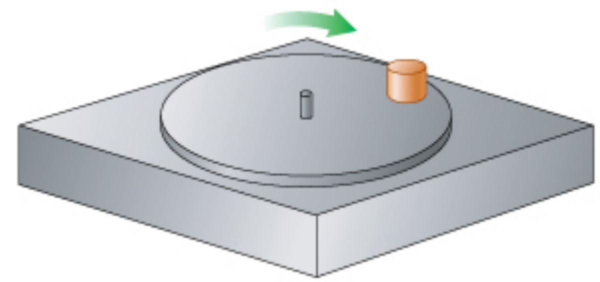
#15 Circular Motion Post-class

Due: 11:00am on Wednesday, September 26, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

± Mass on Turntable

A small metal cylinder rests on a circular turntable that is rotating at a constant speed as illustrated in the diagram .



The small metal cylinder has a mass of 0.20 kg, the coefficient of static friction between the cylinder and the turntable is 0.080, and the cylinder is located 0.15 m from the center of the turntable.

Take the magnitude of the acceleration due to gravity to be 9.81 $\mathrm{m/s^2}$.

Part A

What is the maximum speed $v_{\rm max}$ that the cylinder can move along its circular path without slipping off the turntable?

Express your answer numerically in meters per second to two significant figures.

Hint 1. Centripetal acceleration

If you know a body is in uniform circular motion, you know what its acceleration must be. If a body of mass m is traveling with speed v in a circle of radius R, what is the magnitude $a_{\rm c}$ of its centripetal acceleration?

ANSWER:

- $\frac{mv^2}{R}$
- mv^2R
- v^2R
- $\frac{v^2}{R}$

Hint 2. Determine the force causing acceleration

Whenever you see uniform circular motion, there is a real force that causes the associated centripetal acceleration. In this problem, what force causes the centripetal acceleration?

ANSWER:

- normal force
- static friction
- weight of cylinder
- a force other than those above

Hint 3. Find the maximum possible friction force

The magnitude f_s of the force due to static friction satisfies $f_s \le f_{max}$. What is f_{max} in this problem?

Express your answer numerically in newtons to three significant figures.

ANSWER:

f_{max} = 0.157 N

Hint 4. Newton's 2nd law

To solve this problem, relate the answers to the previous two hints using Newton's 2nd law:

$$\vec{F} = m\vec{a}.$$

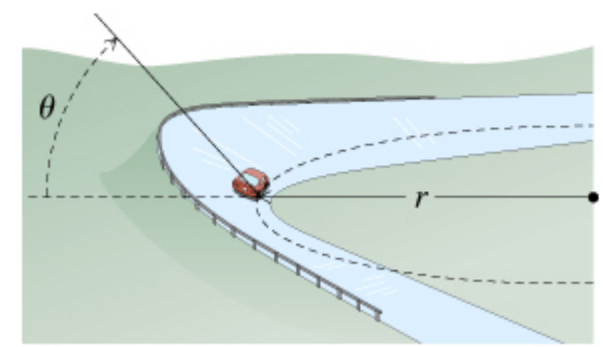
ANSWER:

v_{max} = 0.34 $\mathrm{m/s}$

Correct

± Banked Frictionless Curve, and Flat Curve with Friction

A car of mass M = 1300kg traveling at 60.0$\mathrm{km/hour}$ enters a banked turn covered with ice. The road is banked at an angle θ, and there is no friction between the road and the car's tires. . Use g = 9.80$\mathrm{m/s^2}$ throughout this problem.



Part A

What is the radius r of the turn if θ = 20.0° (assuming the car continues in uniform circular motion around the turn)?

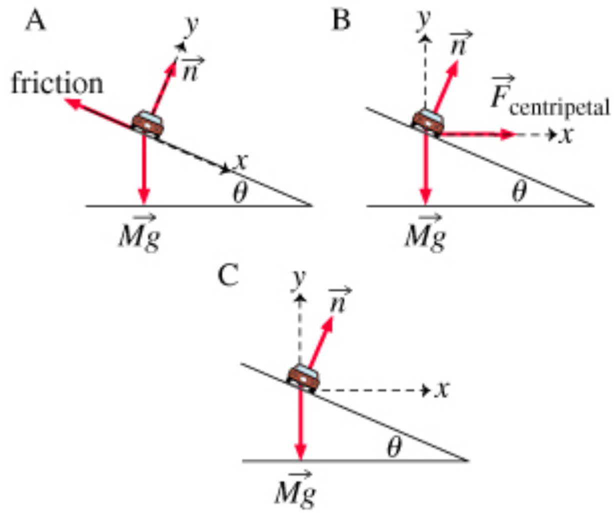
Express your answer in meters.

