Chapter 3: Kinematics in Two Dimensions

Mastering Physics Assignment #1

The first assignment is available at the
Mastering Physics website for PHYS1020UM

It is due on Monday, September 24, at 5 pm

Register for Mastering Physics if you haven't done so already!

(5% of final grade for Mastering Physics assignments)

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

Week	Date		Lecture	Cutnell & Johnson	Topic	Labs/Tests (Tuesdays, Wednesdays, Thursdays)
1	F	Sept 7	1	Chapter 1	Introduction	No lab or tutorial
2	M	10	2			No lab or tutorial
	W	12	3	Chapter 2	Kinematics in one dimension	
	F	14	4			
3	M	17	5			Errors Lecture
	W	19	6	Chapter 3	Kinematics in two dimensions	
	F	21	7			
4	M	24	8			Experiment 1: Measurement of Length and Mass
	W	26	9	Chapter 4	Forces and Newton's laws	
	F	28	10			

This week in the lab: Errors Lecture

Next week: Experiment 1, measurement of length and mass

What's new in this chapter

- Displacement, velocity, acceleration extended to two dimensions
- Motion in x can be separated completely from motion in y, provided air resistance is negligible – treatment of projectile motion
- Relative velocity
- Not yet any physics as such!

Speed, Velocity and Acceleration in One Dimension

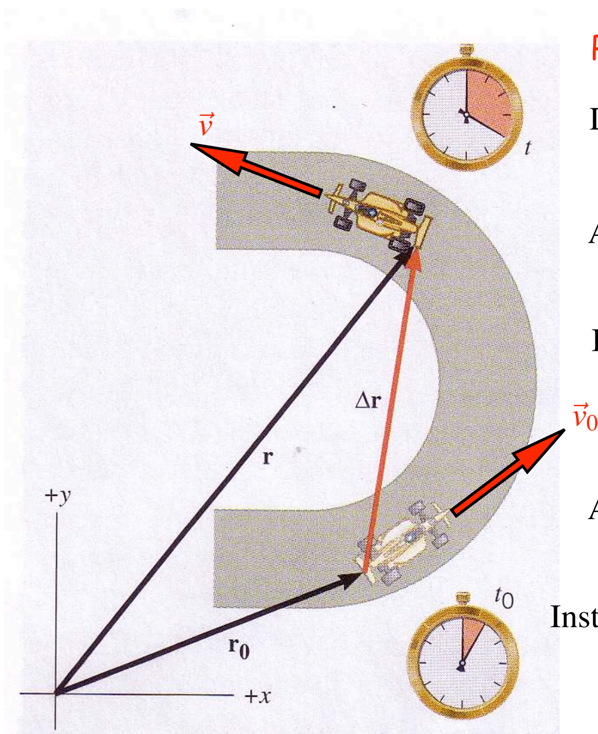
$$\text{Average speed} = \frac{\text{Distance}}{\text{Elapsed time}} = \frac{x - x_0}{t - t_0}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Elapsed time}} = \frac{\Delta\vec{x}}{t - t_0}$$

$$\text{Instantaneous velocity } \vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{x}}{\Delta t}$$

$$\text{Average acceleration} = \frac{\text{change in velocity}}{\text{elapsed time}} = \frac{\vec{v} - \vec{v}_0}{t - t_0}$$

$$\text{Instantaneous acceleration} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t}$$



Position vectors **r**, **r**$_0$ at t, t_0

$$\text{Displacement } \Delta\vec{r} = \vec{r} - \vec{r}_0$$

$$\text{Average velocity} = \frac{\Delta\vec{r}}{t - t_0}$$

$$\text{Instantaneous velocity} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t}$$

$$\text{Average acceleration} = \frac{\vec{v} - \vec{v}_0}{t - t_0}$$

$$\text{Instantaneous acceleration} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t}$$

There is an acceleration whenever there is a change of speed or direction

Clickers!

You drive 1500 m east in 2 minutes, then drive north the same distance in a further 2 minutes.

