D1

What is providing the centripetal force

When an object is moving in a circular part, or a path which is part of a circle (like a car making a turn), the direction of the acceleration is toward the center of the circle. The net force on the object must also be toward the center of the circle. The force on the object directed toward the center of the circle causing the object to move in a circular path is called the centripetal force.

In the following situations, identify the centripetal force.

Centripetal force

1. A ball (the object) attached to a string is being swung in a circular path.

2. The Earth (the object) moves in a nearly circular path around the Sun.

3. A toboggan moves in a circular path along a banked wall around a turn.

4. A car (the object) moves in a circular path around a turn.

5. A person (the object) in the passenger's seat of a car feels pushed up against the door as the car takes a sharp turn.

What would happen if . . .

. . . the string in (1) were broken?

. . . there was suddenly no friction between the car in (4) and the road?

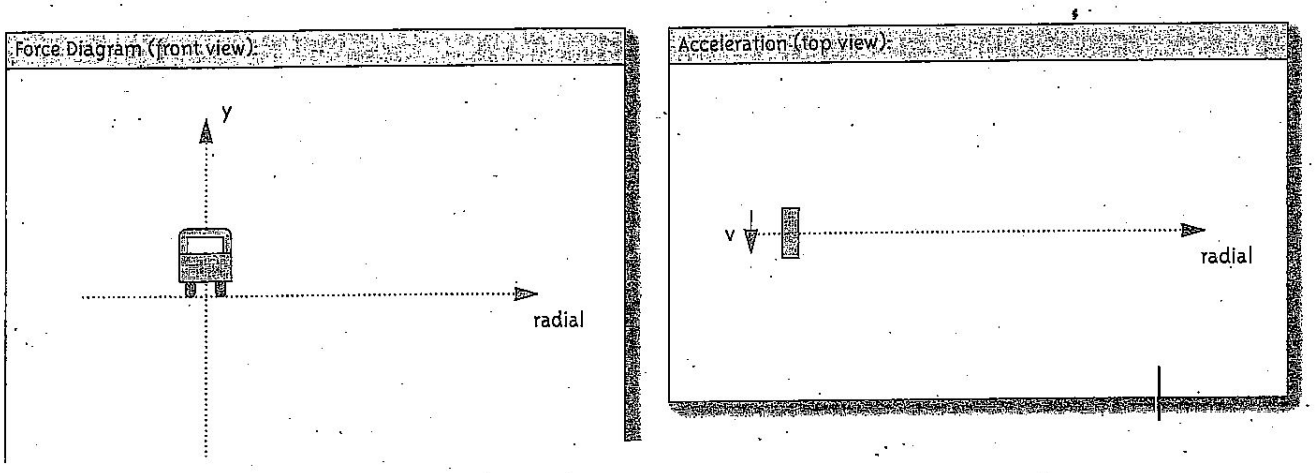
. . . the door in (5) was suddenly opened?

Newton's third law and centrifugal force.

1. If the string exerts an inward force on the ball, then the ball . . .

5. If the car door exerts an inward force on the person, then the person . . .

A 1000-kg car moves at a maximum speed so that it does not skid off the 50-m radius level track. If the coefficient of static friction between the road and wheels is 0.80, what is the maximum speed? Assume that the gravitational constant is 10.0 N/kg = 10.0m/s.



The Department of Transportation wants to build a road that can accommodate cars making a turn at a speed of 22 m/sec. What must be the radius of the turn? (The coefficient of friction is still .8.)

PHY 111 **Introduction to gravity/ orbital motion**

There is a force of gravity between <u>any two</u> objects.

The force of gravity between any two objects is given by Newton's Universal law of gravitation:

$$F_{grav} = G\frac{m_1 m_2}{r^2}.$$

G is called the universal gravitational constant. $G = 6.67 \times 10^{-11}$ (units?)

- (Question: What is meant by "universal"?)

- Use this law to find the force between the Earth and a 1-kg mass located at the surface of the Earth.

$R_{\text{Earth}} = 6.37 \times 10^6$ m $\qquad$ $M_{\text{Earth}} = 5.975 \times 10^{24}$ kg

- Question: Why is the value of the universal gravitational constant so small?

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1. What is the speed of the Earth as the earth travels around the sun in m/s? (Approximately, what is the speed in mph?)

Distance from Earth to sun =

2. If our velocity is so great, why don't we feel the motion?

3. What is the force required to keep the Earth in a "circular" path around the Sun? (How do you calculate the force needed to keep any object in circular motion?)
What is the source of this force?

4. Check: According to Newton's Universal law of gravitation, what is the force of gravity between the earth and the sun?

5. Compare the answers to question 3 and 4. What can you conclude?

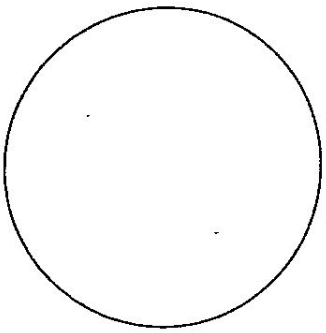
PHY 111 $1/r^2$ Law: Gravitational Force

As an object moves further from a planet or star, the force of gravity between that planet and the object diminishes according to the $1/r^2$ law.

A person standing on the surface of the Earth weighs 160 lbs. On the surface of the Earth, you are 4000 miles from the Earth's center.

When you are 4000 miles above the surface of the Earth, you are actually 8000 miles from the Earth's center.

Find the person's weight at the various distances above the Earth's surface.



Distance from surface (miles)	0	4000	8000	12000	16000
Distance from center (miles)	4000				
Person's weight (lbs.)	160				

According to this law, can an object be truly weightless? Explain.

