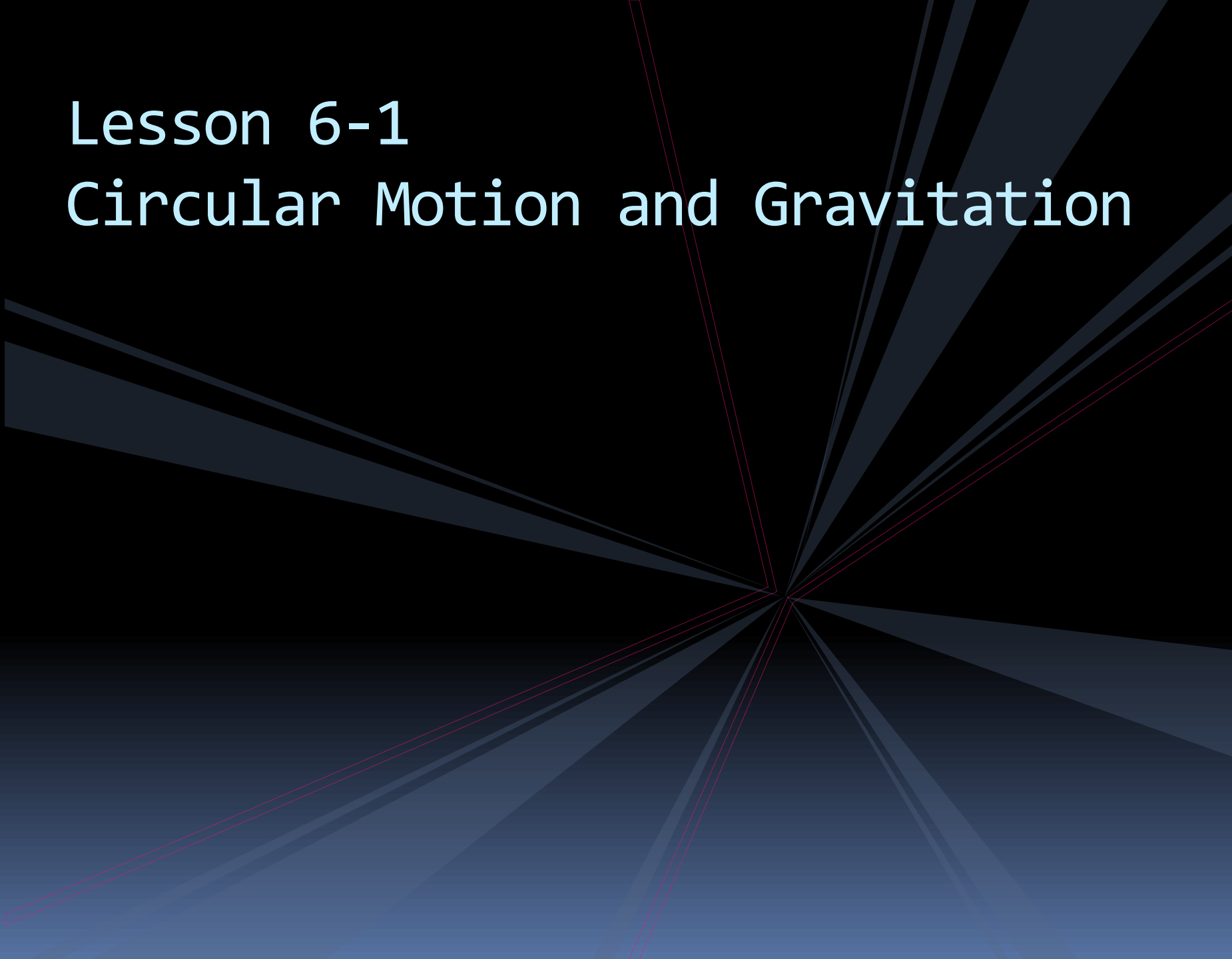# Devil Physics
Baddest Class on Campus
IB Physics

Lesson 6-1
Circular Motion and Gravitation

Review Quiz

1. Give the equation for work done by a force.

2. Given a graph of force versus displacement, how would you determine the work done by a varying force?

3. State the equations for:
   - *Kinetic energy*,
   - *Gravitational potential energy*,
   - *Elastic potential energy*,

4. True or False. Gravitational potential energy can only be calculated by measuring heights from the lowest point to the highest point.

Review Quiz

5. True or False. When friction forces are absent, the total mechanical energy is not conserved.

6. State the work-kinetic energy relation

7. When external forces are present, what is the relationship between work done and mechanical energy?

Review Quiz

8. State the definition of _power_, and its very useful form in mechanics.

9. True or False. In all collisions momentum is always conserved, but kinetic energy is only conserved in elastic collisions

Review Quiz -- Answers

1. **Give the equation for work done by a force.**

   $$W = Fd\cos\theta$$

2. Given a graph of force versus displacement, how would you determine the work done by a varying force?

   - **Understand that the _work done by a varying force_ is given by the _area under the graph_ of _force versus displacement_**

3. **State the equations for:**

   - _Kinetic energy_, $E_k = 1/2\,mv^2$ $E_k = \dfrac{p^2}{2m}$

   - _Gravitational potential energy_, $E_p = mgh$

   - _Elastic potential energy_, $E_e = 1/2\,kx^2$

Review Quiz -- Answers

4. True or **False**. Gravitational potential energy can only be calculated by measuring heights from the lowest point to the highest point.

