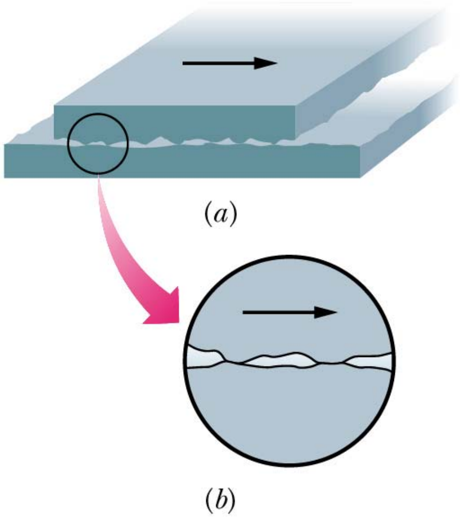
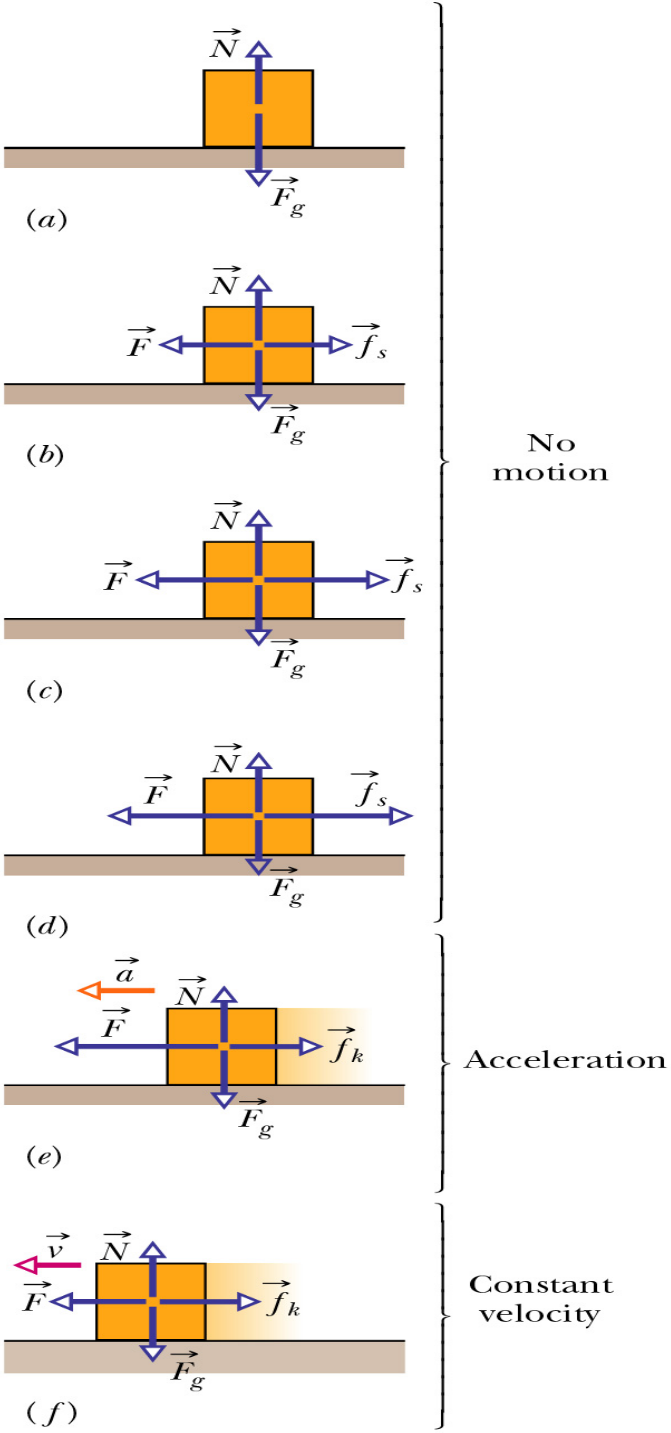
Chapter 6: Force and Motion-II

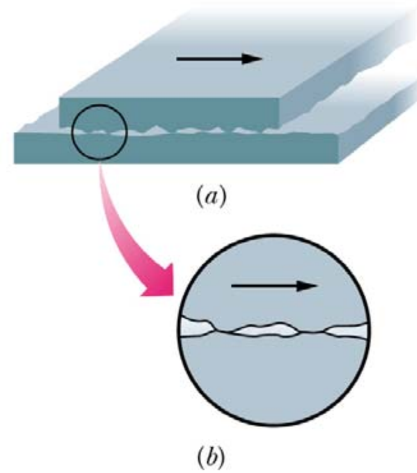
- Friction forces are everywhere in our daily life

- Two kinds of friction forces
  - Static friction force: $\boldsymbol{f}_{\mathbf{s}}$
  - Kinetic friction force: $\boldsymbol{f}_{\mathbf{k}}$



- Direction of frictional force: always opposes the direction of motion (or intended motion) relative to the surface





Friction happens when there is a relative motion (or tendency of relative motion) between two contacting surface.

Static Friction Force

- An applied force F attempts to slide a block along a surface
  - If the block does not move,

$$f_s = F$$

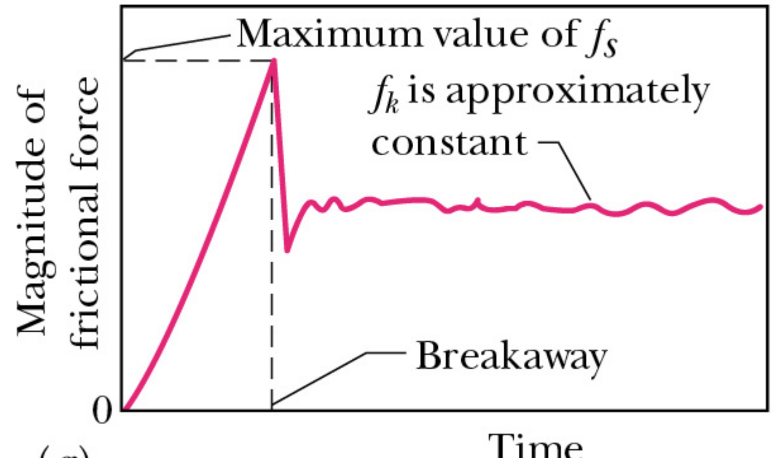
  f_s increases when F increases until ….

