PHYS 102-Concepts of Physics II-Spring 2007
Solutions to Homework #1   100 points possible

1. (12 points) Use $H = \frac{1}{2} gt^2$. Also, there is no air on the Moon, so no air drag.

    (a) $g_{Moon} = 2H/t^2 = 2*2/(1.55)^2$ = about 1.66 m/s^2
    (b) Since there is no air, the feather would take 1.55 seconds also
    (c) We expect the rock to fall faster, since gravity is stronger on the surface of the Earth. To find exactly, use $H = \frac{1}{2} gt^2$ with $g = 9.8\ m/s^2$. This gives t = about 0.639 seconds, which is less than 1.55 seconds as expected.
    (d) With the air drag on the Earth, the feather would take much longer to fall than the rock.

2. (10 points) You can throw the object up such that it just reaches the height of the building. At this point it will begin to fall from rest, just as if you had climbed the building and dropped it. It will probably take several tries to get it to rise the right amount. But once it does, time the descent and use $H = \frac{1}{2} gt^2$, with $g = 9.8\ m/s^2$.

    A more thorough answer would include some brief discussion of error. For example, if your measured descent time is off by 0.2 seconds either way, what error does this imply in the height measurement?

3. (9 pts) The law of inertia states that no <u>net</u> force is needed on an object to keep it moving. But, that doesn't mean there can't be forces. They just have to add up to zero. When a car is moving, there are drag and other frictional forces (such as air drag) acting backwards on the car. So there must be a forward force (transmitted from the engine to the tires) in order to cancel these drag forces.

4. (10 points) For full credit, you need to have made some sketches. In order to balance, your center of mass must be over some part of your support, i.e. your feet. Normally when you rise up on your toes, you shift forward a bit so that your center of mass is over your toes. But with the wall in the way you can't shift forward, and thus you topple over backwards.

5. (20 points) Here are some sample results.

   (a) Suppose you climb 3 flights of stairs, each of 10 steps, and the vertical height of each step is 20 cm.
   (b) This is a total of 6 meters.
   (c) It took 9 seconds to climb the 6 meters. I used a stopwatch.
   (d) If the person's weight is 150 pounds, this is about 68.2 kg.
   (e) Power = work/time = mgh/t = (68.2 kg)(9.8 m/s^2)(6 m)/(9s) = (4010 J)/(9s) = 446 Watts
   (f) This is about 0.6 hp, using the conversion that 746 watts = 1 horsepower.
   (g) 4186 Joules = 1 food calorie, so 4010 Joules gives 0.96 food calories, at 100% efficiency.
   (h) Using the actual 20% efficiency, your body burns five times the number calculated above, or about 4.8 food calories. This is because only 20% of the 4.8 calories is converted into useful work. The rest is wasted as heat.
   (i) (A standard SNICKERS bar has 280 food calories). You **must** take into account the 20% efficiency of your body for this part. The easiest way is to note that I burned 4.8 food calories climbing 30 steps. So to burn 280 calories I must climb (280/4.8)*(30 steps) which gives 1750 steps. That's a lot! To lose weight, it's "easier" to eat less. Trying to burn off calories by exercise alone is difficult.

6. (24 pts) (Must make sketches for parts "a" and "d" for full credit.)

(a) (The 20-lb child is not yet on the plank). The 40-lb child starts at the center, so that the center of mass of the system is between the supports. The board will not tip until the child moves to the right of the right support. As the board just begins to tip clockwise, the force exerted by the left support is zero, so we only need to balance the torques about the right support: (40 lbs)(x) = (10 lbs)(2 ft), which gives x = 0.5 feet. Thus the child will be 0.5 feet to the right of the right support.

(b) It SEEMS like it won't tip, but we have to prove it. To do this, check the total torque about each pivot. If the total torque is <u>clockwise</u> about the left pivot, it won't tip, and if it's <u>counterclockwise</u> about the right pivot, it won't tip. The latter statement is certainly true, because all the torques are counterclockwise about the right pivot. But what about the left pivot? The clockwise torques are (10 lbs)(2 ft) [the plank] and (40 lbs)(2 ft) [the heavy child], and the counterclockwise torque is (20 lbs)(3 ft) [the light child]. The clockwise torques add to 100 ft*lbs, which is more than 60 ft*lbs, and therefore it won't tip.

(c) The plank will certainly not tip to the left, because it didn't tip before, and now the clockwise torques are actually increasing as the heavy child walks to the right. So we only have to worry about it tipping about the right pivot. Check the most extreme case, with the 40-lb child all the way at the end: Clockwise torques = (40 lbs)(3 ft), Counterclockwise torques = (10 lbs)(2 ft) + (20 lbs)(7 ft). The clockwise torques add to 120 ft*lbs, which is not enough to overcome 160 ft*lbs counterclockwise. So the 40 lb child can walk all the way to the right end, and the plank still won't tip.

(d) The question is, can the plank tip counterclockwise about the left pivot? Yes, it can, and if you calculate the torques, you'll find it does so when the 40-lb child is 1 foot to the **right** of the left pivot. In other words, the heavy child can not even walk all the way to the left pivot from the center, because the plank starts to tip before he gets there.

7. (15 pts) First convert everything to metric units. 120 lbs = about 533 Newtons. 400 miles per hour = about 179 m/s.

   Then use F = ma, but rewrite as F = (kg per second)(meters per second). Thus 533 Newtons = (kg per second)(179 meters per second), which means we need about 2.98 kg per second to leave the gun. Since each bullet has a mass of 0.1 kg, this means that 29.8 bullets per second must leave the gun. So, the must fire about 30 bullets per second in order to lift the person+gun off the ground. I don’t know if any gun can actually do this.