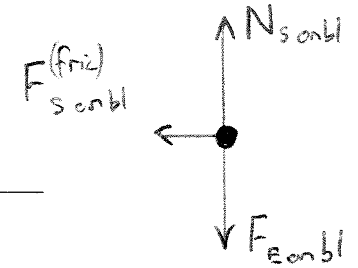
NAME: ______________________________

11) You decide to measure the speed of a bullet in the following experiment: You fire the 20 g (0.02 kg) bullet at a 300 g (0.3 kg) wooden block that is resting on a flat, horizontal surface. Previously you measured the coefficient of kinetic friction between the block and the surface to be $\mu_k = 0.8$. The bullet embeds itself in the block and they slide together for 15 m before coming to a stop. What was the initial speed of the bullet?

(20 points.)

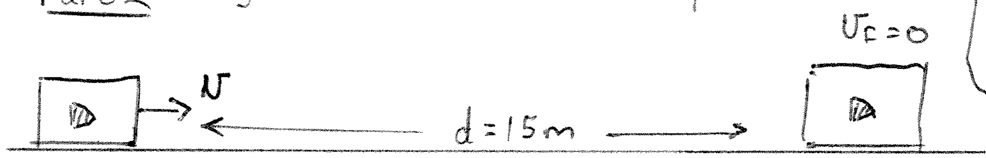


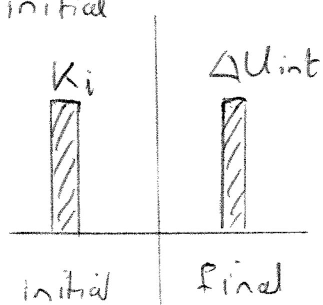
FBD for sliding Block + Bullet

in y: $N_{S\,on\,bl} = F_{E\,on\,bl} = (m_b + m_{bl})g$

in x: $F^{(fric)}_{S\,on\,bl} = \mu N_{S\,on\,bl} = \mu(m_b + m_{bl})g$

Part 2: System sliding to a stop





Bar Chart

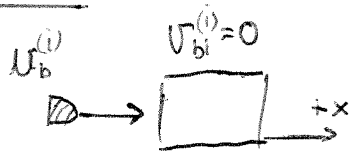
$$\frac{1}{2}(m_b + m_{bl})v^2 = F^{(fric)}d$$

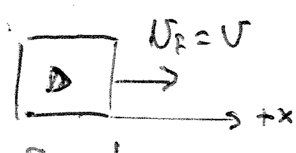
$$\Rightarrow \frac{1}{2}(m_b + m_{bl})v^2 = \mu(m_b + m_{bl})g\,d$$

$$\Rightarrow v = \sqrt{2\mu g d} = \sqrt{2(0.8)(10)(15)}$$

$$= \underline{15.49\ m/s}$$

Part 1: Collision between bullet & block





Assume Δt small & therefore ignore external forces.

$$m_b v_b^{(i)} + 0 = (m_b + m_{bl})v \Rightarrow v_b^{(i)} = \frac{(m_b + m_{bl})}{m_b}v$$

$$= \frac{(0.32\,kg)}{(0.02\,kg)}(15.49\,m/s)$$

$$= \underline{248\ m/s}$$

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12) An amusement park is designing a rollercoaster and needs your recommendations. Their design starts with a long (length unspecified) straight slope angled at 60^0 above the horizontal going straight into a circular loop-the-loop. The radius of the circle is 12 m.

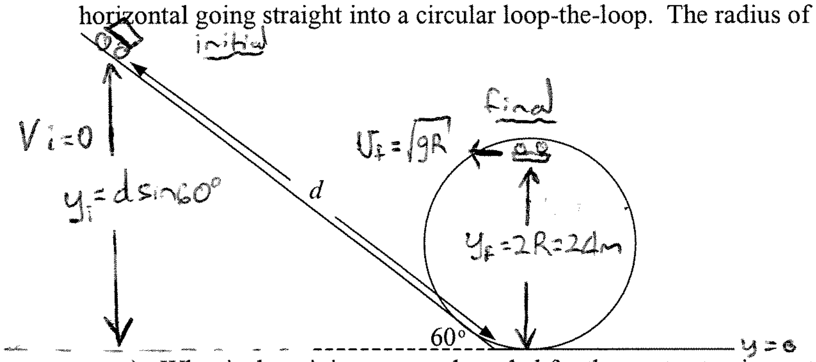


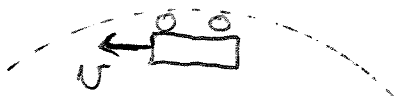
Diagram for part(b)

a) What is the minimum speed needed for the car to stay in contact with the track at the top of the loop?

