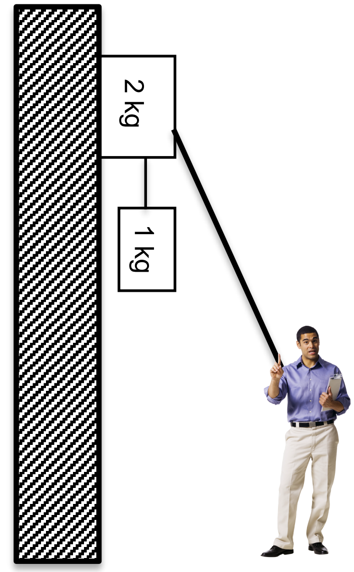
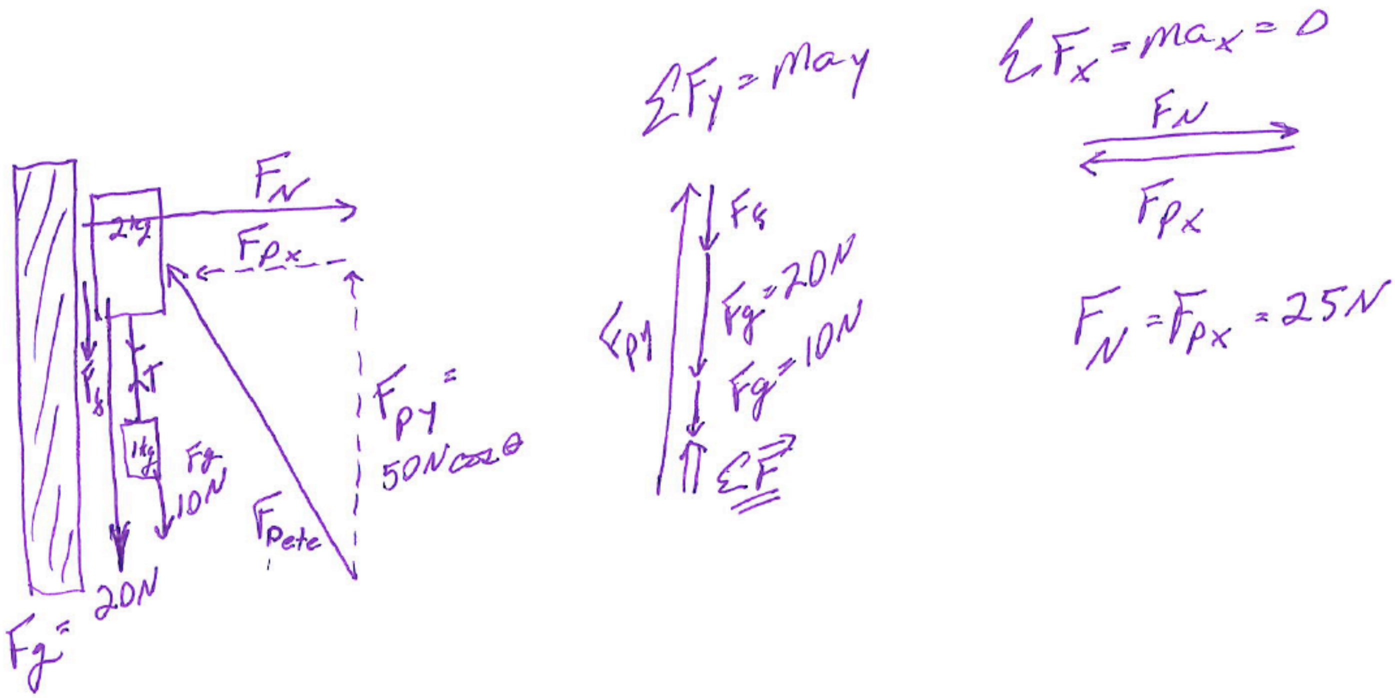
MT2 Feb 22, 2016 Name_________________ You are graded on your ***communication*** of Physics

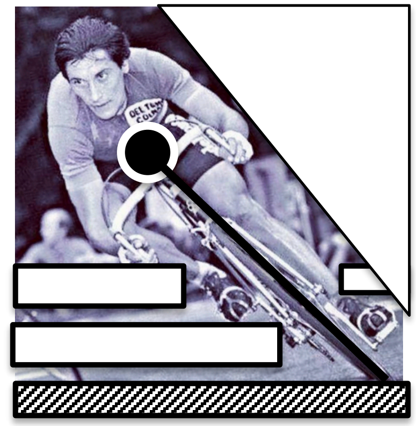



1. I am pushing a toy choo choo train made of two blocks up a wall as shown. The 1 kg block is hanging on a string from the 2 kg block. There is a coefficient of friction of 0.2 between the wall and the bock. I push with a 50 N force on a pole making a 30° angle with the vertical.
   a) If I the block moves 2 meters vertically (up or down), how much work do I do? What Lens do you use for this? I get 87 J
   b) Find the acceleration of the blocks while I am pushing. What lens do you do for this? Can you set the problem up well? Do you need a drawing? I get about 2.8 m/s$^2$
   c) Find the tension in the string joining the blocks while I am pushing. What lens do you do for this? I get about 13 N.