5. True or **False**. When friction forces are absent, the total mechanical energy is not conserved.

6. State the work-kinetic energy relation

$$W = \Delta E_k$$

7. When external forces are present, what is the relationship between work done and mechanical energy? $W = \Delta E$

Review Quiz -- Answers

8. State the definition of _power_, , and its very useful form in mechanics, $$P = \frac{\Delta W}{\Delta t}$$ $$P = Fv$$

9. **True** or False. In all collisions momentum is always conserved, but that kinetic energy is only conserved in elastic collisions

Britannica Concise Encyclopedia
uniform circular motion

Motion of a particle moving at a constant speed on a circle. ***Though the magnitude of the velocity of such an object may be constant, the object is constantly accelerating because its direction is constantly changing.*** At any given instant its ***direction is perpendicular to a radius of the circle*** drawn to the point of location of the object on the circle. The ***acceleration is strictly a change in direction and is a result of a force directed toward the centre of the circle. This centripetal force causes centripetal acceleration.***

Uniform Circular Motion

Essential Idea:

- A force applied perpendicular to its displacement can result in circular motion.

Nature Of Science:

- Observable universe: Observations and subsequent deductions led to the realization that the force must act radially inwards in all cases of circular motion.

International-Mindedness:

- International collaboration is needed in establishing effective rocket launch sites to benefit space programs.

Theory Of Knowledge:

- Foucault's pendulum gives a simple observable proof of the rotation of the earth, which is largely unobservable.
- How can we have knowledge of things that are unobservable?

Understandings:

- Period, frequency, angular displacement and angular velocity
- Centripetal force
- Centripetal acceleration

Applications And Skills:

- Identifying the forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic

Applications And Skills:

- Solving problems involving centripetal force, centripetal acceleration, period, frequency, angular displacement, linear speed and angular velocity

Applications And Skills:

- Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion

Guidance:

- Banking will be considered qualitatively only

Data Booklet Reference:

$$v = \omega t$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$F = \frac{mv^2}{r} = m\omega^2 r$$

Utilization:

- Motion of charged particles in magnetic fields (see Physics sub-topic 5.4)
- Mass spectrometry (see Chemistry sub-topics 2.1 and 11.3)
- Playground and amusement park rides often use the principles of circular motion in their design

Aims:

- Aim 6: experiments could include (but are not limited to): mass on a string; observation and quantification of loop-the-loop experiences; friction of a mass on a turntable
- Aim 7: technology has allowed for more accurate and precise measurements of circular motion, including data loggers for force measurements and video analysis of objects moving in circular motion
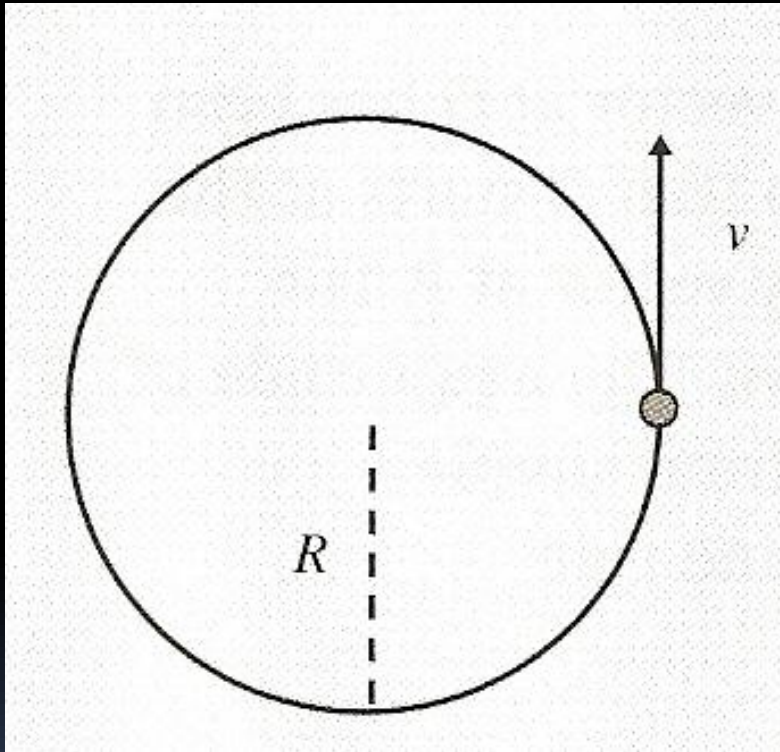
Circular Motion and Centripetal Acceleration
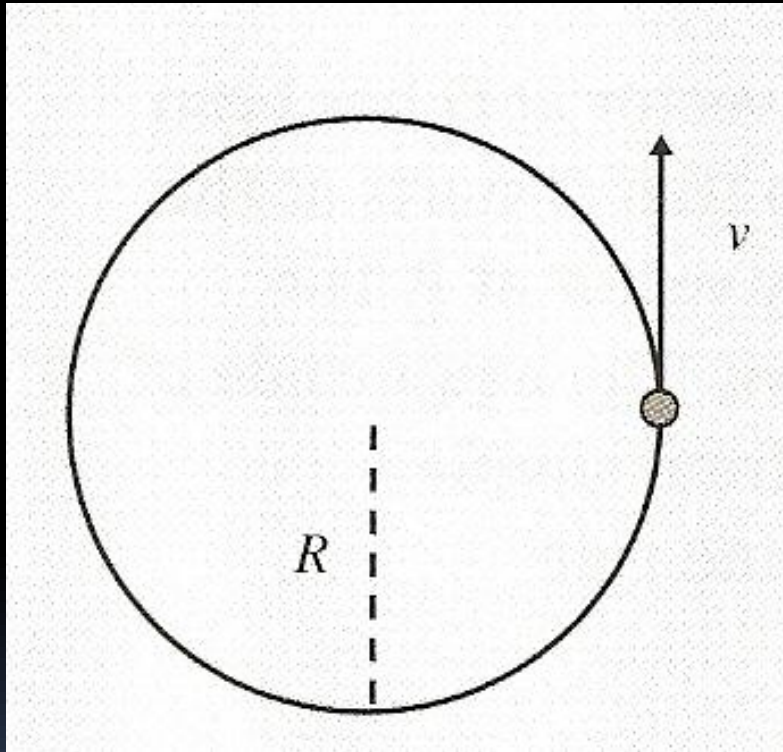
$$v = \frac{2\pi R}{T}$$

