Today 5.4, 5.5

$\boxed{L17}$

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$\boxed{L17}$

Dynamics of circular motion

Today 5.4, 5.5

$\boxed{L17}$

Fundamental forces of nature

$\boxed{L17}$

Today 5.4, 5.5

Monday Start chapter 6

Today 5.4, 5.5 $\boxed{L17}$

Monday Start chapter 6

$\underbrace{\hphantom{Start chapter 6}}$

Work & Kinetic energy

Dynamics of circular motion

Dynamics of circular motion

$$a_{rad} = \frac{v^2}{R}$$ for uniform circular motion

Dynamics of circular motion

$a_{rad} = \frac{v^2}{R}$ for uniform circular motion

Also $v = \frac{\Delta s}{\Delta t}$

Dynamics of circular motion

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Also $V = \frac{\Delta S}{\Delta T} = \frac{2\pi R}{T}$

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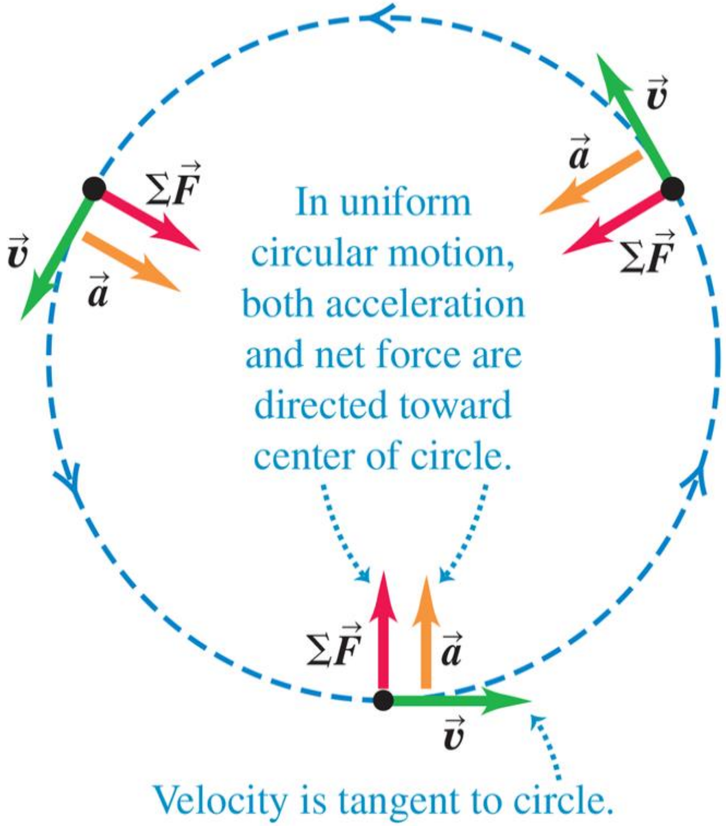
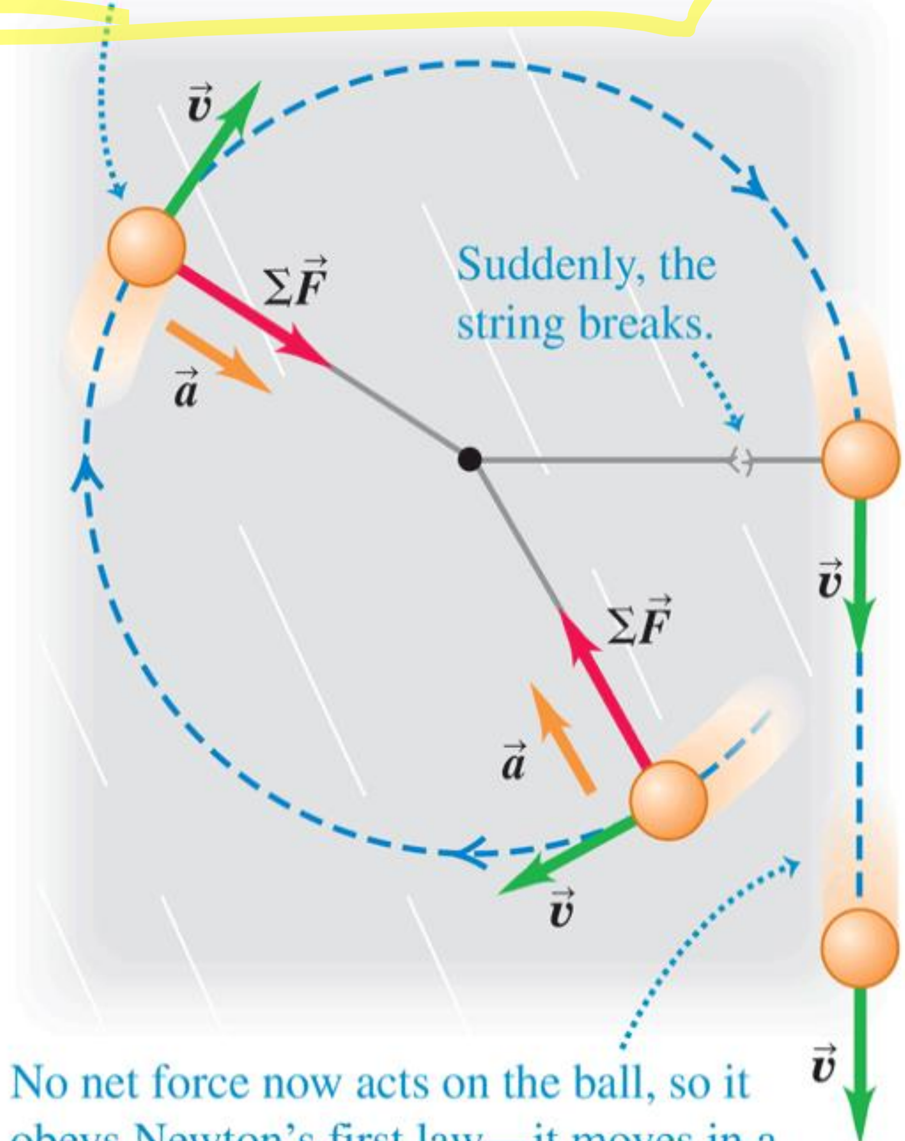


A ball attached to a string whirls in a circle on a frictionless surface.



No net force now acts on the ball, so it obeys Newton's first law—it moves in a straight line at constant velocity.

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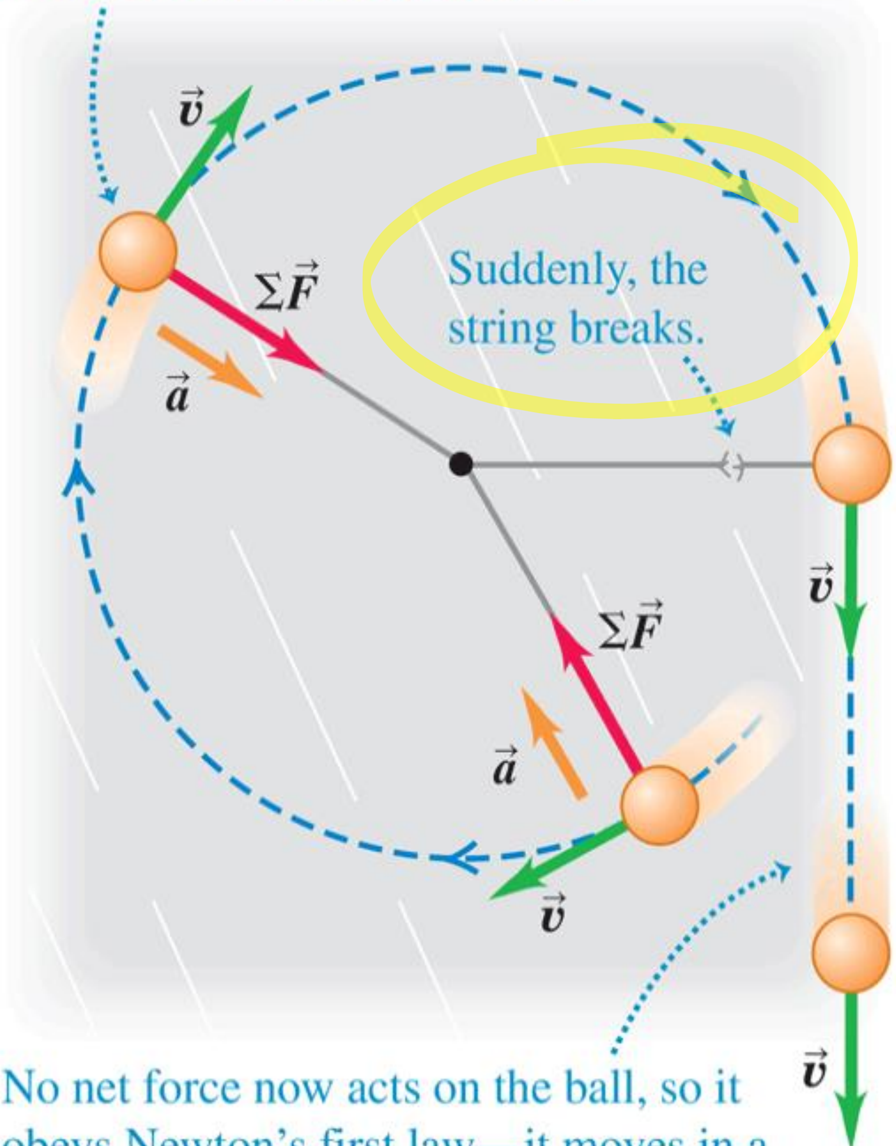

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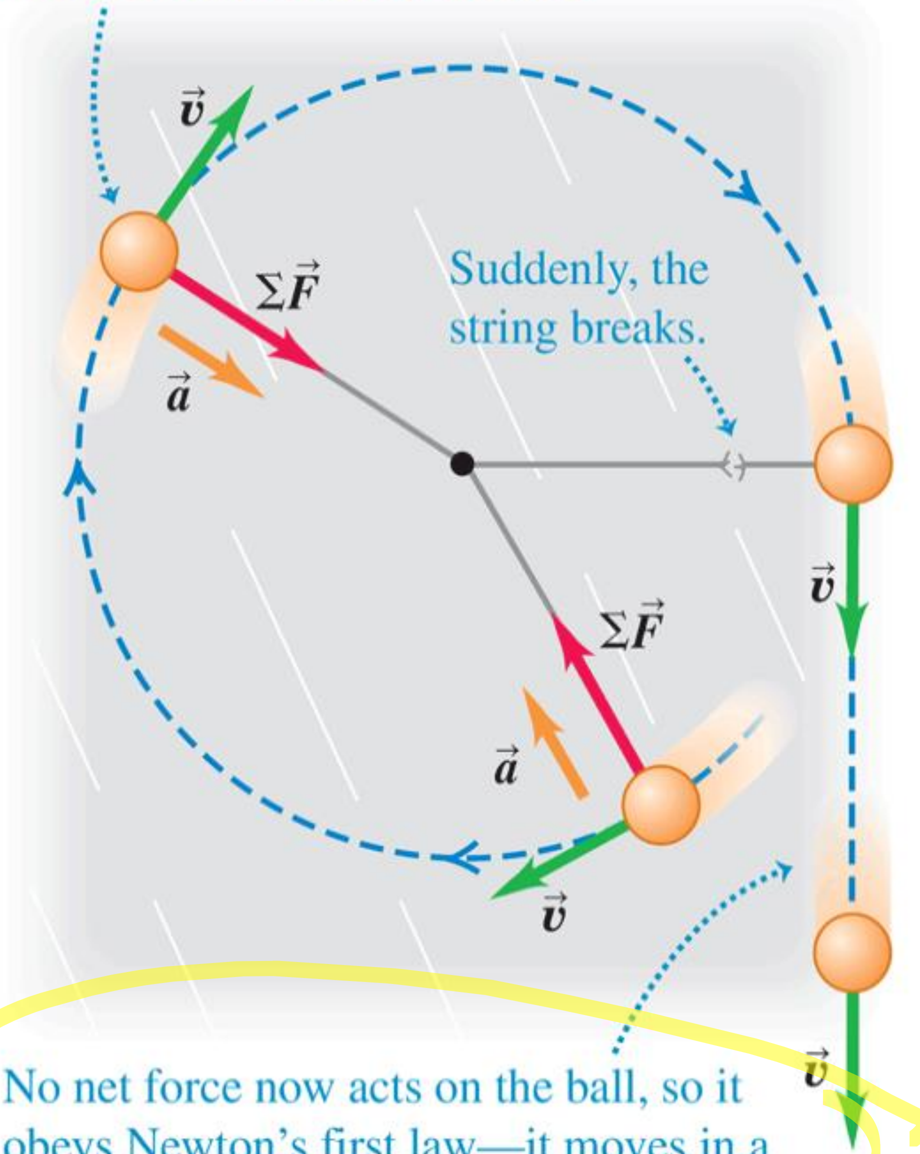

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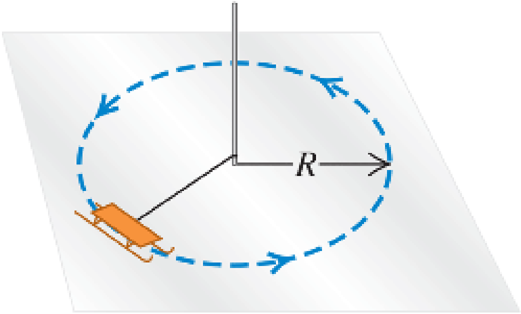
ASU

A sled with a mass of 25.0 kg rests on a horizontal sheet of essentially frictionless ice. It is attached by a 5.00 m rope to a post set in the ice. Once given a push, the sled revolves uniformly in a circle around the post (Fig. 5.31a). If the sled makes five complete revolutions every minute, find the force F exerted on it by the rope.



