

# Ch04: Motion in two and three dimensions (2D and 3D)

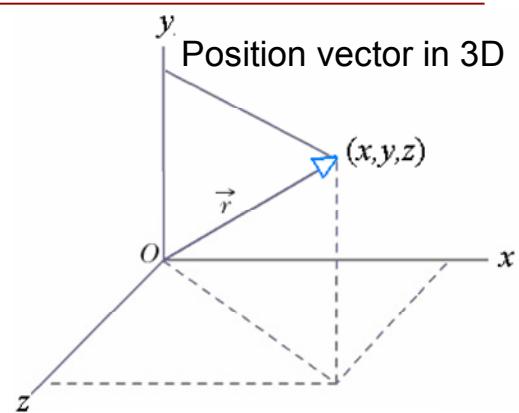
- Displacement, velocity and acceleration vectors
- Projectile motion
- Circular motion
- Relative motion

## 4.2: Position and displacement

- **Position** of an object in 2D or 3D is described by its position vector  $\vec{r}$

- $\vec{r}$  is drawn from origin to the position of the object at a given time. It can be written as

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



- As particle position changed from  $\vec{r}_1$  to  $\vec{r}_2$  during a certain time interval → **displacement** vector that can be written as

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

In components form →  $\Delta\vec{r} = \Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}$

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

## 4.2: Position and displacement

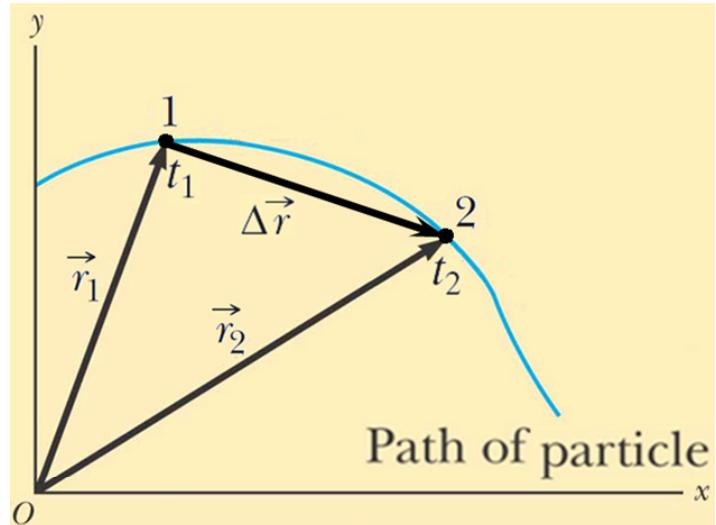
- Displacement vector in 2D is shown in the figure below:

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

$$\downarrow$$
  
$$\Delta \vec{r} = \Delta x \hat{i} + \Delta y \hat{j}$$

$$\Delta x = x_2 - x_1$$

$$\Delta y = y_2 - y_1$$



### 4.2: Position and displacement: Example 1

Rabbit runs across a parking lot. Its position changing according to

$$x = -0.31t^2 + 7.2t + 28$$
  $x$  and  $y$  in meters,  $t$  in seconds. Find its  
 $y = 0.22t^2 - 9.1t + 30.$  position vector at  $t=15\text{s}$  in unit vector notation and in magnitude angle notation

$$x \Big|_{t=15} = (-0.31)(15)^2 + (7.2)(15) + 28 = 66 \text{ m}$$

→ Position vector in unit vectors can be written as

$$y \Big|_{t=15} = (0.22)(15)^2 - (9.1)(15) + 30 = -57 \text{ m}$$

$$\vec{r} = (66 \text{ m})\hat{i} - (57 \text{ m})\hat{j}$$

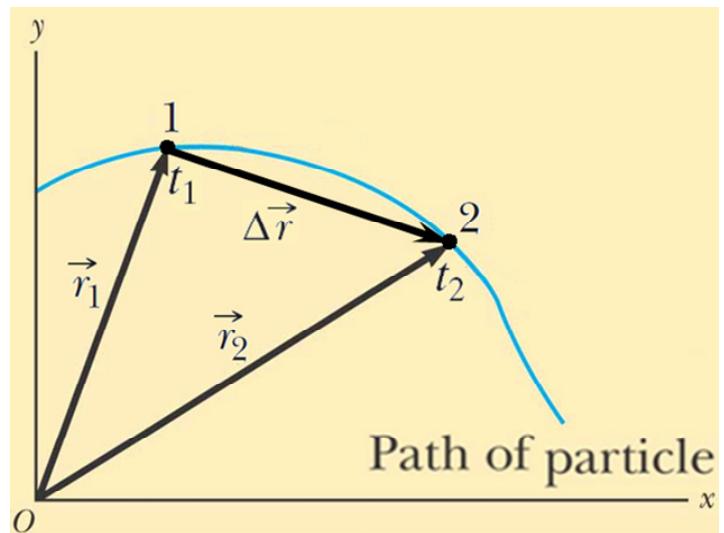
The magnitude from the origin is  $r = \sqrt{x^2 + y^2} = \sqrt{(66 \text{ m})^2 + (-57 \text{ m})^2} = 87 \text{ m}$

at angle  $\theta = \tan^{-1} \frac{y}{x} = \tan^{-1} \left( \frac{-57 \text{ m}}{66 \text{ m}} \right) = -41^\circ$

## 4.3: Average velocity and Instantaneous Velocity

- Since  $\Delta \vec{r}$  occurs in time interval  $\Delta t = t_2 - t_1$
- average velocity**

