

# Newton 3 & Vectors

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### Action/Reaction



- When you lean against a wall, you exert a force on the wall.
- The wall simultaneously exerts an equal and opposite force on you.

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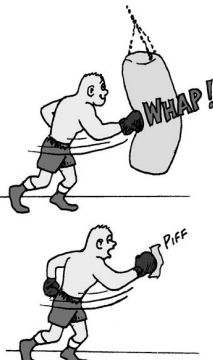
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### You Can Only Touch as Hard as You Are Touched



- He can hit the massive bag with considerable force.
- But with the same punch he can exert only a tiny force on the tissue paper in midair.

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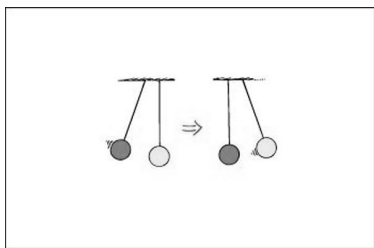
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### Newton's Cradle



- The impact forces between the blue and yellow balls move the yellow ball and stop the blue ball.

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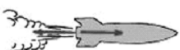
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### Naming Action & Reaction

  
 Action: tire pushes on road    Reaction: road pushes on tire

  
 Action: rocket pushes on gas    Reaction: gas pushes on rocket

  
 Action: man pulls on spring    Reaction: spring pulls on man

  
 Action: earth pulls on ball  
 Reaction: ball pulls on earth

When action is "A exerts force on B,"

Reaction is then simply "B exerts force on A."

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### Newton's Three Laws of Motion

N1:  $\vec{F}_{net} = 0 \Leftrightarrow \vec{a} = 0$  & velocity is constant

N2:  $\vec{a} = \frac{\vec{F}_{net}}{m}$

N3:  $\vec{F}_{on\ A\ by\ B} = -\vec{F}_{on\ B\ by\ A}$

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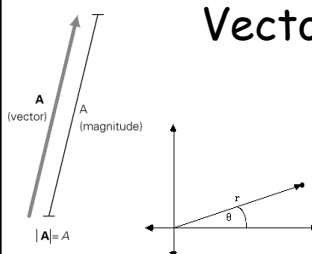
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## Vectors



- A Vector has 2 aspects
- Magnitude ( $r$ ) (size)
- Direction (sign or angle) ( $\theta$ )

Vectors can be represented by arrows  
 Length represents the magnitude  
 The angle represents the direction

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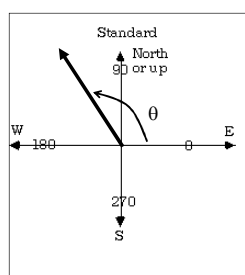
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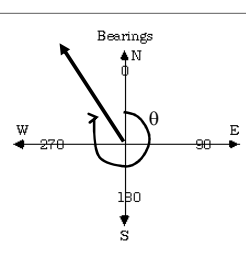
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## Reference Systems

Standard



Bearings



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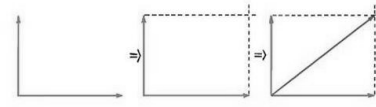
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## Adding Vectors

- The sum of two or more vectors is called their resultant.
- To find the resultant of two vectors that don't act in exactly the same or opposite direction, we use the parallelogram method.
- Construct a parallelogram wherein the two vectors are adjacent sides—the diagonal of the parallelogram shows the resultant.