Hint 1. How to approach the problem

You need to apply Newton's 2nd law to the car. Because you do not want the car to slip as it goes around the curve, the car needs to have a net acceleration of magnitude v^2/r pointing radially inward (toward the center of the curve).

Hint 2. Identify the free-body diagram and coordinate system

Which of the following diagrams represents the forces acting on the car and the most appropriate choice of coordinate axes?



ANSWER:

- Figure A
- Figure B
- Figure C

Hint 3. Calculate the normal force

Find n, the magnitude of the normal force between the car and the road. Take the positive *x* axis to point horizontally toward the center of the curve and the positive *y* axis to point vertically upward.

Express your answer in newtons.

Hint 1. Consider the net force

The only forces acting on the car are the normal force and gravity. There must be a net acceleration in the horizontal direction, but because the car does not slip, the net acceleration in the *vertical* direction must be zero. Use this fact to find n.

Hint 2. Apply Newton's 2nd law to the car in the *y* direction

Which equation accurately describes the equation for the net force acting on the car in the *y* direction?

ANSWER:

- $\sum F_y = n\cos\theta + Mg$
- $\sum F_y = n\sin\theta + Mg$
- (selected) $\sum F_y = n\cos\theta - Mg$
- $\sum F_y = n\sin\theta - Mg$

ANSWER:

n = 1.36×10^{4} N

Hint 4. Determine the acceleration in the horizontal plane

Take the *y* axis to be vertical and let the *x* axis point horizontally toward the center of the curve. By applying $\sum F_x = Ma$ in the horizontal direction, determine a, the magnitude of the acceleration, using your result for the normal force.

Express your answer in meters per second squared.

Hint 1. Apply Newton's 2nd law to the car in the *x* direction

Which equation accurately describes the equation for the net force acting on the car in the *x* direction?

ANSWER:

- $\sum F_x = n\cos\theta$
- $\sum F_x = n\sin\theta$
- $\sum F_x = n\cos\theta + \frac{Mv^2}{r}$
- $\sum F_x = n\cos\theta - \frac{Mv^2}{r}$

ANSWER:

a = 3.57 $\mathrm{m/s^2}$

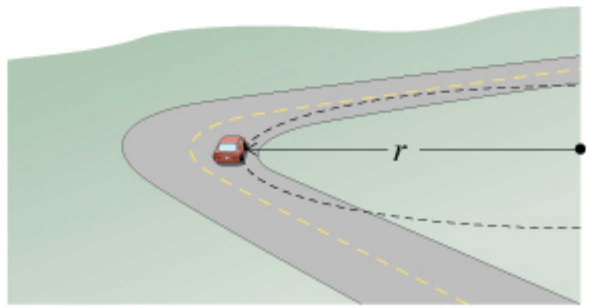
ANSWER:

r = 77.9 m

Correct

Part B

Now, suppose that the curve is level ($\theta = 0$) and that the ice has melted, so that there is a coefficient of static friction μ between the road and the car's tires. What is $\mu_{\rm min}$, the minimum value of the coefficient of static friction between the tires and the road required to prevent the car from slipping? Assume that the car's speed is still 60.0$\rm km/hour$ and that the radius of the curve is given by the value you found for r in Part A.



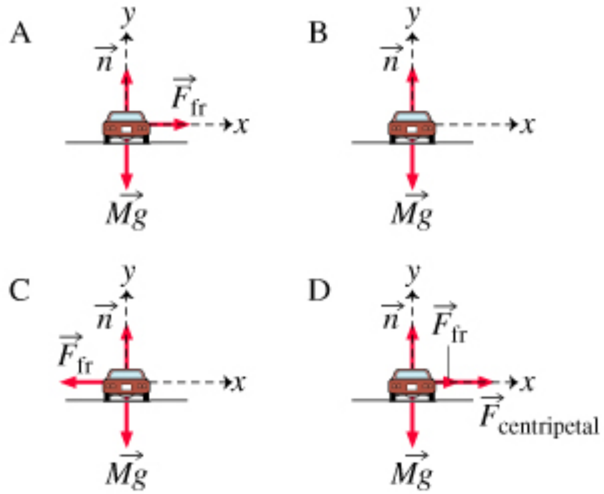
Express your answer numerically.

Hint 1. How to approach the problem

You need to apply Newton's 2nd law to the car. Because you do not want the car to slip as it goes around the curve, the car needs to have a net acceleration of magnitude v^2/r pointing radially inward (toward the center of the curve).