- T is the period in seconds – the time it takes to make one revolution
- 2πR is the circumference or distance around the circle
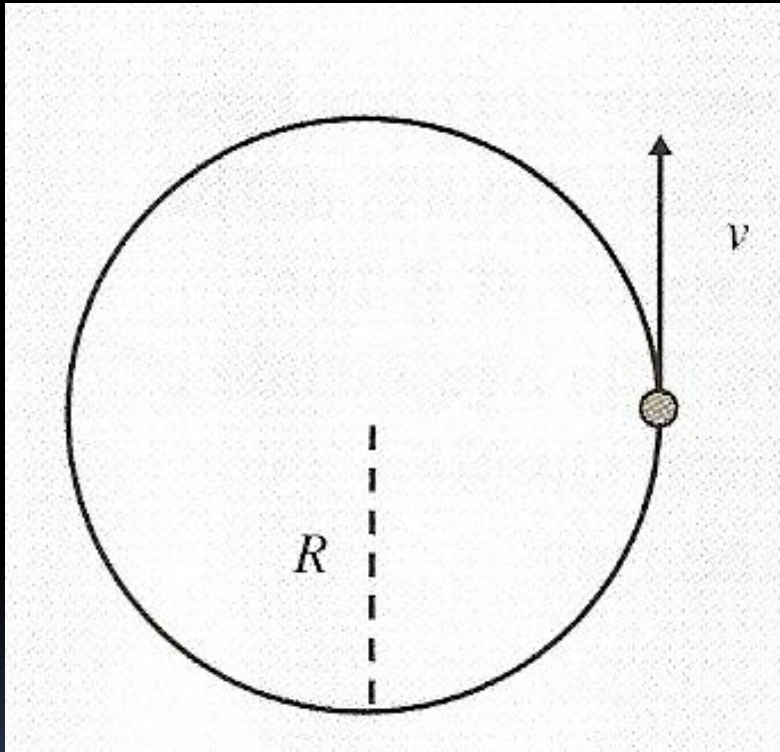
Circular Motion and Centripetal Acceleration

