Problem Set #6 due beginning of class, Tuesday, Feb. 17

#1 Solve the infamous "catching the bus" problem. The bus is at your stop, and you're running at a constant speed of 7 m/s from behind in order to catch it. However, just when you're 20 m behind it (or behind the bus driver to be exact), the bus begins accelerating away from you at 1 m/s^2, and will continue accelerating at 1 m/s^2 unless you can meet eyes with the driver. Set up the problem properly with the right equations, substitution, solving the problem, and only at the end substituting the values in and solving the problem while canceling units properly.

a) Do you catch the bus? If so, at what time? If not, how close do you come?
b) Draw the displacement – time, and velocity – time graphs. Graph yourself and the bus together on each graph.
c) Repeat the above problem with the difference that the bus starts when you are 30 m behind it.

#2 According to the hydrodynamic flow equations you'll learn in PHYS-132, the speed of water coming from a 200 PSI fire house is about 45 m/s. Wikipedia claims these hoses are 25 mm in diameter. Imagine if you were hit with water by one of these hoses, like if you were protesting government support of fossil fuels, and the city called in the fire department to clear the area (please see some drama: https://www.youtube.com/watch?v=K3Iv9okL4QU). I'd like to know the force that this water puts on someone's body. Let's model the water as a moving column that hits you and disperses in all directions (360°) perpendicular to its original direction of travel, as in the figure of the demonstrator at right.

a) * Clearly map out why this problem should be solved with conservation of momentum.
b) * What is the sum total of 1 meter long of the water before and after it hits your body?
c) * Find the force that this water puts on your body. Could it knock you over?

#3 If you hit a baseball at a 20 degree angle above the horizon, at an initial velocity of 20 m/s off the edge of a cliff 50 m high, how far away does it land from the bottom of the cliff? Please solve this three ways (one of the three ways is problem #4, and tell me which you like best:

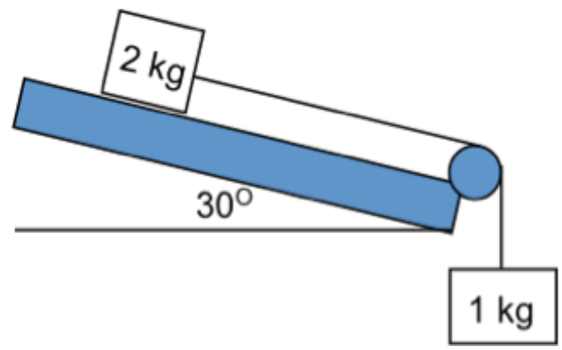
a) Using work-energy, please find the final speed of the ball.
b) Assert what you know about the horizontal component of the ball's velocity throughout its flight, and why you know this. Then, use this information to find the ball's vertical velocity and the angle it makes with the horizontal just before it hits the ground.
c) Knowing the initial and final vertical components of velocity, find the amount of time the ball is in the air, and then the horizontal distance the ball went before landing.

Then try the kinematic method, which is the way it's done conventionally (d-f below):

d) Without finding energy first, please separate the problem into two parts, the horizontal and the vertical. You are looking for the horizontal displacement. However, you need to know how long it is in the air. Please solve the vertical part to find out how long it is in the air. Which lens will you use?
e) Then you can use this time to find the distance that the ball has moved horizontally. Please show all your work and cancel units.
f) Find the final velocity (magnitude and direction), of the ball immediately before it hits the ground.

#4 *This is not directly tested on any exam, but completing this will be helpful to understand how parabolic trajectories work, and be very helpful for anyone interested in learning computer simulations*. Please download the Excel spreadsheet for this HW. The spreadsheet is about hitting a baseball. Notice how the horizontal and vertical displacements are calculated independently, but rely on the initial conditions that you put in in column K. Please figure out how the program works by looking at what it does and feel free to change some numbers (especially in column K). If you mess up the spreadsheet, you can fix it, or you can just download it again. What happens to the value of the angle as time progresses?

a) Explain how the program calculates the position at any given time, and the velocity at any given time. How does the calculation of the horizontal component of velocity differ from that of the velocity's vertical component?
b) If you are hitting on level ground, the story ends when the baseball gets back to 0 m in height. Please play with the velocity of the ball. If you double the initial speed (in column k), what happens to the distance the ball is hit? Can you explain physically why this happens?
c) Change the initial angle of the ball. Does it seem that a 45° angle maximizes the distance the ball is hit? Now hit the ball at an initial velocity of 20 m/s from the top of a 50 m cliff. You can change the initial vertical displacement in G2. Now see which angle maximizes distance. Why has it changed?
d) Now change the angle of the initial velocity, and solve problem #1 above. Which of the three ways to solving the projectile motion problem do you like best? Do you see different advantages to each?



#5 The system at right is started from rest. The coefficient of friction is 0.3. The strings and pulleys are massless and frictionless. The 1 kg mass hits the ground after falling 2 meters

a) How many joules in heat were liberated in the process?
b) What is the change in potential energy as the system falls?
c) without using any kinematic equations, find the speed of the system when the 1 kg mass strikes the floor. What physics concept is used?
d) Using the information above, find the average speed, the time of the fall and the acceleration of the system.
e) Using the above information, find the tension in the string.

#6. Solve the above problem using dynamics as a system. Find the acceleration, tension in the string, and final speed.

#7. Solve the above problem using dynamics as two connected masses, solving the dynamics for each mass. Find the acceleration, tension in the string, and final speed.

Which of the three methods #5, #6, or #7 do you like the most?

#8. If team A and team B are engaged in a tug-o-war, then they want to pull very hard on the rope between them. However, they know that the tension in the rope pulls their team as hard as it pulls the other team, so they are confused. Is there no point in pulling? What are we missing here? Please outline the physics involved and explain what needs to happen in order for one team to win. This is a dynamics problem, can you follow a protocol that is compelling? Is a drawing very important?

#9 Elastic Collisions. Two masses approach each other head-on with equal speeds (v_O = 10 m/s). The one from the left has three times the mass as the one from the right. If you like, the one from the right can be 1 kg, and the one from the left be 3 kg, or just allow them to be m_o and $3m_o$. *My advice is to draw good pictures of before and after as seen in both reference frames (the CMRF and the lab RF), as in the video.*

a) Let's say they have a (totally) inelastic collision, sticking together. What's the final speed?

b) This speed is called the speed of the center of mass. Put yourself in this reference frame… pretend you're moving at this speed watching the collision. What do you see happen (Provide numbers and draw the picture?

c) For b) above, what is the momentum of the ball approaching from the left? From the right? What's the total momentum of the system?

d) For c) above, now say that they have a perfectly elastic collision. What must be the speed of each ball after the collision in this CM reference frame in order to conserve momentum and energy?

e) What would the person in the laboratory frame (the earth's reference frame) see? What are the final speeds of each ball?

f) Find the total momentum of the system before and after the collision

g) Find the total energy of the system before and after the collision

h) Was momentum and energy conserved in this elastic collision?