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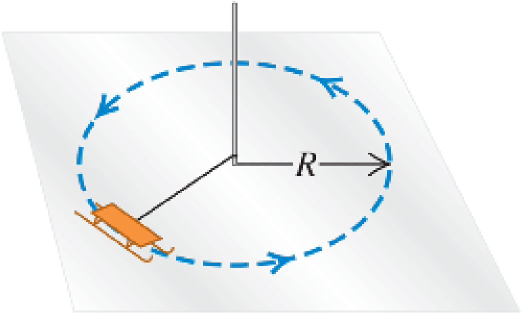
$m = 25 \text{ kg}$



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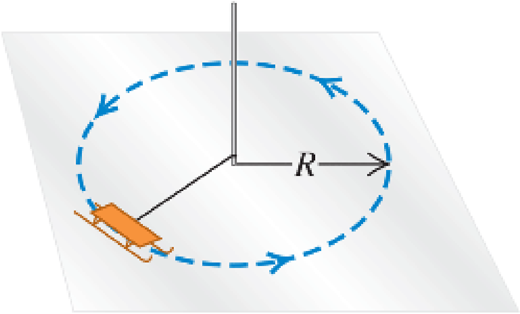

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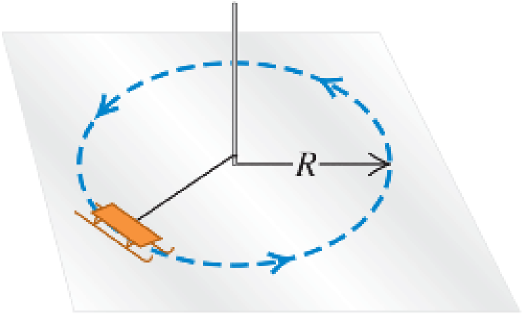

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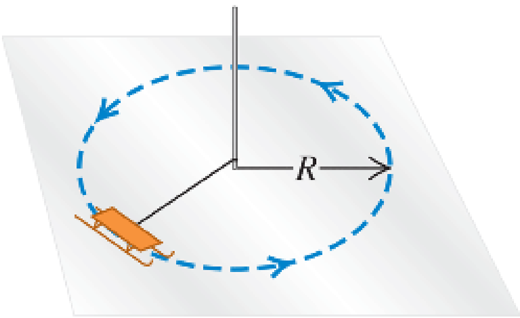
$m = 25\,kg$, $R = 5\,m$, $T = \frac{60\,s}{5} = 12\,s$



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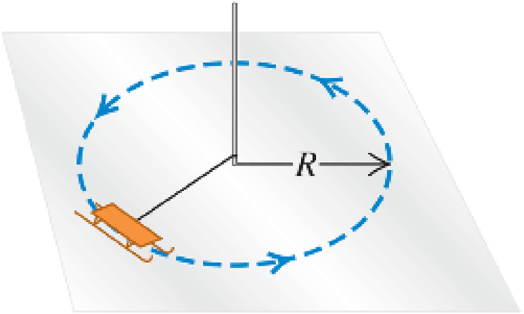

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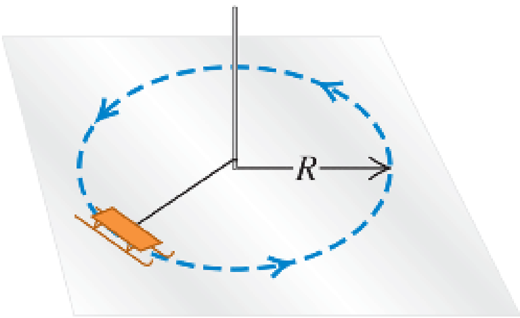

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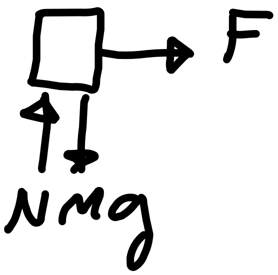

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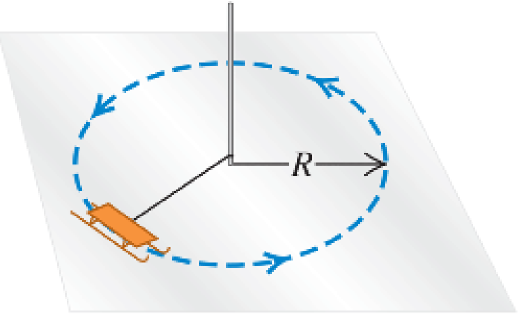

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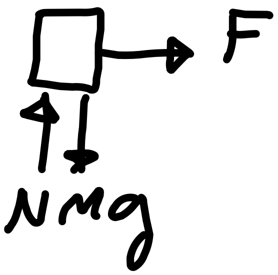

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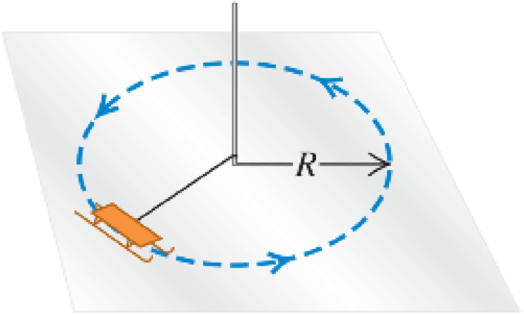

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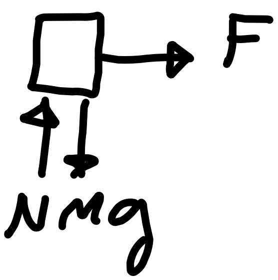

$\sum F_x = m a_x$

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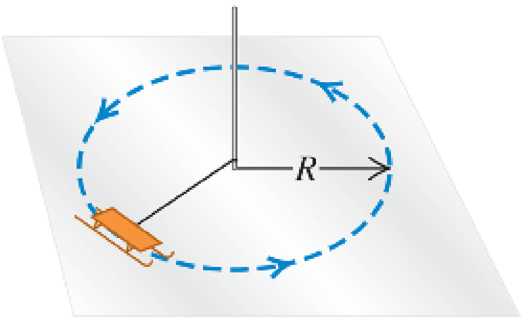

Find F:

y x

F

N mg

$\sum F_x = m a_x \Rightarrow F = m\frac{v^2}{R}$

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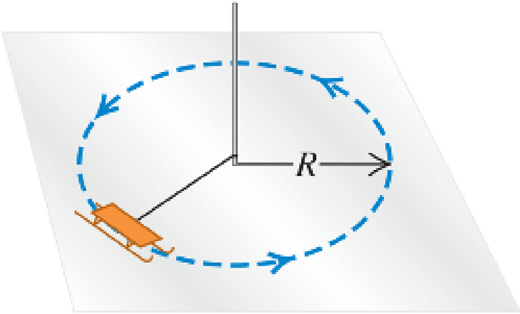

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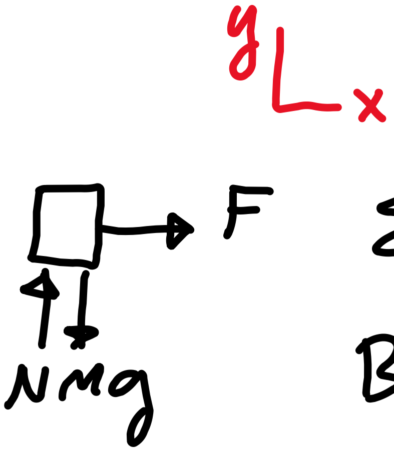

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But $v = \frac{2\pi R}{T}$

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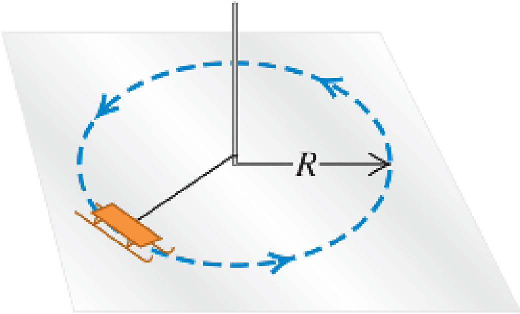

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But $V = \frac{2\pi R}{T}$ so

$$F = m\left[\frac{4\pi^2 R}{T^2}\right]$$

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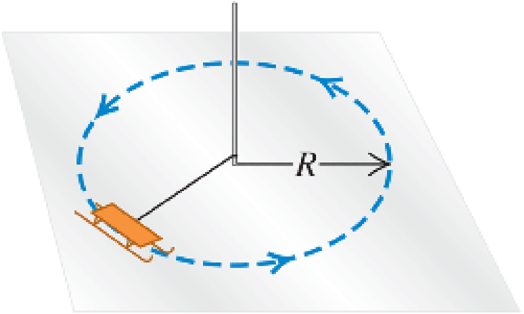

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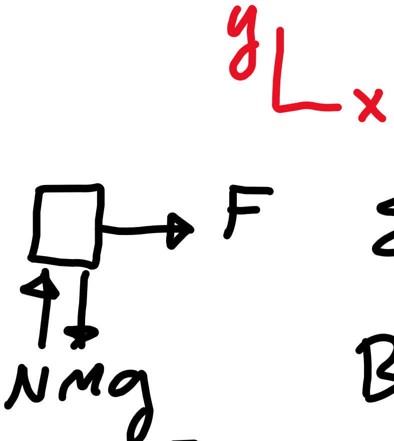

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But $v = \frac{2\pi R}{T}$ so

$$F = m\left[\frac{4\pi^2 R}{T^2}\right] = 25\left[\frac{(4\pi^2)(5)}{12^2}\right] N$$

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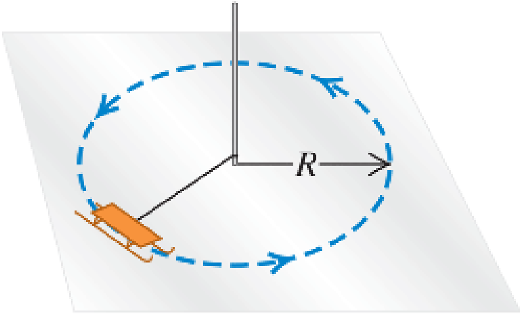

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F $\quad \sum F_x = ma_x \Rightarrow F = m\frac{v^2}{R}$

N mg $\quad$ But $v = \frac{2\pi R}{T}$ so

$$F = m\left[\frac{4\pi^2 R}{T^2}\right] = 25\left[\frac{(4\pi^2)(5)}{12^2}\right]N = \left(\frac{500}{144}\pi^2\right)N$$

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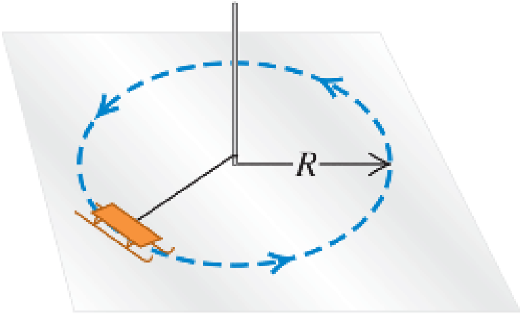

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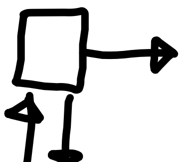

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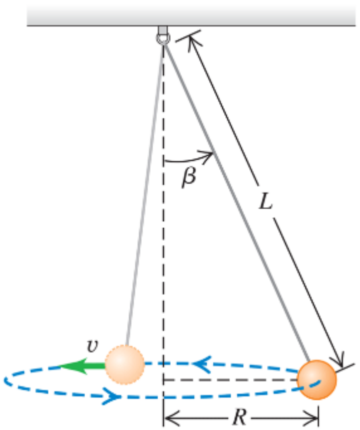
$$\boxed{F = 34.3\,N}$$

ASU

An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).



