مدونة المناهج السعودية

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الموقع التعليمي لجميع المراحل الدراسية

في المملكة العربية السعودية

# PHYS 101

## Ch. 3

## Motion in Two or Three Dimensions

# Chapter 3

## Chapter Three
## ***Motion in Two or Three Dimensions***

- ***Position and Velocity Vectors***
- ***The Acceleration Vector***
- ***Projectile Motion***
- ***Motion in a Circle***

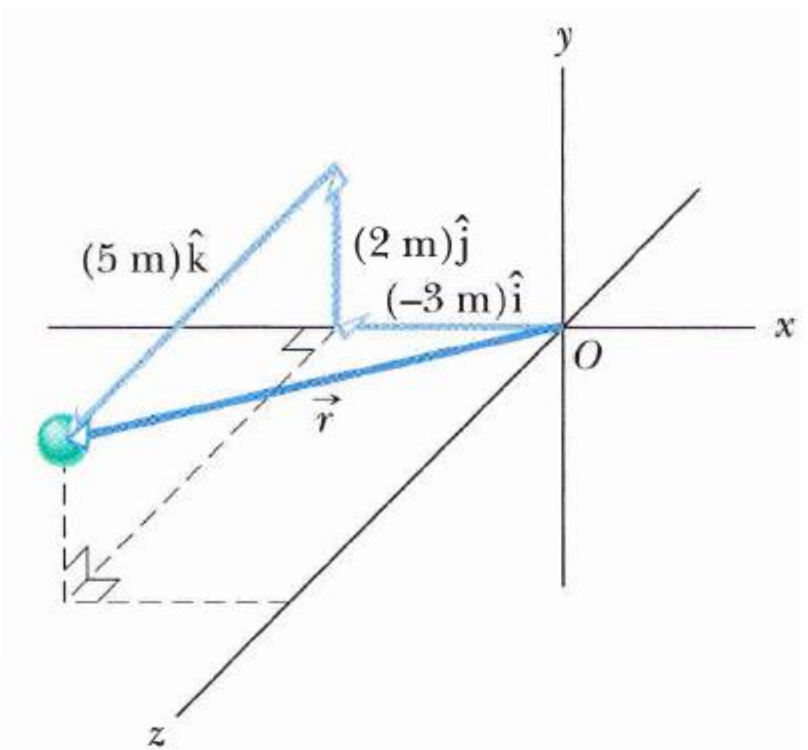
# *Position and Velocity Vectors*

## Position and Displacement

### *Position*

- The location of a particle relative to the origin of a coordinate system is given by:

$$\vec{r} = x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}},$$

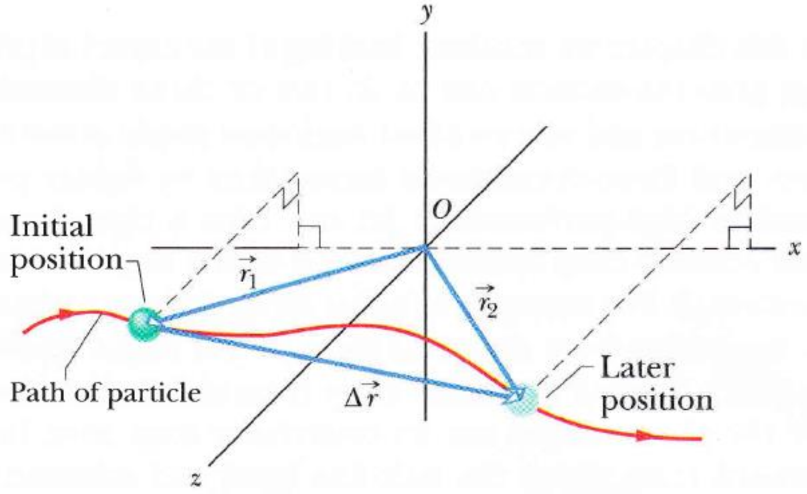



$$\vec{r} = (-3\ \mathrm{m})\hat{\mathrm{i}} + (2\ \mathrm{m})\hat{\mathrm{j}} + (5\ \mathrm{m})\hat{\mathrm{k}}$$

# Position and Velocity Vectors

## Displacement

- The displacement of a particle moves between two position vectors is given by:




$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1.$$

$$\Delta\vec{r} = (x_2 - x_1)\hat{\mathrm{i}} + (y_2 - y_1)\hat{\mathrm{j}} + (z_2 - z_1)\hat{\mathrm{k}},$$

$$\Delta\vec{r} = \Delta x\hat{\mathrm{i}} + \Delta y\hat{\mathrm{j}} + \Delta z\hat{\mathrm{k}}.$$

# *Position and Velocity Vectors*

***Example 1:***

A particle moving from $\overrightarrow{r_1} = 2\hat{i} + 5\hat{j} + 8\hat{k}$ to $\overrightarrow{r_2} = 12\hat{i} + 10\hat{j} + 8\hat{k}$, then the displacement is:

***Solution:***

**(C)**

(A) $10\hat{i} - 3\hat{j}$
(B) $4\hat{i} + 6\hat{j}$
(C) $10\hat{i} + 5\hat{j}$
(D) $5\hat{j}$

# Position and Velocity Vectors

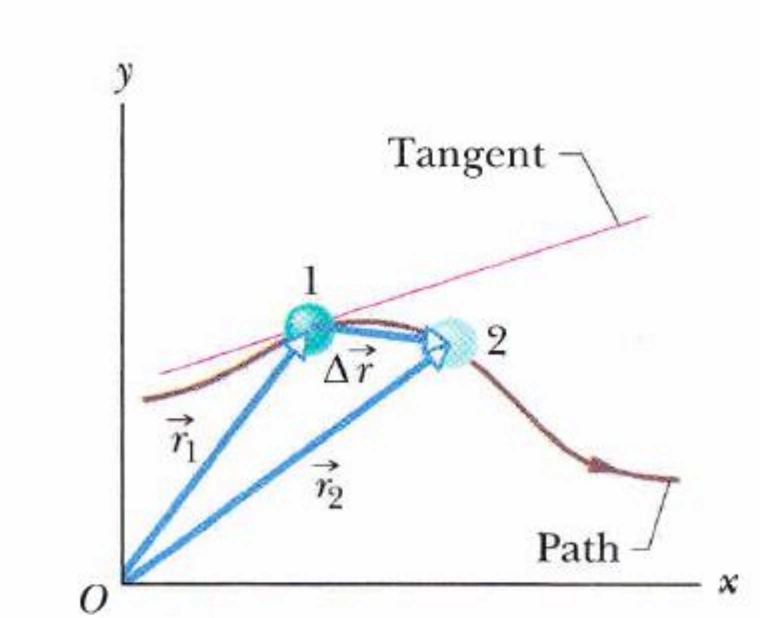
## Average Velocity and Instantaneous Velocity

### Average Velocity

- The average velocity of a particle undergoes any displacement in a time is:

$$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}.$$

$$\vec{v}_{avg} = \frac{\Delta x}{\Delta t}\,\hat{i} + \frac{\Delta y}{\Delta t}\,\hat{j} + \frac{\Delta z}{\Delta t}\,\hat{k}.$$



# Position and Velocity Vectors

## Instantaneous Velocity

- The instantaneous velocity of a particle is given by:

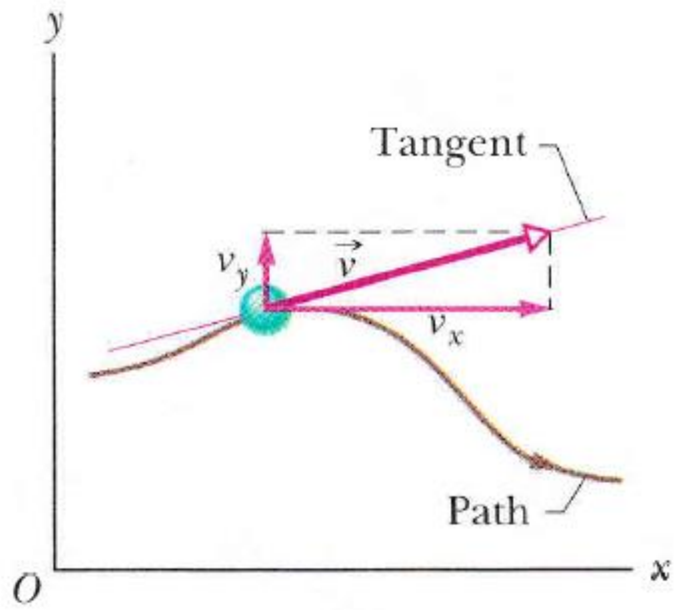
$$\vec{v} = \frac{d\vec{r}}{dt}.$$

$$\vec{v} = \frac{d}{dt}(x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}})$$

$$= \frac{dx}{dt}\hat{\mathrm{i}} + \frac{dy}{dt}\hat{\mathrm{j}} + \frac{dz}{dt}\hat{\mathrm{k}}.$$