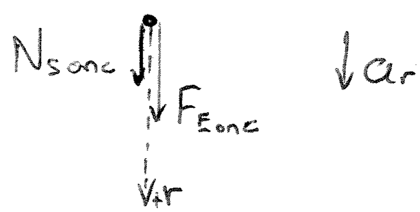
b) What distance up the ramp do you need to release it in order for it to make it around? Make a list of assumptions you are making in solving this part of the problem. If you are unable to determine a minimum speed from part a) make one up for part b) (As always, if you are unsure of some parts of the problem, sketch out a way to solve the problem to get method points, don't give up!)

(20 points)

part(a):



FBD for car at top of loop



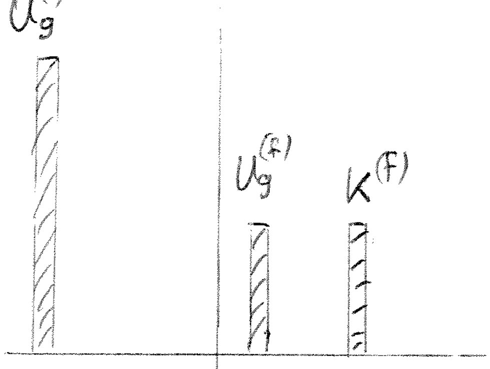
In general: $a_r = \frac{v^2}{R} = \frac{N_{s\,on\,c} + F_{E\,on\,c}}{m_c}$

in the case of minimum speed, $N_{s\,on\,c} \longrightarrow 0$

$$\Rightarrow \frac{v_{min}^2}{R} = \frac{F_{E\,on\,c}}{m_c} = \frac{m_c g}{m_c}$$

$$\Rightarrow v_{min} = \sqrt{gR} = \sqrt{(10m/s^2)(12m)} = 10.95\,m/s$$

Part(b)



$$m_c g y_i = m_c g y_f + \frac{1}{2} m v_f^2$$

$$\Rightarrow g d\sin 60° = g(2R) + \frac{1}{2}$$

$$d = \frac{1}{\sin 60}\left(2\tfrac{1}{2}R\right)$$

$$= \frac{1}{\sin 60}(2.5)(12m)$$

$$= 34.6m \text{ up the ramp}$$

2 major assumptions: ① ignore friction, ② assume car is a point particle.

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13) The amusement park from problem 12) are concerned about the safety of the rollercoaster they are designing. They are concerned that energy lost to internal energy (due to friction between the car and the track) will have a significant effect on the motion of the car. This may lead to the car falling off the loop at the top.

Describe an experiment you could design to figure out the coefficient of friction between the track and the rollercoaster car. You have a police radar gun that can measure the speed of the car at any point, a large enough scale to measure the mass of the car, a suitable measuring device that will measure distances precisely, and unlimited access to the ride. (They will even let you chop up pieces of track and lay them horizontally if you like.) Make sure to include the following in your design:

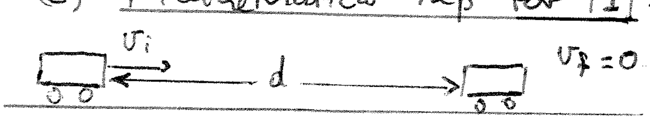
a. A clear description of the experiment with pictures if necessary.
b. Describe what you need to measure in order to find μ.
c. A mathematical description that will allow you to solve for μ, the coefficient of friction between the track and the car while it is moving.
d. Any assumptions you might have to make in figuring out μ.
e. Describe how any assumptions you make may affect your results.

