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King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 5: MOTION IN 1-D (PART 2)

LECTURE NO. 6

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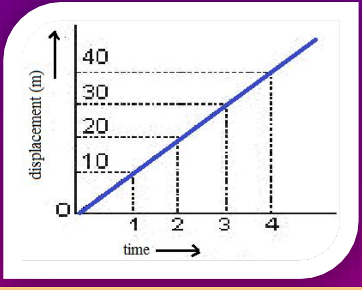
Lecture Outline

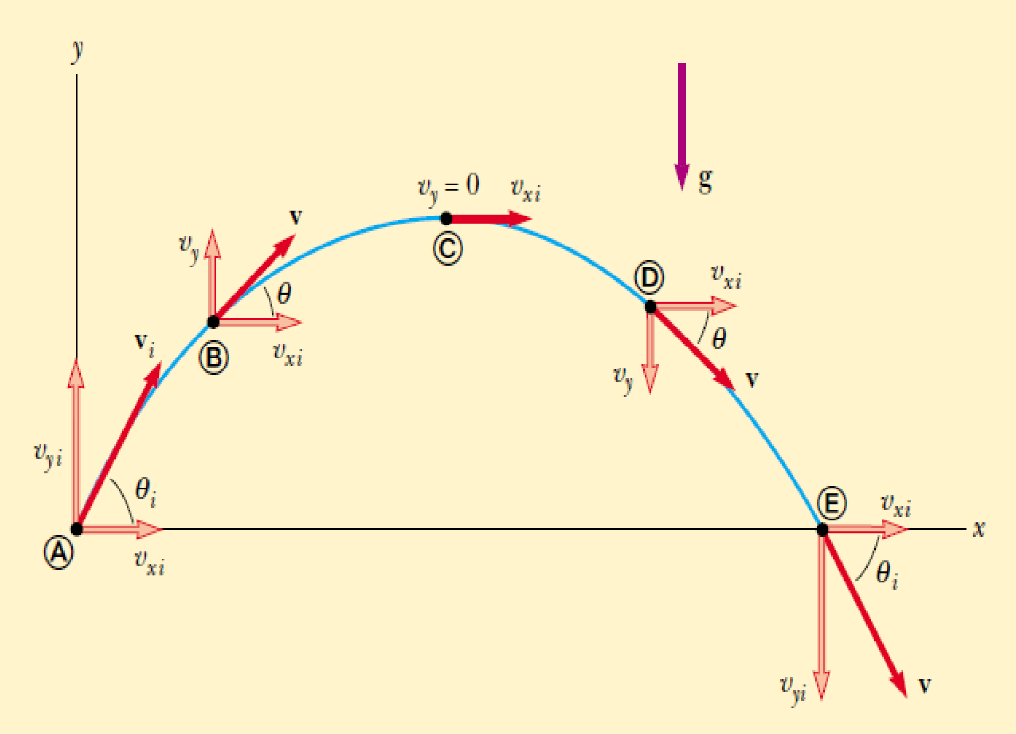
- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6

- *4.3 Projectile Motion*
- *4.4 Uniform Circular Motion*
- *4.5 Tangential and Radial Acceleration*
- *Examples*
- *Lecture Summary*
- *Activities (Interactive Flashes)*
- *Quizzes*

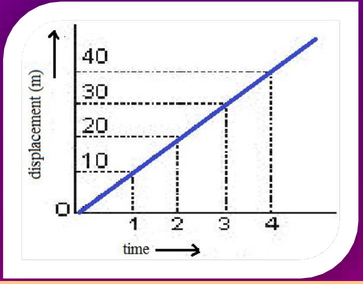


4.3 Projectile Motion

- Anyone who has observed a baseball in motion has observed projectile motion. The ball moves in a curved path, and its motion is simple to analyze if we make two assumptions: (1) the free-fall acceleration g is constant over the range of motion and is directed downward, and (2) the effect of air resistance is negligible.
- We find that the path of a projectile, which we call its trajectory, is always a *parabola*



The parabolic path of a projectile that leaves the origin with a velocity v_i. The x component of v remains constant in time. The y component of velocity is zero at the peak of the path.



4.3 Projectile Motion (x & y equations)

- We will be having 2 sets of equations: 1 for x and 1 for y directions:

Fro x directon:

$$v_{xi} = v_i \cos\theta_i \qquad (4.10a)$$

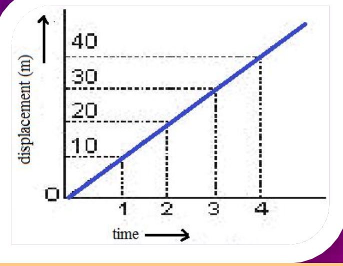
$$x_f = v_{xi} t = (v_i \cos\theta_i)t \qquad (4.11a)$$

Fro y directon:

$$v_{yi} = v_i \sin\theta_i \qquad (4.10b)$$

$$y_f = v_{yi} t + \frac{1}{2} a_y t^2 = (v_i \sin\theta_i)t - \frac{1}{2} g t^2 \qquad (4.12)$$

- Please note that you can solve for x or y independently.



