in the supporting string?

![Diagram of a rod and string](image)

   a. 0.5 mg sin \(\theta\)  b. mg sin \(\theta\)  c. 0.5 mg cos \(\theta\)  d. 0.5 mg  e. mg

16. The gravitational constant G is
   a. equal to g at the surface of the Earth
   b. different on the Moon than on Earth
   c. obtained by measuring the speed of falling objects having different masses
   d. none of the above

Questions 17 – 19 refer to a ball of mass m on a string of length R, swinging around in circular motion, with an instantaneous velocity \(v\) and centripetal acceleration \(a\).

17. What is the centripetal acceleration of the ball if the length of the string is doubled?
a. a/4        b. a/2        c. a        d. 2a        e. 4a

18. What is the centripetal acceleration of the ball if the instantaneous velocity of the ball is doubled?
   a. a/4        b. a/2        c. a        d. 2a        e. 4a

19. What is the centripetal acceleration of the ball if its mass is doubled?
   a. a/4        b. a/2        c. a        d. 2a        e. 4a

20. If we consider the gravitational force $F$ between two objects of masses $m_1$ and $m_2$ respectively, separated by a distance $R$, and we double the distance between the masses, what is the magnitude of the resulting gravitational force between them?
   a. $F/4$        b. $F/2$        c. $F$        d. $2F$        e. $4F$

Part 1 Answers: Write your answers using UPPERCASE LETTERS. (3 points each = 60 points)

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Part 2: Open Response Problems. Listed below are four (4) short answer problems. Complete all four. For each, show as much work as possible, including labeled values, formulae used, units, etc. Place a box around your final answer(s). Be neat and clear with your work. Work hard! Use $g = 9.8 \text{ m/s}^2$.

21. A simple cable-stay bridge consists of a uniform concrete span, with a mass of 15,000 kg, held up by two equal wire cables connected to the bridge’s center. The ends of the 200 m long concrete bridge rest on the edges of a river running underneath the bridge as shown in the diagram below.
During the strength testing of this bridge, engineers placed three large, dense blocks on the bridge. Three masses (5,000 kg, 5,000 kg and 10,000 kg) were placed at 20 m from the left edge, 40 m from the left edge and 30 m from the right edge respectively. Force sensors were placed at both river edges. The force sensor placed at River edge 1 was found to be 110,000 N. However, the force sensor at River edge 2 failed to provide a reading. If this bridge was observed to be in complete equilibrium, determine the upward force caused by the River Edge 2 on the bridge.
22. For a moment, a block is at rest at the top of the incline that is 4 m long. It is released and slides down the incline, then across a horizontal surface, and eventually comes to rest. The coefficient of friction between the block and all surfaces is 0.40. The angle of inclination is 37° above the horizontal. Find

a. the speed at the bottom of the incline
b. the time spent on the incline
c. the time on the horizontal plane before coming to rest
(10 points)
23. An 18 kg mass is hung from an ideal 1.5 m long string. The mass is spun in a horizontal circle at a constant speed. The string makes an angle of 25° with the vertical.
   a. What is the speed of the mass?
   b. What is the period of motion for the mass?
   c. What would the new period be if the mass was doubled to 36 kg, with the angle held constant? Justify your answer.
   d. If the angle is increased with the mass being held constant, does the tension in the string increase, decrease or stay the same? Justify your answer.
(10 points)

24. Consider the pulley apparatus shown below, along with the coefficient of friction indicated.

\[ \mu = 0.20 \]

a. Find the acceleration of the two block system.
b. What is the tension in the rope?
	now the hanging mass is removed from the rope and a downward force of 75 N is placed on the rope.
c. What will be the resulting acceleration of the system?
d. What is the new tension?
e. How much mass should be added to the first block for it to slide at constant velocity?
(12 points)
2. Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has
   a. As much kinetic energy as the lighter one.
   b. Twice as much kinetic energy as the lighter one.
   c. Half as much kinetic energy as the lighter one.
   d. Four times as much kinetic energy as the lighter one.
   e. Impossible to determine

3. A block initially at rest is allowed to slide down a frictionless ramp and attains a speed v at the bottom. To achieve a speed 2v at the bottom, how many times as high must a new ramp be?
   a. 1               b. 2                 c. 3                d. 4                     e. 5                   f. 6

4. A 4 kg mass initially moving at 10 m/s at the bottom of a 37° incline barely makes it to the top before coming to rest. The magnitude of the work done by friction is most nearly
   a. 320 J                  b. 200 J                  c. 120 J                d. 80 J                 e. 0 J

5. A ball of mass m drops off a tower of height h. The force of air resistance if F. What is the ball’s kinetic energy when it hits the ground?
   a. Fh                   b. mgh                   c. mgFh²            d. mgh – Fh               e. mgh + Fh

Questions 5 – 6 refer to the following diagram of a 1 kg mass suspended from a spring whose spring constant is k = 4 N/m. The system is in equilibrium when the center of mass is at point A.

6. If the mass is pulled from point A to point B, a distance of x meters from A, what is the energy stored in the spring?
   a. –kx       b. kx                c. –½kx²               d. ½ kx²                   e. 0

7. At point B, what is the force exerted on the mass by the string, if we now assume that x = 0.25 m?
   a. 1 N, pointing down
   b. 1 N, pointing up
   c. 0.25 N, pointing down
   d. 0.25 N, pointing up
   e. zero

8. A 4 kg mass moving east at 10 m/s collides with a 1 kg mass moving north at 40 m/s. The two masses stick together. Just after the collision, the speed of the combined objects is
   a. 8 m/s                  b. 8√2 m/s               c. 16 m/s                d. 50 m/s                 e. 30 m/s

9. In which of the following situations is momentum NOT conserved?
   a. Two objects coming from opposite directions collide and stick together.
   b. One object traveling parallel to another overtakes the second object and collides inelastically.
c. One object collides with a stationary object and both stick together after collision.
d. After a collision, it is determined that kinetic energy was lost in the system.
e. All of the above.
f. None of the above.

10. A mass on a frictionless surface is attached to a spring. The spring is compressed from its equilibrium position, B, to point A, a distance x from B. Point C is also a distance x from B, but in the opposite direction. When the mass is released and allowed to oscillate freely, at what point or points is its velocity maximized?


11. An open cart on a level surface is rolling without frictional loss through a vertical downpour of rain, as shown above. As the cart rolls, an appreciable amount of rainwater accumulates in the cart. The speed of the cart will
a. increase because of conservation of momentum
b. increase because of conservation of mechanical energy
c. decrease because of conservation of momentum
d. decrease because of conservation of mechanical energy
e. remain the same because the raindrops are falling perpendicular to the direction of the cart's motion

12. A mass m moving right with speed v on a smooth horizontal surface explodes into two pieces. After the explosion, one piece of mass 3m/4 continues in the same direction with speed 4v/3. Find the magnitude and direction for the velocity of the second piece.

a. v/3 to the left
b. The piece is at rest.
c. v/4 to the left.
d. 3v/4 to the left.
e. v/4 to the right.

13. A 2 kg mass slides across a smooth horizontal surface, moving at 5 m/s. It collides with a stationary 3 kg mass, and the two masses tick together. The mechanical energy lost as a result of the collision is closest to
a. 25 J                 b. 20 J                   c. 15 J                 d. 10 J                    e. 5 J

14. A moving object has kinetic energy $K = 100$ J and momentum $p = 50$ kg m/s. What is its mass?

a. 2 kg                  b. 4 kg                      c. 6.25 kg                         d. 12.5 kg                      e. 25 kg

15. A 0.2 kg hockey puck is sliding along the ice with an initial speed of 12 m/s when a player strikes it with a stick, causing the puck to reverse direction with a speed of 23 m/s. The impulse the stick applies to the puck is most nearly
a. -2 Ns             b. -6 Ns             c. -7 Ns             d. -70 Ns               -120 Ns
16. A heavy astronaut floating in space throws a small ball in one direction and subsequently recoils back with a velocity in the opposite direction. Which of the following statements is/are true?
I. The velocity of the ball is equal and opposite to the velocity of the astronaut.
II. The momentum of the ball is equal and opposite to the momentum of the astronaut.
III. The impulse applied to the ball is equal and opposite to the impulse applied to the astronaut.
   a. I only    b. II only    c. I and II only    d. II and III only    e. I, II, and III

17. A block of mass m slides with a speed v₀ on a frictionless surface and collides with another mass M which is initially at rest. The two blocks stick together and move with a speed of v₀/3. In terms of the mass m, mass M is most nearly
   a. m/4    b. m/3    c. m/2    d. 2m    e. 3m

18. The units of the product of momentum and kinetic energy can be expressed as
   a. J²·m/s²    b. J·m/s    c. J²/s·m    d. m/s    e. J²

19. A ball of mass M compresses a spring with a constant of k. The spring is compressed 30 cm and is released. What is the speed the instant the ball passes the equilibrium point?
   a. 0.3√(k/M)    b. 0.3k√M    c. 0.3M√k    d. 0.3 (√k)/M    e. Not enough information to find speed

20. A bullet moving with an initial speed of v₀ strikes and embeds itself in a block of wood which is suspended by a string, causing the bullet-block system to swing and rise to a maximum height h. Which of the following statements is true?
   a. The initial kinetic energy of the bullet before the collision is equal to the kinetic energy of the bullet and block immediately after the collision.
   b. The initial kinetic energy of the bullet before the collision is equal to the potential energy of the bullet and block when they reach the maximum height h.
   c. The initial momentum of the bullet before the collision is equal to the momentum of the bullet and block at the instant they reach the maximum height h.
   d. The initial momentum of the bullet before the collision is equal to the momentum of the bullet immediately after the collision.
   e. The kinetic energy of the bullet and block immediately after the collision is equal to the potential energy of the bullet and block at the instant they reach the maximum height h.

21. An object of mass M traveling at velocity V strikes an object of mass M/2 traveling at V/4 along the same path in the same direction perfectly inelastically. What is the resulting velocity?
   a. √(9MV/8)    b. 3MV    c. 3V/4    d. 4V/M    e. 4V/5

22. During an inelastic collision between two balls, which of the following statements is correct?
   a. Both momentum and kinetic energy are conserved.
   b. Momentum is conserved, but kinetic energy is not conserved.
   c. Momentum is not conserved, but kinetic energy is conserved.
   d. Neither momentum nor kinetic energy is conserved.
   e. Momentum is sometimes conserved, but kinetic energy is always conserved.

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Part 1 Answers (2.5 points each = 52.5 points)

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Listed below are three (3) questions. Answer all three. Each part within the question may not have the same weight. Be sure to show all relevant work. Use \( g = 9.8 \text{ m/s}^2 \). Be sure to circle your final answer(s). Work hard!

23. A bullet of mass \( m \) and velocity \( v_0 \) is fired toward a block of mass \( 4m \). The block is initially at rest on a frictionless horizontal surface. The bullet penetrates the block and emerges with a velocity of \( \frac{v_0}{3} \)

(a) Determine the final speed of the block.

(b) Determine the loss in kinetic energy of the bullet.

(c) Determine the gain in the kinetic energy of the block.
(12 points)
24. A 0.5 kg mass, resting on a smooth frictionless table 1 m high, is pushed into a spring with spring constant \( k = 200 \text{ N/m} \), as shown in the figure. With the spring compressed 0.5 m, the mass is released, and after it loses contact with the spring it collides with a stationary 2 kg mass. A graph of the force exerted on the 2 kg mass during the collision is shown below.

a. Determine the speed of the 0.5 kg mass after it has left the spring, but before it has hit the 2 kg mass.

b. Determine the speed of the 2 kg mass after the collision.

c. Determine the energy lost in the collision.

d. Determine the distance between the landing points of the two objects when they finally strike the ground.
(16 points)

25. A 0.8 kg ball hangs on the end of a 3.0 m cord. It is hit by a child and rises 2.1 m, as shown below.

a. What is the maximum gravitational potential energy of the ball?

b. What was the ball’s velocity immediately after being hit?

c. What was the ball’s kinetic energy immediately after being hit?

d. What is the ball’s momentum immediately after being hit?

e. If the child’s hand is in contact with the ball for 0.09 second, what is the force with which the child’s hand hits the ball?
f. How high will the ball go if the child applies 10 more Newtons of force during the same contact time?

(19.5 points)
7. Which of the following is an equivalent expression for the units of the spring constant k?
   a. kg⋅m²/s²   b. kg⋅m/s    c. kg⋅s²   d. kg/s²   e. kg⋅s/m

8. A box with a 500 N mass inside goes over a hill that has a radius of 60 meters, as shown below. The velocity of the car is 20 m/s. what are the force and the direction that the car exerts on the driver?

   ![Diagram](image)
   a. 840 N, up  b. 160 N, up  c. 160 N, down  d. 840 N, down  e. 500 N, up

Questions 9-10 apply to the following diagram.

9. How much work was done to displace the mass 10 meters?
   a. 40 J  b. 38 J  c. 32 J  d. 30 J  e. 26 J

10. What was the average force supplied to the mass for the entire 10 meter displacement?
    a. 3.2 N  b. 1.2 N  c. 4.4 N  d. 4 N  e. 2.6 N

11. A student weighing 700 N climbs at constant speed to the top of an 8 m vertical rope in 10 s. The average power expended by the student to overcome gravity is most nearly
    a. 1.1 W  b. 87.5 W  c. 560 W  d. 875 W  e. 5,600 W

12. A child pushes horizontally on a box of mass m, which moves with constant speed v across a horizontal floor. The coefficient of friction between he box and the floor is μ. At what rate does the child do work on the box?
    a. μmgv  b. mgv  c. v/μmg  d. μmg/v  e. μmv²

Questions 13-14 apply to the following diagram.
A rock of mass \( m \) is thrown horizontally off a building from a height \( h \), as shown above. The speed of the rock as it leaves the throwers hand at the edge of the building is \( V \).

13. How much time does it take the rock to travel from the edge of the building to the ground?
   a. \( \sqrt{(hV)} \)  
   b. \( h/V \)  
   c. \( hV/g \)  
   d. \( 2h/g \)  
   e. \( \sqrt{(2h/g)} \)

14. What is the kinetic energy of the rock just before it hits the ground?
   a. \( mgh \)  
   b. \( 0.5 \ mV^2 \)  
   c. \( 0.5 \ mV^2 - mgh \)  
   d. \( 0.5 \ mV^2 + mgh \)  
   e. \( mgh - 0.5 \ mV^2 \)

15. If the acceleration of an object is not zero, then all of the following could be constant EXCEPT the object's
   I. speed  
   II. linear momentum  
   III. kinetic energy
   a. I only  
   b. I and II only  
   c. I and III only  
   d. II only  
   e. II and III only

16. Which of the following is not a vector quantity?
   a. displacement  
   b. velocity  
   c. acceleration  
   d. linear momentum  
   e. potential energy

17. Two people, one of mass 100 kg and the other of mass 50-kg, stand facing each other on an ice-covered (essentially frictionless) pond. If the heavier person pushes on the lighter one with a force \( F \), then
   a. the force felt by the heavier person is \(-F/2\).  
   b. the force felt by the heavier person is \(-2F\).  
   c. the magnitude of the acceleration of the lighter person will be 1/2 of the magnitude of the acceleration of the heavier person.  
   d. the magnitude of the acceleration of the lighter person will be twice of the magnitude of the acceleration of the heavier person.  
   e. none of the above.

18. What braking force is applied to a 2500-kilogram car having a velocity of 30 meters per second if the car is brought to a stop in 15 seconds?
   a. 5000 N  
   b. 6000 N  
   c. 8000 N  
   d. 10,000 N  
   e. 12,000 N

19. A 1-kilogram object is moving to the right with a velocity of 6 meters per second. It collides with, and sticks to, a 2-kilogram mass, also moving to the right, with a velocity of 3 meters per second. How much kinetic energy was lost in this interaction?
   a. 1.5 J  
   b. 2 J  
   c. 3 J  
   d. 3.5 J  
   e. 0 J

20. A ball with a mass of 0.2 kilogram strikes a wall with a velocity of 3 meters per second. It bounces straight back with a velocity of 1 meter per second. What was the magnitude of the change in momentum for this ball?
   a. 0.1 kg\cdot m/s  
   b. 0.8 kg\cdot m/s  
   c. 0.4 kg\cdot m/s  
   d. 0.6 kg\cdot m/s  
   e. 0.7 kg\cdot m/s
21. A railroad car of mass \( m \) is moving at speed \( v \) when it collides with a second railroad car of mass \( M \), which is at rest. The two cars lock together instantaneously and move along the track. What is the speed of the cars immediately after the collision?
   a. \( v/2 \)       b. \( mv/M \)       c. \( Mv/m \)       d. \( (m + M)v/m \)       e. \( mv/(m+M) \)

22. The picture above shows two motorized dynamics carts, A and B, that have been placed on a lab table, with cart A to the left of cart B. The motors of each cart are turned on simultaneously and the two carts begin to race towards the right end of the table with constant accelerations. Both the front end of cart A and the front end of cart B reach the right edge of the table at exactly the same time. Which line in the chart below makes the correct comparison of the average velocity and the acceleration of cart B with the average velocity and the acceleration of cart A?
   - The average velocity of cart B is:
     a. less than that of cart A
     b. greater than that of cart A
     c. less than that of cart A
     d. same as that of cart A
     e. greater than that of cart A
   - The average acceleration of cart B is:
     a. same as that of cart A
     b. greater than that of cart A
     c. less than that of cart A
     d. greater than that of cart A
     e. same as that of cart A

23. If the momentum of an object doubles, its kinetic energy
   a. doubles       b. is half       c. quadrupled       d. is quartered       e. is eighthed

Questions 24-25 Apply to the following information and diagrams.
Three objects can only move along a straight, level path. The graphs below show the position \( d \) of each object plotted as a function of time \( t \).

24. The magnitude of the momentum of the object is increasing in which of the cases?
   a. I only       b. III only       c. I and II only       d. I and III only       e. I, II, and III

25. The sum of the forces on the object is zero in which of the cases?
   a. II only       b. III only       c. I and II only       d. I and III only       e. I, II, and III
26. A railroad car with a mass of 40,000 kg is going east at 3 m/s when it collides with a second car whose mass is 25,000 kg and is going east at 1 m/s on the same track. If the two cars couple together, how much kinetic energy was lost in the collision?
   a. 940 J                   b. 3.1x10^4 J                   c. 7.3x10^4 J                   d. 1.8x10^5 J

Part 2: Open Response: Listed below are several questions. Each part within a question may not have equal weight. Show all your work, printing clearly and legibly. Include all units. Perform all calculations using 2-3 decimal places. Place a box around your final answer(s).

27.

A 2.0 kg frictionless cart is moving at a constant speed of 3.0 m/s to the right on a horizontal surface, as shown above, when it collides with a seconds cart of undetermined mass m that is initially at rest. The force F (in kN) of the collision as a function of time t is shown in the graph below, where t=0 (in ms) at the instant of initial contact. As a result of the collision, the cart of mass m acquires a speed of 1.6 m/s to the right. Assume that friction is negligible before, during, and after the collision.

(a) Calculate the magnitude and direction of the velocity of the 2.0-kg cart after the collision.
(b) Calculate the mass m of the second cart.

28. Consider the simple pendulum in the figure below. The ball is released from rest at point A.
a. What will the speed of the ball be as it passes through point B?
b. What will be the ball's speed at point C?

26. A stone thrown downward with a speed of 15.7 m/s from a height of 12.7 m above the ground has a kinetic energy of 293 J when it is 1.29 m above the ground. What is the mass of the stone?

27. A block is initially at rest on an inclined plane at the equilibrium position that it would have if there were no friction between the block and the plane. How much work is required to move the block 10 cm down the plane (a) if the frictional coefficient is $\mu = 0$ and (b) if the frictional coefficient is $\mu = 0.17$?
31. Two identical objects A and B of mass M move on a one dimensional, horizontal air track. Object B initially moves to the right with speed $v_o$. Object A initially moves to the right with speed $3v_o$, so that it collides with object B. Friction is negligible. Express your answers to the following in terms of M and $v_o$.

a. Determine the total momentum for the system of the two objects.

b. A student predicts that the collision will be totally inelastic (the objects stick together on collision). Assuming this is true, determine the following for the two objects immediately after the collision.
   i. the speed
   ii. the direction of motion (left or right)

When the experiment is performed, the student is surprised to observe that the objects separate after the collision and that object B subsequently moves to the right with a speed $2.5v_o$.

c. Determine the following for object A immediately after the collision.
   i. the speed
   ii. the direction of motion (left or right)

d. Determine the kinetic energy dissipated in the actual experiment.
Chapters 10 – 12: Practice Test

Part 1: Multiple Choice Questions: Listed below are multiple choice questions from Chapters 1-12. For each, assume there is only one answer unless otherwise noted. You do not need to show any work for this section. Work hard!

1. At 2 atmospheres of pressure, 100 cubic meters of an ideal gas at 50 degrees Celsius is heated until its pressure and absolute temperature are doubled. What is the new volume of the gas?
   a. 62 m³   b. 100 m³   c. 58 m³   d. 50 m³   e. 112 m³

2. A metal rod is bent into the following shape shown above. If the metal is uniformly heated, the space between the ends will
   a. Increase   b. Decrease   c. Stay the same   d. There is not enough information

3. Consider \( n \) moles of an ideal gas. Which of the following properties of the gas is solely dependent on its temperature?
   I. pressure   II. volume   III. internal energy
   a. I only   b. II only   c. III only   d. I, II and III   e. None

4. An ice cube of mass \( m \) and specific heat \( c_i \) is initially at temperature \( T_1 \), where \( T_1 < 273 \text{ K} \). If \( L \) is the latent heat of fusion of water, and the specific heat of water is \( c_w \), how much energy is required to convert the ice cube to water at temperature \( T_2 \), where \( 273 \text{ K} < T_2 < 373 \text{ K} \)?
   a. \( m[c_i(273 - T_1) + L + c_w(373 - T_2)] \)
   b. \( m[c_i(273 - T_1) + L + c_w(T_2 - 273)] \)
   c. \( c_i(273-T_1) + c_w(T_2 - 273) \)
   d. \( mL + c_w(T_2 - T_1) \)
   e. \( mL + 0.5(c_w + c_i)(T_2 - T_1) \)

5. The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?

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<td>b. Remains the same</td>
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<td>c. Doubles</td>
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<tr>
<td>d. Doubles</td>
<td>Is multiplied by a factor of 4</td>
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<tr>
<td>e. Is multiplied by a</td>
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factor of 4

6. On a new world where $R = 0.25 \text{ L-atm/mol·K}$, an ideal monatomic gas at a temperature of 400 K occupies a volume of 2.5 liters at sea level. How many moles of the gas are there?
   a. 0.00625   b. 0.025   c. 2.5   d. 6.25   e. 12.5

7. When the Kelvin temperature of a gas is quadrupled, what will happen to the $v_{\text{rms}}$?
   a. The $v_{\text{rms}}$ is halved.
   b. The $v_{\text{rms}}$ is doubled.
   c. The $v_{\text{rms}}$ is quadrupled.
   d. The $v_{\text{rms}}$ is unchanged.

8. What is the absolute temperature of -73°C?
   a. 346 K   b. 273 K   c. 200 K   d. 127 K   e. 0 K

9. An ice cube is floating in water in thermal equilibrium. Heat is gradually added to the water without disturbing thermal equilibrium. Which of the following instantly occurs initially?
   a. The ice temperature rises.
   b. The water temperature rises.
   c. Some of the ice melts.
   d. Both (a) and (b) occur.
   e. Options (a), (b), and (c) occur.

10. A cube at rest in a fluid floats so that ¾ of it is submerged. If $\rho$ is the density of the fluid, then the density of the cube is
    a. $\rho$   b. $4\rho/3$   c. $3\rho/4$   d. $\rho/4$   e. $\rho/3$

Questions 11-13 are based on the following information and diagram.

11. What is the melting point of this substance?
    a. 0°C   b. 40°C   c. 80°C   d. 100°C   e. 140°C

12. What is the latent heat of fusion of this substance?
    a. 5 kJ/kg   b. 7.5 kJ/kg   c. 9.5 kJ/kg   d. 11.3 kJ/kg   e. 16.7 kJ/kg

13. What is the specific heat capacity of this substance in the liquid phase?
    a. 0.67 kJ/kg·°C   b. 0.38 kJ/kg·°C   c. 0.18 kJ/kg·°C   d. 0.42 kJ/kg·°C   e. 0.25 kJ/kg·°C
14. What will be the ratio ($\Delta L_1/\Delta L_2$) of thermal expansion between two identical objects whose temperature increases by 50°C (object 1) and decreases by 50°C (object 2)?
   a. 1   b. 0.5   c. 0   d. -0.5   e. -1

15. A cylindrical pipe has a radius of 12 cm in one region where the fluid speed is 0.2 m/s. In another region, the pipe is narrower with a radius of 4 cm. The fluid speed in this region is most nearly
   a. 9 m/s   b. 1.8 m/s   c. 0.6 m/s   d. 0.011 m/s   e. 0.067 m/s

16. An ideal fluid flows through a pipe that runs up an incline and gradually rises to a height H. The cross sectional area of the pipe is uniform. Compared with the flow at the bottom of the incline, the flow at the top is
   a. moving slower at lower pressure
   b. moving slower at higher pressure
   c. moving at the same speed at lower pressure
   d. moving at the same speed at higher pressure
   e. moving faster at lower pressure

17. For an ideal gas in a container with fixed volume and constant temperature, which of the following is true?
   I. Pressure results from molecular collisions with the walls.
   II. The molecules all have the same speed.
   III. The average kinetic energy is directly proportional to the temperature.
   a. I, II and III   b. I and II only   c. II and III only   d. II only   e. I and III only

18. Two identical containers contain 1 mole each of two different monatomic ideal gases, gas A and gas B, with the mass of gas B 4 times that of the mass of gas A. Both gases are at the same temperature. 10 J of heat is added to gas A, resulting in a temperature change of $\Delta T$. How much heat must be added to gas B to cause the same $\Delta T$?
   a. 2.5 J   b. 10 J   c. 40 J   d. 100 J   e. 1,600 J

19. Which of the following is equivalent to 1 Pascal of gas pressure?
   a. 1 kg⋅m$^{-2}$⋅s$^{-2}$   b. 1 kg⋅m$^{-1}$⋅s$^{-2}$   c. 1 kg⋅m$^{-3}$⋅s$^{-2}$   d. 1 kg⋅m$^{-1}$   e. 1 kg⋅m$^{-2}$⋅s$^{-3}$

20. A 200-gram metal block absorbs 1500 joules of heat, and its temperature changes by 150 degrees Celsius. What is the specific heat capacity of this metal?
   a. 7.5 J/g⋅°C   b. 0.13 J/g⋅°C   c. 2.14 J/g⋅°C   d. 0.05 J/g⋅°C   e. 0.62 J/g⋅°C

21. Two equal amounts of water are mixed by gently pouring both into an insulated cup. One part is initially at 90°C and the other part is initially at a temperature $T_i$. If the final temperature of the mixture is 55°C, the $T_i$ is____.
   a. 0°C   b. 20°C   c. 35°C   d. 90°C   e. Impossible to determine with the given information

22. A change in temperature of 75°C is equivalent to a change in absolute temperature of_____.
   a. 348 K   b. 75 K   c. 273 K   d. 198 K   e. 175 K

23. An ideal monatomic gas at a temperature of 400 K occupies a volume of 2.5 liters at sea level. How many moles of the gas are there?
24. The temperature of a substance is a relative measure of the ___.
   a. average kinetic energy of its molecules.
   b. arrangement of its molecules.
   c. bonding between the molecules.
   d. chemical identity of its molecules.