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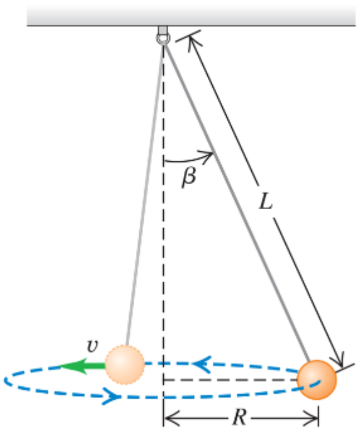

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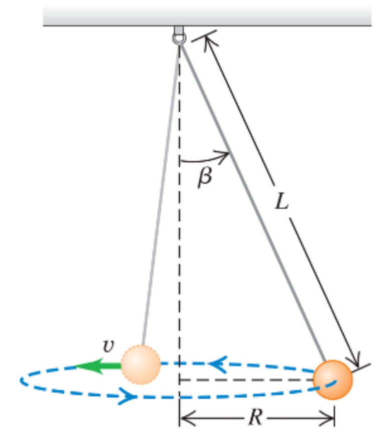
m, L



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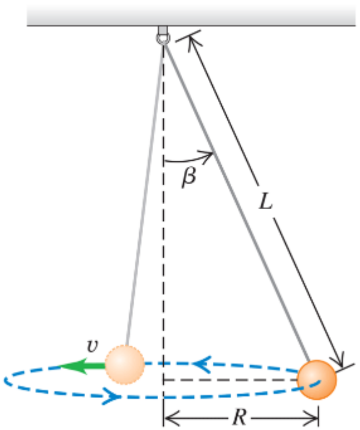
m, L, v



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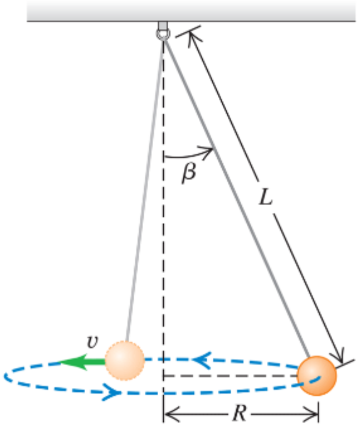

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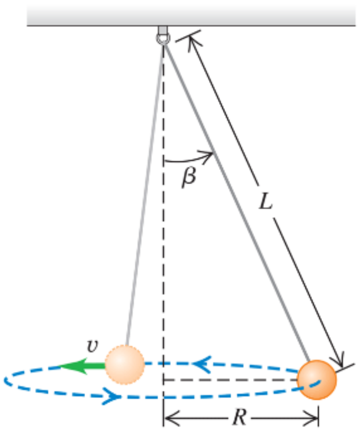
m, L, v, β find F & T:



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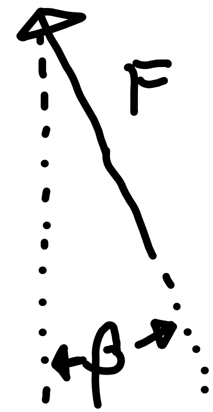

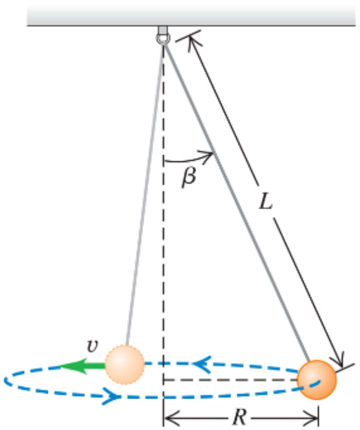

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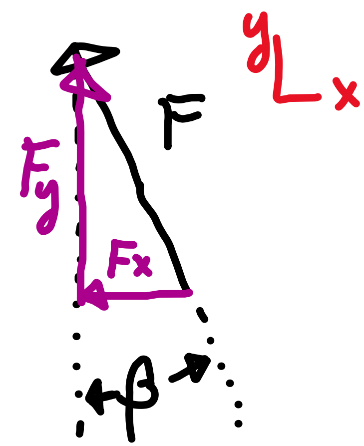

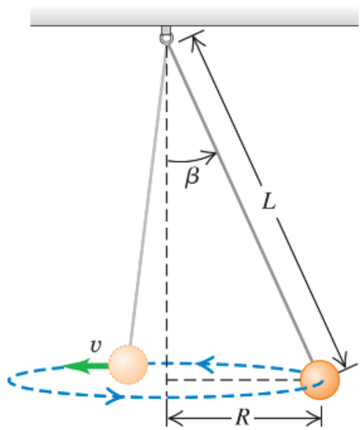

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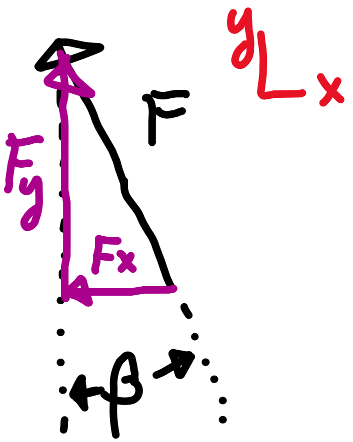

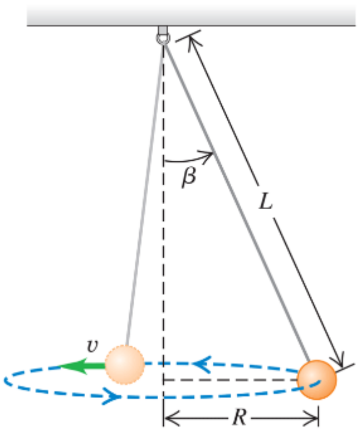

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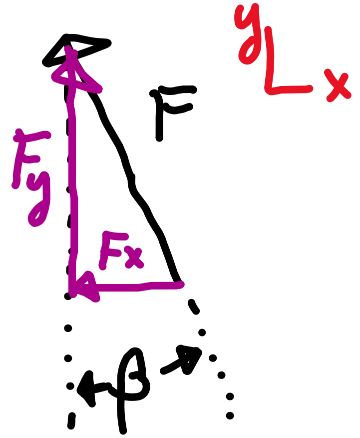
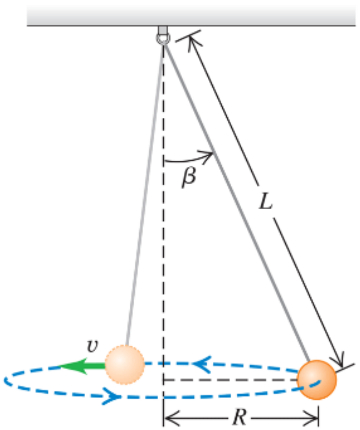
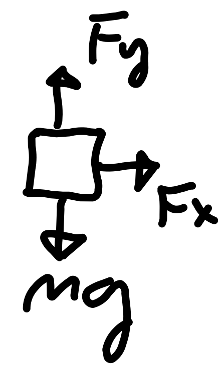




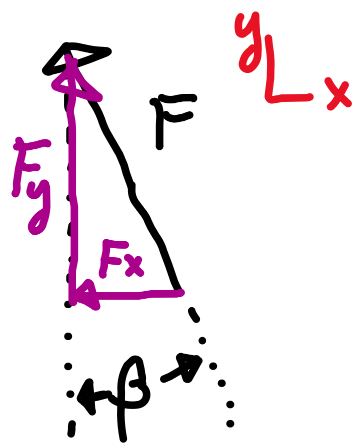


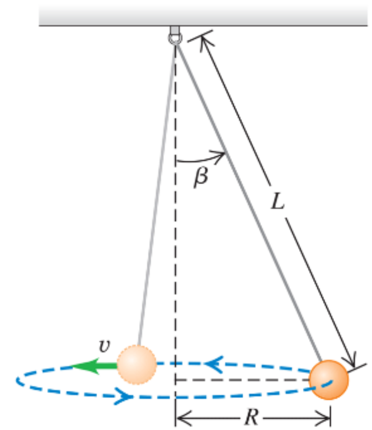
An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

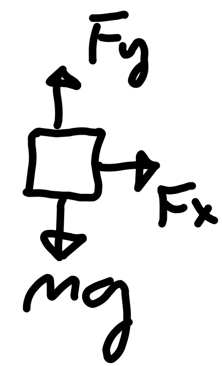
m, L, v, β find F & T:

$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$

$\sum F_x = m a_x$





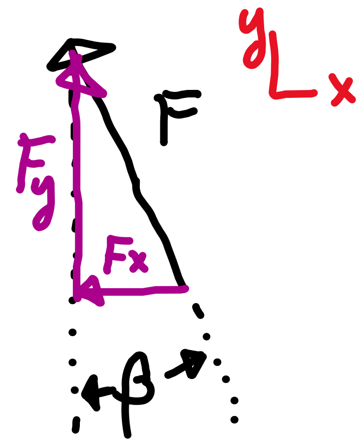


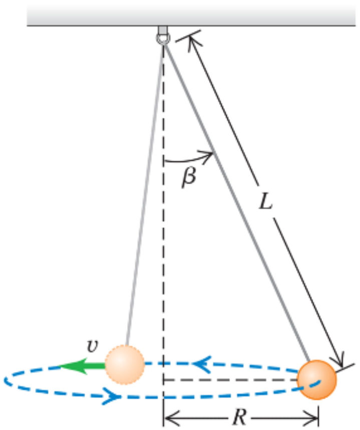
An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

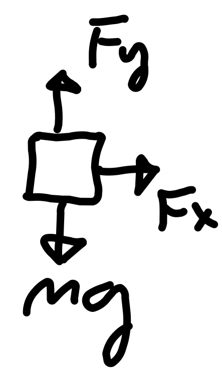
m, L, v, β Find F & T:

$$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$$

$$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$$







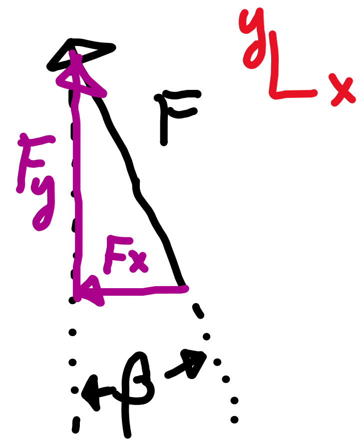
An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

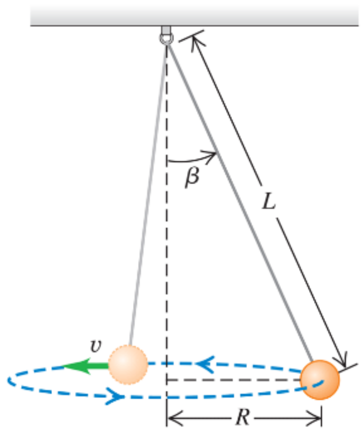
m, L, v, β find F & T:

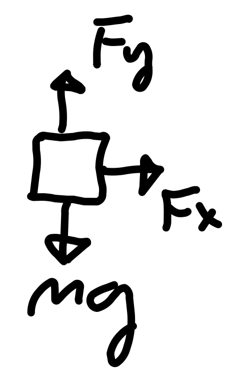
$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$

