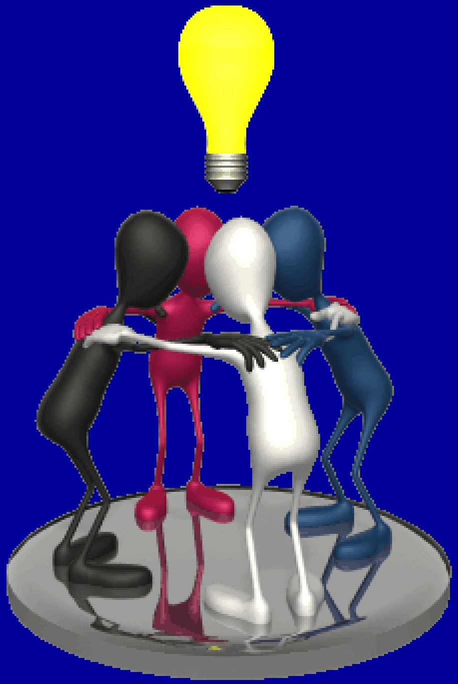
S-23

These are rather dumb people sliding down a slope for fun. What is their velocity after 5 seconds if the slope has an angle of 48o, they start with an initial speed of 0 m/s and the coefficient of kinetic friction is 0.5?

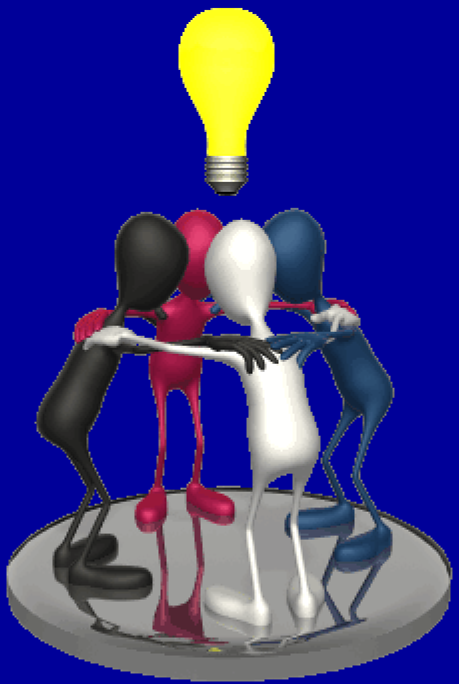
Circular Motion; Gravitation



AP Physics

Chapter 5

Circular Motion; Gravitation



5.1 Kinematics of Uniform Circular Motion

Standard

1E1

Students should understand the uniform circular motion of a particle, so they can

Students should understand the uniform circular motion of a particle, so they can:

a) Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

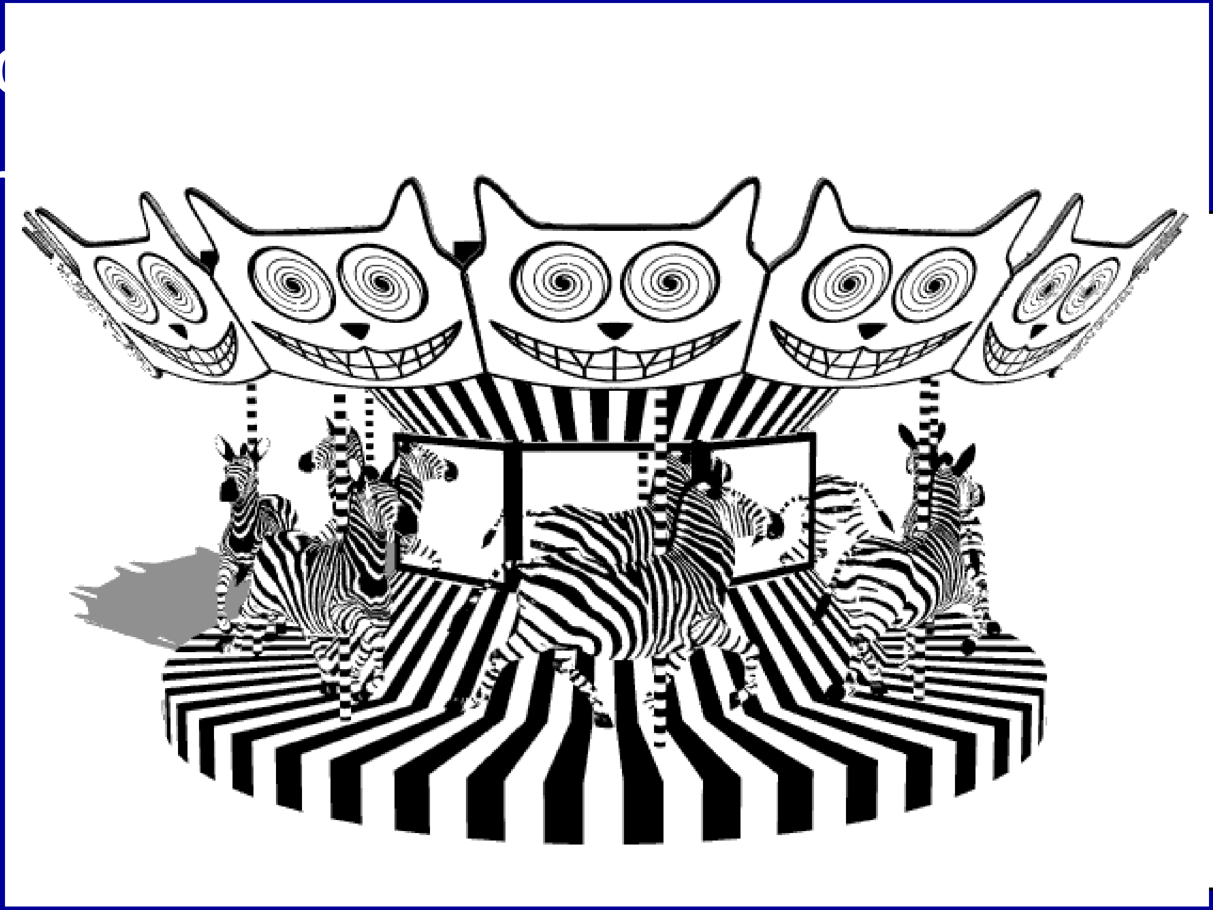
5.1 Kinematics of Uniform Circular Motion

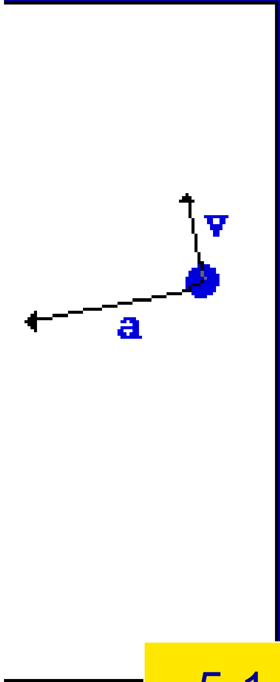
Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Uniform Circular Motion – moves in a circle at a constant speed

Magnitu

Direction



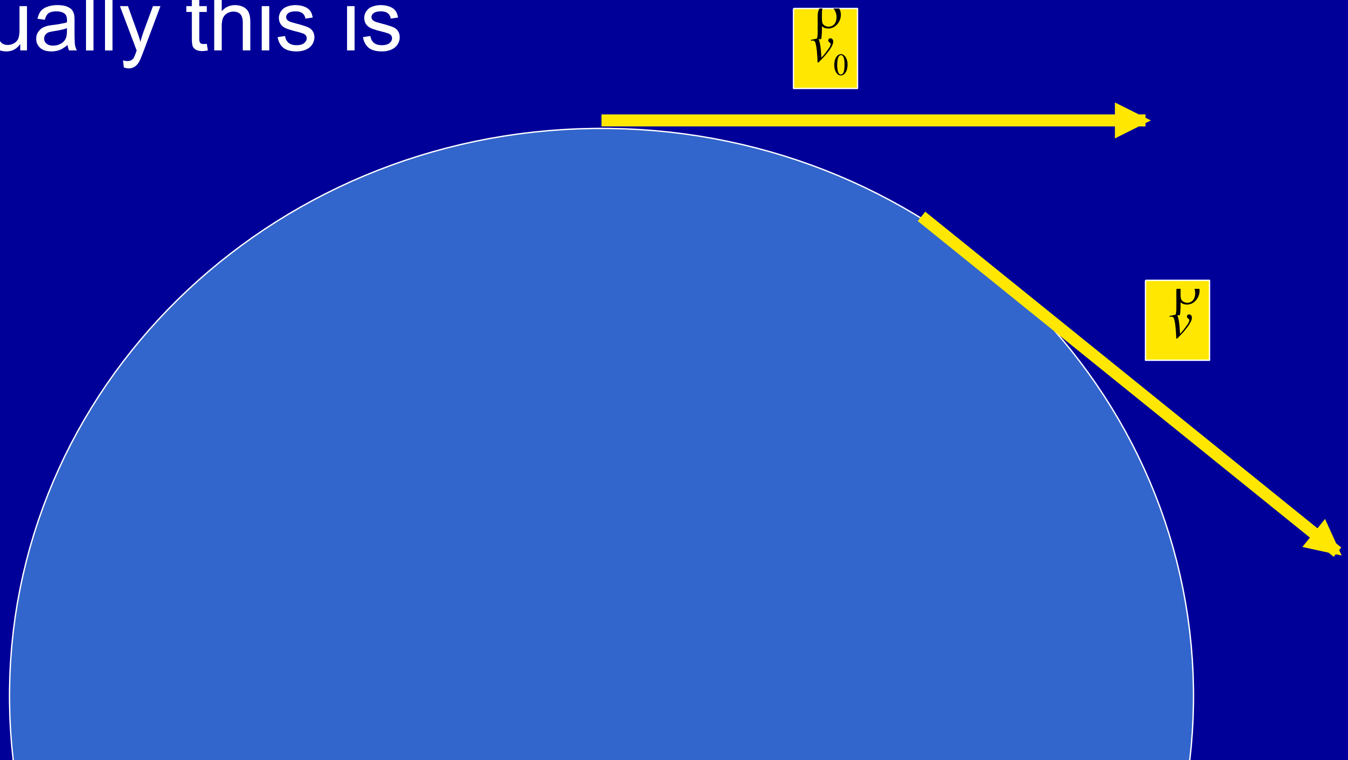


Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

So the acceleration of the object is give as

$$\vec{a} = \frac{\vec{v} - \vec{v}_0}{\Delta t} = \frac{\Delta \vec{v}}{\Delta t}$$

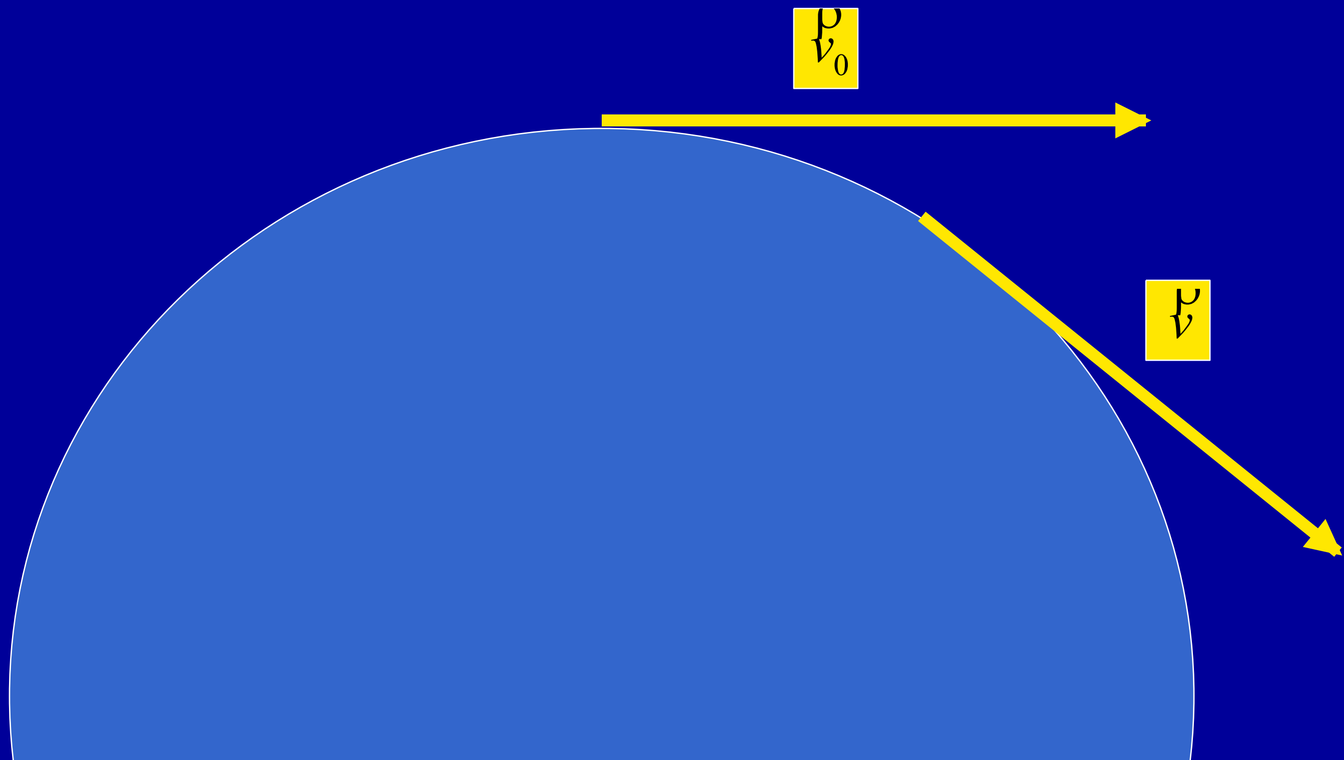
Visually this is



5.1 Kinematics of Uniform Circular Motion

Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Drawing the radius to each point, we get