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



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

## 4.3: Average velocity and Instantaneous Velocity

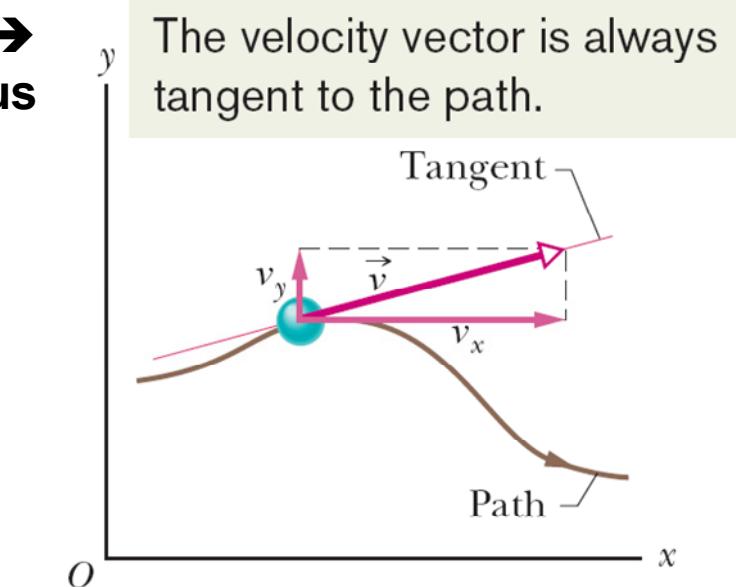
If  $\Delta t$  decrease until  $\Delta t \rightarrow 0$  →  
We will have **Instantaneous velocity (or velocity)**

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

$$\vec{v} = v_x \hat{i} + v_y \hat{j} + v_z \hat{k}$$

$$v_x = \frac{dx}{dt}, \quad v_y = \frac{dy}{dt},$$

$$\text{and} \quad v_z = \frac{dz}{dt}$$



The Speed  $v = |\vec{v}| = \sqrt{v_x^2 + v_y^2}$

## 4.3: Average velocity and Instantaneous Velocity: Example 2

From Ex:1

For the rabbit in the preceding example 1,  
find the velocity  $\vec{v}$  at time  $t = 15$  s.

$$x = -0.31t^2 + 7.2t + 28$$

$$y = 0.22t^2 - 9.1t + 30.$$

$$v_x = \frac{dx}{dt} = \frac{d}{dt}(-0.31t^2 + 7.2t + 28) = -0.62t + 7.2$$

$$\rightarrow v_x \Big|_{t=15 \text{ s}} = -0.62(15) + 7.2 = -2.1 \text{ m/s}$$

$$v_y = \frac{dy}{dt} = \frac{d}{dt}(0.22t^2 - 9.1t + 30) = 0.44t - 9.1$$

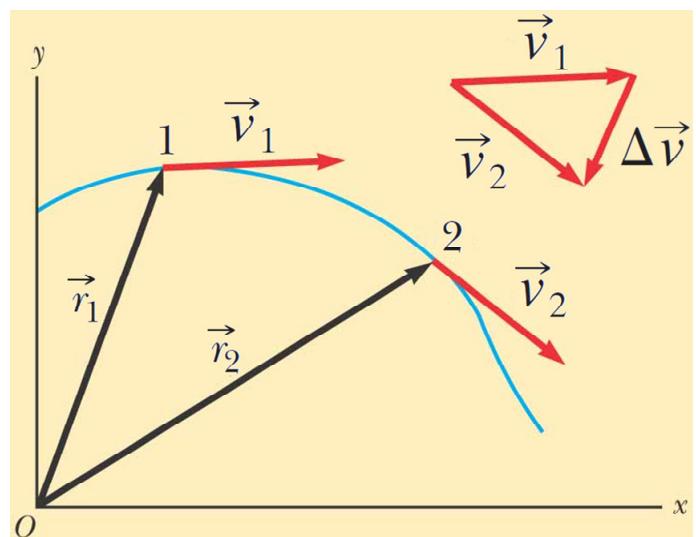
$$\rightarrow v_y \Big|_{t=15 \text{ s}} = 0.44(15) - 9.1 = -2.5 \text{ m/s}$$

$\rightarrow$  Velocity vector is  $\vec{v} = (-2.1 \text{ m/s})\hat{i} + (-2.5 \text{ m/s})\hat{j}$

## 4.4: Average acceleration and Instantaneous acceleration

When a particle's velocity changes from  $\vec{v}_1$  to  $\vec{v}_2$  in a time interval  $\Delta t$ , its **average acceleration** during  $\Delta t$  is

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



- Note that, for an object, acceleration can cause a **change** in the velocity **magnitude** or in the velocity **direction**, or both.

## 4.4: Average acceleration and Instantaneous acceleration

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- For  $\Delta t \rightarrow 0$  we will have **Instantaneous acceleration (or acceleration)**

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

$$\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$$

$$a_x = \frac{dv_x}{dt}, \quad a_y = \frac{dv_y}{dt}, \quad \text{and} \quad a_z = \frac{dv_z}{dt}$$

## 4.4: Average acceleration and Instantaneous acceleration: Example 3

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For the rabbit in the preceding two examples 1 and 2, find the acceleration  $\vec{a}$  at time  $t = 15$  s.

From Ex: 2 we have

$$v_x = -0.62t + 7.2$$

$$v_y = 0.44t - 9.1$$

$$\rightarrow a_x = \frac{dv_x}{dt} = \frac{d}{dt}(-0.62t + 7.2) = -0.62 \text{ m/s}^2$$

$$\text{and } a_y = \frac{dv_y}{dt} = \frac{d}{dt}(0.44t - 9.1) = 0.44 \text{ m/s}^2$$

Hence the acceleration vector is

$$\vec{a} = (-0.62 \text{ m/s}^2) \hat{i} + (0.44 \text{ m/s}^2) \hat{j}$$

## 4.4: Average acceleration and Instantaneous acceleration: Example 4

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The position of a particle moving in the xy- plane is given by