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{T}$$

- Angular Speed
- In one period, the object will sweep out an angle of 2π radians (one circle)
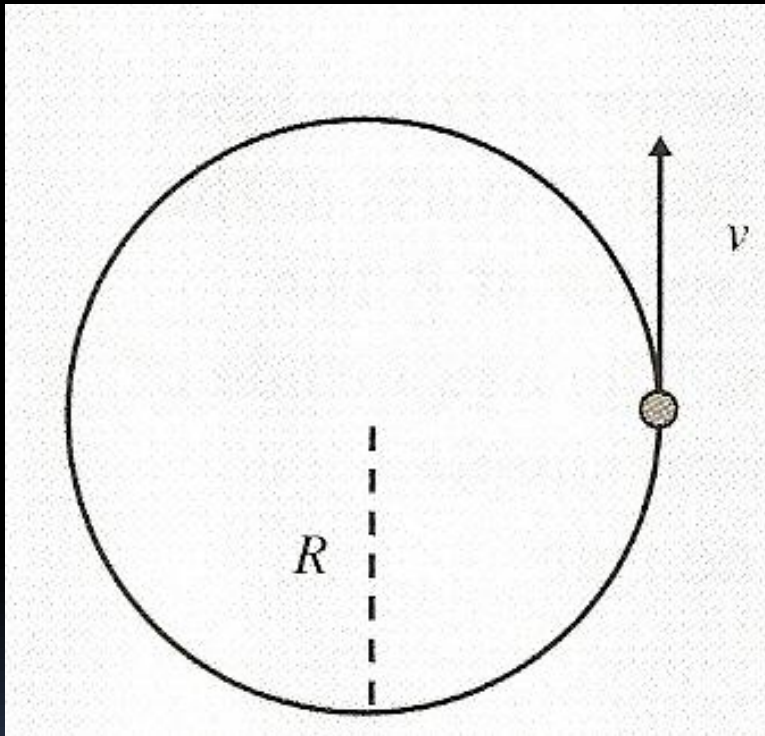- Units are radians per second or just s^{-1}

Circular Motion and Centripetal Acceleration

$$\omega = 2\pi \frac{1}{T} = 2\pi f$$

- Angular Speed
- Since frequency is the inverse of period, angular speed can also be given in terms of frequency
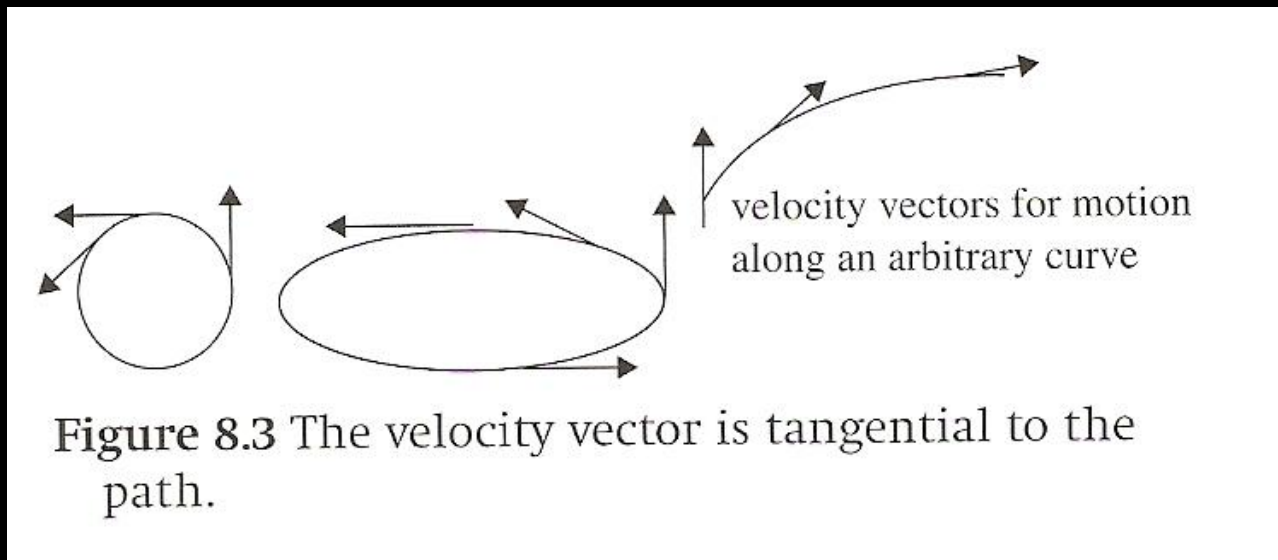
Circular Motion and Centripetal Acceleration

- Even though speed is constant, velocity is not because it is constantly changing direction
- Since the velocity changes, we have acceleration