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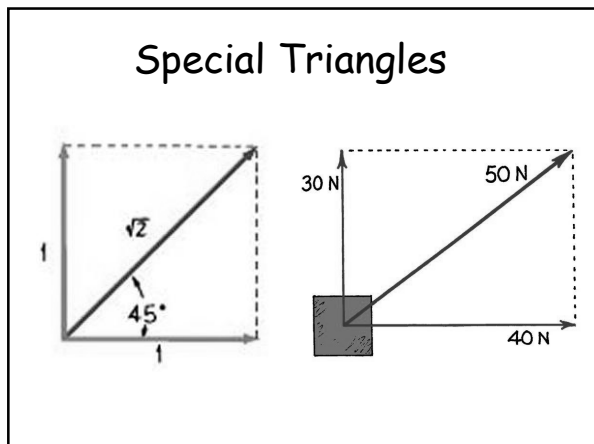
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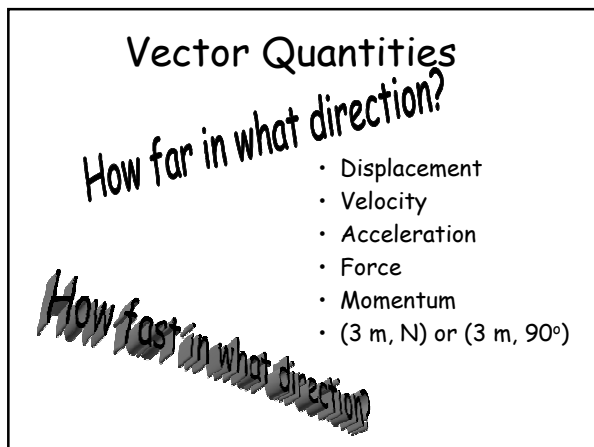
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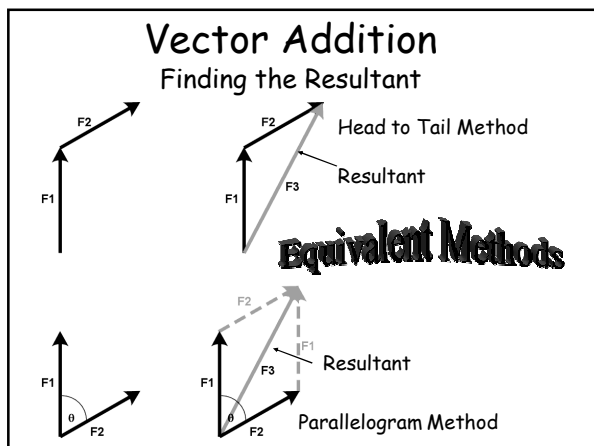
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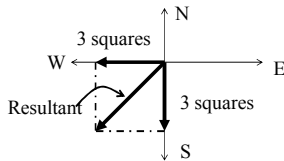
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## A Simple Right Angle Example

Your teacher walks 3 squares south and then 3 squares west. What is her displacement from her original position?

This asks a compound question: how far has she walked AND in what direction has she walked?



Problem can be solved using the Pythagorean theorem and some knowledge of right triangles.

4.2 squares, 225°

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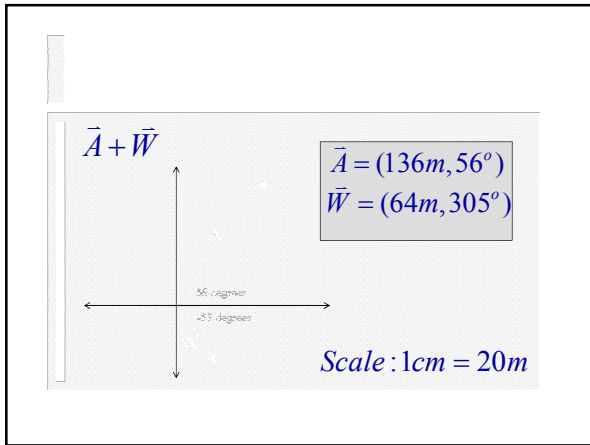
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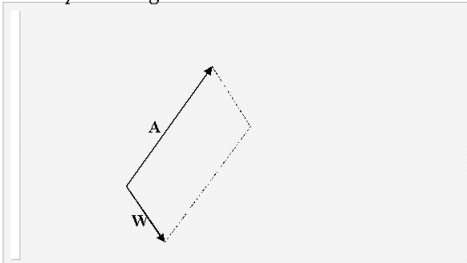
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**Adding Vectors - Parallelogram Method**  
 Step 2 -- Draw the other 2 sides to complete the parallelogram.