4.3 Projectile Motion (trajectory equation)

- We will be having 2 sets of equations: 1 for x and 1 for y directions:

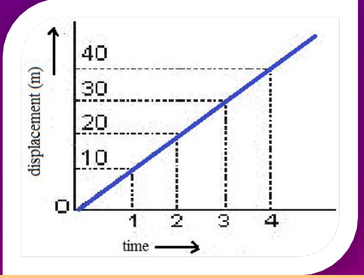
$$(4.11a) \rightarrow t = \frac{x_f}{v_i \cos\theta_i}$$

$$\therefore \mathrm{y_f} = (v_i \sin\theta_i)\frac{x_f}{v_i \cos\theta_i} - \frac{1}{2}g\left[\frac{x_f}{v_i \cos\theta_i}\right]^2$$

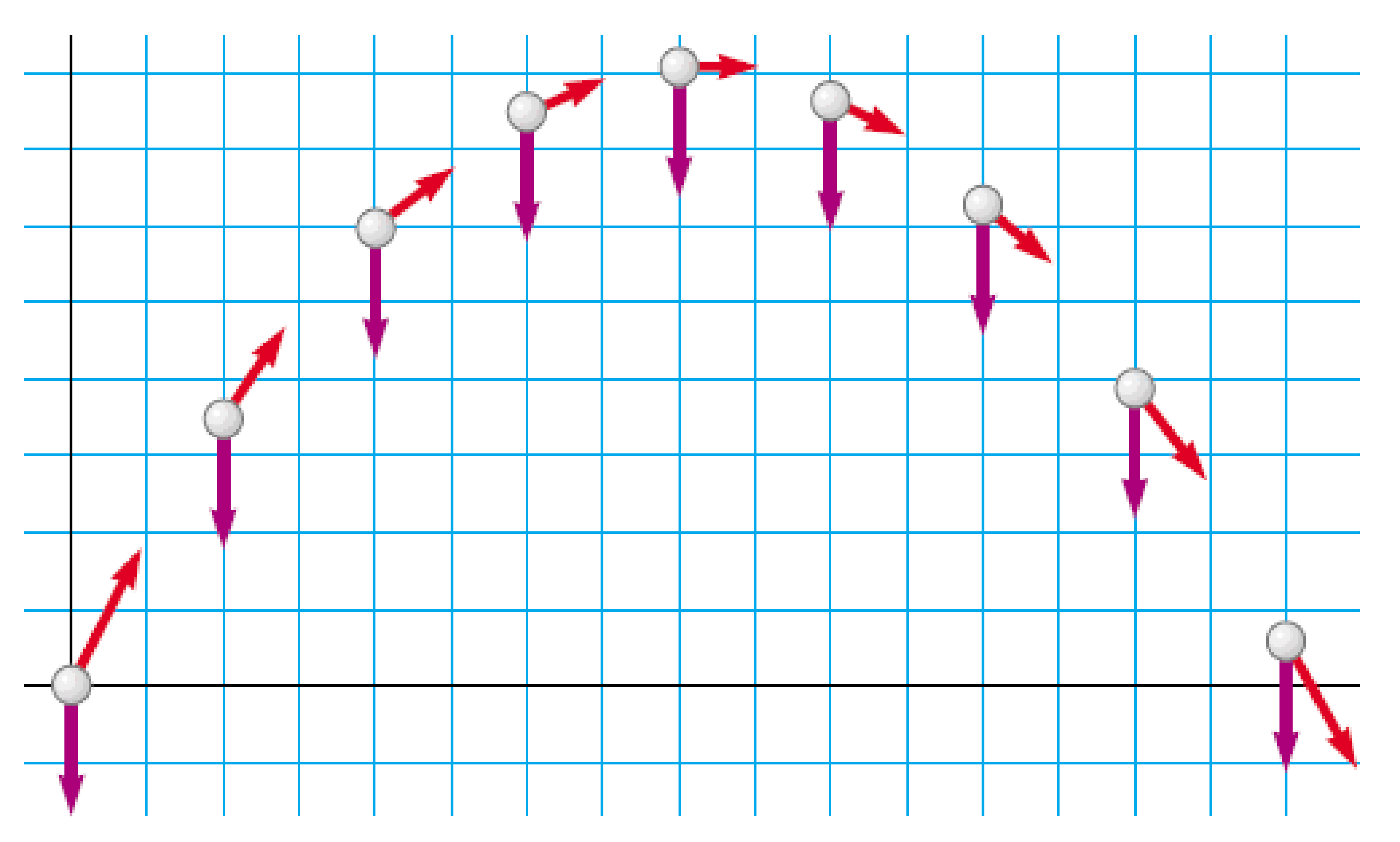
$$\Rightarrow \mathrm{y_f} = (\tan\theta_i)x_f - \frac{g}{2v_i^2 \cos\theta_i^2}x_f^2$$

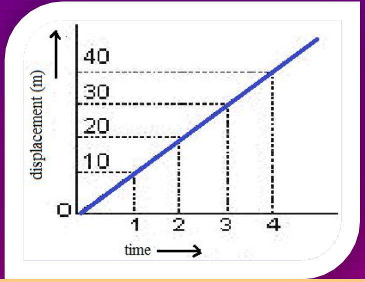
$$OR : y = ax - bx^2$$

- This is the equation of a *parabola* that passes through the origin.