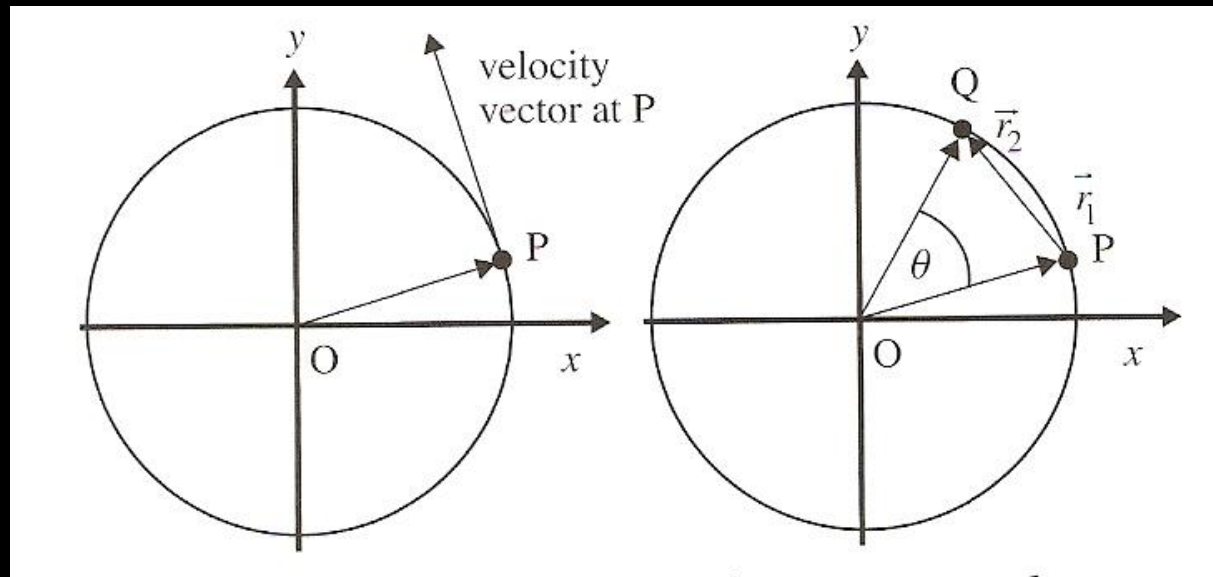$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

Circular Motion and Centripetal Acceleration

Figure 8.3 The velocity vector is tangential to the path.

- In any non-linear motion, velocity is a vector that is always tangent to the displacement
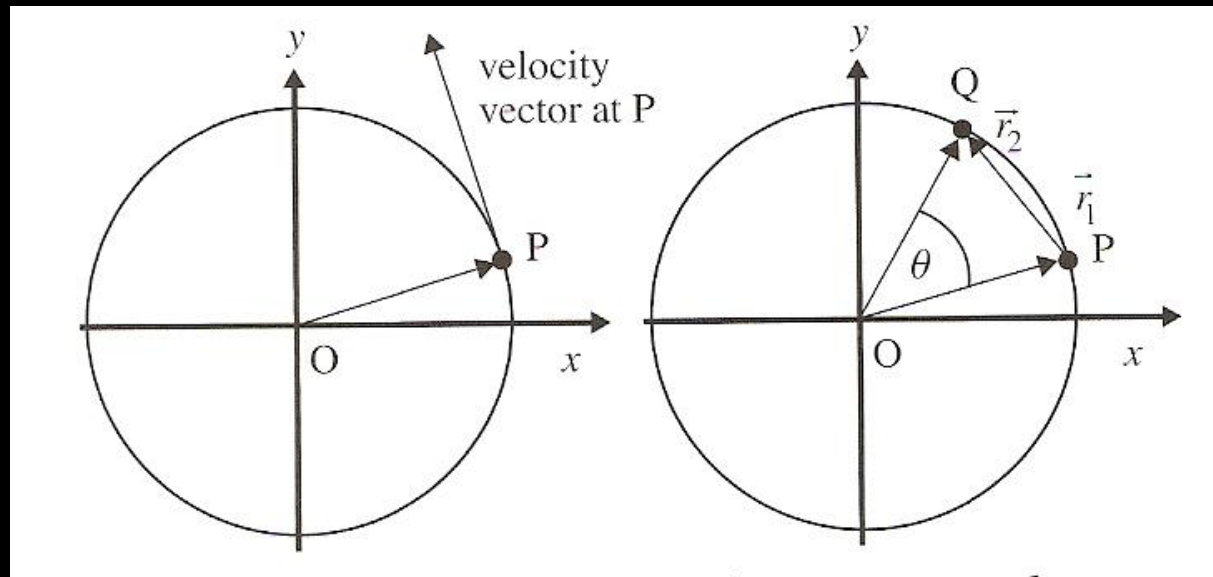
$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}$$

Circular Motion and Centripetal Acceleration

- In circular motion, velocity is a vector that is always tangent to the circle

$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}$$

Circular Motion and Centripetal Acceleration

- When Δt is taken to be infinitely small, the difference between Δr and Δs, the arc length, becomes insignificant

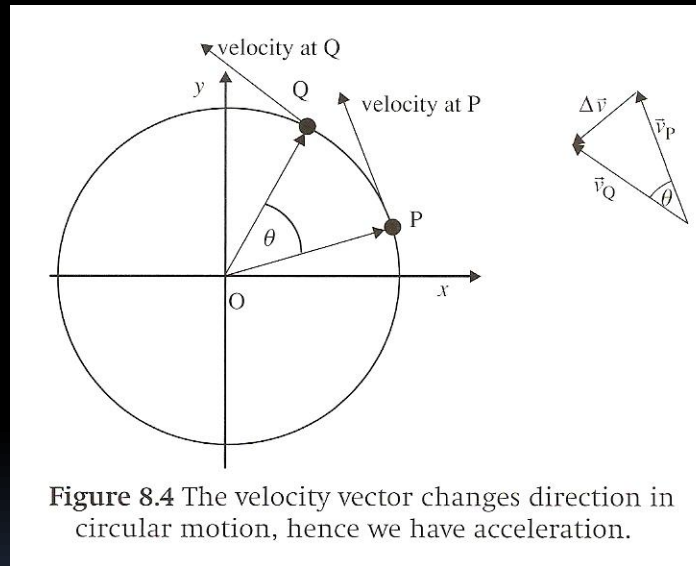$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}$$