# Position and Velocity Vectors

- It always directed along the tangent to the particle's path at the particle's position



# *Position and Velocity Vectors*

***Example 2:***

A particle moves in xy plane as $x(t) = 2t\ (m)$ and $y(t) = t^2 - 1\ (m)$. The velocity of the particle at t=1 s is:

***Solution:***

**(D)**

(A) $\hat{i} + \hat{j}$ (m/s)
(B) $2\hat{i} + \hat{j}$ (m/s)
(C) $2\hat{i} - \hat{j}$ (m/s)
(D) $2\hat{i} + 2\hat{j}$ (m/s)

# The Acceleration Vector

## Average Acceleration and Instantaneous Acceleration

### *Average Acceleration*

- The average acceleration of a particle is velocity changes in a time interval and given by:

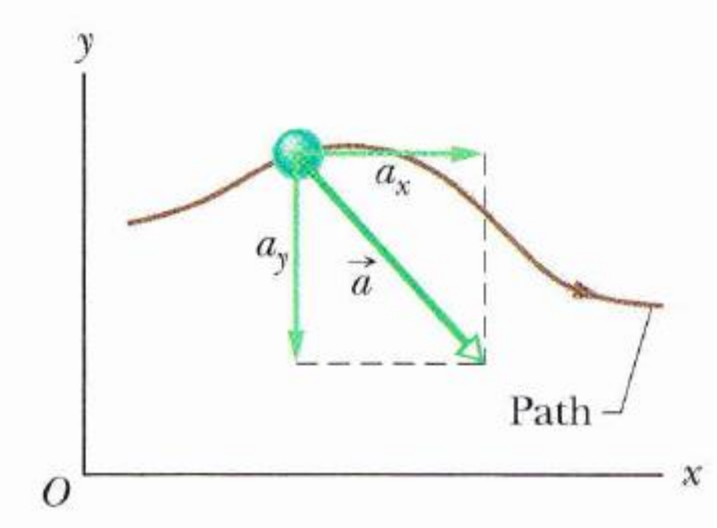
$$\vec{a}_{avg} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\Delta \vec{v}}{\Delta t}.$$

# The Acceleration Vector

## *Instantaneous Acceleration*

- The instantaneous acceleration of a particle is given by:

$$\vec{a} = \frac{d\vec{v}}{dt}.$$




$$\vec{a} = \frac{d}{dt}(v_x\hat{i} + v_y\hat{j} + v_z\hat{k}) = \frac{dv_x}{dt}\hat{i} + \frac{dv_y}{dt}\hat{j} + \frac{dv_z}{dt}\hat{k}.$$

# The Acceleration Vector

***Example 3:***

At t=0, a car moves with velocity $\overrightarrow{v_0} = 2\hat{\imath} + \hat{\jmath}$ (m/s) and acceleration $\vec{a} = 2\hat{\jmath}$ (m/s$^2$). The velocity of the car at t=2 is:

***Solution:***

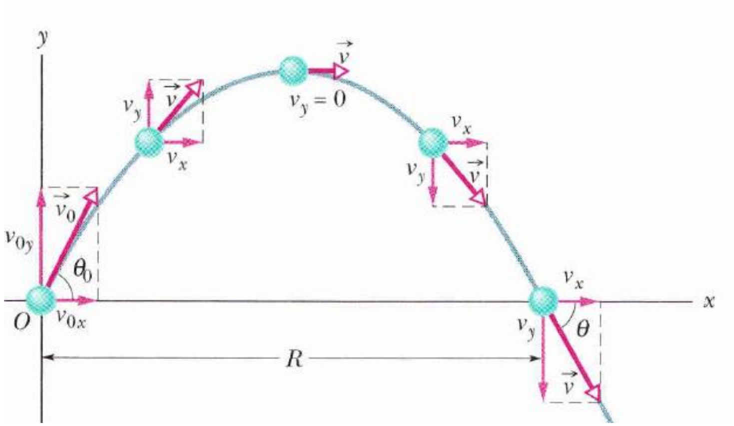
**(B)**

(A) $6\hat{\imath} + \hat{\jmath}$
(B) $2\hat{\imath} + 5\hat{\jmath}$
(C) $2\hat{\imath} + \hat{\jmath}$
(D) $\hat{\imath} + 5\hat{\jmath}$