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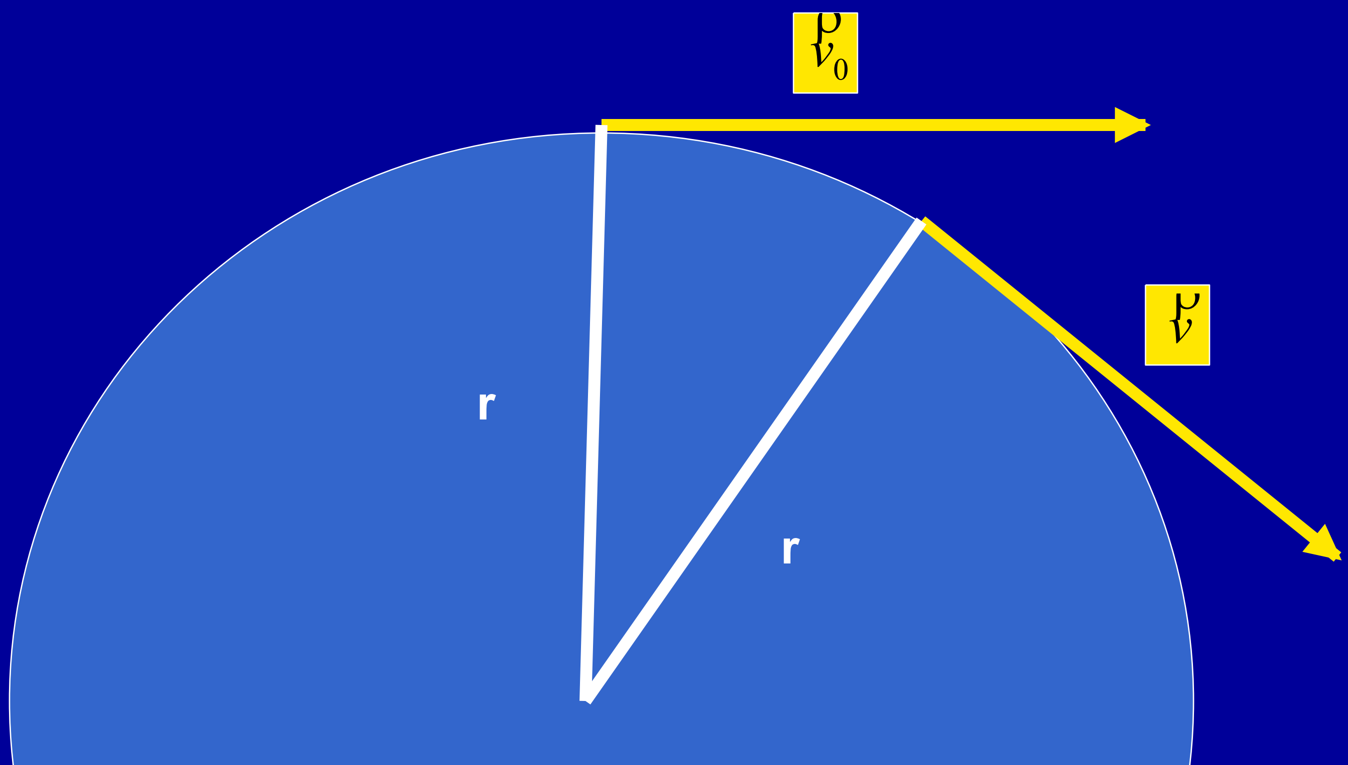
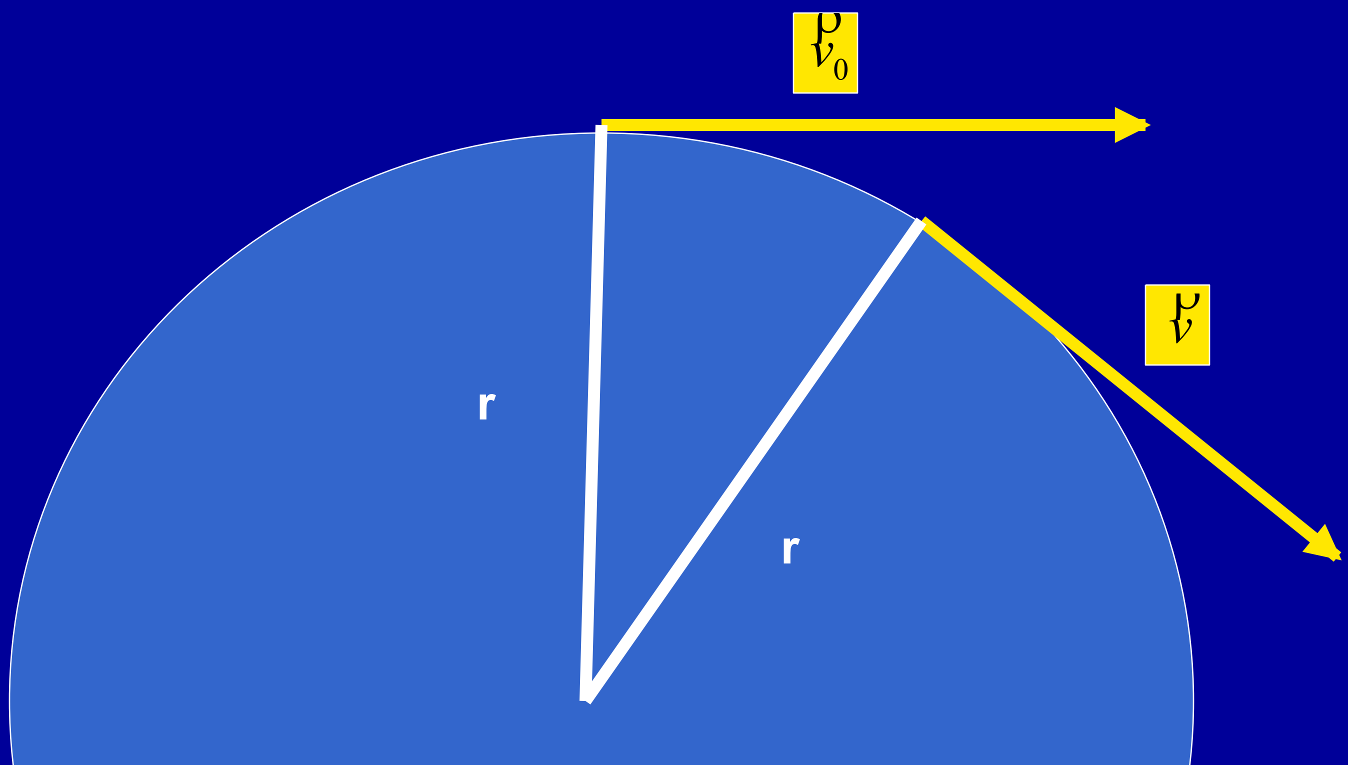


5.1 Kinematics of Uniform Circular Motion

Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Now we draw in the angle and the length between the two velocities



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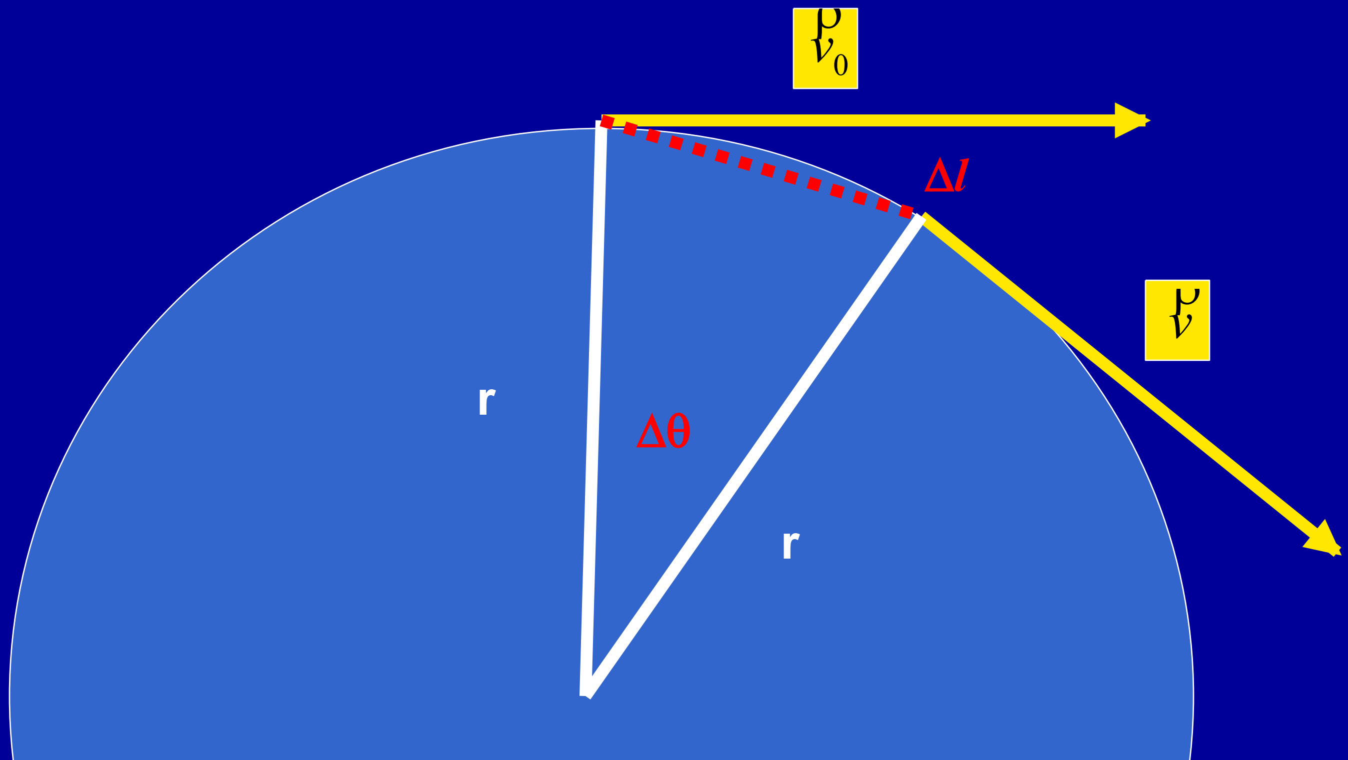
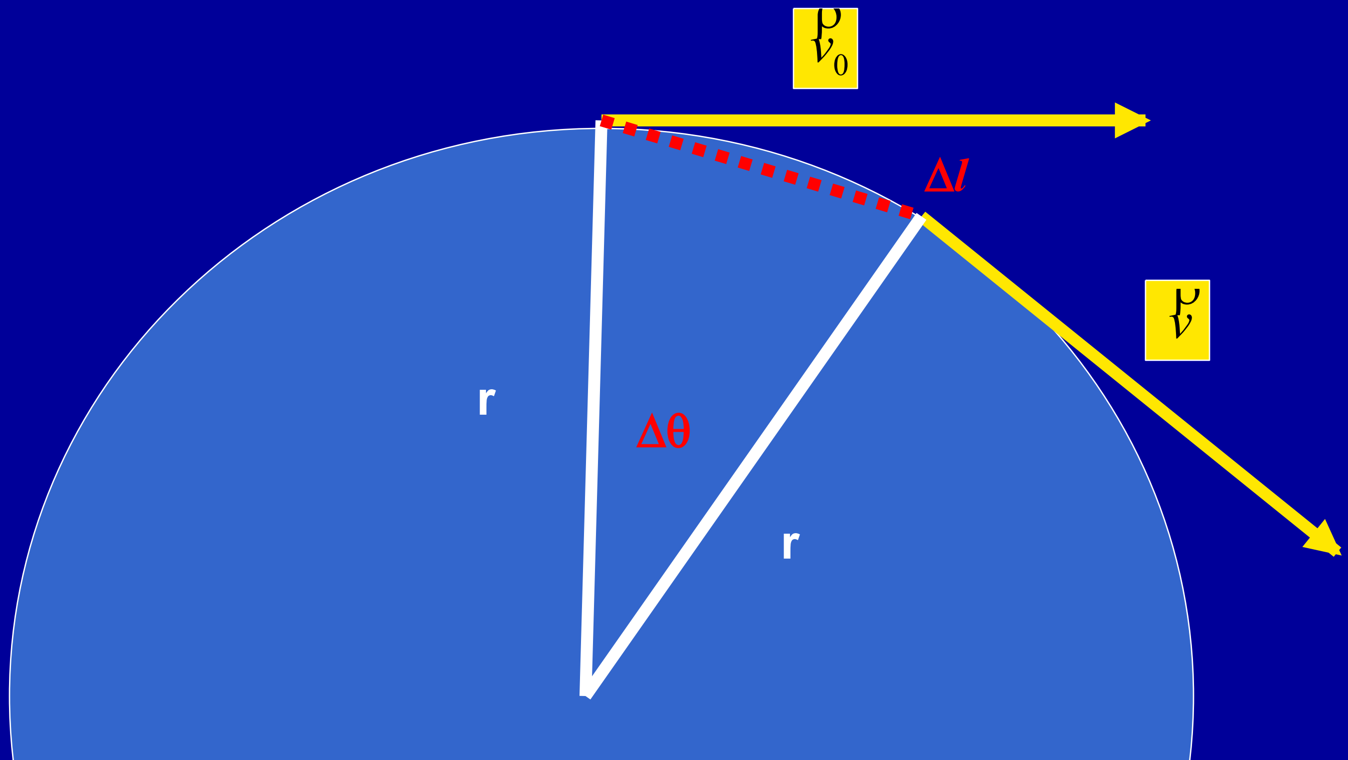