4.3 Projectile Motion (motion diagram)





Time of Flight of a Projectile

- We will consider the maximum height reached by a projectile:

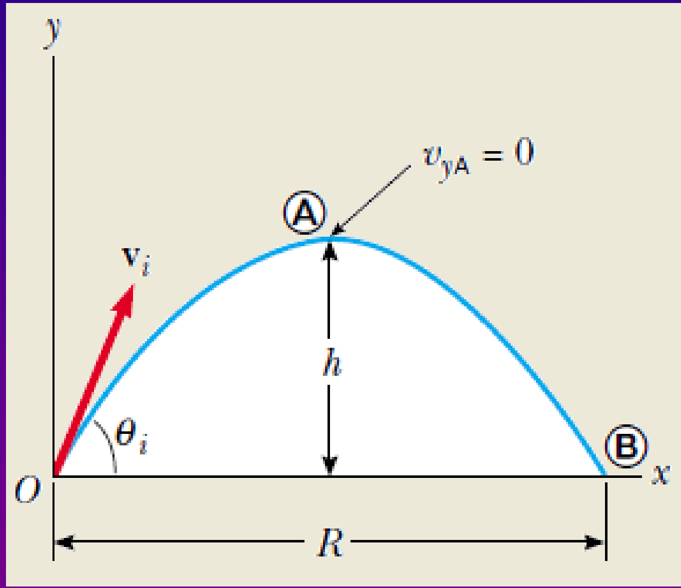
1st: time of fleight: at maxi. height $v_{yf} = 0$

$$\because v_{yf} = v_{yi} + a_y t = 0$$

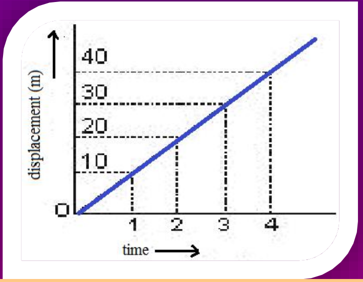
$$\Rightarrow 0 = v_i \sin\theta_i - g t_{\max}$$

$$\Rightarrow t_{\max} = \frac{v_i \sin\theta_i}{g}$$

$$\therefore t_{fleight} = \frac{2 v_i \sin\theta_i}{g}$$



- Time of flight is twice the time required to reach to the max. point. We call this Time-Of-flight and is true only if the projectile final destination is on the same level as its starting point.



Maximum Height of a Projectile

- Maximum height of a projectile can be calculated using last equation:

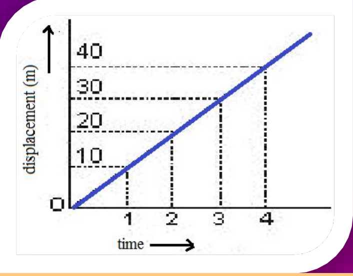
at max. point, t is $t_{\max}$

$$\because y_{\max} = (v_i \sin\theta_i) t_{\max} - \frac{1}{2} g \left[t_{\max}\right]^2$$

$$\therefore y_{\max} = (v_i \sin\theta_i) \frac{v_i \sin\theta_i}{g} - \frac{1}{2} g \left[\frac{v_i \sin\theta_i}{g}\right]^2$$

$$or : h = (v_i \sin\theta_i) \frac{v_i \sin\theta_i}{g} - \frac{1}{2} g \left[\frac{v_i \sin\theta_i}{g}\right]^2$$

$$\therefore h = \frac{v_i^{\,2} \sin\theta_i^{\,2}}{2g} \qquad (4.13)$$



Horizontal Range of a Projectile

- Horizontal Range of a projectile can be calculated using last equation:

$$\because t_{fleight} = \frac{2v_i \sin\theta_i}{g}$$

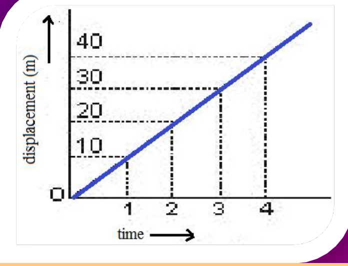
$$\because R = v_{xi} t_{fleight}$$

$$\therefore R = (v_i \cos\theta_i)\frac{2v_i \sin\theta_i}{g} = \frac{2v_i^2 \sin\theta_i \cos\theta_i}{g}$$

