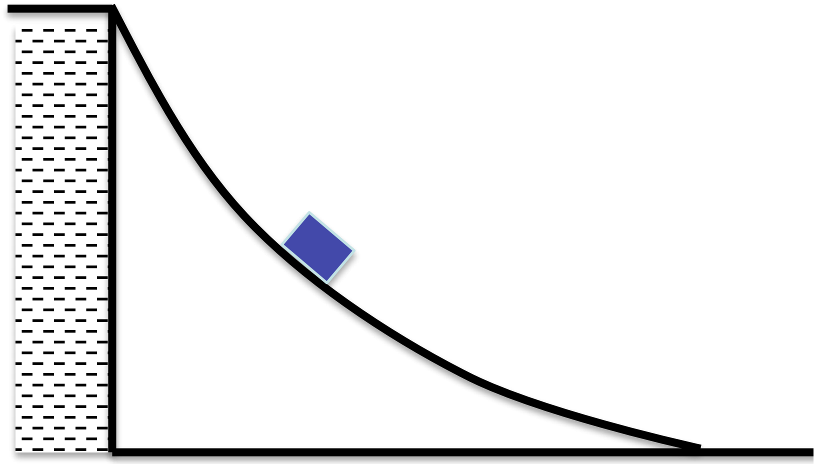
Problem Set #2 due beginning of class, Tuesday, Oct. 4.

#1 Imagine a 5 kg box sliding down a frictionless curved track at the edge of a 60 m high cliff as shown at right. We would like to know how fast it's going at the bottom. Neglect air friction.

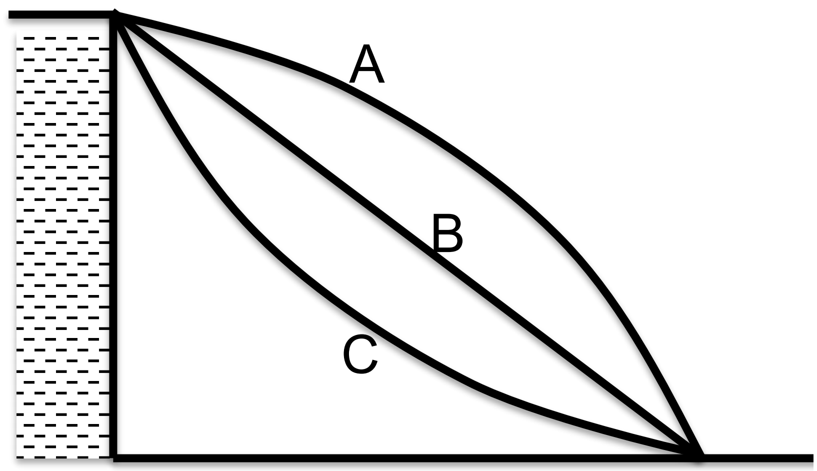


a) Describe using each of the four lenses, what is happening in this process.
Momentum: the block is exchanging momentum with the earth: They both start out at rest, and the two of them maintain equal and opposite momenta.
Energy: See below
Forces: The force of gravity and the normal force act on the block. This causes an acceleration of the block. The problem here is that the force on the block changes as the block moves down the slope according to the slope of the surface. As the line levels off, so does the acceleration of the block. We don't know the slope, and the slope is always changing.
Kinematics: The acceleration along the slope causes the block's speed to increase, so the displacement of the block continues along at a rate that is increasing. This will prove to be an unhelpful lens because we don't havce any time dependent information about the block's position, speed, or acceleration.

b) Which lens is the most helpful to find the final speed of the block at the end? Most useful one is energy because energy is conserved. Potential energy is changed to kinetic energy

c) Please find out the speed at the bottom of the track. Conserving energy, I get $v_f = 34.6$ m/s

Now imagine that there are two other tracks that the box could use as shown at right, bottom.



d) Which track should we use for the fastest final speed, or would all three tracks yield the same final speed? Which lens do you look at this problem through? Please explain your answer. Energy lens shows us that all three lose the same amount of potential, and thus gain the same amount of kinetic, so same final speed.

e) How about if we wanted to know which was going the fastest *half way* down the total length of its path? C, by using the same conservation of energy logic above.

f) If three identical frictionless boxes were released at the top of each track, which would get to the bottom first, or would it be the same for all of them? Please explain your answer in terms of which lens you used. This we can use the energy lens and the kinematics lens. The box on C is always below the bock on A, so it will move faster, dropping even further, going that much faster than A. C gets there first, then B, then A.