Circular Motion and Centripetal Acceleration

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

$$\Delta v = v \sin \theta$$

$$\sin \theta \approx \theta$$

$$\theta = \frac{\Delta s}{R}$$

Figure 8.4 The velocity vector changes direction in circular motion, hence we have acceleration.

$$\Delta s = v \Delta t$$

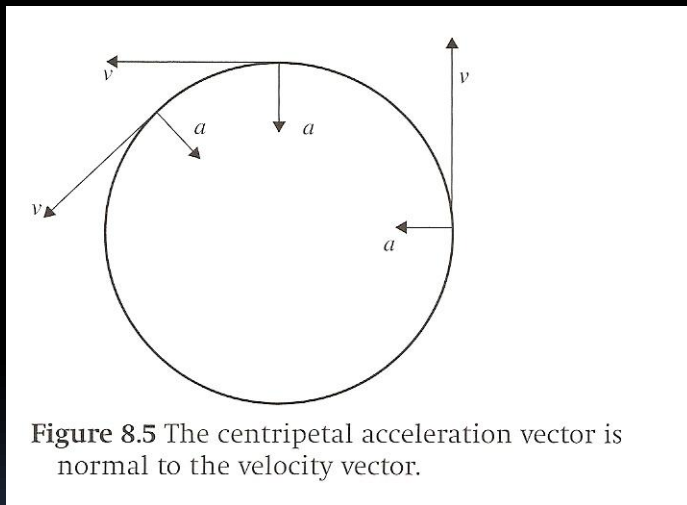$$\Delta v = \frac{v v \Delta t}{R}$$

$$a_c = \frac{v^2}{R}$$

Circular Motion and Centripetal Acceleration

- A body moving along a circle of radius R with a speed v experiences centripetal acceleration that has magnitude given by
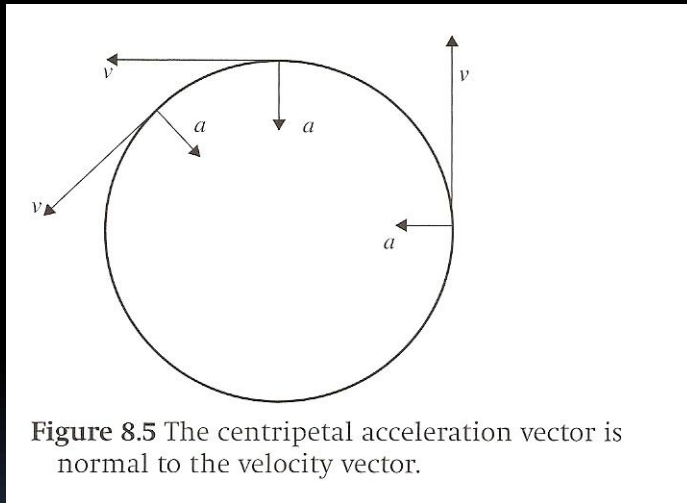
$$a_c = \frac{v^2}{R}$$

and is directed toward the centre of the circle

Figure 8.5 The centripetal acceleration vector is normal to the velocity vector.

Circular Motion and Centripetal Acceleration

Figure 8.5 The centripetal acceleration vector is normal to the velocity vector.
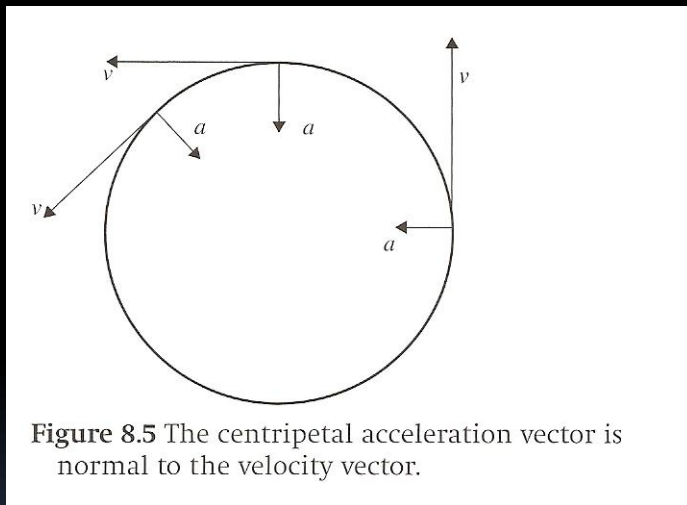
- In terms of angular speed,

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

$$v = \frac{2\pi r}{T}$$

$$a_c = \frac{4\pi^2 r^2}{rT^2} = \frac{4\pi^2 r}{T^2}$$

Circular Motion and Centripetal Acceleration

- In terms of angular speed,

Figure 8.5 The centripetal acceleration vector is normal to the velocity vector.

