Discussion Exercises for Chapters 1-4

(1) In-class discussion of every day examples of displacement, velocity, acceleration. Ask the students to work in groups of 3-4 and describe particularly the velocity and acceleration, and any *change* in these quantities with time. You may need to disallow cars as examples to encourage them to use their imaginations!
Goals: discussing a real-life situation should encourage students to think again about these fairly familiar concepts; also introduces them in a non-threatening way to the discussion side of the course.

Alternate exercises

(1) Exercise: Graphical exercise. Draw three graphs on the blackboard (graphs are x vs t; a straight horizontal line; a straight rising line; an upside-down parabola) Ask the students to sketch the corresponding plots of velocity versus time and acceleration versus time. Collect the results and discuss any differences that arise.
Goals: explore the students' understanding of the three key concepts; introduces interpretation of graphs; could be a good tutorial exercise ...
Variations/extensions: ask the students to sketch the displacement, velocity, acceleration of one of the everyday examples (i.e. a car traveling from one stop sign to the next); toss a ball straight up in the air and catch it: ask them which graph corresponds to the ball's motion

(2) Exercise: Toss a ball in the air and catch it. Ask the students to sketch what the velocity and acceleration vectors look like (a) half-way up (b) at the top (c) at the bottom. Then ask them to compare their drawing to that of their neighbor and discuss any inconsistencies. Then collect some answers and discuss any differences.
Goals: introduction to freely falling objects; can highlight students' confusion about acceleration being present even when there is (instantaneously) no motion; this discussion may come out naturally in the discussion of everyday examples of displacement
Variations/extensions: you could then make a brief presentation on "Freely Falling Objects" as an example of a good student presentation, using the sample handout.

(3) In the first class, you could ask them if they have had any bad or good experiences with physics before and if so, what they were.

Hints for Starting Discussions in Class

A good way to start a discussion is to have the students talk among themselves in groups of 3-4 and then to collect the answers. This method is particularly helpful early in the course before the students are used to active participation. I always write up ALL the answers (in point form) on the board before identifying which answers are correct and why, and which are wrong, and why. This makes it a bit less intimidating, because it's not obvious right away which groups got it wrong. (Sometimes, none of them will get it right, which is interesting too!) A variant on this method is to have them work by themselves on a task for a couple of minutes, and then to compare their results to their neighbor's results and try to resolve any differences. This is useful particularly if you expect confusion on a topic.

Discussion Exercises for Chapter 5 (Newton's Laws)

(1) Exercise: Students work in groups of three to come up with a verbal definition of force. (causes acceleration) Remind them that acceleration is change in velocity. Ask for a description of types of situation where we have a change in velocity (from rest to motion; from one speed to another (in straight line); from one direction to another (constant speed); from one direction AND speed to another) If force causes acceleration, what does it mean if we have no acceleration (no NET force) Point out this is Newton's First Law: $a = 0$ iff $F_{net} = 0$.

(2) Discussion: Instructor defines inertial frame of reference – one that is not accelerating; in which Newton's first law holds. Ask the students to come up with one everyday example of an inertial frame and a non-inertial frame, and to try to figure out how you could tell you were in the non-inertial frame.

(3) Demo: have a heavy book and a sheet of paper that is smaller than the book. Ask the students to discuss in their groups what will happen if you put the piece of paper on top of the book and drop them together, and why? Then do it. (This is a slightly unexpected version of the classic Galileo-style experiment that is unusual enough to catch the students' attention.)

(4) Exercise: Instructor introduces and defines Newton's Third Law. Ask the students to stand up, pair off, put their hands together and push each other. You can demonstrate yourself with a student partner first. After they sit down, ask them to discuss the following: "If you were pushing on your partner, why didn't he or she fall over?" and then collect the answers. This leads nicely into a discussion of a simple Free Body Diagram. You can have the students tell you what forces to draw on your figures and emphasize the rules for FBDs along the way.