   a) solution Probably the first thing to do is the FBD and then the "vector sum of the forces diagram". Because the acceleration is clearly in the vertical direction, I would separate the problem into horizontal forces (summing to 0), and vertical forces (summing to m*a, where I would start with the entire system of masses of 3 kg). For work, you use the dot product. As it's moving vertically, you just take the vertical component of the force.
   b) I could use the energy lens and calculate the heat lost due to friction, and invested in increased potential energy and allow the rest to be kinetic energy. This would allow me to find the final speed and from that the acceleration. However, it's easier to just do dynamics as a system – a 3 kg mass pushed by all the forces (but not tension because this is an internal force acting equal and opposite on both masses). We need to find the vector sum of the forces in the y direction, requiring a calculation of the normal force on the wall in order to get friction, which pulls downward on the block because it's moving upward. As seen below, you can find the normal force to be 25 N = the horizontal component of the compressional force on the stick. This yields a maximum frictional force of 5 N. Then looking at the vertical components, we see that the vertical component of my pushing is ~ 43 N upward, so the total sum of forces in the vertical direction is ~ 8 N upward, yielding an acceleration of about 2.8 m/s$^2$.
   c) In order to find tension, we need to look at one of the masses because the tension is a force acting on one of the masses. This is again a dynamics problem. Looking at the 1 kg mass, we know that the vector sum of the forces = mass*acceleration = ~ 2.8 N upwards. So if gravity is pulling downward at 10 N, then the tension must be pulling it upward at 12.8 N.



2. You are riding a bicycle and bank into a steep turn (of radius 30 m) making an angle with the horizontal of 40 degrees, as shown at right.



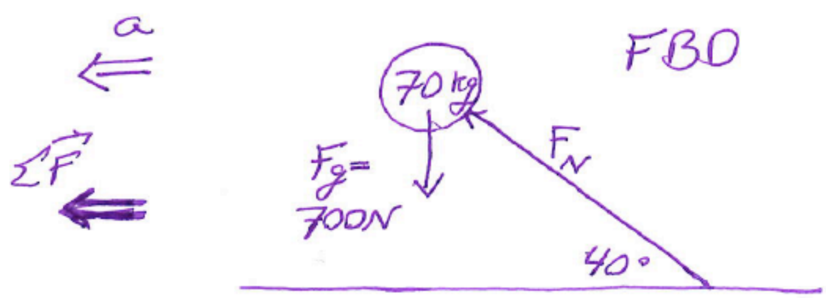
a) About what is your mass? This is not a calculation, just write down the (estimated) mass of your body. Mine is about 70 kg

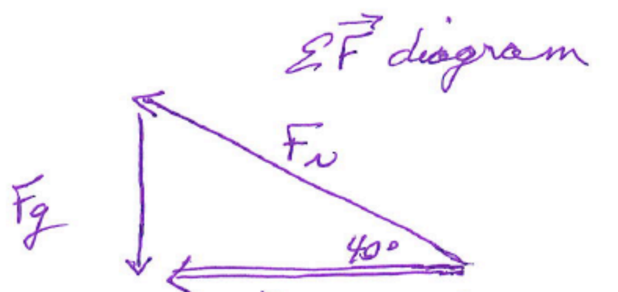
b) About what is your speed as you go around the turn? It is very important here to identify a lens and follow the protocol well. I get a speed of about 19 m/s.

c) About what is the force that the bike frame is putting on your body? I get about 1100 N, for my body.

Many folks forgot about the protocol… what is the direction of the acceleration? Where does this force come from? Can we make a good FBD? Can we make a good "vector sum of the forces" diagram?

This is a dynamics problem. As soon as I know he's going in a circle at constant speed, I know the direction of the acceleration is toward the center of the circle or to the left. Then I draw the FBD, and after that, I draw a the vector sum of the forces diagram added so that the direction of the resultant force (the vector sum of the forces) is pointing in the direction of the acceleration. Then I can use trig to find the total force which is the same as the horizontal component of the normal force that the bike puts on his body… because the vertical component of the normal force must = gravity because $a_y = 0$. From this we get an acceleration ~ 12 m/s$^2$. This is centripetal acceleration. We can solve for v ~ 19 m/s. **MANY** students referred to friction. It it were not for friction, the bike would not be able to make this turn on level ground. Friction does not act on the person's body although it is the force between the tire and the road. It provides the horizontal component of force to accelerate the bike into the circle, but this force could also come from a banked turn. In any case, looking at the forces on the bicyclist's body causing it to accelerate into turn, there are only two forces on the person's body: gravity and the normal force from the bike.