  - f_s has a maximum value: $f_{s,\,max}$

$$f_{s,\,max} = \mu_s N$$

  μ_s : coefficient of static friction

  N : normal force



(g)

Kinetic Friction Force

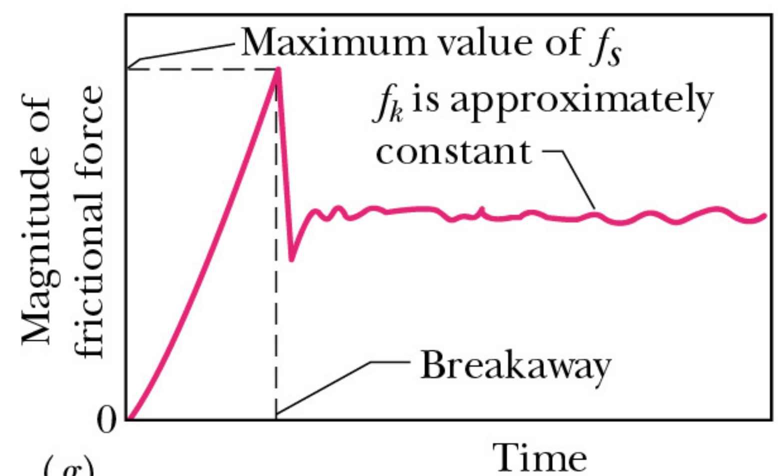
When the body begins to slide, the friction force rapidly decrease to f_{k}

$$f_{\mathrm{k}} = \mu_k N$$

μ_k : coefficient of kinetic friction

N : normal force

– μ_s and μ_k depend on the nature of the contacting surfaces, can be determined experimentally



(g)

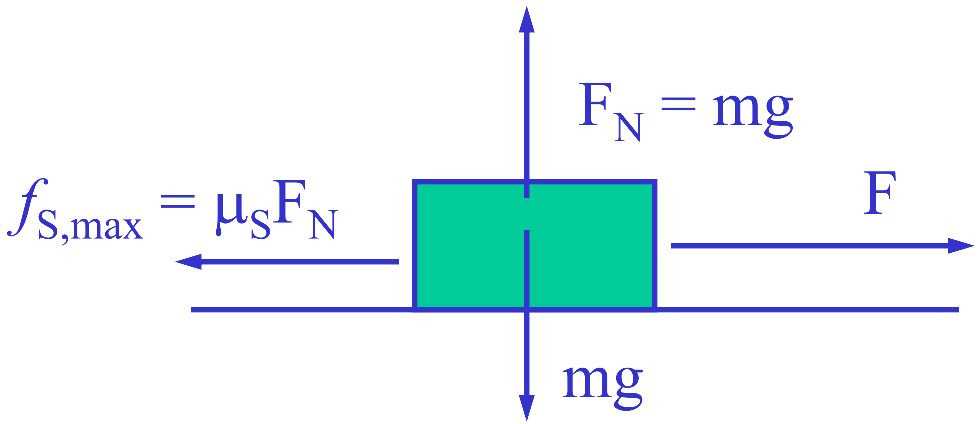
A block lies on a horizontal floor.

a) What is the magnitude of the friction force (f) on it from the floor?

b) If a horizontal force of 5 N is now applied to it, but it does not move, what is f now?

c) If $f_{s,\,max} = 10$ N, will the block move if the horizontal applied force is 8 N?

d) How about 12 N?



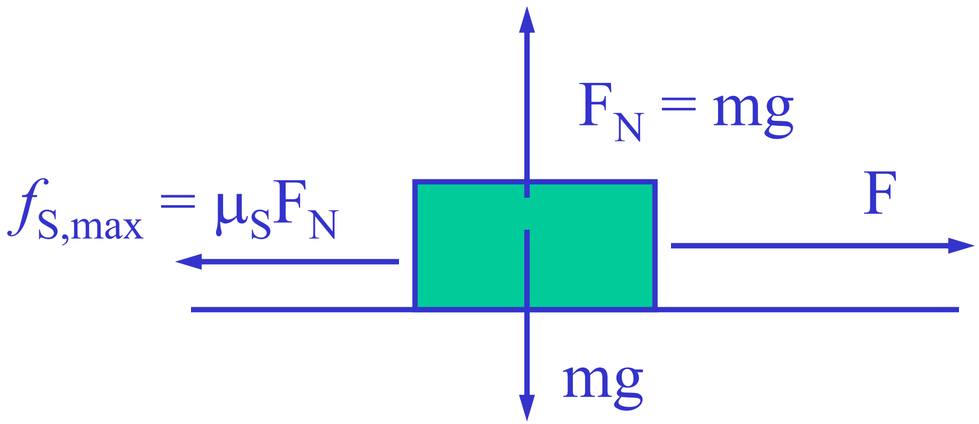
A block lies on a horizontal floor.

a) What is the magnitude of the friction force (f) on it from the floor? $f = 0\text{N}$, but note $f_{S,max} = \mu_S F_N$

b) If a horizontal force of 5 N is now applied to it, but it does not move, what is f now? $f_s = 5\text{N}$

c) If $f_{s,\,max} = 10$ N, will the block move if the horizontal applied force is 8 N? no, because $F < f_s$

d) How about 12 N? yes, because $F > f_s$



You press your physics book flat against a vertical wall with your hand, what is the direction of the friction force on the book exerted by the wall?

A) downward

B) upward

C) out from the wall

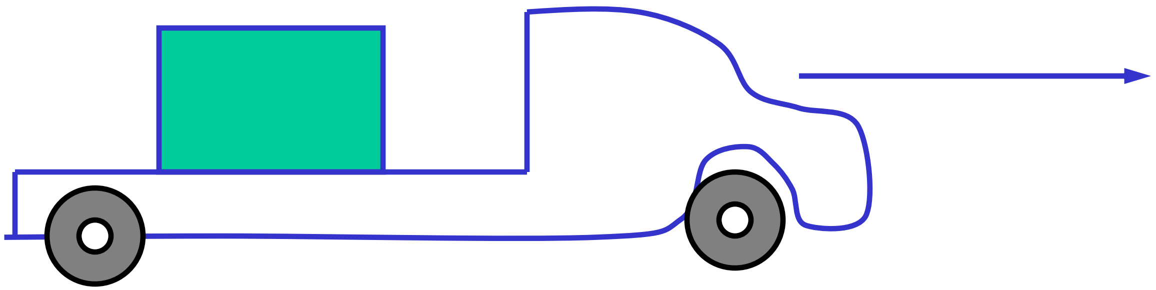
D) into the wall

A crate is located at the center of a flatbed truck. The truck accelerates toward the east, and the crate moves with it, not sliding on the bed of the truck. What is the direction of the friction force exerted by the bed of the truck on the crate.