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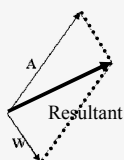
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### Getting the Answer



1. Measure the length of the resultant (the diagonal). (6.4 cm)
2. Convert the length using the scale. (128 m)
3. Measure the direction counter-clockwise from the x-axis. (28°)

$\vec{A} + \vec{W} = (128m, 28^\circ)$

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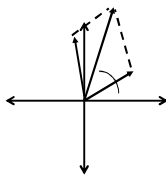
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### Practice Problem

Given  $\mathbf{A} = (20 \text{ m}, 40^\circ)$  and  $\mathbf{B} = (30 \text{ m}, 100^\circ)$ , find the vector sum  $\mathbf{A} + \mathbf{B}$ .



$\mathbf{A} + \mathbf{B} = (43.6 \text{ m}, 76.6^\circ)$

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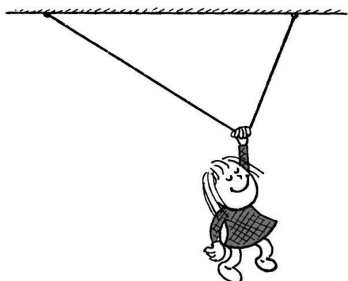
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### Tension



• If the line is on the verge of breaking, which side is most likely to break?

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### Nellie Tension

- (a) Nellie's weight must be balanced by an equal and opposite vector for equilibrium.
- (b) This dashed vector is the diagonal of a parallelogram defined by the dotted lines.
- (c) Tension is greater in the right rope, the one most likely to break.

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### Airplane Velocity Vectors

Tailwind 	Headwind 	Crosswind 

$\vec{v}_{plane,ground} = \vec{v}_{plane,air} + \vec{v}_{air,ground}$

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### Airplane Velocity

- The 60-km/h crosswind blows the 80-km/h aircraft off course.
- Ground Velocity = Air Velocity + Wind Velocity

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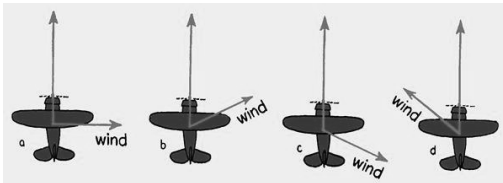
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### Velocity Vector Addition

- Sketch the vectors that show the resulting velocities for each case. In which case does the airplane travel fastest across the ground? Slowest?




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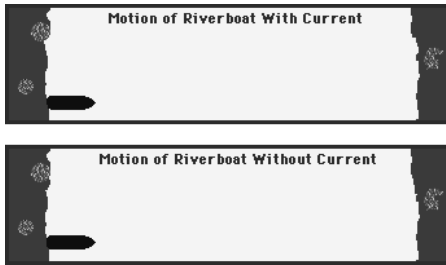
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### Boat in River Velocity



$$\vec{v}_{boat,shore} = \vec{v}_{boat,water} + \vec{v}_{water,shore}$$

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### Concept Check

- Consider a motorboat that normally travels 10 km/h in still water. If the boat heads directly across the river, which also flows at a rate of 10 km/h, what will be its velocity relative to the shore?
- When the boat heads cross-stream (at right angles to the river flow) its velocity is 14.1 km/h, 45 degrees downstream .

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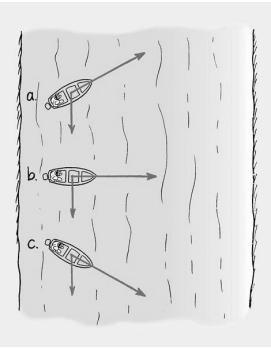
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### Boat Velocity



- (a) Which boat takes the shortest path to the opposite shore?
- (b) Which boat reaches the opposite shore first?
- (c) Which boat provides the fastest ride?

