Assignment VII, PHYS 111 (General Physics I)
Fall 2018
Due 10/19/18 at start of class

As always, please put your clearly written answers on separate paper.

1. The Large Hadron Collider in Switzerland is the largest machine in the world. It is a machine that accelerates subatomic particles to very high Kinetic energies. Currently, the LHC can accelerate particles to about 13 TeV.
   a) What is 13 TeV in Joules?
   b) If a baseball had a Kinetic Energy of 13 TeV, how fast would it be moving? (You might be surprised by your answer).
   c) If you gave an electron an energy of 13 TeV, how fast would it be moving? (Your answer here won't be right....the formula for Kinetic Energy we know is actually only valid for speeds small compared to the speed of light. A refinement of this relationship will be introduced if you take PHYS 230. For now, report the speed as your current equation for Kinetic Energy says it would be, but realize that your answer really isn't right – nothing can move faster than light (3×10^8 m/s).)

2. A car of mass 1500 kg is initially moving at a speed of 30 m/s.
   a) How much Kinetic Energy does the car have?
   b) The engine suddenly turns off and the car skids onto a frozen lake. On this frozen lake, the driver slams and holds the breaks, causing the tires to slide over the ice with a coefficient of kinetic friction of 0.3 (and, as such, the car starts to slow down). How far does the car travel on the ice before it loses half of its initial speed?
   c) Same scenario as part (b), but now we want to know how far does the car travel on the ice until it loses half of its initial kinetic energy?
   d) How far does the car travel before it loses all of its kinetic energy (e.g. it reaches a stop).
   e) Based on your answers to parts b-d, what can you say about the kinetic energy as a function of traveled distance? Sketch a graph of K as a function of d.
   f) Based on your answers to parts b-d, what can you say about the kinetic energy as a function of time? Sketch a graph of K as a function of t.

3. Do two different observers necessarily agree on the kinetic energy of an object? Why or why not? If your answer is "no", give me an example of a scenario where two observers would disagree on the kinetic energy of an object.

4. Remember the projectile motion lab (with the cannons)? Let's say that when firing the ball bearings, the projectiles left the cannon moving at 5.2 m/s. Let's also say that the projectiles had a mass of 23 g (a total guess on my part).

   a) How much kinetic energy did the projectile have upon leaving the cannon?

   b) If the spring was compressed 4.6 cm to obtain the energy required to launch the projectile, what was the spring constant of the spring? (You may assume – though it isn't really true – that all of the spring energy went into kinetic energy of the projectile).

   c) If the spring needed to be compressed 4.6 cm to launch the projectile, how much force did you need to apply in order to load the cannon?

   d) If the higher setting (with the same spring) launched the projectile at 8.4 m/s, how far did you have to compress the spring for this setting?

5. A 95.0 kg firefighter slides down a pole while a constant kinetic frictional force of 285 N retards his motion. The firefighter starts from rest 5.50 meters above ground level.

   a) Calculate the work done on the firefighter by gravity as he slides down the pole.

   b) Calculate the work done on the firefighter by the kinetic frictional force as he slides down the pole.

   c) Calculate the firefighter's speed just before hitting the ground.

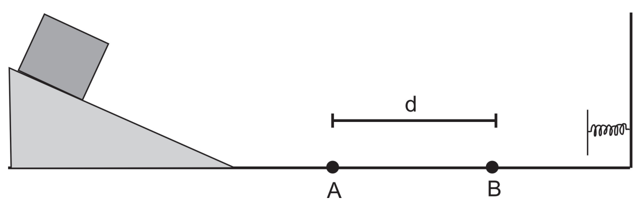
6. A block of mass M slides along a frictionless horizontal table with speed $v_\circ$. Upon reaching the coordinate $x = x_\circ$ the mass slides into and starts to compress a spring with spring constant k.

   a) How far does the spring compress before the mass momentarily stops? (Leave your answer in terms of M, $v_\circ$, and/or k.)

   b) Let's reset the problem and say that now upon reaching the coordinate $x = x_\circ$ the mass slides into and starts to compress a spring with spring constant k AND the table is no longer frictionless, but has coefficient of kinetic friction $\mu = b(x - x_\circ)$ with b some (known) constant. Now how far does the spring compress before the mass momentarily stops? (Leave your answer in terms of M, $v_\circ$, k, and/or b. Your answer should reduce to your answer for part (a) when $b = 0$).

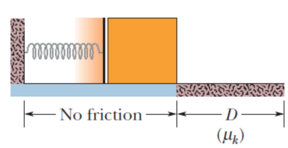
7. A block with mass M is released from height h above the level portion of the track shown below. The track is rough between points A and B, but elsewhere all surfaces are frictionless. As the block traverses the distance d between points A and B it loses mechanical energy E_1 ($E_1 < Mgh$). The spring constant of the spring affixed to the wall is k. Leave all of your answers to this problem symbolically in terms of M, h, g, E_1, and k.

   a) Find the speed of the block at point A the first instant it passes through point A.
   b) Find the speed of the block at point B the first instant it passes through point B.
   c) What is the maximum compression of the spring during the motion of the block?
   d) What is the coefficient of kinetic friction between the block and the rough portion of the track?
   e) Assuming $E_1 < \frac{Mgh}{2}$, how high would the block reach on the first "return trip" up the triangular wedge?



8. A 4.2 kg block is accelerated from rest by a compressed spring of spring constant 732 N/m. The block leaves the spring at the spring's relaxed length and then travels over a horizontal floor with a coefficient of kinetic friction $\mu_k = 0.17$. The frictional force stops the block in distance $D = 11.2$ m. Leave all your answers to this problem numerical (with appropriate units!)

   a) What is the increase in the thermal energy of the block-floor system?
   b) What is the maximum kinetic energy of the block?
   c) What is the original compression distance of the spring?
   d) What was the initial velocity of the block right after breaking contact with the spring?
   e) What is the velocity of the block when it has traveled $D/2 = 5.6$ m from the spring?



(MORE ON BACK!

9. Physicists often are pretty cavalier about the speed of sound and just use the number 343 m/s in our problem solving. In reality, however, the speed of sound in air depends on air temperature (and, to a much lesser extent, humidity, air pressure, and a few other things). Use the following formula to approximate the speed of sound in air as a function of temperature:

$$c_{\text{air}} \approx (331.3 \text{ m/s}) \sqrt{\left(1 + \frac{T}{273.15^\circ \text{ C}}\right)}$$

where T is the temperature in degrees Celcius.

a) What temperature does the air have to be so that 343 m/s is the correct speed for sound?

b) A sound wave has a wavelength of 75 cm at 3°C. What would the wave's wavelength be at a temperature of 17°? (If there are any musicians in the class – this is one of several reasons why you have to retune your instrument when you play in different temperatures!)

10. In lab, you may have used some hollow metersticks. These are pipes that are open on both ends and have a square cross-section.

a) If you were to blow across the open end of one of these metersticks (e.g. treat it like a flute), what is the lowest frequency sound wave you could stably produce? (Assume the speed of sound in air is 343 m/s).

b) What is the second lowest frequency sound wave you could stably produce with the meterstick?

c) Now you plug one end of the tube with some tape. What are the lowest 3 frequency sound waves you can produce with this modified meterstick?