Δv graphically becomes



5.1 Kinematics of Uniform Circular Motion

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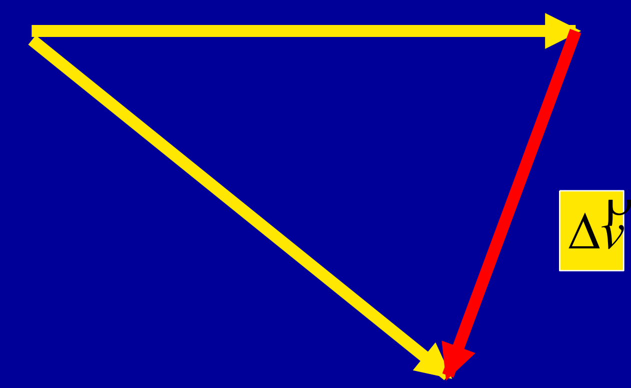
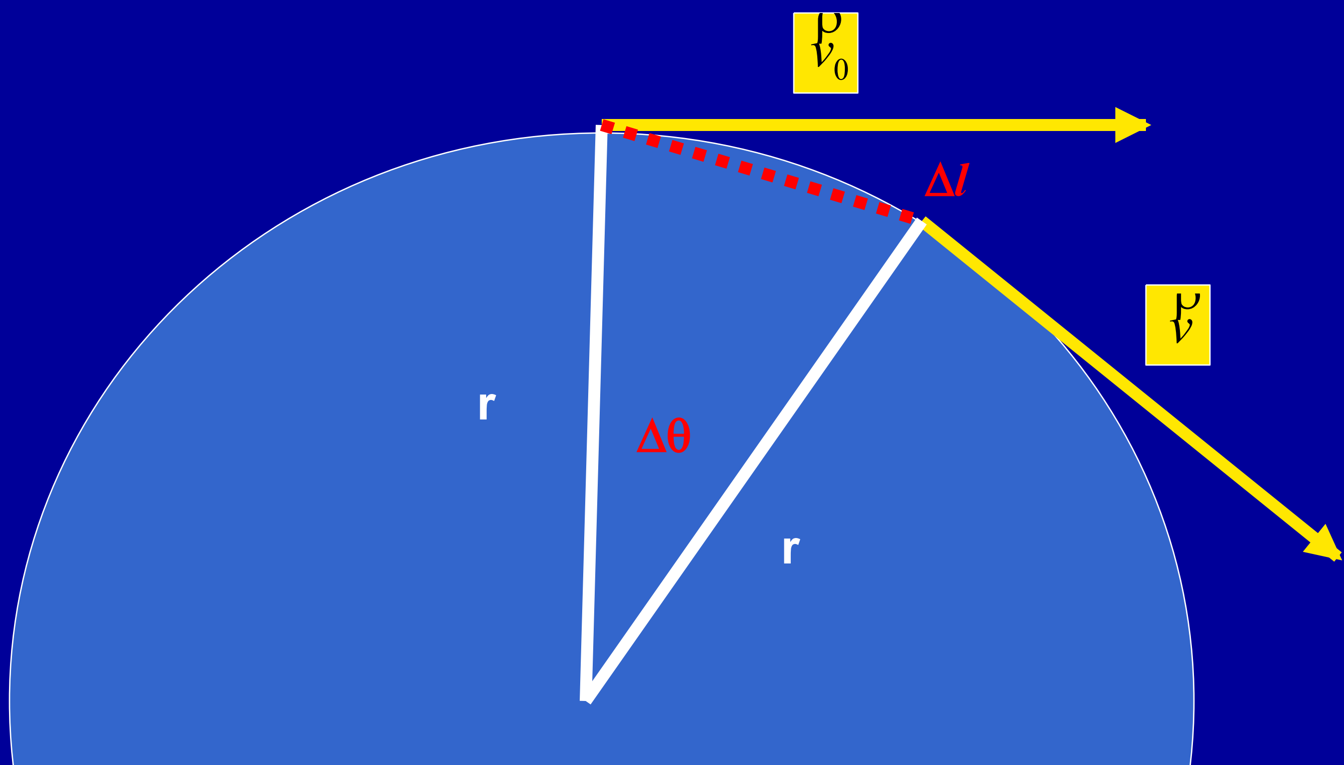
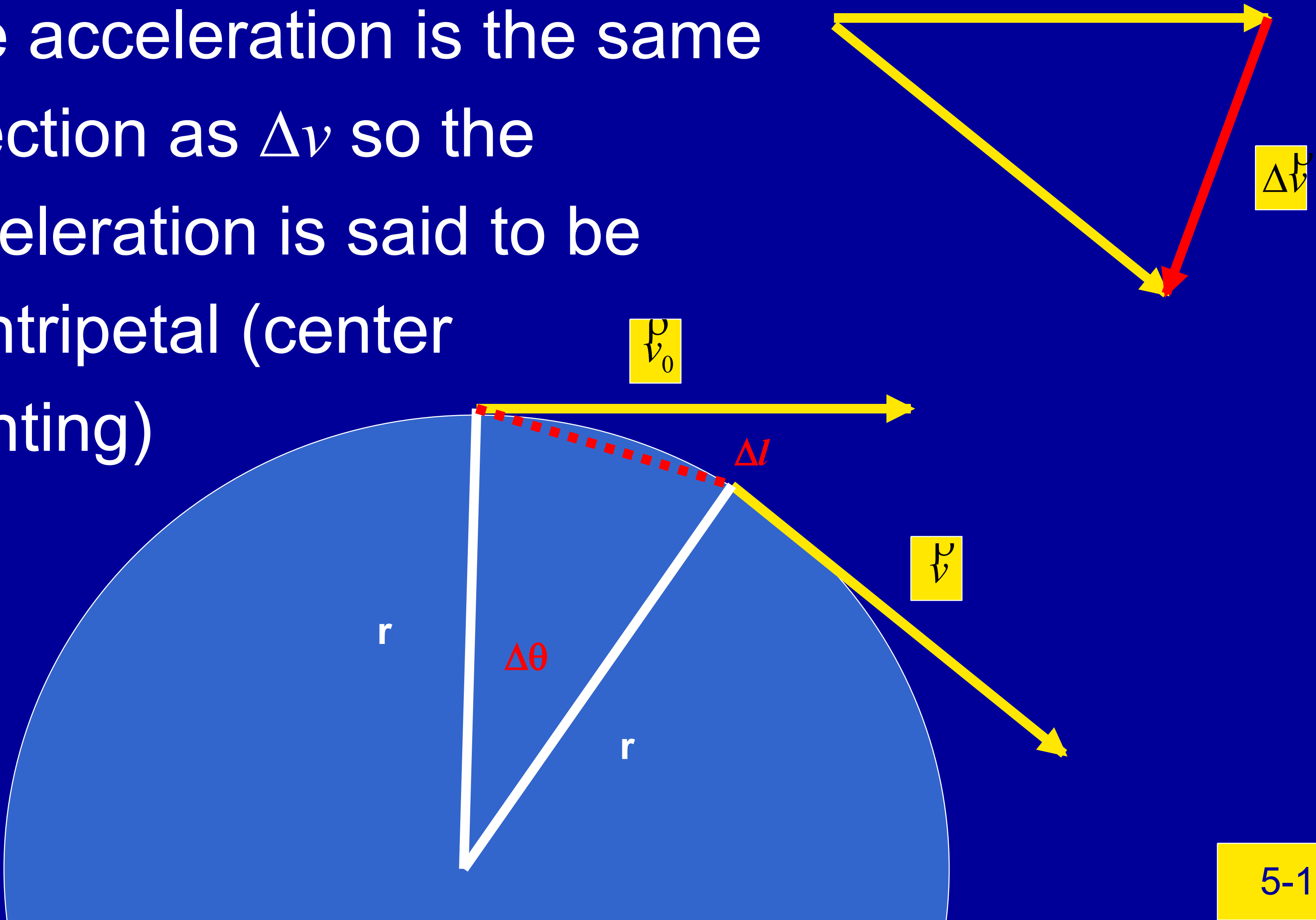




Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

The acceleration is the same direction as Δv so the acceleration is said to be Centripetal (center pointing)



5.1 Kinematics of Uniform Circular Motion

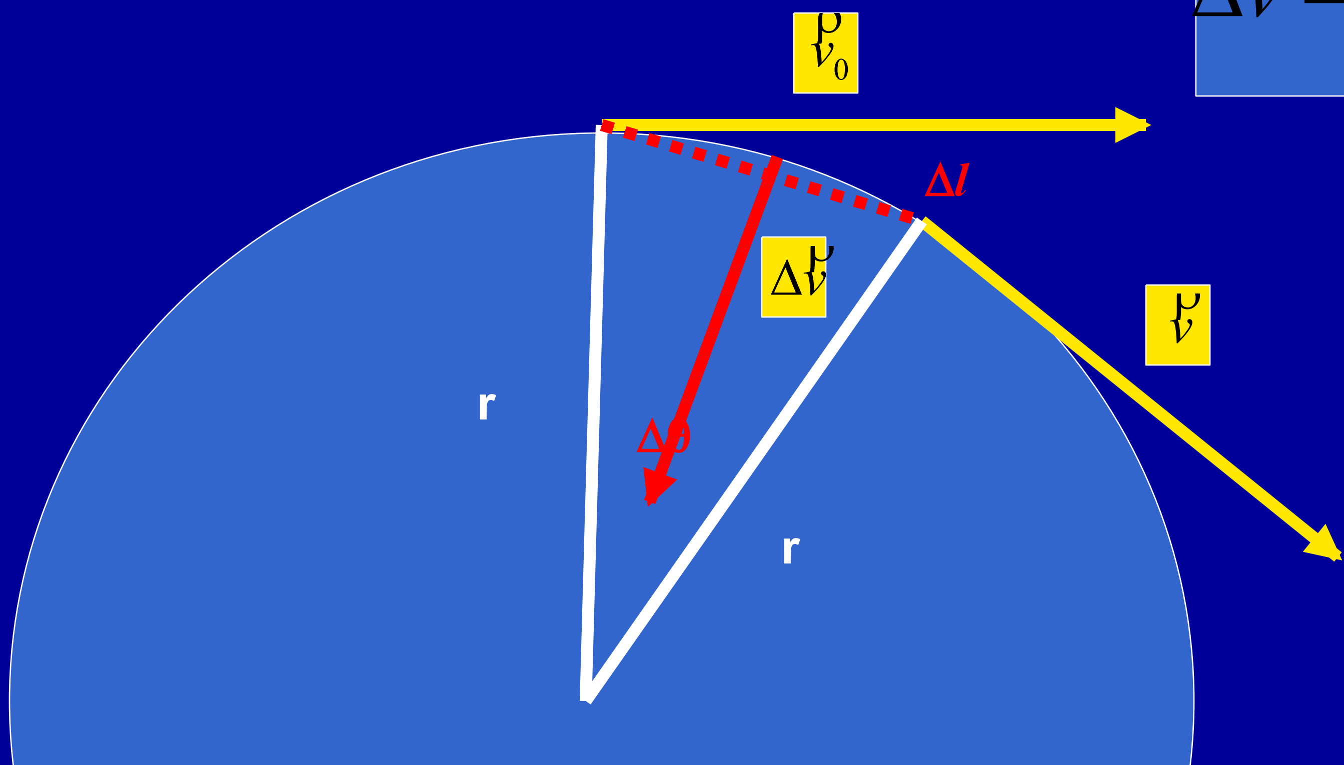
Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

As the time interval becomes shorter

$$\frac{\Delta v}{v} \approx \frac{\Delta l}{r}$$

as t approaches 0, this becomes an exact equality

$$\Delta v = v\frac{\Delta l}{r}$$



5.1 Kinematics of Uniform Circular Motion

Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Since

$$a = \frac{\Delta v}{\Delta t}$$

We can combine with this equation

$$\Delta v = v \frac{\Delta l}{r}$$

To get

$$a_c = \frac{v}{r} \frac{\Delta l}{\Delta t}$$

But

$$\frac{\Delta l}{\Delta t} = v$$

5.1 Kinematics of Uniform Circular Motion

Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Since $a = \frac{\Delta v}{\Delta t}$ $\frac{\Delta l}{\Delta t} = v$

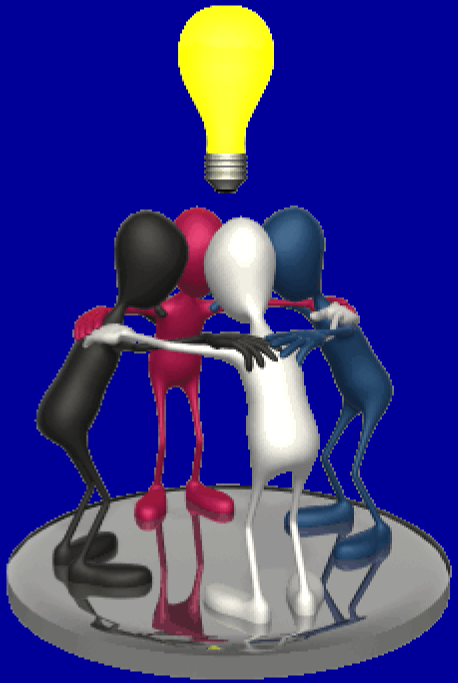
So we get $a_c = \frac{v^2}{r}$

The direction of the acceleration is always toward the middle of the circle

Practice Centripetal Force

Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

Circular Motion; Gravitation



5.2 Dynamics of Uniform Circular Motion

Standard

1E1d

Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force.

5.2 Dynamics of Uniform Circular Motion

Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force.