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### Independence of Velocities

- If the boat heads perpendicular to the current at 20 m/s relative to the river, how long will it take the boat to reach the opposite shore 100 m away in each of the following cases?
- Current speed = 1 m/s
- Current speed = 5 m/s
- Current speed = 10 m/s
- Current speed = 20 m/s

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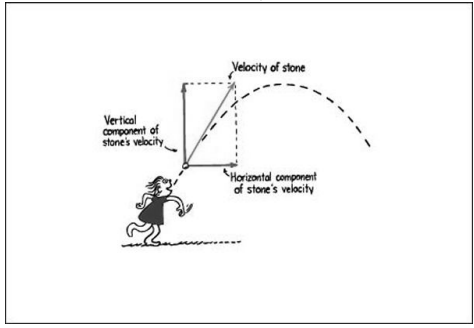
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### Vector Components




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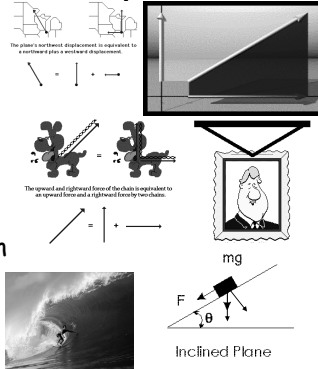
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## Resolving into Components

- A vector can be broken up into 2 perpendicular vectors called components.



- Often these are in the x and y direction.

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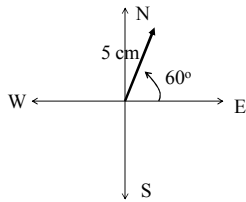
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## Components Diagram 1

$A = (50 \text{ m/s}, 60^\circ)$

Resolve **A** into x and y components.

Let 1 cm = 10 m/s



1. Draw the coordinate system.
2. Select a scale.
3. Draw the vector to scale.

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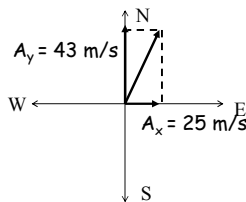
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## Components Diagram 2

$A = (50 \text{ m/s}, 60^\circ)$  Resolve **A** into x and y components.

Let 1 cm = 10 m/s



4. Complete the rectangle
  - a. Draw a line from the head of the vector perpendicular to the x-axis.
  - b. Draw a line from the head of the vector perpendicular to the y-axis.
5. Draw the components along the axes.
6. Measure components and apply scale.

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### Vector Components

Vertical Component  
 $A_y = A \sin \theta$

Horizontal Component  
 $A_x = A \cos \theta$

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### Signs of Components

(a)

(b)

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### Components

- For the following, make a sketch and then resolve the vector into x and y components.

$\vec{A} = (60\text{ m}, 120^\circ)$        $\vec{B} = (40\text{ m}, 225^\circ)$

$A_x = (60\text{ m}) \cos(120) = -30\text{ m}$        $B_x = (40\text{ m}) \cos(225) = -28.3\text{ m}$   
 $A_y = (60\text{ m}) \sin(120) = 52\text{ m}$        $B_y = (40\text{ m}) \sin(225) = -28.3\text{ m}$

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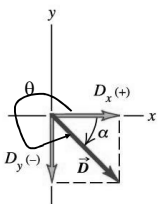
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**(x,y) to (R,θ)**

$$D = \sqrt{D_x^2 + D_y^2}$$

$$\alpha = \tan^{-1}\left(\frac{|D_y|}{|D_x|}\right)$$

$$\theta = 360^\circ - \alpha$$

- Sketch the x and y components in the proper direction emanating from the origin of the coordinate system.
- Use the Pythagorean theorem to compute the magnitude.
- Use the absolute values of the components to compute angle  $\alpha$  -- the acute angle the resultant makes with the x-axis
- Calculate  $\theta$  based on the quadrant

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