#2. I fling a ball upwards at 20 m/s.

a) How many different ways (lenses) can you think of to find out how high the ball gets? Find the maximum elevation. *Answer:* $h_{max} = 20$ *m*

- When I look at something moving up and down without friction on a track or through the air, I always first think of energy. Here, the initial kinetic energy turns to potential energy and back to kinetic energy.
- When all the (initial kinetic) energy is converted to gravitational potential energy, the ball is at the highest elevation.

- I could also use kinematics because I know the acceleration is just a constant gravitational acceleration. Can you find the amount of time it takes the ball to get to the top, and can you find the *average* velocity?
- Inside of this we know that the force of gravity = dp/dt, but this is less helpful.

b) Find the velocity when the ball is 10 m above the take off point. It's important to know that at half the max height, the potential energy is half the maximum potential energy, and you've lost half the kinetic energy, but this doesn't mean that the velocity is half the max velocity. Using energy conservation please show that the speed at 10 m elevation is about 14 m/s.

c) Make a graph of the ball's velocity versus time. The slope of the velocity ⇔ time graph is the acceleration = -g. So, show that the v⇔t graph is a straight line from (x = 0s) (y = 20 m/s) to (x = 4s) (y = -20 m/s).

d) Using the graph above, make a graph of the ball's vertical position versus time. The slope goes from positive 20 m/s upwards to a flat line at 2 s at 20 m, and then the slope becomes more negative until the slope is – 20 m/s at a height of zero at 4s.

#3. Two carts have an inelastic collision, approaching each other from opposite directions, both at speeds of 10 m/s. Cart A, moving to the right, has a mass of 1 kg. Cart B has a mass of 2 kg.

a) What is the total kinetic energy of the system? Using energy lens, I know that we start with kinetic energy and have an inelastic collision, so at least some of the kinetic energy is converted to thermal energy. The total E_K is the sum of the E_K of each cart =

b) What is the total momentum of the system? Looking through the momentum lens, I know that momentum is a vector and must be conserved. So I can arbitrarily call right the positive direction. Adding the momentum as vectors, the total momentum is -10 kgm/s

c) What is the final speed of the system? I don't know what the final kinetic energy of the system because I don't know how much energy was converted to thermal energy, but I know that the total momentum of the 3 kg mass must be the same as the original total momentum, so I find that the speed is about 3.3 m/s to the left.

d) What is the final kinetic energy of the system? I can calculate the total kinetic energy of the 3 kg mass at 3.3 m/s.

e) How much thermal energy was liberated as heat? Conserving energy, we need about 135 J of thermal energy to be liberated because this is how much the kinetic energy decreased.

f) If the collision lasted 0.05 seconds or 1/20 th of a second, what was the magnitude of the average force between the carts? Using a momentum lens, I know that F = dp/dt. The one kg mass changes velocity from 10 m/s to -3.3 m/s in, so the change in momentum is -13.3 kgm/s, yielding a force of about 266 N

#4 I post this Denny Shute discussion separately in a video

#5 Tracker Assignment – Hopefully it went well. You can see how I did it without Tracker.

#6 Cars. a 1000 kg car starts from rest and accelerates with uniform acceleration to 30 m/s in 5 seconds.

Did you draw a good picture? Did you label the things going on? Did you draw it at rest in the beginning and again at higher speed?

a) What was the average power put out by the car's engine? Please put answer in Watts and HP. This is an energy problem. What is the conversion that is happening? Cars are rated by their ability to do mechanical work. I get 90 kW or about 120 HP.

b) Is 30 m/s a very high velocity for a car? Imagine how long it would take to drive a football field.

c) What was the average force put out by the engine? There's a number of ways you could look at this. I would use the energy lens because work is F*dx, or Power is the Force*v. In this case it would be the average velocity. I get 6000 N

d) Then I lock up the wheels providing 10,000 N of force to slow us down, how long are the skid marks? You could use kinematics for this if you wanted, but I would again find this easiest to use energy because the energy used up would be the negative work you did on the car. I get skid marks 45 m long. It would take 3s by the way. Can you get this?

Please make three graphs: *a-t, v-t, x-t.* Ask me if you need help with this.

#7 Please plan your project: hopefully this went well.