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PHY 111 Orbiting the Earth

$$F_{grav} = G\frac{m_1 m_2}{r^2}.$$

1. Use the above expression to find the force of gravity between the Earth and a 100-kg located 200 miles above the surface of the Earth.
(The radius of the Earth is 6.37×10^6 m. 1 mile = 1609 m.)

Note: Is this force much different than the force of gravity at the surface of the Earth?
(Find the force of gravity at the surface. Use $W = mg$. g = 9.8 m/sec^2.)

2. A 100-kg satellite is orbiting the Earth 200 miles above the Earth's surface.
a) Draw a force diagram on that object.

b) What is the centripetal force on the satellite?
Use the centripetal force to find the velocity of the satellite in orbit.

c) Use $v = \frac{2\pi R}{T}$ to find the period of the satellite at an altitude of 200 miles above the Earth.
(Would the period be different if the satellite had a different mass?)

PHY 111 Gravity on the Moon/Period of the Moon's orbit around the Earth

Using the universal law of gravitation, we can calculate the acceleration of gravity on the moon as well as the period of the moon's orbit around the Earth.

1. Knowing the mass and radius of the moon, find the acceleration of gravity at the surface of the moon.

mass of moon = 7.36×10^{22} kg radius of moon = 1.74×10^{6} m

Hint: Finding the acceleration of gravity at the surface of the moon is the same as finding the gravity force between _____.

2. We will calculate the period of the moon in orbit around the Earth.

a) The centripetal force acting on the moon is the same as the force of _____ acting on the moon. Find the centripetal force acting on the moon.

Distance from center of moon to center of Earth: 3.84×10^{8} m

b) Knowing the centripetal force acting on the moon, find the velocity of the moon in orbit.

c) Find the period of the moon in orbit. Express in days

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PHY 111 **Planetary calculations**

Name of your assigned planet: _____

mass = kg radius = m

distance from the sun = m

For your planet, determine
a) the force on a 1-kg object at the planet's surface.

b) the acceleration of gravity at the planet's surface (not a difficult question if you know the answer to part (a) above.

c) the gravitational attractive force between the sun and the planet.

d) Knowing the gravitational force, the mass of the planet and the radius of orbit, find the speed of the planet as it goes around the sun.

f) Knowing the answers to parts (d) and (e), find the time it takes in seconds for the planet to make one full revolution around the Sun. Convert the time from seconds into years (Earth years). If less than 1 year, convert the time into days (that means Earth days).

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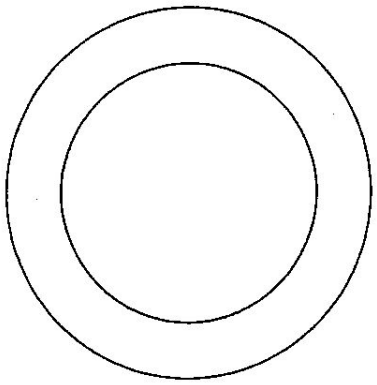
PHY 111 Space station

There is evidence that the bone density of astronauts decreases after a prolonged time in a zero gravity environment.

It has been proposed that a feeling a gravity could be created (called artificial gravity) by building a space station that rotates along the model of a spinning bicycle wheel.

a) Draw a diagram of how the person would stand on the floor of the space station (at the 3 o'clock position) such that the normal force of the floor would push up on an astronaut's feet as he stood. Draw the force diagram for the astronaut.



b) How is the force diagram for this person like the force diagram for a person standing on the floor of an ordinary room? How is it different?

c) This person holds a ball and releases it. Show how the ball travels after he releases it.

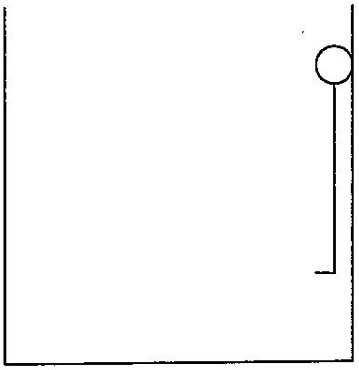
d) If the space station has a radius of 40 m, at what velocity would the space station have to spin so that the normal force on a 50 kg person would be 500 N?

e) At this speed, what would be the period for one rotation of the space station?

PHY 111 **The Spinning Room**

Amusement park rides are fun, not because of speed, but because of acceleration. A particular amusement park ride consists of a rotating cylindrical chamber whose radius is 3 meters. The park advertises that once the chamber is spinning at full speed, the rider feels a centripetal acceleration of 2 "g's", that is the centripetal force is equal twice the acceleration of gravity.

(a) Draw a force diagram showing the forces on a person spinning in the chamber.



(b) With what velocity (m/s) will the person in the chamber be spinning?

$$a = \frac{v^2}{r}$$

(c) What is the time for one revolution of the chamber?

(d) A feature of this ride is that at one point the floor of the chamber lowers and the rider is "stuck" to the wall. What is the minimum coefficient of static friction necessary for this to happen when the chamber is spinning at the rate you found in part (b)?

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PHY 111 **A special orbit: The Clarke Belt**

A special orbit around the earth is located at a radius of 6.62 times the Earth's radius.

Radius of Earth is 6.37×10^6 m.

a) A 50 kg satellite is in orbit in the Clarke belt. What is the gravitational force on that satellite?

Side question: What is the gravitational force on the satellite at this distance compared to the gravitational force on the satellite at the surface of the Earth?

b) What is the velocity of the satellite?

c) What is the period of the satellite?

Side question? Could a satellite be stationary over the North Pole? Over Phoenix?

Side question? The actual satellite period is 23 hr 56 min instead of 24 hr. Why?