

Physics 105 – Fall 2014 – Sections 1 and 3

Dr John S. Colton

Instructor: Dr. John S. Colton, john_colton@byu.edu, N335 ESC.

Instructor Office Hours: 3-4 pm M W, generally to be held in the Physics Tutorial Lab in N304 ESC.

Private meetings are available by appointment.

Textbook: *College Physics*, by Serway & Faughn (6th, 7th editions) or by Serway & Vuille (8th, 9th, 10th editions). Only volume 1 is needed for Physics 105; but volume 2 is used in Physics 106, so if you're planning to take that course also, it may be cheaper to get a book with both volumes combined. Feel free to obtain an inexpensive used copy.

Website: <http://www.physics.byu.edu/faculty/colton/courses/phy105-fall14>. You can navigate there via www.physics.byu.edu → Courses → Class Web Pages → Physics 105 (Colton). The website is your gateway to all things class related: you can go there to turn in homework, access lecture notes, view videos of demos, download practice exams, check your current grade, etc.

Learning Suite: The course will not use Learning Suite at all.

Max: We will use an online system called “Max” for the class calendar, submitting homework answers, checking grades, etc. See below for more information. Max is located at: <http://max.byu.edu>.

Where To Turn Things In: Most of the homework problems are submitted online, but some of them include a portion that you need to physically turn in. These need to be turned in to the boxes outside N357 ESC. Any extra credit papers should also be turned in to that same location.

Where To Pick Things Up: Homework, extra credit papers, and exams will all be returned to the slots outside N357 ESC, just to the right of where you turn things in.

Where To Find Homework Solutions: Homework solutions will be posted in the glass cases outside N361 ESC. Some homework solutions may also be posted online.

Where To Find the TAs: The Physics Department hires many TAs to staff a Tutorial Lab located in N304 and/or N362 ESC. The TAs are available roughly from 9 am to 9 pm every weekday and for several hours on Saturday. If you discover times when TAs are in short supply, or if you discover times when the lab is *overstaffed*, please let the Tutorial Lab coordinator know. He or she will try to shuffle around the TAs, or possibly hire new TAs, in order to run an efficient operation. The coordinator may be contacted via the feedback form here: http://gardner.byu.edu/tas/feedback_tutorial_lab.html.

Learning Outcomes: In this class you will learn the basics of the physics of motion (kinematics), energy and forces (mechanics), heat (thermodynamics), and sound (acoustics). You will learn and apply mathematical methods, reasoning, and general problem solving skills. Specifically, students who successfully complete this course will be able to solve problems and answer conceptual questions involving:

- kinematics and Newton's laws, in both linear and rotational contexts
- energy and momentum, in both linear and rotational contexts
- static and flowing fluids, heat capacity and transfer, ideal gases, laws of thermodynamics, and heat engines
- harmonic motion, waves, interference, and sound

Those are the official university learning outcomes for the course, but I would also like to add some additional goals of my own:

- Students will enjoy the time spent in class and will look forward to coming to class each day.
- Students will discover that physics is interesting and fun, even though it can also be difficult.
- Students will learn to see physics principles at work in the world around them.
- Students' appreciation for the order, simplicity and complexity of God's creations will increase.

Regarding that last point, I do view the study of the sciences as also a spiritual matter. These two quotes are significant to me:

Brigham Young:

Man is organized and brought forth as the king of the earth, to understand, to criticize, examine, improve, manufacture, arrange and organize the crude matter and honor and glorify the work of God's hands. This is a wide field for the operation of man, that reaches into eternity; and it is good for mortals to search out the things of this earth.

Steve Turley (former BYU Physics Department chair):

My faith and scholarship also find a unity when I look beneath the surface in my discipline to discover the Lord's hand in all things (see D&C 59:21). It is His creations I study in physics. With thoughtful meditation, I have found striking parallels between His ways that I see in the scriptures and His ways that I see in the physical world. In the scriptures I see a God who delights in beauty and symmetry, who is a God of order, who develops things by gradual progression, and who establishes underlying principles that can be relied on to infer broad generalizations. I see His physical creations following the same pattern. Just as numerous gospel ordinances and practices serve as types of Christ, His creations are full of types we can use to strengthen our faith, teach us valuable spiritual lessons, and bring us to Christ. These types are so strong that Alma invokes them as a proof to Korihor of the existence of God. In Alma 30:44 we read, "even the earth, and all things that are upon the face of it, year, and its motions, yea and also all the planets which move in their regular form do witness that there is a Supreme Creator."

Grading: If you hit these grade boundaries, you are guaranteed to get the grade shown. Please note that these boundaries are curved a bit from the standard 90-80-70-60 scale. From past semesters I expect the overall class GPA to be about 3.0, but there is no reason it couldn't be higher if you all do well.

A	93%	B+	85%	C+	73%	D+	54%
A-	89%	B	81%	C	65%	D	49%
		B-	77%	C-	58%	D-	45%

Grades will be determined by the following weights:

- Reading assignments and pre-class "warm-up" quizzes: 3%
- In-class "clicker" quizzes: 3%
- Homework: 32%
- 3 Midterm Exams: 42%
- Final Exam: 20%

Clickers: We will use "i-clickers" in class. On the reverse side of your clicker is an alphanumeric ID code for your transmitter. To get credit for your in-class clicker quizzes you must go to Max and register your transmitter ID number via Max → Home → Register iClicker. I suggest you also write the number down for future use because they tend to fade with time.

Identification Number: In order to preserve student anonymity, each of you have been assigned a random ID number, called a "Course ID" or "CID" for short. To learn your Course ID, go to Max → Home → Course ID. Write this ID number and not your name on all work that you turn in to the boxes (extra credit papers and some homework). Since your exams will also be turned back via these same boxes, you will also need to write your ID number and not your name on your exams.

Reading Assignments and Pre-class "Warm-up" Quizzes: Each class period has an associated reading assignment and warmup quiz. To see the reading assignment and access the warmup quiz, go to Max → Home → Calendar, then click on the warmup quiz for that day. These warm-up exercises will be due 15 minutes before class time. Your grade on these warmup quizzes will be based on your answer to the first question, "Did you carefully complete the reading assignment?"—2 points if yes, 1 point if no. You get 0 points if you don't bother to visit the website to answer the question. There will be additional (non-graded) questions on the reading assignment, which you should answer as best you can. We will discuss

them in class. You will not be allowed to make up a missed warm-up exercise **for any reason**. However, to allow for sickness and other emergencies you will be allowed four free warm-ups: the computer will automatically discount your lowest four warm-up exercises.

Class Participation and “Clicker” Quizzes: iClicker-based quiz questions will be given throughout each lecture to encourage student involvement. I will ask you conceptual questions, have you work problems, have you guess what will happen in a demonstration, etc. So that you are not penalized for not yet knowing the correct answers, these “clicker questions” will be graded on participation only. That is, if you transmit any answer, you get full credit. You will not be allowed to make up a missed clicker quiz **for any reason** (tardy, excused absence, unexcused absence, registered late, forgot or lost clicker, etc.). However, so that you are not penalized unduly for missing class when circumstances necessitate, you will get four free clicker quizzes: the computer will automatically discount your lowest four clicker quizzes.

Midterm Exams: Three midterm exams will be given in the Testing Center in the Grant Building and will be available for the days indicated on the calendar. Exams will include worked problems similar to homework problems, as well as conceptual questions related to things we discussed in class. The exams will be predominantly computer graded. Your exam pages (but not your bubble sheets) will be returned to you sorted by the first two digits of your CID number in the bins outside N357 ESC.

Final Exam: A comprehensive final exam will be given during the Final Exam Week in the Testing Center. You may take it any time during that week.

Homework: Please read this information carefully, as it is your responsibility to know the class policies and how to turn in your homework. All homework is due at 11:59 pm on the day marked on the schedule.

We will use Max (<http://max.byu.edu>) to manage our homework assignments. Among other things, Max contains a computerized grading system developed especially for introductory physics classes. Computer grading of the homework has both pluses and minuses. The biggest minus is that because you type your answer in the computer rather than turn in the work to be graded by a human, there is no traditional partial credit. This can be frustrating to students. Instead of the traditional way of assigning partial credit, we give partial credit a different way: we let you submit a problem multiple times if you get it wrong. You get two attempts at a problem for full credit; after that, you start losing points. To allow for emergencies or adding the class late, you will get four free late assignments; after that, late work only counts for half credit. There are no free *dropped* HW assignments, just free *late* ones.

This system offers several major advantages to students and instructors:

- Students get instant feedback as to whether they did the problem correctly.
- Because the HW problems are not assigned directly from the textbook, students can purchase cheap older editions instead of all being forced to use the same, newest edition.
- Each student gets a slightly different—but closely related—problem to work; this makes copying off of other students nearly impossible. (Yes, sadly even at BYU this can be a problem.)
- By not needing to use as many TAs to *grade* the homework, the Physics Department can employ TAs in the Physics Tutorial Lab to help you understand how to *do* the homework.