25. A change of phase takes place at a constant_____. a. pressure b. volume c. temperature d. heat e. none of these

26. The Sun's energy is transmitted to Earth by means of_____.
   a. conduction b. convection c. radiation d. all of these e. none of these

27. A 50 g block of marble (specific heat = 0.9 kJ/kg °C) at 150°C is placed in an insulated beaker containing 200 g of ammonia (specific heat = 4.71 kJ/kg °C) at 20°C. What will be the common temperature of the marble and ammonia when they reach thermal equilibrium? a. 26°C b. 41°C c. 58°C d. 77°C e. 94°C

28. Which of the following statements is true concerning phase changes?
   a. When a liquid freezes, it releases thermal energy into its immediate environment.
   b. When a solid melts, it releases thermal energy into its immediate environment.
   c. For most substances, the latent heat of fusion is greater than the latent heat of vaporization.
   d. As a solid melts, its temperature increases.
   e. As a liquid freezes, its temperature decreases.

29. The figure shown below is a solid block of asphalt containing a small spherical hole near the center of the block. If the block is heated until each side increases in length by 4%, what will happen to the radius of the hole?
   a. It will decrease by 16%.
   b. It will decrease by 12%.
   c. It will decrease by 4%.
   d. It will increase by 4%.
   e. It will increase by 12%.

30. When the Kelvin temperature of a gas is quadrupled, what will happen to the \( v_{rms} \)?
   a. The \( v_{rms} \) is halved.
   b. The \( v_{rms} \) is doubled.
   c. The \( v_{rms} \) is quadrupled.
   d. The \( v_{rms} \) is unchanged.

31. An exerciser invents a device that attaches to her stationary bicycle and converts all the energy expended into heat that heats a cup of water for making tea. What power (in watts) must she produce in order to increase the temperature of 250 g of water from 20°C to 90°C in a time of 10 minutes?
   a. 120 W b. 380 W c. 440 W d. 3.6 kW e. 1.8 MW

32. If a certain mass of a gas occupies a volume \( V \) at standard temperature and pressure, what will be the final volume if the temperature is halved and the pressure is doubled?
   a. 0.5\( V \) b. 2\( V \) c. 0.25\( V \) d. 4\( V \) e. \( V \)
33. If a certain mass of a gas occupies a volume $V$ at standard temperature and pressure, what will be the final volume if the temperature is halved and the pressure remains constant?
   a. $0.5V$  
   b. $2V$  
   c. $V$  
   d. we are not given enough information to calculate the final volume.

34. A cylinder is fitted with a freely moveable piston of area $1.20 \times 10^{-2}$ m$^2$ and negligible mass. The cylinder below the piston is filled with a gas. At state 1, the gas has volume $1.50 \times 10^{-3}$ m$^3$, pressure $1.02 \times 10^5$ Pa, and the cylinder is in contact with a water bath at temperature of $0^\circ$C. The gas is then taken through the following four step process. (We are given enough information to answer this problem.)
   ♦ A 2.50-kg metal block is placed on top of the piston, compressing the gas to State 2, with the gas still at $0^\circ$C.
   ♦ The cylinder is then brought in contact with a boiling water bath, raising the gas temperature to $100^\circ$C at State 3.
   ♦ The metal block is removed and the gas expands to State 4 still at $100^\circ$C.
   ♦ Finally, the cylinder is again placed in contact with the water bath at $0^\circ$C, returning the system to State 1.

   ![Diagram of the process](image)

   Note: Figures not drawn to scale.

   a. Determine the pressure of the gas is State 2.
   b. Determine the volume of the gas in State 2.
   c. Determine the volume of the gas in State 4.

35. A 3.5 kg iron bar initially 1.5 m long is observed to grow by 20%. For this to occur, a container of water vapor at $125^\circ$C was connected to the iron bar through some newly created, ideal converter device. In what physical state is the water (mass = 5.8 kg) at the end of this transition?

Specific Heat of Steam = 2010 J/kg$\cdot^\circ$C
Specific Heat of Liquid Water = 4187 J/kg$\cdot^\circ$C
Specific Heat of Ice = 2090 J/kg$\cdot^\circ$C

213
Latent Heat of Vaporization of Water = 22.6 \times 10^5 \text{ J/kg}
Latent Heat of Fusion of Water = 3.33 \times 10^5 \text{ J/kg}
Specific Heat of Iron = 448 \text{ J/kg}\cdot\text{°C}
Linear Thermal Expansion Coefficient of Iron = 12 \times 10^{-6} /\text{°C}

36. Students are designing an experiment to demonstrate the conversion of mechanical energy into thermal energy. They have designed the apparatus shown below. Small lead beads of total mass M and specific heat c fill the lower hollow sphere. The valves between the spheres and the hollow tube can be opened or closed to control the flow of the lead beads. Initially both valves are open.

a. The lower valve is closed and a student turns the apparatus 180° about a horizontal axis, so that the filled sphere is now on top. This elevates the center of mass of the lead beads by a vertical distance h. What minimum amount of work must the student do to accomplish this?

b. The valve is now opened and the lead beads tumble downs the hollow tube into the other hollow sphere. If all of the gravitational potential energy is converted into thermal energy in the lead beads, what is the temperature increase of the lead?

c. The values of M, h, and c for the students apparatus are M=3.0 \text{ kg}, h=2.00\text{m}, and c=128\text{J/(kg\cdot K)}. The students measure the initial temperature of the lead beads and then conduct 100 repetitions of the "elevate-and-drain" process. Again, assume that all of the gravitational potential energy is converted into thermal energy in the lead beads. Calculate the theoretical cumulative temperature increase after 100 repetitions.
d. Suppose that the experiment were conducted using smaller reservoirs, so that M was one-tenth as large (but h was unchanged). Would your answers to parts (b) and (c) be changed? If so, in what way and why? If not, why not?

37. The experimental diving bell shown below is lowered from rest at the ocean’s surface and reaches a maximum depth of 80 m. Initially, it accelerates downward at a rate of 0.10 m/s² until it reaches a speed of 2.0 m/s, which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross sectional area \( A = 9.0 \text{ m}^2 \). The density of seawater is 1025 kg/m³.

![Diagram of diving bell with hatch and area labeled]

- Top of Bell
- Area \( A = 9.0 \text{ m}^2 \)
- Hatch
- \( r = 0.25 \text{ m} \)

a. Calculate the total time it takes the bell to reach the maximum depth of 80 m.
b. Calculate the weight of the water on the top of the bell when it is at the maximum depth.
c. Calculate the absolute pressure on the top of the bell at the maximum depth.

On the top of the bell there is a circular hatch or door or radius \( r = 0.25 \text{ m} \).

d. Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.
e. What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

38. The cylinder below contains an ideal gas and has a movable, frictionless piston of diameter \( D \) and mass \( M \). The cylinder is in a room with atmospheric pressure \( P_{\text{atm}} \). Express all algebraic answers in terms of the given quantities and fundamental constants.

![Diagram of cylinder with piston and mass labeled]

- \( D \)
- \( M \)
- \( Ga \)

a. Initially, the piston is free to move, but remains at equilibrium. Determine each of the following.
   i. the force that the confined gas exerts on the piston
   ii. the absolute pressure of the confined gas
b. If a net amount of heat is transferred to the confined gas when the piston is fixed in place, what happens to the pressure of the gas? I.e. does the pressure of the gas increase, decrease, or stay the same. Explain your reasoning.

c. In a certain process the absolute pressure of the confined gas remains constant as the piston moves up a distance $x_0$. Calculate the work done by the confined gas during the process.
Part 1: Multiple Choice Questions: Listed below are multiple choice questions from Chapters 10-13. For each, assume there is only one answer unless otherwise noted. List all answers in the section marked “Part 1 Answers.” You do not need to show any work for this section. Work hard!
1. If 400 g of water at 40°C is mixed with 100 g of water at 30°C, the resulting temperature of the water is
   a. 13°C
   b. 26°C
   c. 36°C
   d. 38°C
   e. 44°C

2. An ideal gas is enclosed in a container which has a fixed volume. If the temperature of the gas is increased, which of the following will also increase?
   I. The pressure against the walls of the container.
   II. The average kinetic energy of the gas molecules.
   III. The number of moles of gas in the container.
   a. I only
   b. I and II only
   c. II and III only
   d. II only
   e. III only

3. A heat pump warms a house by absorbing 90 J of heat and doing 60 J of work on the pump. The heat then delivered to the house is
   a. 5,400 J
   b. 150 J
   c. 30 J
   d. 1.5 J
   e. 0.67 J

4. An ideal gas in a closed container initially has volume V, pressure P, and Kelvin temperature T. If the temperature is changed to 4T, which of the following pairs of pressure and volume is possible?
   a. P and V
   b. P and \( \frac{1}{2} V \)
   c. 4P and 4V
   d. 4P and V
   e. \( \frac{1}{4} P \) and V

5. If a gas in a container absorbs 300 J or heat, then has 100 joules of work done on it, then does 50 J of work, the increase in the internal energy of the gas is
   a. 450 J
   b. 400 J
   c. 350 J
   d. 200 J
   e. 100 J
Questions 6 and 7 refer to the following information:
A piece of metal with a mass of 2 kg and specific heat of 200 J/kg°C is initially at a temperature of 120°C. The metal is placed into an insulated container that contains a liquid of mass 4 kg, specific heat of 600 J/kg°C and an initial temperature of 20°C.

6. After a long time, the final equilibrium temperature of the metal and liquid is
   a. 24°C
   b. 34°C
   c. 48°C
   d. 68°C
   e. 100°C

7. In actuality, some of the heat is lost to the surroundings during the heat transfer from the metal to the liquid. This heat loss would result in
   a. A lower equilibrium temperature.
   b. A higher equilibrium temperature.
   c. A lower specific heat for the liquid.
   d. A lower specific heat for the metal.
   e. More heat gained by the liquid.

8. In general, when a solid is heated, it
   a. Expands proportionally to the change in temperature.
   b. Contracts proportionally to the change in temperature.
   c. Expands inversely proportionally to the change in temperature.
   d. Contracts inversely proportionally to the change in temperature.
   e. Does not expand nor contract.

9. A 3 kg block of aluminum is heated so that its temperature increased by 3 degrees. How much heat would be needed to raise the temperature of a 9 kg block of aluminum by 3 degrees?
   a. 9 times as much heat as the 3 kg block
   b. 3 times as much heat as the 3 kg block
   c. The same amount of heat as the 3 kg block
   d. One-third as much heat as the 3 kg block
   e. One-ninth as much heat as the 3 kg block

10. A system has 60 J of heat added to it, resulting in 15 J of work being done by the system, and exhausting the remaining 45 J of heat. What is the efficiency of this process?
   a. 100 %
   b. 60 %
   c. 45 %
   d. 25 %
   e. 15 %
11. A sphere is mass \( m \) and diameter \( d \) is immersed in a liquid of density \( \rho \). The buoyant force on the sphere is
   a. \( \rho \pi d^2 g/6 \)
   b. \( \rho \pi d^3 g/6 \)
   c. \( \rho \pi d^3 g/4 \)
   d. \( \rho \pi d^2 g/3 \)
   e. \( \rho \pi d^3 g/3 \)

12. An amount of an ideal gas is introduced into a container of unchanging volume. Thermal energy is added to the gas, which increases its temperature from 200 K to 400 K. Before heating, the average speed of the gas molecules was \( v_o \), and after heating, the speed is \( v_f \). The ratio of \( v_f \) to \( v_o \) is
   a. \( 1/\sqrt{2} \)
   b. \( \frac{1}{2} \)
   c. \( 1 \)
   d. \( \sqrt{2} \)
   e. \( 4 \)

13. The conversion of molecules to liquid from the vapor state is
   a. Vaporization.
   b. Melting
   c. Freezing.
   d. Regelation.
   e. Condensation.

14. A cube of side length \( L \) is made of a substance that is \( \frac{1}{4} \) as dense as water. When placed in a calm water filled container, the cube will
   a. Float with \( \frac{1}{2} \) \( L \) above the surface.
   b. Sink to the bottom.
   c. Float with \( \frac{1}{4} \) \( L \) above the surface.
   d. Float with \( \frac{1}{4} \) \( L \) below the surface.
   e. Float with \( 3 \sqrt{1/4} \) \( L \) below the surface.

15. An ideal fluid flows through a pipe that runs up an incline and gradually rises to a height \( H \). The cross sectional area of the pipe is uniform. Compared with the flow at the bottom of the incline, the flow at the top is
   a. Moving slower at lower pressure.
   b. Moving slower at higher pressure.
   c. Moving at the same speed at lower pressure.
   d. Moving at the same speed at higher pressure.
   e. Moving faster at lower pressure.
Questions 16-17
A piece of metal with a mass of 1.50 kilograms, specific heat of 200 J/kg · °C, and initial temperature of 100° C is dropped into an insulated jar that contains liquid with a mass of 3.00 kilograms, specific heat of 1,000 J/kg · °C, and initial temperature of 0° C. The piece of metal is removed after 5 seconds, at which time its temperature is 20° C. Neglect any effects of heat transfer to the air or to the insulated jar.

16. The temperature of the liquid after the metal is removed is
   a. 0°C
   b. 4°C
   c. 8°C
   d. 10°C
   e. 20°C

17. The average rate at which heat is transferred while the piece of metal is in the liquid is
   a. 4,000 J/s
   b. 4,800 J/s
   c. 6,000 J/s
   d. 9,600 J/s
   e. 16,000 J/s

18. The floor of a building is made from a square, solid piece of concrete. When the temperature of the floor increases from 20°C to 28°C, each side of the square expands by 0.4 cm. If the temperature of the floor were to decrease from 20°C to 8°C, by how much would each side of the square contract?
   a. 0.2 cm
   b. 0.4 cm
   c. 0.6 cm
   d. 1.0 cm
   e. It cannot be determined without knowing the coefficient of linear expansion of the concrete.

19. A heat engine operates in a cycle between temperatures 700 K and 400 K. The heat input to the engine during each cycle is 2800 J. What is the maximum possible work done by the engine in each cycle?
   a. 1200 J
   b. 1600 J
   c. 2100 J
   d. 2800 J
   e. 4400 J

20. Two identical containers hold different ideas gases, X and Y, at the same temperature. The number of moles of each gas is the same. The molecular mass of gas X is twice that of gas Y. The ratio of the pressure of X to that of Y is
   a. ½
   b. 1
21. An ideal monatomic gas is compressed while its temperature is held constant. That happens to the internal energy of the gas during this process, and why?
   a. It decreases because the gas does work on its surroundings.
   b. It decreases because the molecules of the ideal gas collide.
   c. It does not change because the internal energy of an ideal gas depends only on its temperature.
   d. It increases because work is done on the gas.
   e. It increases because the molecules travel a shorter path between collisions.

22. The figure above shows three isothermal processes for an ideal gas. Which one takes place at the higher temperature?
   a. Process A
   b. Process B
   c. Process C
   d. They all take place at the same temperature.
   e. The answer cannot be determined from the information given.

23. A monatomic ideal gas undergoes an adiabatic expansion. During this process, the temperature of the gas
   a. Remains constant
   b. Increases
   c. Decreases
   d. Increases, then decreases
   e. Decreases, then increases

24. A body having a density of 300 kg/m³ is floating in a container of liquid of unknown density. If one-third of the volume of the body remains above the surface of the liquid, what is the density of the liquid?
   a. 200 kg/m³
   b. 100 kg/m³
   c. 400 kg/m³
   d. 900 kg/m³
   e. 450 kg/m³
25. A balloon is filled with a gas having a density that is half that of the surrounding air. When the balloon is released from rest, what will be its acceleration? (Ignore the mass of the balloon material.)
   a. g/2 upward  
   b. g/2 downward  
   c. 2g upward  
   d. 2g downward  
   e. g upward

26. In terms of the principles of thermodynamics, which of the following statements best describes the reason that a person will feel warm after exercising?
   a. According to the third law of thermodynamics, work generates heat.
   b. Because of the second law of thermodynamics, entropy is decreasing, which increases the temperature.
   c. The temperature increases as the speed increases and the exercise moves the muscles, giving them a higher temperature.
   d. Working muscles must absorb more heat according to the first law of thermodynamics
   e. Muscles are not 100% efficient and must therefore generate waste heat according to the second law of thermodynamics

Questions 27 and 28 refer to the following diagram:

27. What is true for the process D→A?
   a. \( \Delta U = 0 \) \( Q > 0 \)  
   b. \( \Delta U = 0 \) \( Q < 0 \)  
   c. \( \Delta U > 0 \) \( W = 0 \)  
   d. \( \Delta U < 0 \) \( Q = 0 \)  
   e. \( W = 0 \) \( Q = 0 \)

28. What is true for the two step process A→B→C?
   a. \( \Delta U = 0 \) \( Q = 0 \)  
   b. \( \Delta U = 0 \) \( Q > 0 \)  
   c. \( W = 0 \) \( Q > 0 \)  
   d. \( W = 0 \) \( Q < 0 \)
29. The temperature of absolute zero is equal to
   a. 0°C
   b. 100°C
   c. 273°C
   d. -273°C
   e. -100°C

30. The law of entropy states that
   a. Heat always flows spontaneously from a colder body to a hotter one.
   b. Every natural system will tend toward lower entropy.
   c. Heat lost by one object must be gained by another.
   d. The specific heat of a substance cannot exceed a certain value.
   e. Every natural system will tend toward disorder.

31. Heat is added to a block of ice initially at 0°C until the ice changes completely into water. The same amount of heat continues to be added to the liquid water for 15 minutes. Which of the following statements is true?
   a. The temperature of the ice and water remains constant until the end of the 15 minute time period.
   b. The temperature of the ice rises steadily until all of the ice has melted into water.
   c. The temperature of the ice remains constant until all of the ice has melted into water, then the temperature of the water steadily rises for 15 minutes.
   d. The temperature of the ice rises from 0°C to 32°C, then the temperature of the water rises from 32°C to 100°C.
   e. The temperature of the ice remains at 0°C until the ice has melted, then the temperature of the water remains constant at 32°C.

32. Which of the following graphs best represents the relationship between the average kinetic energy of the molecules of a gas and its temperature?
   a. \[ K \]
      \[
      \underline{T}
      \]
   b. \[ K \]
      \[
      T
      \]
Questions 33 and 34 refer to a candle burning inside a metal container, as shown above. Three types of heat transfer are listed below.
   I. Radiation
   II. Conduction
   III. Convection

33. Heat can be transferred to the inside surface of the walls of the container by which of the above?
   a. I only
   b. I and II only
   c. I and III only
   d. II only
   e. I, II, and III only

34. If you touch the outside surface of the metal container, your hand will become warmer directly by which of the above choices?
   a. I only
   b. I and II only
   c. I and III only
   d. II only
   e. III only

Part 1 Answers: Be sure your answer is legible. Pay attention to the arrangement of the question numbers.
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Appendix A3: Additional Homework
AP Physics – Free Body Diagram Exercise

Directions – For the following scenarios, draw and label the FBD(s). Create and/or show all appropriate formulas that you may use to start a theoretical problem.

1. A box is at rest on a level table.

```
\[ \sum F_x = 0 \quad \sum F_y = N - W = ma = m(0) = 0 \]
```

![Diagram of a box on a level surface with forces N (normal) and W (weight)]

2. A box slides down an incline at a constant velocity

3. A box slides down a frictionless incline

4. An elevator accelerates upwards
5. An elevator rises at constant velocity

6. A box is pulled across a non-frictionless horizontal surface by a rope attached at an angle of $\theta$ (where $0^\circ < \theta < 90^\circ$)

7. Two boxes are attached by a small cord around a pulley suspended in midair.

8. A box lying on a flat surface is connected via a string and pulley to another mass that is hanging in the air off the edge of the table.
Suppose you are driving in a convertible with the top down. The car is moving to the right at a constant velocity. You point a rifle directly upward and fire. In the absence of air resistance, where would the bullet land – behind you, ahead of you, or in the barrel of the rifle?
Mr. Staley is traveling from his home to Doherty High. As he leaves his house, he accelerates at 0.25 m/s² from rest for 2 minutes. He then travels at constant velocity for another 5 minutes before realizing that he was wearing mismatched clothing. He turns around (assume to be instantaneous) and returns quickly to his house at twice his maximum velocity reached in the trip. He slams on his brakes at his house (effectively stopping in no time). He then heads back to Doherty, accelerating at 0.50 m/s² for 1 minute, then traveling at constant velocity for the remainder of the trip. (10 additional minutes).

a. What is the displacement between Mr. Staley’s house and Doherty High?
b. What is the total distance traveled by Mr. Staley on his trip?
c. How long was Mr. Staley traveling?
d. What is the maximum velocity reached during the trip?
Two stones are thrown directly upward from the ground. Stone A is thrown with an initial velocity of 30 m/s while stone B is thrown at 10 m/s. Stone B is thrown 5 seconds after stone A is thrown. At what height, if any, do the stones meet?

Work

Reasoning
Chapters 1-3 Sample Open Response Questions

1. Suppose you are driving in a convertible with the top down. The car is moving to the right at a constant velocity. You point a rifle directly upward and fire. In the absence of air resistance, where would the bullet land – behind you, ahead of you, or in the barrel of the rifle?

2. Mr. Staley is traveling from his home to Doherty High. As he leaves his house, he accelerates at 0.25 m/s$^2$ from rest for 2 minutes. He then travels at constant velocity for another 5 minutes before realizing that he was wearing mismatched clothing. He turns around (assume to be instantaneous) and returns quickly to his house at twice his maximum velocity reached in the trip. He slams on his brakes at his house (effectively stopping in no time). He then heads back to Doherty, accelerating at 0.50 m/s$^2$ for 1 minute, then traveling at constant velocity for the remainder of the trip. (10 additional minutes).
   a. What is the displacement between Mr. Staley’s house and Doherty High?
   b. What is the total distance traveled by Mr. Staley on his trip?
   c. How long was Mr. Staley traveling?
   d. What is the maximum velocity reached during the trip?
3. Two stones are thrown directly upward from the ground. Stone A is thrown with an initial velocity of 30 m/s while stone B is thrown at 10 m/s. Stone B is thrown 5 seconds after stone A is thrown. At what height, if any, do the stones meet?

Chapters 1-3 Sample Open Response Questions

1. Suppose you are driving in a convertible with the top down. The car is moving to the right at a constant velocity. You point a rifle directly upward and fire. In the absence of air resistance, where would the bullet land – behind you, ahead of you, or in the barrel of the rifle?

2. Mr. Staley is traveling from his home to Doherty High. As he leaves his house, he accelerates at 0.25 m/s² from rest for 2 minutes. He then travels at constant velocity for another 5 minutes before realizing that he was wearing mismatched clothing. He turns around (assume to be instantaneous) and returns quickly to his house at twice his maximum velocity reached in the trip. He slams on his brakes at his house (effectively stopping in no time). He then heads back to Doherty, accelerating at 0.50 m/s² for 1 minute, then traveling at constant velocity for the remainder of the trip. (10 additional minutes).
   a. What is the displacement between Mr. Staley’s house and Doherty High?
   b. What is the total distance traveled by Mr. Staley on his trip?
   c. How long was Mr. Staley traveling?
   d. What is the maximum velocity reached during the trip?

3. Two stones are thrown directly upward from the ground. Stone A is thrown with an initial velocity of 30 m/s while stone B is thrown at 10 m/s. Stone B is thrown 5 seconds after stone A is thrown. At what height, if any, do the stones meet?
Chapters 9-11 Exam Preparation

Torque: For the following scenarios:

i. Draw a picture of the object(s)
ii. Create the FBD for the principal object (e.g. bar, bridge)
iii. Establish reference frames (for forces and torque)
iv. Use the laws of equilibrium to create the formulas for this scenario

1. A 100-m bridge is laid across a river. The two ends of the bridge rest on each side of the riverbank. Three cars, of mass 500 kg, 1000 kg and 1500 kg, are at rest on the bridge. The 500-kg car is located 25 meters from the left edge. The 1000-kg car is at 45 m from the left edge. The 1500-kg car is located along the bridge such that the force each riverbank exerts on the bridge is equal. If the bridge has a weight of 10,000 N, then
   a. Determine the force that the riverbank exerts on each edge of the bridge.
   b. Determine the location, relative to the left edge of the bridge, of the 1500-kg car.

2. A new dance club opens in Worcester. The hanging sign is supported by a wire and a steel bar, as shown in the diagram below. The bar is 1.5 m long and weighs 200 N.
If the sign has a weight of 150 N, and the angle between the string and the vertical wall is 55°, then
   a. Determine the magnitude of the tension force.
   b. Determine the direction of the force exerted by the wall on the bar.
   c. Determine the magnitude of the vertical and horizontal forces exerted by the wall on the bar.

3. Jack and Jill go up a hill to play on a seesaw. Jack has a mass that is 2.5 times bigger than Jill. If the
   seesaw is 4 meters long, and the fulcrum is at the very center, then:
   a. If Jill sits on the very end of the seesaw, where must Jack sit?
   b. If Jack and Jill both sit on the same end (how cute!), how massive must their friend John be if he
      sits at the other end of the seesaw?