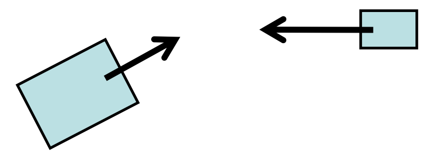

$\Sigma\vec{F} = F_{Nx} = F_N \cos 40°$

$$\tan 40° = \frac{F_g}{F_{Nx}}$$

$$F_{Nx} = \frac{F_g}{\tan 40°}$$

$$\Sigma F = F_{Nx} = 700/0.84 = \underbrace{834\,N = ma_c}_{a_c = \frac{v^2}{R},\ \text{solve for } v}$$

3. You are involved in a nasty collision on slippery ice, shown from above at right. Your 2000 kg car is headed Northeast at 20 m/s, making a 30° angle with the east-west direction, and you hit a 1000 kg car going due west at 35 m/s. The cars stick together.



   a) Find the velocity with which they move off, include direction.
      Which lens do you use for this? I get a final answer of about 6.7 m/s due north.
      The key to this problem is to recognize that momentum is a vector and it is conserved in this collision. You can do this graphically, or by componets. Please decompose the momenta into x and y components and show it. You will see that the x components cancle almost perfectly, so the final x velocity is zero. The y momentum from the large car is 20,000 kg m/s and is shared with the two cars, so the final vertical velocity is 6.7 m/s directly north.

   b) If the collision lasted for about 0.05s, please find the average force exerted on the little car by my car. Include approximate direction. I get a force of about $7 \times 10^5$ N in a direction that is almost directly East, but a little North. The angle the force makes with the east-west is about 11°. Momentum is a vector! A lot of people realized this for the first part, but didn't use 2-D vectors correctly in part b)
      We can use F=ma, where a=dv/dt, or just use F=dp/dt because you already have the momenta. The key thing here is that you need to find the *change* in momentum, not the sum of the momenta or the average momentum. I draw this out below to find the change in momentum of the small car, graphically showing that $p_o + \Delta p = p_f$. It's important to see that this is how we add vectors to find Δp…. ***NOT*** $p_o + p_f = \Delta p$. Some trig should yield that the direction of $\Delta p$ is about 11° North of West, and the magnitude is hardly longer than the x component of 35,000 kgm/s. Dividing this by the amount of time yields the magnitude of the force in that same direction.

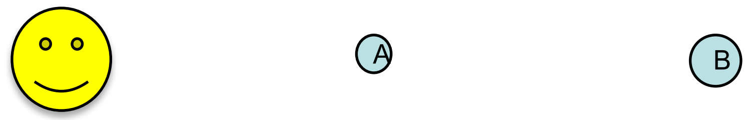
see that $\vec{p}_o + \Delta\vec{p} = \vec{p}_f$

$\vec{p}_f = m\vec{v}_f = 1000\,kg\ 6.7\,m/s\ \hat{y} = 6700\,kg\,m/s\,\hat{y}$

$\vec{p}_o = m\vec{v}_o = 1000\,kg\ 35\,m/s\ (-\hat{x})$

$= -35,000\,kg\,m/s$

Two planets, A and B are orbiting in perfect circles about a massive star (smiling at right). B has twice the mass and is orbiting at twice the radius as A: $M_B = \underline{2}\, M_A$; $R_B = \underline{2}\, R_A$




This problem was a train wreck. I should have started with a question asking what the ratio of forces on these planets was… But the conceptual flaw was that students forgot that acceleration is caused by forces. We don't know what the speeds of these planets are at first, but we can certainly find the ratio of the gravitational forces… it just boils down to the inverse square law. And the mass of the planet has no effect on the acceleration of that planet… drop two different sized masses and watch them accelerate at the same rate.

a) How does the acceleration of planet B compare to the acceleration of planet A?

$a_B$ = _0.25_ $a_A$ ***Please support your answer with clear math reasoning***

First the mass of each planet doesn't have any affect on that planet's acceleration – because if you double the mass of the planet, the force of gravity on the planet will double, but acceleration is F/m, so mass doesn't matter. However, the force of gravity drops off like $1/r^2$, so if you are twice as far away (as planet B is), then the acceleration from gravity drops by a factor of 4.

b) How does the speed of planet B compare to the speed of planet A?

$v_B$ = __~0.71__ $v_A$ ***Please support your answer with clear math reasoning***

if the planets are in uniform circular motion, then the acceleration they experience is $v^2/R$. If you recognize that planet B has twice the radius, but ¼ the centripetal acceleration, we see that the speed of planet B is smaller than that of planet A by a factor of square root 2.