A) to the west

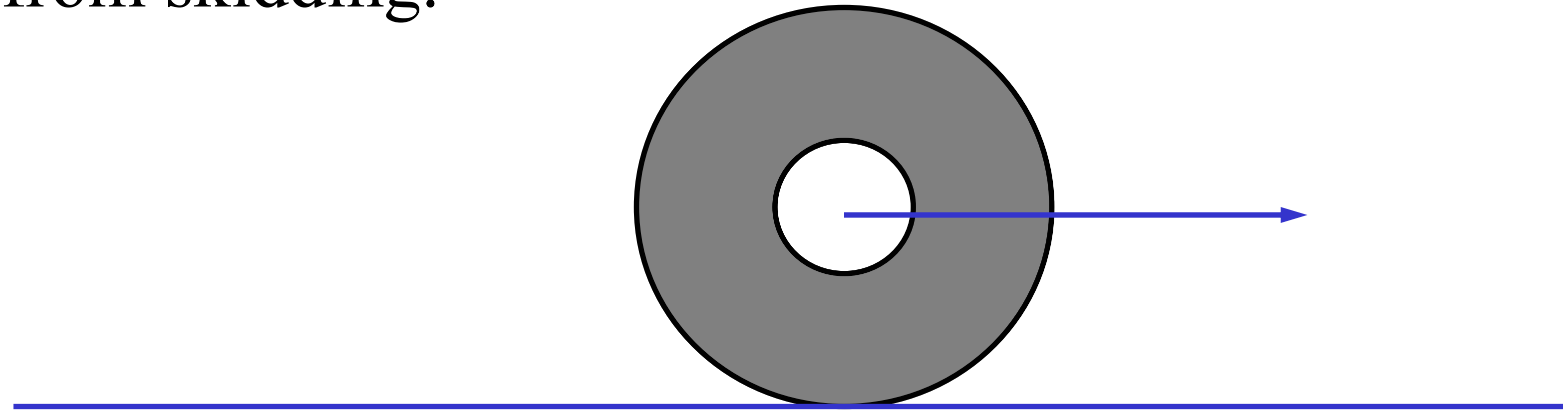
B) to the east

C) there is no friction because the crate is not sliding



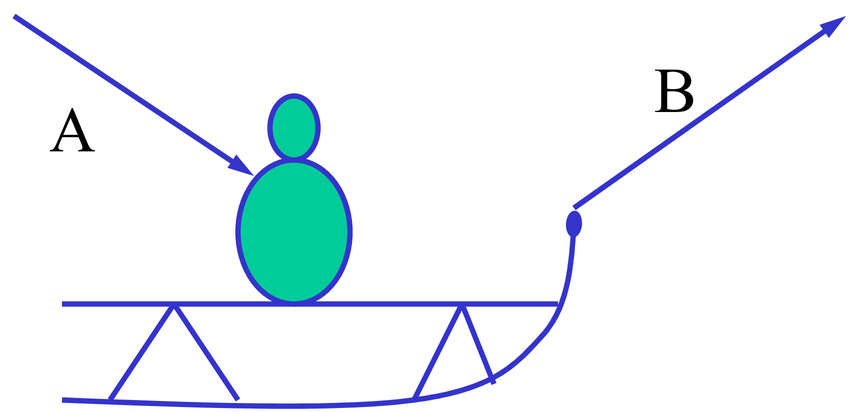
Food for thought

What causes an auto with anti-lock brakes to stop in a shorter distance than a car with regular brakes? The anti-lock brakes work by pulsing the brakes to keep the tires from skidding.



Daily Quiz, February 2, 2005

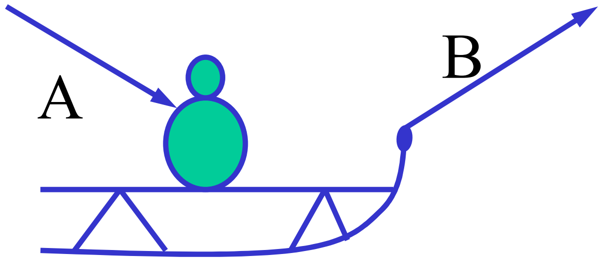
You are playing with your friend in the snow. He is sitting on a sled and asking you to slide him across a flat, horizontal field. You have a choice of pushing him on the shoulder with a force at 30^o below the horizontal, or pulling him with a rope with a force 30^o above the horizontal as shown in figure. Which way is easier for you?



A Quiz

Which way is easier for you?

1) pull him with the rope (B)
2) push him on the shoulder (A)
3) Both are equally hard
4) It was MY turn on the sled, that dirty, rotten ...

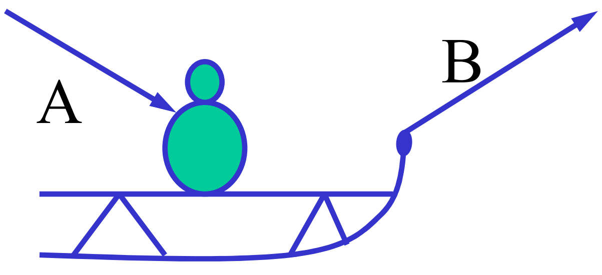


A Quiz

By pushing down, the Normal force is increased, thereby increasing the frictional force.

Which way is easier for you?

1) pull him with the rope (B)

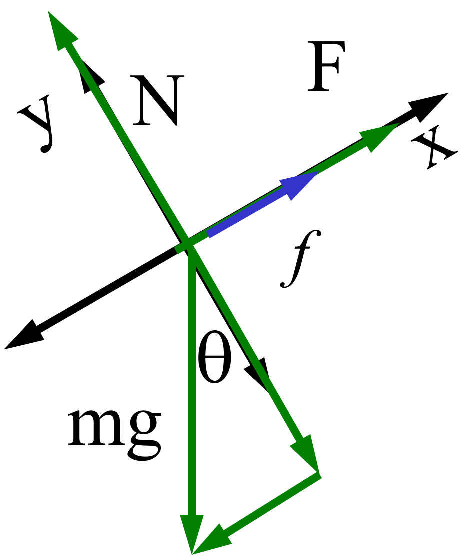


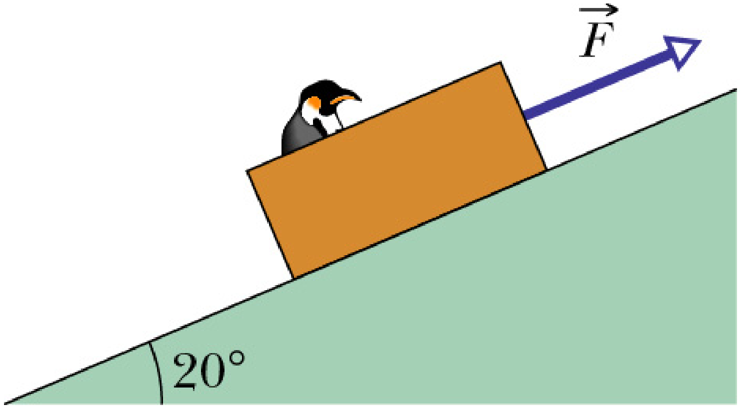
Problem 6-20

A loaded penguin sled weighing 80 N rests on a plane inclined at 20º to the horizontal . Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(a) What is the minimum magnitude of the force **F**, parallel to the plane, that will prevent the sled from slipping down the plane?