Fluid Dynamics:
For the following, be sure to:
   i. Draw a diagram of the objects
   ii. Complete an FBD
   iii. Use Newton’s Laws to develop the governing formula
   iv. Use appropriate subscripts for the terms (e.g. mass, density, volume)
   v. Plug numbers in at the very end.

4. A cylinder of radius 2 cm and height 12 cm is completely submerged in a pool of glycerol (density of
   1400 kg/m³).
   a. What is the density of the cylinder?
   b. If only 50% of the cylinder were submerged, what would be the density?
   c. If the glycerol were replaced by water (density = 998 kg/m³), describe what would happen
      to the cylinder, and determine the percent volume submerged (of the cylinder).
d. If the cylinder were held by a string connected to the bottom of the pool of glycerol (so the cylinder wants to rise to the top), determine the density of the cylinder.

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Complete the following. Show all relevant work.

1. A traditional Atwood machine is displayed below. Knowing that $m_1 = 3m_2$, find the time it will take until $m_1$ strikes the floor, assuming that the system was originally at rest.

2. A box slides across a horizontal, frictionless table. It initially slides at a constant speed of 15 m/s until it slides up a 25° incline, also frictionless. If the box has a mass of 0.75 kg, find the maximum vertical height to which the box rises.
3. A 1.5 kg box is at rest at the top of an incline. It begins to slide down the incline. If the coefficient of friction is 0.40,
   a. Calculate the final speed of the box at the bottom of the incline.
   b. Calculate the time necessary for the box to reach the bottom of the incline.
If the box now slides across a horizontal surface with the same coefficient of friction,
   c. Calculate how far the box will slide before coming to a stop.
   d. Describe how your answers to parts (a) and (c) would change if
      i. The box was increased by a factor of 2.
      ii. The coefficient of friction was reduced by a factor of $\frac{1}{2}$. 
1. The graph above shows the velocity versus time for an object moving in a straight line. At what time after \( t = 0 \) does the object again pass through its initial position?
(A) Between 0 and 1 s
(B) 1 s
(C) Between 1 and 2 s
(D) 2 s
(E) Between 2 and 3 s

2. A body moving in the positive x direction passes the origin at time \( t = 0 \). Between \( t = 0 \) and \( t = 1 \) second, the body has a constant speed of 24 meters per second. At \( t = 1 \) second, the body is given a constant acceleration of 6 meters per second squared in the negative x direction. The position \( x \) of the body at \( t = 11 \) seconds is
(A) +99 m
(B) +36 m
(C) - 36 m
(D) - 75 m
(E) - 99 m

3. The displacement \( x \) of an object moving along the x-axis is shown above as a function of time \( t \). The acceleration of this object must be
(A) zero
(B) constant but not zero
(C) increasing
(D) decreasing
(E) equal to g
4. A 2-kilogram block rests at the edge of a platform that is 10 meters above level ground. The block is launched horizontally from the edge of the platform with an initial speed of 3 meters per second. Air resistance is negligible. The time it will take for the block to reach the ground is most nearly

(A) 0.3 s
(B) 1.0 s
(C) 1.4 s
(D) 2.0 s
(E) 3.0 s

5. A diver initially moving horizontally with speed \(v\) dives off the edge of a vertical cliff and lands in the water a distance \(d\) from the base of the cliff. How far from the base of the cliff would the diver have landed if the diver initially had been moving horizontally with speed \(2v\)?

(A) \(d\)
(B) \(\sqrt{2d}\)
(C) \(2d\)
(D) \(4d\)
(E) can’t be determined without knowing the height of the cliff

6. A truck traveled 400 meters north in 80 seconds, and then it traveled 300 meters east in 70 seconds. The magnitude of the average velocity of the truck was most nearly

(A) 1.2 m/s
(B) 3.3 m/s
(C) 4.6 m/s
(D) 6.6 m/s
(E) 9.3 m/s
7. An object is attached to a spring and oscillates with amplitude $A$ and period $T$, as represented on the graph above. The nature of the velocity $v$ and acceleration $a$ of the object at time $T/4$ is best represented by which of the following?

(A) $v > 0$, $a > 0$
(B) $v > 0$, $a < 0$
(C) $v > 0$, $a = 0$
(D) $v = 0$, $a < 0$
(E) $v = 0$, $a = 0$

8. A projectile is fired with initial velocity $v_0$ at an angle $\theta_0$ with the horizontal and follows the trajectory shown above. Which of the following pairs of graphs best represents the vertical components of the velocity and acceleration, $v$ and $a$, respectively, of the projectile as functions of time $t$?

Open Response Problems:
Vector Component Worksheet
Complete each of the following. Use the component method to determine the required values. Do not assume anything! (i.e. right angles, equal lengths, etc)
For each of the following, find the resultant vector. First draw and label all vectors, resolve each into its x and y components and then add each set of components.

1. A vector has a magnitude of 23 units and is directed 25° East of South. Find the eastward and southward components.
2. A vector \( \mathbf{A} = 44 \text{ N at } 130° \). A vector \( \mathbf{B} = 13 \text{ N at } 205° \). A vector \( \mathbf{C} = 17 \text{ N at } 90° \text{ North of East} \).
3. \( \mathbf{A} = 20\text{N at }45°, \mathbf{B} = 20 \text{ N at }0°, \mathbf{C} = 20 \text{ N South} \).
4. Swimming at an angle of 27° from the horizontal, an angelfish has a velocity vector \( \mathbf{v} \) with a magnitude of 25 m/s. Find the x and y components of \( \mathbf{v} \).
5. Vector \( \mathbf{A} \) has a length of 14 cm at 60° with respect to the x-axis, and vector \( \mathbf{B} \) has a length of 20 cm at 20° with respect to the x-axis.
6. Vector \( \mathbf{A} \) is 9.0 m/s North. Vector \( \mathbf{B} \) is 10 m/s at 10°. Vector \( \mathbf{C} \) is 15 m/s at 225°. Vector \( \mathbf{D} \) is 12 m/s at 335°.
7. A box is placed on a 30° inclined plane. There are forces acting on the block. One force acts perpendicular to the surface of the plane and has a magnitude of 10N. Another force acts due South and has a magnitude of 15N. Another force acts parallel to the surface, is directed up the plane, and has a magnitude of 1.1N. What is the resultant, and where is it directed?
8. A man pushes a lawnmower across his yard. The handle of the mower makes an angle of 50° with the level ground. The man pushes with a force of 150 N directed along the handle. In essence, the force is directed into the ground at an angle of 230°. The mower has an additional force of 45 N acting at 270° and a force of 30 N acting at 90°. What are the resultant, and its direction?

Physics: Chapter 3  Velocity and Acceleration

1. A car accelerates from rest up to a cruising speed of 17 m/s in 12.4 seconds. If the mass of the car is 2500 kg, what force does the car experience?
2. What force is required to accelerate an automobile weighing 2.00\times10^4 \text{ N from } 30.0 \text{ km/hr to } 70.0 \text{ m/hr in } 10.0 \text{ seconds}?
3. A brass block of mass M resting on a horizontal frictionless surface is given a horizontal acceleration of 4.5 m/s² by a force of 8.7 N. (a) What is the mass of the block? (b) What is the weight of the block?

4. (a) Find the net force that produces an acceleration of 6.4 m/s² for a 0.50 kg cantaloupe. (b) If the same force is applied to a 20 kg watermelon, what will its acceleration be?

5. The total horizontal force exerted between the tires of a 1500 kg automobile and the ground is 980 N. If the car starts from rest, how far will it go in 5.0 seconds?

6. What is the mass in kilograms of a bag of sugar that weighs 5.00 lb? (1N = 0.2248 lb)

Answers:
1. 3427 N
2. 2270 N
3. a. 1.9 kg   b. 19 N
4. a. 3.2 N   b. 0.16 m/s²
5. 8.2 m
6. 2.27 kg

Chapter 3: Velocity and Acceleration Worksheet
Answer the following. Show all of your work. Write all values given and assign a symbol to those values. Indicate which formula you will use to solve for the unknown. Include all units. Solve and place a box around your final answer.

1. A car moving along a level road increases its speed uniformly from 16 m/s to 32 m/s in 10.0 seconds.
a. What is the car's acceleration?
b. What is its average speed?
c. How far did it move while accelerating?

2. A boy sliding down a hill accelerates at 1.40 m/s². If he started from rest, in what distance would he reach a speed of 7 m/s?

3. A flowerpot falls from rest from a windowsill 25 m above the sidewalk.
a. How fast is the flowerpot moving when it strikes the ground?
b. How much time does a passerby on the sidewalk directly below have to move out of the way before the pot strikes the ground?

4. A ball initially at rest rolls down a hill with an acceleration of 3.3 m/s².
a. If it accelerates for 7.5 seconds, how far will it move?
b. How far will it have moved if it had started at 4.0 m/s rather than from rest?

5. A car weighs 19,600 N.
a. What is the mass of the car?
b. If a braking force of 1250 N is needed to stop the car, what is its acceleration while braking?

6. What force must be exerted on an electron to move it from rest to a speed of 3.5x10⁷ m/s at a distance of 0.75m?

Chapters 4-5 Sample Quiz Questions
Below is a compilation of old quiz questions through the school year ending in Spring, 2008. Complete at your convenience.

1. A 52-kg box is sliding up a frictionless incline of 58°. This box is connected to a large mass (80 kg) that is suspended over a pulley at the top of the incline.
a. Draw and label an FBD of the situation described above. Be sure to clearly indicate your reference frame.
b. Create the net force equations (both x and y) for each mass.

2. Four forces are known to act on a 50 kg mass. The forces are identified as follows. Find the net force (magnitude and direction),
   a. Force 1 is 100 N and acts at an angle of 60°.
   b. Force 2 is 250 N and acts at an angle of 140°.
   c. Force 3 is 175 N and acts at an angle of 260°.
   d. Force 4 is 150 N and acts at an angle of 315°.

3. At an amusement park there is a ride in which cylindrically shaped chambers spin around a central axis. People sit in seats facing the axis, their backs against the outer wall. At one instant the outer wall moves at a speed of 3.2 m/s, and an 83 kg person feels a 560 N force pressing against his back. What is the radius of the chamber?

4. A 9.75-kg lead brick rests on a level wooden table. If a force of 46.4 N is required to slide the brick across the table at a constant speed, what is the coefficient of friction?

5. At what angle above the horizontal should a curve of radius 150 m be banked (inclined), so cars can travel safely at 25 m/s without relying on friction?

6. Jupiter's moon Europa has an average orbital radius of 6.67x10^8 m and a period of 85.2 hours. Calculate the magnitude of (a) its average orbital speed, (b) the angular velocity, and (c) the centripetal acceleration of Europa.

7. Describe Newton’s Law of Universal Gravitation. In your explanation, you should explain the formula, what is required to use the formula, and its application on Earth.

8. An astronaut weighing 700 N on earth travels to the planet Mars. What does the astronaut weigh on Mars? (The mass of Mars is 0.107 times that of the earth’s mass. The radius of Mars is 0.530 times that of the earth’s radius.)

9. Consider two points on a rotating turntable: Point A is very close to the center of rotation, while Point B is on the outer rim of the turntable.
   a. In which case would the speed of the penny be greater, if it were placed at point A or if it were placed at point B? Explain.
For parts (b) and (c), a penny could be placed on a rotating turntable without moving at either point A or point B.

b. At which point would the penny require the larger centripetal force to remain in place? Justify your answer.

c. Point B is 0.25 m from the center of rotation. If the coefficient of friction between the penny and the turntable is $\mu = 0.30$, calculate the maximum linear speed the penny can have there and still remain in circular motion.

A.P. Physics: Group Assignment 2
Complete the following. Show all work, placing a box around your final answer.

1. Blocks of mass $m$ and $2m$ are positioned on a semicircular frictionless track at a height of $R/4$ above the lowest point. The blocks are released simultaneously and collide elastically. How high does each block rise after the collision?
2. A 1000-kg car collides with a 1200-kg car that was initially at rest at the origin of an x-y coordinate system. After the collision, the lighter car moves at 20 km/h in a direction of 30° with respect to the positive x-axis. The heavier car moves at 12 km/h at -44° with respect to the positive x-axis. What were the initial speed and direction of the lighter car?

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Chapter 10: Sample Problems

1. A wooden board 1.0 m x 15 cm x 2.0 cm has a density of 0.50 g/cm³. The board is floated in water and lead is placed on top of the board. How much lead can be placed on top of the board and have the top of the board level with the water? Assume the experiment is done at 20°C?

2. A bicycle pump has a piston of diameter 1 inch. What minimum force must be exerted on the piston to add air to a tire at a gauge pressure of 60 lb/in²?

3. A container filled part way with water has a total mass of 2.50 kg (container plus water). A piece of lead with a mass of 1.13 kg is suspended from a spring scale. The scale is calibrated to read weight. If the scale is arranged such that the lead is completely submerged in the water, what is the reading on the spring scale? Assume the experiment is carried out at 20°C.

4. Water is traveling at 2.5 m/s from the Colorado River to LA in a pipe which is 1.5 m in diameter. As the pipe lowers 50 m over one of the many hills on its path it tapers to a diameter of 1.3 m. Assuming that the water pressure is 2.0 atmospheres at the top of the hill, what is the pressure at the bottom? Assume a water density of 1.0x10³ kg/m³ and neglect viscosity.

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Identify the error in the work shown below. Explain what needs to be changed to correct the error.

Two identical 1.5 kg balls approach each other. The first travels at 5 m/s and the other moves at 8 m/s. They collide perfectly inelastically. What is the final velocity of the combined mass?
Identify the error in the work shown below. Explain what needs to be changed to correct the error.

A 1200 kg car moving to the right at 13.5 m/s collides inelastically with a truck also moving right at 4.4 m/s. The car comes to a stop after collision, but the truck’s velocity increases to 8.9 m/s. What is the mass of the truck?
The sentence below contains either a single error or no error at all. If the sentence contains an error, choose the one underlined part that must be changed and re-write the corrected sentence. If no errors are present, write NO ERROR.

**Force is increased**

when the **time** interval of an impact is increased.
In an **inelastic** collision, **momentum** can be converted to internal elastic potential energy, **sound energy**, and **internal energy**.
If a collision is perfectly elastic, the value of the total kinetic energy after the collision is equal to zero.

a. zero
b. one
c. half the total initial value
d. twice the total initial value
e. the value before the collision
When two objects push away from each other and their momentum is equal but opposite, the total momentum is **one**.

a. one  
b. zero  
c. less than the initial momentum  
d. greater than the initial momentum  
e. equal to twice that of one object
Fill in the blank with the most appropriate term.

The product of a constant applied force and the time interval during which the force is applied is the ________ of the force for the time interval.
Fill in the blank with the most appropriate term.

To find an object’s mass, divide its _____ by its velocity.
Fill in the blank with the most appropriate term.

A collision in which two objects stick together after colliding is called ___________.
Fill in the blank with the most appropriate term.

Momentum is conserved but kinetic energy is not conserved in a perfectly ______ collision.
Conservation of Linear Momentum – Practice Quiz

\[ F_t = \Delta p = m(v_f - v_i) \quad m_a v_a + m_b v_b = m_a v_{af} + m_b v_{bf} \quad p = mv \]

1. What velocity must a 2.25 kg croquet mallet have in order to have the same momentum as a 1.25 kg ball that has a momentum of 6.25 kg·m/s to the west?
   a. 1.79 m/s to the west  
   b. 1.47 m/s to the west  
   c. 2.78 m/s to the west  
   d. 5.00 m/s to the west  
   e. 6.25 m/s to the west

2. A 1.5 kg rolling pin rolls along a countertop at 6.0 m/s. It collides with and sticks to a 200 gram lump of dough. The doughy rolling pin continues along the countertop. What is the final speed of the doughy rolling pin?
   a. 0.045 m/s  
   b. 5.3 m/s  
   c. 6.8 m/s  
   d. 6.9 m/s  
   e. 45 m/s

3. A tennis ball is dropped from 1.0 m, bounces off the ground, and rises to 0.85 m. What kind of collision occurred between the ball and the ground?
   a. elastic  
   b. inelastic  
   c. perfectly elastic  
   d. perfectly inelastic

4. A helium atom collides with another helium atom in an elastic collision. Which of the following is true?
   a. Both momentum and kinetic energy are conserved.
   b. Momentum is conserved but kinetic energy is not conserved.
   c. Kinetic energy is conserved but momentum is not conserved.
d. Neither momentum nor kinetic energy is conserved.

Short Answer
5. As a bullet travels through the air, it slows down due to air resistance. How does the bullet’s momentum change as a result?

6. How can a small force produce a large change in momentum?

7. A 0.16 kg billiard ball moving to the right at 1.2 m/s has a head on inelastic collision with another ball of doubled mass moving to the left at 0.85 m/s. The first ball moves to the left at 1.3 m/s after the collision. Find the velocity of the second ball after the collision.

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Physics – Chapter 4 FBD Exercise
Directions – On an attached paper, draw and label an FBD for the following scenarios. Draw the forces on the object in **bold** only. Use the hand written, photocopied notes along with your book as a guide. Unless otherwise stated, assume friction to be present.

1. A **book** is at rest on a horizontal table.
2. A **book** is pushed across a horizontal, frictionless table.
3. A **box** is pushed up a hill.
4. A **box** is pulled up a hill by a rope.
5. A **person** is standing in a stationary elevator.
6. A **person** is standing in an elevator that is slowly rising.
7. A **person** is standing in an elevator that is slowly falling.
8. A **box** slides down a hill.

Hint – draw the hill like this.

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Name_______________________ Date_______________

Physics – Forces and Motion

Directions – Complete the problems below. Show all relevant work.

1. What is the mass of a car that accelerates at 2.5 m/s² with a net force of 15,000 N. What is the weight of this car?

2. A 25 kg box slides down a 30° frictionless hill. Find the acceleration of the box as it slides down the hill.

3. A box slides down a 37° incline that has friction. You are told that the frictional force has a magnitude of 5 N. The mass of the box is 40 kg.
   a. Draw and label the FBD for the box.
   b. Establish your reference frame.
   c. Resolve any force not lying on your reference frame.
   d. Create the two force formulas (ΣFx and ΣFy).
   e. Find the acceleration of the box.
f. If the box was released from rest at the top of the hill, determine the length of the hill if the speed of the box is 15 m/s at the bottom of the hill.

4. A box is pulled across a horizontal, frictionless table by a rope that is 45° above the surface of the table. The box has a mass of 75 kg. Determine the tension in the rope if the box accelerates at 1.2 m/s² across the table.
   a. Draw and label the FBD.
   b. Resolve forces based on your reference frame.
   c. Create the force formulas.
   d. Solve for the tension.

Physics Quiz Review

1. A biker travels down the road, accelerating from 45 km/hr to 75 km/hr in 15 seconds.
   a. Calculate the acceleration of the biker.
   b. Calculate how far the biker traveled during these 15 seconds.

2. A car, moving at 30 m/s, slows to a stop in 50 meters. Determine the acceleration of the car.

3. Convert the following:
   a. 2.25x10⁶ mm to km
   b. 0.75 km/hr to m/s
   c. 2 weeks to seconds

4. Find the net displacement for the following vectors: 150 m at 30°, 200 m at 145°, and 125 m at 270°.

Answers:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.a.</td>
<td>0.56 m/s²</td>
</tr>
<tr>
<td>1.b.</td>
<td>247.89 m</td>
</tr>
<tr>
<td>2</td>
<td>9 m/s²</td>
</tr>
<tr>
<td>3.a.</td>
<td>2.25 km</td>
</tr>
<tr>
<td>3.b.</td>
<td>0.21 m/s</td>
</tr>
<tr>
<td>3.c.</td>
<td>1.21x10⁶ sec</td>
</tr>
<tr>
<td>4</td>
<td>R = 35.04 m at 38.27° (in 1st quadrant)</td>
</tr>
</tbody>
</table>
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   a. Calculate the acceleration of the biker.
   b. Calculate how far the biker traveled during these 15 seconds.

2. A car, moving at 30 m/s, slows to a stop in 50 meters. Determine the acceleration of the car.

3. Convert the following:
   a. 2.25x10^6 mm to km
   b. 0.75 km/hr to m/s
   c. 2 weeks to seconds

4. Find the net displacement for the following vectors: 150 m at 30°, 200 m at 145°, and 125 m at 270°.

Answers:

<table>
<thead>
<tr>
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<tr>
<td>1.b</td>
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</tr>
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<tr>
<td>3.c</td>
<td>R = 35.04 m at 38.27° (in 1st quadrant)</td>
</tr>
</tbody>
</table>
Physics
Trigonometry Review

Sin $\theta = \frac{\text{opposite}}{\text{hypotenuse}}$
Cos $\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$
Tan $\theta = \frac{\text{opposite}}{\text{adjacent}}$

Direction – For each triangle, solve for $x$ and $\theta$.

1. 
\[ \begin{array}{ccc} 
6 \text{ m} & \times & \theta \\
14 \text{ m} & & 
\end{array} \]

2. 
\[ \begin{array}{ccc} 
1.0 \text{ cm} & & \theta \\
1.3 \text{ cm} & \times & 
\end{array} \]
3. \(7.7 \text{ m}\)

4.

5. \(3.6 \text{ m}\)

6. \(1.5 \text{ mm}\)
Find the resultant (sum) of the following vectors.

Complete all work on another piece of paper. Turn in this sheet, with your name, and your work.
Complete all work on another piece of paper. Turn in this sheet, with your name, and your work.

Name____________________

Physics
Vector Resolution

Find the resultant (sum) of the following vectors.

A = 50

B = 100

C = 70
Directions:

1. On the axes, create the right triangles for each vector. Label each side of the triangle (e.g. A, A_x, A_y, θ).

2. Use available trig functions (e.g. sine, cosine) to find all components.

3. Label components as positive or negative.

4. Add all x components.

5. Add all y components.

6. Draw another set of axes. Draw the Σx vector. From the end of this vector, draw the Σy vector.

7. The hypotenuse of this new triangle is the net vector.

8. Use trig to find the interior angle near the origin.
Appendix A4: Additional Quizzes
Part 1: Short answer questions. Using complete sentences, answer the following. Include all relevant information.

1. Define Archimedes’ Principle. Then explain it in layman’s terms. From the definition, list and describe the formula(s) that result. Be as descriptive and specific as possible.

2. Briefly define and/or explain the following terms. Include formulae where appropriate.
   Fluid, Hydrostatic Pressure, Pascal, Density, Pascal’s Principle, Equation of Continuity, Torque, Dynamic Equilibrium, Static Equilibrium
Part 2: Open Response problems. Listed below are two problems similar to homework and classwork assignments. Complete both problems. Show as much work as possible. For each, show which formula you are using before you insert values. Label all values, and include units.

3. Find the vertical and horizontal components of force exerted by the wall on the bar suspended as shown below. The weight of the uniform bar is 300 N, and is held in place by a massless string at an angle of $45^\circ$.

![Diagram of a bar suspended by a string at a $45^\circ$ angle, with a horizontal and vertical force labeled as 200 N.]  

4. A wooden block is placed in a container of water. The block floats with 60% of its volume below the water surface. How much of the block is submerged when it floats in methyl alcohol? ($\rho_{alc} = 791 \text{ kg/m}^3$)
Part 1: Short Answer Response: Using complete sentences, answer the following. Include all relevant information.

1. Why (not how) do we need to resolve vectors into their components?

2. For the curve shown below, provide the position versus time graph along with the acceleration versus time graph. Note that the starting position has been indicated on the position versus time graph.

3. Explain the similarities and differences between scalar and vector quantities. Also give three (3) examples of each quantity.

4. Draw a graph of displacement versus time for a ball that rolls across a floor at constant velocity. Label the graph with the following: independent variable, dependent variable, \( x_0 \), \( x \), \( t_0 \), and \( t \). For extra credit, label the ordinate and abscissa.
Part 2: Open Response Problems: Listed below are three (3) problems from or similar to homework problems. For each, begin the problem by creating a list(s) of information, indicating your choice of reference frame, and provide a starting formula.

5. A rock is thrown horizontally from a tall tower of height 49 meters. If its initial velocity is 22 m/s, how far from the point directly below the launch point does the ball strike the ground?

6. A motorcycle rider moving with an initial velocity of 8.0 m/s uniformly accelerates to a speed of 17 m/s in a distance of 30.0-m. (a) What is the acceleration? (b) How long does this take?

*************COMPLETE THIS PROBLEM. SOLVE FOR THE UNKNOWN QUANTITY.*****************

7. A bullet is fired from a gun at a target set a long distance away. It is fired at an angle of 55° with a launch velocity of 5.8 kilometers per second. If the bullet started at ground level, then determine the following:
   a. The maximum range of the bullet if it travels for 500 seconds.
b. The height at which the bullet strikes the target.
c. The vertical velocity of the bullet when it strikes the target.

1. For the curve shown below, provide the position versus time graph along with the acceleration versus time graph. Note that the starting position has been indicated on the position versus time graph.
2. Compare and contrast scalar and vector quantities. Also give two (2) examples of each quantity.

3. Can an object have a nonzero velocity with a zero acceleration? Can an object have a nonzero acceleration with a zero velocity? Explain briefly. Provide one example of each if the answer is yes.
Part 2: Open Response Problems: Listed below are three (3) problems from or similar to homework problems. For each, begin the problem by creating a list(s) of information, indicating your choice of reference frame, and provide a starting formula.

4. A ball is kicked horizontally from a tall tower of height 30 meters. If its initial velocity is 12 m/s, how far from the point directly below the launch point does the ball strike the ground?

5. A car travels from Auburn to Worcester, traveling first at a constant speed $v$ for 5 minutes. Next, the car slows uniformly to a stop, taking an additional 45 seconds. After waiting at a stop light for 10 seconds, the car accelerates up to the same speed, $v$. In the space below, sketch the position – time graph for this object. Use the time intervals provided, but the rest of the sketch does not need to be to scale.

6. A bullet is fired from a gun at a target set a long distance away. It is fired at an angle of 55° with a launch velocity of 5800 meters per second. If the bullet started at ground level, then determine the following:
   d. The maximum range of the bullet if it travels for 500 seconds.
   e. The height at which the bullet strikes the target.
   f. The vertical velocity of the bullet when it strikes the target.
10. Describe Newton’s three (3) Laws of Motion. Include any equations, properly labeled, that might aid in the description.
11. For each of the following situation, draw an FBD on all objects identified in *italics*. Then create the standard starting formulas for the system.
   a. A *book* slides down a steep incline at constant velocity
   b. A *child* swings from a rope and is at the maximum height of its trajectory
   c. *Three masses* are connected via strings and are at rest on the incline. ($\mu = 0$)

12. Compare and contrast horizontal and vertical circles. A complete answer will identify properties or characteristics that both types of motion have in common as well as identify properties that are different for the two motions.