(5) Exercise: Draw three cases of a book on a table (a) by itself (b) being pulled upward by a string (but still in contact with the table) (c) being pushed downward. Have the class help you draw the freebody diagram for the book for each situation. Also write the equations below. (emphasizes that magnitude of normal force depends on what other forces are acting on the object; can also be used to emphasize direction of normal force)

Alternate exercises

(1) Exercise: Drop a ball. Does it accelerate? (yes, from zero velocity initially). What is the force? (no contact force – force of gravity). Now throw the ball up. Ask them to sketch what the force vectors look like (a) half-way up (b) at the top (c) at the bottom. (Or this could be done by anonymous voting – ask them to hold up a piece of paper saying up or down and if they think none, do not hold up anything.) Then collect some answers and discuss any differences. Ask them what this means for the acceleration vector – reinforce the idea that the acceleration is downward even when the motion is upward.

(2) Discussion: Ask the students in groups of three to discuss the difference between mass and weight. As a hint, have them think about an astronaut on the moon. If they need more hints, you could say he weighs less on the moon or that acceleration due to gravity

was 1/6 smaller on the moon. (Illustrates that weight is a force that depends on gravity and mass is a basic property of the object.)
Variations/extensions: Since g falls off as $1/r^2$, estimate by how much your weight changes between the surface of the Earth and flying in an airplane. Would you be able to measure this change in weight with a standard bathroom scale (digital or analog)?

(3) Discussion: Consider a head-on collision between a car and a truck. Which experiences the greater force? Which experiences the greater acceleration?

(4) Why do our feet slip more easily when we are walking down a dirt trail than when we are walking up it?

Discussion Exercises for Chapter 7 and 8 (Newton's Laws; 3-4 classes)

(1) "Discuss the work done by a parent in pushing a stroller completely around the block. (Clears up whether the d in the work equation is total displacement or whether you have to do it in pieces.)

(2) sketch graph of F versus x as below for the parent pushing the stroller in a straight line, but over ice and then through mud (as well as dry pavement) (variable F); "how would we determine the work done in this case"; discuss; give integral form for work

(3) define kinetic energy K; state work-KE theorem: W = K_f - K_i "How could we modify this equation to show the contribution of work done by friction explicitly?" students may have no clue; may also reveal confusion about sign of work done by friction

(4) puzzler – "Ring the Bell" (see picture at start of Chapter 8) – students discuss what is the best strategy? (handy to have a photocopy of picture)

(5) Discussion: "we use chemical energy in walking up stairs and therby gain potential energy. Do we regain this energy as we walk downstairs? If not, where does it go?"

Alternate exercises

(1) (In fall only) What is the power associated with food intake of 2500 kcal/day (1 kcal = 4186 J)? why is our room so hot?

(2) Puzzler at start of Chapter 7 could be a good discussion topic.

(3) Power of Niagara Falls (1.2E6 kg/s with height of 50 m) and convert to number of 60 W light bulbs.

Discussion Exercises for Chapter 9 (Linear Momentum)

(1) Discussion: the movie "Speed"; in the scene at the end, when the subway car jumps the rails to avoid crashing into the end of the tunnel; why is this a good strategy? (many little collisions are better than one big collision; smaller force over longer time)

(Alternatively, if class hasn't seen the movie (which hasn't happened to me yet!), discuss a truck hitting sand cans versus a bridge pillar)

(2) Discussion topic: can you come up with an example of a collision where momentum is NOT conserved?

(3) Demo: drop a small ball above a big ball; small ball shoots off very fast; students discuss why this happened. (Note: this is a good demo but the mathematical discussion is long if you try to derive it from the formulae below; if you want to derive the speed of the lighter ball, I find it good to have an overhead with the formula for the speed of m_1 and m_2 written down as a starting point.)