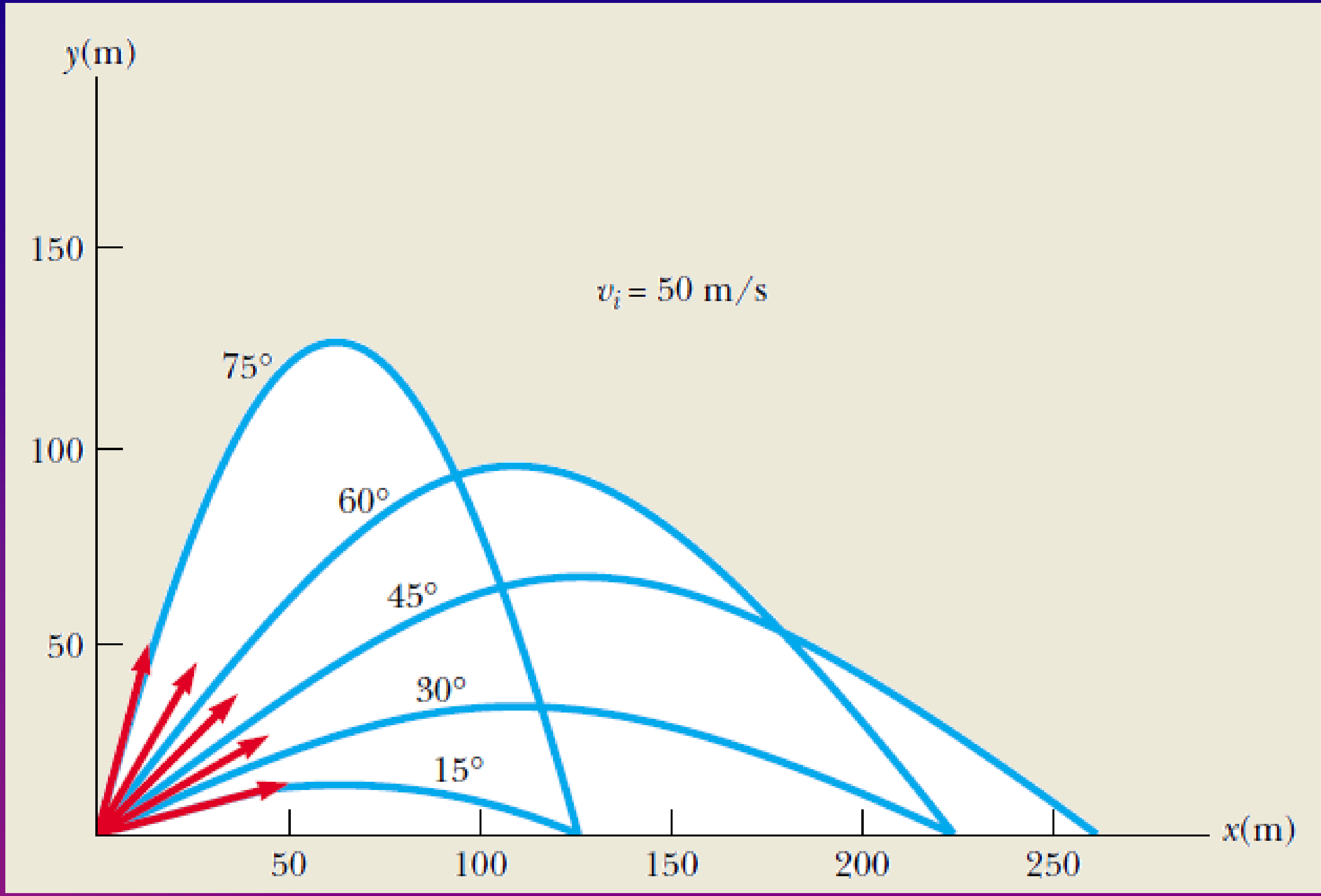
$$\because \sin(2\theta) = 2\sin\theta\cos\theta$$

$$\therefore R = \frac{v_i^2 \sin 2\theta_i}{g} \qquad (4.14)$$

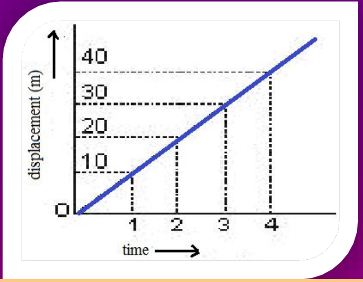
- Not that R is Max. when θ = 45°. $R_{max} = \frac{v_i^2}{g}$



Effect of starting angle on a Projectile



A projectile launched from the origin with an initial speed of 50 m/s at various angles of projection.



Example 4.3 The Long Jump

- A long-jumper leaves the ground at an angle of 20.0° above the horizontal and at a speed of 11.0 m/s.
- (A) How far does he jump in the horizontal direction?

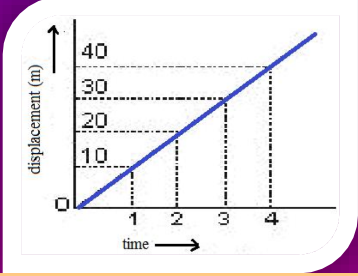
We can find the distance from Range (R):

$$\therefore R = \frac{v_i^{\,2} \sin 2\theta_i}{g} = \frac{11^2 \times \sin 40}{9.8} = 7.94\, m$$

- (B) What is the maximum height reached?

We can use the max. height equation directly:

$$\because h = \frac{v_i^{\,2} \sin \theta_i^{\,2}}{2g} = \frac{11^2 \sin 20^2}{2 \times 9.8} = 0.722\, m$$



Example 4.5 That's Quite an Arm!

- A stone is thrown from the top of a building upward at an angle of 30.0° to the horizontal with an initial speed of 20.0 m/s, as shown in the Figure. If the height of the building is 45.0 m.
- (A) how long does it take the stone to reach the ground?