Part 2: Open Response Problems – Listed below are two problems either from or similar to the homework and classwork problems. Complete both problems. For each, show all necessary work.
13. A 52-kg man is standing in a hot-air balloon that is resting on the ground. What force does the man exert on the balloon under the following conditions?
   a. The balloon accelerates up off the ground with an acceleration of 2.10 m/s².
   b. The balloon rises with a constant velocity of 4.35 m/s.
   c. The balloon decelerates at a rate of 1.45 m/s² until it comes to a stop floating in the air.
   d. The balloon descends at a constant velocity of 4.50 m/s.
   e. The balloon decelerates to a stop on the ground at a rate of 2.00 m/s².

14. A new planet has been discovered past Pluto. This new planet is found to have a mass that is three hundred times that of the Earth. It is noted to move in a circular orbit around the sun at a distance of 10.5 billion kilometers (billion = 1,000 million). How long, in days, will this planet take to travel once around the sun?
   Note: \( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \quad m_{\text{earth}} = 5.94 \times 10^{24} \text{ kg} \quad m_{\text{sun}} = 1.99 \times 10^{30} \text{ kg} \)
Quiz: Chapters 5 & 6
Part 1: Short answer response: Answer the following, writing briefly and concisely. Include all relevant information.
1. Define the Law of Conservation of Mechanical Energy. Be sure to include appropriate formulae.

2. Describe Newton’s Law of Universal Gravitation. In your explanation, you should explain the formula, what is required to use the formula, and its application on Earth.
3. Define the following, using formulas where available. 
Period, Frequency, Radian, Centripetal Force, Centripetal Acceleration, spring constant 
(6 terms)

4. Provide and briefly explain the Work Energy Theorem.

Part 2: Open Response Problems – Listed below are two problems from Chapters 5 and 6. Complete, including all relevant work.
5. A 45 kg suitcase falls from a hot air balloon at a height of 1 km.
   a. In the absence of air friction, what will be the maximum speed reached by the suitcase?
   b. If instead it loses 90% of its potential energy through friction with the air, what kinetic energy does it have just before it strikes the ground? (This means 90% of the total mechanical energy is removed from the object.)
   c. What speed does it have just before it strikes the ground, assuming air friction as mentioned in (b) is present?
6. An astronaut weighing 750 N on Earth travels to the planet Mars.
   a. What is the mass of the astronaut?
   b. What does the astronaut weigh on Mars? (The mass of Mars is 0.107 times that of the earth’s mass. The radius of Mars is 0.530 times that of the earth’s radius.)
AP Physics – Quiz: Chapters 7-9

Directions: Answer the following questions. Include all relevant information, including formulas where appropriate. You do not need complete sentences.

1. Briefly name and describe the three types of collisions.

<table>
<thead>
<tr>
<th>Collision</th>
<th>Characteristics</th>
<th>Formulas implied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

For the three types of collisions above, what is one common similarity?

For the three types of collisions above, what is one thing they do NOT have in common?

2. Briefly define the following terms. Also provide the formulas for the relevant terms.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition/Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Momentum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinetic Energy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. List 4 properties or characteristics of work.

4. A 0.145-kg baseball is thrown by a pitcher, and travels in the direction as indicated below. The ball is traveling 35.2 m/s and is stopped in 0.163 seconds by a catcher’s mitt. (a) What is the average acceleration of the ball? (b) What is the average force on the catcher’s mitt?

\[ v = +35.2 \text{ m/s} \]

5. A steel ball is dropped from a height of 2.37 m onto a flat stone slab. On rebounding, the speed of the ball is 3.94 m/s when it is 1.52 m above the stone slab. Is the collision elastic? You must prove your answer.
5. Demonstrate a conceptual understanding of the following terms by creating a short, concise paragraph linking them together. Be sure to demonstrate the relationships between the terms, how they depend on one another, whether they are proportional, etc. Do NOT create an example problem. You may introduce additional terms, if necessary.
Terms: root mean square speed, internal energy, temperature, gas molecule

6. Briefly define or describe the following terms. Note: writing the formula out in words DOES NOT constitute the definition. For example, “A force is defined as the mass of an object times its acceleration” is NOT a definition. Also, provide the formulas for the relevant terms.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition/Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid</td>
<td></td>
<td></td>
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<tr>
<td>Volume flow rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 2: Open Response Problem – Listed below are three open response problems similar to problems completed in class. Complete all three problems. Be sure you include all work, and you clearly indicate your final answer(s).

7. Water is moving through a closed horizontal pipe. The beginning of the pipe has a radius $R$, through which the water travels with a speed of $5.0 \text{ m/s}$. At some later point, the radius of the pipe is reduced to $R/2$. What is the difference in pressure from the beginning to the end of the pipe?

8. Two iron $10.0 \text{ m}$ long flat bars are separated by $1.0 \text{ cm}$. The linear thermal expansion coefficient for iron is $10.5 \times 10^{-6} ^\circ\text{C}$. If the given temperature is $0^\circ\text{C}$, find the temperature at which the rails will just start to touch.
9. 2 moles of an ideal gas are in a cylindrical container with cross-sectional area of 1.0x10^{-2} m^2. The cylinder is fitted with a light, movable piston. Initially the gas is at atmospheric pressure. A 50 kg mass is placed on top of the piston and the system comes to equilibrium. The temperature at equilibrium is 27°C.

   a. Find the pressure of the gas.
   b. If the temperature is reduced by a factor of 2, what is the new volume of the gas?
   c. After the temperature change, find the change in internal energy of the gas.
Conservation of Mechanical Energy – Quiz

\[ PE = mgh \quad \text{KE} = \frac{1}{2} mv^2 \quad g = 9.8 \text{ m/s}^2 \]

\[ E_a = E_b \quad \text{PE}_a + \text{KE}_a = \text{PE}_b + \text{KE}_b \]

Multiple Choice – choose the most appropriate answer. Write the letter in the space provided.

1. When first hit, a golf ball has a kinetic energy of 96.5 J and travels at a speed of 65.0 m/s. What is its mass?
   a. 0.045 g            b. 2.97 g           c. 5.71 g             d. 22.8 g            e. 45.7 g

2. Which of the following statements are true?
   a. As a car travels along a highway, its kinetic energy must increase.
   b. When a ball falls through the air, its kinetic energy will increase only if friction is not acting on the ball.
   c. As a box slides down a hill, its mechanical energy will decrease because its height is decreasing.
   d. When a ball is kicked from the ground, its kinetic energy is conserved as it rises to a maximum height.

3. If friction acts on an object, which of the following is true?
   a. The total mechanical energy will remain constant because heat is a type of energy.
   b. If the object were falling, the object would have to stop shortly before hitting the ground because some energy is lost.
   c. Friction cannot act, because total energy is always conserved.
   d. The total mechanical energy would decrease as the object moved from one point to another.

4. A father and daughter are throwing a ball back and forth to each other. The ball has a mass of 0.22 kg, and each person is equally strong and can throw the ball with a maximum speed of 4.5 m/s. The father and daughter are facing each other as they throw the ball back and forth. Which of the following is true?
   a. The kinetic energy of the ball is positive as the ball moves right, then it is negative as it moves left. The values of the kinetic energies are equal however.
   b. The kinetic energy of the ball is positive as the ball moves right, then it is negative as it moves left. The values of the kinetic energies are not equal because the father has a greater mass than the daughter.
   c. Both kinetic energies are positive. The values of the kinetic energies are not equal because the father has a greater mass than the daughter.
   d. Both kinetic energies are positive. The values of the kinetic energies are equal however.

5. A ball is thrown with a kinetic energy of 200 Joules. If the ball’s mass is doubled with the same speed, then the new kinetic energy of the ball is
   a. 400 J because the mass is doubled.
   b. 200 J because mass is irrelevant when calculating kinetic energy.
   c. 100 J because if the mass is doubled, it is harder for it to move through the air.

Short Answer: You do not need complete sentences to answer the following.

6. Two friends stand on top of a building. They each throw an identical ball off the building with the same speed. If person A throws the ball straight down and person B throws the ball up, compare the final speed of the balls when they hit the ground. (I.e. does one ball have a greater speed than the other, or are they equal). Explain your answer.
7. Rank the following object based on their total mechanical energy.

(highest)  ____ >   ____  >   ____  >  ____ > ____ (lowest)

A. Ball of mass 4 kg is at rest on top of a 40 m tall building.
B. Plane of mass 1000 kg is moving at 1.5 m/s along the runway at the airport
C. Car of mass 1200 kg cruising at 12.5 m/s along a level road
D. Ball of mass 8 kg moving at 7 m/s while 5.5 m off the ground
E. Truck of mass 1400 kg moving at 9.9 m/s along a level road

Open Response: Showing all necessary work, answer the following. Be sure your final answer is clearly marked.
8. A rocket blasts off from the ground with a kinetic energy of 17.5x10^6 J. The mass of the rocket is 1450 kg. After a few seconds, a scientist observed the speed of the rocket to be 28.0 m/s. How high had the rocket risen?
Conservation of Mechanical Energy – Quiz

PE = mgh  KE = ½ mv²  g = 9.8 m/s²

Ea = Eb  PEa + KEa = PEb + KEb

Multiple Choice – choose the most appropriate answer. Write the letter in the space provided.

1. When first hit, a golf ball has a kinetic energy of 96.5 J and travels at a speed of 65.0 m/s. What is its mass?
   a. 0.045 g  b. 2.97 g  c. 5.71 g  d. 22.8 g  e. 45.7 g

2. Which of the following statements are true?
   a. When a ball falls through the air, its kinetic energy will increase only if friction is not acting on the ball.
   b. As a box slides down a hill, its mechanical energy will decrease because its height is decreasing.
   c. When a ball is kicked from the ground, its kinetic energy is conserved as it rises to a maximum height.
   d. As a car travels along a highway, its kinetic energy must increase.

3. If friction acts on an object, which of the following is true?
   a. If the object were falling, the object would have to stop shortly before hitting the ground because some energy is lost.
   b. Friction cannot act, because total energy is always conserved.
   c. The total mechanical energy would decrease as the object moved from one point to another.
   d. The total mechanical energy will remain constant because heat is a type of energy.

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   a. Both kinetic energies are positive. The values of the kinetic energies are equal however.
   b. Both kinetic energies are positive. The values of the kinetic energies are not equal because the father has a greater mass than the daughter.
   c. The kinetic energy of the ball is positive as the ball moves right, then it is negative as it moves left. The values of the kinetic energies are equal however.
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5. A ball is thrown with a kinetic energy of 200 Joules. If the ball’s mass is doubled with the same speed, then the new kinetic energy of the ball is
   a. 100 J because if the mass is doubled, it is harder for it to move through the air.
   b. 200 J because mass is irrelevant when calculating kinetic energy.
   c. 400 J because the mass is doubled.

Short Answer: You do not need complete sentences to answer the following.

6. Two friends stand on top of a building. They each throw an identical ball off the building with the same speed. If person A throws the ball up and person B throws the straight down, compare the final speed of the balls when they hit the ground. (I.e. does one ball have a greater speed than the other, or are they equal). Explain your answer.
7. Rank the following object based on their total mechanical energy.

(highest) ____ > ____ > ____ > ____ > ____ (lowest)

A. Plane of mass 1000 kg is moving at 1.5 m/s along the runway at the airport
B. Ball of mass 8 kg moving at 7 m/s while 5.5 m off the ground
C. Ball of mass 4 kg is at rest on top of a 40 m tall building.
D. Truck of mass 1400 kg moving at 9.9 m/s along a level road
E. Car of mass 1200 kg cruising at 12.5 m/s along a level road

Open Response: Showing all necessary work, answer the following. Be sure your final answer is clearly marked.

8. A rocket blasts off from the ground with a kinetic energy of $14.5 \times 10^6$ J. The mass of the rocket is 2050 kg. After a few seconds, a scientist observed the speed of the rocket to be 28.0 m/s. How high had the rocket risen?
Appendix A5: Additional Reading
AP Physics
Chapters 9-10 Study Guide

Directions – Answer the following questions. You do not need complete sentences, but you do need complete and thorough answers. The following questions should act as a guide for your studies.

Chapter 9:
1. What is θ in the torque formula?

2. What is the sign convention for torque and what is the “reference frame” for torque situations?

3. What are the two conditions of equilibrium and what type of motion can the object have in each condition?

4. Describe the concept of the cross-sectional area.

5. Explain the similarities and differences between the fulcrum and a pivot point.

Chapter 10:
1. What is density? What is the formula and what are the expected units?

2. Explain Archimedes’s Principle and write this principle in a mathematical (equation) form.
3. Using Newton’s Laws, explain what happens to an object in the following scenarios: (Note: $F_b = \text{Buoyant Force}$)
   i. $F_b = W$
   ii. $F_b < W$
   iii. $F_b > W$

4. Write (and memorize) the equation of continuity and explain this principle in common language. Explain the logic behind this principle.

5. Write (and memorize) Bernoulli’s Equation. For each symbol, write what it stands for and what the units must be for that quantity.

6. In the space below, list and briefly describe items from your reading that you need clarified.

7. Complete the following problem: A hollow block of metal is thrown into a pool of water ($\rho = 998 \text{ kg/m}^3$).
   a. If the block floats with 55% of its volume above water, determine the density of the block.
   b. What would be the density of the block if 90% of its volume were submerged?

Chapter 1 Notes
1.1 Models: used to represent the world; idealized descriptions of a physical system or natural phenomenon
A good model should be able to:
   a. be an explanation for observed and measured phenomenon
   b. be able to predict things we have not yet observed i.e. good models not only explain fully the observation, but go on to predict new observations that were previously unexpected

1.2 Base units a.k.a. fundamental units a.k.a. standard units a.k.a SI units
There are 7 base units. All measured quantities use one or a combination of these units. That is, any unit can be expressed by a combination of just these 7 units.

SI units = Systeme International (Fr.) units = International System of Units
SI units are also referred to as mks units, for the base units meter, kilogram, and second.

BASE UNITS

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
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<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Thermodynamic temperature</td>
<td>Kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of a substance</td>
<td>mole</td>
<td>mol</td>
</tr>
</tbody>
</table>
Scientific notation:
Uses power of 10 to reduce very small or very large numbers to manageable ones.
Notation system is based on powers of 10, which can be represented by prefixes.
Table 1.2 (be familiar with)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^{18}</td>
<td>exa</td>
<td>E</td>
</tr>
<tr>
<td>10^{15}</td>
<td>peta</td>
<td>P</td>
</tr>
<tr>
<td>10^{12}</td>
<td>tera</td>
<td>T</td>
</tr>
<tr>
<td>10^{9}</td>
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<td>G</td>
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<td>10^{6}</td>
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<tr>
<td>10^{1}</td>
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<td>10^{-1}</td>
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<tr>
<td>10^{-9}</td>
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<td>10^{-15}</td>
<td>femto</td>
<td>f</td>
</tr>
<tr>
<td>10^{-18}</td>
<td>atto</td>
<td>a</td>
</tr>
</tbody>
</table>

Ex. Convert the following into scientific notation:

456,000 = ________________
9,110,000,000,000,000 = _______________

Ex. Expand the following from scientific notation:

6.67 \times 10^{-11} = _______________________

8.99 \times 10^9 = ________________________

1.3 Unit Conversion
Conversion factor = term that equals 1, therefore you can multiply any quantity by a conversion factor without changing the value of the measurement.

Ex. Convert the following:
700 milligrams into kilograms:

700 mg = _________________________________ =

25 nanoliters into microliters:

25 ng = _________________________________ =

45 centimeter per second into meters per hour:

45 cm/s = _________________________________ =
1.4 Significant Figures

Measurements made with tools are imprecise, that is, the measurement is only as good as the tool or as good as the user.

Sig-fig rules are used to keep the quantity or calculation within reason to the precision of the measurement.

Ex. If we are using a ruler to measure the length of a paper clip, it is highly unlikely you can get a reading of 2.1546784 inches. More realistically, you could gauge the measurement to one decimal place.

Sig-fig rules:
1. Rounding: 5→9 is rounded up, 0→4 is rounded down.
2. Addition and subtraction of numbers: the term with the fewest decimal sig-figs dictates the number of decimal sig-figs permitted in the answer.
3. Division and multiplication: the factor with the fewest number of sig-figs dictates the number of sig-figs permitted in the answer.
4. Zeroes:
   i. any zero between 2 non-zero digits is significant. (ex. 202 has 3 sig figs)
   ii. any zero after a nonzero but before a decimal is not significant (e. 2000 has 1 sig-fig)
   iii. any zero after decimal but before non-zero is not significant (ex. 0.001 has 1 sig-fig)
   iv. any zero after decimal and after a non-zero digit is significant (ex. 0.00100 has 3 sig-figs)
When you calculate an answer, convert the answer to scientific notation still keeping the correct number of sig-figs.
Ex. \((10.6)(17.9) = 189.74\) (calculator answer) = 190 (sig fig answer) = \(1.9 \times 10^2\) (scientific notation answer)

1.5 Using order of magnitudes in estimations makes conceptualizing problems easier and simplifies multiple choice questions.

Ex. Calculate: \(\frac{(9.11 \times 10^{-31})(5.56 \times 10^{15})^2}{(500)(1.6 \times 10^{-4})}\)

Your choices are
a. \(5.98 \times 10^8\)  
b. \(3.5 \times 10^2\)  
c. \(1.25 \times 10^{-5}\)  
d. \(6.8 \times 10^{12}\)

1.6 Symbols are important. There is a big difference between mg and Mg. Be neat and organized with your work.

Problem solving guidelines (rough idea)
1. Read the problem carefully, listing information given and label the information.
2. If possible, draw and label a diagram of the situation.
3. From the question, list the quantities you need to solve the problem.
4. Determine the relationship between the known and unknown quantities, listing possible equations to be used, etc.
5. If convenient, algebraically rearrange equation so you isolate what you are solving for.
6. Substitute numerical values into the equation (must include units).
7. Solve the problem. Canceling units accurately should yield the units that match the desired quantity.
8. Check your answer. Does the number seem reasonable? Look at the order of magnitude.

AP Physics
Chapter 1 Review Problems

For the following quantities, convert them as indicated.

1. 128070000000 meters
   Scientific Notation (SN): ___________________
   SN and prefix kilo: _____________________
   SN and prefix mega: ____________________
   SN and prefix centi: ____________________

2. 0.000000002563 grams
   Scientific Notation (SN): __________________
   SN and prefix kilo: _____________________
   SN and prefix nano: ____________________
   SN and prefix micro: ____________________

3. 1385 seconds
   Scientific Notation (SN): __________________
   SN and prefix kilo: _____________________
4. 107070000 meters
   Scientific Notation (SN): _________________
   SN and prefix giga: _________________
   SN and prefix mega: _________________
   SN and prefix centi: _________________

5. 0.000267 moles
   Scientific Notation (SN): _________________
   SN and prefix milli: _________________
   SN and prefix micro: _________________
   SN and prefix kilo: _________________

AP Physics
Chapter 1 Review Problems

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SN and prefix giga: ___________________
SN and prefix mega: ___________________
SN and prefix milli: ___________________

5. 0.000267 moles
Scientific Notation (SN): ___________________
SN and prefix milli: ___________________
SN and prefix micro: ___________________
SN and prefix kilo: ___________________
Chapter 2 Notes

**Kinematics** is the branch of physics that deals with the positions and motions of objects in space as a function of time, but does not consider the cause of motion.

**Dynamics** is the study of the causes of motion.

**Mechanics** is the study of motion (both kinematics and dynamics)

2.1 **Reference Frame:** a physical entity (or location) to which we refer the position and motion of objects.

Reference frames allow you to look at the relative positions and motion of objects.

**Coordinate system:** number systems for assigning locations to objects in a reference frame.

The coordinate system can be placed anywhere is a reference frame.

Measurements will come out the same, regardless of the location of the origin.
For ease, when choosing and installing an origin and coordinate system, choose a point that simplifies the problem. (I.e. put the origin at sea level, the ground, etc.)

Whatever origin and system you choose, stick with it throughout the entire problem. This chapter focuses on 1 dimensional motion.

*** Before starting any problem, choose a coordinate system.

Position is a term that reflects how far from the origin an object is located. The change in position (sign included), in reference to the origin, is called the displacement.

Note: displacement (d) is NOT the distance d traveled.

2.2 Any measured quantity can be put into two categories: scalars and vectors. Scalars are quantities that have magnitude only (no direction). Magnitude is a term that represents the number and unit quantities of a measurement. Ex: Think of measurements that do not need direction to properly define:
Vectors are quantities that have a magnitude, but also have a direction component needed to fully describe the measurement.

Ex: Think of measurements that do need direction to properly define:

Speed is an example of a scalar quantity.
Average speed = \( v = \frac{\text{total distance traveled}}{\text{time traveled during the motion}} = \frac{s}{t} \)
The speed of an object does not depend on the mass, weight, size, etc.

Units of speed are \( \frac{\text{distance unit}}{\text{time unit}} \) which can vary. Meters, miles, yards, millimeters etc. are all distance units. Similarly seconds, hours, years, etc. are all time units.

Different books use different symbols to represent the same quantities.
Time is almost always \( t \), but \( d, s, l, h, x, y \), or others can often represent distance. The problem will dictate what the symbol stands for.

When the speed of an object is made in a certain direction, this is a vector quantity.
Vector quantities are often represented by bold letters (\( \mathbf{v} \) vs. \( v \)) or by arrows (\( \rightarrow \)) placed over the letter.
Velocity is a vector that represents the speed of an object AND the direction the object travels in.

Average velocity = \( v_{ave} = \frac{\text{displacement}}{\text{time}} = \frac{\Delta x}{\Delta t} = \frac{(x_f-x_i)}{(t_f-t_i)} = \frac{(x_2-x_1)}{(t_2-t_1)} \)

Remember displacement ≠ distance traveled

For coordinate plane purposes, choosing the origin at the initial position and saying that \( t_i = 0 \) makes the problem easier to solve and understand.

2.3 Graphical Interpretation
Horizontal axis = x-axis = abscissa = independent variable
Vertical axis = y-axis = ordinate = dependent variable

Time is independent because it does not change. Velocity, displacement, position all can change, usually depending on the time elapsed and so are dependent.

Relate the graphs of position-, displacement-, and velocity-versus time graphs.

Note what the area under a curve represents (look at units)
Note what the slope represents. (look at units)
***ANY graph you are given in a problem – analyze for the slope and area under the graph. These pieces of information are usually required to solve the problem.
2.4 Instantaneous velocity = \( v_{\text{ins}} \) = velocity measured at a specific instant in time
This quantity is useful if the graph of velocity is curved.
The slope of the tangent line to the velocity curve at a specific time is the value of the instantaneous velocity.

\[
V_{\text{ins}} = \lim_{x \to 0} \frac{\Delta x}{\Delta t}
\]
As \( \Delta t \to 0 \), the interval \( \Delta x \) approaches a linear curve so we can approximate \( v_{\text{ins}} \) by \( v_{\text{ave}} \)
Magnitude of \( v_{\text{ins}} \) = speed = \( v \)

2.5  average acceleration = \( a = \frac{\Delta v}{\Delta t} \)
The acceleration is the time rate of change of the velocity.
(Rate usually implies “per time”, as in the change in velocity per time interval…)
Note that the units = velocity/time = distance/time/time.

Instantaneous acceleration = acceleration of the object at a specific time = slope of tangent line to the acceleration curve.

2.6  Assuming constant acceleration lets manipulate equations.

Use \( v = \frac{\Delta d}{\Delta t} = \frac{\Delta x}{\Delta t} \)
Use \( a = \frac{\Delta v}{\Delta t} \)
Use \( v_{\text{ave}} = \frac{v_f + v_i}{2} \)
By combining these equations, extending \( \Delta x \) to be \((x_f - x_i)\) and \( t_i = 0 \), then
THE BIG 5 Equations
List here: Symbols Units

\[ v^2 = v_0^2 + 2a\Delta x \]

\[ v = v_0 + at \]

\[ x = x_0 + v_0t + \frac{1}{2}at^2 \]

\[ x = x_0 + v_{ave}t \]

\[ x = x_0 + \frac{1}{2}(v + v_0)t \]

These 5 equations are used constantly and in conjunction with each other in almost any kinematics problem you see. ***for any problem, there can/will be a variety of solutions. Using these equations can provide different paths to the same answer. As long as you don’t change the reference frame, or make up new equations, you will solve the problem correctly.***

Example: A bowling ball is released from the top of a smooth incline. After 5.68 seconds the ball has traveled 12.0 m. One second later it has reached the bottom of the incline. (a) Assuming constant acceleration, what is the ball’s acceleration? (b) How long is the incline? Hint: Remember Problem Solving Strategy – Chapter 1
2.7 *Freely falling bodies*: objects moving under the influence of gravity (a constant acceleration)
Through the work of Galileo and Robert Boyle, the acceleration of gravity, $g$, was defined. Gravity is a term that is used in conjunction with force and acceleration. There is a force due to gravity; there is acceleration due to gravity. Gravity is a concept, an idea. The force due to gravity pulls objects toward each other’s center of mass. Typically, we would say that the force of gravity (a.k.a. weight) pulls objects toward the center of the earth.

Forces produce acceleration. The pull of the earth on objects produces an acceleration “$g$.” The standard value for $g$ is 9.8 m/s$^2$. This value is good for objects at sea level. We assume any object on the earth is accelerated downward with a value of $g$. In reality, $g$ changes based on altitude. Higher altitude (and in general the farther from the earth’s center), the lower the value of $g$, and vice versa. This is a measured value, meaning the value (sign) of $g$ depends on the coordinate system imposed. This is different from the prior use of kinematics formulae where the choice of reference frame did not alter the outcome. $g$ is a vector quantity. $g$ can be positive or negative:
Note: we see that mass of objects (the size) should not affect the acceleration. In reality, there exists air resistance, extraneous forces on masses that affect acceleration.

Let’s relate $v$ and $g$:
Throw a ball in the air. Explain the changes of $v$ and $g$ along its path.