Read the problems: To access a HW assignment, go to Max → Home → Calendar, then click on the homework assignment for that day. A typical HW problem will look something like this:

- 1-1 Suppose your hair grows at a rate of **0.031 inch** per day. Find the rate at which it grows in nanometers per second. Since the distance between atoms in a molecule is on the order of 0.1 nm, your answer suggests how rapidly atoms are assembled in this protein synthesis.

5 pts

nm/s (± 0.2 nm/s)

The number in the highlighted field changes from student to student.

Work the problems: Assume that all numbers given in the problem are exact. If you are given 2.2 m/s, it means 2.2000000..., to as many digits as you wish to imagine. At the end of the problem is a field for you to enter your answer, along with the units you must use. Following that is the specified tolerance of the answer—how close you have to come to the computer’s answer to get credit. For example, “ ± 0.2 nm/s” would mean your submitted number needs to be within 0.2 nm/s of the computer’s answer. Tip: when working a problem, only round the final number. Do not round off any numbers along the way; rounding before your final answer can lead to compounded errors that cause the final answer to be outside the specified precision range.

Enter your answers: If a very large or very small value needs to be written in scientific notation, indicate the power of 10 with an “e.” For example, 3.00×10^8 would be written 3.00e8, and 1.6×10^{-19} would be written 1.6e-19. Do not put any spaces, commas, or “x”s in the number. Do put in negative signs where appropriate.

Submit your answers: After entering in an answer or answers, click the “Submit Assignment” button at the bottom of the page. If you got a problem wrong, the computer will show you the answer you should have gotten, and will allow you to try again. It will also change the highlighted number for your next attempt.

Try again: You have 3 tries to get the problem right before the 11:59 pm deadline. You will receive 5 points for problems done correctly on the first or second tries, 3 points for the third try, and no points thereafter. If a problem has multiple parts to it, the points are divided equally; for example, each part of a two-part problem would be worth 2.5 points.

Late credit: Any points generated by tries submitted after the deadline will be counted as late. As mentioned above you get four free late assignments, chosen to maximize your points. You will receive 60% credit for all other late points. You will get no credit for any HW submitted after the last reading day.

Special case 1: Extra credit HW problems: Some HW problems are labeled “Extra Credit Activity”. These problems will be graded the same as regular problems, except you will not be penalized if you skip them. If you do them, they allow you to increase your score beyond the listed maximum for that assignment.

Special case 2: Multiple-choice questions: Some HW problems are multiple choice, or include multiple-choice parts. You only get one try on those problems/parts.

Special case 3: Free-body diagrams: Some problems require turning in a hardcopy “free-body diagram” (FBD), which will be graded by the TA. Read the “Free Body Diagrams” document later in this syllabus to learn what is expected for those. There are forms for you to use at the end of this syllabus packet. Turn in your FBD forms to the boxes just outside N357 ESC. The boxes are sorted by CID. The points from your FBDs will be added to the computer graded points for the assignment. These diagrams are worth a total of 2 points per problem. If a problem has multiple FBDs associated with it, the points are divided accordingly (e.g. each diagram of a two-FBD problem would be worth 1 point). No resubmissions are

permitted for the FBDs if you get them wrong. You will get no credit for any FBDs turned in after the last reading day.

Other instructions:

1. Keep an organized homework notebook. Write neatly and use plenty of space. Many exam questions will be very similar to homework problems so you need to be able to review the homework problems even after you submit them, in order to study for the exams.
2. Use the PEANuT method for solving problems:
 - a. Draw a **P**icture so you can visualize the problem
 - b. Identify the fundamental **E**quations
 - c. Work the **A**lgebra to get a formula for your answer
 - d. Only then, plug in **N**umbers (with their units)
 - e. **T**hink about whether your answer makes physical sense

Read the “How To Solve Physics Problems” document later in this syllabus for more details.

Additional Resources:

Study advice from Dr. Colton. Read the “How To Study For This Physics Course” and “Advice For Struggling Students” documents later in this syllabus packet. Use the “List of Important Equations and Concepts” document given later in this packet as a reference as you work homework problems and prepare for exams.

Textbook. Your textbook has a bunch of worked example problems. Take advantage of it—don’t just read the worked problems, but try to work them out yourself before looking at the book’s solutions. Then try to understand the general principles involved in how the book approaches a given problem, not just the specific solution for that particular problem.

Help from students and TAs. As outlined in the “How To Study For This Physics Course” document below, there are many ways to get help from fellow students and from TAs. See that document for details.

Private tutors. Here’s a message board where you may be able to find physics majors who are willing to be personal tutors (for a fee): http://groups.google.com/group/byu_physics_tutors

Even more worked problems. Here are some places you can find additional worked problems. I’m sure there are many similar things available that I haven’t listed here.

- The University of Oregon has a physics problem database: <http://zebu.uoregon.edu/~probs/>
- *Student Solutions Manual and Study Guide*, by Gordon, Teague, and Serway (this is mentioned in the preface to your textbook)
- *3,000 Solved Problems in Physics (Schaum's Solved Problems)*, by Alvin Halpern
- *Schaum's Outline of Beginning Physics I: Mechanics and Heat*, by Alvin Halpern
- *Schaum's Outline of College Physics*, by Frederick Bueche and Eugene Hecht
- *How to Solve Physics Problems*, by Robert Oman and Daniel Oman

Cheating: The following are unacceptable behaviors and are considered cheating. Do not do them.

- Giving someone else your clicker to answer in-class quizzes for you, or agreeing to take someone else’s clicker to answer quizzes for him/her.
- Copying HW solutions from online homework websites.
- Getting someone else to work HW problems for you, or giving someone else your solutions so they can submit HW answers without having done the work (although *talking to*, *collaborating with*, and *getting help from* other people are all just fine).

- Storing “illegal” information in your calculator memory for exams. (I will give you an equation sheet with many equations on it, but some other equations I will expect you to know by heart.)

I can't outline all of the ways to cheat, so use both your head and conscience to guide you. To quote King Benjamin, “And finally, I cannot tell you all the things whereby ye may commit sin; for there are divers ways and means, even so many that I cannot number them.” –Mosiah 4:29.

Extra Credit: There are several ways to earn extra-credit points.

Homework. As mentioned above, extra-credit homework problems will periodically show up on the homework assignments.

Noticing physics going on around you. If you notice something interesting in the world around you that relates to something we've recently discussed in class, please write it up and send a paragraph to the TA in an email. The TA will select some “honorable mentions” to forward on to me, and I'll select one to share with the class each class period. You get 1 point of extra credit for submitting an applicable anecdote, 3 points if you are an honorable mention, and 5 points if I share your story with the class. Each extra credit point is the equivalent of +1 on one of your midterms. The points will be recorded in the “Exams” section of Max.

Physics-related lecture. You may attend a physics-related lecture; to get extra credit you must turn in a brief report (1 page maximum) of what you learned. Include this information in your report: (1) name of speaker, (2) time/place of lecture, and (3) some info about what kind of physics was discussed, (4) at least one interesting thing that you learned. This could be one of the weekly Physics Department colloquia (warning: these often—but not always—get very technical), an honors lecture, a university forum, a planetarium show, or any other physics-related science lecture that you can find. If there is any question about whether a given lecture may be appropriate, please email me to ask. Your report will be graded out of 3 points, the maximum score being the equivalent of +3 points on one of your midterms. The points will be recorded in the “Exams” section of Max. You may attend two physics-related lectures for extra credit during the semester, and your report(s) must be turned in on or before the last reading day.

Photo contest. In the spirit of the American Association for Physics Teachers' annual photo contest, <http://www.aapt.org/Programs/contests/photocontest.cfm>, we will have a class photo contest. I did this last year, see <http://www.physics.byu.edu/faculty/colton/courses/phy105-fall13/photocontest/>. Here are the rules:

1. You must have been the photographer yourself, although the photo can be one that you took before the semester. (Note this is different than last year, where I allowed photos taken by others if the student was in the picture.) Submitting your photo gives me permission to share it with the class.
2. The photo should be high quality. A low resolution photo will substantially decrease your chances of winning. It's OK to use Photoshop or other programs to do basic touch-up functions such as improving the white balance. Also, last year I got a ton of photos of icicles and duck ponds. Please don't submit photos of those unless your photo is just amazing.
3. You must write a paragraph describing the physics involved in your photo. See the photos at the above link for examples. Your paragraph will be judged on the accuracy and relevance of the physics (it must relate to some topic we covered this semester), how interesting it would be for the class to read, and the correctness of your English. Spelling and grammatical errors will substantially decrease your chances of winning.
4. Each student can submit up to two photos.
5. Send me your photo(s) and paragraph(s) via email, before the deadline marked on the calendar. Please send the photos as jpg attachments to the email, rather than pasting them into the email or into an attached document.