$\sum F_x = m a_x \Rightarrow F_x = m\frac{v^2}{R}$

$\sum F_y = m a_y$







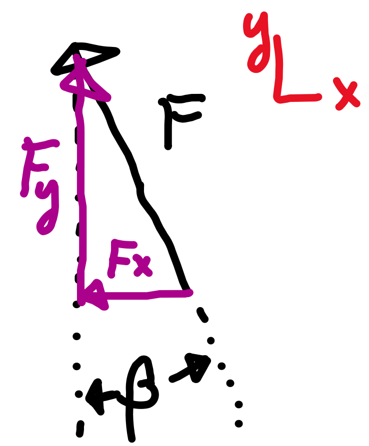
An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

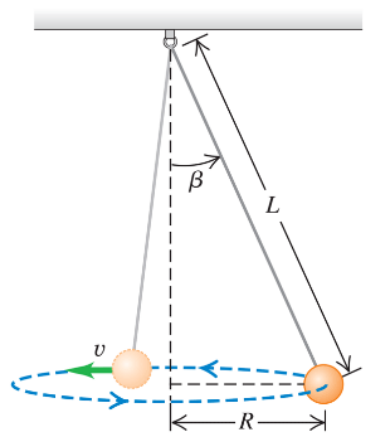
m, L, v, β Find F & T:

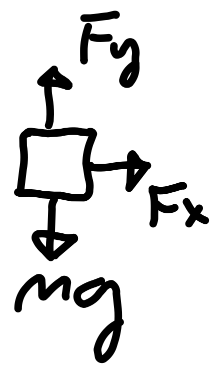
$$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$$

$$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$$

$$\sum F_y = m\cancel{a_y}^{\,0}$$







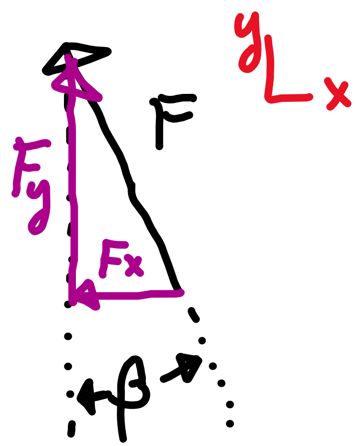
An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

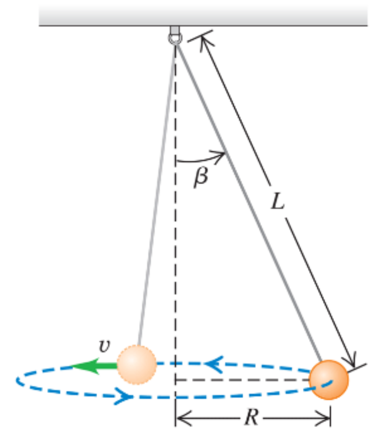
m, L, v, β find F & T:

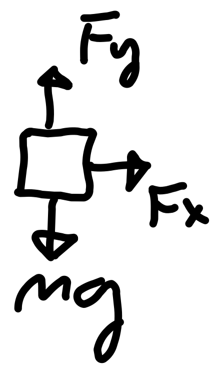
$$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$$

$$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$$

$$\sum F_y = m\cancel{a_y}^{\,0} \Rightarrow F_y = mg$$







An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

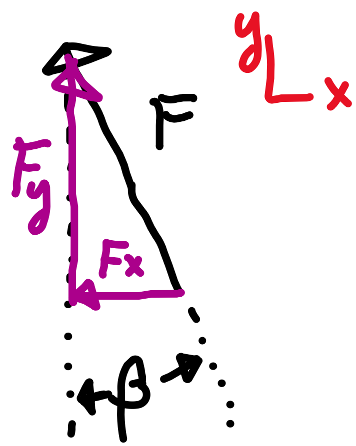
m, L, v, β find F & T:

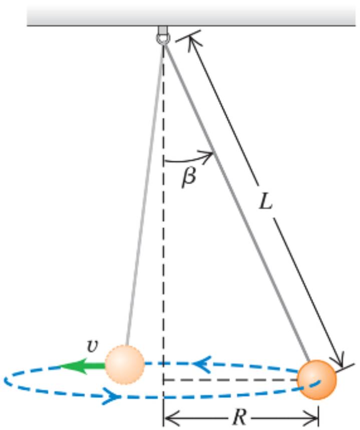
$$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$$

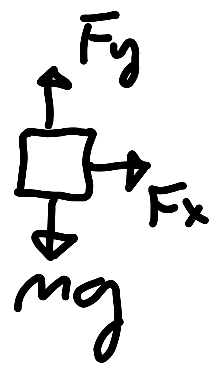
$$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$$

$$\sum F_y = m\cancel{a_y}^{\,0} \Rightarrow F_y = mg$$

$$F_y/F_x = \left(m\frac{v^2}{R}\right)/(mg)$$







An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

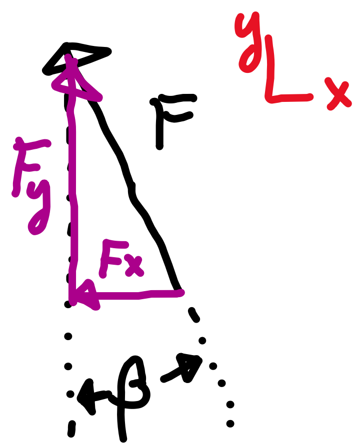
m, L, v, β find F & T:

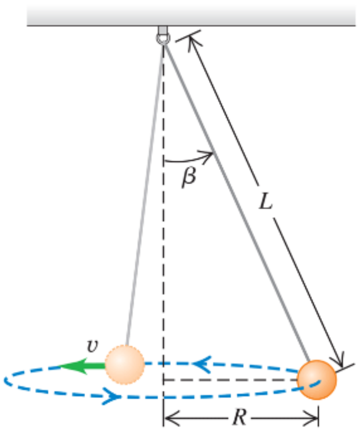
$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$

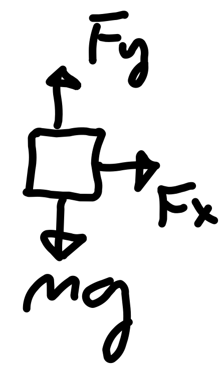
$\sum F_x = m a_x \Rightarrow F_x = m\frac{v^2}{R}$

$\sum F_y = m\cancel{a_y}^{0} \Rightarrow F_y = mg$

$F_y/F_x = (m\frac{v^2}{R})/(mg) \Rightarrow \frac{F\sin\beta}{F\cos\beta} = \frac{v^2}{gR}$



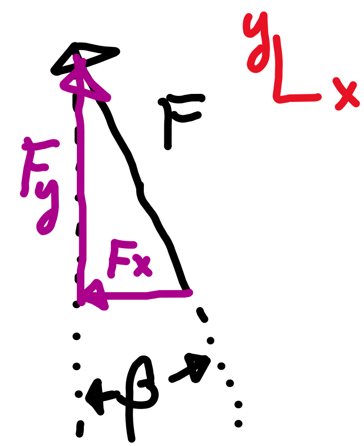


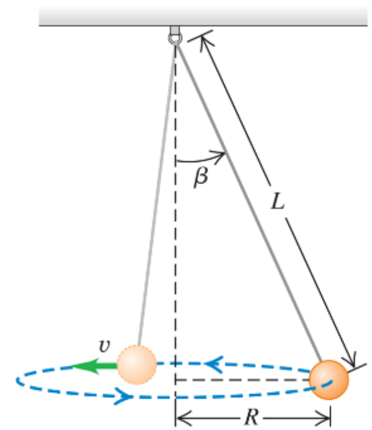


An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

m, L, v, β Find F & T:

$$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$$



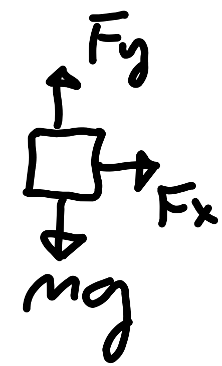


$$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$$

$$\sum F_y = m\cancelto{0}{a_y} \Rightarrow F_y = mg$$

$$F_y/F_x = \left(m\frac{v^2}{R}\right)/(mg) \Rightarrow \frac{F\sin\beta}{F\cos\beta} = \frac{v^2}{gR}$$

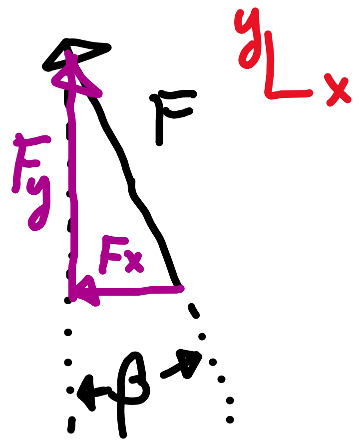
$$\Rightarrow \tan\beta = \left(\frac{2\pi R}{T}\right)^2\left(\frac{1}{gR}\right)$$

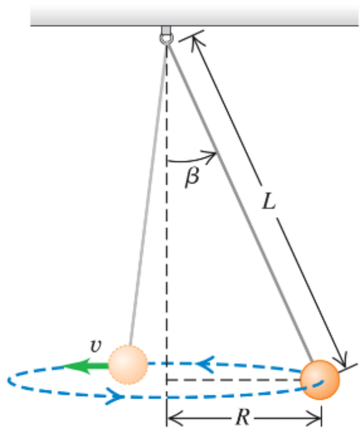


An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

m, L, v, β find F & T:

$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$





$\sum F_x = m a_x \Rightarrow F_x = m\frac{v^2}{R}$

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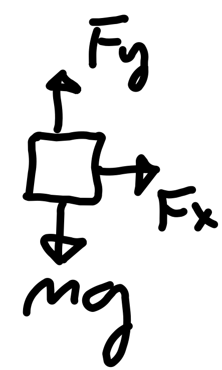

An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

m, L, v, β find F & T:

$\vec{F} = F\hat{i}\sin\beta + F\hat{j}\cos\beta$

$\sum F_x = ma_x \Rightarrow F_x = m\frac{v^2}{R}$

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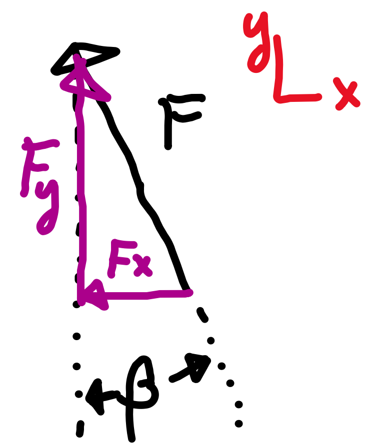

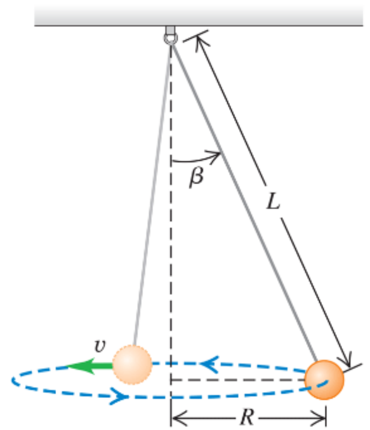

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m, L, v, β find F & T:

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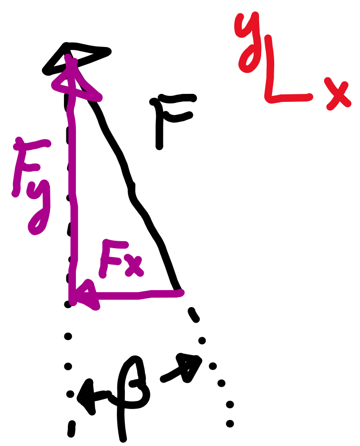

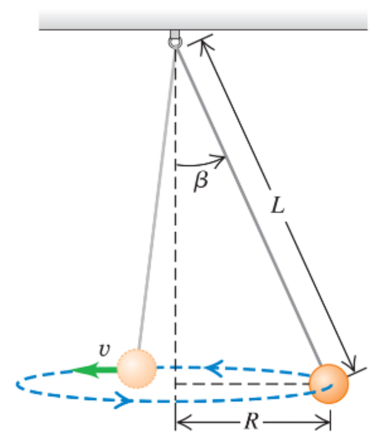

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But $R = L\sin\beta \Rightarrow \boxed{T = 2\pi\sqrt{L\cos\beta/g}}$

An inventor designs a pendulum clock using a bob with mass m at the end of a thin wire of length L. Instead of swinging back and forth, the bob is to move in a horizontal circle at constant speed v, with the wire making a fixed angle β with the vertical direction (Fig. 5.32a). This is called a *conical pendulum* because the suspending wire traces out a cone. Find the tension F in the wire and the period T (the time for one revolution of the bob).