F=ma so

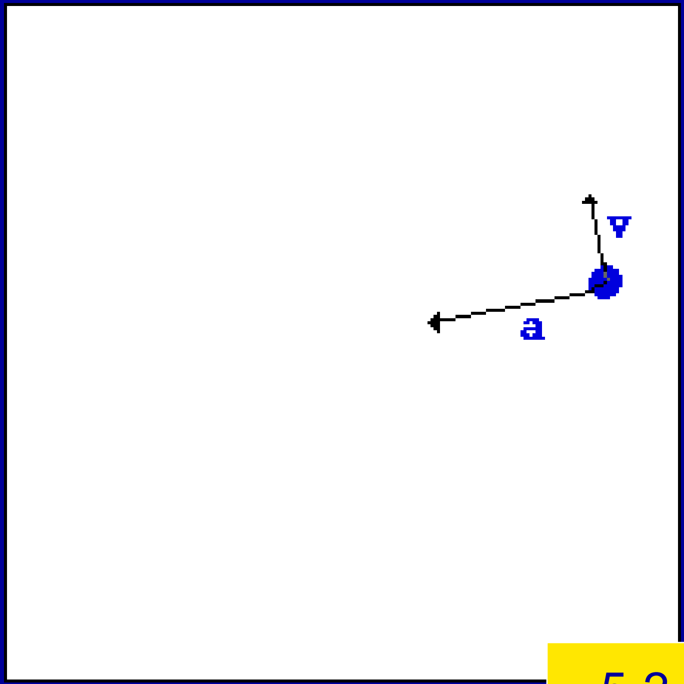
$$\Sigma F = ma$$

$$\Sigma F = m\frac{v^2}{r}$$

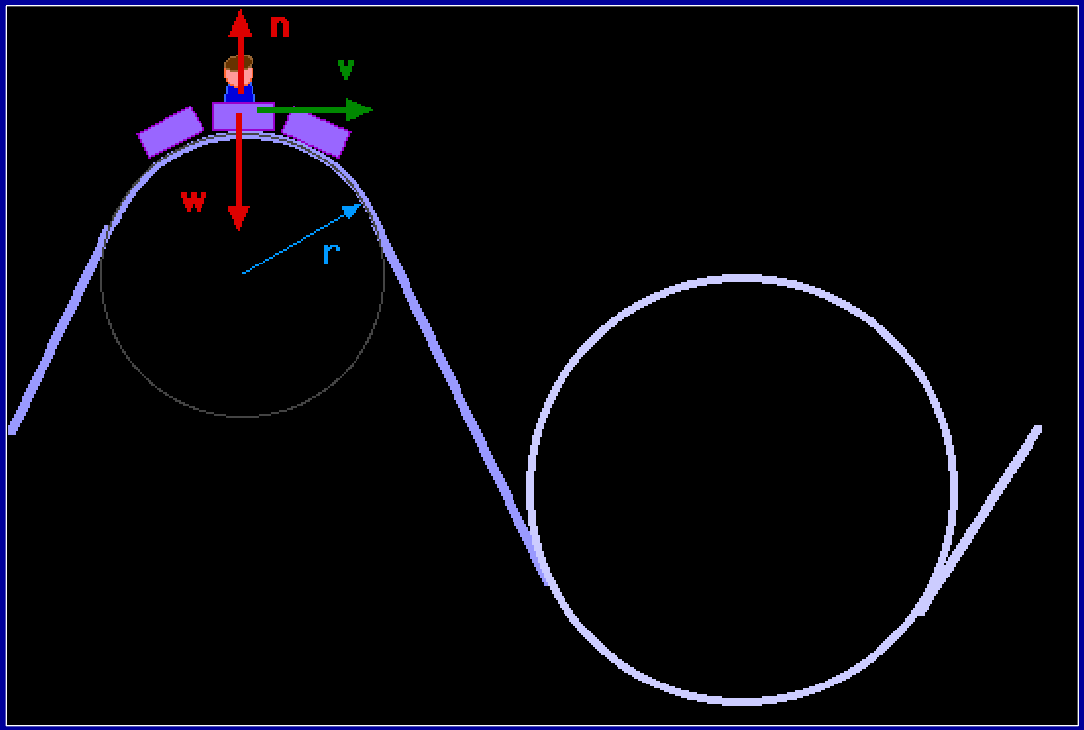
Directed toward the center

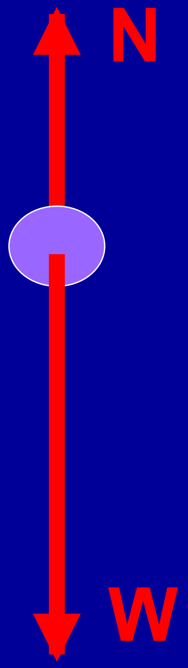
Force is sum other forces

NOT a separate force



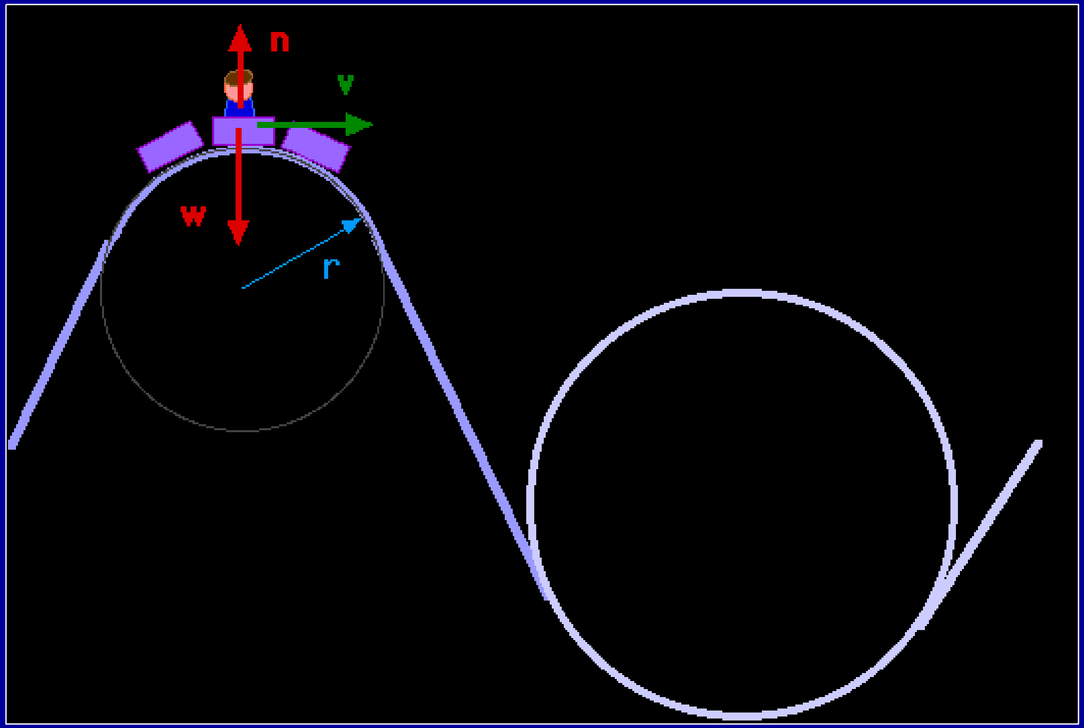
Roller Coaster Analysis

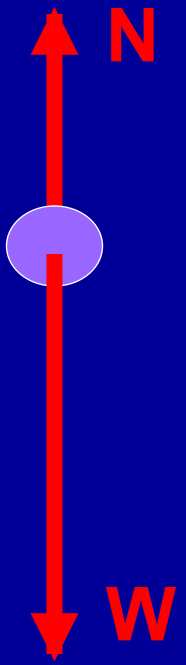




Free Body diagram?

Roller Coaster Analysis

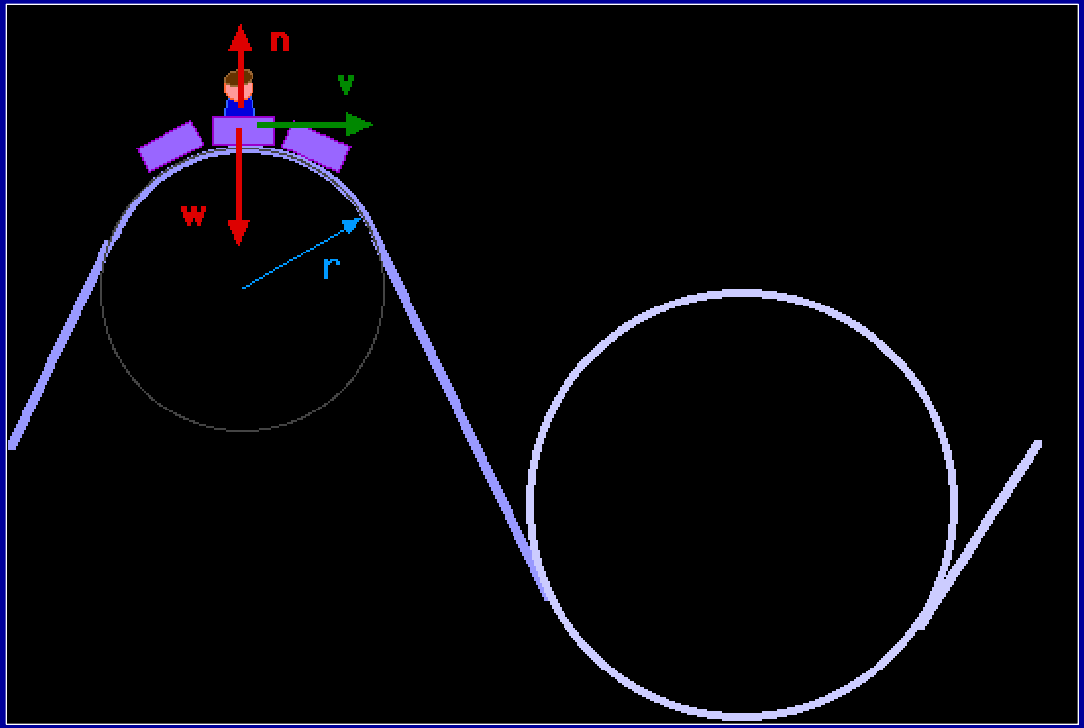


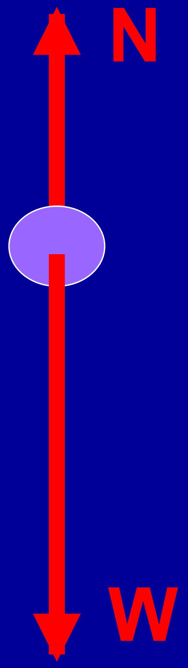


Equation?

Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force.

Roller Coaster Analysis





Equation? $F_c = W - N = mv^2/r$

5.2 Dynamics of Uniform Circular Motion

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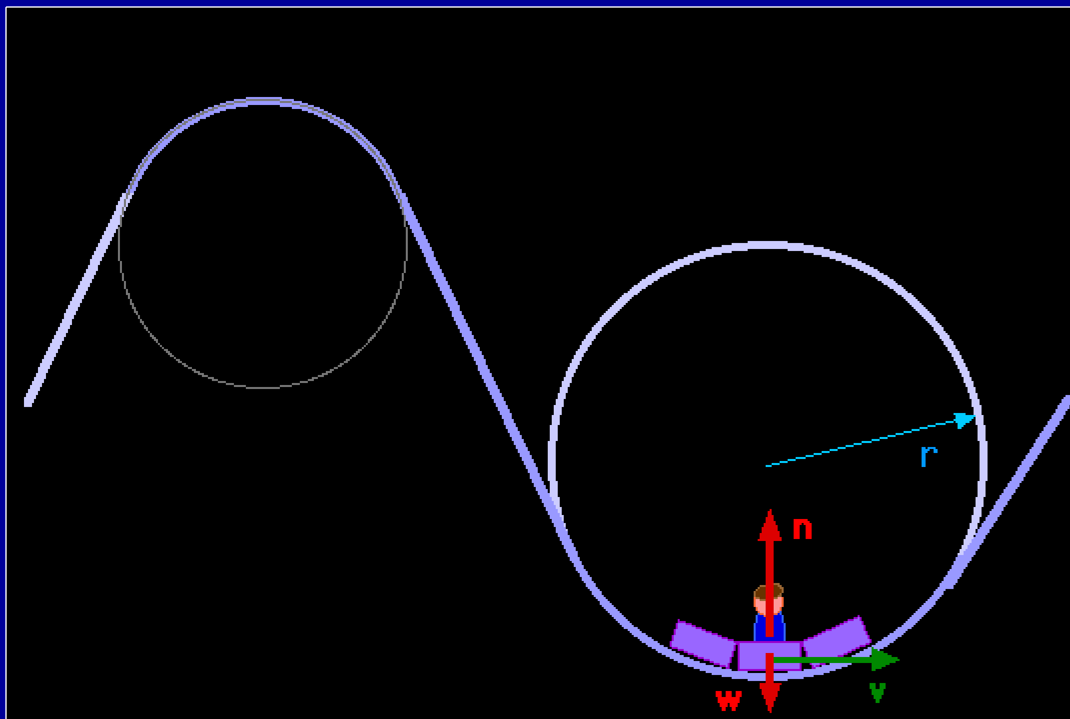

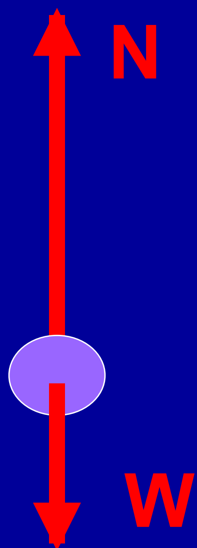

Free Body Diagram?

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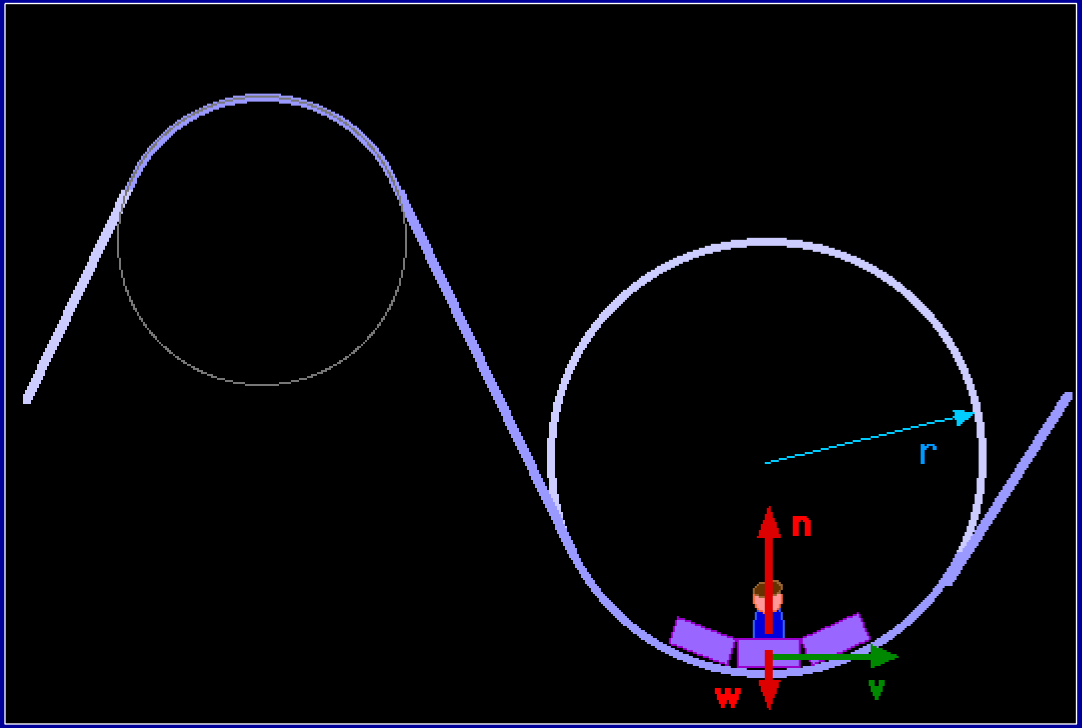

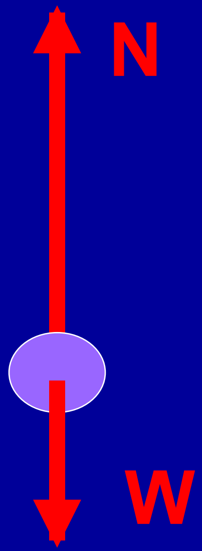

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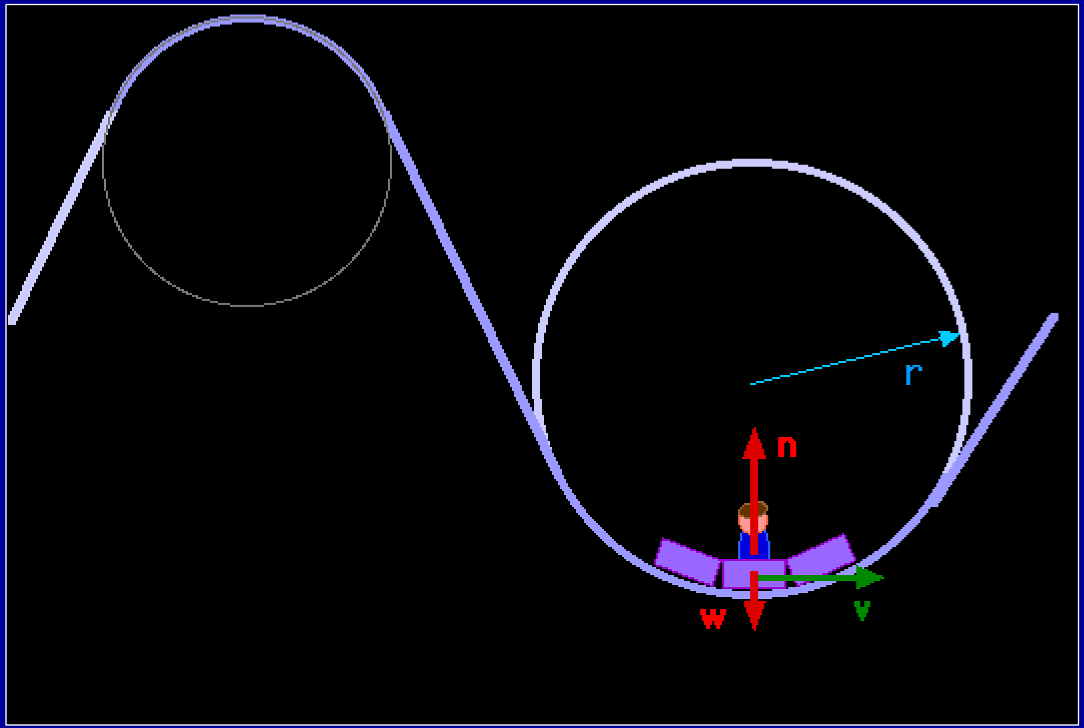

