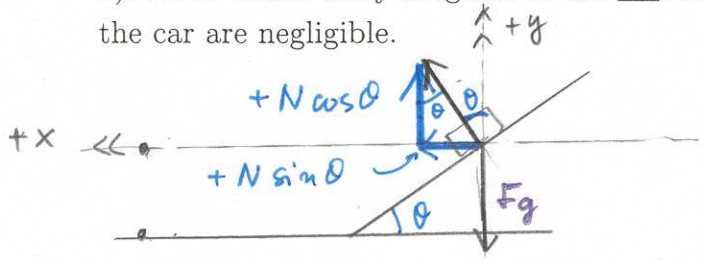
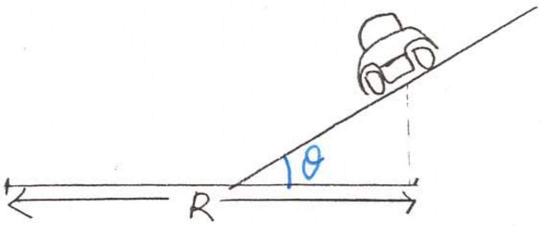
PHYSICS 161, Spring 2003

Discussion Quiz , Tuesday, April 1

Q1). A car is travelling away from us **with constant speed** on a banked road having a curve of radius R. The coefficient of friction μ_s between the road and the tires of the car is **non-zero**. However, if the car travels at the *designated* speed, it does not have to rely on friction to negotiate the curve.

a). Draw a free body diagram of the car. Assume that drag forces f_{drag} acting on the car are negligible.





b). Choose an appropriate coordinate system. Indicate your choice of coordinate system next to the free body diagram. Write down the $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$ equations for the car.

$\Sigma F_x = m a_x$ $\qquad$ $\Sigma F_y = m a_y$ (0)

$N\sin\theta = m a_r$ $\qquad$ $N\cos\theta - F_g = 0$

$\boxed{N\sin\theta = m\frac{v^2}{R}}$ eq 1. $\qquad$ $\boxed{N\cos\theta - mg = 0}$ eq 2.

c). If we want the designated speed to be $v = 15m/s$ (roughly $33mi/hr$), at what angle should the road be banked? ($R = 20\,m$)

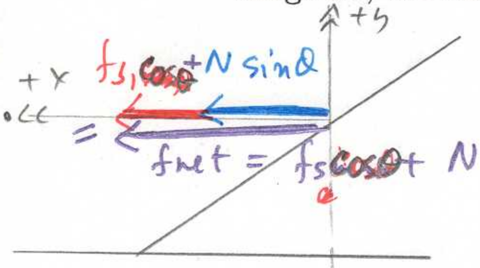
Using eq 2 above, $N = \frac{mg}{\cos\theta}$. substituting this in eq 1, we find $\frac{mg\sin\theta}{\cos\theta} = \frac{mv^2}{R} \Rightarrow \tan\theta = \frac{v^2}{gR} = \frac{(15m/s)^2}{(10m/s^2)(20m)} = 1.13$

$\Rightarrow \boxed{\theta \cong 48^\circ}$

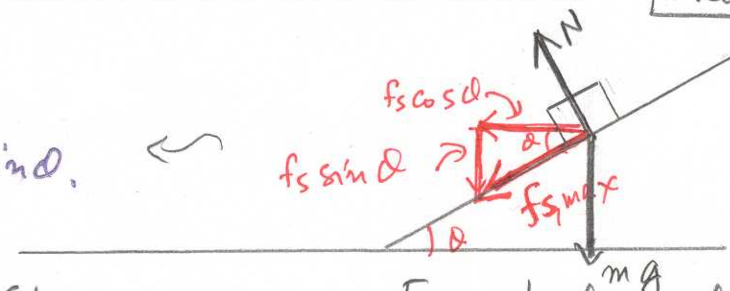
d). Drivers can generally be expected to ignore the posted speed signs. Suppose we are interested in knowing what is the maximum speed which a car could possibly have without skidding out of the curve.

d1) Below, redraw a free body diagram to handle this question. On your diagram, indicate the net force in the radial direction.

$\boxed{F_{net,r} = N\sin\theta + f_s\cos\theta}$.



NET FORCE Diagram.

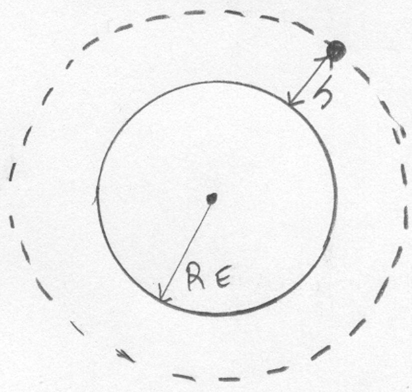


Free body diagram.