**Chapter 3 Notes**

Motion in 2 dimensions: sometimes we will be able to independently analyze the 1 dimensional components of 2 dimensional motion.

3.1 Scalars – quantities defined by magnitude (# and unit) only
Vectors – quantities defined by both magnitude and direction
Objects can have both scalar and vector properties concurrently (i.e. an object can have a mass and a velocity at the same time)

Examples of scalar quantities:

Examples of vector quantities:

Notation: vectors are either written as **bold** letters or marked with a superscript arrow: $\mathbf{v}$

On diagrams and graphs, arrows → represent vectors. The relative size (length) of the arrow indicates the magnitude of the arrow. The direction the arrow points in is the direction of the vector.
The magnitude of a vector refers to the absolute value of the vector, i.e. it tells you the strength or magnitude of a vector.

Magnitude of \( \mathbf{A} \) = \( |\mathbf{A}| \)

Magnitude is always a scalar (because direction is now irrelevant) and is always positive.

3.2 You can add scalars that all have the same units. If the units are different, use the unit conversion techniques to get all the same units.

With vectors, the direction components of each quantity must be considered. When you add vectors, the sum of these is the resultant.

Adding the magnitudes of vectors does not always equal the magnitude of the resultant!

Any vector (weight, velocity, acceleration, etc.) is added in the same way, assuming identical units.

Adding Vectors – 3 methods:
1. Graphical Method – draw all vectors to scale, using protractors for angles and rulers for length. Place all vectors tip-to-tail, and the resultant vector runs from the tail of the first to the tip of the last vector. Measure its length (magnitude) and direction based on the starting vector.

2. Parallelogram Method – (done with only 2 vectors at a time) – draw 2 vectors with their tails joined at a common point. Use these vectors as the sides of a parallelogram. The resultant vector runs diagonally from the common point across the parallelogram. Use this resultant with another vector, if there are more than 2 vectors. Repeat until all vectors have been added. (from this, we find that vector addition is commutative, meaning you can add vectors in any order and will get the same resultant.)

3. Component method (discussed in a later section)
Example – Parallelogram Method
Negative of a vector: given a vector \( \mathbf{a} \), the negative of \( \mathbf{a} \), \(-\mathbf{a}\), has the same magnitude but the direction is exactly reversed (180° difference).

Subtraction of vectors: \( \mathbf{a} - \mathbf{b} = \mathbf{c} \); treat as the addition of \( \mathbf{a} \) and the negative of \( \mathbf{b} \), then use the procedures for the addition of vectors.

Multiplication of vectors by a scalar: scalar multiples will shrink or stretch the magnitude of a vector. If the scalar is negative, the direction is reversed.

<table>
<thead>
<tr>
<th>Scalar (c)</th>
<th>Effect on ( \mathbf{a} ); meaning how does ( c \mathbf{a} ) compare to ( \mathbf{a} )?</th>
</tr>
</thead>
<tbody>
<tr>
<td>( c = 1 )</td>
<td>no change (( c \mathbf{a} = \mathbf{a} ))</td>
</tr>
<tr>
<td>( c &lt; 0 )</td>
<td>direction of ( \mathbf{a} ) is reversed, magnitude can change</td>
</tr>
<tr>
<td>( 0 &lt; c &lt; 1 )</td>
<td>shrinking of vector, direction stays the same</td>
</tr>
<tr>
<td>( c &gt; 1 )</td>
<td>( \mathbf{a} ) is magnified, direction stays the same</td>
</tr>
</tbody>
</table>

3.3 Resolution of vectors (this is the basis for the third method of adding vectors)

Just as you can add 2 vectors to get one new vector, you can break a vector into 2 (or more) other vectors. The individual
vectors that make up the resultant vector are called the component vectors.
In 2 dimensions, resolve a vector into components that lie along the x- and y- axes (i.e. the components should be perpendicular to each other)

Resolving a vector into components means finding the magnitude of the x- and y-components (usually assigning a + or – value based on your reference frame)

Trigonometry is always useful. Typically for components that are perpendicular and lie along the standard axes, then
\[ A_x = A \sin \theta \]
\[ A_y = A \cos \theta \]

Where \( \theta \) is the angle between the vector and the x-axis (note these formulas should only be used if your notation and drawing are based on the same premise given. If not, use SOHCAHTOA to find the component formulas.)

Third Method of Adding vectors: Component or Resultant Method
- Place all vector origins at the same common point, and place
  a coordinate system (reference frame) around it.
  (Hint – place origin or coordinate system at common point of
  all vectors)
Resolve each vector into x- and y-components (noting that
  some can be + or -)
Sum all the x-component vectors. This is the x-component of
  the resultant. Do the same for the y-components. Use the trig
  formulas to find the magnitude and direction of the resultant
  vector (Pythagorean and SOHCAHTOA)

For 3 dimensional vectors, resolve the vector into its x-, y-
  and z-components, and follow the same procedure.
3.3 Whenever you state some quantity or property of an object, it usually requires a reference object (reference or inertial frame)
Meaning, your motion/properties might depend on the observers point of view, or own properties or motion.

3.6 Kinematics in 2 dimensions: The kinematics equations for velocity, displacement and acceleration can only be applied to one dimensional motion. If an object travels in 2 dimensions as aspect of that motion must be resolved. Then use the Big 5 equations for each direction (x and y) individually. You can combine quantities again, if needed.

3.7 Projectile Motion:
2 dimensional motion can be broken into horizontal and vertical components of motion.
Horizontal motion will have constant velocity (gravity is the only acceleration and will not affect horizontal motion.) Vertical motion will have constant acceleration (g).
For projectile motion problems:
1. establish a coordinate system (that will not change in the problem)
2. for the initial position, velocity and acceleration vectors, resolve these into x- and y-components.
3. Identify quantities known and quantities needed.
4. Use the kinematics equations, knowing time for horizontal and vertical motions are equal.

Objects with horizontal motion (v is constant) and vertical motion (acceleration is constant) take on a parabolic path.

Special formulas: \[ y = -\frac{gx^2}{2v_0^2} \] = formula for trajectory (y position) for an object launched horizontally

\[ R = \frac{v_0^2 \sin 2\theta}{g} \] = Range formula = range of object launched from the ground and returning to the same height

Class Exercise: Find the trajectory of an object launched from a platform horizontally with an initial horizontal velocity of \( v_0 \).

Find the horizontal distance traveled (range) of an object launched from the ground and landing on the ground. Show work for both.

Chapter 4 Notes
Newtonian mechanics, a.k.a. classical mechanics, deals with kinematics and dynamics of the macroscopic world.
Newtonian mechanics is predominately based on Newton’s Laws of motion (which do NOT apply to the microscopic world and to objects traveling near the speed of light, c)

4.1 Nicolas Copernicus (1473-1543) published work in favor of the heliocentric theory (his initial ideas were rejected, for at the time the geocentric theory was deeply rooted in society)
Galileo and Johannes Kepler helped to substantiate and validate Copernicus’ ideas.
Observations by Kepler:
• Planets closer to the sun travel faster than planets farther away from the sun.
• Taking an individual planet, than planet travels faster when nearer the sun in its orbit than when it is farther from the sun in its orbit.

Q. What would these two observations lead you to believe?
A. The sun was the cause of the planet's motion, AND, the sun’s influence might decrease with an increase in the distance between them

By the mid-1600’s (0660-1670) people began to believe that the sun created a force (F) on planets but the size of F depended on the distance between them.

\[ F \propto \frac{1}{r^2} \] for \( F = \) force, \( r = \) distance, \( \alpha = \) proportionality symbol

Written like this, this would be an inverse-square force.

Review Proportions:
4.2 A force is a “push or pull” from one object onto another.
- Each force exists as an interaction between 2 objects.
- Forces do not always cause motion (e.g. gravity)
- Force is not a property (like mass, speed, etc.)
- Forces are vector quantities (having magnitude and direction)

Net Force: vector sum of all forces acting simultaneously on an object.
Net Force a.k.a. Resultant force a.k.a. Unbalanced force

The Net force determines the motion of an object (if any)

When you exert a push or pull on an object, you are touching it. This constitutes a **contact force** (direct interaction).
When a stone drops, gravity (the force of) pulls it down.
Since the Earth is not directly touching the stone, this constitutes a **field force** (the force acts through space)
There are 4 Fundamental Forces in nature. All forces either are one of these or fall into one or some of these categories, depending on the type of molecular interactions.
1. **GRAVITATIONAL**: acts between all masses, gives weight (a field force), gives motion to objects
2. **ELECTROMAGNETIC**: covers both electric and magnetic forces, responsible for holding atoms and molecules together and for the structure of matter (contact
forces fall into this category: contact forces ∈ electromagnetic forces)

3. STRONG NUCLEAR: holds the atomic nucleus together
4. WEAK NUCLEAR: acts between all matter (mainly seen in the subnuclear particles)

4.3 Newton’s Laws of Motion:
Newton’s First Law: Law of Inertia
- An object has a constant velocity unless there is a net force acting on it.
- Objects at rest tend to stay at rest while objects in motion tend to stay in motion unless acted on by a net force.
- Every object continues in its state of rest, or of uniform motion in a straight line unless compelled to change that state by forces acting on it.

The Law of Inertia assumes the net force acting on an object is zero.
Example: a bowling ball rolling down the lane in the absence of friction theoretically would roll forever.

Inertia: property of matter that causes objects to resist changes in motion.
To describe the position and motion of objects, we will use reference frames.
If you choose a reference frame for which Newton’s first law is valid, this is called an inertial reference frame. If your reference frame is chosen such that Newton’s first law is not valid, this is a noninertial reference frame.
4.4 Newton’s first law states $\Sigma F = F_{\text{net}} = \text{zero} = 0$. Newton’s Second law describes the change of motion that occurs when a non-zero net force acts on it.

Newton’s Second Law: Law of Acceleration

- The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed. (This is Newton’s original translation.)
- The rate of change of momentum with time is proportional to the net applied force and is in the same direction.
- $\Sigma F \propto \Delta (mv)/\Delta t$ where $mv =$ momentum

With careful choosing of units, the proportionality constant can be set equal to one, therefore
$\Sigma F = \Delta (mv)/\Delta t$
For most cases, the mass does not change in a situation hence it is constant
$\Sigma F = m\Delta v/\Delta t$ where $\Delta v/\Delta t =$ acceleration (a)
$\Sigma F = ma$

Note this law says $\Sigma F = ma$, not just F. The a here represents the net acceleration the object will experience.
If you choose an individual force, then $F = ma$ where a is the acceleration only this force would create.
It is the force that causes the acceleration, not vice versa. Acceleration cannot exist without a force to create it.

Just like the kinematics equations, these vectors can be broken into components. Force vectors can only be analyzed along perpendicular, one-dimensional axes.

\[ \Sigma F_x = m a_x \quad \Sigma F_y = m a_y \quad \Sigma F_z = m a_z \]

Vector Sums (from 4.2 – Vector Sums)
Since forces and accelerations are vectors, for them to be set equal to each other (F and ma), the magnitude and direction must be equal.
\[ \Sigma F = ma. \] If you have a larger mass, the larger the force needed to give it a particular acceleration. Hence, mass is a quantitative measure of the inertia of a body.

Looking at units:
- \( F = \) ?
- \( m = \) kilogram = kg
- \( a = \) meter per second per second = m/s\(^2\) or \( F = \) kg
\( (m/s^2 = \) Newton = N

A force of 1 Newton (N) acting on a 1-kg mass gives it an acceleration of 1 m/s\(^2\).

Table 4.3 shows some alternate unit systems.

### 4.5 Weight of an object on earth is the gravitational force exerted on it by the earth.
- \( F = ma \) where on earth \( a = g. \)
- \( F = \) weight = W

Therefore we can rewrite this as \( W = mg \)
So, weight is a body in a specified reference frame is the force which, when applied to a body, would give it an acceleration equal to the local acceleration of free fall in that reference frame.

This is a useful definition; if we were on the moon, you still would have weight, but you calculate it using the “g” value of that reference frame, not always “g” of the earth.

The mass of an object remains constant regardless of the reference frame. (because it is a scalar)

For an object on the ground, it is at rest (i.e. no net acceleration). Gravitational force (weight) still acts on it.

According to Newton’s first law, $\Sigma F = ma = 0 = m(0)$

Since gravity acts down toward the center of the earth, the earth must exert a force on the brick upward.

The *NORMAL force* is the force provided by the ground perpendicular to the surface of contact between the two objects.

Normal force $= N = F_N = \text{resistance of the ground to the motion of the brick acted by gravity.}$

The normal force is a contact force, meaning two objects must be touching for it to exist. It acts perpendicular to the plane of contact.

4.6 Newton’s Third Law: Law of Action-Reaction

- For every action (force), there is a reaction force, and the action and reaction forces are equal in magnitude, opposite in direction and act upon different bodies.

- If body A exerts a force of body B, $F_{AB}$, then B exerts a force of A ($F_{BA}$) where $F_{AB} = -F_{BA}$
Forces always occur in pairs. When applying Newton’s second law, each force is considered independently. Meaning, we usually look at just the forces acting on one object at a time, not all the forces acting in the entire system. Choosing a reference frame is important!!! (example 4.8)

Weightlessness: weight measured to be zero (mass in unchanged)

4.7 Atwood’s Machine
Assumes a weightless cord, weightless pulley, frictionless TENSION \((T)\) = force provided by a cord or rope on an object.
If a rope is connected to 2 objects, the tension at each end of the rope is the same, because it is the same rope that creates the 2 forces.

Drawing the vector diagram for each body showing all forces acting is called a FREE-BODY DIAGRAM (FBD). Choosing a coordinate system with pulleys and inclines like this poses a certain challenge: see example
The tension $T$ in the cord is the same at each end (if we neglect the effects of the pulley), and thus the acceleration caused by the tension must be equal for both masses. These problems lead to simultaneous equations (2 variables with 2 equations to solve for them)

Strategy:
1. Choose and isolate objects, draw FBD on those objects only.
2. Label all forces as vector arrows (giving approximate direction and magnitude)
3. Choose a coordinate system, resolve vectors as needed (label forces + or -)
Tension is always less than the force of gravity on any given object, and thus the acceleration produced by the tension force is always less than \( g \).
Review the Problem Solving Strategy on p. 119 regarding Newton problems.

4.8 In reality, FRICTION exists as a retarding force to one object moving in relation to another.
Principles of frictional behavior:
   a. For objects in relative motion, the friction always acts in a direction opposite to the direction of motion.
   b. The friction force is proportional to the normal force.
   c. For solid objects, the friction is roughly independent of the surface area in contact between the 2 objects.
   d. The friction force depends on the nature of the material.

These are not laws, hence are not absolute (meaning there exists exceptions)

When there is no relative motion between the surfaces of 2 objects, they are said to be in static motion.
As said in principle b, there is a relationship between the normal and frictional forces. There is a proportionality constant to relate these. There are two types of proportionality constants, and depend on if the object has some net relative motion.
If the object has no relative motion, there is a COEFFICIENT OF STATIC FRICTION \( \mu_s \) where
\[ F_f = \text{force of friction} \leq \mu N \] for static motion (static friction)
\[ F_f, N \] are forces (Newton’s)
\[ \mu = \text{coefficient of static friction} = \text{dimensionless} \] (no units b/c of the ratio of forces)

Note that the \( F_f \) has an upper limit of \( \mu N \). If there is a large external force, the object will move (although friction is still present)
If the object moves while friction is present, then
\[ F_f = \mu N \] where \( F_f \) is the kinetic frictional force (moving object) and the frictional force is at its maximum value.

Note that \( F_f \leq \mu N \) and \( F_f = \mu N \) are subject to conditions, thus do not always hold (ex. Excessive speeds, large \( N \), etc.)

In general, \( \mu \) is held constant. In reality, as the object begins to slide, \( \mu \) decreases.
\[ \mu_s = \text{coefficient of static friction} \]
\[ \mu_k = \text{coefficient of kinetic friction} \]
In general, for identical surface conditions, \( \mu_s > \mu_k \)

Frictional forces arise primarily from molecular forces in the regions of real contact. (i.e. roughness/smoothness is not good indicators of friction)
4.9 *Equilibrium* = state of motion in which the velocity is constant.
If object is moving AND in equilibrium, the object is in *DYNAMIC equilibrium.*
If object has zero velocity, object is in *STATIC equilibrium.*

***Up to now we would only consider translational motion, where the object as a whole entity moves in a given direction. Rotational motion in which the object spins relative to itself will be dealt with next chapter.***

*Statics* = study of objects and forces in equilibrium.

\[ F_{\text{net}} = \Sigma F = F_1 + F_2 + F_3 + \ldots F_n \]
Again, we need to separate vectors (including forces) into their components.

4.10 It is important to remember that Newton’s Laws do not apply to every object and every situation. The Laws tend to break down for the microscopic scale and for the extremely high speeds.
To further explain other circumstances (microscopic, high speeds...) incorporating Einstein’s relativity, Quantum theory and general relativity would need to occur.
Chapter 5 Notes

5.1 Uniform Circular Motion

A Radian is a unit of angular measure. \( \theta = \frac{s}{r} \) where \( s \) = arc length, \( r \) = radius, \( \theta \) = angle subtended by the arc length s.

\( \theta \) is a dimensionless unit (note ratio of \( s \) to \( r \) leaves no units). Radians as a unit can be introduced into a problem, and can be removed from a problem without the need for cancellation.

If you take a full circle, then \( s = 2\pi r \), then if \( \theta = \frac{s}{r} = \frac{2\pi r}{r} = 2\pi \)

There are \( 2\pi \) radians in a full circle.

1 revolution = 360° = \( 2\pi \) radians (rad) (this will serve as your unit conversion equalities)

Uniform Circular Motion refers to an object traveling around a circular path of radius \( r \) with constant speed \( v \). (not velocity!)

In linear motion, speed was a ratio of distance traveled to the time.

For circular motion, the speed can remain the same, but the velocity is constantly changing due to the changing direction.

If the velocity is constantly changing, then there must be some acceleration.

Where is the acceleration pointed?

Drawing of 2 velocity vectors approaching each other, \( \Delta v \) points toward center/
The acceleration points toward the center of the circle as the object travels about a circular path of radius $r$.

*Centripetal Acceleration* = acceleration directed toward the center of a circle. Centripetal = “center seeking” (as opposed to centrifugal = center fleeing)

How do we calculate the centripetal acceleration?

$$a = \frac{\Delta v}{\Delta t}$$

we know $\Delta \theta = \text{arc length}/\text{radius} = s/r$

$s = v \cdot \Delta t$

$$\Delta \theta = \frac{v \cdot \Delta t}{r}$$

The length $\Delta v$ can be compared to applying a velocity vector $v$ across an angle $\theta$, or $\Delta v = v\theta$

$$a = \frac{v^2}{r} = a_c = \text{centripetal acceleration}.$$  

The *period* $T$ is the time needed for an object to complete one full revolution around its circular path.

Assuming that the object travels at constant speed $v$, then the distance traveled is $2\pi r$...

Distance = velocity x time = $2\pi r = Tv$ or $v = 2\pi r/T$
Using \( a_c = \frac{v^2}{r} \), then we can combine these to get another
formula
\[ a_c = 4\pi^2 \frac{r}{T^2} \]

Period \( T \) is the time for 1 revolution.
How many revolutions can an object make per unit of time?
**Frequency** = \# of complete revolutions (cycles) an object
makes per unit of time.
\[ f = \frac{1}{T} = \frac{1}{\text{Period}} \quad \text{Units} = \frac{1}{\text{sec}} = \text{sec}^{-1} = \text{hertz} = \text{Hz} \]

What rate does \( \theta \) change?
Angular velocity = \( \omega \) (omega, not \( w \)) = rate of change of the
angle \( \theta \)
\[ \omega = \frac{\Delta \theta}{\Delta t} = \frac{\Delta s}{r \Delta t} = \frac{\Delta s}{r \Delta t} \]
remembering \( \frac{\Delta s}{\Delta t} = v \)
\[ \omega = \frac{v}{r} \quad \text{where the units are rad/sec} \]

Why do we keep plugging in radians?
To remind us that the angle measure is not in degrees.

With some manipulation,
\[ \omega = \frac{v}{r} = \frac{\Delta \theta}{\Delta t} \]
\[ \omega = 2\pi \text{ rad} / \text{T} = 2\pi f \text{ rad/sec} \]
Note units do not change!
Notice that we can incorporate the frequency into \( \omega \).
The angular velocity is sometimes also known as angular
frequency.
\[ a_c = \frac{v^2}{r} \], and \( v = \omega r \)
5.2 Force needed for circular motion

Objects accelerate because there is some net force acting on them (Newton’s Law of Acceleration)

The **Centripetal Force** \(F_c\) is a net force directed toward the center of the circle and causes centripetal acceleration.

\[ F_c = ma_c = mv^2/r \] (and again, you can then substitute in manipulations with T, f, \(\omega\), \(\theta\)...)  

Imagine in a car, you go around a curve. The friction between the tires and the road alter the path of a car. What about you?

In reality, inertia keeps you traveling in a straight line. The car door (or seat) pushes *you* in a new direction of motion.

To the passenger, they feel as though a force was pushing them out of the car. This observed force is the Centrifugal force (an apparent outward force)

To an outside observer, they would see the car push you into the circular path.

The centrifugal force is not typically considered a force, because it is perceived incorrectly.

To compensate, often curved roads are inclined (with the inner edge down) so that this apparent force is reduced (and also to reduce skid and accidents).
The angle $\theta$ is the banking angle for a car on a path of radius $r$ and velocity $v$ for the car NOT to skid and maintain a constant speed.

Car on incline, determine banking angle.

5.3 Keplers Laws of Planetary Motion
Johannes Kepler (before Newton) did work on planetary motion and orbits.

Kepler’s Laws:
1. The orbit of each planet is an ellipse and the sun is at one of the foci.
2. An imaginary line from the sun to a moving planet sweeps out equal areas in equal intervals of time.

3. The ratio of the square of a planet's period of revolution to the cube of its average distance from the sun is a constant. This constant is the same for all planets.
\[ k = \frac{T^2}{R^3} \] where \( T \) = period, \( R \) = distance from planet to the sun. See table 5.1 on page 159

5.4 The Law of Universal Gravitation.
Newton made his inverse-square force when doing initial work on gravity.
Imagine 2 objects. Is there a gravitational force between them? What would make the force greater? Weaker? Newton found that the mass of the two objects, as well as the distance between their centers of mass was important.

\[ F \propto \frac{m_1 m_2}{r^2} \] and introduce a proportionality constant to get an equation
\[ F_g = \frac{G m_1 m_2}{r^2} \]  
*****\( r \) is the distance between the CENTERS OF MASS of the two objects. This is Newton’s Law of Universal Gravitation. Gravitational forces exist between ANY two objects.

The center of mass = center of gravity = geometric center of an object

\[ G = \text{Universal Gravitational Constant (determined by experiment)} \]
We know \( W = mg \), there \( W \) = force due to gravity and \( m \) is the mass receiving the force

Thus \( W = F_g = mg = \frac{G m_1 m_E}{r^2} \) where \( m_E \) = mass of Earth
Hence \( g = \frac{G m_E}{r^2} \) (Thus for different places on Earth (where \( r \) is different), the gravitational acceleration changes)

5.5 The Universal Gravitational Constant \( G \)
\[ G = 6.673 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \]  
This number is often credited to Henry Cavendish (~1798)

5.6 Gravitational Field Strength
Gravity is NOT a contact force, it is a field force (i.e. can act over distances)
The Gravitational Field is the influence one mass has on the surrounding space in such a way that another mass will experience a force in the direction of the first mass.
Gravitational Field Strength is determined at any point in space, and is the gravitational force per unit mass on a test mass $m_o$

$$\Gamma = \frac{F}{m_o} = \frac{m_o a}{m_o} = a$$

The field strength is the acceleration $m_o$ would experience by $F$

Test masses are considered to be very small, so they do not exert a field that interferes with the gravitational force $F$.

$\Gamma$ is a vector (because the Force $F$ is a vector)

On Earth, $\Gamma = \frac{F}{m_o} = \frac{G m_o m_E}{r^2} / m_o = \frac{G m_E}{r^2} = g$

Review in the book the concept of field lines, or lines of force. We will look at field lines more closely when we do magnetism and electric fields.
Chapter 6 Notes

6.1 Work (W) is a quantity defined as the product of the magnitude of a constant force F by the distance x through which the force acts.

Work only exists if the force moves the object.
Work exists only if the force has a component parallel to the direction of motion.
I.e. only the component of the force that is parallel to the displacement contributes to the work.

\[ W = F \cdot x \cdot \cos \theta \]  where \( \theta \) is the angle between the force and the direction of motion.

Note that we only want a component of the force. Thus, the work is not necessarily in the direction of the applied force. Therefore, work is NOT a vector, but a scalar.
Work can be positive or negative.
When F is in the direction of motion, work is positive. When the force is opposite the direction of motion, work is negative.

Units: \( W = \text{Force} \times \text{Distance} = \text{Newton} \times \text{Meter} = \text{Nm} = \text{Joule} = J \)
\[ 1J = 1 \text{ Nm} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^2 \]

The Joule is named after James Prescott Joule (1818-1889).

6.2 This work formula is applicable for constant forces only. If an object is subjected to different forces, then the individual work calculations must be made and then added together.

An extension of this principle is Hooke’s Law (with regards to springs)

Hooke’s Law with respect to (w.r.t) a spring: the extension (or compression) of a spring is proportional to the force applied.

If \( x = \) displacement of spring from its equilibrium position, then
\( F \propto x \), and if we go from a proportionality to an equality \( F = kx \), where \( k = \) “spring constant” and is a value unique to each spring.
Examine the graph of Force vs. Displacement
The area under the curve = work done by the spring
\[ W = \frac{1}{2} Fx = \frac{1}{2} kxx = \frac{1}{2} kx^2 \]
Thus, work done by stretching (or compressing) a spring = \[ W_s = \frac{1}{2} kx^2 \] [note that the work is positive]

6.3 Energy is the ability to do work.
Ex. A compressed spring has the ability to do work, therefore it has energy. An uncompressed spring will not compress on its own, and nor will it stretch on its own, thus it does not have any energy.
There exist many forms of energy (mechanical, electrical, chemical, thermal, etc.)