Set up free-body force diagram.



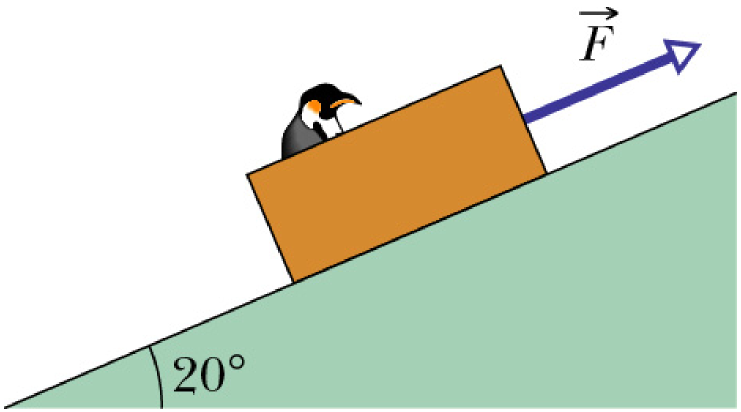


Notice that *f* is pointing with F because without F the penguin will slide *down* the plane.

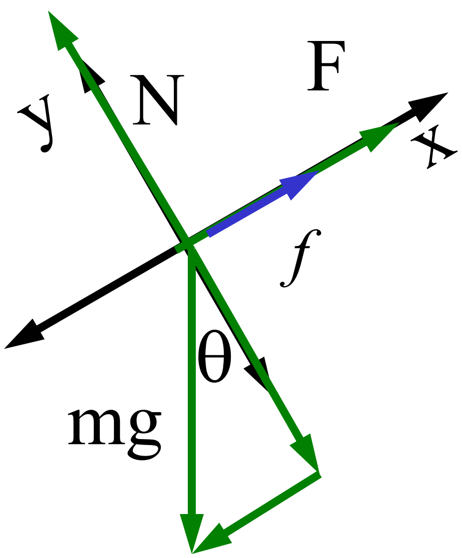
Problem 6-20

A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal . Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(a) What is the minimum magnitude of the force **F**, parallel to the plane, that will prevent the sled from slipping down the plane?



Set up free-body force diagram.



Apply Newton's Second Law

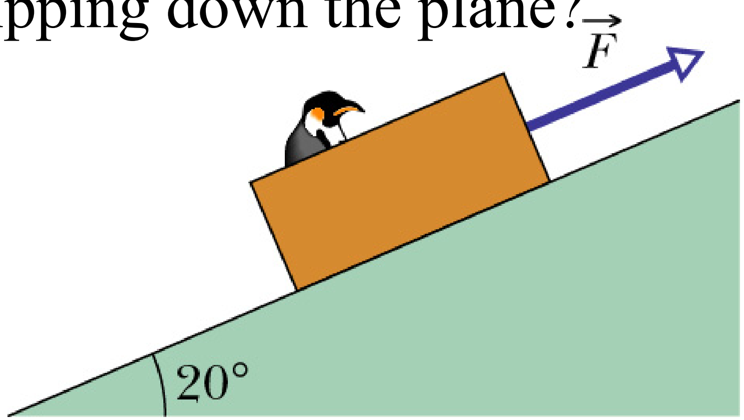
$$x: \quad F - mg\sin\theta + f_s$$
$$= F - mg\sin\theta + \mu_s N = 0$$

$$y: \quad N - mg\cos\theta = 0$$

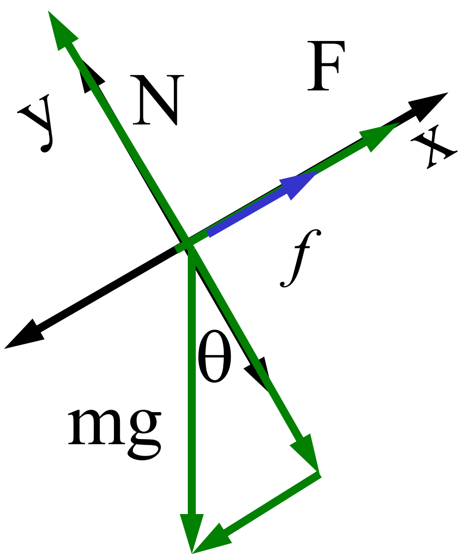
Problem 6-20

A loaded penguin sled weighing 80 N rests on a plane inclined at 20^{o} to the horizontal . Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(a) What is the minimum magnitude of the force **F**, parallel to the plane, that will prevent the sled from slipping down the plane?



Set up free-body force diagram.



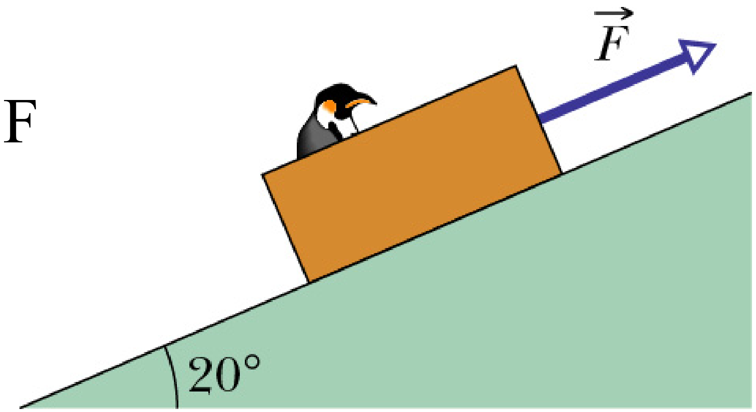
Apply Newton's Second Law

$$F = mg\sin\theta - \mu_s mg\cos\theta$$
$$= (80)\sin(20) - 0.25(80)\cos(20)$$
$$= 27.36\text{N} - 18.79\text{N} = 8.57\text{N}$$

Problem 6-20

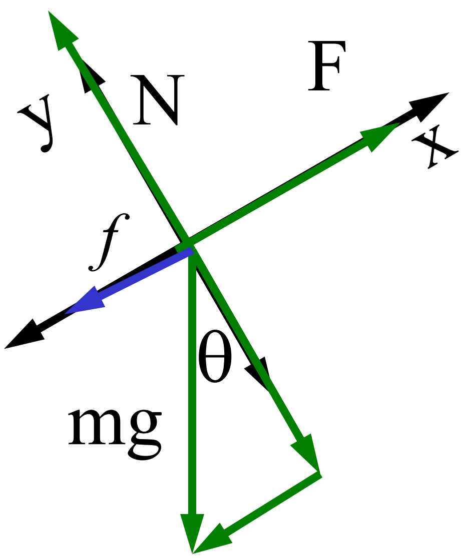
A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal . Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(b) What is the minimum magnitude **F** that will start the sled moving up the plane?