6. I will rank the photos based on a score of 60% photo and 40% description. Depending on the number and quality of submissions, I'll choose approx. 2 winners and 15 honorable mentions. Winners will be announced the last day of class.
7. Extra credit will be awarded thusly: 2 points for submitting, 7 points for being an honorable mention, and 12 points for being one of the winners. (Each point is the equivalent of +1 points on a midterm.)

BYU Policies:

Prevention of Sexual Harassment: BYU's policy against sexual harassment extends to students. If you encounter sexual harassment or gender-based discrimination, please talk to your instructor, or contact the Equal Opportunity Office at 801-422-5895, or contact the Honor Code Office at 801-422-2847.

Students with Disabilities: BYU is committed to providing reasonable accommodation to qualified persons with disabilities. If you have any disability that may adversely affect your success in this course, please contact the University Accessibility Center at 801-422-2767, room 1520 WSC. Services deemed appropriate will be coordinated with the student and your instructor by that office.

Children in the Classroom: The serious study of physics requires uninterrupted concentration and focus in the classroom. Having small children in class is often a distraction that degrades the educational experience for the entire class. Please make other arrangements for child care rather than bringing children to class with you. If there are extenuating circumstances, please talk with your instructor in advance.

Free-Body Diagrams

(If this doesn't make sense to you at the beginning of the semester, please return here after we discuss Newton's Second Law problems in class.)

Some homework problems will require turning in hardcopy "free-body diagrams" (FBDs). **Use the forms at the end of the syllabus packet.** Follow the instructions below for what to draw on your forms.

A free-body diagram is a useful tool to solve problems involving Newton's Second Law. It is simply a representation of an object that includes all of the forces acting on the object. First, **draw the object by itself**—for example, if the object is sitting on a table, do not draw the table in the diagram. That is why this is called a "free"-body diagram.

Next, **draw vectors representing the forces** acting on the object. Each vector should be an arrow attached to the object, starting at the point where the force acts and going outward in the direction of the force. Stronger forces should be drawn with longer arrows.

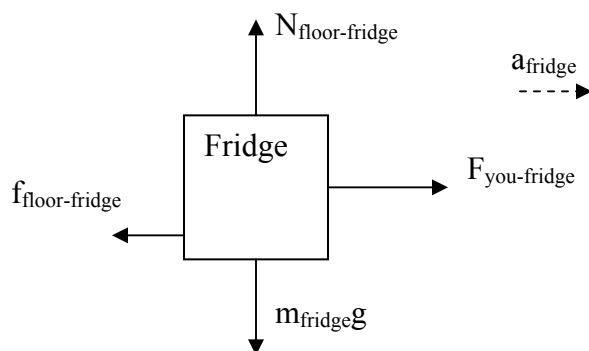
Label each vector with a symbol, using different symbols for different forces. Use mg or w (for *weight*) to label the force of gravity acting on the object. Do not use mg or w for any other force—for example, if the object is sitting on a table, the force of the table acting upward on the object is a normal (pushing) force, not a gravitational force. Even though the normal force may be numerically equal to the weight of the object for that situation, it is still a different force and must *not* be labeled mg or w .

With rare exceptions such as gravity, **give each label subscripts** which clarify what is giving the force and what is receiving the force. For example, $F_{\text{you-fridge}}$ below refers to a force of you on the fridge.

If you need to draw two or more free-body diagrams representing different objects in a single situation, be sure to **use different symbols for different forces**. For example, do not use mg or w for two different objects: use m_1g or w_1 for one and m_2g or w_2 for the other. The only exceptions to this rule are (a) for partner forces which must be equal because of Newton's Third Law, and (b) for tensions pulling inward at the two ends of a massless rope (possibly on a massless pulley) which also must be equal. In these situations you may use the same symbol for the forces.

If an object is moving or accelerating, then it is often helpful to draw vectors showing the direction of the velocity and/or acceleration, but **do not attach the velocity and acceleration vectors to the object**. If you do, you run the risk of getting them confused with the force vectors in the free-body diagram.

Example of free-body diagram for you pushing a refrigerator across the floor to the right with a force F :



How To Solve Physics Problems: PEANuT

Here's the "PEANuT method" for solving physics problems which I myself use. It's not just what I do, though; if you talk to any physics professor, you'll find they all follow this same sort of procedure.

Picture – Always draw a picture, often with one or more FBDs. Make sure you understand the situation described in the problem. Include the relevant given information on your picture.

Equations – Work forward, not backward. That means look for equations that contain the *given* information, not equations that contain the *desired* information. What major concepts or "blueprint equations" will you use? Write down the general form of the equations that you plan to use. Only after you've written down the main equations should you start filling things in with the specific information given in the problem.

Algebra – Be careful to get the algebra right as you solve the equations for the relevant quantities. Use letters instead of numbers if at all possible. Even though you (often) won't have any numbers at this stage, solving the algebra gives you what I really consider to be the answer to the problem. And write neatly!

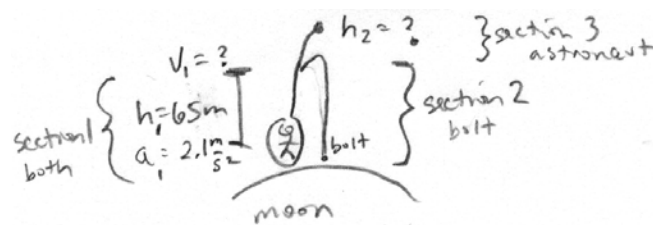
Numbers – After you have the answer in symbolic form, plug in numbers to obtain numerical results.

Use units with the numbers, and make sure the units cancel out properly. Be careful with your calculator—I typically punch in all my calculations *twice* to double-check myself.

Think– Does your final answer make sense? Does it have the right units? Is it close to what you were expecting? In not, figure out if/where you went wrong.

Example problem: Using a rocket pack, an astronaut accelerates upward from the Moon's surface with a constant acceleration of 2.1 m/s^2 . At a height of 65 m , a bolt comes loose. The free-fall acceleration on the Moon's surface is about 1.67 m/s^2 . (a) How fast is the astronaut moving at that time? (b) How long after the bolt comes loose will it hit the Moon's surface? (c) How high will the astronaut be when the bolt hits?

Colton solution: (notice how I use the five steps given above)



(a) $v_f^2 = v_o^2 + 2a \Delta x$ for astronaut, section 1

$$v_1^2 = 0^2 + 2a_1 h_1$$

$$v_1 = \sqrt{2a_1 h_1} = \sqrt{2(2.1 \frac{\text{m}}{\text{s}^2})(65\text{m})}$$

$$= \boxed{16.523 \text{ m/s}}$$

(b) $y = y_o + v_{oy}t - \frac{1}{2} g t^2$

$$0 = h_1 + v_1 t - \frac{1}{2} g_{\text{moon}} t^2$$

$$\frac{1}{2} g_{\text{moon}} t^2 - v_1 t - h_1 = 0$$

(b) cont

quadratic formula:

$$t = \frac{-v_1 \pm \sqrt{v_1^2 + 4(\frac{1}{2} g_{\text{moon}})(h_1)}}{2(\frac{1}{2} g_{\text{moon}})}$$

$$t = \frac{-16.523 \frac{\text{m}}{\text{s}} \pm \sqrt{(16.523 \frac{\text{m}}{\text{s}})^2 + 2(1.67 \frac{\text{m}}{\text{s}^2})(65\text{m})}}{1.67 \frac{\text{m}}{\text{s}^2}}$$

$$= \boxed{23.15 \text{ s}}$$

(use positive root, a negative time doesn't make sense)

(c) Height of section 3 is given by that time

$$y = y_o + v_{oy}t + \frac{1}{2} a_1 t^2$$

$$y = 65\text{m} + (16.523 \frac{\text{m}}{\text{s}})(23.15\text{s})$$

$$+ \frac{1}{2}(2.1 \frac{\text{m}}{\text{s}^2})(23.15)^2$$

$$y = \boxed{1010 \text{ m}}$$

When I first did part (c), I got 0 m. This didn't seem right (using the final step, "think"), so I had to figure out what went wrong. I had used the wrong acceleration.