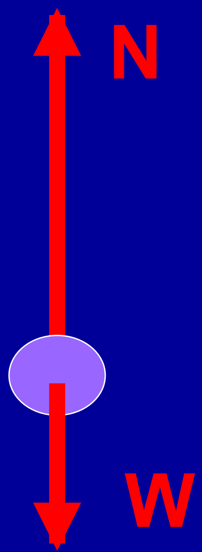

Equation? $N - W = mv^2/r$

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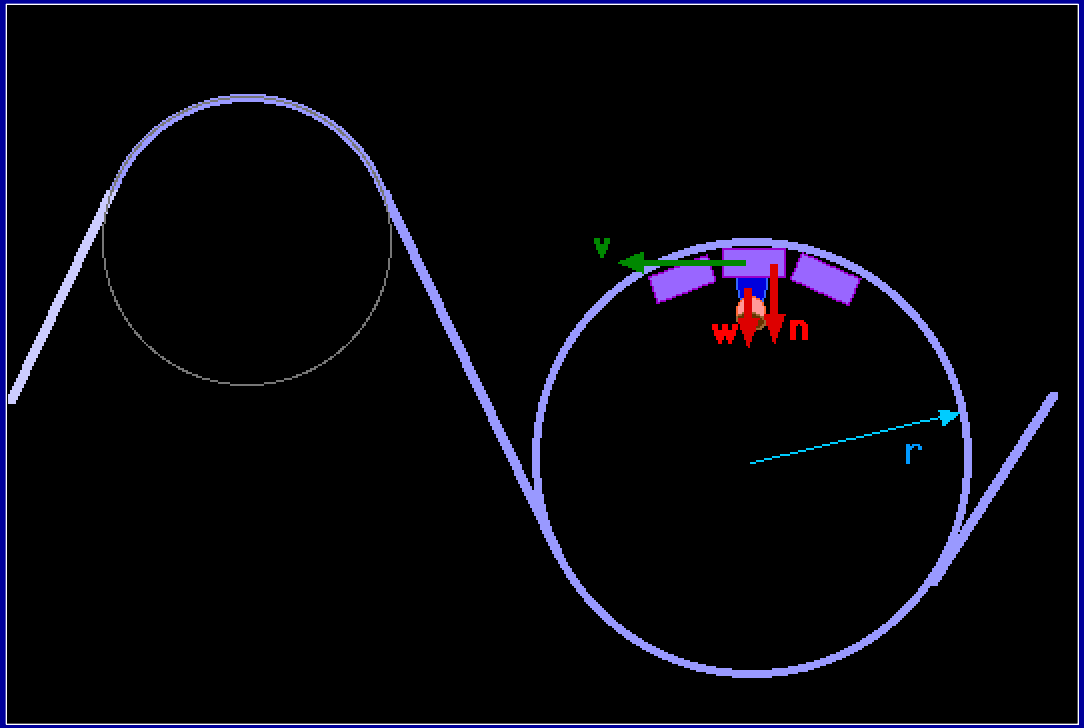
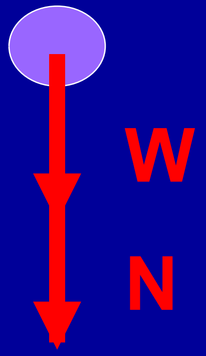
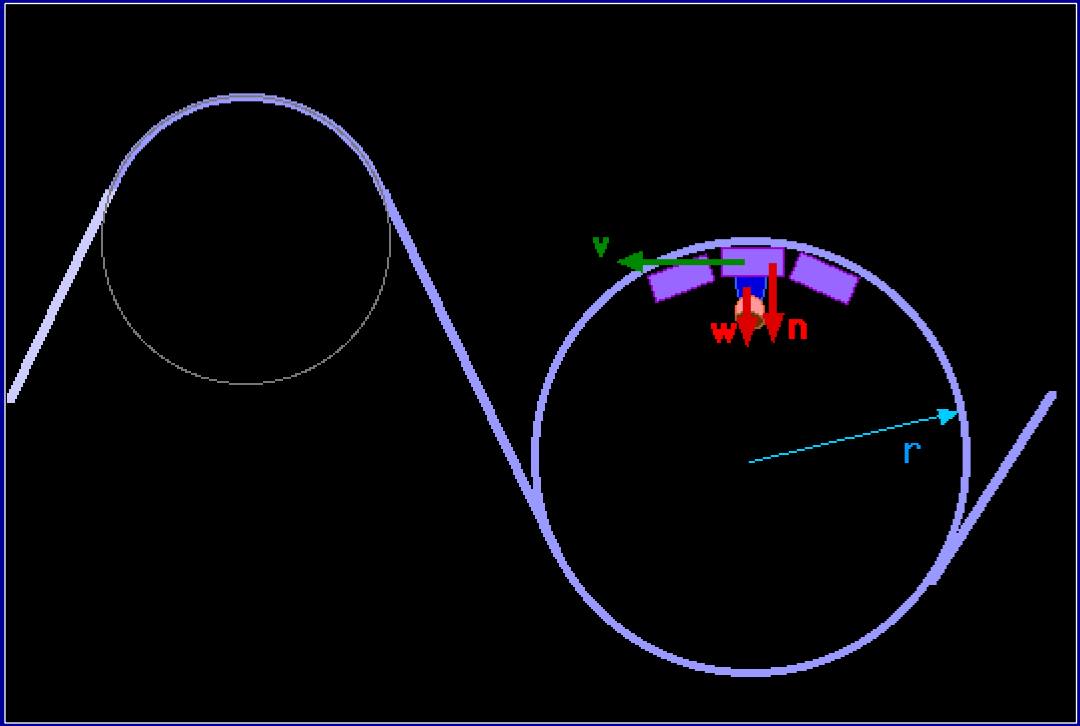
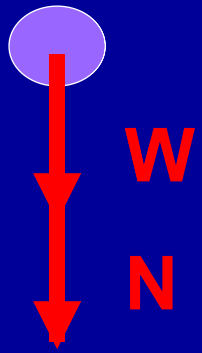




Free Body Diagram?

Roller Coaster Analysis





Equation?

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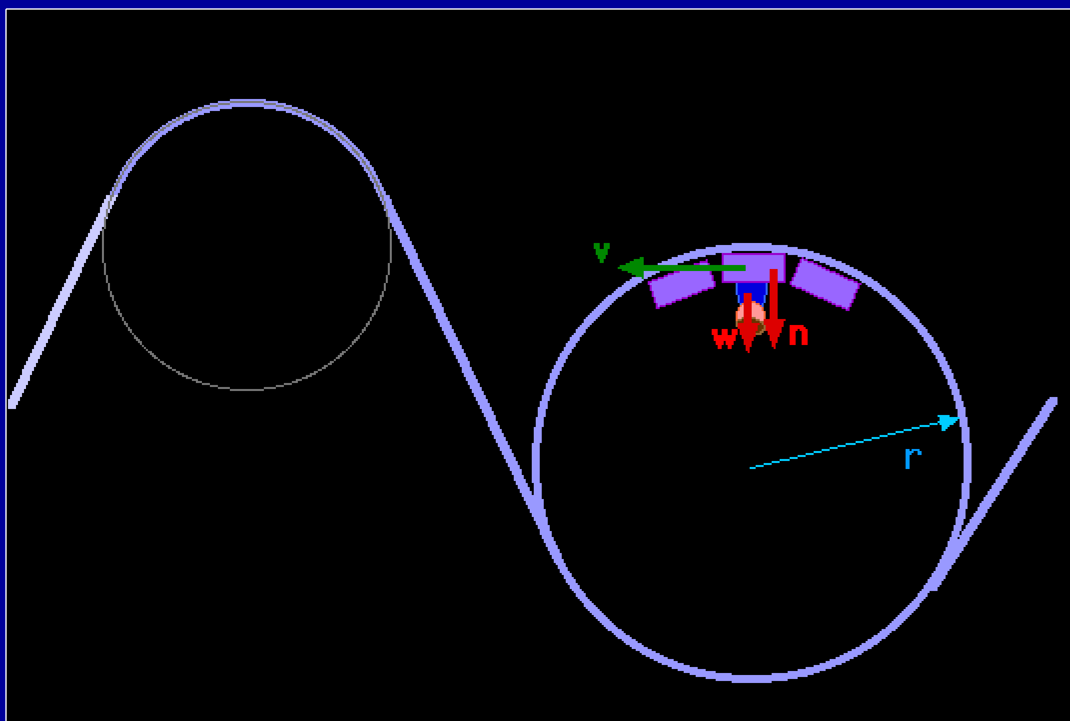
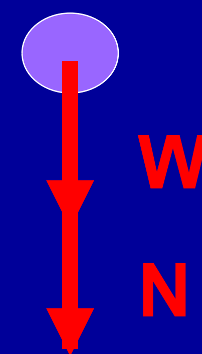




Equation? $N+W=mv^2/r$

Standard

1E1b

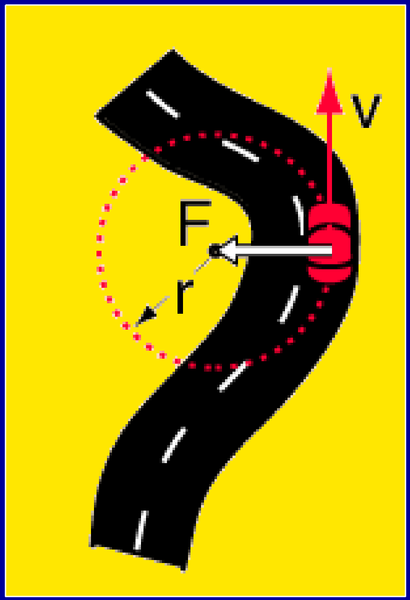
Describe the direction of the particle's velocity and acceleration at any instant

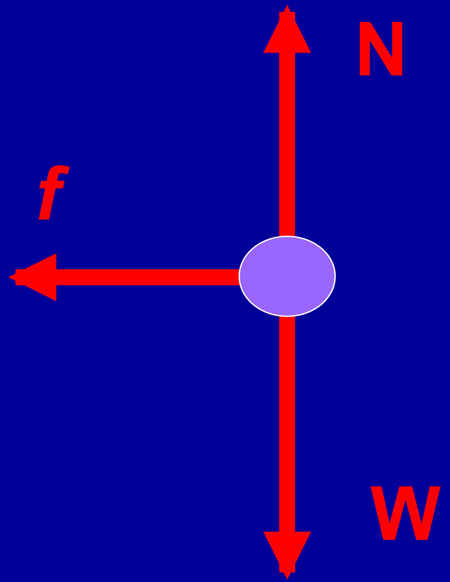
during the motion.

5.2 Dynamics of Uniform Circular Motion

Describe the direction of the particle's velocity and acceleration at any instant during the motion.

Horizontal Circle





Caused by friction so

Free body diagram?

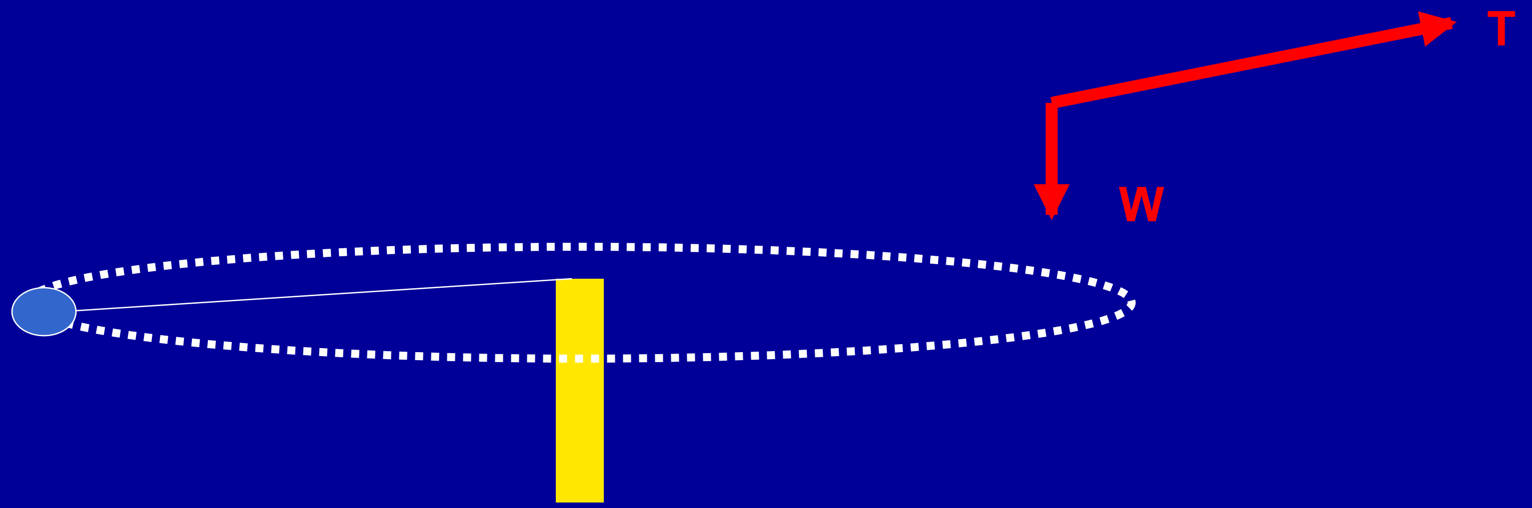
Equation?

$f = mv^2/r$

5.2 Dynamics of Uniform Circular Motion

Describe the direction of the particle's velocity and acceleration at any instant during the motion.

Horizontal Circle – String with mass



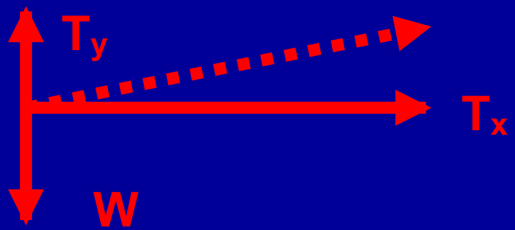
Free Body Diagram?

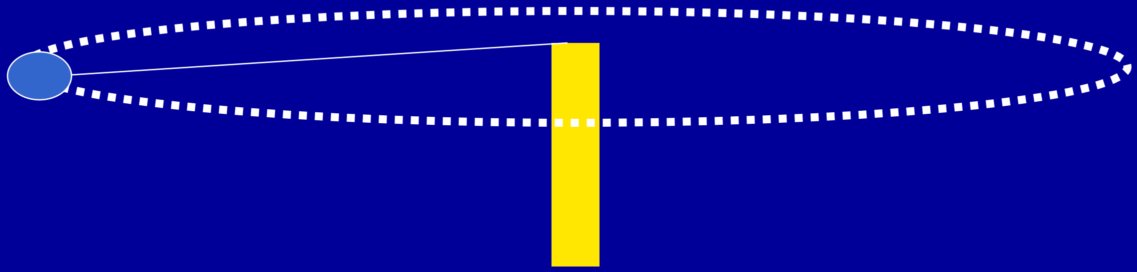
Must calculate x and y components of tension

5.2 Dynamics of Uniform Circular Motion

Describe the direction of the particle's velocity and acceleration at any instant during the motion.