$\vec{r}(t) = 2t^2\hat{i} + 3t\hat{j}$  where  $r$  is in meter and  $t$  is in seconds. Find

a) the average velocity in the time interval  $t = 2\text{s}$  and  $t = 4\text{s}$

$$\begin{aligned}\vec{v}_{avg} &= \frac{\Delta \vec{r}}{\Delta t} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \frac{\vec{r}(4) - \vec{r}(2)}{4 - 2} = \frac{2(4^2)\hat{i} + 3(4)\hat{j} - 2(2^2)\hat{i} - 3(2)\hat{j}}{4 - 2} \\ &= \frac{(32 - 8)\hat{i} + (12 - 6)\hat{j}}{2} = (12\hat{i} + 3\hat{j}) \text{ m/s}\end{aligned}$$

b) Velocity and speed of the particle at  $t = 3\text{s}$

$$\vec{v}(t) = \frac{d\vec{r}}{dt} = 4t\hat{i} + 3\hat{j} \Rightarrow \vec{v}(3) = 4(3)\hat{i} + 3\hat{j} = 12\hat{i} + 3\hat{j} \text{ m/s}$$

$$speed = |\vec{v}| = \sqrt{12^2 + 3^2} = \sqrt{153} = 12.37 \text{ m/s}$$

c) The acceleration at  $t=3\text{s} \rightarrow \vec{a} = \frac{d\vec{v}}{dt} = 4\hat{i} \text{ m/s}^2$  at any time ( $\vec{a}$  is constant)

## 4.4: Average acceleration and Instantaneous acceleration: Example 5

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A particle starts from the origin at  $t = 0$  with an initial velocity having an  $x$  component of  $20 \text{ m/s}$  and a  $y$  component of  $-15 \text{ m/s}$ . The particle moves in the  $xy$  plane with an acceleration in the  $x$  direction only ( $a_x = 4.0 \text{ m/s}^2$ ). Find

a) The components of the velocity vector at any time and the total velocity vector at any time.

$$v_x = v_{0x} + a_x t = (20 + 4t) \text{ m/s}$$

$$v_y = v_{0y} = -15 \text{ m/s} \quad (a_y = 0)$$

$$\Rightarrow \text{velocity vector} \quad \vec{v}_f = v_x \hat{i} + v_y \hat{j} = ((20 + 4t)\hat{i} - 15\hat{j}) \text{ m/s}$$

b) Calculate the velocity and speed of the particle at  $t = 5 \text{ s}$ .

$$\vec{v}_{(t=5)} = (20 + 4(5))\hat{i} - 15\hat{j} = (40\hat{i} - 15\hat{j}) \text{ m/s}$$

$$speed = |\vec{v}_{(t=5)}| = \sqrt{40^2 + (-15)^2} = \sqrt{1825} = 42.7 \text{ m/s}$$

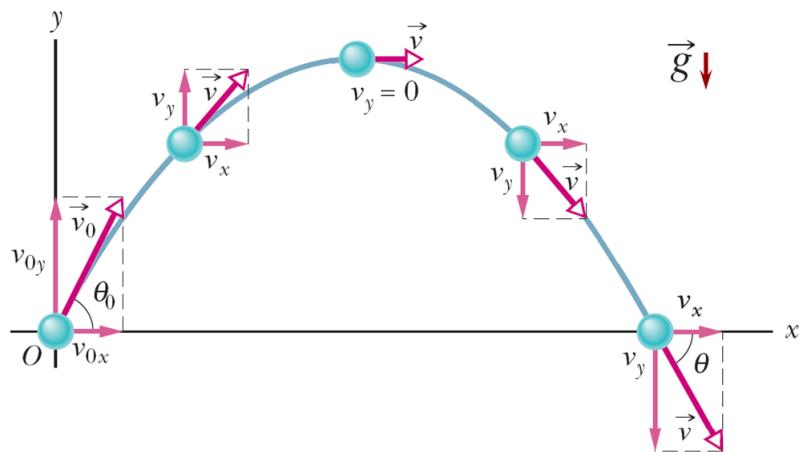
## 4.5: Projectile Motion

■ Projectile motion is an example of motion in 2D

■ Consider the Two assumptions:

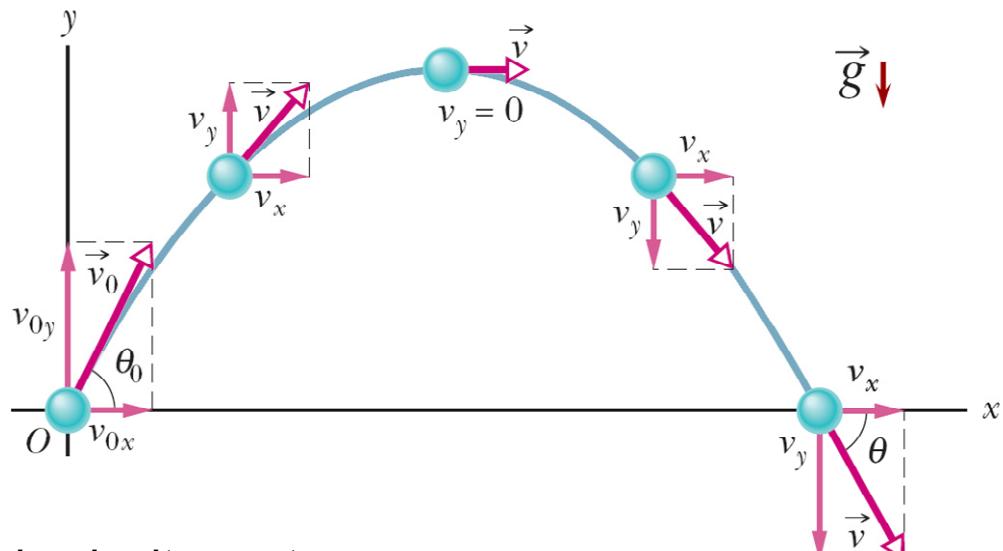
- 1) The object has an initial velocity  $\vec{v}_0$ , and is launched at an angle  $\theta_0$

- 2) Free-fall acceleration ( $g$ ) is constant (neglect air resistance)



- Then the **trajectory** (path) of the projectile is a parabola.
- The velocity changes magnitude and direction
- The acceleration in the y-direction is constant (-g).
- The acceleration in the x-direction is zero.