Energy is transferable, meaning it can change forms. You can convert thermal energy to mechanical energy, etc.
6.4 Kinetic Energy, KE or K, is energy associated with motion. Objects in motion have energy because they can do work upon impact with another object. We will assume all the mass of the object is at a single point at that object’s geometric center.

\[ K = \frac{1}{2} mv^2 \]

If \( W = Fx \), and \( F = ma \), and by substitution of other kinematics equations, then
\[ W = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 \]

This formula for \( K \) \([K = \frac{1}{2} mv^2]\) is for an object’s translational (linear) motion only, as opposed to its rotational kinetic energy.

Work-Energy Theorem: the work done on a particle by the net force acting on it is equal to the change in its kinetic energy of the particle.
\[ W = \Delta K = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 \]
If \( v > v_0 \), then \( \Delta K > 0, W > 0 \)
If \( v < v_0 \), then \( \Delta K < 0, W < 0 \)

6.5 Potential Energy, PE or U, is equivalent to stored energy.
One must do work to give an object potential energy. Energy is stored until it is used as one of its forms.
Potential energy is also called energy of position, because its value is based on its relative position to another object.
If one does work against gravity to put an object into a position, the object has been given gravitational potential energy.
\[ W = Fx = Fh = mgh \] (the force is comparable to the weight)
\[ U = \text{Potential energy} = mgh \text{ where } h = \text{height above some reference level.} \]
\[ U \] is not an intrinsic property, like mass. It is based solely on the position of the object.
Thus, you need a reference frame!

You can choose points that make \( U = 0 \). Physically this is irrelevant, because we will consider an object’s CHANGE in position, so the choice of origin will not affect the answer. We are interested in the relative change in height.

Springs have potential energy also.
\[ W_s = U_s = \text{elastic potential energy} = \frac{1}{2} kx^2 \]
Elastic potential energy is always positive. For either compression or expansion, the spring exerts a force in a direction that would move the spring back to its equilibrium position.

6.6 Conservative force: work done by a conservative force depends only on the initial and final positions of the object. The \( x \) calculated is independent of the path taken. Examples of conservative forces include springs and gravity. You can write an expression for the potential energy of conservative forces. You cannot for the non-conservative forces.
Friction is a non-conservative force. It depends on the forces that vary with time, speed of the object, path taken, etc.

Objects can have potential and kinetic energy simultaneously. Objects can have potential without kinetic, and kinetic without potential.

The TOTAL energy of an object stays constant. Thus, at any point in an objects path, the sum of $K + U = \text{constant} = \text{Total energy} = E_t$
(this sum is the total mechanical energy).

In these circumstances (constant gravity, no outside forces, all conservative forces, no friction) energy is conserved, meaning $E_1 = E_2$.

Law of Conservation of Mechanical Energy:

$K_2 + U_2 = K_1 + U_1$ or

$\Delta K + \Delta U = 0$, or

$W = \Delta K = -\Delta U$ for work done by a conservative force.
Conservation Laws are those that state some quantity is the same before and after an event or interaction. There are relatively few conservation laws. Ex.

6.7 When friction enters a situation, mechanical energy is NOT conserved. (this is true for any non-conservative force)
The work done by friction is essentially negative. For all conservative forces: \( E_{\text{initial}} = E_{\text{final}} \)
For non-conservative forces included, \( E_{\text{final}} < E_{\text{initial}} \) as expected (because some energy is lost due to friction)
Friction and other non-conservative forces use up energy, and so are labeled “dissipative forces.”
***Energy is not lost; it is converted into some other non-mechanical form.

Thus, for any interaction, \( E_{\text{initial}} = E_{\text{final}} + W_{\text{friction}} \)

6.8 Power is the time rate of doing work.
\[ P = \Delta W/\Delta t \]
Units: Joules/seconds = Watt (W) named after James Watt, the builder of the steam engine.
1 horsepower = 1 hp = 746 W
\[ P = \Delta W/\Delta t = F \Delta x/\Delta t = Fv = \text{Force} \times \text{Velocity} \] (alternate forms of the formula)
This definition of power applies to all types of work (mechanical, electrical, and thermal)

Chapter 7 Notes
There exists a difference between linear momentum and angular momentum. We will introduce the law of conservation of linear momentum first.
7.1 **Linear momentum** = property of all objects = product of the mass of an object and its velocity (Therefore momentum is a vector, and the direction is important to consider) 
\[ p = \text{momentum} = (\text{mass}) \cdot (\text{velocity}) = mv \]

7.2 When objects collide, they exert forces on each other. The length of time that these forces coexist has great effects on the resulting motion. The **IMPULSE** is the force applied times the length of time (\(\Delta t\)) through which the force acted. 
\[ \text{Impulse} = J = F \cdot \Delta t = \Delta p = \text{(change in momentum)} \]
F here is the average force, since the force usually spikes during a collision and thus is not constant. Look at a graph of the force versus time. Look at area and slope. What do they mean?

7.3 If no net force acts on an object, then 
\[ \Delta p = \Delta mv/\Delta t = m \cdot (\Delta v/\Delta t) = ma = \Sigma F_{\text{net}} = 0. \]
Thus, \(\Delta p = 0\), or the objects momentum remains constant when the net force acting on it is zero.
OR, p = mv = constant (v does not change)
In systems with multiple objects, each object may exert forces on the others, thus causing a change in momentum. HOWEVER, the total momentum of the system is constant whenever the net external force on the system is zero. This is the Law OF CONSERVATION OF LINEAR MOMENTUM. (External forces are those that another object causes on the system, like gravity)

7.4 Collisions
Provided there are no external forces acting on a system, the total momentum before a collision equals the total momentum after a collision.

\[ m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2' \]

\( m_1, m_2 \) are constant masses (these do not change)
\( v_1, v_2 \) are the pre-collision velocities
\( v_1', v_2' \) are the post-collision velocities

Notice that these formulae look somewhat similar to kinetic energy. There are collisions where momentum is conserved while kinetic energy is not.

If kinetic energy is conserved, the collision is called \textit{ELASTIC}. This is seen when the objects collide and completely bounce off each other without a real change in shape (ex. 2 billiard balls, marbles, etc.)
If two objects stick together after impact (completely – like 2 balls of clay), the collision is **PERFECTLY INELASTIC**, and kinetic energy is NOT conserved.

If a collision has some of both of these characteristics (the balls do not stick together, but there is some “mushing together”), the collision is **INELASTIC** and kinetic energy is NOT conserved. (Ex- kick a nerf ball, soccer ball)

If the collision is perfectly inelastic, objects stick together and move with the same final velocity

\[ m_1 v_1 + m_2 v_2 = m_1 v' + m_2 v' \] (both have the same final velocity)

\[ = (m_1 + m_2) v' \]

In elastic and inelastic collisions, each object AFTER the collision has a unique velocity. Usually this means more information is needed, or another set of formulae.

***YOU NEED A REFERENCE FRAME!***

If kinetic energy is conserved (elastic collisions only), the

\[ KE_1 + KE_2 = KE_1' + KE_2' \]

Table to Compare 3 Types of Collisions:
7.5 When you get into 2D and 3D, we can resolve motion into its components like before with forces and kinematics. 
\[ m_1v_{1x} + m_2v_{2x} = m_1v'_{1x} + m_2v'_{2x} \] etc for the y and z component. This requires a reference frame!

If there are three objects, then simply add the extra term in for the extra object. \((m_3v_3\ etc.)\)

7.6 If the masses of objects change in a system, momentum is still conserved. The new mass will slow the speed of the original mass, while the new mass attains greater speed. There are no set formulae for changing mass problems. Formulae must be created to fit each problem. (Read section on thrust, but this section will not have a heavy focus (if any) on the exam (mine or AP))
Chapter 8 Notes

Applying the conservation laws (which are true for every case, following the set conditions) can solve many problems. The laws of conservation of energy and linear momentum allow you to get simultaneous equations, which can then be manipulated.

8.1 Again, elastic collisions imply that kinetic energy is conserved, and momentum is conserved. By KE conserved, we would see objects recoiling to the same height (paths are symmetrical). Again, in inelastic or perfectly inelastic collisions, kinetic energy is NOT conserved.
8.2 In 1 dimension, we do need to consider a reference frame.
Below are the systems of equations that can be created.
\[ p_i = p_f \quad \text{E}_i = \text{E}_f \]
\[ p_1 + p_2 + \ldots + p_n = p_1' + p_2' + \ldots + p_n' \quad \text{KE}_i + \text{PE}_i = \text{KE}_f + \text{PE}_f \]

Here you may have multiple dimensions, thus multiple sets of momentum equations.
For elastic collisions, we usually have two objects, and with kinetic energy being conserved...
\[ m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2' \quad \text{AND} \quad \text{KE}_1 + \text{KE}_2 = \text{KE}_1' + \text{KE}_2' \]

For every problem, start with these basic equations and then tailor them to fit the problem.
One thing to note:
The difference in relative speed before the collision equals the difference in relative speed after the collision. This relationship is irrelevant of the masses of the objects.

8.3 Remember, energy is a scalar quantity. It does not need resolved components.
For some problems, you can have 3 set of formulae (1 KE conservation set, 2 conservation of momenta sets – x and y components)
8.4 Read this section, but it will not have a large focus on the exam.

8.5 The initial velocity needed to raise objects to a certain height above where the gravitational field changes from a constant value

\[ v_o = \left( \frac{2gh_R}{(R+h)} \right)^{1/2} \]

8.6 The escape velocity needed NOT to fall back to the earth again = escape speed

\[ v_{esc} = \left( \frac{2GM_e}{R_e} \right)^{1/2} \] ***the mass of the escaping object is irrelevant
A lot of this chapter is analogous to kinematics. To date, we have dealt with translational motion (object as an entire solid, stationary object with respect to itself) moving in a linear manner, and circular motion – objects moving in circles (again, object not having any internal rotation). Now we can combine translational and rotational motion.

9.1 Rigid bodies are those that do not deform as they move, either in translational or rotational motion. For rigid bodies, we can separately analyze the translational and rotational motion. To review: in terms of rotational/angular motion:

\[ \theta = \text{angular measure (in radians)} = \frac{s}{r} \]

\[ \omega = \frac{\Delta \theta}{\Delta t} = \text{angular velocity} \]

What would the rate of change of angular velocity be? Angular acceleration = \( \alpha = \frac{\Delta \omega}{\Delta t} \)
From chapter 5, we can relate angular motion to linear motion
\[ v = r \cdot \omega, \]  
\[ a = r \cdot \alpha \]  
where \( a \) is the instantaneous acceleration
All these terms assume a constant radius.
Objects can have centripetal acceleration without having angular acceleration!

For rotational motion, there is always centripetal acceleration and there is angular acceleration if and only if the angular velocity changes.

9.2 Linear  
\[ x \]  
\[ v \]  
\[ a \]  
\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]  
\[ v^2 = v_0^2 + 2 a \Delta x \]  
\[ v = \Delta x / \Delta t \]  
\[ a = \Delta v / \Delta t \]  
\[ v = v_0 + at \]

Angular  
\[ \theta \]  
\[ \omega \]  
\[ \alpha \]  
\[ \theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2 \]  
\[ \omega^2 = \omega_0^2 + 2 \alpha \Delta \theta \]  
\[ \omega = \Delta \theta / \Delta t \]  
\[ \alpha = \Delta \omega / \Delta t \]  
\[ \omega = \omega_0 + \alpha t \]

9.3 For an object, you can sometimes apply 2 equal and opposite forces to it, and no motion is produced. Other times, motion can be created when the forces do not act
along the same line, even though the net force is zero.

Torque ($\tau$) is a quantity measuring how effectively a force causes rotation.

$$\tau = Fr \sin \theta$$  \hspace{1cm} r = absolute value of the distance between an axis or pivot point and the placement of the force

F = force applied (is a vector, but the sign will be determined later)

$\theta$ = angle between force and the direction of $r$

When $\theta = 90^\circ$ maximum torque is achieved.
When $\theta = 0^\circ$, no torque is produced.

Sometimes we see the term lever arm. The lever arm is the quantity $r \sin \theta$, which is the perpendicular distance from the axis of rotation to the line of action of the force.
The Sign convention for torque: positive (+) torque is that tending to produce a counterclockwise motion. Negative (-) torque is that tending to produce a clockwise motion.

The location of the pivot point (axis) is crucial to determining (+) and (-) torque. Bar with same forces, differing pivot points

\[ \tau = Fr \sin \theta = \text{Nm} \quad \text{(units)} \]

We don’t call the units for torque joules (though they do equal joules) because joules imply energy and work, which are scalars.

Torque is a vector, and we don’t want confusion.

The direction of torque is perpendicular to the plane containing the line of action of the force and the distance from the axis to the point of application of the force.

9.4 Equilibrium can be achieved by ensuring there is no translational or linear acceleration.
1st condition of equilibrium: \( \Sigma F = 0 \) ensuring there is no translational or linear acceleration.
2nd condition of equilibrium: $\Sigma \tau = 0$ ensuring there is no rotational or angular acceleration.

If both conditions are met, the object is in equilibrium. If the object is not moving at all, this is STATIC EQUILIBRIUM. If the object does have some constant motion, this is DYNAMIC EQUILIBRIUM.

When 2 forces of equal magnitude and opposite directions cause torque on an object (therefore do NOT lie along the same line), these 2 forces are called a couple.

For pivots, an object like a wedge, on which another object rests and rotates about is the axis. This wedge object is the fulcrum.

If an object is placed on a fulcrum, if the objects' center of mass is located above the fulcrum, no net torque is produced by the weight of the object itself.

When you place objects on a fulcrum, the fulcrum exerts a force up on the system.

9.5 When you apply forces to objects, they are deformed (either stretched or compressed).
The tensile stress = ratio of the magnitude of the applied force to the cross sectional area of the object. 
Stress = force/area = F/A  
(A is the cross sectional area, use whatever formula applies to the shape of the cross-section.)

The tensile strain is the ratio of the change in length to the initial length before the force was applied. 
Strain = change in length/initial length = ΔL/L₀  
(there are no units here)

Tensile forces = forces pulling object apart

Compressive forces = forces squishing object

Shearing force = forces applied at an angle (very strong!)

You can have tensile strain, tensile stress, compressive strain, compressive stress, shearing strain, and shearing stress.

Young’s Modulus = Y = stress/strain = (F/A)/(ΔL/L₀) 
units = N/m²

Remember springs: F = kx...through manipulation, k = YA/L₀
Young’s Modulus is a number unique to every material which gives a relative indication as to how well/poorly it can deform and change shape.
If you put tensile stress on an object, it stretches. Up to a point, that deformity is reversible. This region on a graph of stress vs. strain (the amount of stress that can be applied while the strain effects are reversible) is the ELASTIC region. After a certain strain, the effects are irreversible. This is the PLASTIC region. There is a permanent deformation. If the stress continues to rise, the object breaks at the FRACTURE region.

9.6 In linear motion, a force is used to change an object's velocity. In angular of rotational motion, a torque is used to overcome the object's inertia and get it revolving.

Linear: $F = ma$  multiply both sides by $r$
$Fr = mar$ (assume $F$ and $r$ are $\perp$)$\tau = mar$ (find angular equivalent for $a$)
$\tau = m(\alpha r)r$
$\tau = m\alpha r^2$
$\tau = I \alpha$ I is called the moment of inertia.

I is a quantity relating how the mass in an object is located (is different for different shapes – see TABLE 9.3) Depending on the shape, the formula for $I$ can change (it is still based on $I = mr^2$)
This formula is an extension of Newton’s Second Law. Objects will rotate differently if the mass is spread out differently.

9.7 To compare velocity and angular velocity, we had to multiply $\omega$ by $r$.
Similar idea for acceleration and distance. $a = \alpha r$, $s = \theta r$
Similar idea for momentum
Linear momentum = $p$, angular momentum = $L$ thus $p = r \cdot L$
Angular momentum = $L = m \cdot r v$
$$\tau = F r$$ and remember $\Delta p = F \Delta t$
$$\tau = (\Delta p/\Delta t)r = rm\Delta v/\Delta t$$ and if $r$ and $m$ are constant...
$$\Delta L = (rmv)/\Delta t = \Delta L/\Delta t$$
$L = rmv$
$L = mr^2 \omega$
$L = I\omega$ (and again you can substitute in any other formula for $I$
depending in the object’s shape from table 9.3)

9.8 $\Delta L = (I\omega)_f - (I\omega)_i = I_f \omega_f - I_i \omega_i$
When $\Delta L = 0$, $\tau = 0$. Thus, no torque produces no angular momentum.

Law of Conservation of Angular Momentum: when the net applied torque on an object is zero, its angular momentum is conserved.
Based on this law, we see that an object's moment of inertia can change.

9.9 Objects traveling with rotational motion can have rotational kinetic energy also.

\[ KE_{\text{rot}} = \frac{1}{2} I \omega^2 \] (analogous to linear kinetic energy and work)

\[ W_{\text{rot}} = \frac{1}{2} I_f \omega_f^2 - \frac{1}{2} I_i \omega_i^2 \]

Note that the units for \( KE_{\text{rot}} \) and \( W_{\text{rot}} \) are still joules.

9.10 Now we can incorporate translational and rotational motion.

Assume a disk rolls down a hill (no slipping, no friction)
At the top of the plane, \( E_{\text{tot}} = PE = mgh \).
At the bottom, \( E_t = mgh \) (Law of Conservation of Mechanical energy)
The object, as a whole entity, has translational motion, therefore \( KE = \frac{1}{2} mv^2 \), and has rotational motion \( KE_{\text{rot}} = \frac{1}{2} I \omega^2 \).

Thus \( E_t = KE + KE_{\text{rot}} = \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \)

For these problems, the object's center of mass should be moving in a straight line. If so, \( v = r \omega \).
If not, then the object has rotational motion and circular motion.
We will rarely, read as never, see this complicated an example.

Chapter 10 Notes

10.1 Fluids are substances that can flow; cannot maintain its own shape; has no rigidity.
In general, fluids are either gases or liquids (although some heterogeneous mixtures of solids and liquids apply)
Liquids exert pressure on the bottom of containers.

Pressure = force exerted per unit area (like stress)
P = F/A = N/m² = Pascal = Pa [look at table 10.1 for alternate units for pressure]
The atmosphere exerts a pressure on all objects everywhere. This is the atmospheric pressure. The common measuring devices (tire gauge, etc) lists only the pressure in excess of the atmosphere.

Earth, column of air above an object

Gauge Pressure = pressure measured that is in excess of the atmospheric pressure.

Total Pressure on an object = gauge pressure + atmospheric pressure

Another formula for pressure

\[ P = \rho gh \]

\( \rho \) = density of fluid = Mass/Volume
\( g \) = acceleration due to gravity
\( h \) = height of fluid in the container

\[ P = \frac{F}{A} = mg/A = \rho V g/A = \rho h g A/A = \rho gh \]
Note that the cross-sectional area in this case is irrelevant in the calculation of pressure, ... SO
Liquids of the same density have the same pressure at the same height in ANY container regardless of the size.

Pool of water, lake of different depths

To compare the pressure at 2 different points:
\[ \Delta P = \Delta(\rho gh) = \rho g \Delta h \quad \text{(where } \rho, g \text{ are constants)} \]
so if \( \Delta h \uparrow \Delta P \uparrow \) and vice versa

***The pressure caused by the water is really only dependent of the depth (and therefore the mass) of the water above it.
We do need to factor in atmospheric pressure also!

10.2Pressure at any point = \( P_A = P_{\text{atm}} + \rho gh \)

Note that a reference frame is needed here.

Pascal’s Principle: the pressure applied at one point in an enclosed fluid is transmitted undiminished to every part of the fluid and to the walls of the container.

What does this mean?
PA = Patm + ρgha  if Patm increases, then the new pressure PB = Patm + ρghb  (PB increases by the same amount as the added pressure)

Manometers and barometers are 2 devices used to measure pressure. Each relies on Pascal’s Principle and the fact that the difference in pressures from 2 points can be used to determine the pressure at a 3rd point.

10.3 Archimede's Principle: A body, whether completely submerged or partially submerged in a fluid, is buoyed upward by a force that is equal to the weight of the displaced fluid.

Buoyant force = weight of fluid in the volume displaced by the object.  New FBD of floating objects

Objects float if their average density is less than that of the fluid they are in.
U = Buoyant force, W = weight of object
If U = W, object remains at a given depth
If U>W, object rises in the fluid
If U<W, object sinks in the fluid

10.4 Surface Tension is created because there is a net unbalanced force for molecules of a liquid at the surface of their containers. This force causes the liquid to resist any increases in its surface area (i.e. objects falling inward), so objects will float on the surface.

To minimize this surface tension, objects naturally minimize their surface area. Adopting a spherical shape (smallest surface area per unit volume) does this.

Cohesion = attractive force between liquid molecules that hold the liquid together (2 like molecules)
Adhesion = attractive force between unlike molecules

Capillary action = liquid rises up in a small tube (small internal diameter). Adhesion and cohesion working together cause this.
When fluid flows: each element (molecule) of a fluid follows a path called a streamline. When multiple streamlines flow smoothly with no crossover, it is called laminar flow. When the fluid’s velocity exceeds a certain amount, the streamline paths crossover and the flow is turbulent. (irregular, complex motion of the streamline paths)

When we analyze smooth laminar flow, we will assume (very akin to real life effects) that fluid is not compressible. If this is true, the amount of fluid entering a pipe must equal the amount that leaves (in equal intervals of time)

What affects the flow and the amount of fluid – AREA of the pipe and the VELOCITY of the fluid thought the pipe

\[ v_1 A_1 = v_2 A_2 \]  
Equation of continuity

The flow of material (mass of fluid) though a tube of changing cross-section is constant when the density of the fluid is constant.
Analyze the Equation of Continuity for proportionalities
The rate of flow of a fluid = Volume/Time = m³/s

10.6 More factors are involved. Pressure of the fluid in the pipe (caused by the height of the fluid) is a big factor to consider.
By combining the laws of the conservation of mass and mechanical energy, work energy theorem and equation of continuity, we get BERNOULLI’S EQUATION. This equation assumes no friction, liquid is incompressible and the flow of the fluid is steady.

\[ P_1 + \rho gh_1 + \frac{1}{2} \rho v_1^2 = \text{constant} = P_2 + \rho gh_2 + \frac{1}{2} \rho v_2^2 \]

\( P_1 \) = pressure at point 1
\( h \) = height of fluid at a point based on some reference frame
\( v \) = velocity (speed) of fluid in the pipe

10.7 Viscosity is a property of fluids that indicates its internal friction.
Greater viscosity indicates greater resistance to flow.
Temperature has a big effect on viscosity (increase in temp \( \rightarrow \) increase in flow \( \rightarrow \) decreased viscosity)
The pipe walls directly slow the flow of fluid. Thus, fluid nearer the pipe walls move the slowest.
A pressure difference is required for flow to occur in a non-ideal (viscous) fluid

We are forgoing 10.8 and 10.9
Chapter 11 Notes

11.1 Phases of matter = distinct forms or states of matter: solid, liquid, gas

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In reality, all phases are compressible, but liquids and solids compress so little (before breaking) that they are virtually incompressible.

*Temperature:* the number assigned to an object as an indication of its warmth

*Thermometer:* device used to measure temperature

Objects are in thermal equilibrium if they have the same temperature.

Energy is essentially an indication as to the relative motion of molecules in any state of matter.

Temperature is also an indicator as to an object's energy.

11.2 There are a variety of thermometers; all working on the basis that their properties (like volume or resistance) change with changes in temperature.
Celsius Temperature scale: 0°C = freezing point of water
100°C = steam point (boiling) of water

The values of these numbers (0 and 100) are arbitrary.
Fahrenheit temperature scale: 32°F = freezing point of water
100°F = boiling point of water

\[ T_f = \frac{9}{5} T_c + 32 \]
this is the conversion factor from Celsius to Fahrenheit

Kelvin temperature scale: uses intervals equal to those of the Celsius scale, but the zero point is well defined (therefore not arbitrary)
0 Kelvin = 0 K (we don’t use the ° symbol) is also known as absolute zero, or the lowest temperature (for this scale) that can be reached.

\[ T_k = T_c + 273.15 \]
Absolute zero came about where if you compress a gas, and it does not liquefy, its volume would be zero at this temperature.

11.3 Objects expand when heated.
*Linear thermal expansion* = expansion in 1 dimension caused by changes in the temperature of an object.

\[ \Delta L = L_o \alpha \Delta T \]
\[ \Delta L = \text{change in length} = L_f - L_i = L - L_o \]
L₀ = initial length
α = Linear thermal expansion coefficient (units = 1/°C)
ΔT = change in temperature = T_f - T_i

The coefficient α varies for different materials (see table)
Note that if ΔT < 0, ΔL < 0 (i.e. objects expand when heated, and contract – shrink – when cooled)
Similarly, objects will also expand (or contract) in 3 dimensions – volume.

Volumetric Expansion
ΔV = V₀βΔT
ΔV = change in volume
β = Volumetric thermal expansion coefficient

β ≈ 3α roughly (see table)

Most substances expand and contract smoothly.
Water is the exception. Water is most dense at 4°C, therefore will sink in a container (like a pond, etc.) Thus the water at the top will get colder and freeze first.
Also, ice is less dense than water and will float.
Otherwise, ice would sink, and the top water would freeze, ice sinks, etc. and all water would freeze and then we would die. (Bummer)

11.4 Heat is a form of energy; it can be transferred between objects.
Objects with higher temperature have more heat (therefore have more energy)

Ways to measure heat:
Btu = British thermal unit = energy required to raise 1 lb. of water by 1°F

Cal = calorie = metric unit = heat needed to raise 1 g of water by 1°C

Cal = Calorie = 1000 cal = 1 kcal

Joule = mechanical equivalent of heat (thermal energy converted to mechanical energy)

***1 cal = 4.187 Joules know this!

See table 11.2 for conversion factors of energy units.
Joules are the appropriate SI unit for heat.

11.5 Calorimetry = measuring of heat exchanged, produced, etc.

Based on a variety of experiments (similar materials of different mass, same mass and different materials, etc.) measuring temperature change, it was found:

Heat capacity = amount of heat required to change an objects temperature by 1 °C.

Different materials and different masses have different heat capacities.
Specific heat capacity = a.k.a. SPECIFIC HEAT = heat required per unit mass to change the temperature of a substance by one degree.