Horizontal Circle – String with mass





Free Body Diagram?

Must calculate x and y components of tension

Equation?

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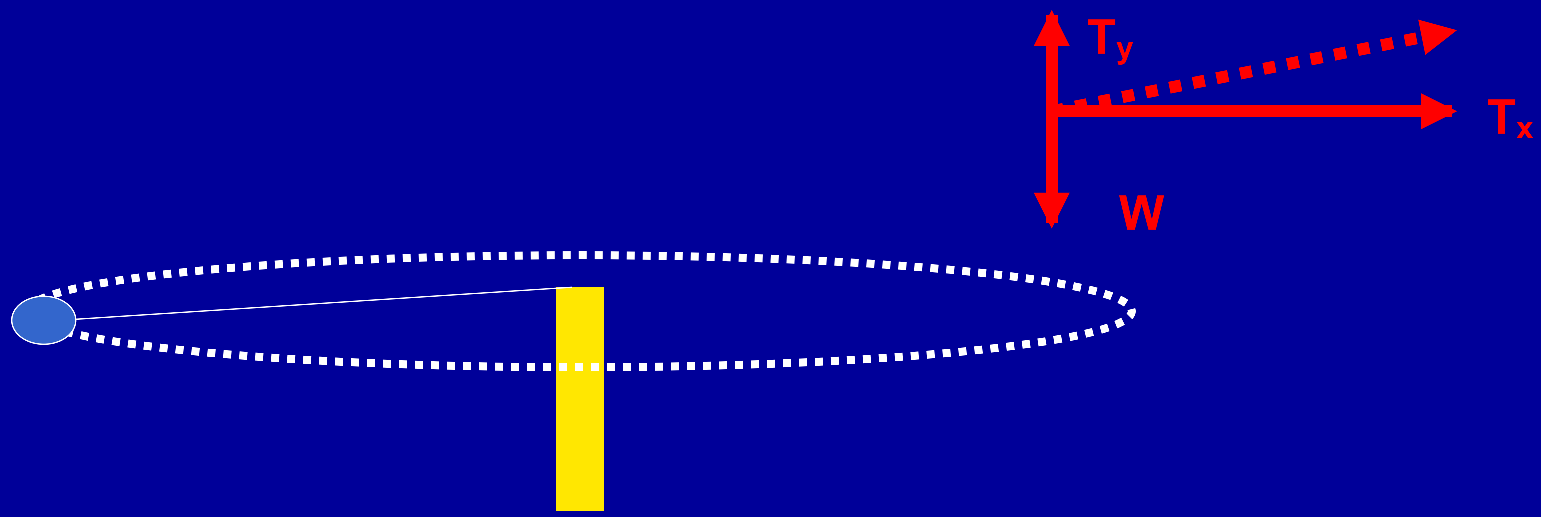


Must calculate x and y components of tension

Equation? $T_x = mv^2/r$

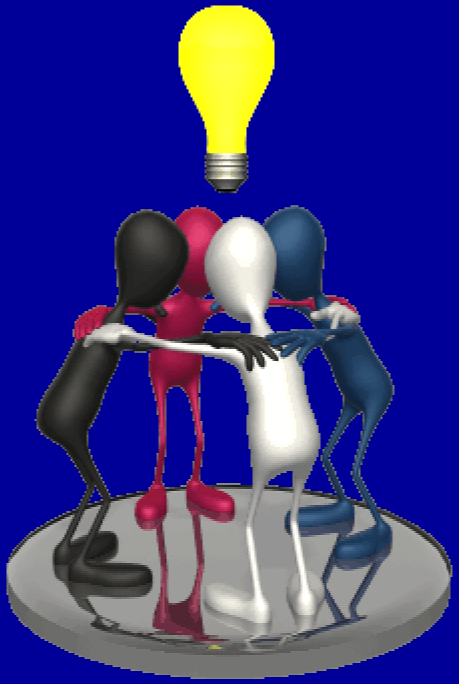
S-24

A horsey named “Dumbo” drives his master and cart off a cliff. The horse has a mass of 250 kg, the cart has a mass of 400 kg and the coefficient of friction between the cart and ground is 0.45.

A. If they are being pushed off the cliff by a crazed Korean dude. (2000 N force), what is the acceleration of the cart?

B. What is the force between the cart and the horse?

Circular Motion; Gravitation

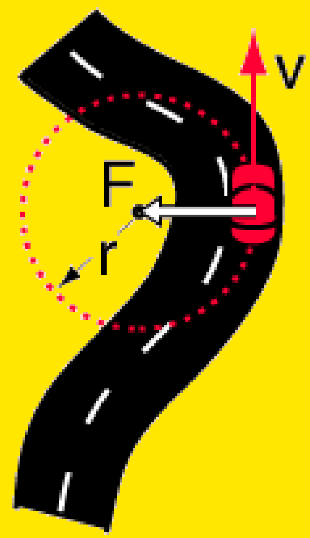


5.3 Highway Curves, Banked and Unbanked

5.3 Highway Curves, Banked and Unbanked

Unbanked Curve

A 1000 kg car rounds a curve on a flat road of radius 50 m at a speed of 14 m/s. If μ=0.60 will the car make the curve?



$$f = \frac{mv^2}{r}$$

$$\mu N = \frac{mv^2}{r}$$

$$\mu mg = \frac{mv^2}{r}$$

$$F_c = \frac{mv^2}{r}$$

$$F_c = \frac{(1000)(14)^2}{(50)}$$

$$F_c = 3920N$$

$$f = \mu mg$$

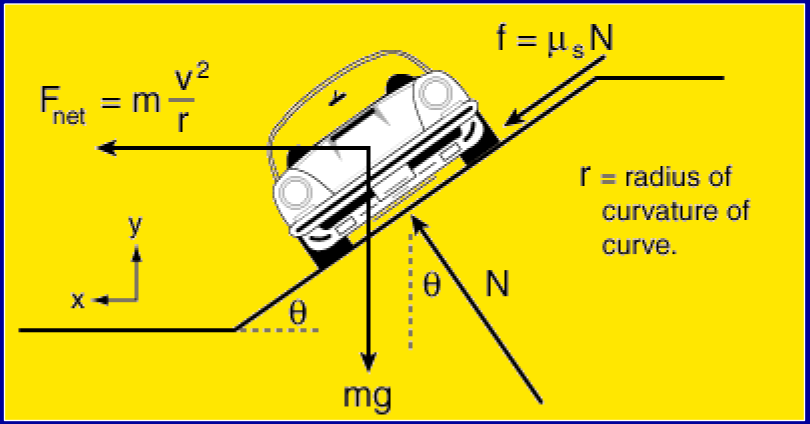
$$f = (0.60)(1000)(9.80)$$

$$f = 5880N$$

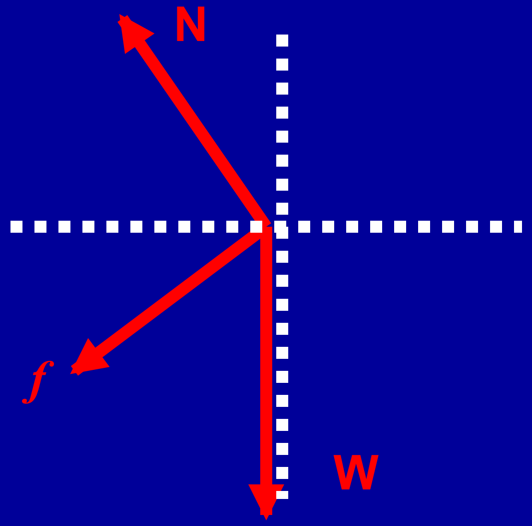
5.3 Highway Curves, Banked and Unbanked

Banked Curve

What is the fastest that a Car can travel if the angle Of the bank is 30º and the Radius of the curve is 50m if μ=0.60?



Free Body diagram



5.3 Highway Curves, Banked and Unbanked

Banked Curve

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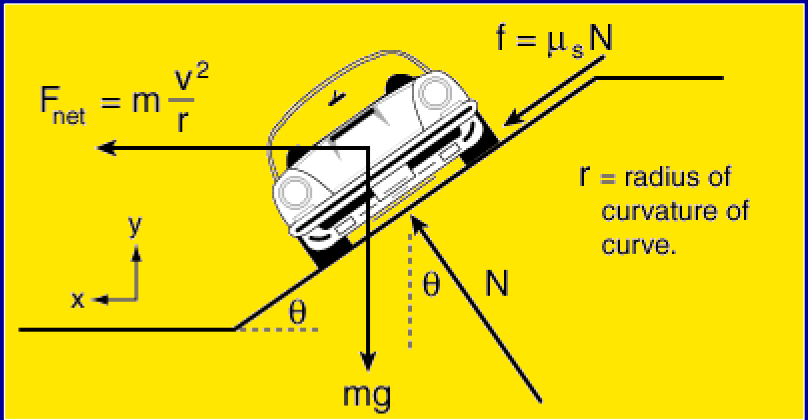
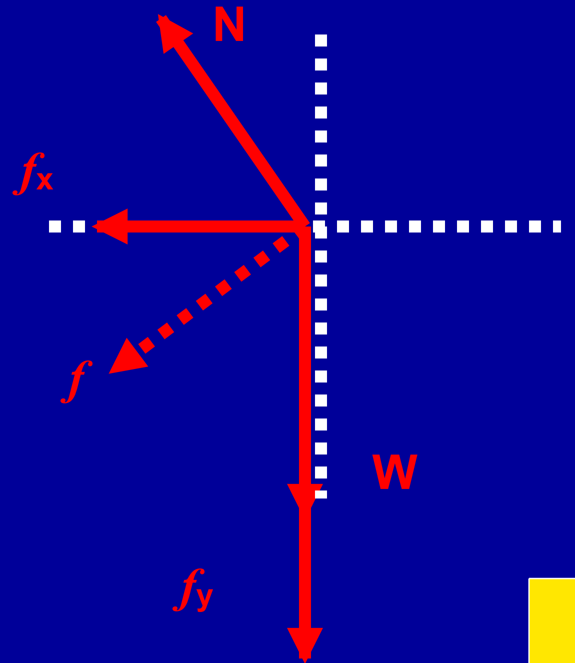
Free Body diagram





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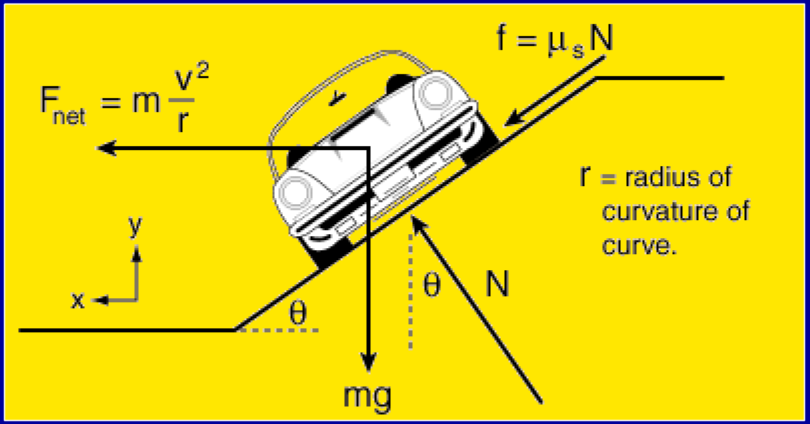
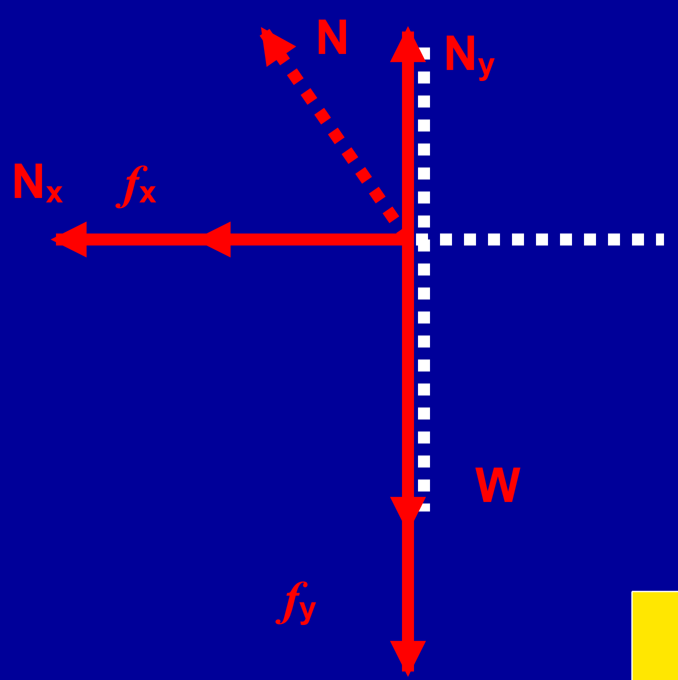


Free Body diagram



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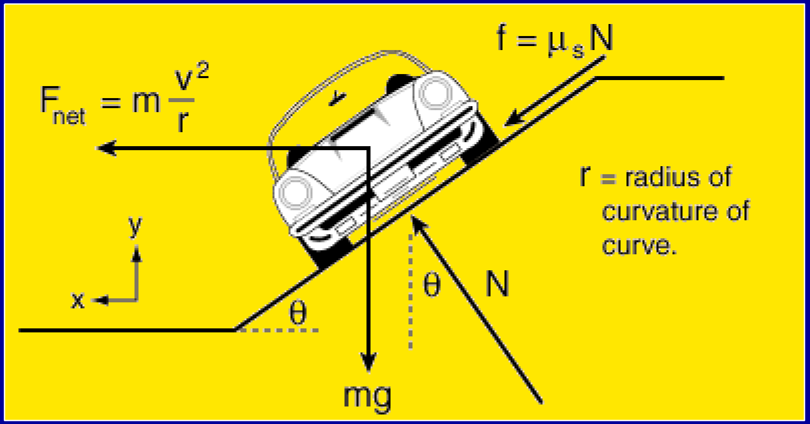
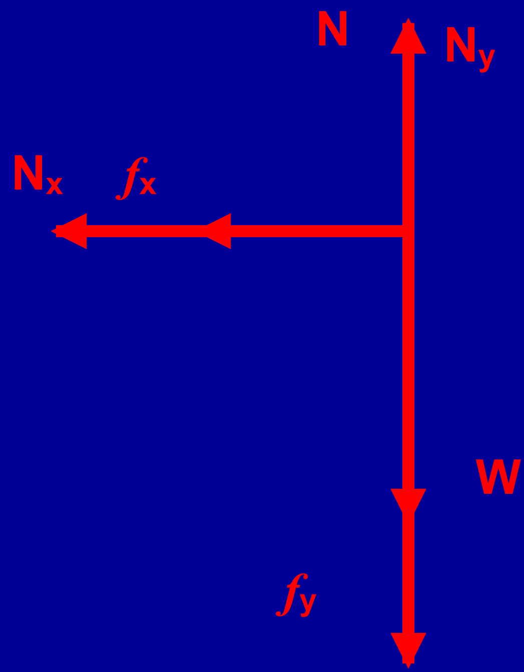