# Projectile Motion

## Projectile Motion

- The projectile motion is the motion of a particle that is launched with an initial velocity $\vec{v}_0$ and initial angle $\theta_0$.
- The particle's horizontal acceleration is zero during its flight and free fall acceleration –g for its vertical acceleration.
- The projectile is launched with an initial velocity $\vec{v}_0$ that can be written as

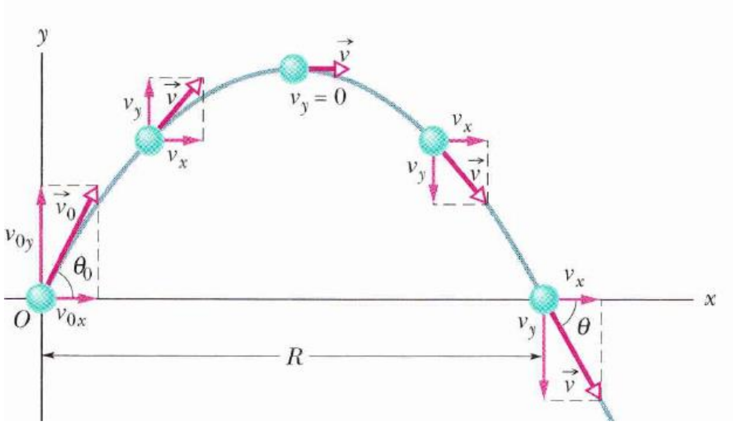



$$\vec{v}_0 = v_{0x}\hat{\mathrm{i}} + v_{0y}\hat{\mathrm{j}}.$$

# Projectile Motion

- The components $v_{0x}$ and $v_{0y}$ can then be found if we know the angle $\theta_0$ between $\vec{v}_0$ and the positive $x$ direction as follows:

$$v_{0x} = v_0 \cos \theta_0 \quad \text{and} \quad v_{0y} = v_0 \sin \theta_0.$$



# Projectile Motion

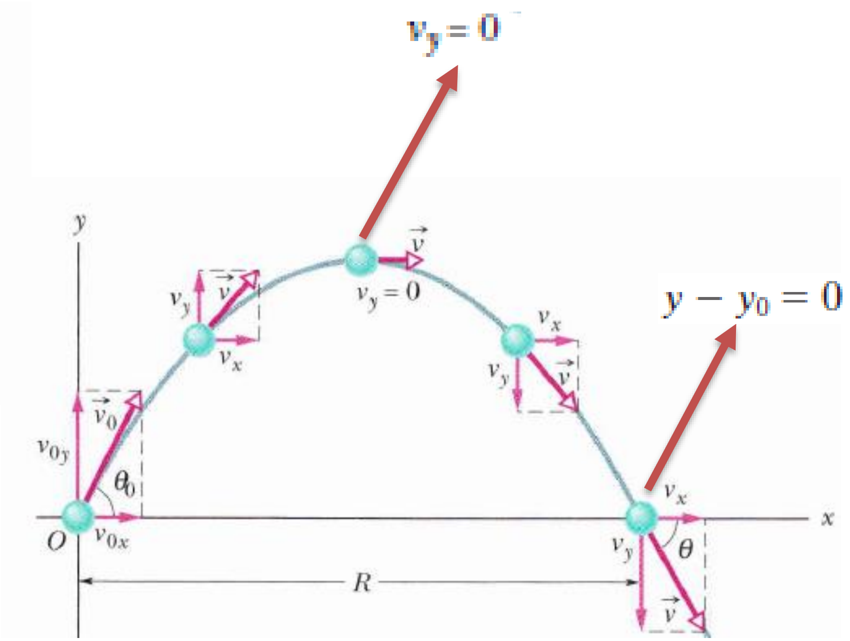
- If $\vec{v}_0$ is expressed as a magnitude $v_0$ and angle $\theta_0$, the particle's equations of motion along the horizontal $x$ axis and vertical $y$ axis are:

$$x - x_0 = (v_0 \cos \theta_0)t,$$

$$y - y_0 = (v_0 \sin \theta_0)t - \tfrac{1}{2}gt^2,$$

$$v_y = v_0 \sin \theta_0 - gt,$$

$$v_y^2 = (v_0 \sin \theta_0)^2 - 2g(y - y_0).$$



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# Projectile Motion

***Example 4:***

A boy kicks a ball at an angle of $40^0$ to the horizontal with speed of 14.0 m/s. The time it takes to reach the highest point is:

***Solution:***

**(A)**

(A) 0.92 s
(B) 0.77 s
(C) 0.15 s
(D) 1.12 s

# Projectile Motion

### The Equation of the Path

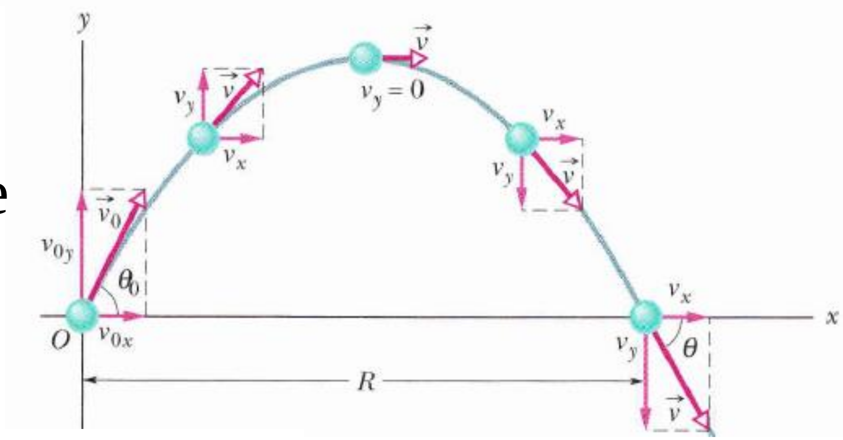
- The trajectory (path) of the particle in projectile motion is given by:

$$y = (\tan \theta_0)x - \frac{gx^2}{2(v_0 \cos \theta_0)^2}$$

### The Horizontal Range

- The particle horizontal range is given by:

$$R = \frac{v_0^2}{g} \sin 2\theta_0.$$




The horizontal range $R$ is maximum for a launch angle of 45°.

# Projectile Motion

***Example 5:***

A boy kicks a ball at an angle of $40^0$ to the horizontal with speed of 14.0 m/s. The maximum height that the ball can reach is:

***Solution:***

**(B)**

(A) 9.87 m
(B) 4.13 m
(C) 15.33 m
(D) 12.68 m

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# ***Projectile Motion***

***Example 6:***

Referring to question 5, the horizontal range that the ball can reach is:

***Solution:***

**(D)**

(A) 9.87 m
(B) 14.7 m
(C) 15.33 m
(D) 19.7 m

# Projectile Motion

***Example 7:***

A projectile is launched to achieve a maximum range of 140 m, the speed of the projectile must be:

***Solution:***

**(C)**

(A) 17 m/s
(B) 27 m/s
(C) 37 m/s
(D) 45 m/s

# Projectile Motion

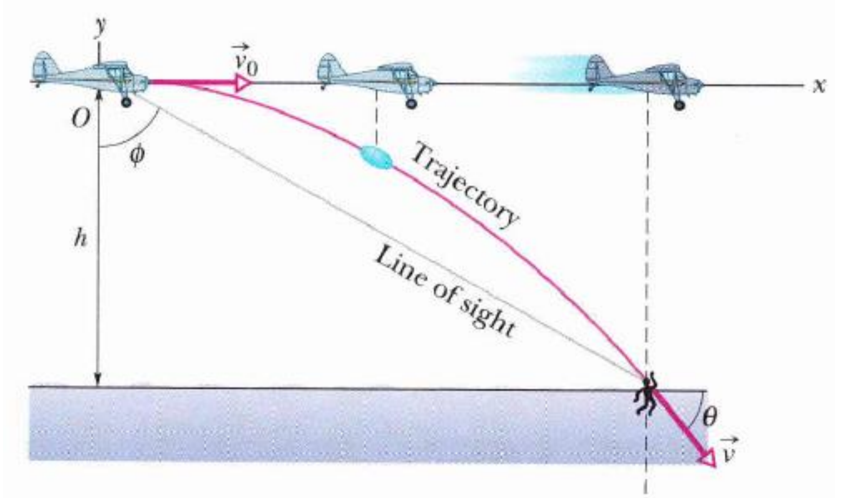
- The motion of an object which is thrown with initial velocity from a certain height,

  - The angle = 0.