## 4.5: Projectile Motion



The initial velocity vector of projectile motion is  $\vec{v}_0 = v_{0x} \hat{i} + v_{0y} \hat{j}$

where  $v_{0x} = v_0 \cos \theta_0$  and  $v_{0y} = v_0 \sin \theta_0$

## 4.6: Projectile Motion analysis

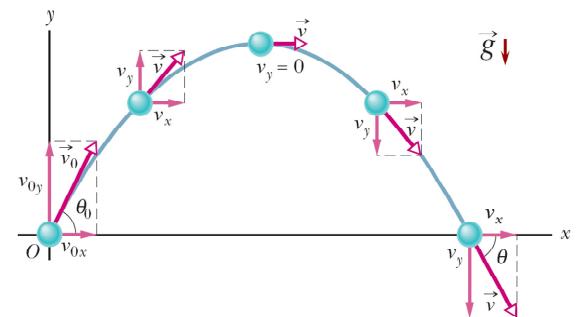
We'll analyze projectile motion as a superposition of two independent motions (x and y directions):

Constant velocity motion in the horizontal direction (x)	Free-fall motion in the vertical direction (y)
$v_x = v_{0x} = v_0 \cos \theta_0 = \text{constant}$	$v_y = v_{0y} - gt$
$x - x_0 = \Delta x = v_x t = v_{0x} t$	$y - y_0 = \Delta y = v_{0y} t - \frac{1}{2} g t^2$

From  $\Delta x$  and  $\Delta y$  (where  $x_0$  and  $y_0 = 0$  at  $t = 0$ )

→ we eliminate t → equation of the projectile path is

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



## 4.6: Projectile Motion analysis: the maximum height and horizontal range

Ex: Assume the projectile is launched with initial speed  $v_0$  at angle  $\theta_0$ , if the **maximum height** is  $h$  and the **horizontal range** is  $R$ . Determine

a)  $h$  and b)  $R$

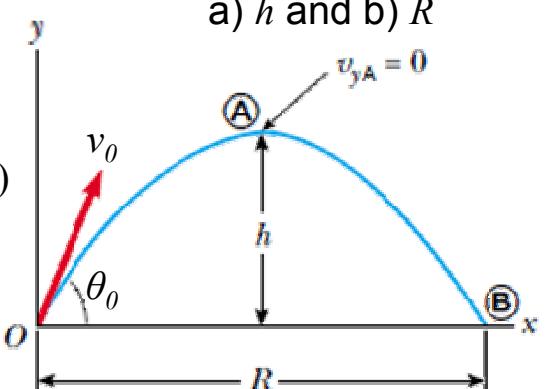
a)  $h$  is in y-axis →  $a_y = -g$ ; to find  $h$  we use

$$h = \Delta y = v_{0y} t_A - \frac{1}{2} g t_A^2 \quad (t_A; \text{time to reach max. hight } h)$$

$t_A$  can be found using

$$v_y = v_{yA} = v_{0y} - g t_A \quad (\text{at max. hight, } v_{yA} = 0)$$

$$\Rightarrow 0 = v_{0y} - g t_A \Rightarrow t_A = \frac{v_{0y}}{g} \quad \text{But } v_{0y} = v_0 \sin \theta_0 \Rightarrow t_A = \frac{v_0 \sin \theta_0}{g}$$



$$\text{hence } h = v_0 \sin \theta_0 \frac{v_0 \sin \theta_0}{g} - \frac{1}{2} g \left( \frac{v_0 \sin \theta_0}{g} \right)^2 \Rightarrow h = \frac{v_0^2 \sin^2 \theta_0}{2g}$$

## 4.6: Projectile Motion analysis: the maximum height and horizontal range

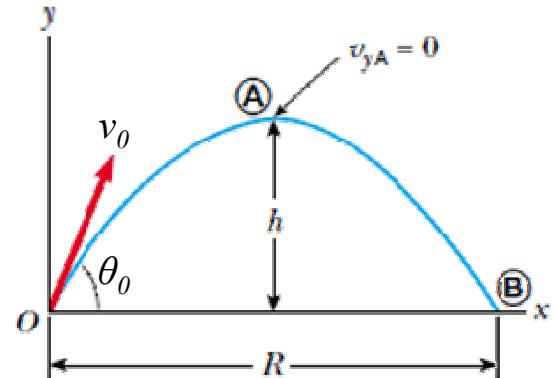
Assume the projectile is launched with initial velocity  $v_i$  at angle  $\theta$ , if the **maximum height** is  $h$  and the **horizontal range** is  $R$ . Determine a)  $h$  and b)  $R$

b)  $R$  is in x-direction  $\rightarrow a_x=0$

$$\Rightarrow R = v_{0x} t_B = v_0 \cos \theta_0 (2t_A)$$

$$R = v_0 \cos \theta_0 \left( 2 \frac{v_0 \sin \theta_0}{g} \right) = \frac{v_0^2 2 \cos \theta_0 \sin \theta_0}{g}$$

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



The max range  $R_{\max}$  is at angle  $\theta=45^\circ$  ( $\sin 2\theta = \sin 90^\circ = 1$ )

$$\Rightarrow R_{\max} = \frac{v_0^2}{g}$$

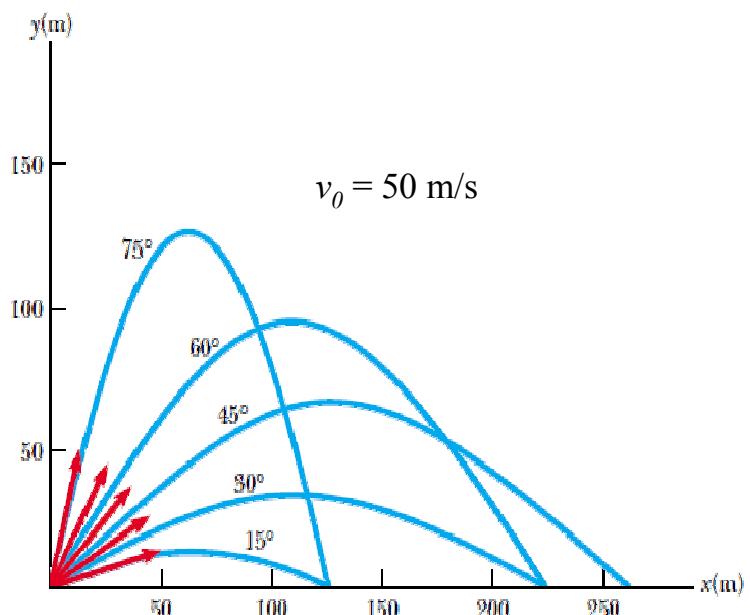
## 4.6: Projectile Motion analysis: the maximum height and horizontal range

