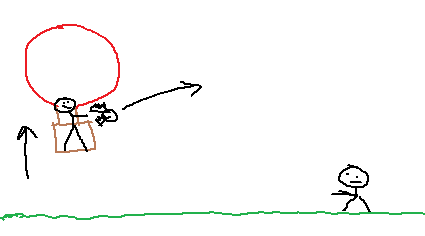
**Homework 5 Solutions due 2/15**

**Problem 1.** You’re in a hot-air balloon, accelerating upwards at a rate of 2m/s2. But you left your dog in the car with the windows rolled up. Luckily your friend is on the ground, because he doesn’t like heights, and he’s pretty sure you’re going to run into a power line anyway. So after 10s you throw your keys to him with a speed of 30m/s and horizontally w/r to the balloon.



(a) What is the initial position of the keys (x0, y0), i.e. the position after 10s?

Since the balloon is accelerating upwards, the position would be:



So the initial position of the keys is (0m,100m).

(b) What is the initial velocity of the keys (v0x v0y), i.e. the velocity after 10s, and just after you’ve thrown them. Be careful here ☺.

And the initial velocity (in the y—direction) would be:



But then, they’re also going horizontally with speed vx = 30m/s. So the initial velocity would be: (30m/s,20m/s).

(c) Write down an equation for x(t) and vx(t).

These would be:



And,



(d) Write down an equation for y(t) and vy(t).

These are:



And,



(e) To what maximum height do the keys rise?

This will occur when vy = 0. So we can solve for t,



And then plug that time into the y-equation:



(f) When do they hit the ground?

It will hit the ground when y = 0. So let’s plug that into the y-equation.



(g) And at what x-position?

The x coordinate would be:



(h) What would be the magnitude and direction of its velocity when it hits the ground? (Hint: it’s NOT zero ☺)

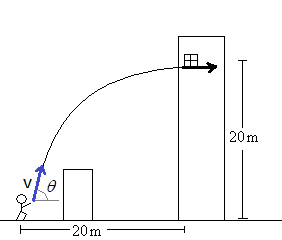
We can ascertain these by plugging in the time into the v equations:



And combined, these would be:



**Problem 2.** Your friend, Amelie, is locked in the Bastille for protesting Louis XVI. Fortunately for her, you have the keys. But you can’t get closer than 20m from the tower because of a barricade. And she’s 20m up in the tower. At what angle and speed must you throw the keys in order for them to land in her cell with a horizontal velocity, i.e. at the top of their trajectory?

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(a) Write down an equation for x(t) and vx(t). You don’t know the initial velocity in the x-direction. So you’ll just leave it as a symbol.



And,



(b) Write down an equation for y(t) and vy(t). You don’t know v0y either, so just leave it as a symbol.



And,



(c) Now take these four equations and plug in what, if anything, you know about the final values: x, y, vx, vy, and solve them for t, v0x, and v0y.

The four equations are:



We can plug the v0y equation into the y equation just above it to get:



And now plug t into the x equation (the top one) to get v0x,



And now we can use the vy equation (bottom one) to get v0y,



(d) Give the magnitude and direction of the necessary velocity then.

This is:



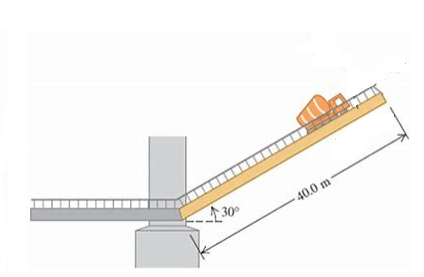
**Problem 3.** What’s the terminal velocity of a penny? Consider that mpenny = 0.003kg, its radius is about 1cm, and its coefficient of aerodynamicity is 0.5, say. The density of air is 1.2kg/m3.

So from N2L,

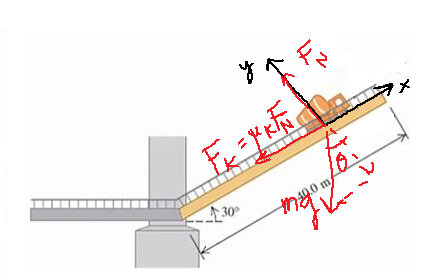


**Problem 4.** You were talking on your cell phone again. Not paying attention, you found yourself headed towards a draw bridge at v = 20m/s. You slam on the brakes (bad move because now your tires are going to skid, meaning that kinetic friction, not static friction, is going to slow you down). Suppose μs = 0.85, and μk = 0.67 (Google). We want to figure out if you’ll go off the bridge or not?