Now f points *down* the plane because F will cause motion *up* the plane

Set up free-body force diagram.

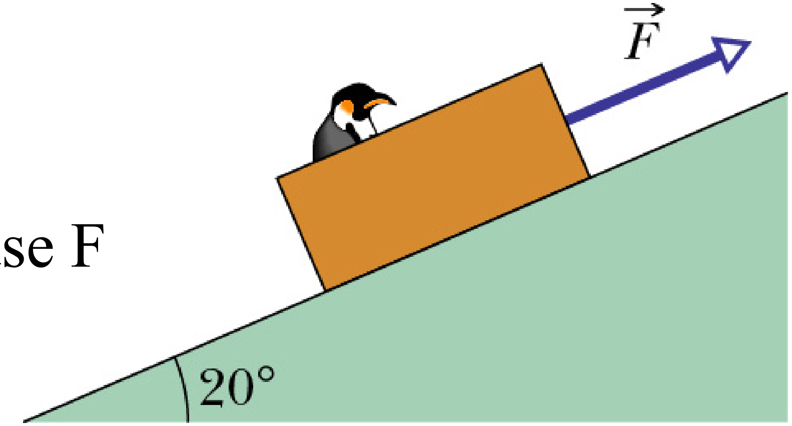


Apply Newton's Second Law

$$F = mg\sin\theta + \mu_s mg\cos\theta$$
$$= (80)\sin(20) + 0.25(80)\cos(20)$$
$$= 27.36\text{N} + 18.79\text{N} = 46.15\text{N}$$

Problem 6-20, continued

c) What value of **F** is required to move the sled up the plane at constant velocity?



Now *f* points *down* the plane because F causes motion *up* the plane

Constant velocity => zero acceleration => forces are balanced

$F = mg \sin\theta + \mu_k mg \cos\theta$

$= 27.36N + 11.28N = 38.64N$ will cause the sled to move up the inclined plane at constant velocity

Aerodynamic Drag

Notice that a dropped object will first accelerate and then keep descending at a constant velocity.

That means the acceleration decreased to zero, which means there had to be another force to counteract mg. This force is called "drag".

$|\vec{D}| = 1/2 C\rho A v^2$

C = drag coefficient
ρ = air density
A = cross sectional area
v = speed

$D - mg = ma = 0$

$\Rightarrow \tfrac{1}{2} C\rho A v_t^2 - mg = 0$

$$v_t = \sqrt{\frac{2mg}{C\rho A}}$$

Chapter 6: Uniform circular motion

- For uniform circular motion, the centripetal acceleration

  $$a = v^2/R$$

  which is caused by a force called centripetal force F

  $$F = ma = m(v^2/R)$$

  - direction of F: points radially inward
  - Centripedal force is <u>not</u> a new kind of force

Question: What are the centripetal forces exerted on the following object which are in uniform circular motion?

A) A ball attached to the end of a string

B) A satellite moving around the Earth

C) A car driving in a circle

D) A car driving in a circle on a tilted track

Question: What are the centripetal forces exerted on the following object which are in uniform circular motion?

A) A ball attached to the end of a string

tension on the string

B) A satellite moving around the Earth

Gravitational Force

C) A car driving in a circle

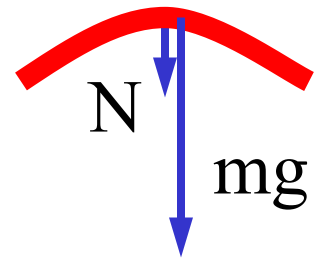
friction

D) A car driving in a circle on a tilted track

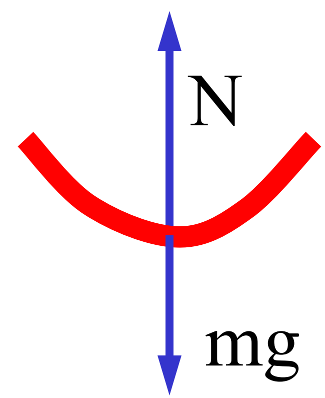
friction and gravitational force

When you ride in a Ferris wheel at constant speed, what are the directions of your acceleration a and the normal force N when you are:

(a) at the top of the wheel



$$\mathbf{N + mg = mv^2/r \implies N = mv^2/r - mg}$$



(b) at the bottom of the wheel

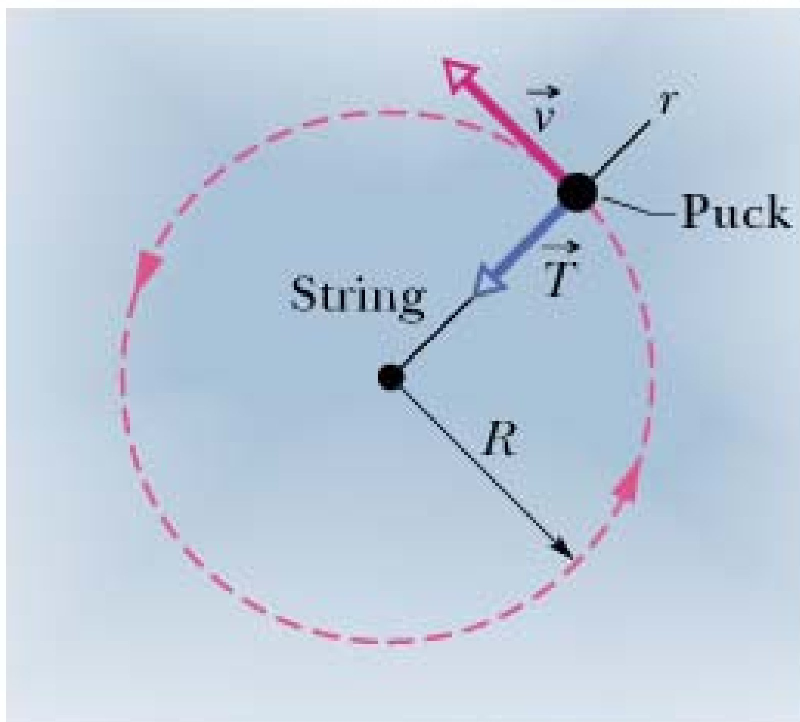
$$\mathbf{N - mg = mv^2/r \implies N = mg + mv^2/r}$$

(c) at which point, is the normal force the largest in magnitude?