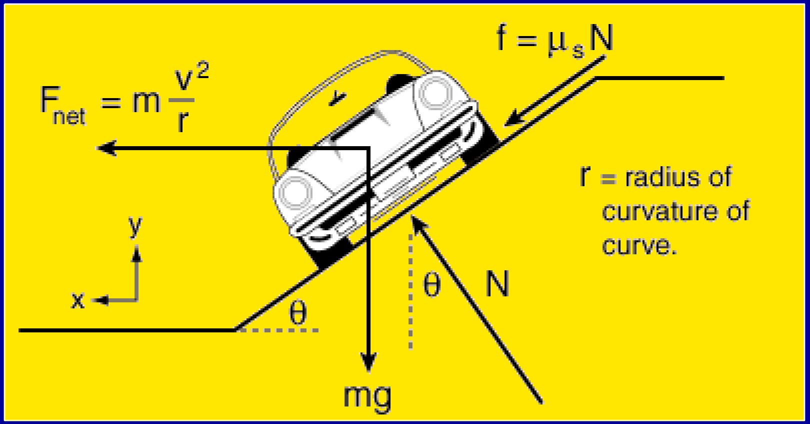
5.3 Highway Curves, Banked and Unbanked

Banked Curve

$$\Sigma F_x = \frac{mv^2}{r}$$

$$\Sigma F_x = N\sin\theta + f\cos\theta$$

$$\Sigma F_x = N\sin\theta + \mu N\cos\theta$$

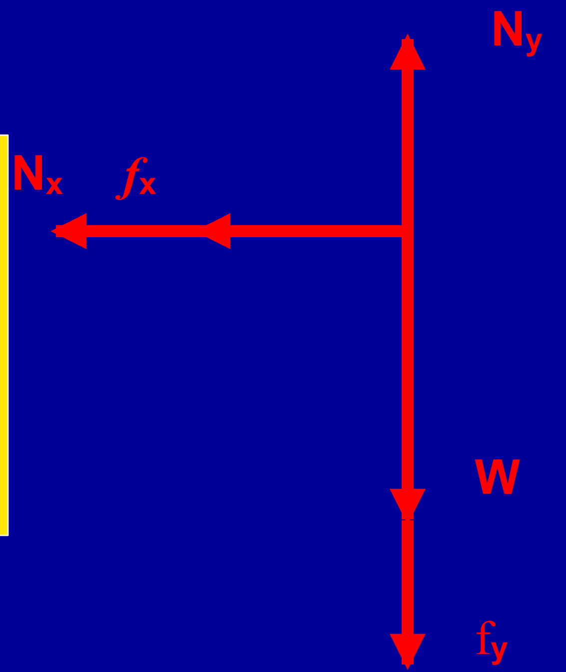


What is N?

$$\Sigma F_y = N\cos\theta - f\sin\theta - W$$

$$\Sigma F_y = N\cos\theta - \mu N\sin\theta - mg$$

$$0 = N\cos\theta - \mu N\sin\theta - mg$$



5.3 Highway Curves, Banked and Unbanked

Banked Curve

$$0 = N\cos(30) - (.60)N\sin(30) - (1000)(9.80)$$

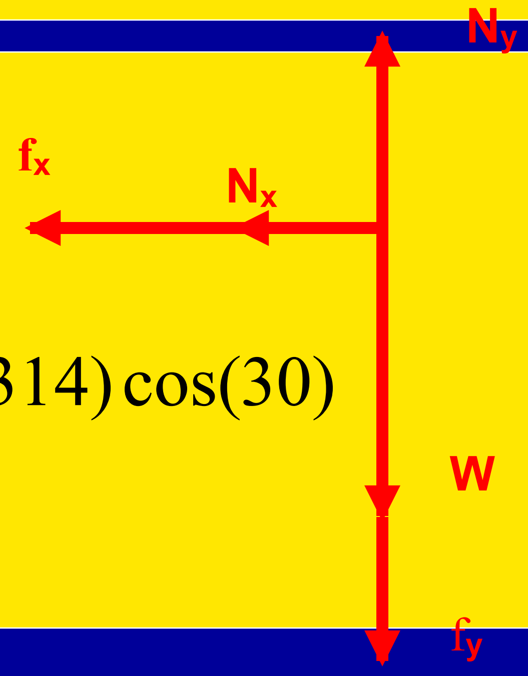
$$0 = .866N - .3N - 9800$$

$$N = 17314N$$

$$\frac{mv^2}{r} = N\sin\theta + \mu N\cos\theta$$

$$\frac{(1000)v^2}{50} = (17314)\sin(30) + (.6)(17314)\cos(30)$$

$$v = 29.7m/s$$



S-25

cute llama. The

n't talk to him.

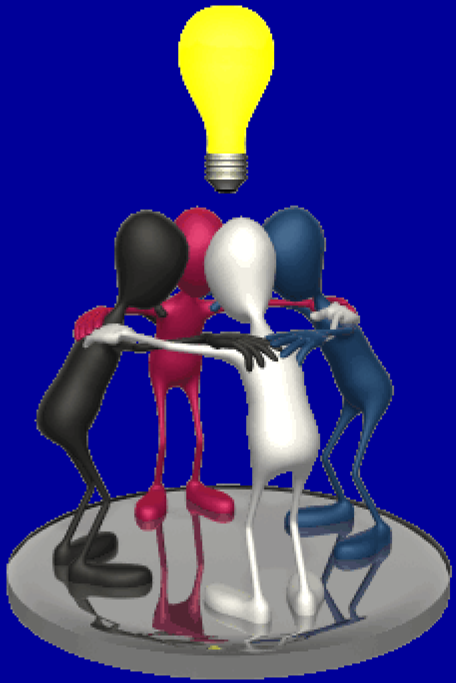
n old truck and

goes for a ride. If the truck hits a 60.0 m radius curve doing 40 m/s, what is the minimum coefficient of friction that will allow the truck to stay in the curve?

S-26

A rope is tied to an elephant and he is spun at the end of it. If the elephant has a mass of 2400 kg, the string has a radius of 12 m, and the string makes 20 revolutions every 31 s, what is the tension on the string?

Circular Motion; Gravitation



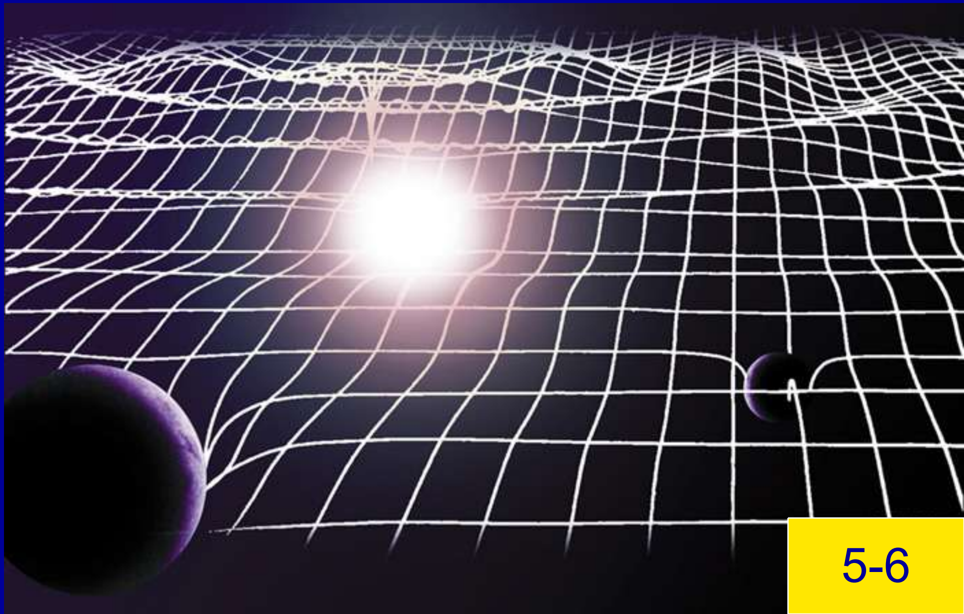
5.6 Newton’s Law of Universal Gravitation

5.6 Newton's Law of Universal Gravitation

Through experiments Newton found that the force of gravity

1. Directly proportional to the masses
2. Inversely proportional to the square of distances between the masses

$$F \approx \frac{m_1 m_2}{r^2}$$



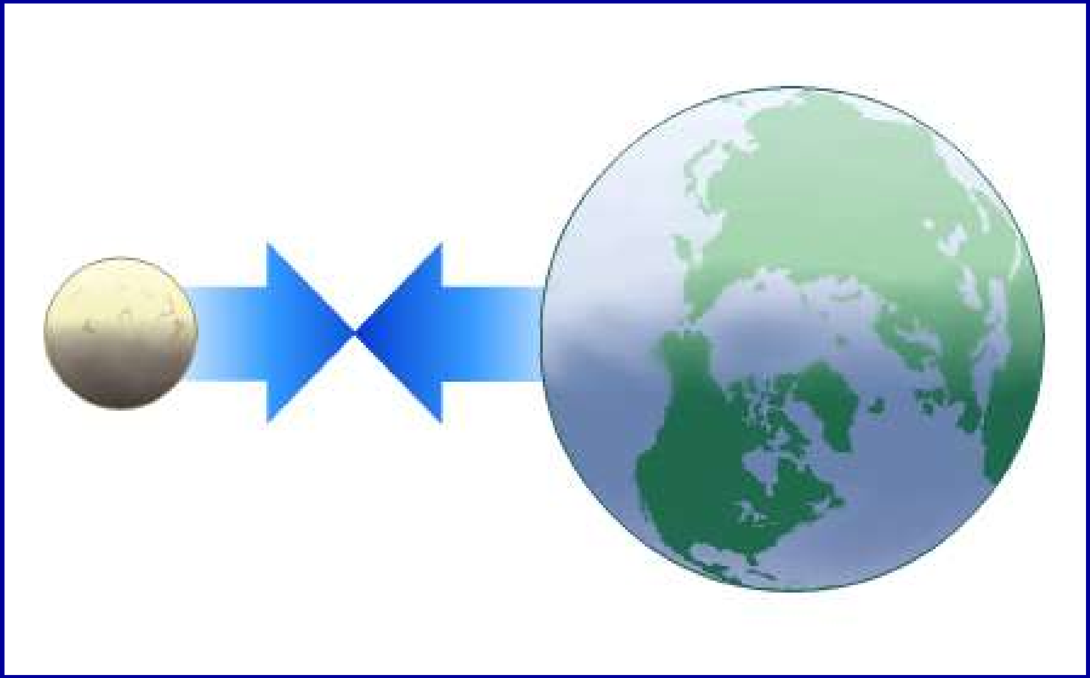
5.6 Newton's Law of Universal Gravitation

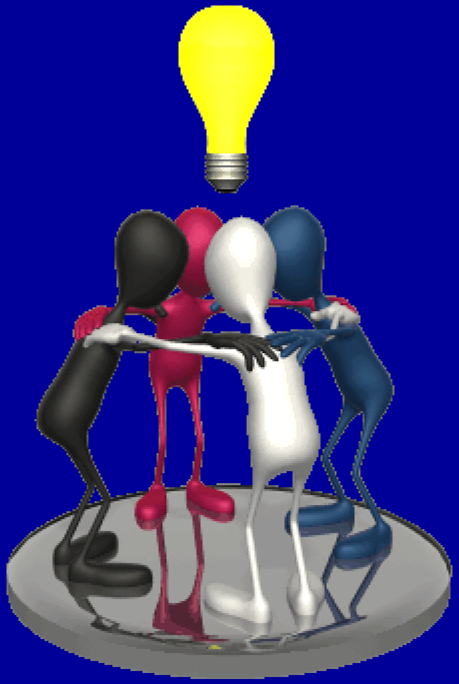
To convert to SI units we must add in the Universal Gravitational Constant (G)

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

So

$$F = G\frac{m_1 m_2}{r^2}$$





5.7 Gravity Near the Earth's Surface

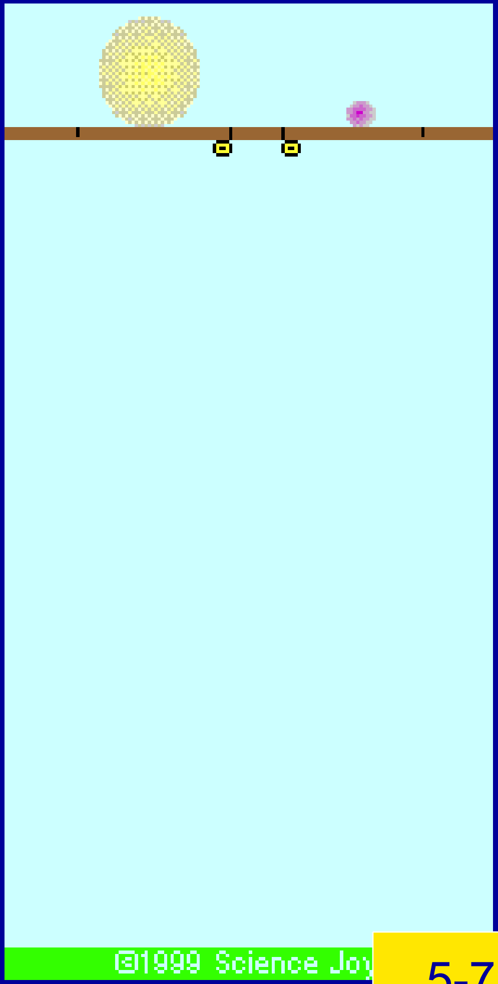
5.7 Gravity Near the Earth's Surface

Near the earth, the Law of Universal Gravitation becomes

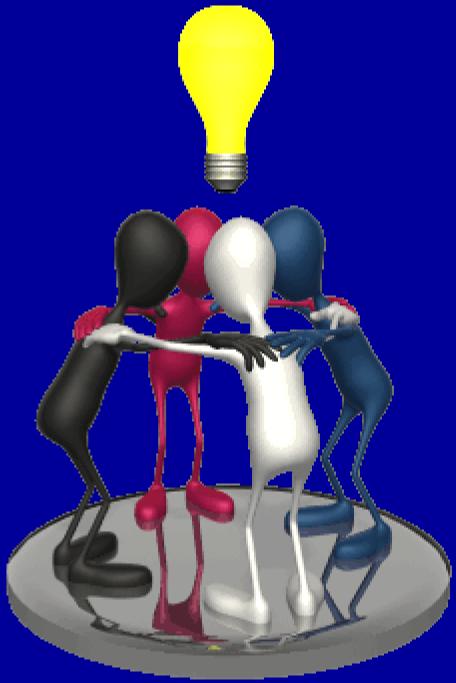
$$mg = G\frac{mm_E}{r^2}$$

The mass cancels and we have

$$g = G\frac{m_E}{r^2}$$



Circular Motion; Gravitation



5.8 Satellites and “Weightlessness”

5.8 Satellites and "Weightlessness"

Satellites orbit the earth when their velocity is great enough to balance out the force of gravity