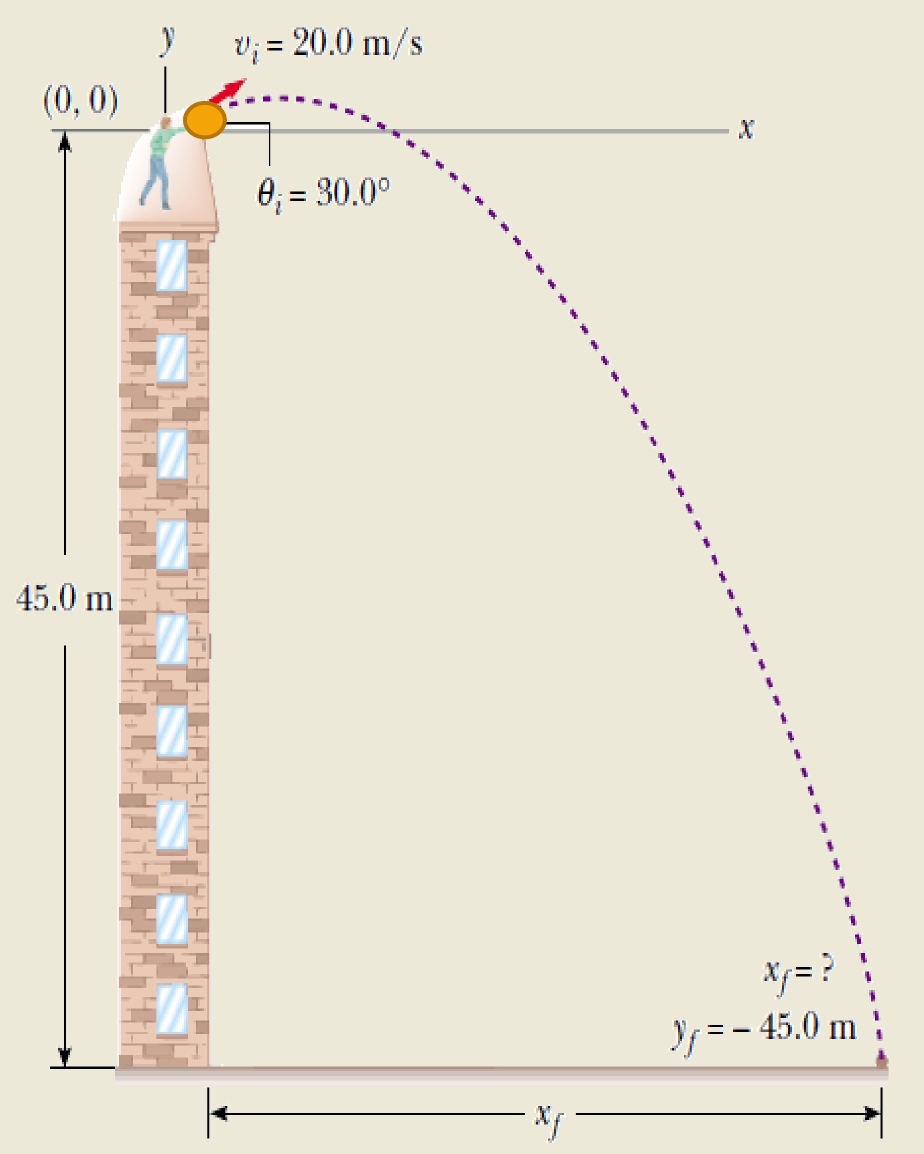
$$\because y_f = (v_i \sin\theta_i)t - \frac{1}{2}gt^2$$

$$\because v_i = 20\ m/s,\quad \theta_i = 30^o,\ y_f = -45\ m$$

$$\Rightarrow -45 = (20\sin 30)t - \frac{1}{2}\times 9.8t^2$$

$$\Rightarrow 4.9t^2 - 10t - 45 = 0$$

$$\text{Solving}: t = \frac{10 \pm \sqrt{100+882}}{9.8} = 4.22s$$



Example 4.5 (Continued)

- (B) What is the speed of the stone just before it strikes the ground?

To solve: we must find components of velocity (v_{xf} and v_{yf}) just at the ground level. Then we calculate the magnitude = speed

$$v_{xf} = v_{xi} = 20\cos 30 = 17.32\ m/s$$

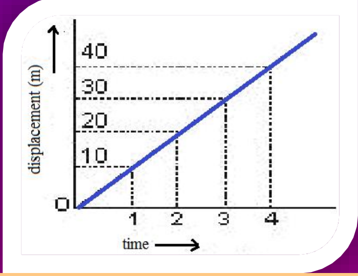
$$\because v_{yf} = v_{yi} - gt = v_i \sin 30 - 9.8t$$

$$\therefore v_{yf} = 20\sin 30 - 9.8(4.22) = -31.36 m/s$$

$$\Rightarrow speed = v_f = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{17.32^2 + (-31.36)^2} = 35.9 m/s$$

- (C) What is the distance between the building and the striking point?

$$\because x_f = v_{xi} t = 20\cos 30(4.22) = 73.1m$$



Example 4.6 a package dropped by airplane

- A plane drops a package of supplies to a party of explorers. If the plane is traveling horizontally at 40.0 m/s and is 100 m above the ground, *where does the package strike the ground relative to the point at which it is released?*