High specific heat substances require a large amount of heat to change their temperature.

\[ Q = mc\Delta T \]
Q = amount of heat (joules, cal, Btu) lost or gained by an object
m = mass of object
c = specific heat of the material of mass m
\( \Delta T = \) temp change caused by Q \( (***) \) if Q\(<0, \Delta T <0) \\
We have seen a law of conservation of mechanical energy. Thermal energy can easily be converted into mechanical energy.
In general, there is a law of conservation of energy (all types)

For a system, \((\text{Heat gained}) + (\text{Heat lost}) = 0\).
This is the equivalent of saying that the total thermal energy in a system is constant.

Ex. A cup of hot coffee is mixed with cold cream. Find the equilibrium temperature.
11.6 During phase changes (solid ⇔ liquid ⇔ gas), energy changes while the temp stays the same.

Diagram = Phase change

The energy added (removed) during phase changes is put into the intermolecular bonds (either making or breaking).
The heat energy put in or absorbed during a phase change is the Heat of Transformation (a.k.a. Latent Heat)
L = latent heat of transformation
L = Q/m

If the phase change is between solids and liquids, L is called the \textit{latent heat of fusion} \( L_f \).
If the phase change is between liquids and gases, L if called the \textit{latent heat of vaporization} \( L_v \).
11.7 Heat energy can be transferred by conduction, convection or radiation.

*Conduction* = thermal energy is transferred without any net movement of the material. This is usually between objects in contact, or the same object routes energy evenly through itself (like a stovetop)

*Convection* = thermal energy is transferred through a mass motion of flow of some fluid. The energy passes from one object to another by passing through a fluid (ex air, water)

*Radiation* = thermal energy transfer required no contact nor fluid (ex. Energy from the sun)

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Chapter 13 Notes

Thermodynamics is the relationship between heat and work. Thermo = heat, dynamics = motion (work required for motion)
13.1 From chapter 12, objects in thermal equilibrium do not transfer heat (i.e. no net heat flow) because objects have the same temperature (i.e. same heat, i.e. same energy)

The **Zeroth Law of Thermodynamics** (because it precedes the 1st law in terms of logic) states that if object A is in thermal equilibrium with object C, and object B is in thermal equilibrium with object C, then A and B are in thermal equilibrium.

When analyzing a situation, there is the system and an environment to consider. A thermodynamic system is any collection of objects. The environment is everything else (i.e. rest of universe)

The thermodynamic system and the environment interact by heat flow and/or work done.

**Internal energy** is the total kinetic and potential energies associated with the atoms comprising the entire system.

For these objects (like gases), the potential energy can be though of as energy in a certain phase (the gas phase has more internal energy than solids, etc.)
13.2 Remember conservation of energy \( \rightarrow \) in any thermodynamic system, energy is neither created nor destroyed.

\[
\Delta U = Q - W
\]

\( \Delta U \) = change in internal energy of a thermodynamic system
\( Q \) = neat heat INTO a system
\( W \) = work done BY the system (i.e. giving heat energy elsewhere)

**1st Law of Thermodynamics**: the change in internal energy of a system equals the difference between the heat taken in by the system and the work done by the system.

If \( Q < 0 \), heat is given out by the system.
If \( W < 0 \), work is done on the system, and energy is taken in.

When movement of an object is all mechanical, the 1\textsuperscript{st} law is easy to apply. Remember energy can take many forms and is easy to spread.

There can be many situations of problems you will encounter.
4 popular situations or processes are:

- **Adiabatic** process = system has the same heat before and after an event (no heat enters or leaves)

- **Isothermal** = system has the same temperature
Isochoric = system has the same volume

Isobaric = system has the same pressure

In an adiabatic process: $Q$ is the heat entering/leaving a system. For this process, $Q = 0$. Therefore $\Delta U = Q - W = -W$

In an isothermal process, temperature is constant. Since temperature is a measure of the internal energy, $\Delta U = 0$. Therefore $Q = W$.

In an isochoric process, the volume is constant. If the volume of an object changes, there is work done ($\text{Work} = \text{Force} \times \text{Distance}$, and here $d=0$) therefore $W = 0$ when $d = 0$. $Q = \Delta U$ (no work is done on the system, and any heat added/subtracted changes the internal energy)

In an isobaric process, the pressure remains constant. $W = P\Delta V$ $W =$ work (J), $P =$ pressure (Pa), $\Delta V =$ $\Delta$Volume ($m^3$)
We usually see this principle applied to heat engines (cylinder filled with a gas and a piston)

The 1st law of thermodynamics allows reversible processes. The system remains in or near equilibrium to be reversible.

If, though, energy is lost (due to friction), then attaining equilibrium is impossible, therefore reversible processes are not allowed.

Machines (or systems) that can do this (i.e. \(Q = W\) because if no energy is lost or gained, \(\Delta U = 0\)) are called perpetual motion machines, because energy taken in is converted entirely into work.

13.3 Since \(W = P \Delta V\), the area under a \(P\) vs. \(\Delta V\) curve would equal work.

The French engineer Sadi Carnot claimed all movements were due to heat (indirectly or directly) and that heat flowed from objects of higher temp to objects of lower temp. He developed a near perfect, ideal engine. (**this engine is ideal, and cannot be built**)
His engine transformed heat into work. It is based on using an ideal gas.

Of the 4 steps in his engine, a vocab lesson:

- A **heat reservoir** is a body of enormous capacity that can supply (give) thermal energy without lowering its own temperature (a never ending well of energy)

- A **heat sink** is a cold body that can absorb energy without raising its own temperature.

- **Perfect insulators** are substances where no heat can flow through.

4 steps to the Carnot Cycle (all steps are reversible)

1. Isothermal Process – the temperature of the gas rises to the temperature of the heat reservoir. The gas receives energy and expands, and does work on the piston. $\Delta U = 0$, so $Q = W$, where $Q_h$ is the heat taken in supplied by the reservoir.

2. Object is insulated $(Q = 0)$, the load on the piston is reduced, the gas expands (adiabatic curve). Here, as the object does work, $\Delta U$ goes down.

3. Object is placed in a heat sink. $Q_c = $ heat expelled (therefore is negative) to the environment. Work = $W = Q_c$, therefore $W < 0$, therefore work is done on the system

4. The load is increased (adiabatic compression), the object/system is insulated, and the volume decreases.
OVERALL: work is the net heat flow into a system. 
\[ W = \left| Q_h \right| - \left| Q_c \right| \]
for \( Q_h \) = heat in by the reservoir
\( Q_c \) = heat out into the heat sink

Thermal efficiency is a ratio showing how well an engine uses energy given to it

\[ \text{Efficiency} = \frac{W}{Q_h} = \frac{\text{work done by engine}}{\text{energy added to engine}} \]

Ideally, \( W = Q_h \) (i.e. no heat is lost, so all energy given is converted into work)

Also; \( \text{Efficiency} = \frac{W}{Q_h} = \frac{\left| Q_h \right| - \left| Q_c \right|}{\left| Q_h \right|} = 1 - \frac{T_c}{T_h} \)
From the Ideal Gas Law, temperature is directly proportional to the energy of a system, therefore is proportional to the energy taken in or out.

\[
\text{Efficiency} = \frac{W_{\text{output}}}{W_{\text{input}}} = \frac{F_0 d_0}{F_i d_i}
\]

\( F = \text{force applied to the system} \)

\( d = \text{distance } F \text{ is applied over} \)

13.4 Carnot’s Cycle and Engine work on the belief that energy flows from high temperature objects to low temperature objects. A refrigerator is based on a reversed Carnot Cycle. I.e. work put into the system and transfer heat from a low temp object to a high temp object.

\textit{Coefficient of performance} (cp.) = \frac{\text{(Heat extracted from a cold reservoir)}}{\text{(work supplied)}}

This idea is similar to thermal efficiency.

If the system is designed to remove heat from a system, (like a refrigerator) then this formula finds \( \text{c.p. refrigerator} \)

If the system is designed to add heat in, it is a heat pump. \( \text{c.p. heat pump} = \frac{Q_h}{W} \)
13.5 *2nd Law of Thermodynamics* (2 versions)
Clausius ⇒ Heat cannot, by itself, pass from a colder to a warmer body.

Kelvin-Planck – It is impossible for any system to undergo a cyclic process whose sole result is the absorption of heat from a single reservoir at a single temperature and the performance of an equivalent amount of work. The 1<sup>st</sup> Law does not imply this.

13.6 *Entropy* is a measure of how much energy or heat is unavailable for conversion into work.

We really (like potential energy) are interested in the change in entropy of a system.

\[ \Delta S = \text{change in entropy} = \frac{Q}{T} \quad \text{(joules/Kelvin)} \]

Entropy is conserved in the entire universe. If \( \Delta S \uparrow \) for a system, \( \Delta S \downarrow \) for the environment.
Conservation of Mechanical Energy

Energy is something all objects have. There are many forms: kinetic, potential, thermal, nuclear, etc. Mechanical Energy is energy that an object uses to move. There are two forms:
- Kinetic Energy (KE) – energy an object uses to actually move about. The greater the KE, the faster the object moves. \( KE = \frac{1}{2} mv^2 \)
- Potential Energy (PE) – energy an object has stored. Energy provided by gravitational forces. Object has to be able to fall (i.e. object has to be some height above a zero height chosen by you). \( PE = mgh \)

An object can have one, both, or neither form of energy at any time, depending on your reference frame and the motion of the object.

Because total energy is conserved, we can set the total energy at any point (A, B, C) equal to any other point. This statement can be written as a formula: \( E_A = E_B \)

Ex. A 0.25 kg ball is thrown upward from the ground. The initial speed is 10 m/s. What is the speed of the ball when it is 4 m above the ground?

Work: 

Notes:
Example Problems: Using the above strategy and required work, complete the following.

1. While baking cookies for Mr. Staley (hey thanks!), you drop a 125 gram egg off the counter. The counter is 1.5 m high. The egg was dropped from rest. How fast was it moving when it hits the ground?

2. A soccer player kicks a ball from the ground. A fan in the stands observes the ball to rise to a maximum height of 17 m. How fast was the ball kicked from the ground?

3. An owl flying around sees a mouse on the ground, 15 m below. If the owl is flying at 5 m/s and starts to dive toward the mouse, how high off the ground is the owl when its speed is 10 m/s?
4. An owl flying around sees a mouse on the ground, 15 m below. If the owl is flying at 5 m/s and starts to dive toward the mouse, how fast is the owl moving when has traveled half the distance to the mouse?
1. Fill in the missing information in the table below.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δx</td>
<td></td>
<td></td>
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<tr>
<td>v_f</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
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<td></td>
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<tr>
<td>t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v_i</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v_avg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Convert the following terms. Show mathematically appropriate work.

Ex. Convert 28 Mm to m.

\[
\text{m} = \frac{28 \text{ Mm} \times (10^6 \text{ m})}{(1 \text{ Mm})} = 2.8 \times 10^7 \text{ meters}
\]

a. 68 km/hr to m/s

b. 24 hr to seconds

c. 0.521 cm/s to m/s

Formulas:
3. A car accelerates from rest for 20 s. (a) What is its final speed? (b) How far did the car travel?

4. A jogger runs 3 segments of a race: 20 m at 0°, 35 m at 130°, and 18 m at 250°. What is the jogger’s final displacement?
Strategy

1. Read and decode the question.

2. As you read, list and label the physical information.

3. Identify and label the unknown.

4. On the list, convert any quantity so that the units all match. Desired units include meters, seconds, kilograms, and others that will be identified.

5. Find the best formula to use.

6. Use algebra to re-write the formula so that you are solving for the unknown. I.e. get the missing quantity in the numerator and by itself.

7. Plug in the numbers from the list and solve.

8. Use logic – does the answer make sense?

Sample Problem

A car travels down the highway at an average velocity of 110 km/hr. If the car travels from Worcester to Boston, a distance of 72 kilometers, how long does this trip take?
### Physics – Unit Conversions

Directions: In each box below, replace the metric prefix with its value. Then write the two possible conversion factors. There are several examples of unit conversions on the back of this paper. Use the work from this front side to help you.

<table>
<thead>
<tr>
<th>1 mm = __________</th>
<th>1 cm = __________</th>
<th>1 Mg = __________</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 μg = __________</td>
<td>1 km = __________</td>
<td>1 hr = __________</td>
</tr>
<tr>
<td>1 min = __________</td>
<td>1 mg = __________</td>
<td>1 Mm = __________</td>
</tr>
<tr>
<td>1 cs = __________</td>
<td>1 μs = __________</td>
<td>1 kg = __________</td>
</tr>
<tr>
<td>1000 m = __________</td>
<td>10^{-3} g = __________</td>
<td>10^{6} s = __________</td>
</tr>
<tr>
<td>1000000 g = __________</td>
<td>10^{3} s = __________</td>
<td>10^{-2} m = __________</td>
</tr>
</tbody>
</table>
$10^{-6} \text{ g} = \underline{\hspace{1cm}}$   $60 \text{ min} = \underline{\hspace{1cm}}$   $60 \text{ s} = \underline{\hspace{1cm}}$

Example: Convert 55 km to cm

1. Convert 0.075 $\mu$g to kg

2. Convert 170 seconds to hours

3. Convert $1.45 \times 10^{-4}$ kg to cg

4. Convert 25 km/hr to m/s
5. Convert 0.075 Mm/min to m/s
The scientific method is a way to ask and answer scientific questions by making observations and doing experiments.

The **steps of the scientific method** are:

1. Ask a question
2. Do background research
3. Construct a hypothesis
4. Test your hypothesis by doing an experiment
5. Analyze your data and draw a conclusion
6. Communicate your results

It is important for your experiment to be a fair test. A “fair test” occurs when you change only one factor or variable and keep all other conditions the same.

Note – You may have seen other phrases used for these six steps. Regardless of the names of the steps of the scientific method, the process you take is the same.

**Overview of the scientific method**

The scientific method is a process for experimentation that is used to explore observations and answer questions. Scientists use the scientific method to search for cause and effect relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way.

Just as it does for a professional scientist, the scientific method will help you to focus your science project question, construct a hypothesis, design, execute, and evaluate your experiment.
Ask a question: The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where?

And in order for the scientific method to answer the question it must be about something that you can measure, preferably with a number.

Do Background Research: Rather than starting from scratch in putting together a plan for answering your question, you want to be a savvy scientist using library and Internet research to help you find the best way to do things and insure that you don’t repeat mistakes from the past.

Construct a Hypothesis: A hypothesis is an educated guess about how things work: “If ______[I do this]_____, then ______[this] ______will happen.”

You must state your hypothesis in a way that you can easily measure, and of course, your hypothesis should be constructed in a way to help you answer your original question.

Test Your Hypothesis by Doing an Experiment: Your experiment tests whether your hypothesis is true or false. It is important for your experiment to be a fair test. You conduct a fair test by making sure that you change only one factor at a time while keeping all other conditions the same.

You should also repeat your experiments several times to make sure that the first results weren’t just an accident.

Analyze Your Data and Draw a Conclusion: Once your experiment is complete, you collect your measurements and analyze them to see if your hypothesis is true or false.
Scientists often find that their hypothesis was false, and in such cases they will construct a new hypothesis starting the entire process of the scientific method over again. Even if they find that their hypothesis was true, they may want to test it again in a new way.

**Communicate Your Results:** To complete your science project you will communicate the results to others in a final report and/or display board. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster at a scientific meeting.

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an iterative process.
Appendix A6: Additional Practice Multiple Choice
AP Physics

Chapters 5 & 6 Sample Exam Questions

Multiple Choice – Circle the correct answer. Keep any work in case of an error.

2. A ball is dropped off a cliff of height \( h \). Its velocity upon hitting the ground is \( v \). At what height below the starting point is the ball’s velocity equal to \( \frac{v}{2} \)?
   a. \( \frac{h}{4} \)  
   b. \( \frac{h}{2} \)  
   c. \( \frac{h}{\sqrt{2}} \)  
   d. \( \frac{h}{8} \)  
   e. \( \frac{h}{2} \cdot \sqrt{2} \)

3. A mass hangs from two ropes at unequal angles, as shown below. Which of the following makes correct comparisons of the horizontal and vertical components of the tension in each rope?

   Horizontal Tension  
   a. Greater in Rope B  
   b. Equal in both Ropes  
   c. Greater in Rope A  
   d. Equal in both Ropes  
   e. Greater in Rope B

   Vertical Tension  
   Greater in Rope B  
   Greater in Rope A  
   Equal in both Ropes

4. An object rolls along level ground to the right at constant speed. Must there be any forces pushing the object to the right?
   a. Yes: the only forces that act must be to the right.  
   b. Yes: but there could also be a friction force acting to the left.  
   c. No: no forces can act to the right.  
   d. No: while there can be forces acting, no force must act.  
   e. The answer depends on the speed of the object.

5. A mass \( m \) is attached to a mass \( 3m \) by a rigid bar of negligible mass and length \( L \). Initially, the smaller mass is located directly above the larger mass, as shown below. How much work is necessary to flip the rod \( 180^\circ \) so that the larger mass is directly above the smaller mass? The bar pivots around the stationary point indicated in the diagram.
6. A ball rolls horizontally with speed \( v \) off a table of height \( h \) above the ground. Just before the ball hits the ground, what is its speed?
   a. \( \sqrt{2gh} \)           b. \( v\sqrt{2gh} \)           c. \( \sqrt{v^2 + 2gh} \)  
   d. \( v \)            e. \( v + \sqrt{2gh} \)

7. Which of the following must be true of an object in uniform circular motion?
   a. Its velocity must be constant.
   b. Its acceleration and its velocity must be in opposite directions.
   c. Its acceleration and its velocity must be perpendicular to each other.
   d. It must experience a force away from the center of the circle.
   e. Its acceleration must be negative.

8. A planet of mass \( m \) orbits in a circle around a sun. The speed of the planet in its orbit is \( v \); the distance from the planet to the sun is \( d \). What is the magnitude and direction of the net force experienced by the planet?
   a. \( \frac{v^2}{d} \) toward the sun
   b. \( \frac{mv^2}{d} \) toward the sun
   c. \( \frac{mv^2}{d} \) away from the sun
   d. \( \frac{mv^2}{d} \) along the orbital path
   e. \( \frac{v^2}{d} \) along the orbital path

9. A satellite orbits the moon in a circle of radius \( R \). If the satellite must double its speed but maintain a circular orbit, what must the new radius of its orbit be?
   a. \( 2R \)              b. \( 4R \)               c. \( \frac{1}{2} R \)             d. \( \frac{1}{4} R \)              e. \( R \)

10. The space shuttle orbits 300 km above the Earth’s surface. The Earth’s radius is 6400 km. What is the gravitational acceleration experienced by the space shuttle?
    a. 4.9 m/s\(^2\)           b. 8.9 m/s\(^2\)                c. 9.8 m/s\(^2\)              d. 10.8 m/s\(^2\)               e. Zero

11. Two identical balls of mass \( m = 1.0 \) kg are moving toward each other. What is the initial kinetic energy of the system consisting of the two balls if ball A moves to the right at 6 m/s and ball B moves to the left at 6 m/s?
    a. 0 J                    b. 1 J                   c. 12 J                      d. 18 J                   e. 36 J

12. A 500 gram block on a flat table slides 2.0 m to the right. If the coefficient of friction between the block and the table is 0.1, how much work is done on the block by the table?
    a. 0.5 J              b. 1.0 J                     c. Zero              d. 100 J            e. 50 J

13. A block has 1500 J of potential energy and 700 J of kinetic energy. Ten seconds later, the block has 100 J of potential energy and 900 J of kinetic energy. Friction is the only external force acting on the block. How much work was done on the block by friction?
    a. 600 J                   b. 200 J                 c. 1400 J            d. 1200 J                    e. 120 J
14. A satellite orbits the moon far from its surface in a circle of radius \( r \). If a second satellite has a greater speed, yet still needs to maintain a circular orbit around the moon, how should the second satellite orbit?
   a. with a radius \( r \)
   b. with a radius greater than \( r \)
   c. with a radius less than \( r \)
   d. only an eccentric elliptical orbit can be maintained with a larger speed
   e. no orbit at all can be maintained with a larger speed

15. A mass attached to a spring, while lying on a flat frictionless table, experiences a potential energy \( U \) that varies with distance \( x \) as shown in the graph below. The mass is released from position \( x = 0 \) with 10 J of kinetic energy. Which of the following describes the long term motion of the mass?
   a. The mass eventually comes to rest at \( x = 0 \).
   b. The mass slows down with constant acceleration, stopping at \( x = 5 \) cm.
   c. The mass speeds up with constant acceleration.
   d. The mass oscillates, never getting farther than 5 cm from \( x = 0 \).
   e. The mass oscillates, never getting farther than 10 cm from \( x = 0 \).

Questions 15 and 16 refer to the following information:
Ancient warriors used a crude device known as a slingshot. Examples include David in the biblical story of David v. Goliath and the Ewoks in Return of the Jedi. The warrior throws rocks using a circular motion device. A rock is attached to a string. A warrior whirls the rock in a horizontal circle above his/her head, then lets go, sending the rock toward the head of the enemy.

16. What force provides the rock’s centripetal acceleration?
   a. The vertical component of the string’s tension.
   b. The horizontal component of the string’s tension.
   c. The entire tension of the string.
   d. The gravitational force on the rock.
   e. The horizontal component of the gravitational force on the rock.

17. The warrior whirls the rock and releases it from a point above his/her head and to the right. The rock initially goes straight forward. Which of the following describes the subsequent motion of the rock?
   a. It will continue in a straight line forward, while falling due to gravity.
   b. It will continue forward but curve to the right, while falling due to gravity.
   c. It will continue forward but curve to the left, while falling due to gravity.
   d. It will fall straight down to the ground.
   e. It will curve back toward the warrior and hit him/her in the head.
18. A space shuttle orbits Earth 300 km above the surface. Why can’t the Shuttle orbit 10 km above Earth?
   a. The Space Shuttle cannot go fast enough to maintain such an orbit.
   b. Kepler’s laws forbid an orbit so close to the surface of the Earth.
   c. Because r appears in the denominator of Newton’s Law of Gravitation, the force of gravity is much larger closer to the Earth; this force is too strong to allow such an orbit.
   d. The closer orbit would likely crash into a large mountain such as Everest because of its elliptical nature.
   e. Much of the Shuttle’s kinetic energy would be dissipated as heat in the atmosphere, degrading the orbit.

Open Response Questions – Answer these as you would a traditional exam problem. Show all work on attached paper.

19. Consider two points on a rotating turntable: Point A is very close to the center of rotation, while Point B is on the outer rim of the turntable.
   a. In which case would the speed of the penny be greater, if it were placed at point A or if it were placed at point B? Explain.

For parts (b) and (c), a penny could be placed on a rotating turntable without moving at either point A or point B.

b. At which point would the penny require the larger centripetal force to remain in place? Justify your answer.

c. Point B is 0.25 m from the center of rotation. If the coefficient of friction between the penny and the turntable is $\mu = 0.30$, calculate the maximum linear speed the penny can have there and still remain in circular motion.

20. At what angle above the horizontal should a curve of radius 150 m be banked (inclined), so cars can travel safely at 25 m/s without relying on friction?

21. A skier starts from rest at the top of a hill. The skier coasts down the hill and up a second hill, as the drawing below illustrates. The crest of the second hill is circular, with a radius of $r = 36$ m. Neglect friction and air resistance. What must be the height $h$ of the first hill so that the skier just loses contact with the snow at the crest of the second hill?
22. The motor of a ski boat generates an average power of $7.50 \times 10^4$ W when the boat is moving at a constant speed of 12 m/s. When the boat is pulling a skier at the same speed, the engine must generate an average power of $8.30 \times 10^4$ What is the tension in the tow rope that is pulling the skier?
Chapter 7-8: Sample Test Questions

Multiple Choice Questions. Listed below are various sample multiple choice questions that would be covered by the upcoming test. Complete all questions. Keep your work for these questions, so we can analyze them later.

1. In a perfectly inelastic collision:
   a. total kinetic energy is constant
   b. the velocity of separation equals the velocity of approach
   c. the final momentum is always zero
   d. the colliding objects stick together

2. A ball with a mass of 0.25-kg moving at 5 m/s makes a head-on collision with a second ball of mass 0.50 kg that is initially at rest. If the collision is elastic, what is the speed of the first ball after the collision?  
   a. –1.7 m/s  
   b. –2.2 m/s  
   c. 2.5 m/s  
   d. 3.8 m/s  
   e. 0 m/s

3. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown below. The 0.2-kg object overtakes and collides with the 0.1-kg object. Immediately after the collision, the y component of the velocity of the 0.2-kg object is 1 m/s upward. What is the y component of the velocity of the 0.1-kg object immediately after the collision?
   a. 2 m/s downward  
   b. 0.5 m/s downward  
   c. 0 m/s  
   d. 0.5 m/s upward  
   e. 2 m/s upward

4. A stationary object explodes, breaking into three pieces of masses m, m, and 3m. The two pieces of mass m move off at right angles (along the +x and +y axes) to each other with the same magnitude of momentum mV. What are the magnitude and direction of the velocity of the third piece having mass 3m?
   
<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ( \sqrt{3} ) V</td>
<td>( \sqrt{3} )</td>
</tr>
<tr>
<td>b. ( \sqrt{3} ) V</td>
<td>( \sqrt{3} )</td>
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<tr>
<td>c. ( \frac{\sqrt{2}}{3} ) V</td>
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   a. –1.7 m/s  
   b. –2.2 m/s  
   c. 2.5 m/s  
   d. 3.8 m/s  
   e. 0 m/s

3. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown below. The 0.2-kg object overtakes and collides with the 0.1-kg object. Immediately after the collision, the y component of the velocity of the 0.2-kg object is 1 m/s upward. What is the y component of the velocity of the 0.1-kg object immediately after the collision?
   a. 2 m/s downward  
   b. 0.5 m/s downward  
   c. 0 m/s  
   d. 0.5 m/s upward  
   e. 2 m/s upward

4. A stationary object explodes, breaking into three pieces of masses m, m, and 3m. The two pieces of mass m move off at right angles (along the +x and +y axes) to each other with the same magnitude of momentum mV. What are the magnitude and direction of the velocity of the third piece having mass 3m?
   