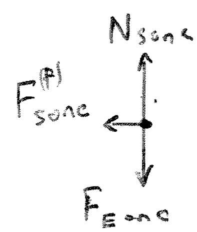
(20 points)

(a) & (b) 2 possible experiments: [1] Lay out a long horizontal piece of track. Start the car moving. At some pre-marked point, measure its speed with the radar. Then let it run until it stops. Measure how far the car rolled from the pre-marked point. From this info, I should be able to determine μ_k

[2] Roll the car, starting from rest down the sloping track. Measure the speed of the car at the bottom of the track BEFORE it enters the loop. Measure d, the distance between the release point and the bottom of the loop. Check the angle of inclination of the slope. μ_k can be determined from this.

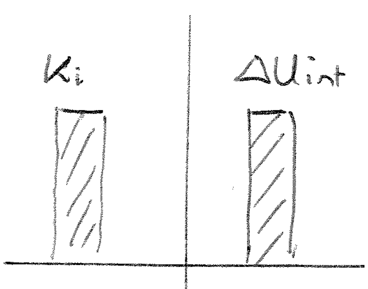
(c) Mathematical Rep for [1]:





$N_{S on C} = F_{E on C}$

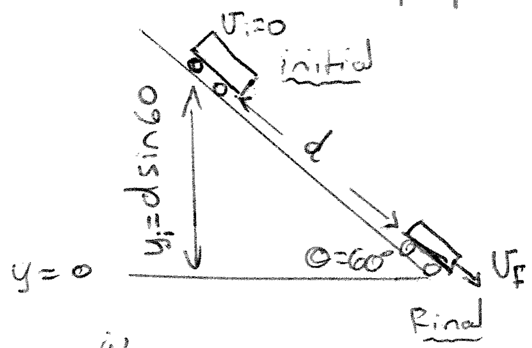
so $F^{(f)}_{S on C} = \mu_k N_{S on C} = \mu_k m_c g$

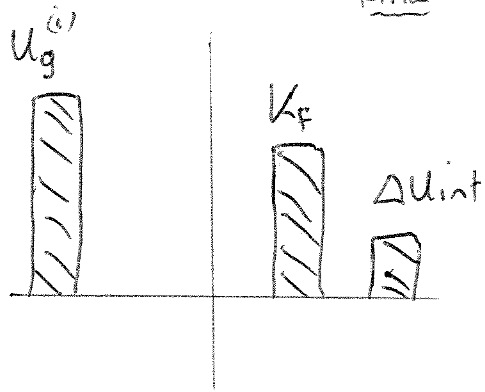


$\frac{1}{2} m_c v_i^2 = F^{(f)} d = \mu_k m_c g d$

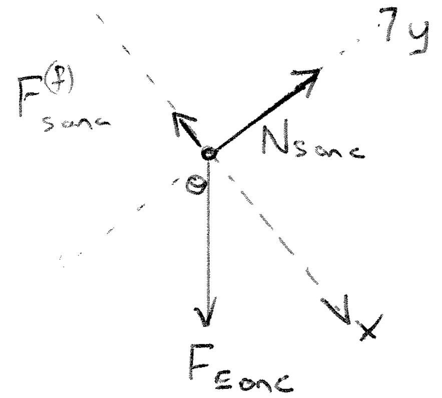
$\Rightarrow \mu_k = \frac{v_i^2}{2gd}$

(c) Mathematical Rep for [2]





FBD for car rolling down slope:



in y dir: $N_{s\,on\,c} = m_c g \cos\theta$

$\therefore F^{(f)}_{s\,on\,c} = \mu_k N_{s\,on\,c} = \mu_k m_c g \cos\theta$

$$m_c g y_i = \frac{1}{2} m_c v_f^2 + F^{(f)} d$$

$$\Rightarrow m_c g d \sin 60 = \frac{1}{2} m_c v_f^2 + \mu_k m_c g d \cos 60$$

$$\Rightarrow \mu_k = \frac{g d \sin 60^\circ - \frac{1}{2} v_f^2}{g d \cos 60^\circ}$$

(d) & (e) Experiments [1] & [2]. Assume uniform track so μ does not vary.
- Assume hard inelastic surfaces.
- Ignore all other external interactions (especially air resistance)

1st 2 assumptions will cause μ_k to vary randomly & expt. would be somewhat unreliable.

Air resistance would make μ_k appear artificially large.