Hint 2. Identify the correct free-body diagram

Which of the following diagrams represents the forces acting on the car as it goes around the curve? $F_{\rm fr}$ represents the friction force.



ANSWER:

- Figure A
- Figure B
- Figure C
- Figure D

Hint 3. Calculate the net force

What is the net force F_{net} that acts on the car?

Express your answer in newtons.

Hint 1. How to determine the net force

Newton's 2nd law tells you that

$$\sum \vec{F} = m\vec{a}.$$

Because you do not want the car to slip as it goes around the curve, the car needs to have a net acceleration of magnitude v^2/r pointing radially inward (toward the center of the curve).

ANSWER:

F_{net} = 4640 N

Hint 4. Calculate the friction force

If the coefficient of friction were equal to μ_{min}, what would be F_{fr}, the magnitude of the force provided by friction? Let m be the mass of the car and g be the acceleration due to gravity.

Hint 1. Equation for the force of friction

The force of friction is given by

$$F_{fr} = \mu n.$$

Hint 2. Find the normal force

What is the normal force n acting on the car?

Enter your answer in newtons.

Hint 1. Acceleration in the *y* direction

Because the car is neither sinking into the road nor levitating, you can conclude that $a_y = 0$.

ANSWER:

n = 1.27×10^4 N

ANSWER:

- ○ $F_{\rm fr} = \dfrac{\mu_{\rm min}}{Mg}$
- ◉ $F_{\rm fr} = \mu_{\rm min} M g$

ANSWER:

$\mu_{\rm min}$ = 0.364

Correct

Exercise 5.54

A small button placed on a horizontal rotating platform with diameter 0.328$\rm m$ will revolve with the platform when it is brought up to a rotational speed of 42.0$\rm rev/min$, provided the button is a distance no more than 0.143$\rm m$ from the axis.

Part A

What is the coefficient of static friction between the button and the platform?

ANSWER:

0.282

Correct

Part B

How far from the axis can the button be placed, without slipping, if the platform rotates at 64.0 $\mathrm{rev/min}$?

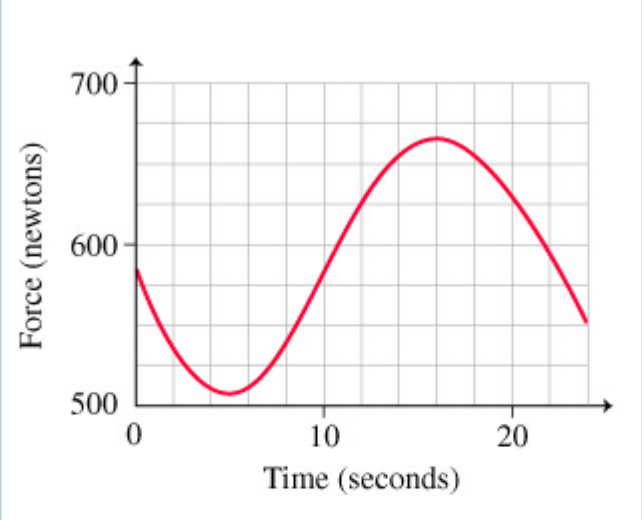
ANSWER:

6.16×10^{-2} m

Correct

± A Ride on the Ferris Wheel

A woman rides on a Ferris wheel of radius 16 m that maintains the same speed throughout its motion. To better understand physics, she takes along a digital bathroom scale (with memory) and sits on it. When she gets off the ride, she uploads the scale readings to a computer and creates a graph of scale reading versus time. Note that the graph has a minimum value of 510 N and a maximum value of 666 N .



Part A

What is the woman's mass?

Express your answer in kilograms.

Hint 1. How to approach the problem

The woman is moving in a circle with constant speed. To maintain this motion she must experience a net acceleration (called centripetal acceleration) directed toward the center of the Ferris wheel.

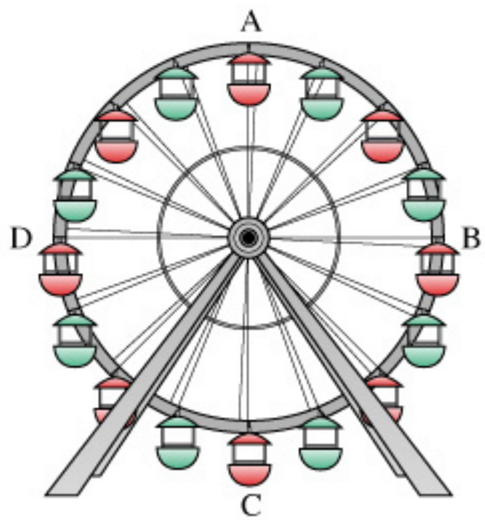
Draw and analyze the woman's free-body diagram at a wisely chosen point on the circular path and use Newton's 2nd law to determine her mass.