m, L, v, β Find F & T:

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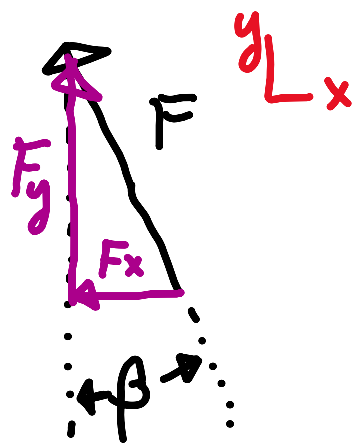

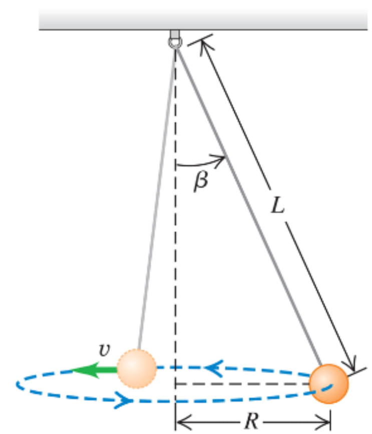

$$\sum F_x = m a_x \Rightarrow F_x = m\frac{v^2}{R}$$

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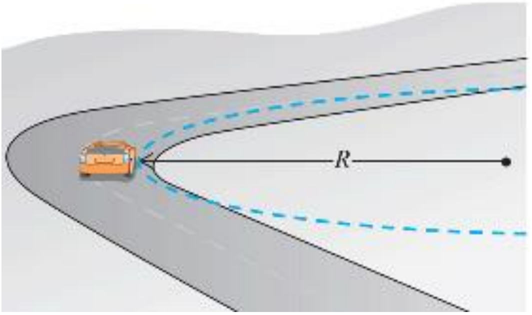
But $R = L\sin\beta \Rightarrow \boxed{T = 2\pi\sqrt{L\cos\beta/g}}$

$$\boxed{F = \frac{mg}{\cos\beta}}$$

The sports car in Example 3.11 (Section 3.4) is rounding a flat, unbanked curve with radius R (Fig. 5.33a). If the coefficient of static friction between tires and road is μ_s, what is the maximum speed v_{max} at which the driver can take the curve without sliding?



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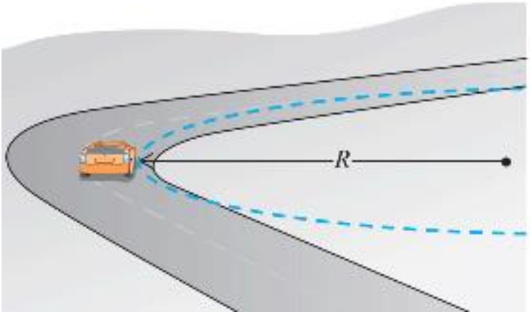
R



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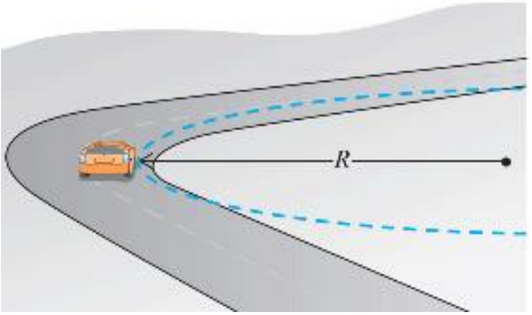
R, μ_s



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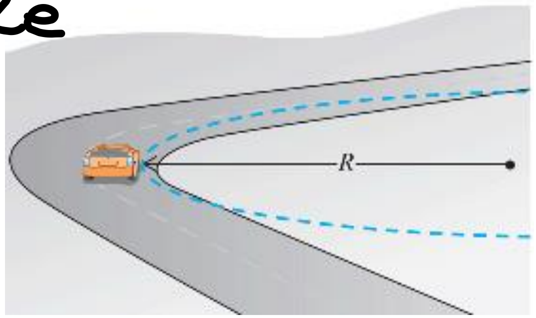
R, μ_s find v_{max} for no slide



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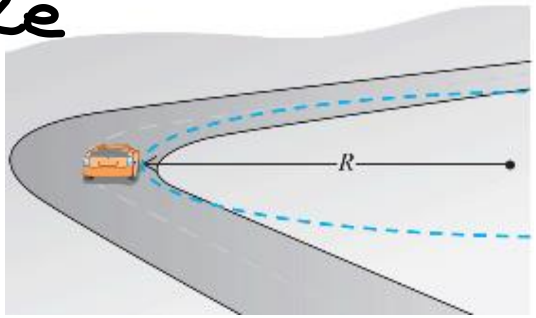

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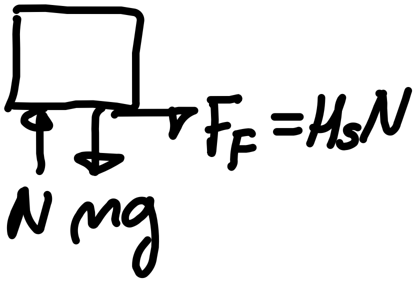

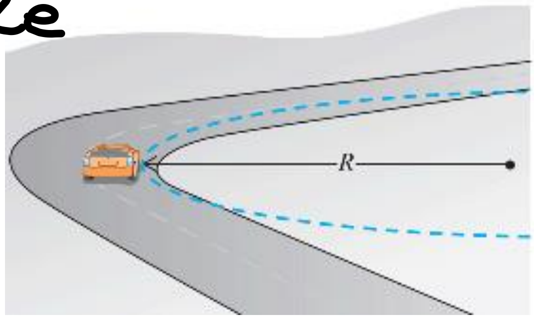

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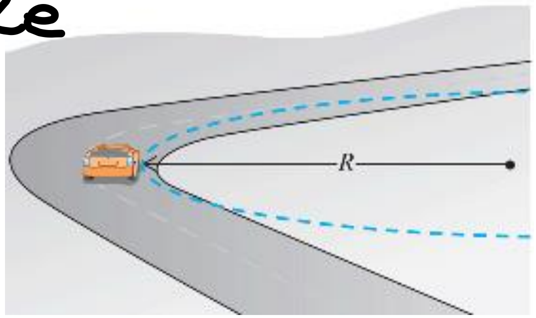
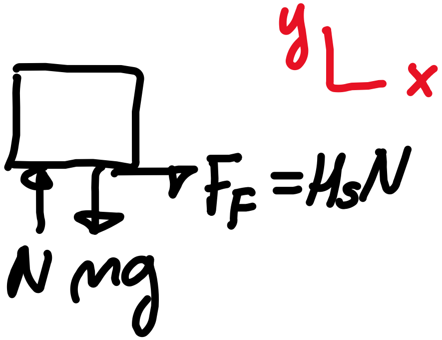
R, μ_s find v_{max} for no slide





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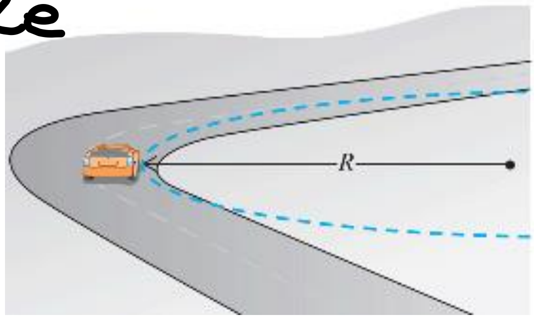
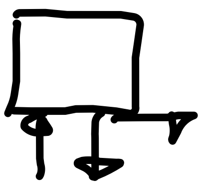


y x



$F_F = \mu_s N$

N mg

$\sum F_y = 0$

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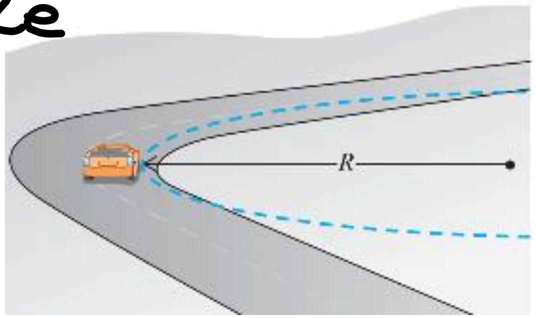

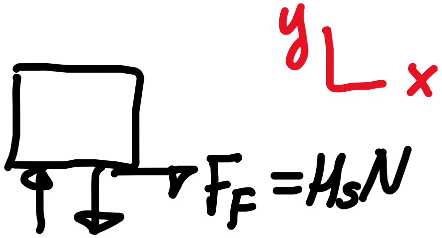

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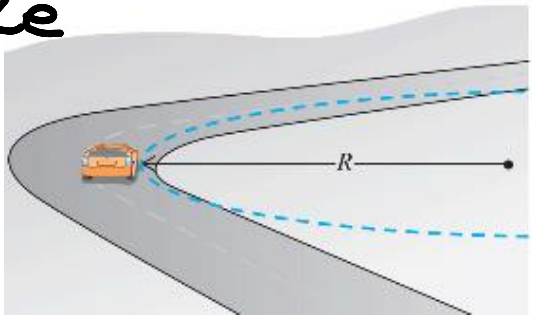

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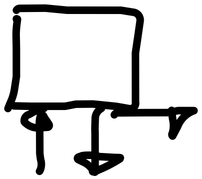

$F_F = \mu_s N$

N mg

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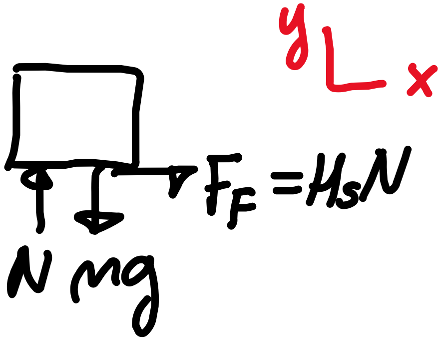
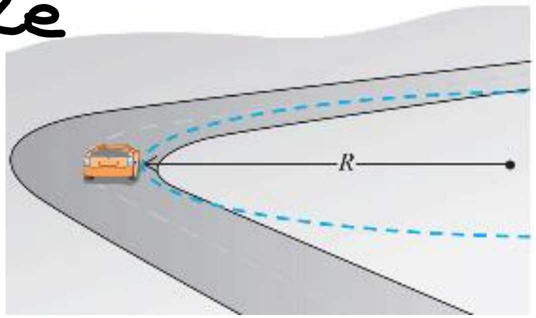
R, μ_s find v_{max} for no slide



$$\sum F_y = \cancel{0} \Rightarrow N = mg$$

$$\sum F_x = ma_x \Rightarrow \mu_s N \leq m\frac{v^2}{R}$$



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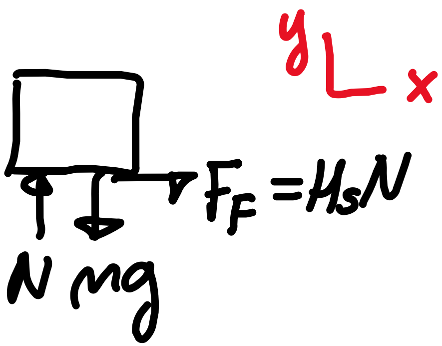

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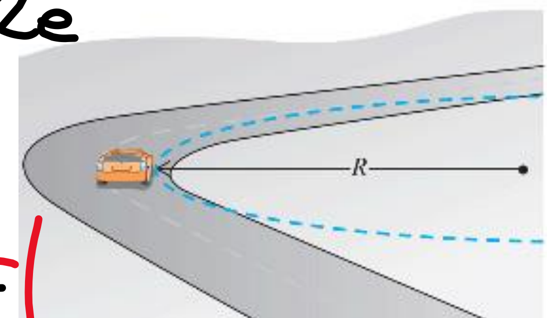

when $v = v_{max}$ for no slide $\le$ is $=$

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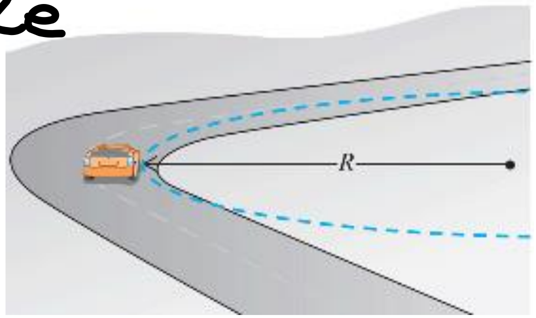
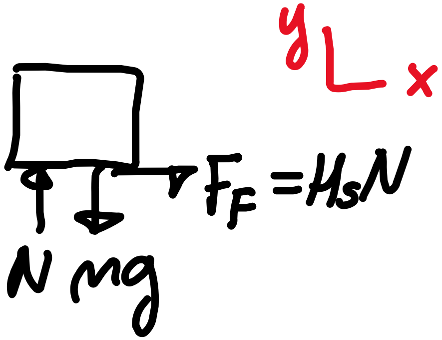