How To Study For This Physics Course

- (1) Take advantage of the TAs in the Tutorial Lab to help you better understand concepts and how to solve problems.
- (2) Form a study group; I recommend you meet at least twice a week. Use your study group to talk about key concepts, work through homework problems, and study for exams. To find people, talk to students who sit near you in class, students you meet in the Tutorial Lab, post to the class discussion forum, etc.
- (3) Do the reading assignment for each class period. Look over the corresponding material in the “List of Important Equations and Concepts” document later in this syllabus, to help you see which equations & concepts are truly vital. For each equation in the Important Equations list, find the corresponding equation in the textbook and mark it. Go back after class and look at things again, paying particular attention to the worked problems in the textbook.
- (4) Attend class. Take notes on the lecture slides I post before class. After class, talk to your study group or TAs about things you didn’t understand. If you have to miss class, print out the filled-out lecture slides I post after class and watch the appropriate demo videos on the class website.
- (5) After class, go back over your notes from class and add in comments explaining things to yourself.
- (6) Work the assigned homework problems! For the most part, you learn physics by *doing* physics. Start on the problems as soon after class as possible while the material is still fresh in your mind. Try to work all problems using only the equations found in the “List of Important Equations and Concepts” document rather than picking random equations out of the textbook that may or may not apply.
- (7) Use the PEANuT method for solving problems.
- (8) Keep an organized homework notebook so that you can use your homework solutions to study for exams. As you go, clearly identify the *type* of problem each one is, such as “Kinematics”, “Newton’s Second Law”, or “Conservation of Energy”. Be neat!
- (9) Work on the homework problems first on your own, then with your study group, and then if need be get help from the TAs. Your goal should not be to memorize how to do the specific problems that were assigned, but rather to **master the general strategies, concepts, and skills**. Exam problems will be similar to homework problems in terms of the methods used to solve them, but the equations you end up will in general be different. If you get help on homework, be sure to learn the concepts and steps used to solve the problem, and think about other similar problems that could be written to test those concepts.
- (10) Consult my homework solutions to see how I myself did the problems. They are posted a day or two after the homework due-date in the glass cases outside N361 ESC.
- (11) To prepare for exams, review warmup quizzes, the “List of Important Equations and Concepts” document, and class notes (clicker quizzes, demo videos, etc.). Work through the past exams I’ve posted to the class website, review all of your homework problems, and if you have time work through extra problems from the textbook (answers to the odd-numbered problems are given at the end of the book).
- (12) For some added assistance, feel free to stop by my office hours, held in the Tutorial Lab.

There is no sure way to succeed in a physics course. You may do everything suggested here and still not do as well as you would like. Make sure you aren’t skimping on the hours, though. The BYU Undergraduate Catalog states that “The expectation for undergraduate courses is three hours of work per week per credit hour for the average student who is appropriately prepared [i.e., 6 hours per week on homework for a typical 3 credit class]; much more time may be required to achieve excellence”. Some students can get by with fewer hours but others may need to put in even more time than that. Unfortunately, spending extra time is still not a guarantee of a great grade. If you are putting in the hours but still struggling, please see the additional advice in the next section. Some of that is similar this list, but there are also some new ideas.

Advice for Struggling Students

At the end of Fall 2013 I asked students this question: “If you struggled early on but then were able to turn it around, what are some specific things you did that helped you, that could be useful for future students to know?” I received more than 100 responses. I read through all of their recommendations and grouped them into common categories. Here are all the ideas that were mentioned by at least three students, along with selected quotes from the students themselves.

Use a study group, and explain things to each other (9 students)

- At first I was doing the homework and all assignments all on my own. It became frustrating when I couldn't figure something out. When I started to do the homework with two of my friends it really helped.
- I started explaining the questions to other students. That helped me the most: teaching.
- The TAs were helpful, but they usually just gave the answers. When I started working with other students and we figured things out together, the concepts stuck a lot better.
- After completing the homework I would often try to help my friends and other students understand the homework. This really solidified concepts for me.

Use the Tutorial Lab (16 students)

- I did all my homework in the TA lab so I could get the help I needed while we were learning.
- I found that using the TAs and their knowledge really helped me to understand and review concepts.
- Lots and lots and lots of time in the physics lab!
- Live in the lab!

Use a study group AND ALSO the Tutorial Lab (6 students)

- I was struggling early on but I found I did so much better after I got in a study group and visited the TA lab at least twice a week.
- Do every HW assignment in the TA lab. Study exams with someone else. These things really helped me turn it around.
- GO TO THE HOMEWORK LABS! Not just on the day that the homework is due; go in the day before when there are a lot less people. It's also very helpful to get together in groups to do the homework and study. Talking through the problems and concepts and explaining them helps the material become more complete.

Don't overuse the Tutorial Lab/study groups; stand on your own (14 students)

- I was totally dying, and I had never ever failed a test in my life until this course. Then I made some adjustments and turned it around. I realized that I had created a crutch by going into the TA lab and getting the homework done even when I wasn't learning that much of it. So I took more time on my own—not around other students or TAs—and worked through concepts with the book. That helped me develop how to think like a physics person. Then when I would get help it made a lot more sense.
- Learn how to solve all the problems by yourself without your book, notes, TA etc. Before I started doing that, sometimes I would fool myself into thinking I knew how to solve problems when I really didn't.
- I think a big thing is to go to the physics tutorial lab AFTER you've tried doing the hw questions by yourself, that way you aren't just memorizing how to do a problem but you're getting help on concepts that you don't understand.

Don't focus solely on getting the right answer (5 students)

- I made sure that I understood concepts and why I needed to take certain steps toward a solution instead of just trying to get the right answer.

Work on a schedule and do homework early (8 students)

- I really struggled at first. I felt frustrated with the homework that it took so long to do. What I finally did (and it helped a lot!) was establish a definite schedule in which I did the homework. I went into the physics lab every single time, on a day when it wasn't usually busy, like a Wednesday morning and I just sat there until I got the homework done.
- I would do the homework a day early so that I could talk with the TAs when few people were there.
- Did homework before the night it was due, so that I wasn't rushed and tempted to copy the necessary equation from someone else in order to turn in the assignment on time.

Go over the exams posted to the class website to prepare for exams (15 students)

- Reviewing the old exams helped me prepare exponentially better for the exams.
- Work on the practice tests. The only way to learn physics is to PRACTICE, PRACTICE, PRACTICE!
- The past exams online were what saved me. I ran through at least one of them each time we had a midterm.

Go back over the homework problems to prepare for exams (10 students)

- I went to the tutorial lab and re-did all of the homework assignments before the exam.
- Do the homework problems to study for the tests!

Go over the posted exams AND ALSO the HW problems to prepare for exams (8 students)

- I did best when I went through all the practice tests and every homework problem and made sure I understood how to do them as well as understand the concepts. I found that I understood the concepts much better the more I practiced problems. Just wish I would have done it that way for all the exams.

Work extra practice problems (5 students)

- For me it was just doing as many practice problems as possible. It was tough for me to start to think like a physicist because it didn't come naturally. So, doing as many practice problems as I could got me in that mindset so that I could start looking at everything we learned that way.
- Work problems until you are blue in the face, and then do them again.
- Do problems over and over. The more time you put into doing physics, the easier it will be later.

Prepare for/pay attention during lectures (4 students)

- I struggled early on because I didn't take notes on the worked problems. Once I took more thorough notes that covered EVERYTHING in the lectures, I feel like I came to grasp concepts better and understand homework problems more easily.
- I would print off the slides before lecture and try to answer the iclicker questions before going to class.

Don't freak out if you can't understand the textbook (5 students)

- I stopped worrying so much about the book, and focused on being able to master the HW assignments.
- I started devoting more time to doing the homework problems and less time doing reading.

Take some time to review concepts, including going over posted lecture notes (6 students)

- I spent a lot of time just sitting listening to music trying to visualize in my mind what was happening. The better my mental image was the more likely I was to figure out how to set up the math. (I learned that trick from reading Einstein's Biography.)
- Before the exams I also looked back through all the power points from the lectures that were posted on the website and made sure I understood everything on them.

Use the *List of Important Equations and Concepts* from the syllabus (3 students)

- For the last exam instead of just doing practice problems, I went through the summary of equations and made sure I understood each equation. Because my understanding of the equations was better, I was able to almost automatically know which equations to use on the exam.

Put in more hours (3 students)

- Most importantly, because I knew I was struggling, I knew I had to put in more study time in order to understand the material.
- Above all I was committed and willing to do whatever it took to get the grade I wanted, including spending long hours on campus most days.

Use outside resources (4 students)

- I watched and rewatched khanacademy.org videos.
- I found some websites online that really helped me grasp the background of some of the concepts. Khan Academy and Freelance Professor were both very useful.
- I loved online resources (Yahoo answers, Khan Academy).

Consider getting a tutor (5 students)

- I got a tutor. I met with him for at least 2 hours per week and went over the homework and prepared for tests. It helped a lot.

Don't give up hope (6 students)

- The later topics just clicked more.
- The second half of the semester was much easier after I learned how to think more like a physicist.
- Most importantly, DON'T GIVE UP.

Physics 105 List of Important Equations and Concepts

When my daughter took AP Physics in high school (the equivalent of this class), she had a hard time understanding things because her teacher made the class memorize every single equation in the textbook! There was no attempt on the teacher's part to identify which equations were most fundamental. That led me to create this document for you. The equations here involve only the basic definitions and laws of physics (with rare exceptions). This list gives you **all the equations you need** for all of the homework and exam problems. That is, any equation you need that is not given here can be relatively easily derived from these equations.