Hint 2. Find the extreme points on the circular path

The bathroom scale does not record the gravitational force acting on the woman. If it did, the reading would not vary as she rides the Ferris wheel. Instead, the scale records the normal force acting on the woman, which can vary as she moves along the circular path and experiences different accelerations. This normal force is sometimes referred to as an *apparent weight*, because it mimics the feelings of being heavier or lighter.

Note that the normal force is equal in magnitude to the gravitational force on the flat surface of the earth, so the *apparent weight* is just called the *weight* in this static situation.

As the woman travels along the circular path, her apparent weight fluctuates between a maximum value and a minimum value. At what location (A - D) will the apparent weight be a maximum? Where will it be a minimum?



Enter the letters that correspond to the correct positions separated by a comma.

Hint 1. Analyze the free-body diagram

Draw a free-body diagram for the woman. Assume that the $+y$ direction points vertically upward. Which of the following statements are true for *every* point on the circle traveled by the woman?

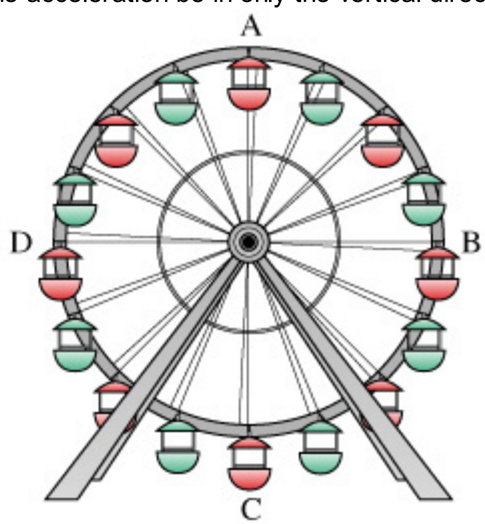
Check all that apply.

ANSWER:

- [ ] The gravitational force acting on the woman points in the $+y$ direction.
- [x] The gravitational force acting on the woman points in the $-y$ direction.
- [x] The magnitude of the gravitational force acting on the woman is constant.
- [x] The normal force points in the $+y$ direction.
- [ ] The normal force points in the $-y$ direction.
- [ ] The magnitude of the normal force is constant.

Hint 2. Analyze the acceleration

At all times during the woman's motion, she experiences a net acceleration (called centripetal acceleration) directed toward the center of the Ferris wheel. At what location (A - D) will the acceleration be in only the vertical direction?



Check all that apply.

ANSWER:

- [x] A
- [ ] B
- [x] C
- [ ] D

Hint 3. Applying Newton's 2nd law

Since the normal force and graviational force are the only forces acting on the woman in the vertical (*y*) direction,

$$(\sum F)_y = n - mg = ma_y,$$

where n and mg are the magnitudes of the normal force and the gravitational force, respectively.

Apply what you know about the acceleration of the woman in the *y* direction at certain points along the circular path to determine when n will be a maximum or minimum.

ANSWER:

C,A

Hint 3. Find the acceleration of the woman

What is the acceleration a_c of the woman?

Express your answer in meters per second squared.

Hint 1. How to approach the problem

You can use the information from the problem statement and the graph to determine the woman's speed. This can be used to find her centripetal acceleration:

$$a_c = \frac{v^2}{r}.$$

Hint 2. Find the woman's speed

What is the speed v of the woman?

Express your answer in meters per second.

Hint 1. Determining the speed

Since the Ferris wheel turns at constant speed, the distance d the woman travels during some time interval is given by $d = vt$, where v is the speed and t is the time. For a complete cycle, the distance traveled is the circumference of the Ferris wheel and the time required is one period T. Thus for a Ferris wheel of radius R,

$$v = \frac{(2\pi R)}{T}.$$

Hint 2. Find the period

The easiest way to determine the speed of the woman is to calculate the distance she travels during one complete cycle of motion and divide this by the time that it takes to complete this cycle. The time for a complete cycle is called the period T. What is the period of the Ferris wheel?

Express your answer in seconds.

ANSWER:

T = 22 s

ANSWER:

v = 4.57 $\mathrm{m/s}$

ANSWER:

a_c = 1.31 $\mathrm{m/s^2}$

ANSWER:

m = 60 kg

Correct

Score Summary:

Your score on this assignment is 106.6%.
You received 42.65 out of a possible total of 40 points.