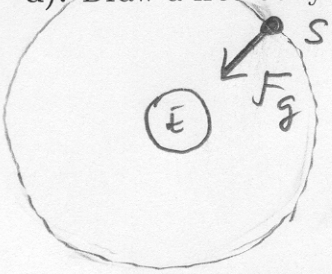
PHYSICS 161, Spring 2003

Discussion Quiz, Thursday, April 3

Q1). A satellite is a freely falling object launched such that it has just the right velocity to travel in a circular orbit at some height h above the surface of the earth. The force of gravitational attraction between the earth and the satellite is given by $F_g = G\frac{m_E m_S}{r^2}$, where m_E = mass of teh earth and m_S is the mass of the satellite. In the following, **assume negligible air drag**.



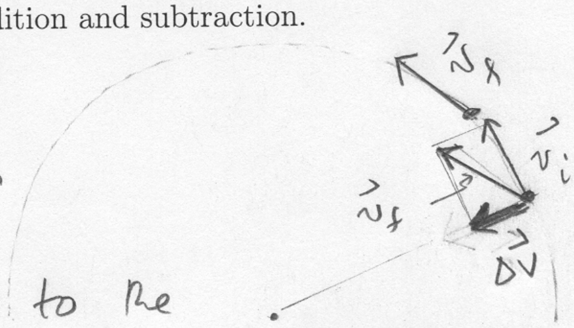
a). Draw a free body diagram of the satellite.



b). As the satellite goes around the earth in a fixed orbit, does its speed increase, decrease or remain the same? Briefly explain how your answer is consistent with your free body diagram and Newton's laws. There is no net force in the tangential direction so $a_{tangential} = 0$ due to N2. So v, being tangent to circle, is constant.

c). Another 161 student looking at your free body diagram is a bit confused and asks "Why doesn't the satellite fall down back to the earth? Shouldn't there be a force pushing the satellite away from the earth?" Construct a complete and convincing argument to help the student understand what is going on. Assume that the student is in full command of vector addition and subtraction.

If $\vec{F}_{net}$ is radially in towards the earth $\Rightarrow$ $\vec{a}$ is radially in toward the earth. Then, since $\vec{v}_i \neq 0$, $\vec{v}_f = \vec{v}_i + \Delta\vec{v}$. So $\vec{v}_f$ is not towards the earth but tangent to the circle.



d). Write down the $\Sigma F_r = m_S a_r$ equation for the satellite and find the speed v of the satellite.

$$\Sigma F_r = m_S a_r \quad \Rightarrow \quad \boxed{v = \sqrt{\frac{G m_E}{(R_E + h)}}}$$

$$\frac{G m_E \cancel{m_S}}{(R_E+h)^{\cancel{2}}} = \frac{\cancel{m_S} v^2}{\cancel{(R_E+h)}}$$

PHYSICS 161, Spring 2003

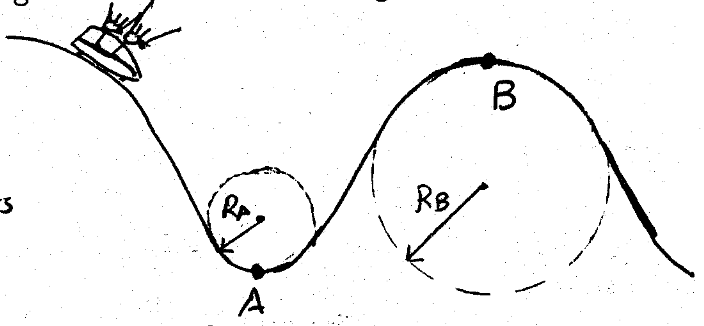
Discussion Quiz, Friday, April 4

Q1). A roller coaster car moving with **constant speed** v has a mass m when fully loaded with passengers. Assume that the drag forces acting on the car are negligible.

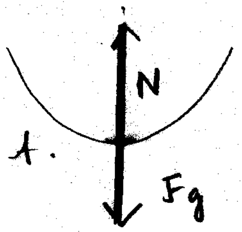
$m = 500$ kg

$R_A =$ 10 meters

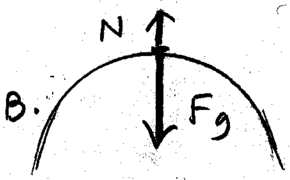
$R_B =$ 15 meters



a). Draw a free body diagram of the car when its at point A. Make sure that the length of the force vectors you draw is reasonably indicative of their relative magnitudes.



b). Draw a free body diagram of the the car when its at point B. Follow the same instructions as in part (a).



c). Is the accelration of the car at point A equal to, greater than or less than at point B? Why? speed at both A and B is v.

But $R_A < R_B \Rightarrow a_r^A = \frac{v^2}{R_A} > a_r^B = \frac{v^2}{R_B}$

d). What is the <u>maximum speed</u> the car can have and still remain on the track at point B?

To find the maximum speed the car can have such that it doesn't leave the track, we use N2:

$$\Sigma F_r = m a_r$$

$$mg - N = \frac{m v^2}{R_B}$$

Now we set $N = 0$,

$$\cancel{m} g = \frac{\cancel{m} v_{max}^2}{R_B}$$

$$\Rightarrow v_{max}^2 = R_B g$$

$$\cong (15 m)(10 m/s^2)$$

$$v_{max}^2 \cong 150 \ m^2/s^2$$

$$\Rightarrow \boxed{v_{max} = 12.25 \ m/s}$$