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

$$v = r\omega$$

$$a_c = \frac{r^2\omega^2}{r} = r\omega^2$$

Tangential Acceleration

- If the magnitude of the velocity changes, we have tangential acceleration.

- This is a vector in the same direction as the velocity vector if speed is increasing, in the opposite direction if decreasing

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

Tangential and Centripetal Acceleration

- When velocity direction and magnitude are changing, we have both centripetal acceleration and tangential acceleration

- *The total acceleration is the vector sum of the vectors representing these accelerations*

Centripetal Forces

- If a mass moves in a circle, there must be a force present because we have mass and acceleration

- If the speed is constant (no tangential acceleration), the direction of the acceleration, and therefore the force, are toward the centre of the circle
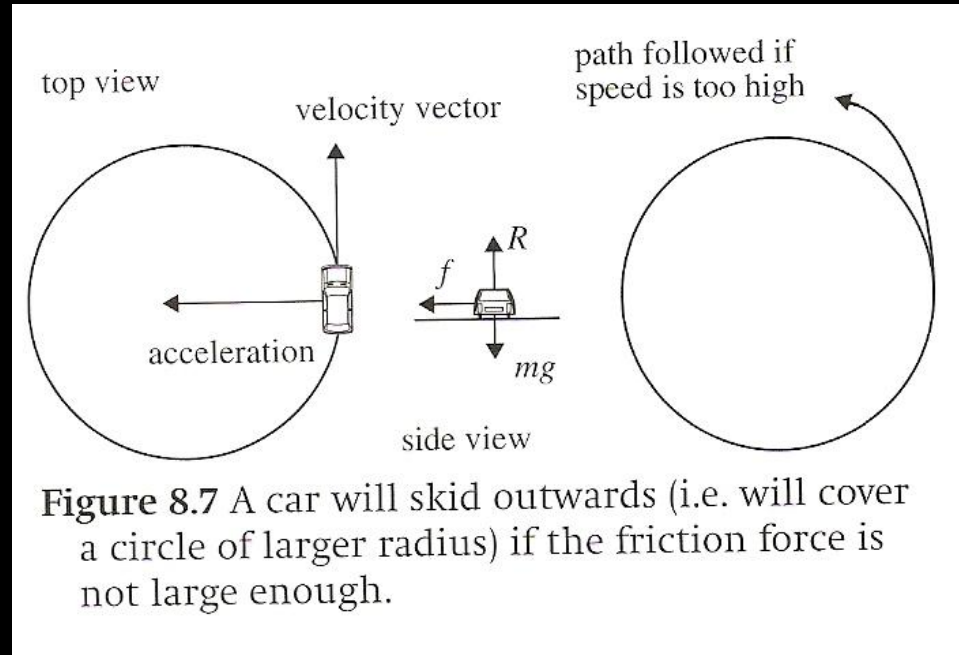
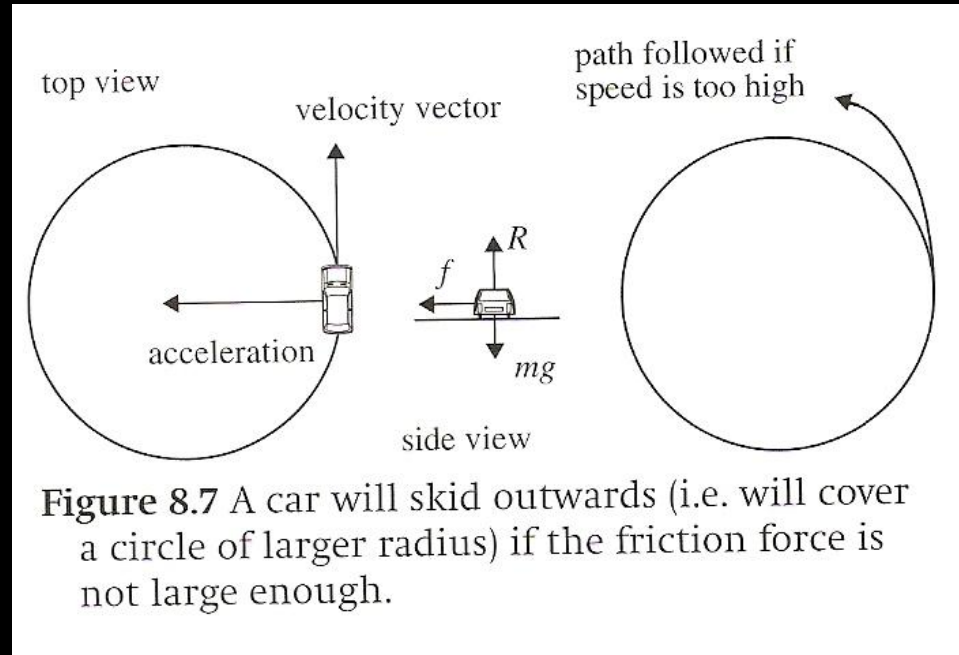# Centripetal Forces

$$F = ma$$

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

$$F = m\omega^2 r$$

Centripetal Forces

Figure 8.7 A car will skid outwards (i.e. will cover a circle of larger radius) if the friction force is not large enough.