Chapter 2. Motion in One Dimension

The **displacement** Δx of an object is defined as

$$\Delta x = x_f - x_i$$

where x_i is the initial position and x_f is the final position. Note that a negative displacement means that the object has moved in the $-x$ direction.

The **average velocity** v_{ave} during a time interval Δt is defined as

$$v_{ave} = \frac{\Delta x}{\Delta t}$$

where Δx is the object's displacement during that time interval. This is also the **instantaneous velocity** if either (a) the velocity is constant or (b) the time interval Δt is sufficiently small. Note that a negative velocity means that the object is moving in the $-x$ direction.

The **average acceleration** a_{ave} during a time interval Δt is defined as

$$a_{ave} = \frac{\Delta v}{\Delta t}$$

where Δv is the change in the object's velocity during that time interval. This is also the **instantaneous acceleration** if either (a) the acceleration is constant or (b) the time interval Δt is sufficiently small. Note that a negative acceleration means that the object's acceleration is in the $-x$ direction. That can happen if the object is either moving to the left and increasing in speed, or moving to the right and decreasing in speed.

If an object's acceleration a is constant, then we have the following relations during the time interval from 0 to t :

$$v_{ave} = \frac{v_i + v_f}{2}$$
$$v = v_0 + at$$
$$x = x_0 + v_0t + \frac{1}{2}at^2$$
$$v_f^2 = v_0^2 + 2a\Delta x$$

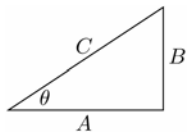
where v_{ave} is the average velocity over the time interval, v_i (also written v_0) is the velocity at time = 0, v_f (also just written v) is the velocity at time = t , x_0 is the position at time = 0, x is the position at time = t , and Δx is the displacement during the time interval ($= x - x_0$). These are called the basic **kinematic equations**.

For objects which are freely falling vertically downward, use these same equations, substituting y for x

and setting $a = -g$ (where g is defined as a positive number, $g = +9.8 \text{ m/s}^2$). Acceleration is downward, in the $-y$ direction.

Chapter 3. Vectors and Two-Dimensional Motion

The only trigonometry you need to know for this course are the following relations for a right triangle:



$$\begin{aligned} A &= C \cos \theta \\ B &= C \sin \theta \\ C &= \sqrt{A^2 + B^2} \\ \tan \theta &= B/A \end{aligned}$$

For **projectile motion** in two-dimensions near the Earth's surface, there is no acceleration in the x -direction, and an acceleration of $-g$ in the y -direction. If the projectile's initial velocity is at an angle θ relative to the horizontal, it has horizontal and vertical components of:

$$\begin{aligned} v_x &= v \cos \theta \\ v_y &= v \sin \theta \end{aligned}$$

For projectiles, the basic kinematic equations written for both x and y become:

$$\begin{aligned} v_x &= v_{0x} \\ x &= x_0 + v_{0x}t \\ v_y &= v_{0y} - gt \\ y &= y_0 + v_{0y}t - \frac{1}{2}gt^2 \\ v_{fy}^2 &= v_{0y}^2 - 2g\Delta y \end{aligned}$$

Consider a boat crossing a river and being observed from the shore. The velocity of the boat relative to the ground is the velocity of the boat relative to the river combined with the velocity of the river relative to the ground, in a vector sum: $\vec{v}_{bg} = \vec{v}_{br} + \vec{v}_{rg}$, where the velocities in this equation are read as \vec{v}_{bg} is "velocity of boat relative to the ground", etc. A similar equation can be written to give the **relative velocity** for any object in a moving medium:

$$\vec{v}_{13} = \vec{v}_{12} + \vec{v}_{23}$$

where "1", "2", and "3" are the appropriate labels for the situation... for example, for an airplane flying in the wind you could use the labels "a" (for airplane), "g" (for ground) and "w" (for wind) to get $\vec{v}_{ag} = \vec{v}_{aw} + \vec{v}_{wg}$. Keep in mind that because these are vectors, direction matters! Even in 1D problems, you must keep track of which quantities are positive and which are negative.

Chapter 4. The Laws of Motion

Newton's First Law, also called the "law of inertia" states that an object's velocity will not change unless acted on by an outside force, which means:

$$\vec{a} = 0 \text{ unless there's a net outside force}$$

Newton's Second Law describes the acceleration a produced by forces acting on an object having mass m , namely

$$\Sigma \vec{F} = m\vec{a}$$

where the Greek letter sigma, Σ , represents a summation, i.e. adding up all of the forces acting on the object. The forces must be added as a vector sum. $\Sigma \vec{F}$ is also called the “net force”. The acceleration will always be in the same direction as the net force.

Newton’s Third Law states that forces always come in pairs, equal in magnitude and opposite in direction, namely

$$\vec{F}_{12} = -\vec{F}_{21}$$

where the forces in this equation are read as \vec{F}_{12} is “force of object 1 on object 2”, etc.

There are four particularly common forces that comprise what I call our “tool box”. The first of these is the **force of gravity**, aka the weight of an object and typically given the symbol w . Near the surface of the earth, an object’s weight is

$$w = mg$$

where m is the mass of the object and g is the **acceleration of gravity**, $g = +9.8 \text{ m/s}^2$.

The second is the **normal force**, typically given the symbol N . This is the force exerted by a surface on an object, which arises because atomic-level forces prevent the object from entering inside the surface. The force is always perpendicular (or “normal”) to the surface.

The third is the force of **tension** of a rope pulling on an object, typically given the symbol T . It always pulls the object inward, towards the rope.

The fourth is **friction**, typically given the symbol f . The force of friction depends on whether the object is at rest on a surface (static friction) or sliding along the surface (kinetic friction). The force of static friction f_s between an object and a surface is given by

$$f_s \leq \mu_s N$$

where μ_s is the coefficient of static friction and N is the normal force exerted by the surface on the object. Note that the value of f_s may vary from zero up to $\mu_s N$, depending on how much force is required to prevent the object from sliding on the surface. If more force than $\mu_s N$ is required, then the object will slide.

The force of kinetic friction f_k between an object and a surface is given by

$$f_k = \mu_k N$$

where μ_k is the coefficient of kinetic friction and N is the normal force exerted by the surface on the object. This is the appropriate friction equation to use when the object is sliding on the surface.

Chapter 7. Rotational Motion and the Law of Gravity (2nd half of chapter)

An object moving in a circle has an inward-pointing **centripetal acceleration**, a_c . It is given by

$$a_c = \frac{v^2}{r}$$

where v is the object’s tangential speed and r is the radius of the circle. This acceleration typically goes on the *right hand side* of Newton’s Second Law (multiplying the mass); that is, all of the real inward & outward forces go on the left hand side of the equation and combine to produce this acceleration.

Newton's Law of Gravity describes the gravitational force F_g between any two objects, namely

$$F_g = \frac{GMm}{r^2}$$

where M and m are the masses of the two objects, r is the distance between the centers of the two objects, and G is the universal gravitation constant, $G = 6.674 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$.

The equation for **orbital velocity**, the speed of a satellite traveling in a circular orbit, can be derived through Newton's Second Law by using Newton's Law of Gravity as the only force on the left hand side, and centripetal acceleration substituting in for a on the right hand side.

division between exam 1 and exam 2

Chapter 5. Energy

The **work** W done on an object by a force F is defined as

$$W = (F \cos \theta)d$$

where d is the distance the object moves while the force is acting on it and θ is the angle between \vec{F} and \vec{d} (the displacement vector). $F \cos \theta$ is called the "parallel component of the force", written as $F_{//}$, so the work is also given by

$$W = F_{//}d$$

If the force is in the same direction as the motion, $W = Fd$. If the force is in a direction opposite to that of the motion, $W = -Fd$ and the work done is negative. The net work W_{net} done is the total work done by all of the forces acting on the object, or (equivalently) the work done by the net force.

The **kinetic energy** KE of an object is given by

$$KE = \frac{1}{2}mv^2$$

where m is the object's mass and v is the object's velocity.

The **work-energy theorem** is a version of the **law of conservation of energy**, and states that

$$KE_i + W_{net} = KE_f$$

where W_{net} is the net work done on an object and KE_i and KE_f are the initial and final kinetic energies, respectively. It's important to recognize that in this equation W_{net} represents the work done by all forces acting on the object.

For some forces, expressions for a **potential energy** (PE) can be obtained. These are called **conservative forces**. They are conservative in that all of the energy expended as work acting against the force can be recovered later. The energy is stored in the meantime, but not lost irrecoverably (e.g. into heat). An alternate version of the law of conservation of energy is often used when such conservative forces are present, namely

$$KE_i + PE_i + W_{net} = KE_f + PE_f$$

where W_{net} now represents only the work done by nonconservative forces, because the work done by conservative forces has been included via the potential energy terms.