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

$\rightarrow$  we can have same range if the projectile is launched at two different angles (for same initial speed) so that

$$\theta_1 + \theta_2 = 90^\circ$$

ex: 15 and 75  $\rightarrow$   
 $\sin 30^\circ = \sin 150^\circ$



## 4.6: Projectile Motion analysis: example 6

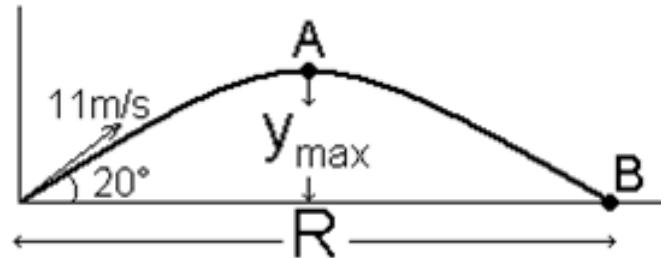
A long-jumper leaves the ground at an angle of  $20.0^\circ$  above the horizontal and at a speed of 11.0 m/s.

- (A) How far does he jump in the horizontal direction ?
- (B) What is the maximum height reached?

Solution: follow exactly same as previous for h and R

$$A) \quad R = \frac{v_0^2 \sin 2\theta}{g} = \frac{11^2 \sin 40^\circ}{9.8} = 7.94m$$

$$B) \quad y_{\max} = h = \frac{v_0^2 \sin^2 \theta}{2g} = 0.722m$$



## 4.6: Projectile Motion analysis: example 7

A pirate ship 560 m from a fort defending a harbor entrance. A defense cannon, located at sea level, fires balls at initial speed  $v_0 = 82$  m/s.

- a) At what angle  $\theta_0$  from the horizontal must a ball be fired to hit the ship?
- b) What is the maximum range of the cannonballs?

Solution: a)  $R = \frac{v_0^2 \sin 2\theta_0}{g}$

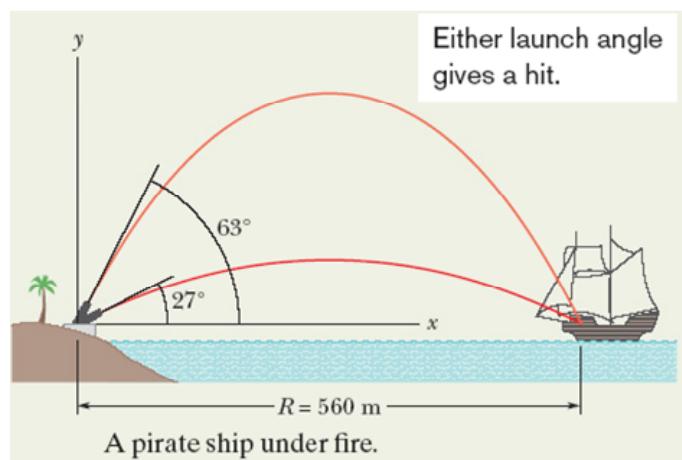
$$\rightarrow \theta_0 = \frac{1}{2} \sin^{-1} \frac{gR}{v_0^2}$$

$$= \frac{1}{2} \sin^{-1} \frac{(9.8 \text{ m/s}^2)(560 \text{ m})}{(82 \text{ m/s})^2}$$

$$= \frac{1}{2} \sin^{-1} 0.816.$$

$$\theta_0 = 27^\circ \quad \text{and} \quad \theta_0 = 63^\circ$$

b)  $R_{\max}$  is at  $\theta = 45^\circ \rightarrow R = \frac{v_0^2}{g} \sin 2\theta_0 = \frac{(82 \text{ m/s})^2}{9.8 \text{ m/s}^2} \sin (2 \times 45^\circ) = 686 \text{ m}$



## 4.6: Projectile Motion analysis: example 8

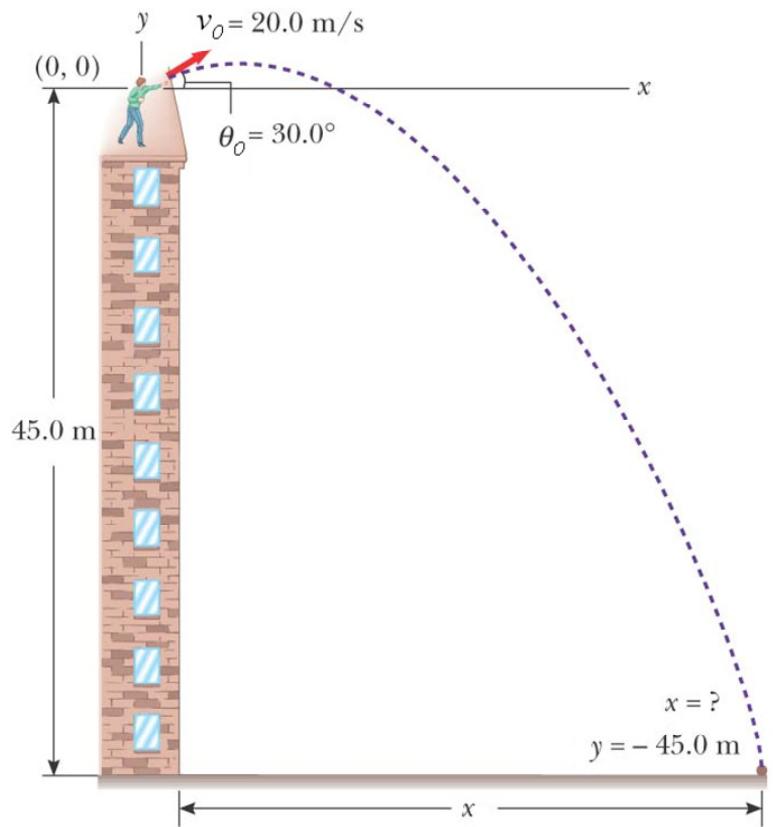
Stone is thrown as shown with

$$v_0 = 20 \text{ m/s}$$

$$\theta_0 = 30^\circ$$

$$h_{building} = 45 \text{ m}$$

- a) Time  $t$  to reach the ground
- b) Speed of stone before it strikes the ground  $v_f$
- c) Horizontal distance  $x_f$