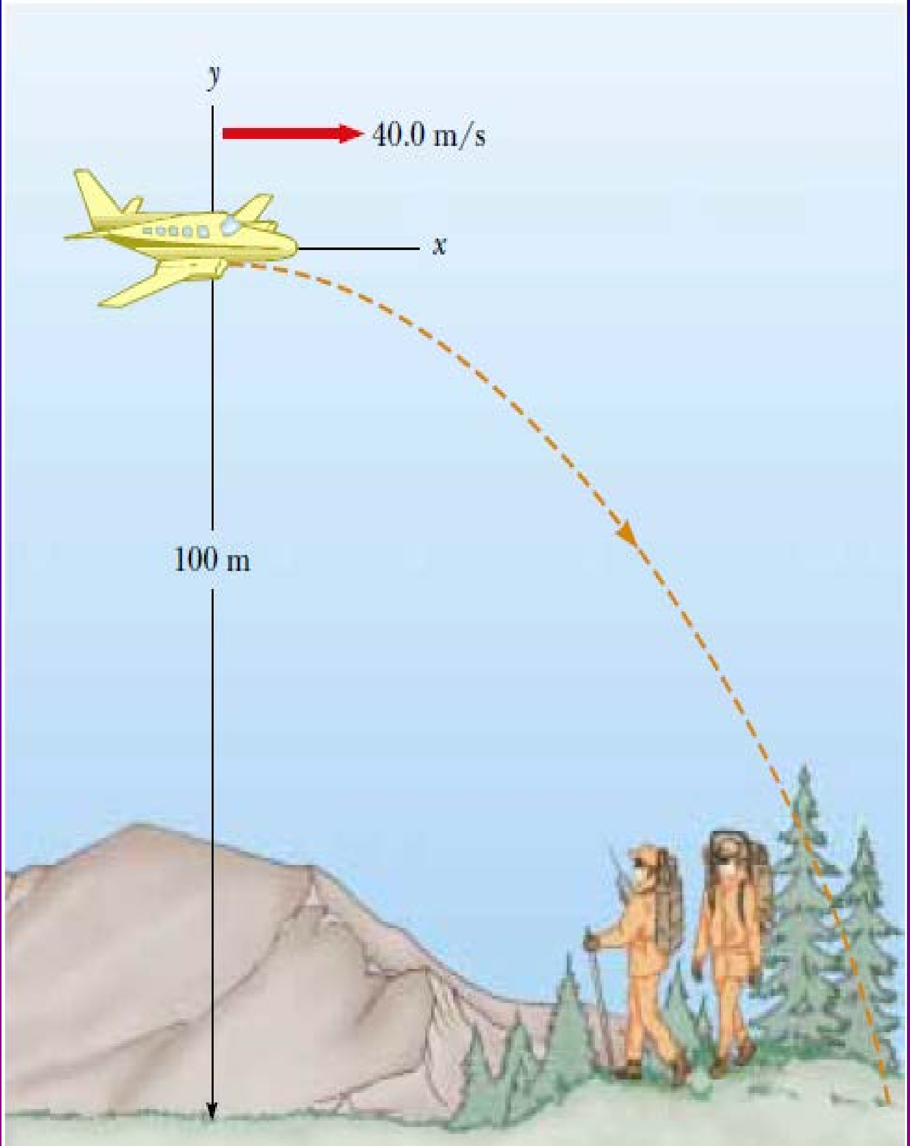
$$\because x_f = v_{xi} t = 40t \quad \text{(we need t)}$$

$$\because y_f = v_{yi} t - \frac{1}{2} g t^2$$

$$\therefore -100 = 0 - \frac{1}{2} \times 9.8 t^2$$

$$\Rightarrow t = \sqrt{\frac{2 \times 100}{9.8}} = 4.52 s$$

$$\therefore x_f = 40 \times 4.52 = 181 m$$

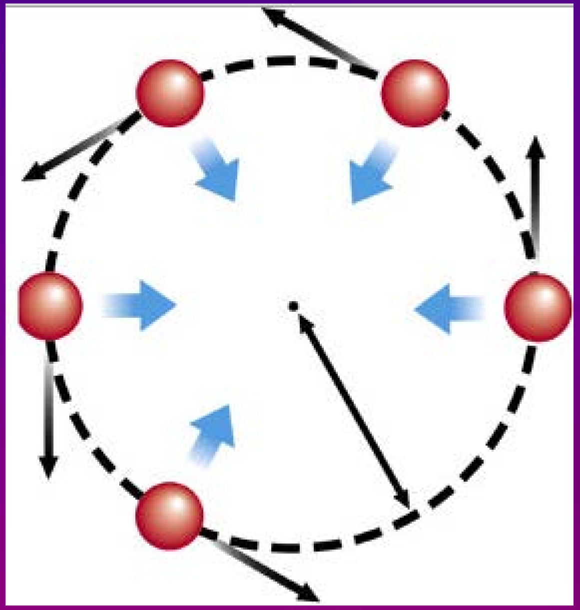


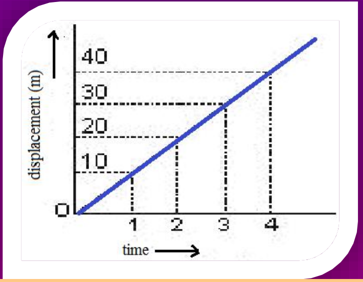
4.4 Uniform Circular Motion

- A *uniform circular motion* is of an object (e.g. a car) moving in a circular path with constant speed v.
- *Note: even though speed is constant: velocity is not.*
- We consider velocity not constant in three cases:
  1. Magnitude of v is changing
  2. Direction of v is changing
  3. Both of magnitude and direction are changing
- centripetal acceleration is given as follows:

$$a_c = \frac{v^2}{r} \qquad (4.15)$$

- where: v is the speed, r is the radius of circulation.
- Period of circulation: $T = \frac{2\pi r}{v}$ (4.16)





