PHYS 101- Concepts of Physics - Fall 2006
Homework #2
Due in class Thursday November 2nd

You must mostly type your work. But, as on all assignments this semester, hand-write equations and drawings as needed-just please be neat.

You should write enough for each problem so that we know you've done some work and understand the principles involved. In other words, **show your work**. Numerical answers alone will receive only partial credit.

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1. Measure the angle of the sun above the horizon, in Charlottesville, between 12:30 and 1:30 pm Daylight time, or between 11:30 am and 12:30 pm Standard time. We are still on Daylight time until Sunday Oct. 29, 2006. Be sure to state your location, date, and time, and show your work.

2. Exercise # 18 on page 49 of Hobson, 4th edition (Brownian Motion).

3. Exercise # 20 on page 49 of Hobson, 4th edition (Dog following scent).

4. For this experiment you will need at least one thin plastic bottle with a screw-on cap. I recommend the 20-ounce soda bottles that seem to be ubiquitous around grounds. It's better to have two or three available, so you'll have back-ups in case the first one doesn't seal well, or gets damaged during the experiment. You may also need some matches and a candle.

   - Remove all the liquid from the bottle, and dry fairly well. It doesn't have to be perfectly dry, but shake out most droplets.
   - With the cap removed, heat the air inside the bottle. One way to do this is to hold the bottle upside-down over a match or candle flame for about 5 seconds. But be careful: if you hold the bottle too close, the plastic will melt and deform, and you won't be able to seal the bottle. Several inches away is probably close enough--you can check by holding your hand above the flame, and deciding if the air feels hot. Another way to heat the air is to run very hot water over the bottle for 5 seconds or so, and then screw the cap on while the water is still flowing over it. There are other methods. For example, if you want to be adventurous, try pouring a bit of very hot water (almost boiling) into the bottle, allow a few seconds for the steam to fill the bottle, then seal.
   - Once the air is heated, make sure you've quickly screwed on the cap until it's snug. Place the sealed bottle in a freezer for a minute or two. (A refrigerator is probably OK too.)

   (a) Briefly summarize your procedure (how dry was the bottle, how far and how long above the flame, or explain other method ,etc.)
   (b) What happened to the bottle? Make before and after sketches of the bottle's shape.
   (c) Discuss why this works by carefully explaining what happens to the number of air molecules, the speed of the air molecules, and the air pressure inside the bottle:

      - with the cap removed, but before heating the air
      - after heating the air, but with cap still removed
      - after heating the air, with cap in place
      - after the bottle is cooled

   (d) Suppose you could keep the bottle sealed the entire time, and still heat the air inside the bottle (with a laser or something like that). Would this change the outcome of the experiment? Explain.

5. Problem # 8 on page 69 of Hobson, 4th edition (Drop rock off cliff.)
6. Problem # 7 on page 89 of Hobson, 4th edition (Force on bullet.) As a follow-up question, assume the gunpowder burns as the bullet travels 30 centimeters down the barrel of a gun, after which the burning

ends and the bullet maintains a constant speed thereafter. For how many seconds is the bullet accelerated? How fast, in meters per second, will the bullet be travelling as it emerges from the gun? Convert this to miles per hour, and compare to the speed of sound in air. Is this bullet "supersonic"? Explain. (Use 343 m/s for the speed of sound in air.)

7. This question pertains to climbing stairs, and the calories burned during that activity. A gym stair-stepper simulates this motion.

   (a) Find the mass, in kilograms, of a person who weighs 150 pounds.
   (b) Go to www.nautilus.com and look up the specifications of the "**StairMaster® StepMill® 7000PT".** What is the height of each step in cm? How many meters is that? What is the least and greatest number of steps that can be climbed per minute?
   (c) Using the correct formula and the information above, calculate the amount of work done, in Joules, by a 150-pound person in 30 minutes of climbing the StairMaster. Calculate this for both the lowest stepping rate and the greatest stepping rate.
   (d) Assuming the human body is 100% efficient at converting food energy into work, convert the answers in part (c) to food calories.
   (e) In reality the human body is typically only about 20% efficient. That is, you have to burn more calories than you calculated in part (d), because only 20% of them will be converted into work. (The rest are wasted to heat.) Knowing this, modify your part (d) answers into realistic numbers of calories burned.
   (f) Now let's compare our answers to a web site which calculates "calories burned." Go to www.changingshape.com and find the "Calories Burned Calculator". Find their answers for "Light Stair Climbing" and "Heavy Stair Climbing." You'll find that your answers do not agree with theirs. How close does the "Light Stair Climbing" seem to be to the lower extreme given by Nautilus? What about the "Heavy Stair Climbing" to the upper extreme? Briefly explain how choosing the number of steps climbed per minute could account for the disagreement.

8. For this problem, assume the hood of your car is very slippery. You are driving in a straight line at constant speed, with a friend sitting on your hood. Then, you suddenly veer off to the left. What happens to your friend? Make careful "before" and "after" sketches of this scenario, as viewed from above the car (from a helicopter, say), and explain in physics language what happens to your friend and why. Is it correct to say that your friend has been "thrown off the hood"? Why or why not?

9. Locate an isolated building with a large, flat side. Stand about 100 feet away and clap your hands once. You should hear an echo shortly after the clap. Slowly walk toward the building, clapping your hands occasionally. What changes about the time between a clap and when you hear the echo? At some point you should notice that you no longer hear the echo because it comes too soon after the direct sound.

   Calculate the time between the direct sound and the echo for a distance of 100 feet from the building. Be sure to show your work. Does this time approximately agree with your experimental results? Explain.

10. Most large objects emit a range of electromagnetic waves, and the details depend on the surface temperature of the object. The higher the temperature, the higher the average energy of the radiation emitted. The peak wavelength of that range is given by the following formula:

$$\text{Peak Wavelength (in meters)} = \frac{0.0029}{(\frac{5}{9} T_{Fahrenheit} + 255)}$$

The surface temperature of the sun is about 10,000 degrees Fahrenheit, and that of the human body is about 90 degrees Fahrenheit. Find the peak wavelength emitted by these two objects, compare to the information in section 9.3 of your text, and explain whether or not your answers make sense.