R, μ_s find V_{max} for no slide



$$\Sigma F_y = 0 \Rightarrow N = mg$$

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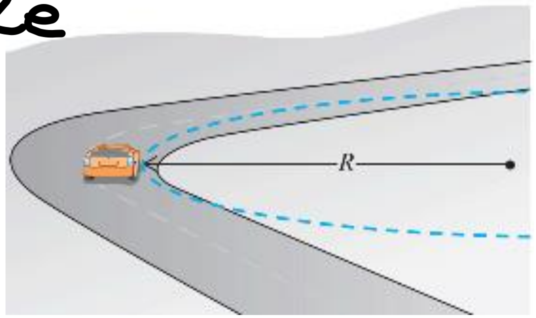

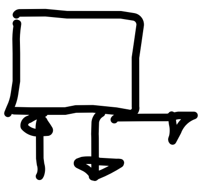

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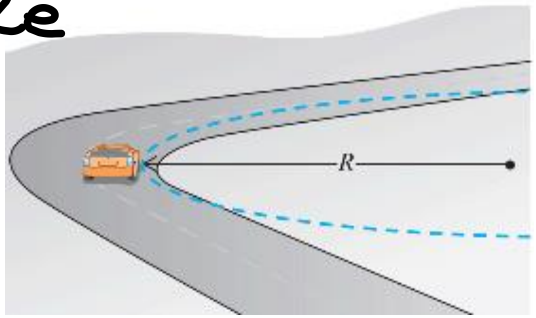

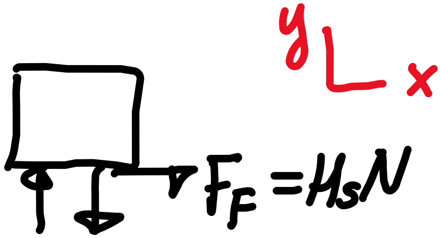

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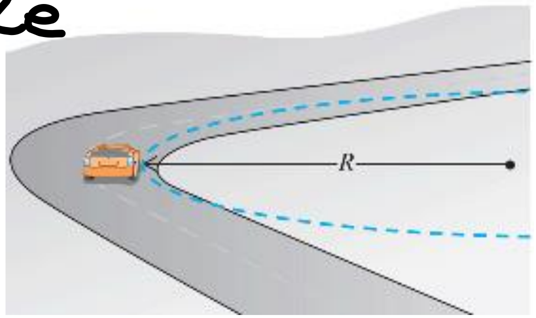

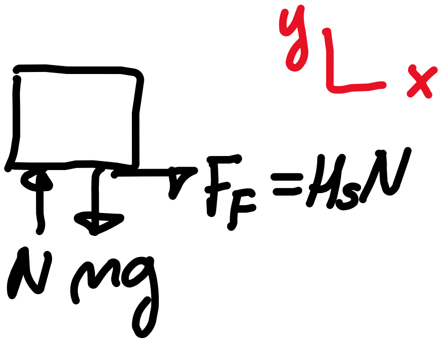

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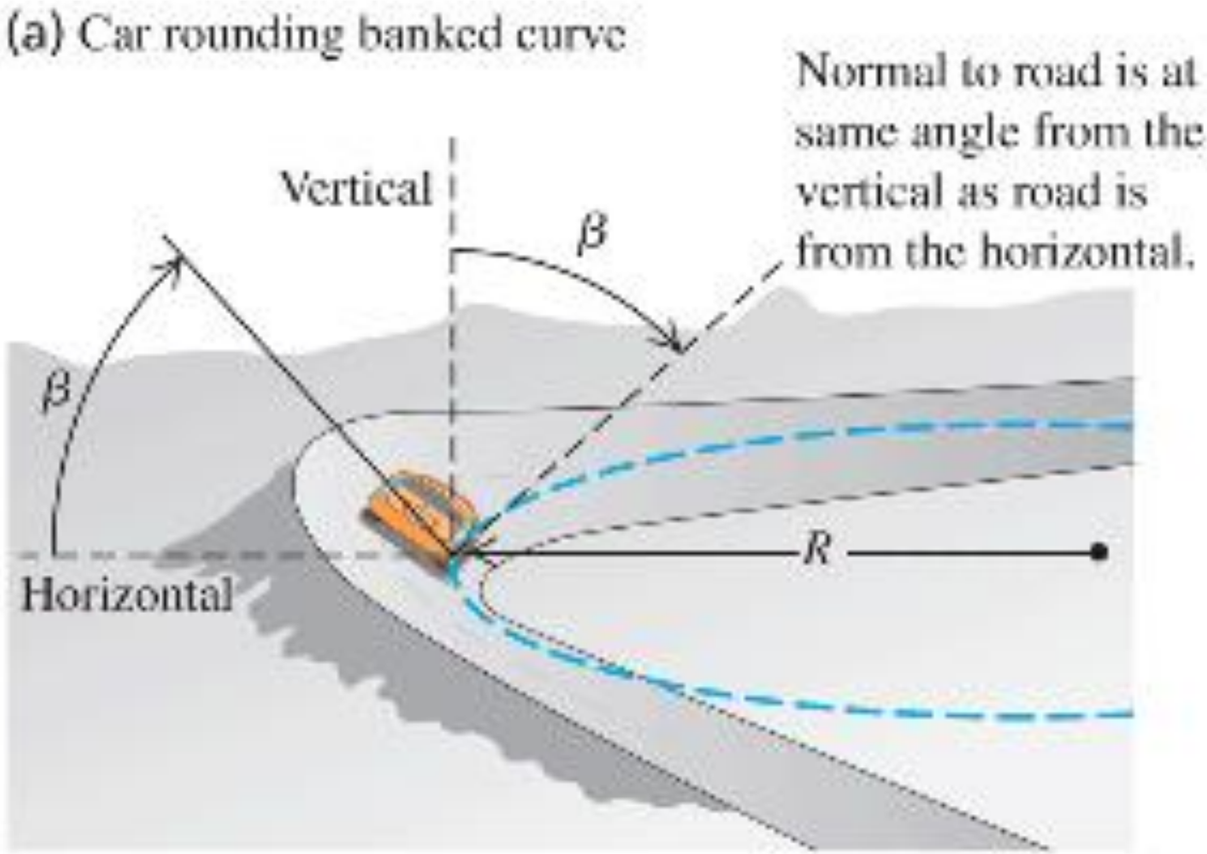
$$\Rightarrow \boxed{v_{max} = \sqrt{\mu_s g R}}$$

For a car traveling at a certain speed, it is possible to bank a curve at just the right angle so that no friction is needed to maintain the car's turning radius. Then a car can safely round the curve even on wet ice. (Bobsled racing depends on this idea.) Your engineering firm plans to rebuild the curve in Example 5.21 so that a car moving at a chosen speed v can safely make the turn even with no friction (Fig. 5.34a). At what angle β should the curve be banked?



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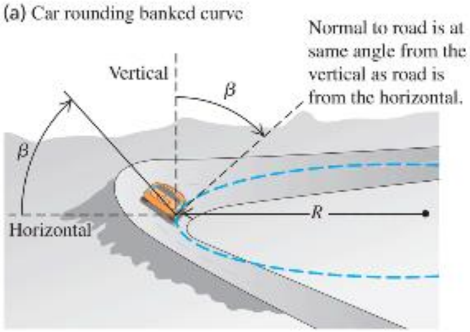

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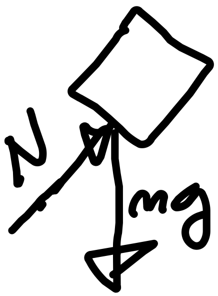

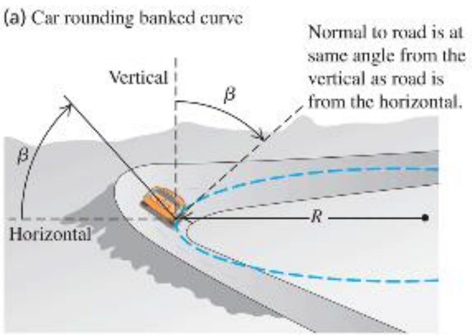

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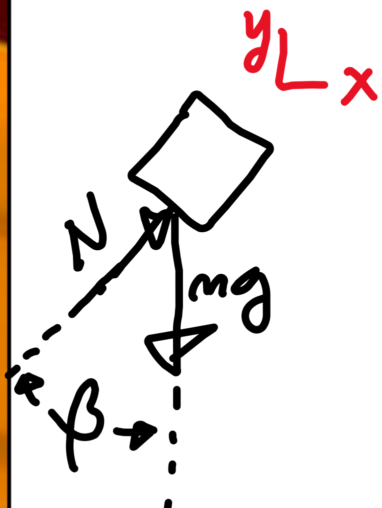

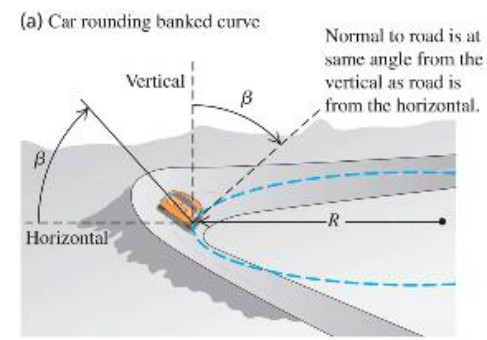

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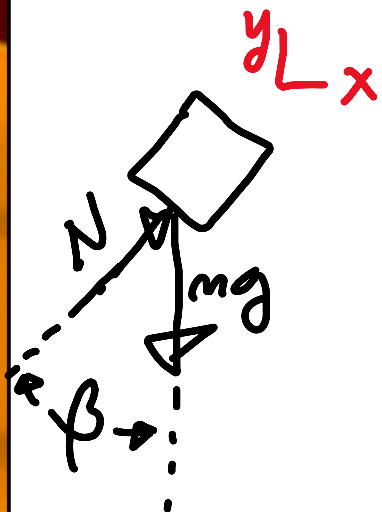
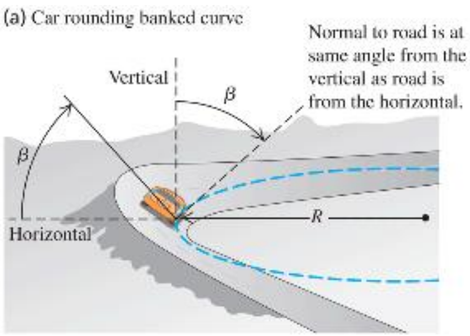


$$\vec{N} = N(\hat{i}\sin\beta + \hat{j}\cos\beta)$$



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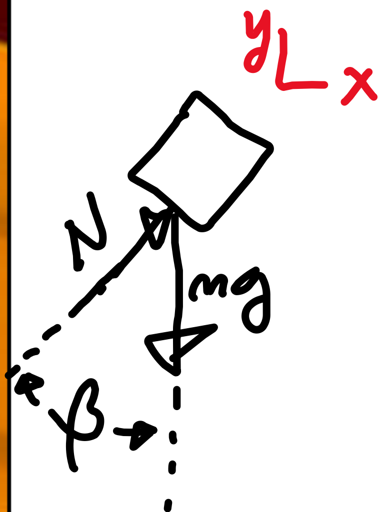
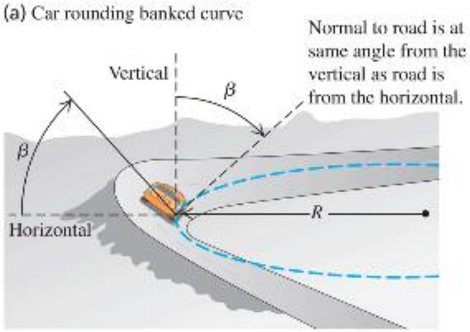