Discussion Exercises for Chapter 13 (Simple Harmonic Motion)

(1) Introduction by instructor; $F \propto x$; F and x in opposite directions (restoring force) –> this is “Simple Harmonic Motion”, where position is a sinusoidal function of time; $x = Acos(\omega t + \phi)$ (define constants); Discussion with class: what situations have we seen so far where force has these properties? (springs; pressure with depth; buoyant force on a floating object that is displaced)

(2) Discussion: suppose we have a spring with a block attached to it. We pull the spring out 5 cm and let it oscillate. Then we pull it out 10 cm and let it oscillate. How do the periods of the two situations compare? (Are the same: emphasize that for spring, period etc. only depend on k and m, not the amplitude A)

(3) Instructor writes down equations for v and a; discussion with class: what are the maximum values for a, v, x? point out that if you are given ω and x and v at t=0, you can solve for ϕ and A (see textbook); Student Exercise: instructor sketches $x = Acos(\omega t)$ on the board; ask them to sketch v vs. t and a vs. t; compare to neighbors, discuss; point out that x, v, a are out of phase

(4) Discussion with class: two swings, one of length 3 m, the other of length 2 m. A 20 kg girl swings in the long swing; then a 40 kg boy. How do the periods of their swinging compare? What if the girl swings in the 2 m swing? point out that period depends only on L and g, not on m of bob at end of pendulum

Discussion Exercises for Chapter 15 (Fluids)

(1) Key introductory concepts: Un-ionized states of matter; continuity between fluid and gas in some circumstances (both held together by weak cohesive forces and walls of container). Compressibility: why in gas and liquid; why so different in solid. Concepts of volume and density. What are the characteristics of fluids?

(2) (whole class discussion i.e. ask for volunteers without group discussion first) Familiar experiences of pressure changes: ears popping driving down ”the mountain”; ears hurting while skin-diving; changes while in a plane; someone steps on you in high heels

(3) Group discussion: Effect of Arctic icecap melting on sea-level (none except for Greenland’s ice) versus effect of Antarctic’s icecap melting on sea-level (substantial)

(4) Flow Characteristics: types of flows; laminar (smooth path, v(x,y,z) but not t); turbu-

lent (eddies, whirlpools); ask for examples from class. Viscosity: degree of internal friction; layers move relative to each other; ask for examples from class

(5) Group discussion: Why does stream of water get narrower as it comes out of the faucet? Or, why does water squirt out of hose faster when you cover up part of the whole with your thumb? Or both together, with pictures from the textbook to stimulate discussion

Alternative Exercises

(1) (possible discussion topic, either for groups or the whole class) Why not use water in barometer? (density is 13.6×10^3 versus 1×10^3)

(2)more discussion; describe importance of pressure difference i.e. a hose lying filled with water; water doesn't shoot out unless pressure difference; $(P_1 - P_2)Ad = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$. Garden hose example; cover area with thumb and speed goes up. Water towers and mgh connection; open to atmospheric pressure at both ends; $mgy_2 - mgy_1 = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$; $v = \sqrt{2gh}$, Torricelli's law

Discussion Exercises for Chapter 16 (Wave motion)

(1) Discussion (whole class): "What are some of the different types of waves that you have heard of?" sound, water, rope, light, radio waves, microwaves, X-rays; divide into mechanical waves and EM waves

(2) Discussion (small groups or whole class): "What are some of the things that we need in order to have mechanical waves?" a medium (no sound in a vacuum); a source of the disturbance; physical connection between adjacent portions of the medium

(3) Discussion (small groups): put up picture of ocean wave from start of Chapter 16, or another better picture of water waves; "What are some of the things we might want to know in order to describe these waves to someone?" height (amplitude), time between arrival of waves (period), bird's eye view of separation of waves (wavelength), how fast they are moving (wave velocity); point out that we are aiming to put this information together into a concise mathematical formula to describe the waves.