## 4.6: Projectile Motion analysis: example 8

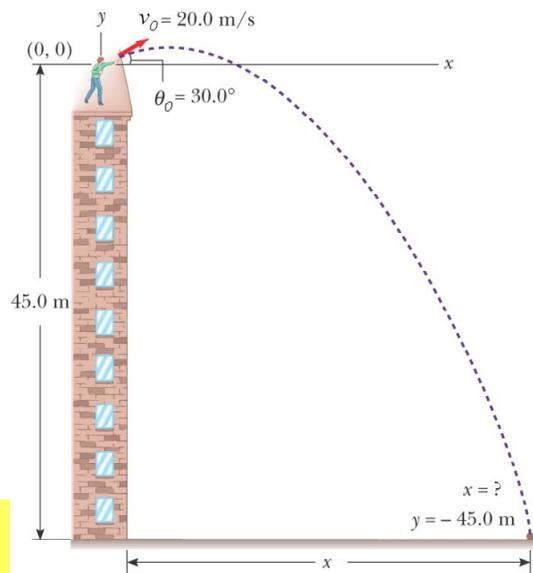
Solution:

$$v_{0x} = v_0 \cos \theta = 20 \cos 30^\circ = 17.3 \text{ m/s}$$

$$v_{0y} = v_0 \sin \theta = 20 \sin 30^\circ = 10 \text{ m/s}$$

$$\begin{aligned} \text{a)} \quad \Delta y &= v_{0y}t - \frac{1}{2}gt^2 \Rightarrow -45 = 10t - \frac{1}{2}(9.8)t^2 \\ &\Rightarrow -4.9t^2 + 10t + 45 = 0 \text{ solve for } t \\ &\Rightarrow t = 4.22 \text{ s} \end{aligned}$$

$$\begin{aligned} \text{b)} \quad v_y &= v_{0y} - gt = 10 - 9.8(4.22) = -31.4 \text{ m/s} \\ v_x &= v_{0x} = 17.3 \text{ m/s} \\ \Rightarrow \vec{v} &= (17.3\hat{i} - 31.4\hat{j}) \text{ m/s} \\ \text{speed} &= |v_B| = \sqrt{17.3^2 + (-31.4)^2} = 35.9 \text{ m/s} \end{aligned}$$

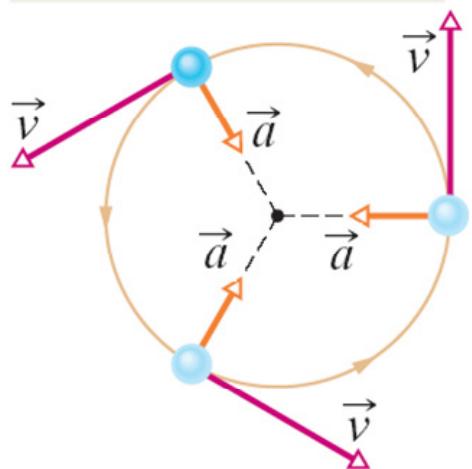


$$\begin{aligned} \text{c)} \quad \Delta x &= v_x t \\ &\Rightarrow x = 17.3(4.22) = 73 \text{ m} \end{aligned}$$

## 4.6: Uniform circular motion

- Circular motion is an example of motion in 2D
- consider a particle forced to move around a circle of radius  $r$  at **constant speed** → **uniform circular motion** →  $\vec{v}$  only changes direction
- Examples: wheels, disks, motors, etc.

The acceleration vector always points toward the center.

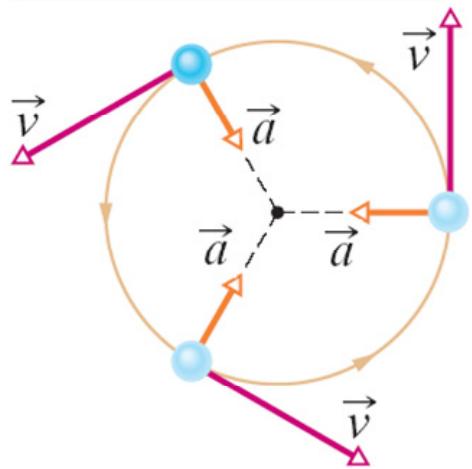


The velocity vector is always tangent to the path.

## 4.6: Uniform circular motion

- For uniform circular motion, The acceleration is always directed *radially inward (towards the center)*. it is usually called a **centripetal acceleration** (meaning “center seeking” acceleration )

The acceleration vector always points toward the center.



$$a = \frac{v^2}{r} \quad (\text{centripetal acceleration}),$$

where  $v$  is the speed and  $r$  is the radius

See proof at the text book

The velocity vector is always tangent to the path.

