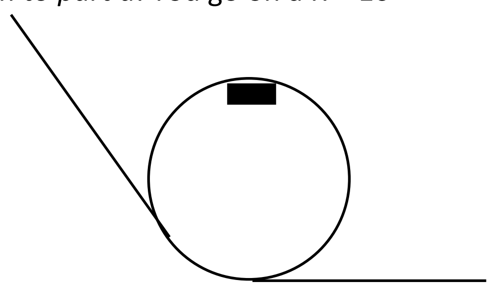
PS#9 Due Tuesday Dec. 6 in class. Remember to start each question with a description of the lens and method.

1) 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 (~100 mph!). 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 the Dakota Access Pipeline, and the fire department was called 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 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 volume, mass and momentum of a 1-meter column of water *before* it hits your body?
c) What is the momentum of water *after* it hits your body?
d) How long did it take the water to change momentum?
e) Find the force that this water puts on your body. Could it knock you over?

2) *If you think you've already done this problem before, just skip down to part d*. You go on a R = 10 m, loop-de-loop ride at the carnival, but you have to choose how high to start the cart. Say you have a mass of 70 kg, like your instructor and you are sitting on a scale that reads in kg. We've already solved this problem in



a) If you start from a vertical height of 40 m, what does the scale under you read as you are at the top of the loop? What does it read at the bottom of the loop as you enter the loop? Is this a good ride for pregnant women? How does it feel as you round the bottom of the loop?
b) What would happen if you decide to start the cart at the same height as the top of the loop? Why would this happen?
c) Please find the minimum vertical height, above the ground that you must start the ride.
d) Let's say that the object is instead a hollow sphere that is rolling without slipping. How would this change the problem? Can you do part a) and c) above for this scenario? Essentially, this is what we're asking: for a) would the rolling sphere be going faster than the frictionless cart or slower – how much faster or slower – is the acceleration greater or less?; and for b) in order to make it around the loop without falling, would the hollow sphere need to start from higher or lower than the frictionless cart? How much higher or lower?

3) Take a bicycle wheel and spin it very fast, then support the horizontal axel only at one end (some distance "x" from the center of the wheel's hub, letting the other side "fall".

a) Draw a good picture and explain what is happening. Be sure to indicate in the picture the direction of omega of the wheel, and the angular momentum of the wheel… as well as the direction of the torque on the wheel due to gravity… as well as the direction of precession. Yes, please label all of these vectors with the correct direction. This is what students often have difficulty with. You may want to put in more than one picture to get everything labeled correctly.
b) If I spin the wheel in the other direction at the same omega how would this change the precession of the wheel? *Explain why according to the physics model we've been using?*
c) If I spin the wheel with a larger omega how would this change the precession of the wheel? *Explain why according to the physics model we've been using.*
d) If I hold the wheel on my finger closer to the wheel itself how would this change the precession of the wheel? *Explain why according to the physics model we've been using.*
e) If instead of a wheel with all the mass at the rim, it was a disk of uniform density, how would this change the precession of the wheel? *Explain why according to the physics model we've been using.*

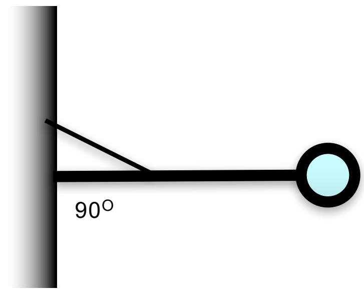
4) If you hit a baseball at a 20 degree angle above the horizon, at an initial velocity of 20 m/s off the edge of a cliff 50 m high, we would like to know everything about the future of this ball. Ignore air friction. Please solve this two ways, and tell me which you like best:
a) Using work-energy, 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 solve the above problem using kinematics, 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.
g) Which way do you like best?

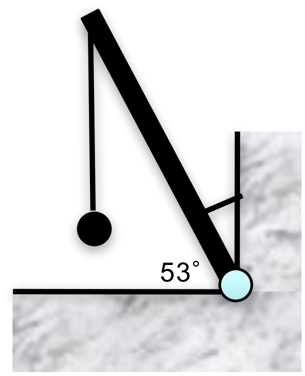
5) Solve the infamous "catching the bus" problem. The bus is at your stop, and you're running at a constant speed of 7 m/s from behind in order to catch it. However, just when you're 20 m behind it (or behind the bus driver to be exact), the bus begins accelerating away from you at 1 m/s^2, and will 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.

6) In class, you saw me spin a turntable at an elevation of about 1 m, with a penny at a radius of about 20 cm. The penny slides off the turn table and hits the floor about 0.5 meters from where it was on the turn table. Please estimate the coefficient of friction between the penny and the turn table.



7) Remember the problem #1 from PS#8? What happens to the tension as we bring the string closer to the pivot point? Please estimate the tension in the string at right for a mast supporting a 100 kg sphere and the reactive force at the pivot.



8) In the diagram at right, a post of some length supports a 100 kg ball. From the drawing at right (make your own better drawing), estimate the tension on the string and the reactive force at the pivot.