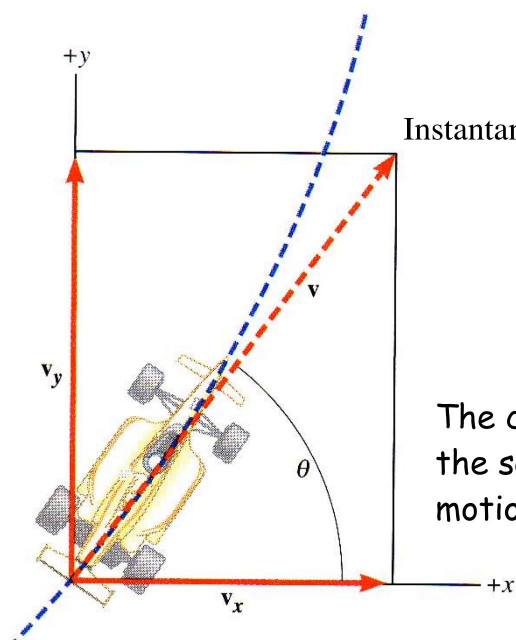
What can be said about the average speeds and velocities for the two parts of the trip?

a) The average speeds are the same, and the average velocities are the same.

b) The average speeds are the same, but the average velocities are different.

c) The average speeds are different, but the average velocities are the same.

Vectors can be resolved into components



$$v_x = v\cos\theta$$
$$v_y = v\sin\theta$$

The components separately follow the same laws of motion as if the motion were in a straight line

Equations of motion in two dimensions

Same as before, only with subscripts for each direction of motion

$$v_x = v_{0x} + a_x t \qquad v_y = v_{0y} + a_y t$$

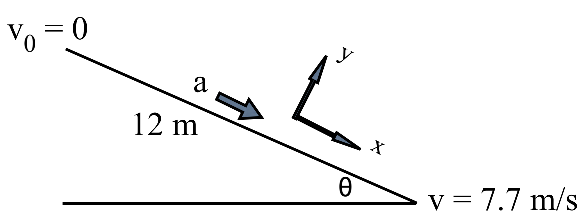
$$x - x_0 = v_{0x} t + \frac{1}{2} a_x t^2 \qquad y - y_0 = v_{0y} t + \frac{1}{2} a_y t^2$$

$$x - x_0 = \frac{1}{2}(v_{0x} + v_x) t \qquad y - y_0 = \frac{1}{2}(v_{0y} + v_y) t$$

$$v_x^2 = v_{0x}^2 + 2a_x(x - x_0) \qquad v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$$

For projectile motion: $a_x = 0$, $a_y = -g$

3.8: A skateboarder rolls down a 12 m ramp, reaching a speed of 7.7 m/s at the bottom. What is her average acceleration?

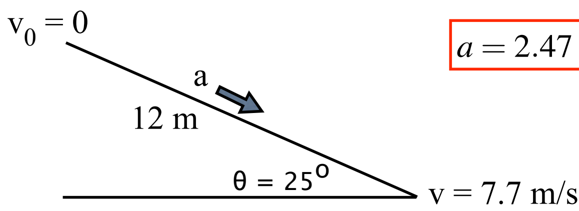


Tilt the x-axis to point down the slope

$$v^2 = v_0^2 + 2ax$$

$$7.7^2 = 0 + 2a \times (12 \text{ m}) \quad \rightarrow \quad \underline{a = 2.47 \text{ m/s}^2}$$

If $\theta = 25^o$, what is the acceleration parallel to the horizontal?



$a = 2.47 \text{ m/s}^2$

Acceleration parallel to horizontal $= a\cos\theta = 2.47\cos 25^\circ = 2.24 \text{ m/s}^2$

A spacecraft is travelling with a velocity of v_{0x} = 5480 m/s along the +x direction. Two engines are fired for 842 seconds.

Engine one: a_x = 1.20 m/s^2
Engine two: a_y = 8.40 m/s^2

Find final v_x, v_y.

Acceleration in x direction: $v_x = v_{0x} + a_x t \ = 5480 + 1.2 \times 842 = 6490 \text{ m/s}$

Acceleration in y direction: $v_y = v_{0y} + a_y t \ = 0 + 8.4 \times 842 = 7073 \text{ m/s}$

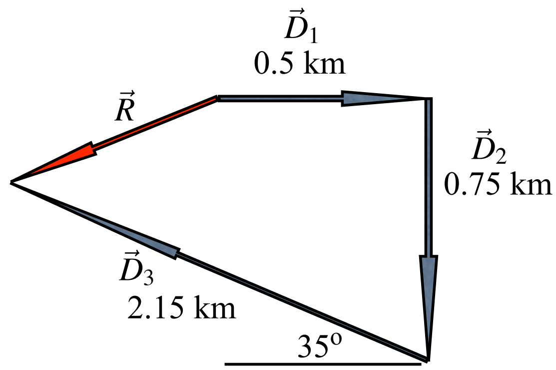
Final speed:

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{6490^2 + 7073^2} = 9600 \text{ m/s}$$

3.10: A person walks 0.5 km east, 0.75 km south and 2.15 km at 35° north of west in 2.5 h.

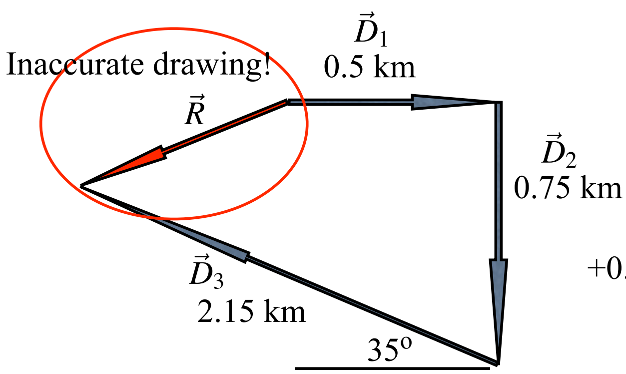
Find the displacement from the starting point and average velocity.

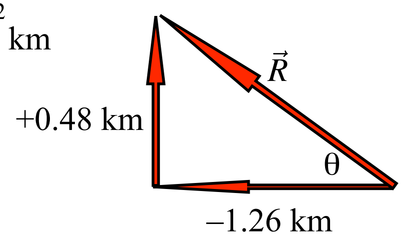
$\vec{R} = ?$



$$\vec{R} = \vec{D}_1 + \vec{D}_2 + \vec{D}_3 \qquad \rightarrow R_x = D_{1x} + D_{2x} + D_{3x}$$

$$R_y = D_{1y} + D_{2y} + D_{3y}$$





$$R_x = D_{1x} + D_{2x} + D_{3x} = 0.5 + 0 - 2.15\cos 35^\circ = -1.26 \text{ km}$$

$$R_y = D_{1y} + D_{2y} + D_{3y} = 0 - 0.75 + 2.15\sin 35^\circ = +0.48 \text{ km}$$

$$R = \sqrt{R_x^2 + R_y^2} = 1.35 \text{ km}$$

Angle to west direction: $\tan\theta = 0.48/1.26 \quad \rightarrow \theta = 20.9^\circ$ north of west

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time}}$$

$$= \frac{1.35\text{ km at }20.9^\circ\text{ north of west}}{2.5\text{ h}}$$

$$= 0.54\text{ km/h at }20.9^\circ\text{ north of west}$$

Clickers!

A power boat, starting from rest, maintains a constant acceleration. After a certain time t, its displacement and velocity are $\vec{\mathbf{r}}$ and $\vec{\mathbf{v}}$.

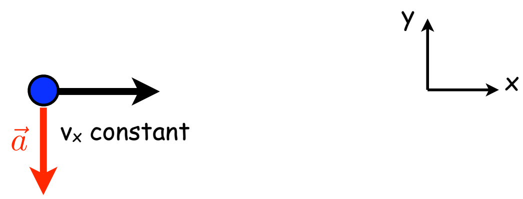
At time 2t, what would be its displacement and velocity, assuming the acceleration remains the same?

a) $2\vec{\mathbf{r}}$ and $2\vec{\mathbf{v}}$,
b) $2\vec{\mathbf{r}}$ and $4\vec{\mathbf{v}}$,
c) $4\vec{\mathbf{r}}$ and $2\vec{\mathbf{v}}$,
d) $4\vec{\mathbf{r}}$ and $4\vec{\mathbf{v}}$.

Projectile Motion

- Consider motion in x and y separately
- Ignore air resistance → velocity in x-direction is constant
- Write down positions in x and y as a function of time
- Remember that the projectile travels up and down (y) in the same time that it is travelling sideways (x)

Projectile Motion



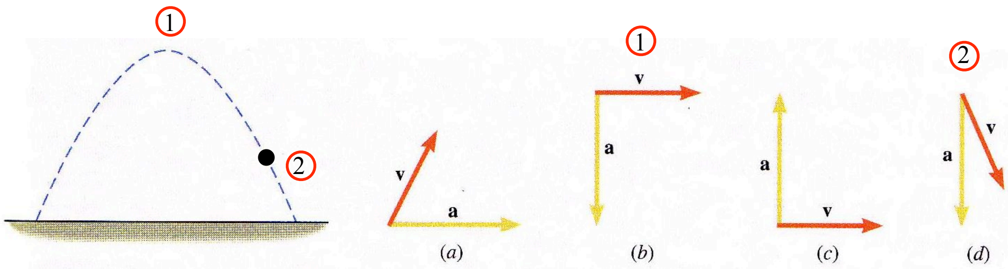
In absence of air resistance: no forces act in x-direction, so v_x, the speed in x-direction is constant throughout the path.

Speed changes in y-direction because of gravity.

Clickers!

The projectile has velocity $\vec{v}$ and acceleration $\vec{a}$

There is no air resistance



Which of (a), (b), (c) and (d) could **not** represent the directions of the vectors at any point of the trajectory?

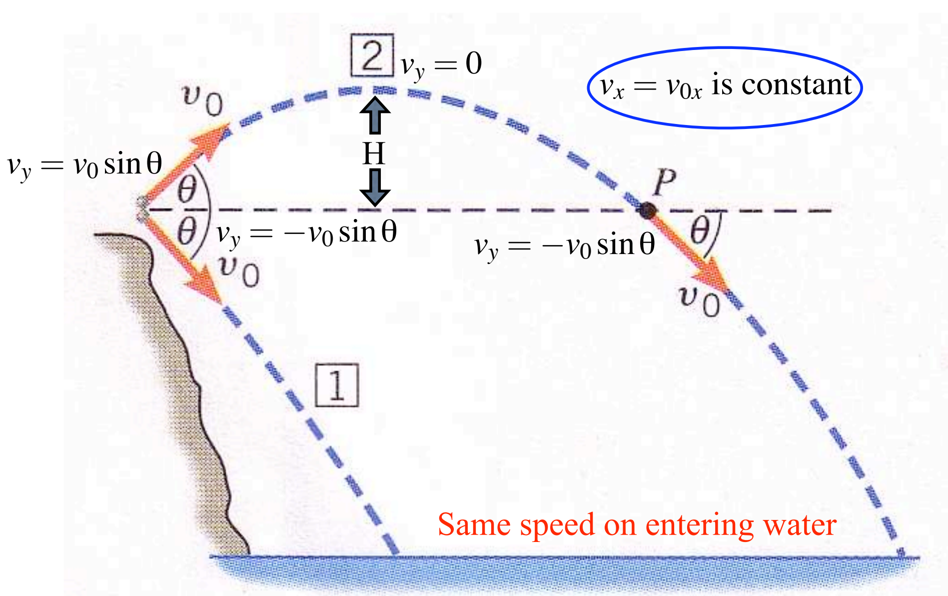
A: (a)

B: (b)

C: (c)

D: (d)

E: (a) and (c)



Stones 1 and 2 are thrown with the same speed, v_o, but at angles θ above and below the horizontal. Which hits the water with the greater speed?

Stone 2 at P has the same velocity as stone 1 at the start → same speed when they hit the water