## 4.6: Uniform circular motion

during this acceleration at constant speed, the particle travels the circumference of the circle (a distance of  $2\pi r$ ) in time T

$$\text{for 1 cycle} \Rightarrow T = \frac{2\pi r}{v} \Rightarrow v = \frac{2\pi r}{T} \quad \text{note that } v = \frac{\text{arc length}}{\text{time}} = \frac{\Delta\theta r}{t}$$

- $2\pi r$  is the circumference (محيط) of the circle (one revolution)
- T is the period (time needed to complete one revolution (rev.))
  - Ex 9: find the acceleration at the edge of a wheel of radius 35 cm spinning at  $6 \times 10^2$  rev./min

$$a_c = \frac{v^2}{r}, \text{ but } v = \frac{2\pi r}{T}, \text{ hence we need } T \longrightarrow \begin{array}{l} 600 \text{ rev.} \sim 60 \text{ s} \\ 1 \text{ rev.} \sim T \end{array}$$

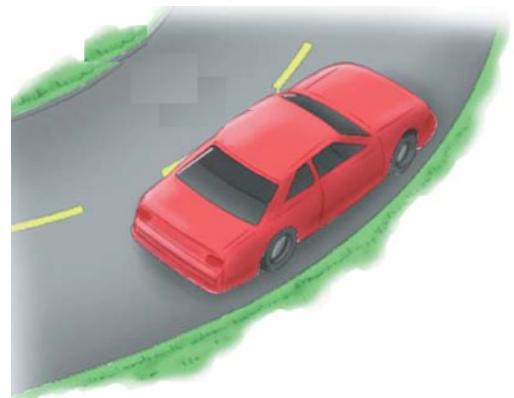
$$\Rightarrow 600T = 60 \text{ s} \quad \longrightarrow \quad v = \frac{2\pi r}{T} = \frac{2\pi(0.35 \text{ m})}{0.1 \text{ s}} = 22 \text{ m/s}$$

$$\Rightarrow T = \frac{60}{600} = 0.1 \text{ s} \quad a_c = \frac{v^2}{r} = \frac{(22)^2}{0.35} = 1400 \text{ m/s}^2 \text{ towards center}$$

## 4.6: Uniform circular motion: Example 10

- Ex: A car traveling at 120km/h rounds a corner with a radius of 125m. Find the car centripetal acceleration.

$$v = 120 \text{ km/h} \left( \frac{1000 \text{ m}}{\text{km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) = 33 \text{ m/s}$$

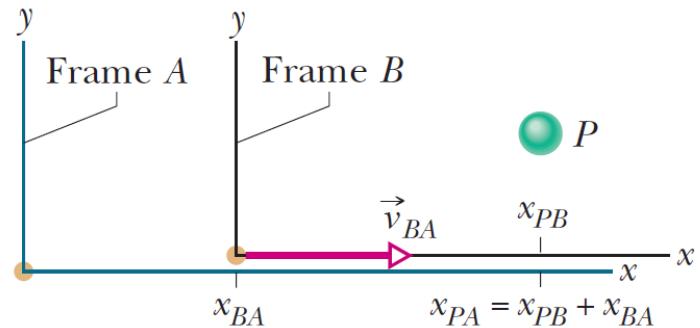


$$\Rightarrow a_c = \frac{v^2}{r} = \frac{(33)^2}{125} = 8.7 \text{ m/s}^2 \text{ towards the center}$$

## 4.8: Relative Motion in One Dimension

- The velocity of a particle depends on the **reference frame** (محور اسناد) of whoever is observing or measuring the velocity

Suppose Alex (stationary frame A) and Barbara (frame B moving at constant speed) watch car P which is moving at speed  $v$ . Both frames (A and B) will have different quantities (position, velocity, and acceleration). At the instant shown,  $x_{BA}$  is the coordinate of B in the A frame. Also, P is at coordinate  $x_{PB}$  in the B frame.



→ The coordinate of P in the A frame is

$$x_{PA} = x_{PB} + x_{BA}$$

## 4.8: Relative Motion in One Dimension

- the velocity components are the time derivative of the position equation  $x_{PA} = x_{PB} + x_{BA}$

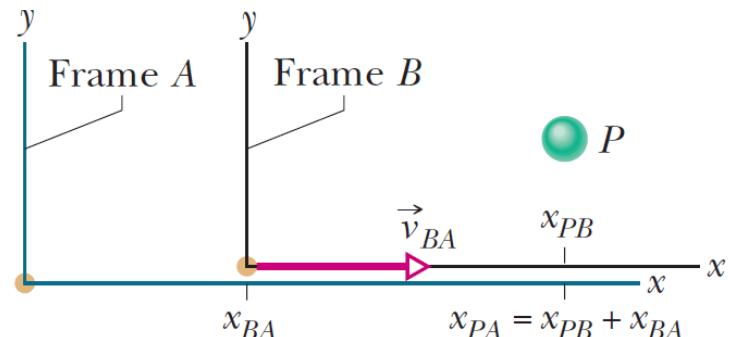
$$\rightarrow \frac{d}{dt}(x_{PA}) = \frac{d}{dt}(x_{PB}) + \frac{d}{dt}(x_{BA})$$

$$\rightarrow v_{PA} = v_{PB} + v_{BA}$$

Differentiate velocity with respect to time → acceleration

$$\frac{d}{dt}(v_{PA}) = \frac{d}{dt}(v_{PB}) + \frac{d}{dt}(v_{BA})$$

$$\rightarrow a_{PA} = a_{PB}$$



## 4.8: Relative Motion in One Dimension: Example 11

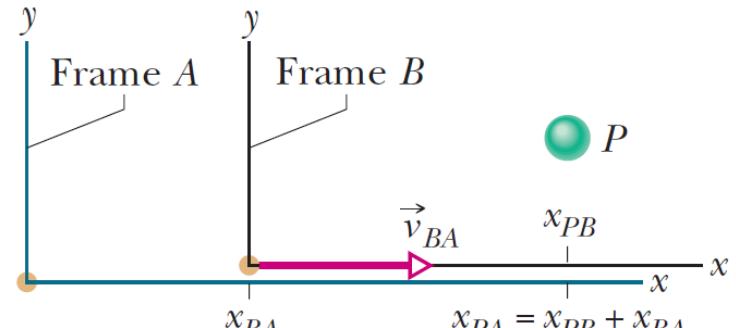
Barbara's velocity relative to Alex is a constant 52 km/h and car  $P$  is moving in the negative direction of the  $x$  axis. a) If Alex measures a constant -78 km/h for car  $P$ , what velocity will Barbara measure