(4) Sketch a snapshot of a wave (sine wave) y vs x at some instant t. Ask volunteers to identify what variables from the previous discussion they can from this graph (amplitude and wavelength); can sketch a sine wave at some later time t+dt; point out wave velocity =dx/dt for a crest; sketch at time t+T later and identify T as time for next crest to reach a given point; point out that f=1/T is the number of crests that pass a point per second

(5) Graphical exercise: before class, sketch $y = 2/(x^2 + 1)$ on an overhead and label it t=0. "If the wave is moving to the right with a speed of 1 m/s, sketch what y(x) looks like at t=2 s"; students work together in groups; collect the sketch; "Can you write a new function that describes y(x) at time t=2 s?" $y = 2/((x-2)^2 + 1)$; "How far has the wave traveled in t=2 s?; "In general, if the wave is moving to the right at speed v, how far does it travel in time t?" dx = vt; "So, can we write down a general expression that will tell us what y is at any x and at any time t?" $y = 2/((x - vt)^2 + 1)$

(6) Discussion (small groups): show Figure 16.8 on an overhead (superposition of two waves; constructive interference); "What are some of the things that are happening in this sequence of pictures?" (label that t increases downward and hide caption); waves pass through each other without being changed; combination of separate waves to produce a resultant wave is called intereference; constructive versus destructive interference.

Alternate Exercises

(1) Graphical exercise: Problem 16.2 (on an overhead); students do in small groups; collect and discuss on the board

Discussion Exercises for Chapter 37 (Interference)

(1) Discussion (small groups): "What are some of the reasons that might explain why we don't see interference of light any time we have 2 light sources?"; need coherent light sources; incoherent light sources have small random changes in phase every 10^{-8} s; also hard to observe because wavelength is so short; helps if source is monochromatic; get sources in constant phase relationship by using one source to illuminate two slits

(2) Discussion (small groups): "What pattern would you expect to see with three slits instead of two in Young's Double Slit experiment?"; large and small maxima, one each

(3) Discussion (whole class): Where have you seen thin films? (oil on water, coatings on camera lenses, butterfly wings, peacock feathers, hummingbird throats)

(4) Discussion (small groups): If we treat a peacock feather as a 2-layer structure, how must the thickness vary to produce the pattern of colors we see? (I use a crude sketch of the color pattern in a peacock feather to stimulate the discussion here; this was good, brought out some confusion in one class)

Alternate Exercises

(1) Discussion: Q37.4 (what would happen in a double slit if we had white light instead of monochromatic light?)

Discussion Exercises for Chapter 38 (Diffraction and Polarization)

(1) Discussion (small groups): "What happens to the distance between the dark bands if I make the slit width smaller i.e. half as wide?"; to illustrate that slit width and dark band separation vary inversely

(2) Discussion (small groups): "Suppose we wanted to take a picture and actually see a planet around a nearby star. What things would we need to know to figure out how big a telescope we would need?" distance to star; distance of planet from star; wavelength of picture; (ignore relative brightness for now); typical values (for the non-astronomers!) might be 10 pc = 3e17 m, 1 AU = 1.5e11 m, and 1 micron; minimum telescope diameter turns out to be only 2.4 m! Why we can't see planets right now is because the star is so much brighter than the planet that its diffraction pattern swamps the tiny signal from the

planet.

(3) Demo and discussion: take two sheets of polarizer. Put them at 90 degrees to each other on overhead projector so no light gets through; take a third sheet and put it on top at 45 degrees; still no light, of course; move the third sheet to be IN BETWEEN the first two; light should come through; class discusses what is going on

Alternate exercises

(1) Van Gogh museum: had to stand 7 m away from painting for it to look really good; what was typical size of brush strokes on the painting?

Discussion Exercises for Chapter 17 (Sound)

(1) Introduction: could start with discussion: what kinds of things produce sound? are there different kinds of sound (like there are different kinds of EM radiation)? three types of sound waves: audible, infrasonic (elephants, whales?), ultrasonic (dogs, medical imaging); sound waves are longitudinal waves; particles in medium vibrate to produce changes in density and pressure; high and low pressure regions

(2) Has anyone ever heard the Doppler effect? Where?

Alternate exercises

(1) discussion topic: how does a megaphone work?

Discussion Exercises for Chapter 18 (Standing Waves)

(1) Discussion: how does temperature affect ability of string and wind instruments to hold their pitch?

(2) discussion: Act 26 (Can you hear the beat frequency?) (see Johann Beda's notes – basically, say you have two high frequencies (above audible limit), like 100 kHz and 110 kHz, whose difference is in the audible limit. Ask them if they will be able to hear the beat frequency?)