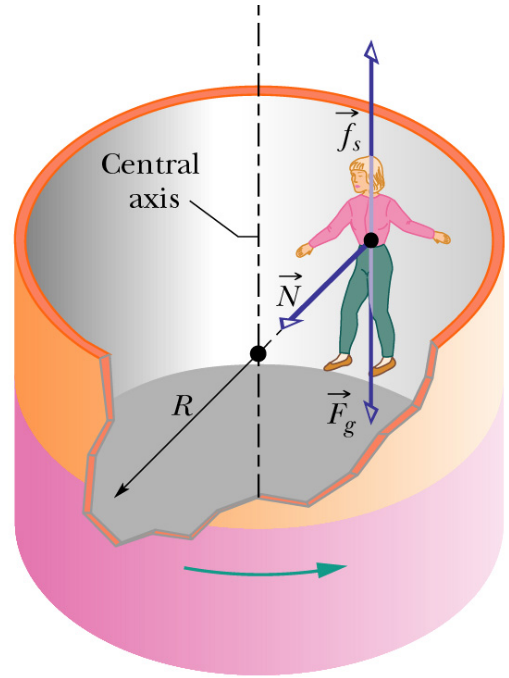
Definitely at the bottom!

tension on the string causes the object to move in a circle

$$\vec{a}_C = \frac{v^2}{R}$$



Example: (Sample problem 6-8 in the book) In the figure, a person is riding the Rotor. Suppose that the coefficient of static friction μ_s between the rider's clothing and the canvas is 0.4 and the cylinder's radius R is 2.1m.

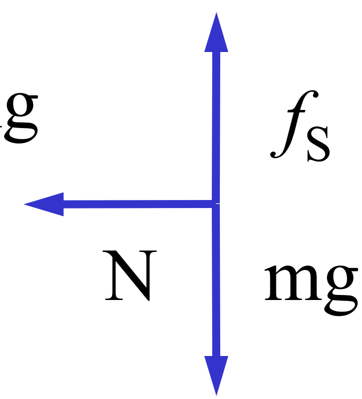


(A) What minimum speed v must the cylinder and rider have if the rider is not to fall when the floor drops.

$$\vec{N} = m\vec{a}_C = m\frac{v^2}{R} \qquad \vec{a}_C = \frac{v^2}{R}$$

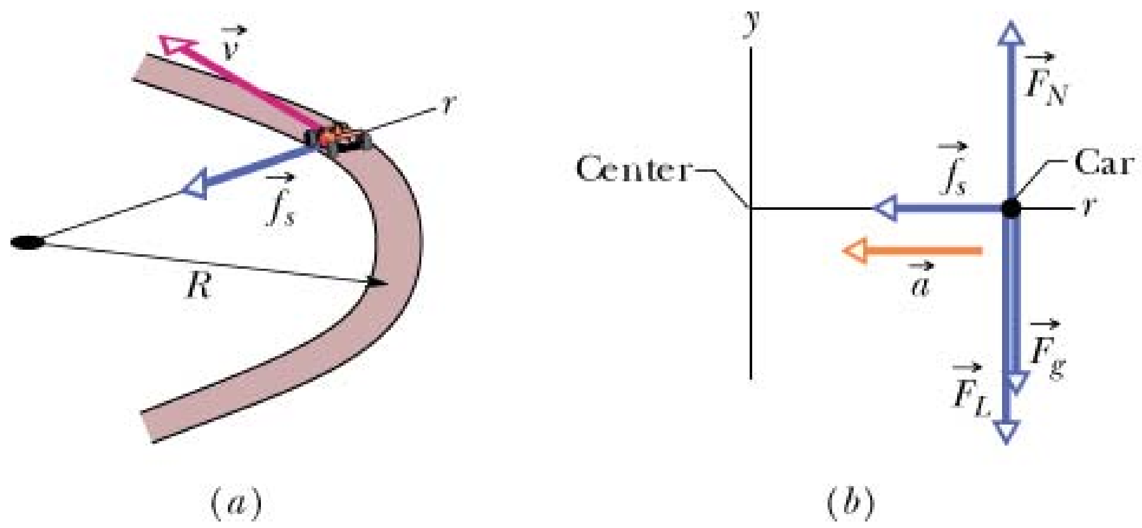
$$\mu_S m\frac{v^2}{R} = mg \qquad f_S = \mu_S N = mg$$

$$v = \sqrt{\frac{Rg}{\mu_S}} = 7.17\text{m/s}$$



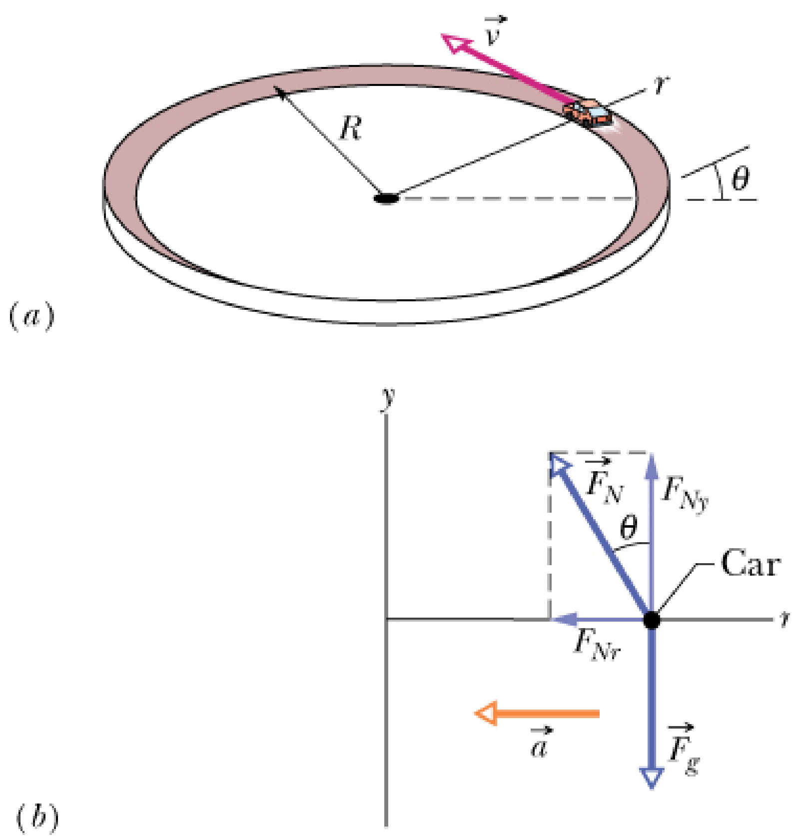
Car rounding a flat curve

Friction is causing the car to move in a circle.