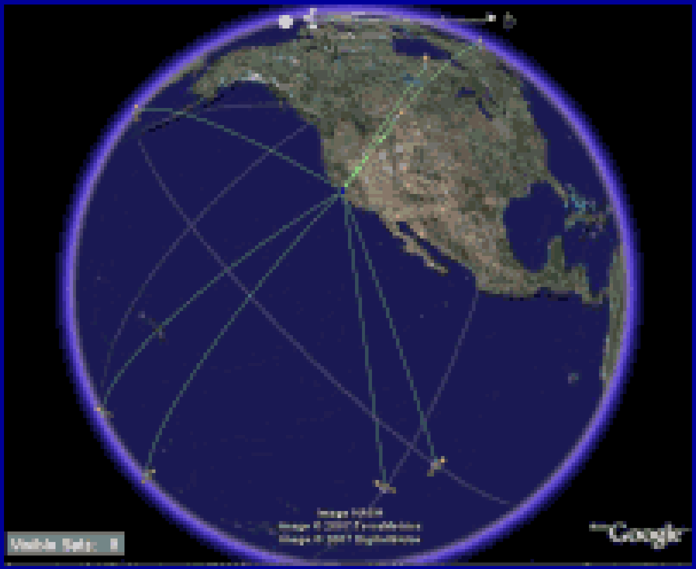
$$W = G\frac{mm_E}{r^2}$$

$$W = \frac{mv^2}{r}$$

$$\frac{mv^2}{r} = G\frac{mm_E}{r^2}$$

$$v^2 = G\frac{m_E}{r}$$

$$v = \sqrt{G\frac{m_E}{r}}$$



5.8 Satellites and "Weightlessness"

Apparent weightlessness

If we are standing in an elevator, the free body diagram is

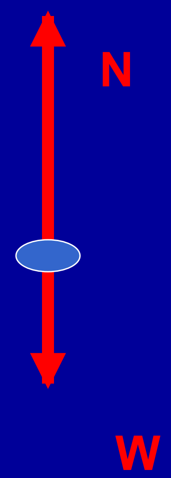
The equation

$$N - mg = 0$$

5.8 Satellites and "Weightlessness"

Apparent weightlessness

If the elevator accelerates upward



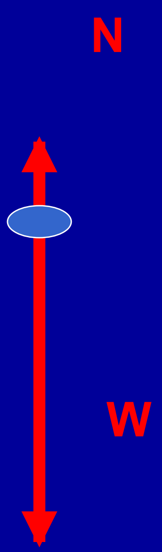
$$N - mg = ma$$

5.8 Satellites and "Weightlessness"

Apparent weightlessness

If the elevator accelerates downward

$$N - mg = ma$$

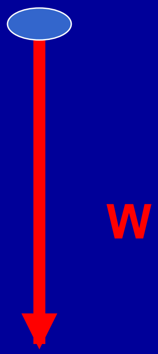


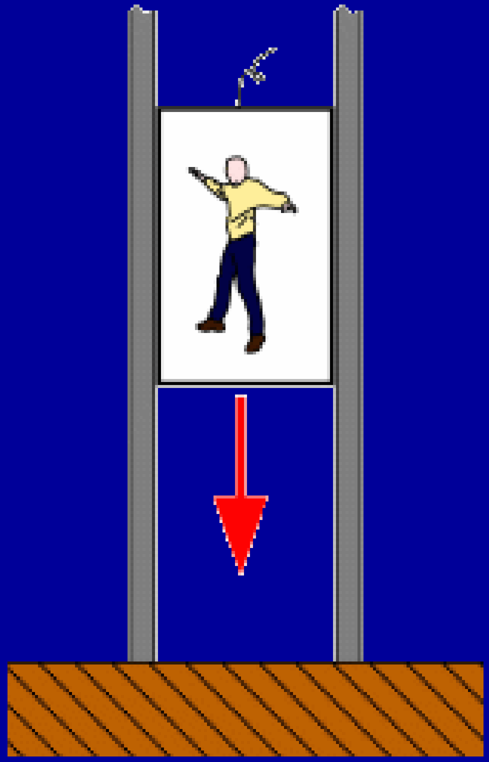
5.8 Satellites and "Weightlessness"

Apparent weightlessness

If the rope on the elevator breaks

$$mg = ma$$





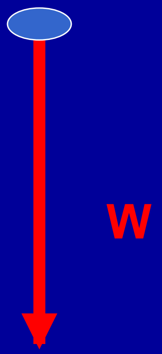
5.8 Satellites and "Weightlessness"

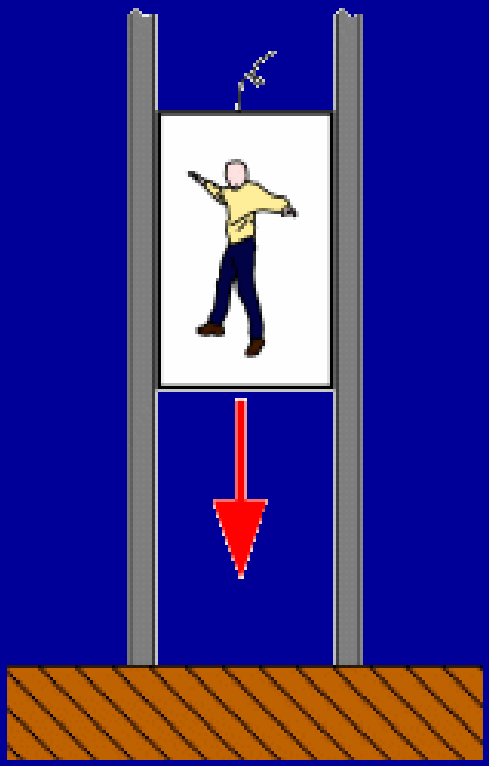
Apparent weightlessness

Everything moves at same acceleration

no force upward, apparent weightlessness

$$mg = ma$$





S-27

Bob's dog "Kille

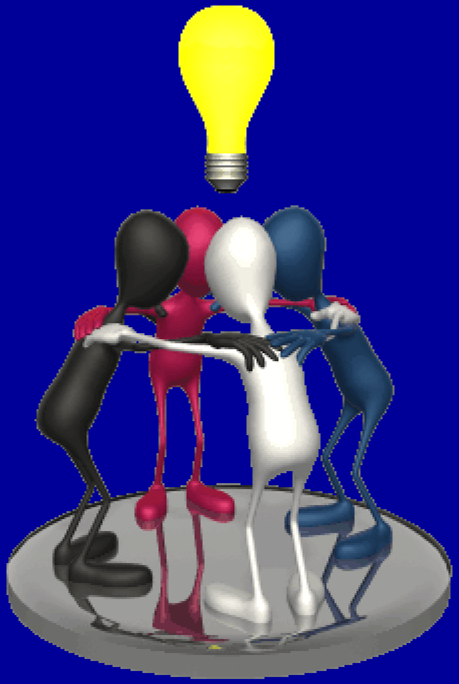
in a tree. If the

mass of 55 kg,

the coefficient c

between the dog and tree so that he doesn't slide down? Assume that each tree pushes inward with a force of 300 N.

Circular Motion; Gravitation



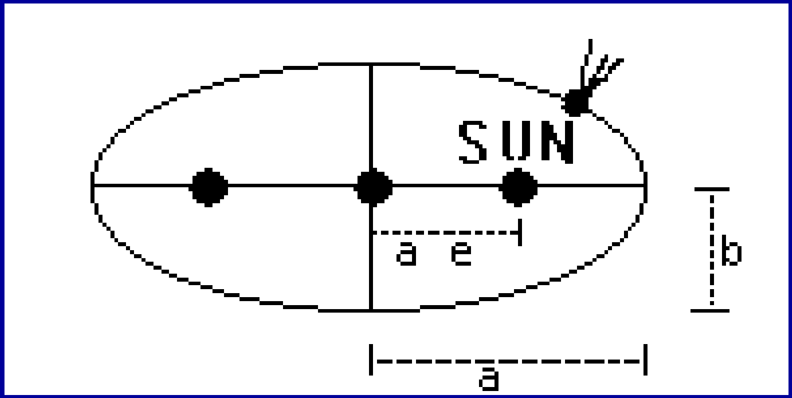
5.9 Kepler's Laws and Newton's Synthesis

5.9 Kepler's Laws and Newton's Synthesis

Johannes Kepler – 50 years before Newton came up with three findings

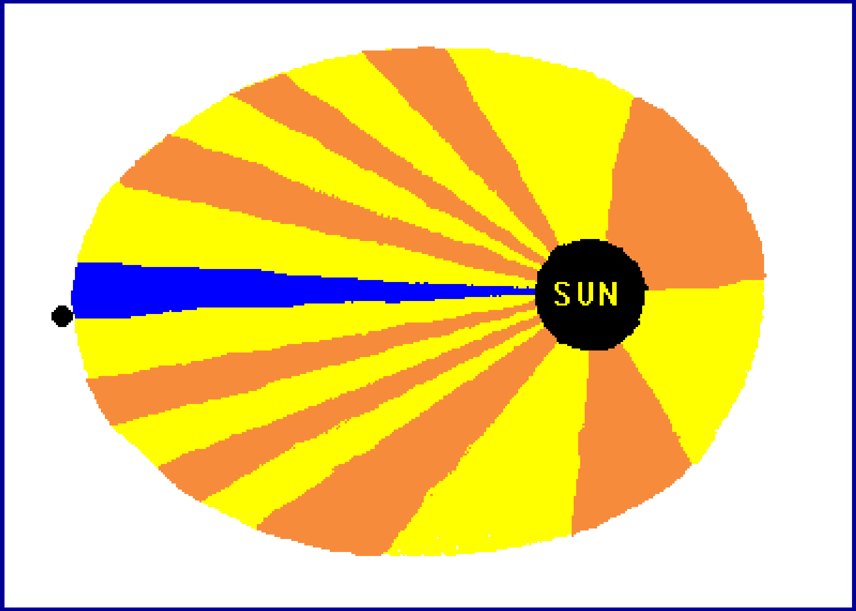
Kepler's Laws of Planetary Motion

Kepler's First Law – the path of each planet around the Sun is an ellipse with the sun at one focus



5.9 Kepler's Laws and Newton's Synthesis

Kepler's Second Law – Each planet moves so that an imaginary line drawn from the sun to the planet sweeps out equal areas in equal periods of time



5.9 Kepler's Laws and Newton's Synthesis

Kepler's Third Law – the ratio of the squares of the periods T of any two planets revolving about the Sun is equal to the ratio of the cubes of their mean distances, s, from the Sun?

5.9 Kepler's Laws and Newton's Synthesis

Kepler's Third Law – the ratio of the squares of the periods T of any two planets revolving about the Sun is equal to the ratio of the cubes of their mean distances, s, from the Sun?

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{s_1}{s_2}\right)^3$$

5.9 Kepler's Laws and Newton's Synthesis

s is the semimajor axis of the ellipse

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{s_1}{s_2}\right)^3$$

S-25

A hammer in the hammer toss has a mass of 7.257 kg, and the world record toss is 86.74m Assuming that the hammer followed projectile motion after leaving the throwers hands and was launched at 40^{o} to the horizontal from 1.00 m above the ground, what was the centripetal force on the hammer right before it was launched?

Practice Problems

S-26

Jo Jo the 7kg cat isn't very smart. He is standing on a fan (r = 4.5 m).

A. What is the maximum speed the fan can go with the cat on it if the coefficient of friction is 0.45?

B. What will be the cats pathway if the friction isn't strong enough?

Practice Problems

S-27

The USS Defiant is in orbit around the earth at a height of 500 km above the earth's surface.

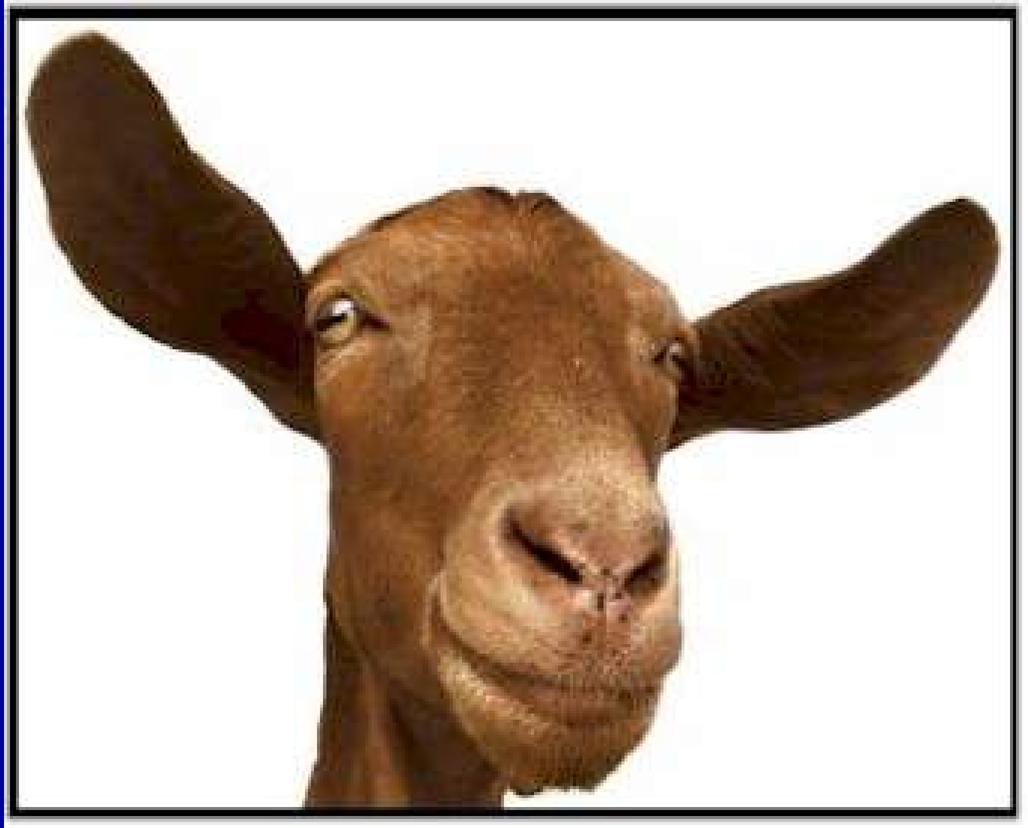
A. What is its velocity to maintain the orbit

B. What is the acceleration due to gravity at this point?

Practice Problems

S-28

The "Goat of Happiness" wishes you well on your test.



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