Gravitational force is conservative. As mentioned above, the gravitational force F_g (aka weight w) on an object of mass m near the Earth's surface is given by

$$F_g = w = mg \text{ (directed downward)}$$

The associated **gravitational potential energy** is

$$PE_g = mgy$$

where y is the height of the object above some reference level of your choosing.

Spring force is also conservative. The force F_s exerted by a compressed or stretched spring is given by **Hooke's law**

$$F_s = -kx$$

where x is the distance the spring is compressed or stretched and k is the spring's "spring constant". The minus sign means that the force is directed opposite the direction of the compression (or stretch).

The associated **spring potential energy** is

$$PE_s = \frac{1}{2}kx^2$$

Note that PE_s is always positive, for a compressed as well as a stretched spring.

From the end of Chapter 7: As mentioned, gravity is a conservative force. When using Newton's Law of Gravity as given above for situations away from the surface of the Earth, the **gravitational force** is given by

$$F_g = \frac{GMm}{r^2}$$

and the associated **gravitational potential energy** PE_g is

$$PE_g = -\frac{GMm}{r}$$

where all symbols are as described above. Unlike the equations for gravity near the surface of the Earth where you are free to set the zero of potential energy at a reference level of your choosing, this formula requires you to use $r = \infty$ as the point with zero potential energy.

The equation for **escape velocity**, namely the minimum speed a projectile would need to escape the "gravitational well" of a planet or star, can be derived through conservation of energy by using the initial kinetic energy $\frac{1}{2}mv_0^2$ and the initial potential energy of gravity (a negative number!) on the left hand side, and noting that the final kinetic and potential energies on the right hand side are both zero.

Chapter 6. Momentum and Collisions

The **momentum** of an object is defined as

$$\vec{p} = m\vec{v}$$

where m is the object's mass and v is the object's velocity. Because velocity is a vector, momentum is also a vector.

The **law of conservation of momentum** says that if all forces on a collection of objects are internal (i.e. only between the objects), then the total momentum of the collection is conserved. We can also consider momentum to be conserved if the interactions between objects happen so quickly that the effect of external forces can be neglected, such as in most collisions and explosions. This means

$$\Sigma \vec{p}_i = \Sigma \vec{p}_f$$

where the Greek letter Σ again represents a summation, i.e. adding up the momenta of all of the objects present. The momenta must be added as a vector sum.

An **elastic collision** is a very special kind of collision where energy is conserved in addition to momentum. This is not generally the case. In 1D elastic collisions with two objects, combining the equations for conservation of energy and conservation of momentum results in this new equation which I call the **velocity reversal equation**:

$$(v_1 - v_2)_i = (v_2 - v_1)_f$$

where v_1 and v_2 represent the velocities of the two objects (and may be negative).

A force F acting on an object for a short time Δt is said to deliver an **impulse** to the object:

$$\text{impulse} = \vec{F}\Delta t$$

The **impulse-momentum theorem** connects this impulse to the object's change in momentum, Δp :

$$\vec{F}\Delta t = \Delta \vec{p}$$

Chapter 7. Rotational Motion and the Law of Gravity (1st half of chapter)

The **angular displacement** $\Delta\theta$ of a rotating object is given by

$$\Delta\theta = \theta_f - \theta_i$$

where θ_i is the initial angle and θ_f is the final angle. By convention, counter-clockwise rotation is a positive angular displacement, and clockwise rotation is a negative angular displacement.

The **average angular velocity** ω_{ave} during a time interval Δt is defined as

$$\omega_{ave} = \frac{\Delta\theta}{\Delta t}$$

where $\Delta\theta$ is the object's angular displacement during that time interval. This is also the **instantaneous angular velocity** if either (a) the angular velocity is constant or (b) the time interval Δt is sufficiently small. Note that a positive angular velocity means that the object is rotating counter-clockwise, and a negative angular velocity means that the object is rotating clockwise.

The **average angular acceleration** α during a time interval Δt is defined as

$$\alpha_{ave} = \frac{\Delta\omega}{\Delta t}$$

where $\Delta\omega$ is the change in the object's angular velocity during that time interval. This is also the **instantaneous angular acceleration** if either (a) the angular acceleration is constant or (b) the time interval Δt is sufficiently small.

If an object's angular acceleration α is constant, then we have the following relations during the time interval from 0 to t :

$$\omega_{ave} = \frac{\omega_i + \omega_f}{2}$$

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega_f^2 = \omega_0^2 + 2\alpha \Delta\theta$$

where ω_{ave} is the average angular velocity over the time interval, ω_i (also written ω_0) is the angular velocity at time = 0, ω_f (also just written ω) is the angular velocity at time = t , θ_0 is the position at time = 0, θ is the position at time = t , and $\Delta\theta$ is the displacement during the time interval ($= \theta - \theta_0$). These are called the **basic angular kinematic equations**. They are identical to the basic kinematic equations with the simple substitutions:

$$x \rightarrow \theta$$

$$v \rightarrow \omega$$

$$a \rightarrow \alpha$$

If an object is moving in a circle of radius r , then its **tangential distance** traveled s , **tangential speed** v , and **tangential acceleration** a are related to the angular displacement θ , angular velocity ω , and angular acceleration α , namely

$$s = r\theta$$

$$v = r\omega$$

$$a_{tan} = r\alpha$$

where all angles must be given in radians.

Chapter 8. Rotational Equilibrium and Rotational Dynamics

The **torque** τ on an object produced by a force F about a given axis is defined as

$$\tau = r(F \sin \theta)$$

where r is the distance from the axis to the spot where the force is applied and θ is the angle between \vec{F} and \vec{r} (the distance vector). $F \sin \theta$ is called the “perpendicular component of the force”, written as F_{\perp} , so the torque can also be written as

$$\tau = rF_{\perp}$$

Alternately, the $\sin \theta$ factor can be grouped with r , where $r \sin \theta$ is called the **lever arm**, written as r_{\perp} , and is the distance from the axis to the line through which the force acts:

$$\tau = r_{\perp} F$$

If the force vector is in line with the distance-from-the-axis vector, there is no torque. If they are perpendicular then $\tau = rF$.

Newton’s Second Law for Torques (my name) describes the relationship between the net torque on an object $\Sigma \tau$ and the angular acceleration α of the object,

$$\Sigma \tau = I\alpha$$

where I is the **moment of inertia** of the object about the axis through which the torque is acting. This is identical to Newton’s Second Law with the simple substitutions

$$F \rightarrow \tau$$

$$m \rightarrow I$$

$$a \rightarrow \alpha$$

A special case of Newton’s Second Law for Torques occurs when there is no net torque. In that case,

there is no angular acceleration. Or, looked at in reverse, if there is no angular acceleration there must be no net torque. This is the case in **equilibrium** situations: if an object is neither accelerating nor angularly accelerating, there must be no net force and no net torque. The two equations $\Sigma \vec{F} = 0$ and $\Sigma \tau = 0$ (from Newton's Second Law and Newton's Second Law for Torques) generally provide an excellent starting point for solving problems involving equilibrium situations.

The **moment of inertia of a point mass** (mass m) about a given axis is given by

$$I = mr^2 \quad \text{for a point mass}$$

where r is the distance from the axis to the point mass.

The **moments of inertia for extended objects** of mass m and radius R , are given by

$$I = \frac{2}{5}mR^2 \quad \text{for a solid sphere}$$

$$I = mR^2 \quad \text{for a hoop or cylindrical shell}$$

$$I = \frac{1}{2}mR^2 \quad \text{for a solid disk}$$

$$I = \frac{1}{12}mL^2 \quad \text{for a rod rotating about its center}$$

$$I = \frac{1}{3}mL^2 \quad \text{for a rod rotating about its end}$$

The **rotational kinetic energy** of an object is given by

$$KE = \frac{1}{2}I\omega^2$$

where I is the object's moment of inertia and ω is the object's angular velocity. This is very analogous to translational kinetic energy, $KE = \frac{1}{2}mv^2$.

The **angular momentum** L of a rotating object is defined as

$$L = I\omega$$

where I and ω are as in the previous equation. This is very analogous to regular momentum, $\vec{p} = m\vec{v}$, although note that the units of L and p are different. By convention, an object rotating counter-clockwise has a positive angular momentum, and one rotating clockwise has a negative angular momentum.

Even if objects are not rotating, they still possess what I call **hidden angular momentum**. For a point mass object (or one where the dimensions of the object are small compared to r), this is given by

$$L = rp \sin \theta = r_{\perp} p = rp_{\perp}$$

where r is the distance from the potential rotation axis to the object, p is the object's regular momentum, and θ is the angle between the distance-from-the-axis vector and the momentum vector. $r_{\perp} = r \sin \theta$ is like the lever arm in torque problems, and $p_{\perp} = p \sin \theta$ is the perpendicular component of the momentum. If the momentum vector is in line with the distance-from-the-axis vector, there is no angular momentum. If they are perpendicular, then $L = rp$. By convention, an object moving the same direction as a counter-clockwise rotation about the axis has a positive angular momentum, and one moving the opposite direction has a negative angular momentum.