- Think of a car driving in a circle;
- The force of friction between the tires and the road provide the centripetal force

Centripetal Forces

Figure 8.7 A car will skid outwards (i.e. will cover a circle of larger radius) if the friction force is not large enough.
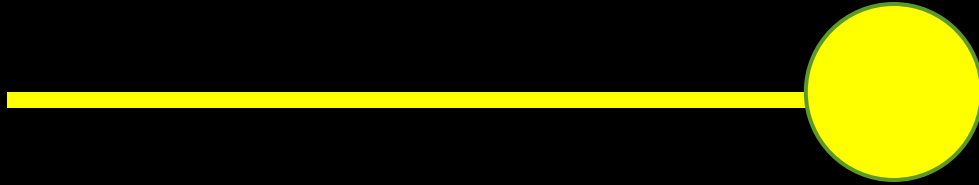
- Since the centripetal force is at right angles to the motion, there is never any work done

$$W = Fs\cos\theta = 0$$
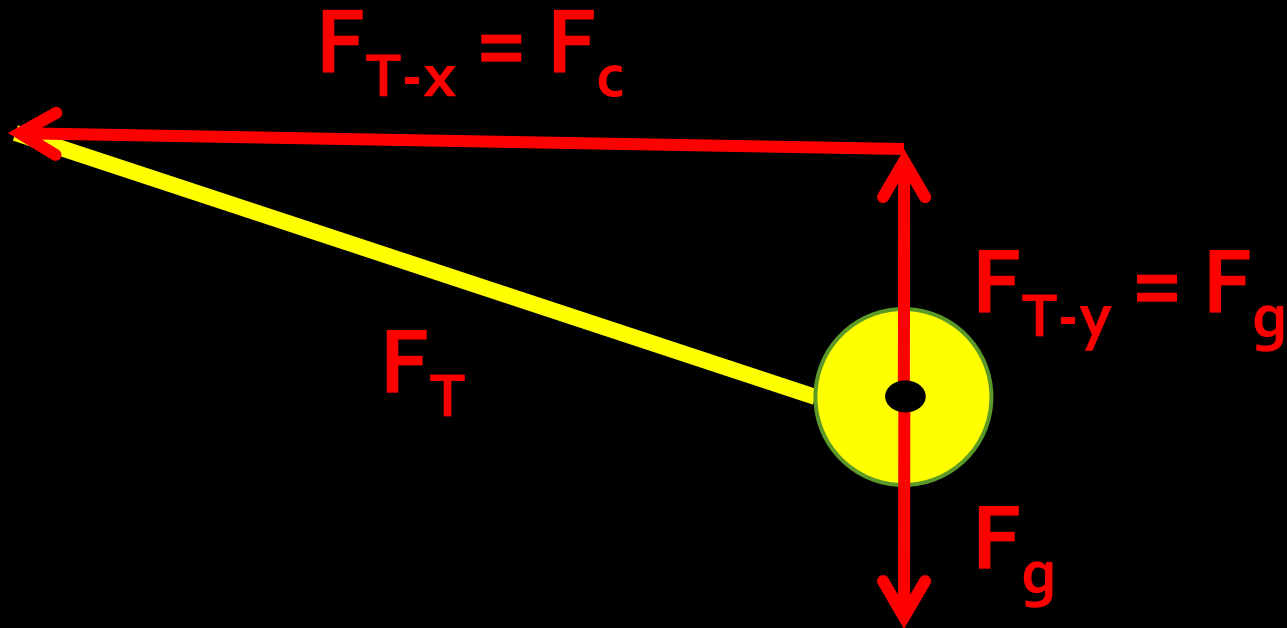
Ball on a String

- *Can a ball on a string rotate in a plane parallel to the earth's surface, i.e. horizontally?*

Ball on a String

F_g

- *Can a ball on a string rotate in a plane parallel to the earth's surface, i.e. horizontally?*
- *If so, what is supporting its weight?*

Ball on a String

$F_{T-x} = F_c$

$F_{T-y} = F_g$

F_T

F_g

Summary Video

Understandings:

- Period, frequency, angular displacement and angular velocity
- Centripetal force
- Centripetal acceleration

Data Booklet Reference:

$$v = \omega t$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

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Applications And Skills:

- Identifying the forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic

Applications And Skills:

- Solving problems involving centripetal force, centripetal acceleration, period, frequency, angular displacement, linear speed and angular velocity

Applications And Skills:

- Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion

Essential Idea:

- A force applied perpendicular to its displacement can result in circular motion.

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IB Physics

Questions?

HOMEWORK

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