  -The following two equations can be used to find all variables in this case:

$$x = v_0 t$$

$$y = \frac{1}{2} g t^2$$



# *Projectile Motion*

***Example 8:***

A toy car runs on a horizontal table with 3 m/s. The angle it makes with the horizontal when it leaves the table is:

***Solution:***

**(A)**

(A) Zero
(B) $45^0$
(C) $60^0$
(D) $90^0$

# Projectile Motion

***Example 9:***

A stone is thrown horizontally from the top of a tall building. It follows a path that is:

***Solution:***

**(D)**

(A) circular
(B) two straight lines
(C) a straight line
(D) parabolic

# Motion in a Circle

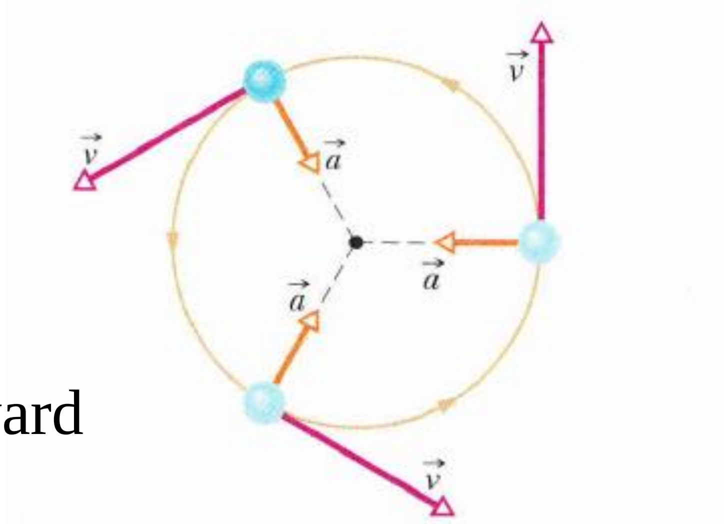
## Uniform Circular Motion

- If a particle travels along a circular arc of radius at constant speed, it is in uniform circular motion.
- Its acceleration can be given by:

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

where $r$ is the radius of the circle
$v$ is the speed of the particle.

(centripetal acceleration),

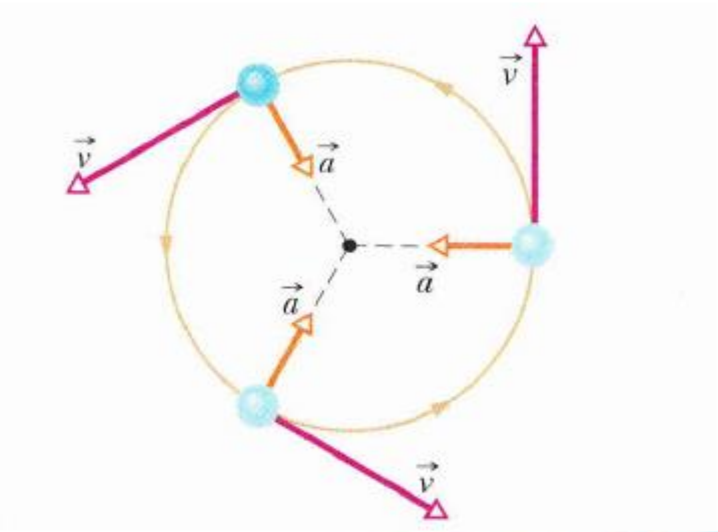



- The acceleration direction is toward the centre of the circular arc.

# Motion in a Circle

- The particle period is the time for the particle to complete a circle can be given by:

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



# *Motion in a Circle*

***Example 10:***

The velocity and acceleration of a body in a uniform circular motion are:

***Solution:***

**(B)**

(A) differed by $45^0$
(B) perpendicular
(C) differed by $135^0$
(D) parallel

# Motion in a Circle

***Example 11:***

A car rounds a 20 m radius curve at 10 m/s. The magnitude of its acceleration is:

***Solution:***

**(D)**

(A) zero
(B) 2 $m/s^2$
(C) 4 $m/s^2$
(D) 5 $m/s^2$

# Motion in a Circle

***Example 12:***

A truck is traveling with a constant speed of 20 m/s. When the truck follows a curve in the road, its centripetal acceleration is 4.0 m/s$^2$. The radius of the curve is:

***Solution:***

**(C)**

(A) 225 m
(B) 144 m
(C) 100 m
(D) 81 m