The **law of conservation of angular momentum** says that if all torques on a collection of objects are internal (i.e. only between the objects), then angular momentum is conserved, i.e. the total initial angular momentum of all the objects must equal the total final angular momentum, namely

$$\Sigma L_i = \Sigma L_f$$

where as usual the Greek letter Σ represents a summation. The signs of the angular momenta (positive vs. negative, using the conventions given above) must be taken into account.

division between exam 2 and exam 3

Chapter 9. Solids and Fluids

The **density** ρ of an object is defined as

$$\rho = m/V$$

where m is the object's mass and V is the object's volume.

The **pressure** P exerted by an object or a fluid (liquid or gas) on a surface is defined as

$$P = F/A$$

where F is the force exerted by the object or fluid on the surface and A is the area of contact (which would generally be the entire surface area in the case of a fluid).

The **pressure of a liquid at a depth** below the surface of the liquid is given by

$$P = P_0 + \rho gh$$

where P_0 is pressure at the surface of the liquid (usually the atmospheric pressure there), ρ is the density of the liquid, g is the standard acceleration of gravity, and h is the depth below the surface.

Archimedes' principle states that the **buoyant force** B of a fluid on a submerged object is equal to the weight of the fluid that is displaced by the object, namely

$$B = m_{\text{displaced fluid}} g$$

where $m_{\text{displaced fluid}}$ is the mass of the displaced fluid, g is the standard acceleration of gravity, and $m_{\text{displaced fluid}} g$ represents the weight of the displaced fluid. Since the mass of the displaced fluid is the fluid's volume multiplied by the displaced volume, Archimedes' principle is often represented in this alternate form

$$B = \rho_{\text{fluid}} V_{\text{object}} g$$

where ρ_{fluid} is the density of the fluid and V_{object} is the volume of the portion of the object which is displacing the fluid. V_{object} is the whole volume if the object is fully submerged, but it's only the volume of the submerged portion if the object is only partially submerged (for example, when a boat is floating on the surface of a lake).

The **volume flow rate** or "VFR" of a liquid is the amount of volume that flows past a given point, per unit time, and is given by

$$VFR = Av$$

where A is the cross-sectional area and v is the velocity of the flowing liquid. If the liquid is incompressible (as we will assume), then the volume flow rate is constant everywhere along the flowing liquid. This is represented by what I call the **garden hose equation**,

$$A_1 v_1 = A_2 v_2$$

where "1" and "2" just refer to any two arbitrary points in the flow.

Bernoulli's Equation represents conservation of energy for a fluid, and is also typically written in terms of two arbitrary points in the flow, 1 and 2:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

where ρ is the fluid's density, g is the standard acceleration of gravity, and P , v , and y are the fluid's pressure, velocity, and vertical height at a given point, respectively.

Chapter 10. Thermal Physics

Temperature is a measure of the average kinetic energy of atoms or molecules in a given region of space. The relationships between Fahrenheit, Celsius, and Kelvin temperature scales are defined by these two equations:

$$T_F = \frac{9}{5}T_C + 32$$

$$T_K = T_C + 273.15$$

where T_F is the Fahrenheit temperature, T_C is the Celsius temperature, and T_K is the Kelvin temperature.

The SI unit for temperature is Kelvin, so if a given equation refers to T , it means the Kelvin temperature. Since the Kelvin and Celsius scales have the same “size” of degrees, when a temperature difference is specified either can be used:

$$\Delta T_C = \Delta T_K$$

The change of length ΔL of some object due to **thermal expansion** is given by

$$\Delta L = \alpha L_0 \Delta T$$

where α is the coefficient of linear expansion, L_0 is the initial length of the object, and ΔT is the change in temperature. If the object is cooled down, ΔT is negative, and ΔL is negative. (The object gets shorter.)

The change of volume ΔV of a solid or a liquid due to thermal expansion is given by

$$\Delta V = \beta V_0 \Delta T$$

where β is the coefficient of volume expansion, V_0 is the initial volume of the liquid, and ΔT is the change in temperature. For liquids the value of β is given, but for solids it's not—instead, β is related to the tabulated values of α , via:

$$\beta = 3\alpha$$

The **ideal gas law** is

$$PV = nRT$$

where R is the **universal gas constant**, $R = 8.314 \text{ J/mol}\cdot\text{K}$, and P , V , n , and T are the pressure, volume, number of moles, and temperature of the gas, respectively. A mole of gas is defined to be **Avogadro's number** N_A of molecules, $N_A = 6.022 \times 10^{23}$. The ideal gas law can also be expressed in terms of the number of molecules N instead of the number of moles n , namely

$$PV = Nk_B T$$

where k_B is **Boltzmann's constant**, $k_B = 1.381 \times 10^{-23} \text{ J/K}$. Boltzmann's constant relates to the universal gas constant R and Avogadro's number N_A via:

$$R = k_B N_A$$

The average translational kinetic energy of a single molecule of an ideal gas, trans. KE_{ave} , can be obtained through **kinetic theory**, and is given by:

$$\text{transl. } KE_{ave} = \frac{3}{2} k_B T$$

where T is the temperature of the gas and k_B is Boltzmann's constant. Since translational kinetic energy is $\frac{1}{2}mv^2$, this equation can also be expressed as

$$\frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$$

where m is the mass of a single molecule (in kg), and v_{ave} is the average or more specifically the "rms" (root mean square) speed of the molecules. This equation gives one a way to solve for average speed as a function of temperature. This equation applies to all molecules, since it can be derived without any indication as to whether the molecules are (for example) diatomic or monatomic.

The **equipartition theorem** (not mentioned by name in the textbook, but part of our kinetic theory discussion) describes the average amount of energy each **degree of freedom** (channel into which energy can be absorbed for each molecule) will receive from thermal interactions with its surroundings, namely

$$E_{\text{degree of freedom}} = \frac{1}{2}k_B T$$

where T is the temperature and k_B is Boltzmann's constant.

The equipartition theorem is consistent with the $\frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$ equation given above for all types of molecules since the *translational* kinetic energy, the energy relevant to the $\frac{1}{2}mv^2$ expression, always involves just three degrees of freedom regardless whether the molecule is diatomic or monatomic.

Chapter 11. Energy in Thermal Processes

Heat is the transfer of thermal energy from one object or system to another. The heat Q required to raise the temperature of an object by ΔT is given by

$$Q = mc\Delta T$$

where m and c are the mass and **specific heat** of the object, respectively. If the object gets hotter (positive ΔT), then Q is positive: thermal energy is flowing into the object. If the object gets colder (negative ΔT), then Q is negative: thermal energy is flowing out of the object.

The heat Q required to change some substance from solid to liquid (melt) or from liquid to gas (boil) is given by

$$Q = mL$$

where m is the mass of the substance and L is the **latent heat** for the process. Q is negative (i.e. heat must be taken away) if going from liquid to solid, or from gas to liquid.

If heat flows from one object to another, then conservation of energy requires that the heat energy lost by the one must equal the heat energy gained by the other,

$$|Q|_{\text{lost by 1}} = |Q|_{\text{gained by 2}}$$

where absolute values have been used so that each side of the equation represents a positive number. This equation, combined with the previous two equations, allows one to solve **calorimetry** problems, where two (or more) objects at different temperatures are allowed to come to thermal equilibrium with each other at some common final temperature.

The heat transferred per time through a medium via **thermal conduction** is given by

$$\frac{\Delta Q}{\Delta t} = kA \frac{T_2 - T_1}{L}$$

where ΔQ is the heat transferred, Δt is the amount of time, T_1 and T_2 are the temperatures of the two objects, and k , A , and L are the thermal conductivity, cross-sectional area, and length of the medium, respectively.

The heat emitted by an object, per time, via **radiation** is given by

$$\frac{\Delta Q}{\Delta t} = e\sigma AT^4$$

where ΔQ and Δt are as before, e , A , and T are the **emissivity**, surface area, and temperature of the object, respectively, and σ is the **Stefan-Boltzmann constant**, $\sigma = 5.670 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$. Since heat radiated by the immediate surroundings will be absorbed by the object, the net heat loss of the object will be

$$\left(\frac{\Delta Q}{\Delta t} \right)_{net} = e\sigma A (T_{object}^4 - T_{surroundings}^4)$$

Chapter 12. The Laws of Thermodynamics

When one changes the state of a gas by changing pressure, volume, and/or temperature, the change is often represented as a path on a **P-V diagram**, where volume is plotted as the x -axis and pressure is plotted as the y -axis. The work W done on the gas is given by:

$$|W_{on}| = \text{area below the path on the P-V diagram}$$

with the caveat that if the path goes from right to left (decreasing volume) W_{on} is positive, and if the path goes from left to right (increasing volume) W_{on} is negative.