- Alex (stationary frame A), Barbara (moving frame B) and car is observed moving object P.  $\Rightarrow v_{BA} = 52 \text{ m/s}$  and  $v_{PA} = -78 \text{ km/h}$ ,

hence  $v_{PA} = v_{PB} + v_{BA}$

$$-78 \text{ km/h} = v_{PB} + 52 \text{ km/h.}$$

$$v_{PB} = -130 \text{ km/h.}$$



- b) If car brakes to a stop relative to Alex in time  $t = 10 \text{ s}$  at constant acceleration, what is its acceleration relative to Alex and Barbara?

$$a_{PA} = \frac{v - v_0}{t} = \frac{0 - (-78 \text{ km/h})}{10 \text{ s}} = \frac{1 \text{ m/s}}{3.6 \text{ km/h}} = 2.2 \text{ m/s}^2.$$

## 4.9: Relative Motion in Two Dimensions

- Our two observers are again watching a moving particle  $P$  from the origins of reference frames  $A$  and  $B$ , while  $B$  moves at a constant velocity relative to  $A$
- From the arrangement of the three position vectors shown, we can relate the vectors with

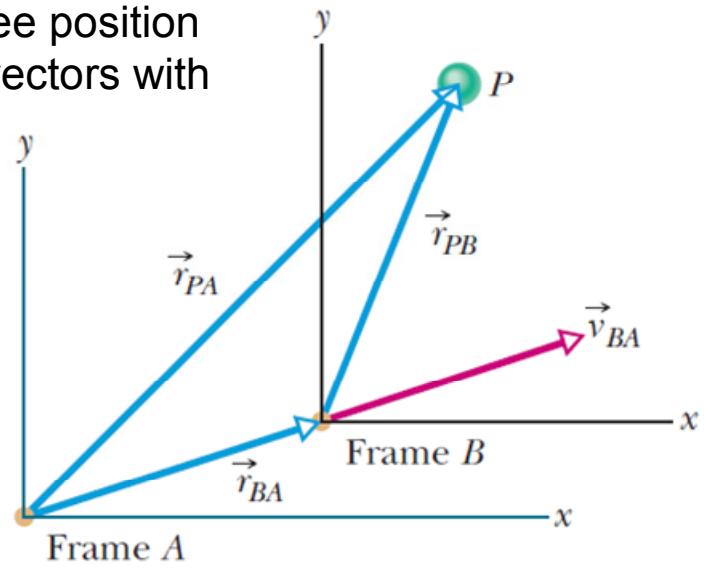
$$\vec{r}_{PA} = \vec{r}_{PB} + \vec{r}_{BA}$$



$$\vec{v}_{PA} = \vec{v}_{PB} + \vec{v}_{BA}$$



$$\vec{a}_{PA} = \vec{a}_{PB}$$



## 4.9: Relative Motion in Two Dimension: Example 12

- A plane is to move due east with velocity  $\vec{v}_{PG}$  (relative to ground) when flying in a blowing wind of velocity  $\vec{v}_{WG}$  (of speed 65km 20° east of north relative to ground). If the plane speed is 215km at angle  $\theta$  south of east relative to wind ( $\vec{v}_{PW}$ ), find the plane speed relative to ground and the angle  $\theta$

$$\vec{v}_{PG} = \vec{v}_{PW} + \vec{v}_{WG}$$

From y-components

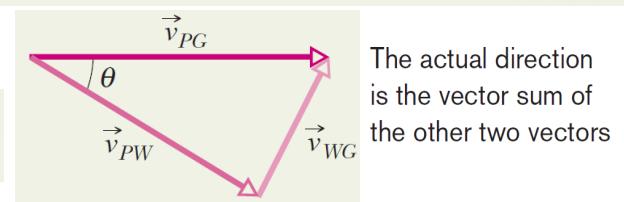
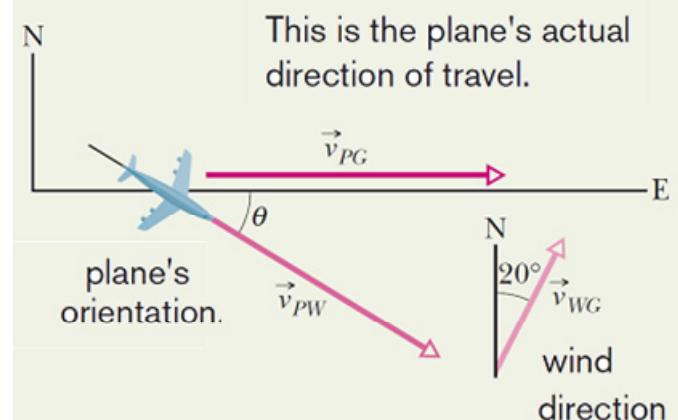
$$v_{PG,y} = v_{PW,y} + v_{WG,y}$$

$$0 = -(215 \text{ km/h}) \sin \theta + (65.0 \text{ km/h})(\cos 20.0^\circ)$$

$$\theta = \sin^{-1} \frac{(65.0 \text{ km/h})(\cos 20.0^\circ)}{215 \text{ km/h}} = 16.5^\circ$$

$$v_{PG} = v_{PG,x} = v_{PW,x} + v_{WG,x}$$

$$v_{PG} = (215 \text{ km/h})(\cos 16.5^\circ) + (65.0 \text{ km/h})(\sin 20.0^\circ) \\ = 228 \text{ km/h.}$$



## 4.9: Relative Motion in Two Dimension: Example 13

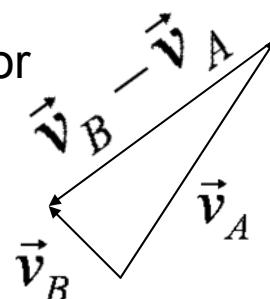
Car A is moving with velocity  $\vec{v}_A = (3\hat{i} + 7\hat{j}) \text{ m/s}$

Car B is moving with velocity  $\vec{v}_B = (-2\hat{i} + 2\hat{j}) \text{ m/s}$

Find velocity of car B with respect to A ( $v_{BA}$ ):

by vectors

A will see this vector  
when looking at B



$$\Rightarrow \vec{v}_{BA} = \vec{v}_B - \vec{v}_A = (-5\hat{i} - 5\hat{j}) \text{ m/s}$$