Car rounding a banked curve

for the example in the book 6-10



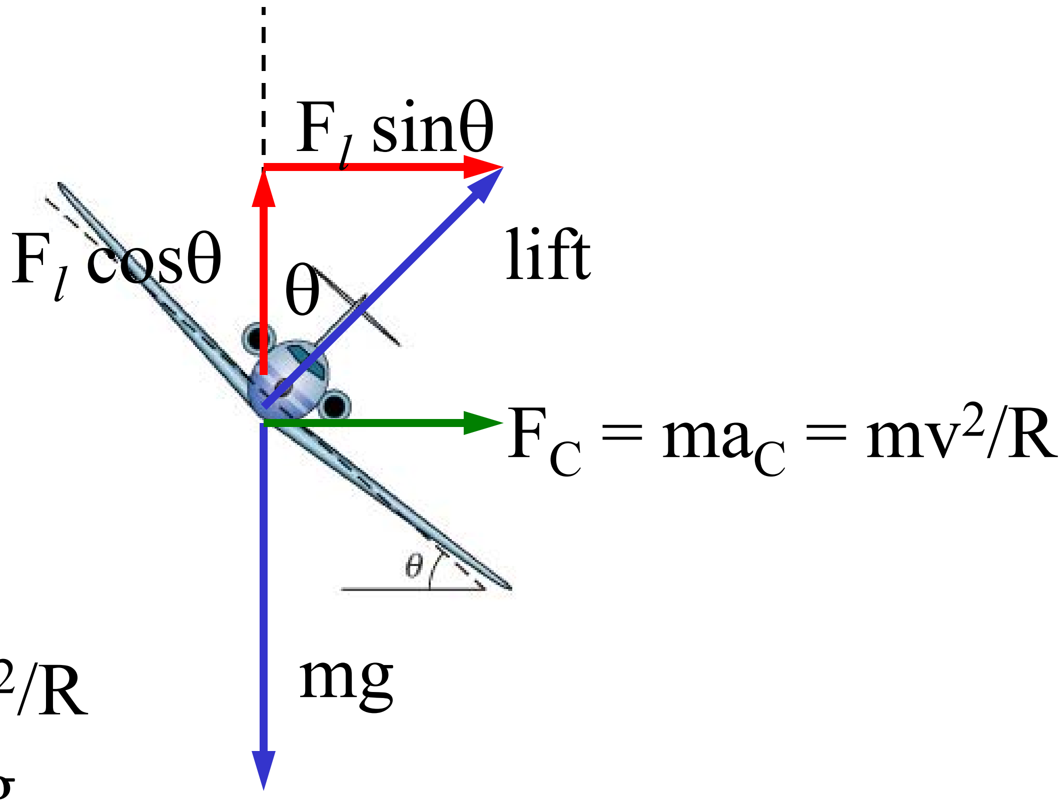
$$\underset{0}{\cancel{f_S}} + F_N = m\vec{a}_C = m\frac{v^2}{R}$$

$$\frac{F_{Nr} = F_N \sin\theta = m\dfrac{v^2}{R}}{F_{Ny} = F_N \cos\theta = mg}$$

$$\tan\theta = \frac{v^2}{gR}$$

Problem Chapter 06-47

v = 480 km/h and $\theta = 40^o$. What is the radius?



r: $F_l \sin\theta = mv^2/R$

y: $F_l \cos\theta = mg$

Problem 6-47 continued

47. The free-body diagram (for the airplane of mass m) is shown below. We note that $\vec{F}_\ell$ is the force of aerodynamic lift and $\vec{a}$ points rightwards in the figure. We also note that $|\vec{a}| = v^2 / R$ where $v = 480$ km/h $= 133$ m/s.

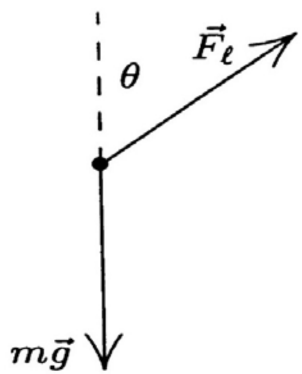
Applying Newton's law to the axes of the problem (+x rightward and +y upward) we obtain