Applied to two different situations, the area calculation gives us

$$|W_{on}| = |P\Delta V| \text{ (constant pressure change)}$$

$$|W_{on}| = |nRT \ln(V_2/V_1)| \text{ (constant temp. change)}$$

where all of the symbols are as you'd expect. I used absolute values in those equations because the best way of judging whether W_{on} is positive or negative is the increasing volume/decreasing volume rule given above.

The **first law of thermodynamics** is

$$\Delta U = Q_{added} + W_{on}$$

where ΔU (also called ΔE_{int}) is the change of **internal energy** of the object or system, Q_{added} is the heat flowing into that object or system (a negative number if heat leaves the substance), and W_{on} is the work done on that object or system.

The first law means that for an **adiabatic process**, where no heat is added or subtracted from a gas, the work on the gas is equal in magnitude to the change in the gas's internal energy:

$$|W_{on}| = |\Delta U| \text{ (adiabatic change)}$$

The equipartition theorem applied to monatomic gases (3 translational degrees of freedom) and to diatomic gases (3 translational and 2 rotational degrees of freedom, near room temperature) gives rise to these equations for internal energy U (also called E_{int}) as a function of temperature T :

$$U = \frac{3}{2} Nk_B T = \frac{3}{2} nRT \text{ (monatomic)}$$

$$U = \frac{5}{2} Nk_B T = \frac{5}{2} nRT \text{ (diatomic, near 300K)}$$

where N is the number of molecules, n is the number of moles, k_B is Boltzmann's constant, and R is the universal gas constant.

The relationship between heat and work in a **heat engine** is given by

$$Q_h = |W_{net}| + Q_c$$

where Q_h is the heat absorbed from the hot reservoir (i.e. the heat produced by burning fuel), $|W_{net}|$ is the net work done by the engine and Q_c is the magnitude of the heat exhausted to the cold reservoir.

The **thermal efficiency** e of a heat engine is defined as

$$e = \frac{|W_{net}|}{Q_h}$$

where the symbols are as in the previous equation, and can also be written as

$$e = 1 - \frac{Q_c}{Q_h}$$

The **Carnot theorem** states that the maximum thermal efficiency of any heat engine operating between high and low temperatures of T_h and T_c is given by

$$e_{max} = 1 - \frac{T_c}{T_h}$$

division between exam 3 and final exam

Chapter 13. Vibrations and Waves

The **frequency** f of an oscillation is related to its period T by

$$f = \frac{1}{T}$$

The **angular frequency** ω of an oscillation is related to its frequency f by

$$\omega = 2\pi f$$

The angular frequency ω of an oscillating weight (mass m) attached to a **spring** (spring constant k) is given by

$$\omega = \sqrt{\frac{k}{m}}$$

and its period of oscillation T is

$$T = 2\pi \sqrt{\frac{m}{k}}$$

The angular frequency ω of an oscillating **pendulum** (length L) is given by

$$\omega = \sqrt{\frac{g}{L}}$$

and its period of oscillation T is

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where g is the standard acceleration of gravity.

The velocity v of any wave is related to its wavelength λ and frequency f via

$$v = \lambda f$$

The velocity v of a wave traveling on a string is given by

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension in the string and μ is the **linear mass density**, i.e. the mass of the string per unit length,

$$\mu = m/L$$

Chapter 14. Sound

Sound waves are longitudinal pressure oscillations that get transmitted through a medium such as air. The speed of sound in air is typically given as 343 m/s, but that is really only accurate if the air's temperature is 20°C. In general the speed of sound in air, v , depends on temperature T (in Kelvin) as:

$$v = 331 \text{ m/s} \sqrt{\frac{T}{273K}}$$

or equivalently (and in my opinion easier to remember)

$$v = 343 \text{ m/s} \sqrt{\frac{T}{293K}}$$

The **intensity** I of a sound wave is defined as

$$I = P/A$$

where P is the sound power (energy per unit time) passing through an area A .

The **decibel level** β of a sound wave is given by

$$\beta = 10 \log\left(\frac{I}{I_0}\right)$$

where I is the intensity (power per area) and I_0 is a reference intensity, namely the threshold of human hearing $1.0 \times 10^{-12} \text{ W/m}^2$. The inverse relation is given by

$$I = I_0 10^{\beta/10}$$

The intensity of a sound wave typically falls off with an **inverse square law**, $I \sim 1/r^2$, or

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

where I_1 and I_2 are the intensities of the wave at distances r_1 and r_2 , respectively, from its source.

The **Doppler equation** describes how a frequency detected by an observer, f' , is shifted from the frequency emitted by the source, f , namely:

$$f' = f \frac{v \pm v_o}{v \mp v_s}$$

where v is the speed of sound, v_o is the speed of the observer, and v_s is the speed of the source. The choices of signs depend on the directions of the velocities of the source and observer. Use + in the numerator when the observer is moving toward the source and – when the observer is moving away from the source. Use – in the denominator when the source is moving toward the observer and + when the source is moving away from the observer.

A **sonic boom** is the shock wave that forms when an object travels faster than the speed of sound. The angle θ between the path of a supersonic aircraft and its shock wave is given by

$$\sin \theta = v/v_s$$

where v is the speed of sound and v_s is the speed of the aircraft (source). The ratio v_s/v is called the **Mach number**.

If waves interfere with their reflections, **standing waves** can form. The fundamental (lowest) frequency f_1 of a standing wave on a string fixed at both ends (“closed-closed”), and its associated wavelength λ_1 , are given by

$$\begin{aligned}\lambda_1 &= 2L \\ f_1 &= v/\lambda_1 = v/(2L)\end{aligned}$$

where v is the velocity of the waves and L is the length of the string.

The allowed frequencies of the **harmonics**, i.e. higher frequency modes of oscillation, are given by

$$f_n = nf_1$$

where n is the number of **antinodes** (places of maximum vibration) in the mode, and can be any integer. Those last three equations also apply to standing waves in an air column inside a pipe with both ends open (“open-open”), with n being the number of pressure antinodes, v the velocity of sound, and L the length of the pipe.

For a pipe closed at one end (“open-closed”), the fundamental wavelength and frequency are given by

$$\begin{aligned}\lambda_1 &= 4L \\ f_1 &= v/\lambda_1 = v/(4L)\end{aligned}$$

and the allowed frequencies of the higher harmonics are

$$f_n = nf_1$$

where n can be any odd integer. In this case, n is not the number of antinodes in the standing wave.

When two waves with frequencies f_1 and f_2 interfere with each other, they produce **beats**, with a beat frequency f_{beat} given by

$$f_{beat} = |f_2 - f_1|$$

Physics 105 – Fall 2014
Homework Set 6

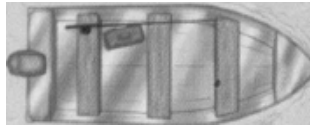
CID: _____

Score: _____ out of 4 points

6-5. (a)



6-6. (a)



7-1. (a)



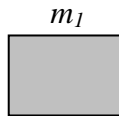
7-2. (a)



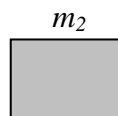
(b)



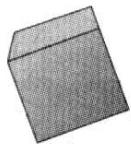
7-3. (a)



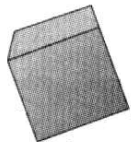
(b)



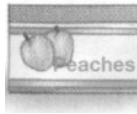
7-4.



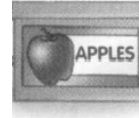
7-5.



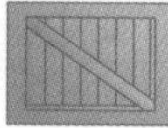
8-3. (a)



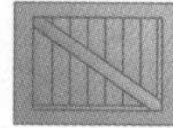
(b)



8-4. (a)



(c)



8-6. (a) at point A



(c) at point B



9-1. (a)



(b)



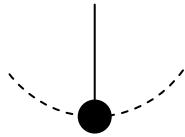
9-2 (a)



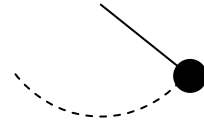
9-3 (a)



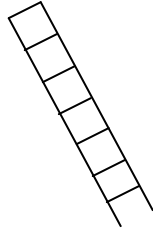
10-5. (a)



(b)



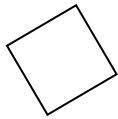
15-2. (a)



15-3. (a)



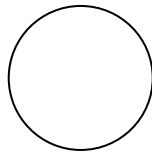
16-1. (a)



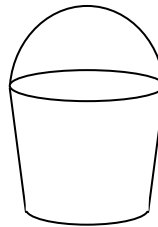
(b)



16-2. (a)



(b)



Physics 105 – Fall 2014
Homework Set 19

CID: _____

Score: _____ out of 4 points

19-1. (a)



19-2. (a)