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<td>( \sqrt{3} )</td>
</tr>
<tr>
<td>c. ( \frac{\sqrt{2}}{3} ) V</td>
<td>( \sqrt{2} )</td>
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<tr>
<td>d. ( \frac{\sqrt{2}}{3} ) V</td>
<td>( \sqrt{2} )</td>
</tr>
<tr>
<td>e. ( \sqrt{2} ) V</td>
<td>( \sqrt{2} )</td>
</tr>
</tbody>
</table>
Sample Questions: Chapters 11-13
1. The heat added to a thermodynamic system minus the work done is
   a. heat lost from the system.
   b. change in internal energy.
   c. total heat added to the system.
   d. Carnot efficiency of the system.
2. In an adiabatic process
   a. the temperature remains constant.
   b. the temperature increases at a constant rate.
   c. heat flows at a constant rate into or out of the system.
   d. no heat flows into or out of the system.
3. In an isothermal process
   a. the temperature remains constant.
   b. the temperature increases at a constant rate.
   c. heat flows at a constant rate into or out of the system.
   d. no heat flows into or out of the system.
4. Refrigerators and air conditioners are
   a. Carnot engines.
   b. reversible Otto cycle engines.
   c. Kelvin engines.
   d. heat pumps.
5. In any physical process
   a. the entropy of the rest of the universe increases.
   b. the entropy of the rest of the universe decreases.
   c. the total entropy remains constant.
   d. entropy flows from high to low.
6. The first law of thermodynamics is a statement of
   a. thermal equilibrium between systems.
   b. conservation of energy.
   c. relationships between heat and equilibrium.
   d. external factors influencing thermodynamic equilibrium.
7. According to the first law of thermodynamics, what percentage of mechanical energy can be turned into heat energy?
   a. 0%         b. 25%         c. 50%        d. 100%
8. A 50-kilogram box is pushed up a 1.5-meter incline with an effort of 200 Newtons. The top of the incline is 0.5 meter above the ground. How much work was done to overcome friction?
   a. 55 J          b. 75 J          c. 245 J            d. 300 J          e. 400 J
9. The incline is question 8 is an example of a simple machine. On the basis of the information provided, what is the efficiency of this machine?
   a. 68%          b. 100%          c. 18%           d. 72%          e. 82%
10. Isobaric changes in an ideal gas imply that there is no change in
    a. volume       b. temperature       c. pressure         d. internal energy       e. potential energy.
11. What is the maximum efficiency of an engine operating between a heat source at 127°C and a heat sink at 27°C?
    a. 25%   b. 33%   c. 50%   d. 67%   e. 79%
12. What happens to the pressure P, of an ideal gas, if the temperature is increases by a factor of 2 and the volume is increased by a factor of 8?
a. P decreases by a factor of 16.
b. P decreases by a factor of 4.
c. P decreases by a factor of 2.
d. P increases by a factor of 4.
e. P increases by a factor of 16.

13. A confined ideal gas undergoes a cyclical process in three steps—an isobaric step, followed by an isochoric step, followed by an isothermal step. Which of the following must be true?
   a. The change in internal energy of the gas is equal to the work done during the isobaric step.
   b. The change in internal energy of the gas is equal to the work done during the isobaric step minus the work done during the isothermal step.
   c. The work done during the isothermal step is equal but opposite to the work done during the isochoric step.
   d. The total work done during the cycle is positive.
   e. The total work done during the cycle is equal but opposite to the net amount of heat transferred.
Chapter 13: Sample Exam Questions

1. A container holding 0.25 kg of water at 20°C is placed into the freezer compartment of a refrigerator at -5°C. How much energy must be removed from the water to turn it into ice at the freezer temperature?

2. 100 g of water at 50.0°C is mixed with 300 g of water at 40.0°C. Neglecting work and energy provided to mix the water, what is the change in entropy of the 400-g system?

3. A refrigerator maintains inside temperature of 5.0°C when the exterior temperature is 25.0°C. It maintains the same interior temperature when the room temperature is 30.0°C. How big is the percentage change in the coefficient of performance for the two cases?
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Appendix A7: Additional Practice Open Response
A ball of weight 5 newtons is suspended by two strings as shown above.
a. In the space below, draw and clearly label all the forces that act on the ball.

b. Determine the magnitude of each of the forces indicated in part (a).

A crane is used to hoist a load of mass $m_1 = 500$ kilograms. The load is suspended by a cable from a hook of mass $m_2 = 50$ kilograms, as shown in the diagram above. The load is lifted upward at a constant acceleration of 2 m/s$^2$.
a. On the diagrams below draw and label the forces acting on the hook and the forces acting on the load as they accelerate upward.
b. Determine the tension $T_1$ in the lower cable and the tension $T_2$ in the upper cable as the hook and load are accelerated upward at 2 m/s$^2$. Use $g = 10$ m/s$^2$. 
One-tenth of a mole of an ideal monatomic gas undergoes a process described by the straight-line path AB shown in the p-V diagram below.

(a) Show that the temperature of the gas is the same at points A and 1-3.
(b) How much heat must be added to the gas during the process described by A → B?
(c) What is the highest temperature of the gas during the process described by A → B?
One mole of a monatomic ideal gas enclosed in a cylinder with a movable piston undergoes the process ABCDA shown on the P-V diagram above.

a. In terms of $P_o$ and $V_o$ calculate the work done by the gas in the process.

b. In terms of $P_o$ and $V_o$ calculate the net heat absorbed by the gas in the process.

c. At what two lettered points in the process are the temperatures equal? Explain your reasoning.

d. Consider the segments AB and BC. In which segment is the amount of heat added greater? Explain your reasoning.
AP Physics
Chapters 11-13 Sample Open Response Question
Timed Practice Problem

(15 min)
Four samples of ideal gas are each initially at a pressure $P_o$ and volume $V_o$, and a temperature $T_o$ as shown on the diagram above. The samples are taken in separate experiments from this initial state to the final states I, II, III, and IV along the processes shown on the diagram.

a. One of the processes is isothermal. Identify which one and explain.

b. One of the processes is adiabatic. Identify this one and explain.

c. In which process or processes does the gas do work? Explain.

d. In which process or processes is heat removed from the gas? Explain.

e. In which process or processes does the root-mean-square speed of the gas molecules increase? Explain.
A 0.020-kilogram sample of a material is initially a solid at a temperature of 20° C. Heat is added to the sample at a constant rate of 100 joules per second until the temperature increases to 60° C. The graph above represents the temperature of the sample as a function of time.

a. Calculate the specific heat of the solid sample in units of joules per kilogram°C.

b. Calculate the latent heat of fusion of the sample at its melting point in units of joules per kilogram.

c. Referring to the three intervals AB, BC, and CD shown on the graph, select the interval or intervals on the graph during which:
   i. The average kinetic energy of the molecules of the sample is increasing
   ii. The entropy of the sample is increasing
A proposed ocean power plant will utilize the temperature difference between surface seawater and seawater at a depth of 100 meters. Assume the surface temperature is 25° Celsius and the temperature at the 100-meter depth is 3° Celsius.

a. What is the ideal (Carnot) efficiency of the plant?

b. If the plant generates useful energy at the rate of 100 megawatts while operating with the efficiency found in part (a), at what rate is heat given off to the surroundings?

c. A nuclear power plant operates with an overall efficiency of 40 percent. At what rate must mass be converted into energy to give the same 100-megawatt output as the ocean power plant above? Express your answer in kilograms per second.

The diagram below represents the Carnot cycle for a simple reversible (Carnot) engine in which a fixed amount of gas, originally at pressure $p_o$ and volume $V_o$ follows the path ABCDA.
d. In the chart below, for each part of the cycle indicate with +, -, or 0 whether the heat transferred $Q$ and temperature change $\Delta T$ are positive, negative, or zero, respectively. ($Q$ is positive when heat is added to the gas, and $\Delta T$ is positive when the temperature of the gas increases.)

<table>
<thead>
<tr>
<th></th>
<th>$Q$</th>
<th>$\Delta T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AB$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$BC$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CD$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$DA$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A child takes a 0.45-kg block of ice at 0 °C, places it on a large marble slab, and watches the ice melt.

a. What is the entropy change of the ice (water)?
b. If the source of heat (the marble slab) is very massive and remains at a constant 20 °C, what is the entropy change of the marble?
c. What is the total entropy change?
A pendulum consists of a small object of mass \( m \) fastened to the end of an inflexible cord of length \( L \). Initially, the pendulum is drawn aside through an angle of 60° with the vertical and held by a horizontal string as shown in the diagram above. This string is burned so that the pendulum is released to swing to and fro.

a. In the space below draw a force diagram identifying all of the forces acting on the object while it is held by the string.

b. Determine the tension in the cord before the string is burned.

c. Show that the cord, strong enough to support the object before the string is burned, is also strong enough to support the object as it passes through the bottom of its swing.

d. The motion of the pendulum after the string is burned is periodic. Is it also simple harmonic? Why, or why not?
A coin C of mass 0.0050 kg is placed on a horizontal disk 0.14 m away from the center, as shown above. The disk rotates at a constant rate in the counterclockwise direction as seen from above. The coin does not slip, and the time it takes for the coin to complete one revolution is 1.5 s.

a. The figure below shows the disk and the coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.

b. Determine the linear speed of the coin.

c. The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

d. If the experiment is part (c) were repeated with an identical coin glued on top of the first coin, how would this affect the answer to part (c)? Explain your reasoning.
2. A block slides on a semicircular frictionless track as shown below.

a. If it starts from rest at point A, what is its speed when it reaches the bottom of the track at point B?
b. Draw a free body diagram of the block at the instant it is at point B.
c. What force does the track exert on the block when it passes through point B if the block’s mass is 1.25 kg?
PROBLEM 1: One mole of an ideal monatomic gas, initially at point A at a pressure of 1.0 \times 10^5 \text{ newtons per meter squared} and a volume of 25 \times 10^{-3} \text{ meter cubed}, is taken through a 3-process cycle, as shown in the pV diagram above. Each process is done slowly and reversibly. For a monatomic gas, the heat capacities for constant volume and constant pressure are, respectively, \( C_v = (3/2)R \) and \( C_p = (5/2)R \), where \( R \) is the universal gas constant, 8.32 J/mole K. Determine each of the following:

a. the temperature of the gas at each of the vertices, A, B, and C, of the triangular cycle
b. the net work done by the gas for one cycle
c. the net heat absorbed by the gas for one full cycle
d. the heat given off by the gas for the third process from C to A
e. the efficiency of the cycle
PROBLEM 2: One mole of an ideal monatomic gas is taken through the cycle abca shown on the diagram above. State a has volume \( V_a = 17 \times 10^{-3} \) cubic meter and pressure \( P_a = 1.2 \times 10^5 \) pascals, and state c has volume \( V_c = 51 \times 10^{-3} \) cubic meter. Process ca lies along the 250 K isotherm. The molar heat capacities for the gas are \( C_p = 20.8 \) J/mole K, and \( C_v = 12.5 \) J/mole K. Determine each of the following.

a. The temperature \( T_b \) of state b
b. The heat \( Q_{ab} \) added to the gas during process ab
c. The change in internal energy \( U_b - U_a \)
d. The work \( W_{bc} \) done by the gas on its surroundings during process bc

The net heat added to the gas for the entire cycle 1,800 joules. Determine each of the following.

e. The net work done by the gas on its surroundings for the entire cycle
f. The efficiency of a Carnot engine that operates between the maximum and minimum temperatures in this cycle

PROBLEM 3: An ideal gas initially has pressure \( p_0 \), volume \( V_0 \), and absolute temperature \( T_0 \). It then undergoes the following series of processes:

I. It is heated, at constant volume, until it reaches a pressure 2\( p_0 \).
II. It is heated, at constant pressure, until it reaches a volume 3\( V_0 \).
III. It is cooled, at constant volume, until it reaches a pressure \( p_0 \).
IV. It is cooled, at constant pressure, until it reaches a volume \( V_0 \).

a. On the axes below
   i. draw the p-V diagram representing the series of processes;
   ii. label each end point with the appropriate value of absolute temperature in terms of \( T_0 \).

b. For this series of processes, determine the following in terms of \( p_0 \) and \( V_0 \).
   i. The net work done by the gas
   ii. The net change in internal energy
   iii. The net heat absorbed

c. Given that \( C_p = (5/2)R \) and \( C_v = (3/2)R \), determine the heat transferred during process 2 in terms of \( p_0 \) and \( V_0 \).
PROBLEM 4: A freezer contains 20 kilograms of food with a specific heat of $2 \times 10^3$ J/kg°C. The temperature inside the freezer is initially $-5^\circ$ C. The freezer motor then operates for 10 minutes, reducing the temperature to $-8^\circ$ C.

a. How much heat is removed from the food during this time? The freezer motor operates at 400 watts.

b. How much energy is delivered to the freezer motor during the 10-minute period?

c. During this time, how much total heat is ejected into the room in which the freezer is located?

d. Determine the temperature change in the room if the specific heat of air is $700$ J/kg°C. Assume there are 80 kilograms of air in the room, the volume of the air is constant, and there is no heat loss from the room.

PROBLEM 5: The p V-diagram above represents the states of an ideal gas during one cycle of operation of a reversible heat engine. The cycle consists of the following four processes.

<table>
<thead>
<tr>
<th>Process</th>
<th>Nature of Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>Constant temperature ($T_h = 500$ K)</td>
</tr>
<tr>
<td>BC</td>
<td>Adiabatic</td>
</tr>
<tr>
<td>CD</td>
<td>Constant temperature ($T_c = 200$ K)</td>
</tr>
<tr>
<td>DA</td>
<td>Adiabatic</td>
</tr>
</tbody>
</table>
During process A B, the volume of the gas increases from $V_o$ to $2V_o$ and the gas absorbs 1,000 joules of heat.

a. The pressure at A is $p_o$. Determine the pressure at B.

b. Using the first law of thermodynamics, determine the work performed by or on the gas during the process A B.

c. During the process AB, does the entropy of the gas increase, decrease, or remain unchanged? Justify your answer.

d. Calculate the heat $Q_c$ given off by the gas in the process CD.

e. During the full cycle ABCDA is the total work the gas performs on its surroundings positive, negative, or zero? Justify your answer.
AP Physics
Chapter 5 Sample Open Response Problems

1. Ball A is attached to one end of a rigid massless rod, while an identical ball B is attached to the center of the rod. Each ball has a mass of \( m = 0.50 \) kg, and the length of the entire rod is \( 2L \) (\( L = 0.40 \) m). This arrangement is held by the empty end of the rod and is whirled about in a horizontal circle at a constant rate, so each ball is in uniform circular motion. Ball A travels at a constant speed of \( v_a = 5.0 \) m/s. Find the tension in each half of the rod.

2. At an amusement park there is a ride in which cylindrically shaped chambers spin around a central axis. People sit in seats facing the axis, their backs against the outer wall. At one instant the outer wall moves at a speed of \( 3.2 \) m/s, and an 83 kg person feels a 560 N force pressing against his back. What is the radius of the chamber?

3. A curve of radius 120 m is banked at an angle of 18°. At what speed can it be negotiated under icy conditions where friction is negligible?

4. A skateboarder rolls down a ramp, and three forces act on her: her weight of magnitude 675 N, a frictional force of magnitude 125 N and a normal force of 612 N. Determine the net work done by the three forces when she coasts for a distance of 9.2 m.
AP Physics  
Chapter 5 Assignment

1. A ball of mass $M$ is attached to a string of length $R$ and negligible mass. The ball moves clockwise in a vertical circle, as shown below. When the ball is at point $P$, the string is horizontal. Point $Q$ is at the bottom of the circle and point $Z$ is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

![Diagram of a ball moving in a vertical circle](image)

On the figures below, draw and label all the forces exerted on the ball when it is at points $P$ and $Q$, respectively.

![Forces at $P$ and $Q$](image)

a. Derive an expression for $v_{\text{min}}$, the minimum speed the ball can have at point $Z$ without leaving the circular path.

b. The maximum tension the string can have without breaking is $T_{\text{max}}$. Derive an expression for $v_{\text{max}}$, the maximum speed the ball can have at point $Q$ without breaking the string.

c. Suppose that the string breaks at the instant the ball is at point $P$. Describe the motion of the ball immediately after the string breaks.

2. An amusement park ride consists of a vertical cylinder with a radius of 2.6 m that rotates about its vertical axis. Riders stand initially on a floor that drops away after the ride starts and leaves them stuck to the vertical wall. If the coefficient of friction between the rider and the wall is 0.66, what minimum rotational speed is required for the rider not to slide down?

3. To study circular motion, two students use the hand held device shown below, which consists of a rod on which a spring scale is attached. A polished glass tube attached at the
top serves as a guide for a light cord attached to the spring scale. A ball of mass 0.200 kg is attached to the other end of the cord. One student swings the ball around at constant speed in a horizontal circle with a radius of 0.500 m. Assume friction and air resistance are negligible.

a. Explain how the students, by using a timer and the information given above, can determine the speed of the ball as it is revolving.
b. The speed of the ball is determined to be 3.7 m/s. Assuming the cord is horizontal as it swings, calculate the expected tension in the cord.
c. The actual tension in the cord as measured by a spring scale is 5.8 N. What is the percent difference between this measured value of the tension and the value calculated in part b?
d. The students find that, despite their best efforts, they cannot swing the ball so that the cord remains exactly horizontal.
   i. On the picture of the ball below, draw vectors to represent the forces acting on the ball and identify the force that each vector represents.

ii. Explain why it is not possible for the ball to swing so that the cord remains exactly horizontal.
iii. Calculate the angle that the cord makes with the horizontal.

4. A ball attached to a string of length L swings in a horizontal circle, as shown below, with a constant speed. The string makes an angle θ with the vertical, and T is the magnitude of the tension of the string. Express your answer to the following in terms of the given quantities and fundamental constants.
a. On the figure provided, draw and label vectors to represent all the forces acting on the ball when it is at the position shown in the diagram. The lengths of the vectors should be consistent with the relative magnitudes of the forces.
b. Determine the mass of the ball.
c. Determine the speed of the ball.
d. Determine the frequency of revolution of the ball.
e. Suppose that the string breaks as the ball swings in its circular path. Qualitatively describe the trajectory of the ball after the string breaks but before it hits the ground.
Chapter 11-12: Open Response Problems

1. A concrete highway in Alaska consists of slabs 12m in length. How wide must the expansion joints be to allow for thermal changes over the temperature range from -30°C to 30°C? Assume the concrete is of a special type which has a linear expansion coefficient of 9x10^-6°C.

2. A cup of negligible heat capacity and heat conductivity holds 210 g of hot water at 90°C. A 200-g black at 27°C is immersed in the water and comes to equilibrium with the water. What is the final temperature of the block of glass?

3. How many calories are required to change 800 grams of ice at -20°C to steam at 135°C?

4. A Styrofoam cooler with a surface area of 0.75 m^2 and an average thickness of 2.5 cm is filled with 2 kg of ice at a temperature of 0°C and taken on a fishing trip. How long will it take the ice to melt if the thermal conductivity of Styrofoam is 3.2x10^-4 W/cm°C and the outside temperature is 35°C? Neglect the specific heat of the Styrofoam. (hint: look at equation 11.9- the heat flow equation)

5. An upright glass cylinder 75 cm tall and 3.0 cm in diameter is fitted with a light piston that is free to slide. The cylinder is closed at its lower end. First the piston is placed on the cylinder. Initially the piston sinks to 73 cm from the bottom of the cylinder. Water is poured into the cup-like cavity formed by the top of the piston and the cylinder walls until the entire cavity is full. At what fraction of the total height of the cylinder will the piston be? Assume the lower portion of the cylinder contains an ideal gas at constant temperature.

6. Calculate the root mean square velocities in a gas at 300 K which is a mixture of diatomic molecules H_2 (M = molecular mass = 2.0x10^{-3} kg/mol) and diatomic deuterium molecules D_2 (M = 4.0x10^{-3} kg/mol).

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Name __________________

Physics Exam Review

The exam will cover the following concepts:
- Unit Conversions
- Knowledge of the metric prefixes
- Identifying kinematics quantities
- Properly labeling information, choosing the most appropriate formula, solving for the unknown quantity
- Reading, finding the slope of, and finding the area of graphs, specifically position vs. time, velocity vs. time, acceleration vs. time

Unit Conversions Review:

I will provide you the following prefixes, in exactly this format:

\[
M = 10^6 \quad k = 10^3 \quad c = 10^{-2} \quad m = 10^{-3} \quad \mu = 10^{-6}
\]

Sample Problems:

a. Given the quantity 58 km/hr, convert this into 5 different units (e.g. m/s, cm/min, etc)

b. Convert 98 km/hr to m/s

c. Convert 1200 seconds to hours

Kinematics Review:

I will provide you with the following formulas, in exactly this format:

\[
\Delta x = v_i t + \frac{1}{2} a t^2 \quad v_f^2 = v_i^2 + 2a\Delta x \quad v_f = v_i + at \quad v_{avg} = \frac{\Delta x}{t}
\]

You need to know the standard units for each term:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>General Form of units</th>
<th>Examples</th>
<th>Standard Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>t</td>
<td>time</td>
<td>sec, hr, min</td>
<td>sec</td>
</tr>
<tr>
<td>Initial Velocity</td>
<td></td>
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<tr>
<td>Final Velocity</td>
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<td></td>
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</tr>
<tr>
<td>Average Velocity</td>
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<tr>
<td>Acceleration</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Displacement

Problem Solving:
To choose the most appropriate formula, first make a list of the given and missing information from the problem.
Then, identify the unknown. Find the formula or formulas that contain this unknown.
Then, choose the formula with the least missing information. Ideally, the formula used will only have one missing quantity (what the problem is asking for). Convert units, rearrange the formula, plug in the values and solve.

Sample Problem:
A jogger accelerates at 0.75 m/s² from rest for 7 seconds. (a) How fast is the jogger moving after 7 seconds? (b) How far did the jogger run during these 7 seconds?

Graphical Analysis Review:
What does the slope of the position vs. time graph mean?
What does the slope of the velocity vs. time graph mean?
What does the slope of the acceleration vs. time graph mean?
What does the area under the position vs. time graph mean?
What does the area under the velocity vs. time graph mean?
What does the area under the acceleration vs. time graph mean?

Given the following graph:

<table>
<thead>
<tr>
<th>t (s)</th>
<th>v (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>24</td>
<td>30</td>
</tr>
</tbody>
</table>

a. What is the dependent variable?
b. What is the independent variable?
c. During what time interval(s) is the velocity of the object constant?
d. During what time interval(s) is the object accelerating?
e. At what time(s) is the object stationary?
f. Determine the total displacement of the object.
g. Find the acceleration of the object from 8 to 15 seconds.
h. Find the acceleration of the object from 18 to 24 seconds.
i. In words, briefly describe the motion of the object. What is object doing during each segment of the motion?

Other questions:
a. Compare and contrast distance and displacement.
b. For the following phrases, what physics quantity is implicitly known?
   i. How far…
   ii. How long…
   iii. How fast…
   iv. From rest…
   v. Comes to a stop…
   vi. An object is thrown…
   vii. Constant velocity (***you know several quantities here!)
1. During a relay race along a straight road, the first runner on a three-person team runs \(d_1\) with a constant velocity \(v_1\). The runner then hands off the baton to the second runner, who runs \(d_2\) with a constant velocity \(v_2\). The baton is then passed to the third runner, who completes the race by traveling \(d_3\) with a constant velocity \(v_3\).

a. In terms of \(d\) and \(v\), find the time it takes for each runner to complete a segment of the race.

Runner 1 ____________ Runner 2 ____________ Runner 3 ____________

b. What is the total distance of the race course?

______________________________________________________________________________

c. What is the total time it takes the team to complete the race?

______________________________________________________________________________

2. For each of the following problems, clearly show all required steps of our class problem solving process.

a. During take off, a plane accelerates at 4 m/s\(^2\) and takes 40 s to reach take off speed. What is the velocity of the plane at takeoff?

b. A car with an initial speed of 31.4 km/h accelerates at a uniform rate of 1.2 m/s\(^2\) for 1.3 s. What is the final speed and displacement of the car during this time?

3. Below is the velocity-time graph of an object moving along a straight path. Use the information in the graph to fill in the table below.

For each of the lettered intervals below, indicate the motion of the object (whether it is speeding up, slowing down, or at rest), the direction of the velocity (+, −, or 0), and the direction of the acceleration (+, −, or 0).

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Motion</th>
<th>(v)</th>
<th>(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(C)</td>
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<td>(D)</td>
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<tr>
<td>(E)</td>
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</tbody>
</table>

Multiple Choice Questions - Write the letter of the correct answer in the space provided.

_____ 1. Which of the following situations represents a positive displacement of a carton? Assume positive position is measured vertically upward along a \(y\)-axis.

a. A delivery person waiting for an elevator lowers a carton onto a dolly.

b. When the elevator doors open, the delivery person lifts the dolly over the threshold of the elevator.

c. The delivery person pushes the dolly to the back of the elevator while pressing a floor button.

d. The door closes and the elevator moves from the 10th to the 4th floors
2. Rank in decreasing order the displacements of objects having the following pairs of average velocity and time of motion.
   I. $v_{avg} = +2.0 \, \text{m/s}, \Delta t = 2.0 \, \text{s}$
   II. $v_{avg} = +3.0 \, \text{m/s}, \Delta t = 2.0 \, \text{s}$
   III. $v_{avg} = -3.0 \, \text{m/s}, \Delta t = 3.0 \, \text{s}$
   a. I, II, III  
   b. II, III, I  
   c. II, I, III  
   d. III, II, I

3. Rank in decreasing order the distances traveled by objects having the following pairs of average velocity and time of motion.
   I. $v_{avg} = +2.0 \, \text{m/s}, \Delta t = 2.0 \, \text{s}$
   II. $v_{avg} = +3.0 \, \text{m/s}, \Delta t = 2.0 \, \text{s}$
   III. $v_{avg} = -3.0 \, \text{m/s}, \Delta t = 3.0 \, \text{s}$
   a. I, II, III  
   b. II, III, I  
   c. II, I, III  
   d. III, II, I

The graph below shows the motion of a dog pacing along a fence. Refer to the graph to answer questions 4-7.

4. For the five time intervals shown, during how many intervals does the dog have the same average velocity?
   a. 0  
   b. 1  
   c. 2  
   d. 3

5. For the five time intervals shown, during how many intervals does the dog pace at the same average speed?
   a. 0  
   b. 1  
   c. 2  
   d. 3

6. Describe the dog’s motion when it is at 1.0 m.

6. Describe the dog’s motion when it is at 1.0 m.

7. What is the dog’s average velocity for total displacement?