$$\vec{F}_\ell \sin\theta = m\frac{v^2}{R}$$
$$\vec{F}_\ell \cos\theta = mg$$

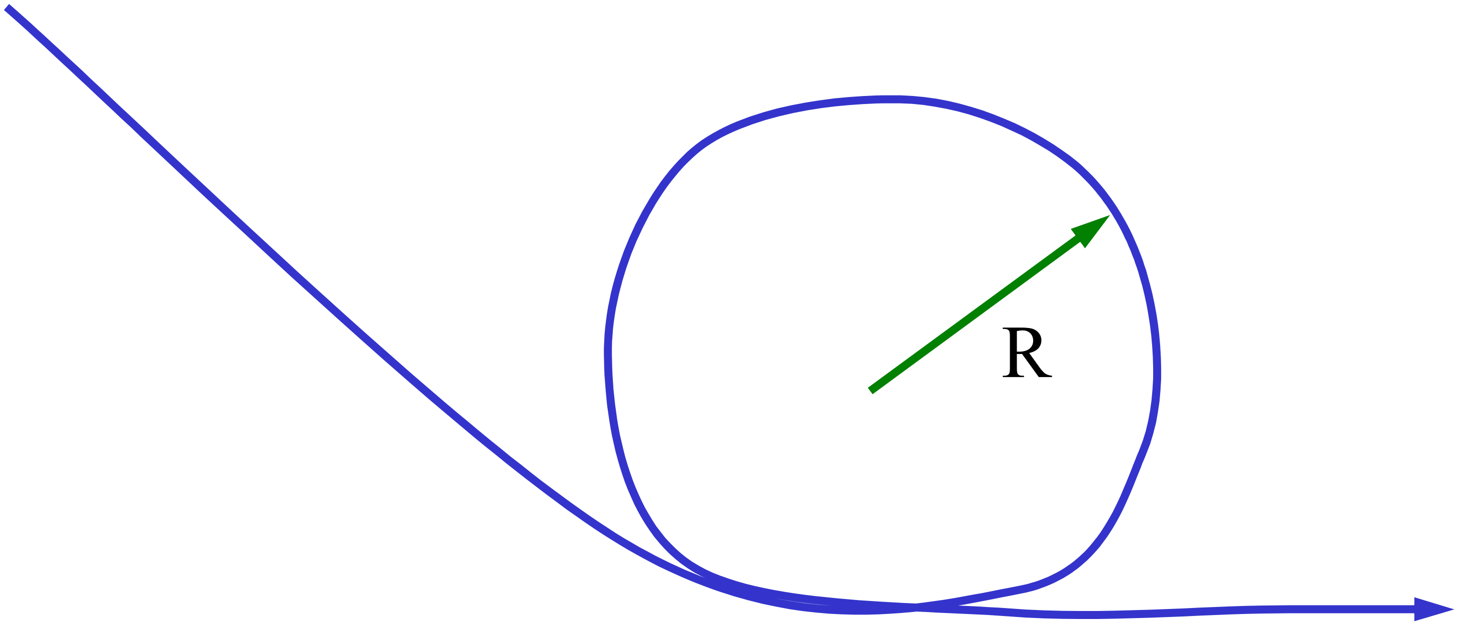
where $\theta = 40°$. Eliminating mass from these equations leads to

$$\tan\theta = \frac{v^2}{gR}$$

which yields $R = v^2/g \tan\,\theta = 2.2 \times 10^3$ m.



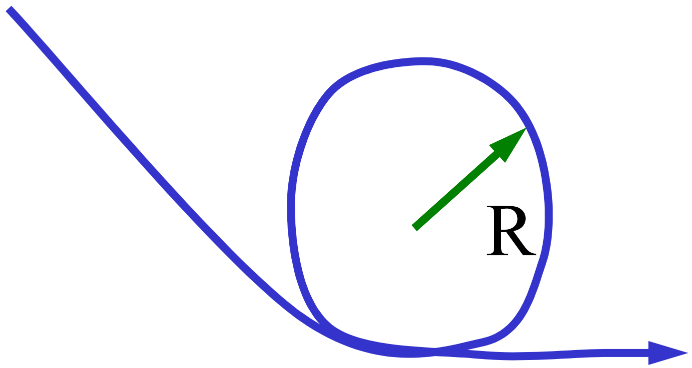
A Quiz



The "Corkscrew" ride at Cedar Point has an inverted section. Assume that the radius is 5 m. What is the minimum speed that must be maintained at the top to keep the car on the track? For this problem, let $g = 10\ m/s^2$

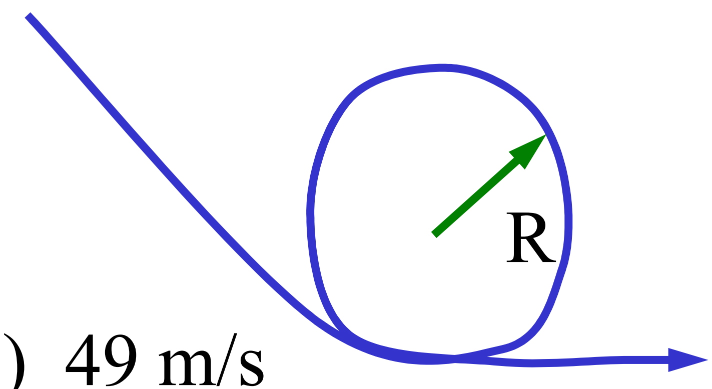
A Quiz

0) 0 m/s
1) 5 m/s
2) 7 m/s
3) 49 m/s
9) none of the above



The “Corkscrew” ride at Cedar Point has an inverted section. Assume that the radius is 5m. What is the minimum speed that must be maintained at the top to keep the car on the track? For this problem, let $g = 9.8\ m/s^2$

A Quiz

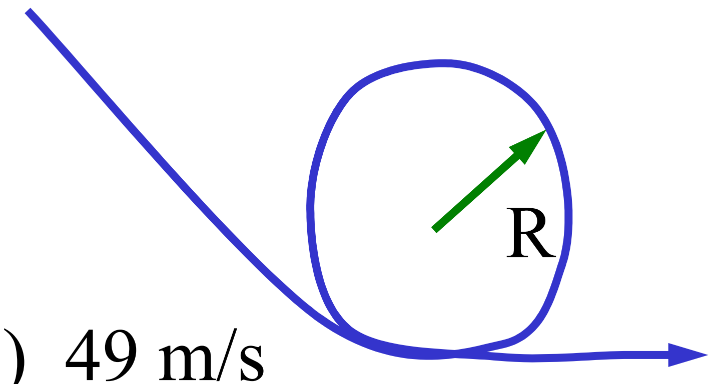


$v_{minimum} = ?$

0) 0 m/s 1) 5 m/s 2) 7 m/s 3) 49 m/s
9) none of the above

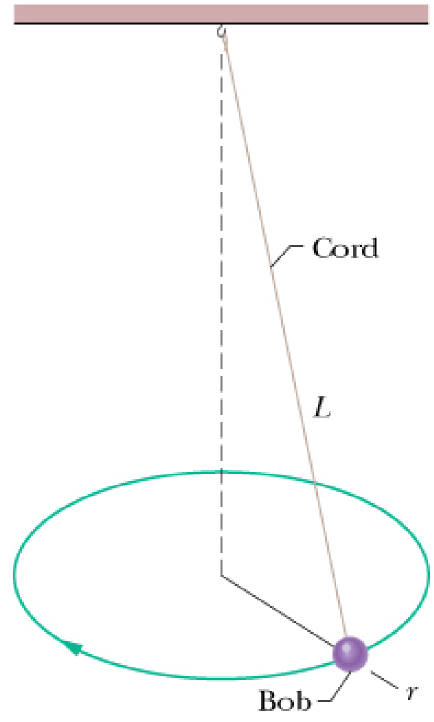
A Quiz

$$v_{minimum} = \sqrt{gR} = \sqrt{(9.8)(5)} = \sqrt{49} = 7.0 m/s$$



0) 0 m/s 1) 5 m/s 2) 7 m/s 3) 49 m/s
9) none of the above

Problem Chapter 06-52



m = 0.040 kg, L = 0.90m, circumference = 0.94 m.

Find:

A) String tension

B) period of motion