4.5 Tangential and Radial Acceleration

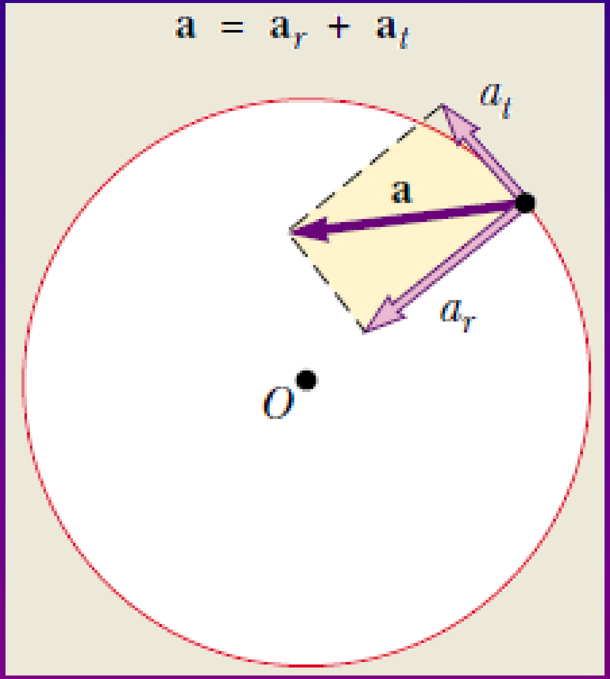
- In circular motion; there are 2 different accelerations: Radial: a_r and Tangential: a_t.
- Total Acceleration is the Vector sum of both of these 2 components.

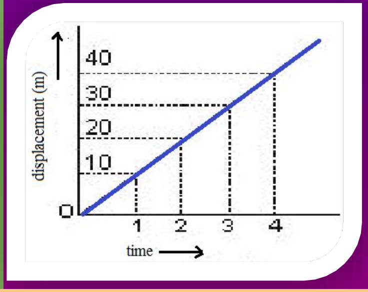
$$a = a_r + a_t \qquad (4.17)$$

where:

$$a_t = \frac{dv}{dt} \quad \text{and} \quad a_r = -a_c = -\frac{v^2}{r}$$

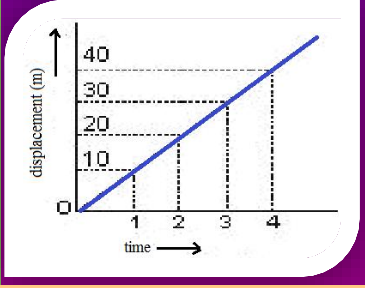
$$\therefore a = \sqrt{a_r^2 + a_t^2}$$





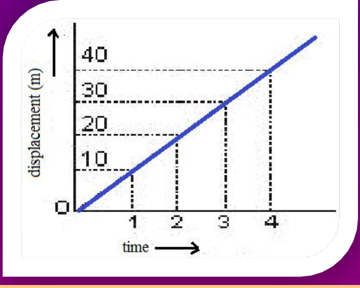
Lecture Summary

- Projectile motion is one type of two-dimensional motion under constant acceleration, where $a_x = 0$ and $a_y = -g$.
- It is useful to think of projectile motion as the superposition of two motions:
  - (1) constant-velocity motion in the x direction
  - (2) free-fall motion in the vertical direction subject to a constant downward acceleration of magnitude $g = 9.80\ m/s^2$.
- A particle moving in a circle of radius r with constant speed v is in uniform circular motion.
- If a particle moves along a curved path in such a way that both the magnitude and the direction of v change in time, then the particle has an acceleration vector that can be described by two component vectors: (1) a radial component vector a_r that causes the change in direction of v and (2) a tangential component vector a_t that causes the change in magnitude of v.

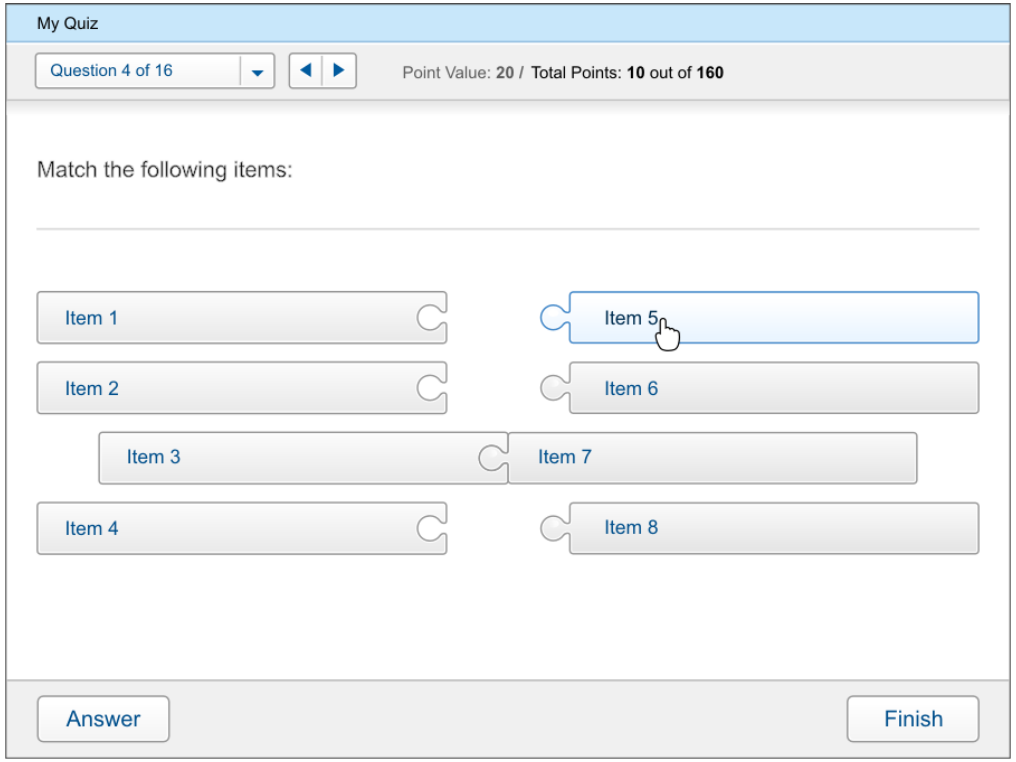


Activity Flash

- In the next slide you will be allowed to run an interactive flash.
- There will be a quiz about the flash.
- In this flash: please do the following:
  1. Set Initial speed to: 40 m/s
  2. Set Initial Launch angle to: 50o
  3. Press RUN and wait for the projectile to land.
  4. Record the following results:
     - *Time Of Flight*
     - *Horizontal Range*
     - *Magnitude of velocity in the moment of landing*
- Please answer the quiz that will be given upon finishing the flash using the results you recorded.



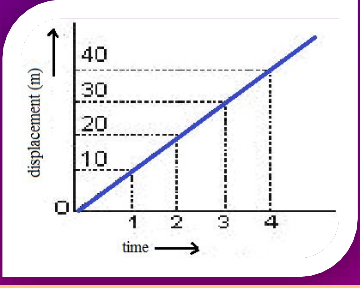
Quiz on Projectile Interactivity Flash



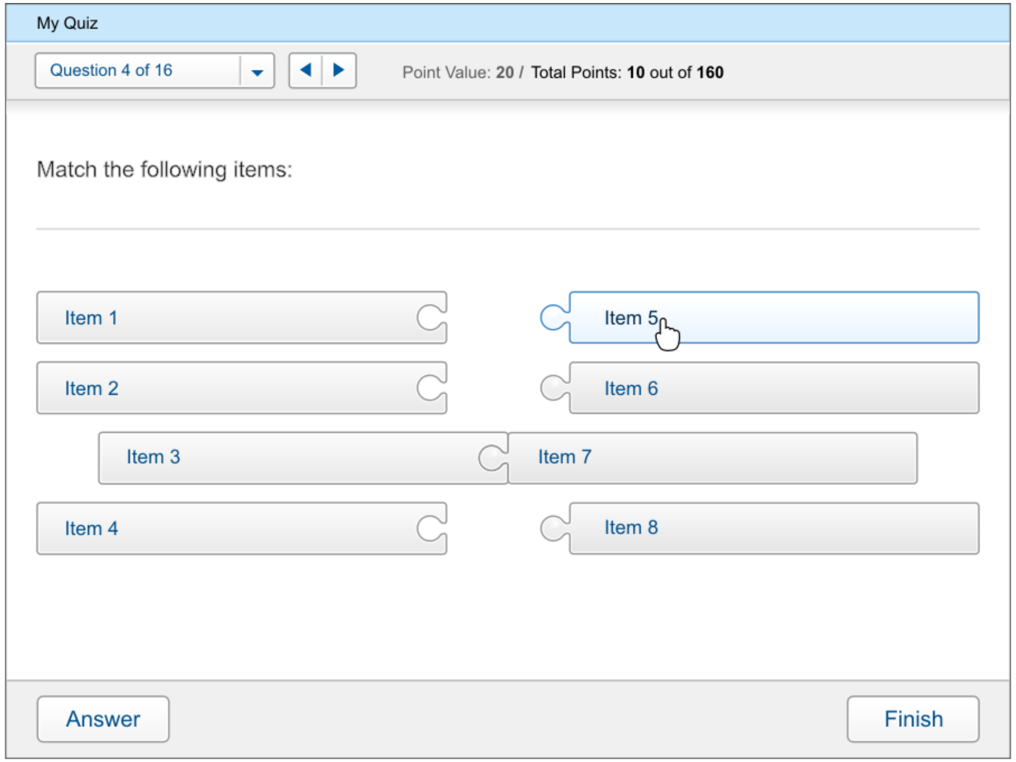
Click the **Quiz** button on iSpring Pro toolbar to edit your quiz

Review Quizzes:

- *Please allow about 30 minutes to answer all Quizzes in the next slide.*
- *You can easily move to the end of presentation by clicking outside the quiz area.*



Quizzes 4.3-4.10



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THE END!