$$\sum F_x = ma_x$$



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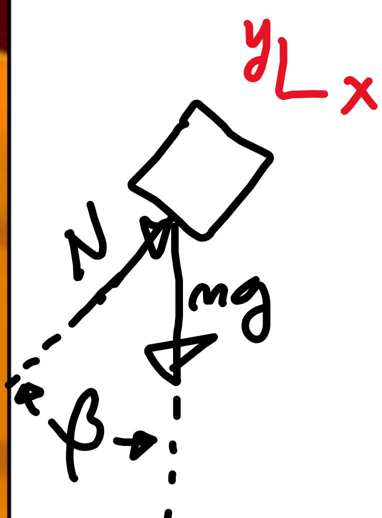
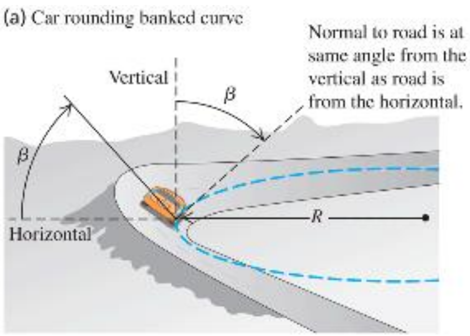


$$\vec{N} = N(\hat{i}\sin\beta + \hat{j}\cos\beta)$$

$$\sum F_x = ma_x \Rightarrow N\sin\beta = m\frac{v^2}{R}$$



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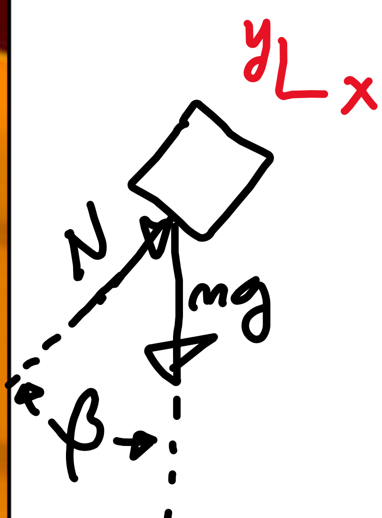

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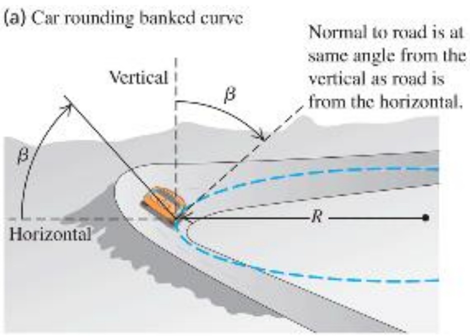

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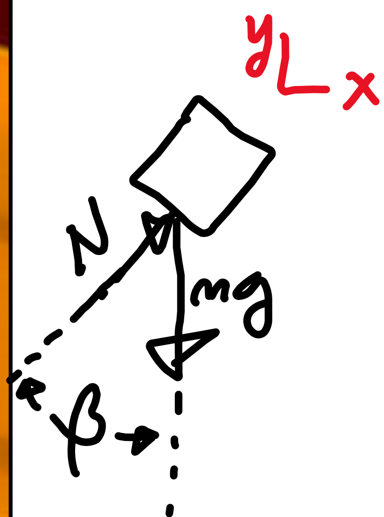
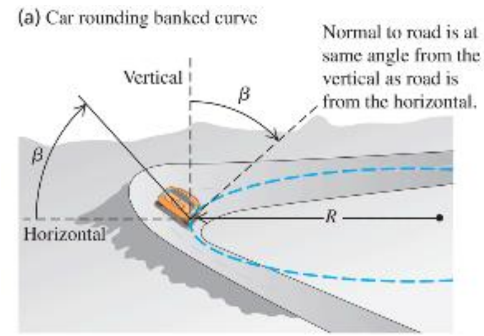


$$\vec{N} = N(\hat{i}\sin\beta + \hat{j}\cos\beta)$$

$$\sum F_x = m a_x \Rightarrow N\sin\beta = m\frac{v^2}{R}$$

$$\sum F_y = 0 \Rightarrow N\cos\beta = mg$$



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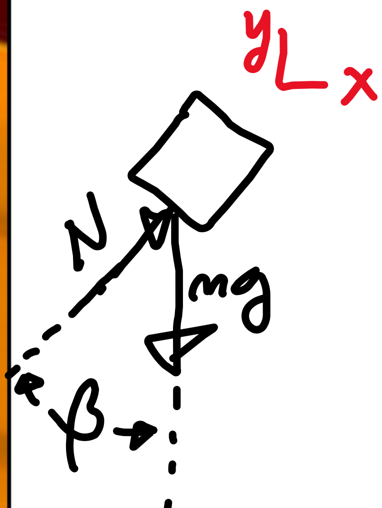

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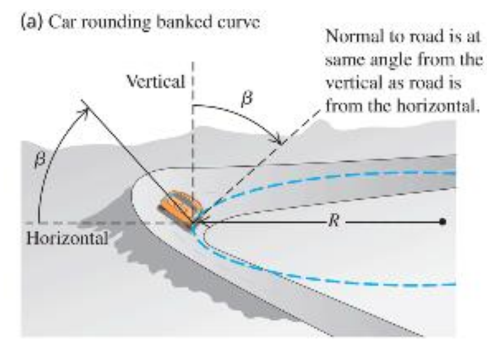

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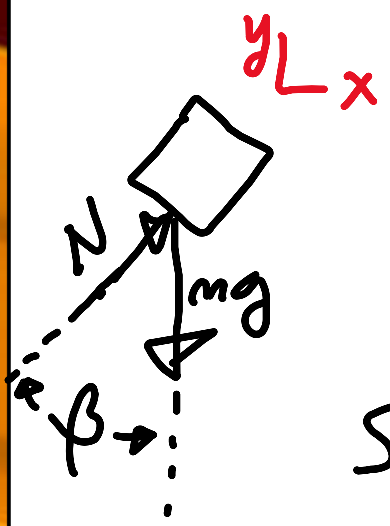

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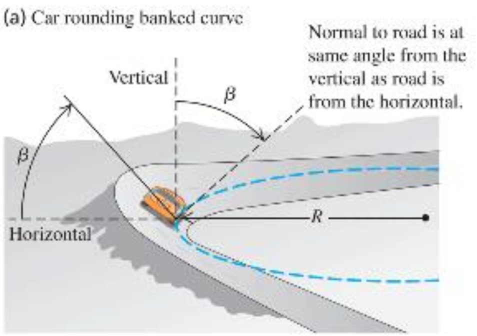

$$\sum F_x = m a_x \Rightarrow N\sin\beta = m\frac{v^2}{R}$$

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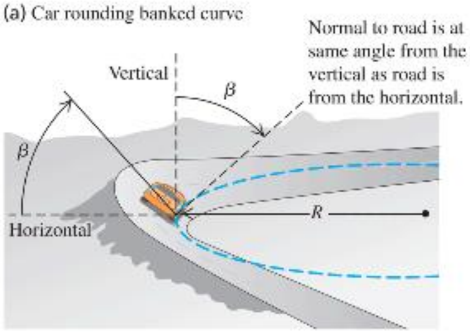

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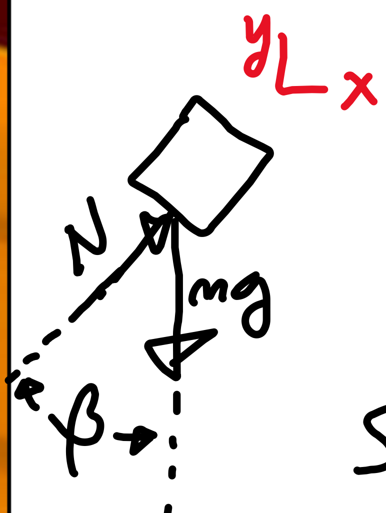

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So $$\left(\frac{mg}{\cos\beta}\right)\sin\beta = m\frac{v^2}{R} \Rightarrow \tan\beta = \frac{v^2}{gR}$$

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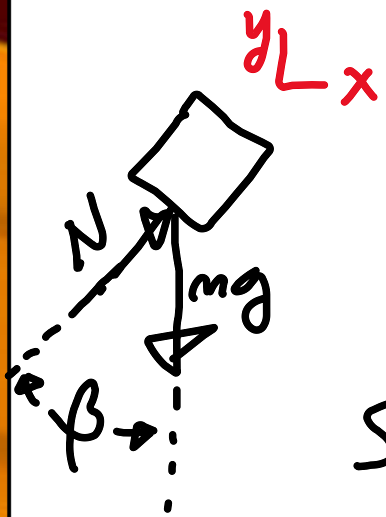
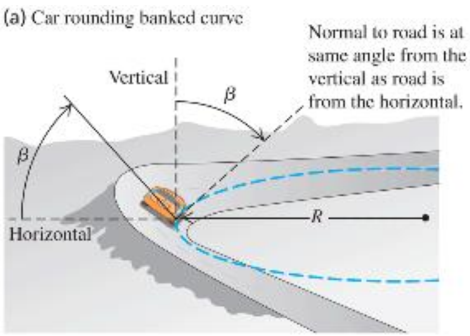


$$\vec{N} = N(\hat{i}\sin\beta + \hat{j}\cos\beta)$$



$$\sum F_x = m a_x \Rightarrow N\sin\beta = m\frac{v^2}{R}$$

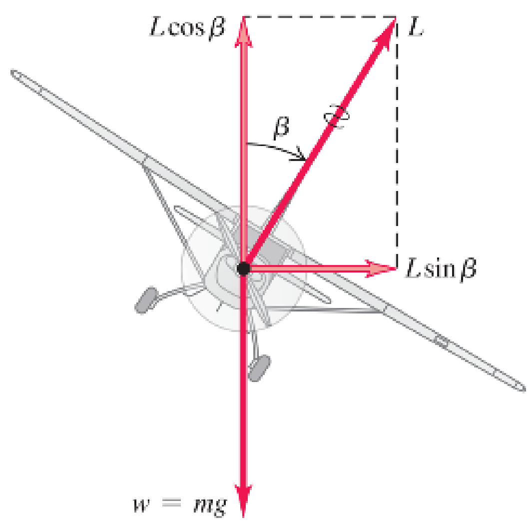
$$\sum F_y = 0 \Rightarrow N\cos\beta = mg \Rightarrow N = \frac{mg}{\cos\beta}$$

So $$\left(\frac{mg}{\cos\beta}\right)\sin\beta = m\frac{v^2}{R} \Rightarrow \tan\beta = \frac{v^2}{gR}$$

$$\Rightarrow \boxed{\beta = \tan^{-1}\left(\frac{v^2}{gR}\right)}$$

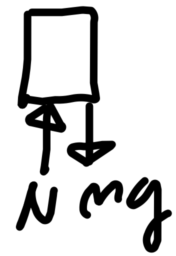
The results of Example 5.22 also apply to an airplane when it makes a turn in level flight (Fig. 5.35). When an airplane is flying in a straight line at a constant speed and at a steady altitude, the airplane's weight is exactly balanced by the lift force $\vec{L}$ exerted by the air. (The upward lift force that the air exerts on the wings is a reaction to the downward push the wings exert on the air as they move through it.) To make the airplane turn, the pilot banks the airplane to one side so that the lift force has a horizontal component, as Fig. 5.35 shows. (The pilot also changes the angle at which the wings "bite" into the air so that the vertical component of lift continues to balance the weight.) The bank angle is related to the airplane's speed v and the radius R of the turn by the same expression as in Example 5.22: $\tan \beta = v^2/gR$. For an airplane to make a tight turn (small R) at high speed (large v), $\tan \beta$ must be large and the required bank angle β must approach 90°.