(a) What is your acceleration up the bridge?



Forces look like this:



Doing N2L in the y-direction we have:



And in the x-direction we have:



(b) Write down equations for vx(t) and x(t).

And now we have:



(c) Now determine when you’ll stop and how far up the bridge you’ll have gone.

So it will stop when

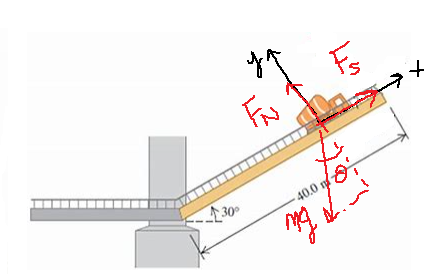


And will have traveled a distance,



(e) Suppose you put the parking break on immediately when you come to rest. Does it prevent you from sliding back down?

Now our forces are:



In order for us not to move we need:



And,



To find out if this is feasible, we need to compare Fs and Fsmax­. If our requisite Fs < Fsmax, then we’re good. So we check,



This checks out so we’re good. The truck would be held stationary by the static friction force.

**Problem 5.**  Spoiler Alert! In ‘The Winter Soldier’, Steve Rogers tries to incapacitate Bucky Barnes by throwing his shield at him. But the Winter Soldier just catches it instead. What!? Suppose the Winter Soldier has a mass m = 100kg, the shield has a mass of 10kg, that it was thrown at 30m/s (about 67 mph), and that it was caught in the span of about a quarter second (i.e. slowed from 30m/s to 0m/s in that span).

(a) What force must the Winter Soldier have exerted? Convert to pounds too.

Let FWS/S be the force the Winter Soldier exerted on the shield. Then, applying N2L to the shield,

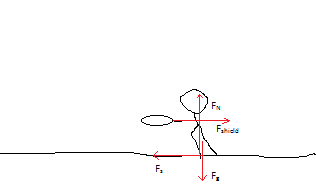


Negative sign just indicates force is to the ‘left’. And this correlates to, just concerning ourselves with the magnitude:



(b) The Winter Soldier didn’t even slide backwards when he caught it. What again!? What minimum coefficient of friction must there have been between his shoes and the concrete for this to have happened.

A depiction of forces would look like this. Now let’s apply N2L to the Winter Soldier. The force he exerted on the shield, is the same the shield would exert on him.





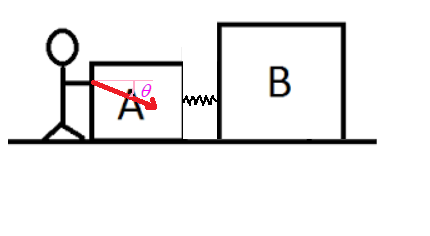
And,



So then,



**Problem 6.** Your summer job consists of moving crates back and forth, for no good reason, just like the job you’ll have when you graduate. Crate A has mass mA = 10kg, and crate B has mass B = 20kg. You apply a 300N force force at an angle of 20° below the horizontal. The coefficient of friction between the box and floor is μk = 0.5. The spring connecting box A and B has a stiffness k = 200N/m.



(a) Write down the x and y N2L for block 1. You should solve for the normal force, and have an equation for ax in terms of an unknown Δx (compression of the spring).



And,



(b) Write down the x and y N2L equations for crate B. You should solve for the normal force, and have an expression for the acceleration in terms of the unknown Δx.



And,



(c) Solve the equations for the acceleration of the boxes, and the compression of the spring.

