PHYS 101-Concepts of Physics-Fall 2006
Solutions to Homework #2
100 points possible
(1.-10 pts 2.- 5 pts 3.-5 pts 4.-15 pts 5.-10 pts 6.-10 pts 7.-15 pts 8.-10 pts
9.-10 pts 10.-10 pts)

1. You should be getting good enough at measuring the angle of the sun to be correct within one or two degrees. Here are some sample numbers: Oct. 26th, 39 degrees. Oct 31st, 37 degrees.

2. Brownian motion is caused by collisions of a particle (such as the tiny smoke particles shown in class) with the surrounding molecules (air molecules in that case). If the particle is small enough, the unevenness in the collisions will cause it to move around enough that the motion can be observed. On the other hand, if the particle is fairly large, the unevenness in the collisions won't cause enough motion to be observed, and it will just appear to be at rest.

3. In order to smell something, the molecules of the substance being smelled must actually travel up the nose of the "observer"—in this case the dog. The convict may have something on his shoes or feet that is distinctive. If so, those molecules will be deposited on the ground, and some of them will randomly be jostled up into the air near the ground. Those molecules are what the dog is trying to detect.

4. (a) I shook all the water out of a 20-ounce soda bottle, held it over a match flame for about 10 seconds, and then quickly screwed on the cap. (There are other ways to heat the air inside, but you must explain.) It seemed to seal tightly. I then put the bottle in a refrigerator for about 2 minutes.

   (b) The sides of the bottle caved in, and you should have drawn this.

   (c) The basic reason why this works is that molecules are forced out of the bottle as it's heated. Once the sealed bottle cools down, the pressure inside the bottle is less than outside the bottle. The greater outside pressure crushes the bottle somewhat. Here is a summary at the various steps:

   > <u>before starting</u>-- the air pressure inside the bottle is the same as outside the bottle, as are the number of molecules for that volume, and the speed of the molecules
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   > <u>heating the air with cap removed</u>--now the molecules speed up; the pressure attempts to increase, but since the bottle is open, what actually happens is that enough molecules leave the bottle to exactly equalize the pressure to that of the surroundings. So the number of molecules inside is now lower, but the pressure is the same inside as outside of the bottle.
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   > <u>inside air still hot, with cap in place</u>--nothing has a chance to change yet, so speed of molecules is still high, pressure is same as outside the bottle,

and number of molecules is still less than comparable volume outside the bottle

after bottle is cooled--now the molecules slow down, but the number of molecules is still low, therefore the pressure inside the bottle decreases. Since the pressure outside the bottle is higher than inside, the bottle gets crushed somewhat.

(d) With the bottle sealed the entire time, the number of molecules would always be the same, but the pressure will change. As the air inside is heated, the bottle will expand (and possibly explode). When the air inside is later cooled in a freezer, the bottle may cave in slightly, but not as much as in the previous experiment, and when it returns to room temperature, the conditions inside the bottle are back to normal, and the bottle should return to its original shape.

5. Using the formula $H = ½ g t^2$, with t = 6 seconds, we get H = 176.4 meters. However, this will only be truly accurate if the object dropped encountered no air resistance. In the real world, this is never the case. So is the actual height of the cliff more, or less, than 176.4 meters? Take an extreme case. Imagine dropping an object through water or syrup. The time of descent would then be really long, like 100 seconds or something. If you blindly applied the formula above, you would incorrectly conclude that the cliff was really high (like 30 miles or something like that). Of course the cliff is actually lower than that. In our case, with the object dropped through air and the time measured to be 6 seconds, the difference is not so extreme, but the cliff is still actually lower than 176.4 meters.

6. To find the force on the bullet, use F = ma. This gives F = (0.01 kg)(1 million m/s^2) which equals 10,000 Newtons. Now assume this acceleration only lasts for a distance of 0.3 meters. We can apply the same formula as in problem #5, except rewrite as $D = ½ a t^2$. Putting in numbers gives $t = 7.7 \times 10^{-4}$ seconds. To find the exit speed, use v = at, which gives v = about 775 m/s, or about 1730 mph. (I've rounded off, but your answers should be fairly close.) This bullet is moving much faster than the speed of sound in air (about 343 m/s) and is therefore "supersonic."

7. (a) 1 kg weighs about 2.2 pounds on the surface of the Earth, so 150 lbs translates to m = 68.2 kg

(b) Each step is 20.3 cm high (= 0.203 meters) and the range for steps per minute is 24 to 162.

(c) Work = Force x Distance, which for vertical motion can be written W = mgh. For 24 steps per minute for 30 minutes this gives h = 146.16 meters, and for 162 steps per minute h= 986.58 meters.

So

For 24 steps per minute W= (68.2 kg)(9.8 m/s^2)(146.16 m) = 97,687 Joules
Similarly for 162 steps per minute W = 659,390 Joules

(d) Since 1 food calorie = 4186 Joules,

24 steps per minute gives 23.3 calories burned, and 162 steps per minute gives 157.5 calories burned.

(e) with only 20% efficiency, your body will burn 5 times more calories than the numbers above, so this gives

117 calories (24 steps per minute for 30 minutes)
788 calories (162 steps per minute for 30 minutes)

(f) For a 150 lb person for 30 minutes, the web site gives 136 calories for "light stair climbing" and 272 calories for "heavy stair climbing". So, apparently their definition of light stair climbing is pretty close to the lower extreme of the referenced stair stepper, but their definition of heavy stair climbing is nowhere near the upper extreme.

8. If the hood is slippery, there is little or no friction to change the horizontal motion of the person on the hood. So, in both the "before" and "after" sketches the person should be going in a straight line. It's the car whose motion changes. From inside the car, it looks like the person has been "thrown off the hood." But this is not a valid frame of reference, since it's accelerating, and thus gives a misleading observation. In fact, the car slips out from under the person. Your drawing should show a viewpoint from above the car, and clearly show the person continuing in a straight line, while the car turns left.

9. If you stand 100 feet from the building (about 30.5 meters), the sound must travel a total of 200 feet (61 meters) from your hand, to the building, and back to your ears. Using vt=d, this gives 343(t)=61. This gives a time of about 0.18 seconds. The direct sound reaches your ears almost immediately, since your hands are near your ears, and the echo will arrive 0.18 seconds later. When I tried it, I found that this is a long enough delay to perceive. As you get closer to the building, the delay gets less and less, until you can't distinguish the echo from the direct sound.

10. Using the formula given:

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

Gives 5 x 10^{-7} meters for T = 10,000 degrees F (the sun), and 9.5 x 10^{-6} meters for T = 90 degrees F (human). According to the chart on page 196 of Hobson 4^{th} edition, the "sun" wavelength is right in the middle of the visible spectrum, which makes sense because the sun emits a lot of visible light (although not exclusively). The "human" wavelength also makes sense because it's about in the middle of the infrared spectrum, and as demonstrated in class, humans emit a lot of infrared radiation.