Figure 5.35



A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP



A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

$$\sum F_y = ma$$

TOP

A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

$$\sum F_y = ma$$

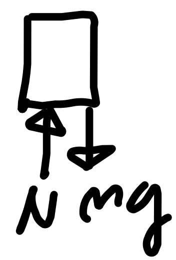
$$-N + mg = m\frac{v^2}{R}$$

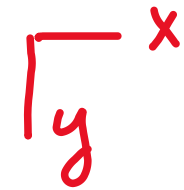
A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

$$\Sigma F_y = ma$$

$$-N + mg = m\frac{v^2}{R} \Rightarrow \boxed{N = m\left(g - \frac{v^2}{R}\right)}$$





A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

$$\Sigma F_y = ma$$

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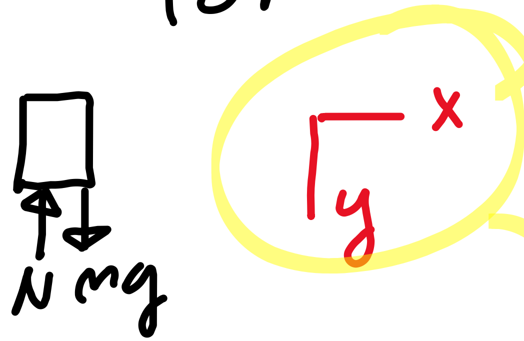
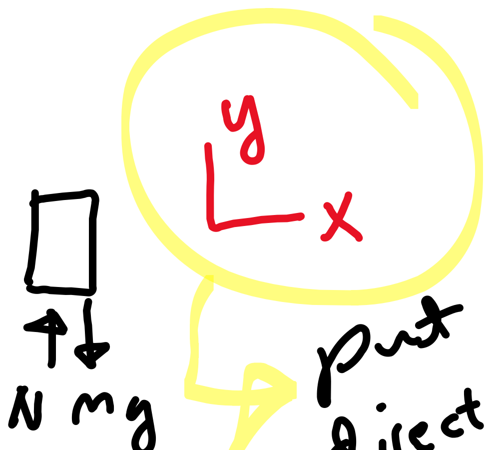


Bottom



put y in direction of +a

A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

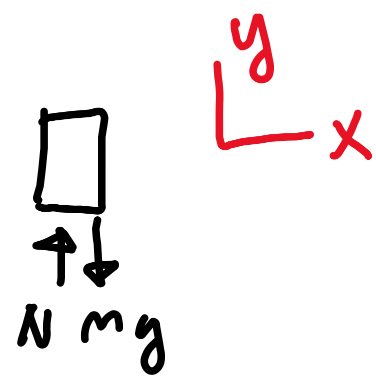
TOP

$$\sum F_y = ma$$

$$-N + mg = m\frac{v^2}{R} \Rightarrow \boxed{N = m\left(g - \frac{v^2}{R}\right)}$$

Bottom

$$\sum F_y = ma$$



A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

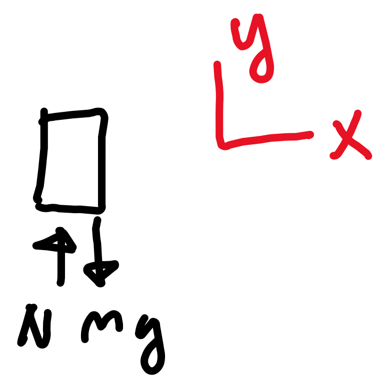
$$\Sigma F_y = ma$$

$$-N + mg = m\frac{v^2}{R} \Rightarrow \boxed{N = m\left(g - \frac{v^2}{R}\right)}$$

Bottom

$$\Sigma F_y = ma$$

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



A passenger on a carnival Ferris wheel moves in a vertical circle of radius R with constant speed v. The seat remains upright during the motion. Find expressions for the force the seat exerts on the passenger when at the top of the circle and when at the bottom.

TOP

$$\sum F_y = ma$$

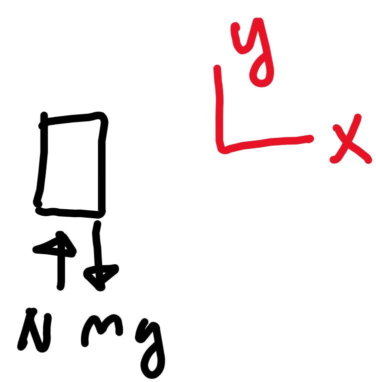
$$-N + mg = m\frac{v^2}{R} \Rightarrow \boxed{N = m\left(g - \frac{v^2}{R}\right)}$$

Bottom

$$\sum F_y = ma$$

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

$$\Rightarrow \boxed{N = m\left(\frac{v^2}{R} + g\right)}$$



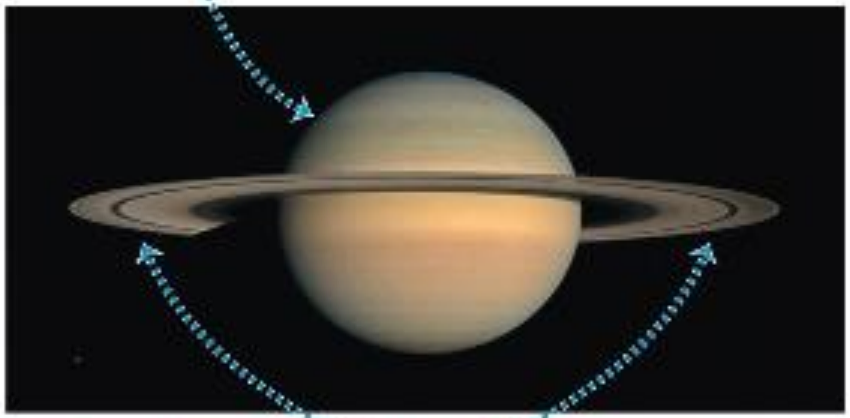
Fundamental Forces of nature

Fundamental forces of nature

* Gravitation

(a) The gravitational interaction

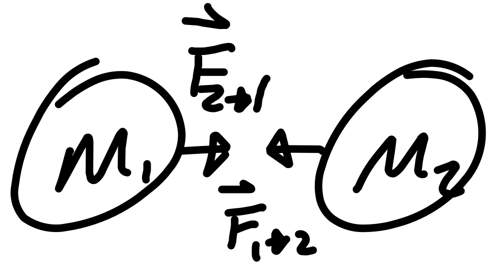
Saturn is held together by the mutual gravitional attraction of all of its parts.



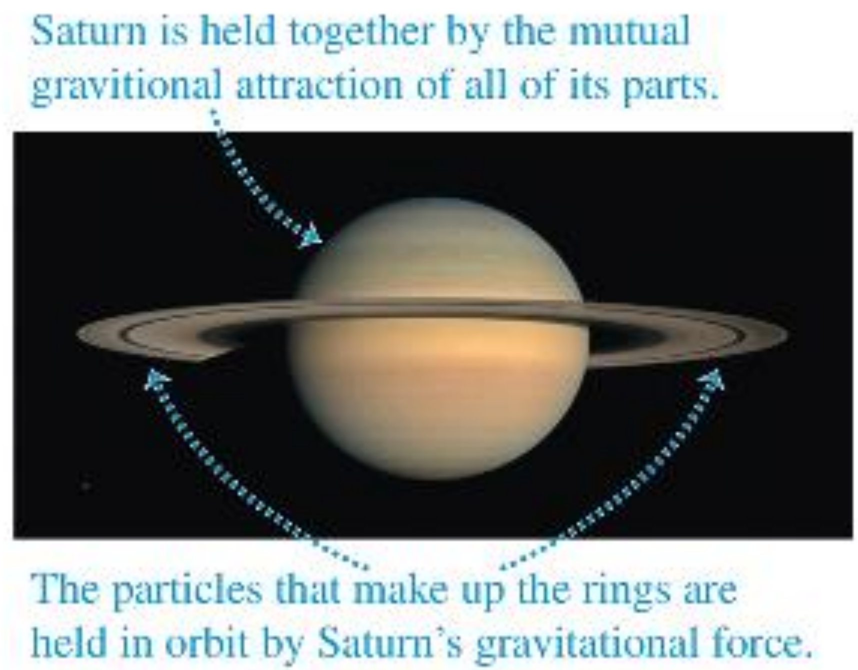
The particles that make up the rings are held in orbit by Saturn's gravitational force.

Fundamental Forces of nature

* Gravitation



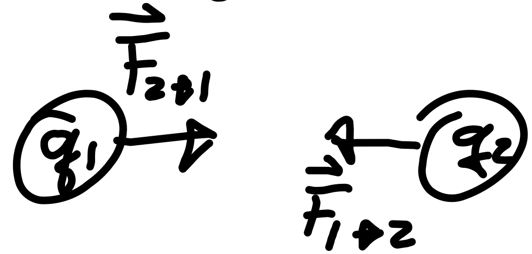
(a) The gravitational interaction



ASU

Fundamental Forces of nature

* Gravitation
* Electromagnetic



(b) The electromagnetic interaction

The contact forces between the microphone and the singer's hand are electrical in nature.

This microphone uses electric and magnetic effects to convert sound into an electrical signal that can be amplified and recorded.

Fundamental Forces of nature

* Gravitation
* Electromagnetic

(b) The electromagnetic interaction

The contact forces between the microphone and the singer's hand are electrical in nature.

This microphone uses electric and magnetic effects to convert sound into an electrical signal that can be amplified and recorded.

Fundamental forces of nature

* Gravitation
* Electromagnetic
* Strong

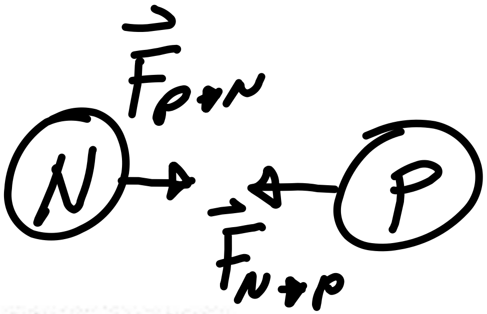
(c) The strong interaction

The nucleus of a gold atom has 79 protons and 118 neutrons.

The strong interaction holds the protons and neutrons together and overcomes the electric repulsion of the protons.

Fundamental forces of nature

* Gravitation
* Electromagnetic
* Strong



(c) The strong interaction

The nucleus of a gold atom has 79 protons and 118 neutrons.

The strong interaction holds the protons and neutrons together and overcomes the electric repulsion of the protons.

Fundamental Forces of nature

* Gravitation
* Electromagnetic
* Strong
* weak

(d) The weak interaction

Scientists find the age of this ancient skull by measuring its carbon-14—a form of carbon that is radioactive thanks to the weak interaction.

ASU

Fundamental Forces of nature

* Gravitation
* Electromagnetic
* Strong
* weak

$n \rightarrow p + e^- + \bar{\nu}_e$

(d) The weak interaction

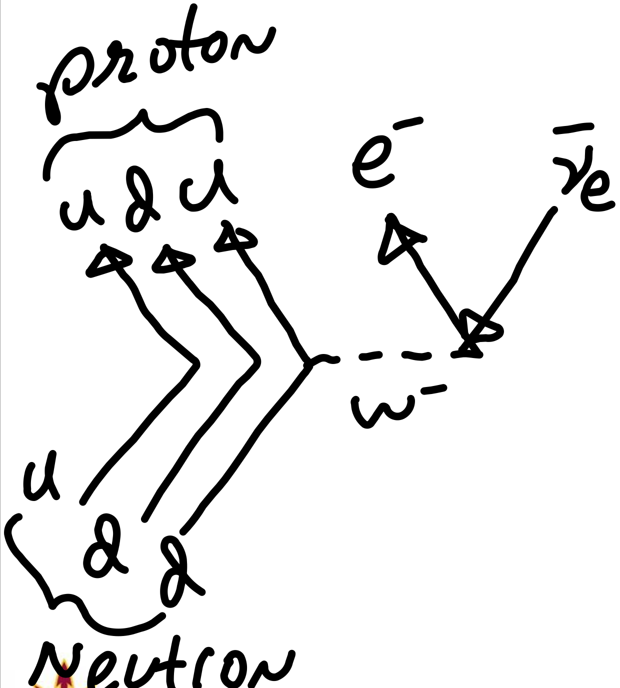
Scientists find the age of this ancient skull by measuring its carbon-14—a form of carbon that is radioactive thanks to the weak interaction.

ASU

Fundamental Forces of nature

* Gravitation
* Electromagnetic
* Strong
* weak

$$n \rightarrow p + e^- + \bar{\nu}_e$$



(d) The weak interaction

Scientists find the age of this ancient skull by measuring its carbon-14—a form of carbon that is radioactive thanks to the weak interaction.