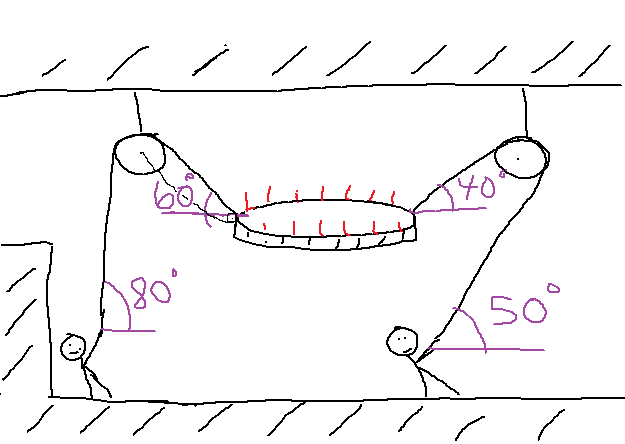
Setting the two accelerations equal to each other we can solve for Δx,



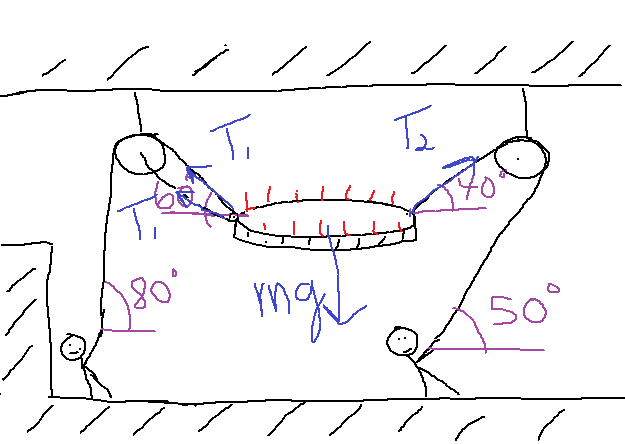
And the acceleration will be:



**Problem 7.**  Suppose you’re helping your mideval friend raise a 150kg chandelier at a constant upwards velocity of 10cm/s. With what forces do you each pull? Note – not all angles matter, and also note that the left pulley is draped over a small pulley-like attachment on the chandelier.



Forces are:



And applying N2L,



And



Plugging the first equation into the second, we have:

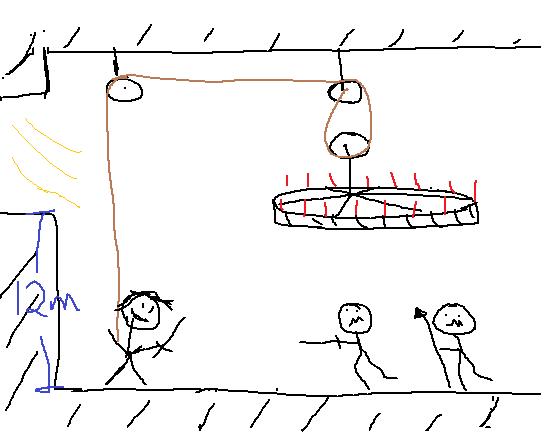


And then plugging this into the T2 equation, we get:

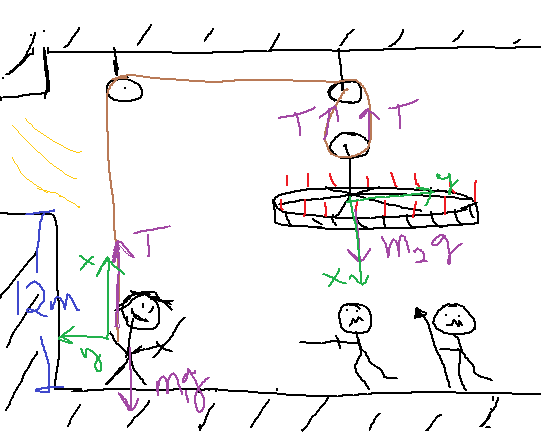


**Problem 8.** You (m = 50kg) finally got your 150kg chandelier installed (and replaced a pulley or two), but now you are being attacked by the King’s men - scoundrels. So you cut the rope. The chandelier falls on the bad guys, and pulls you up. We want to figure out how long it takes for you to get up to the window.

(a) Calculate your upward acceleration. Pay special attention to the rope attached to the chandelier. And can you see that as our hero goes up, he will have twice the acceleration as the chandelier as it falls (because he’s attached to one rope, but the chandelier is attached to two)?



Drawing forces:



Applying N2L to both you and the chandelier, we have:



And,



Now these two accelerations are related via a1x = 2a2x. So filling this relationship in…



Plugging this into either acceleration equation, we have:



(b) Write down the equation for your position, as a function of time x(t), and get t.

Then to get time, we use:



(c) What is the tension in the rope?

We just have to fill the a back into one of those equations:

