

### Speed and Velocity

**speed** the distance traveled per unit of time. Speed is a scalar, a quantity that is described by magnitude alone. Constant speed refers to a fixed distance per unit of time. Average speed includes the total distance and total time.

**velocity** the displacement of an object per unit of time. Since displacement includes a direction, so does velocity. Speed with direction. Velocity is a vector a quantity that has both magnitude and direction.

**vector** a quantity that has both magnitude and direction

**reference frame** the position from which an event is observed

**motion map** an image that represents the position, velocity, and acceleration of an object at one-second intervals

**scalar** a quantity that is described by magnitude alone

### Speed and Velocity (cont)

**Motion and reference frame** All motion is relative. It depends on a reference frame. An object may appear to move faster or slower depending on the reference frame.

**average velocity** The slope of a line changes when the velocity of an object changes -> The steeper the slope, the greater the velocity. The average velocity will be different than any of the other. Any point on the line will give only an instantaneous velocity.

**change in direction** A change in direction is represented when the line on a position-time graph changes from a positive slope to a negative slope or from a negative slope to a positive slope. A negative slope indicates an object moving towards the origin. A positive slope indicates an object moving away from the origin.

### Speed and Velocity (cont)

**No motion** horizontal line - means object is not moving -> The object's position does not change

**Motion** Displayed in a vector !

### Formula

**speed**  $s = d/t \rightarrow 50 + 30 = 80$  miles,  $1+1 = 2h \rightarrow 80 \text{ miles}/2h = 40 \text{ mph}$

**velocity**  $v = \Delta x/t$

**average velocity**  $v_{avg} = \Delta x/\Delta t = x_f - x_i/t_f - t_i \rightarrow 100 \text{ m in } 10.61 \text{ s} \rightarrow x_f = 100 \text{ m}, x_i = 0 \text{ m}, t_f = 10.61 \text{ s}, t_i = 0 \text{ s} \rightarrow v_{avg} = 100 \text{ m} - 0 \text{ m} / 10.61 \text{ s} - 0 \text{ s} = 100/10.61 = 9.43 \text{ m/s}$

### Acceleration

**positive acceleration** an increase in velocity over time

**negative acceleration** a decrease in velocity over time

**acceleration** the rate at which velocity changes over time

**constant** staying the same; unchanging

**Positive acceleration** speeds up in the positive direction. slows down in the negative direction



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## Acceleration (cont)

Negative acceleration slow down down in the positive direction. speeds up in the negative direction.

Slope of the line on a velocity vs. time graph represents acceleration. Positive slope = acceleration, negative slope = negative acceleration

## acceleration

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

## Acceleration example

Example: A race car moving west speeds up from 17 m/s to 47 m/s in 2 seconds. What is the car's acceleration?

$v_i = 17 \text{ m/s}$   
 $v_f = 47 \text{ m/s}$   
 $t = 2 \text{ s}$

$a = \frac{47 \text{ m/s} - 17 \text{ m/s}}{2 \text{ s}} = 30 \text{ m/s}^2$   
 $a = 15 \text{ m/s}^2$

## Displacement during constant acceleration

Displacement during constant <b>velocity</b>	$\Delta x = vt$
Displacement during acceleration	$\Delta x = \frac{1}{2}(v_f + v_i)t$
Total displacement is the sum of the two	$\Delta x = v_i t + \frac{1}{2}(v_f + v_i)t$
Terms are combined	$\Delta x = \frac{1}{2}(v_f + v_i)t$
When the initial position is not <b>zero</b>	$x_f = x_i + \frac{1}{2}(v_f + v_i)t$

## Formula

Two vectors added at a right angle (90°)	$R^2 = A^2 + B^2$
Magnitude and sign of component vectors	$A_x = A \cos \theta$ $A_y = A \sin \theta$
Magnitude of the resultant vector	$R^2 = R_x^2 + R_y^2$
Angle or direction of the resultant vector	$\tan \theta = \frac{R_y}{R_x}$

## Horizontal motion example

### EXAMPLE

Riley and Miguel are playing catch. Riley throws the ball at an angle of 25° relative to the ground at a speed of 23.0 m/s. The ball travels 42.0 m to Miguel, who catches the ball. How long was the ball in the air?

Given:

$$\theta = 25^\circ$$

$$v_i = 23.0 \text{ m/s}$$

$$\Delta x = 42.0 \text{ m}$$

$$\Delta t = ?$$

The equation that we need to use is:

$$\Delta x = (v_i \cos \theta) \Delta t$$

$$\Delta t = \frac{\Delta x}{(v_i \cos \theta)}$$

$$= \frac{42.0 \text{ m}}{(23 \text{ m/s})(\cos 25^\circ)}$$

$$= 2.0 \text{ s}$$

## Key concepts

### Review: Key concepts

	Horizontally Launched Projectile	Projectile Launched at an Angle
Horizontal Motion	$v_x = \text{constant}$ $\Delta x = v_x \Delta t$	$v_x = v_o \cos \theta = \text{constant}$ $\Delta x = (v_o \cos \theta) \Delta t$
Vertical Motion	$v_y = a_y \Delta t$ $v_y^2 = 2a_y \Delta y$ $\Delta y = \frac{1}{2} a_y (\Delta t)^2$	$v_y = v_o \sin \theta + a_y \Delta t$ $v_y^2 = v_i^2 (\sin \theta)^2 + 2a_y \Delta y$ $\Delta y = (v_o \sin \theta) \Delta t + \frac{1}{2} a_y (\Delta t)^2$

## vectors

quadrant a quarter of the coordinate plane

components the two parts of a vector that are perpendicular to each other

resultant vector the sum of two or more vectors

vector resolution the process by which the components of a vector are determined

Properties of a vector A vector is a quantity that has both magnitude and direction. Examples of vectors: Displacement, velocity, acceleration. Vectors are drawn using an arrow

## More

### Magnitude of the Resultant Vector

$$R^2 = A^2 + B^2$$

$$A = 300 \text{ m} \quad B = 300 \text{ m}$$

$$R^2 = 300^2 + 300^2$$

$$R^2 = 180,000$$

$$R = 424.26 \text{ m}$$



### Components of Vectors

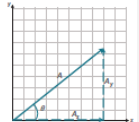
A vector that is diagonal is made up of a horizontal part and a **vertical** part.

The components of a vector are the two parts of a vector that are **perpendicular** to each other.

$$A_x = A \cos \theta \quad \cos \theta = \frac{A_x}{A}$$

$$A_y = A \sin \theta \quad \sin \theta = \frac{A_y}{A}$$

**Vector resolution** is the process by which the components of a vector are determined.



## Sign of a component

Second quadrant	First quadrant
$A_x < 0$ (-)	$A_x > 0$ (+)
$A_y > 0$ (+)	$A_y > 0$ (+)
Third quadrant	Fourth quadrant
$A_x < 0$ (-)	$A_x > 0$ (+)
$A_y < 0$ (-)	$A_y < 0$ (-)

The sign of a component depends on the quadrant of the coordinate system it is in.

## Projectile Motion

projectile an object that is set in motion following a path in which the only force acting on it is gravity.

inertia the natural tendency of objects to resist a change in motion

## Projectile Motion (cont)

**projectile motion** the curved motion that results from the combination of an object's horizontal inertia and the force due to gravity pulling the object downward. I.e. A ball rolling of the table, A player shooting a jump shot -> Projectiles follow a parabolic path

**parabolic** having the shape of a parabola

**vectors** Vectors are used to describe motion in two dimensions. Vectors can be broken down into x and y components. The components of a vector are the two parts of a vector that are perpendicular to each other

## Add

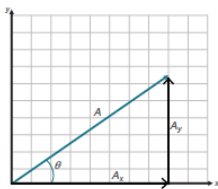
$$\cos \theta = \frac{A_x}{A}$$

$$\sin \theta = \frac{A_y}{A}$$

If we rearrange these we now get:

$$A_x = A \cos \theta$$

$$A_y = A \sin \theta$$



## Horizontal

### Horizontally Launched Projectiles

• Horizontal motion:

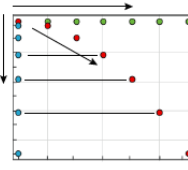
• Velocity is **constant**.

• **Acceleration** is zero.

• Vertical motion:

• Velocity is changing.

• Acceleration is **-9.8** m/s<sup>2</sup>.



### Horizontally Launched Projectiles

• Horizontal motion:

•  $v_x = \text{constant}$

$$v_x = \frac{\Delta x}{\Delta t}$$

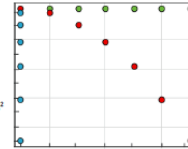
•  $\Delta x = v_x \Delta t$

• Vertical motion:

•  $v_y = a_y \Delta t$  **-9.8** m/s<sup>2</sup>

•  $v_y^2 = 2 a_y \Delta y$

•  $\Delta y = \frac{1}{2} a_y (\Delta t)^2$



## Horizontal example

### Horizontally Launched Projectiles

EXAMPLE

A pencil rolls off a desk that is 0.76 m tall. If the pencil hits the floor 0.32 m from the base of the desk, how fast was the pencil rolling?

Given:

$$\Delta y = -0.76 \text{ m}$$

$$\Delta x = 0.32 \text{ m}$$

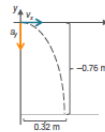
$$a_y = -g = -9.8 \text{ m/s}^2$$

Unknown:

$$v_x = ?$$

We can use the equation:

$$\Delta x = v_x \Delta t$$



SOLVE FOR T

To solve for  $v_x$ , we first need to solve for time,  $t$ , by rearranging the formula:

$$\Delta y = \frac{1}{2} a_y (\Delta t)^2$$

Plugging in values we have:

$$\Delta t = \sqrt{\frac{2 \Delta y}{a_y}}$$

$$\Delta t = \frac{2(-0.76 \text{ m})}{\sqrt{-9.8 \text{ m/s}^2}}$$

$$\Delta t = 0.39 \text{ s}$$

## continued

So if we rearrange our first formula to solve for  $v_x$ , we get:

$$v_x = \frac{\Delta x}{\Delta t}$$

$$v_x = \frac{\Delta x}{\Delta t}$$

$$= \frac{0.32 \text{ m}}{0.39 \text{ s}}$$

$$= 0.82 \text{ m/s}^2$$