

Physics 101 Lecture 3

Kinematics: Vectors and Motion in 1 Dimension

Review! Kinematics: Free Fall, A Special Case

- Free Fall: motion caused by *gravity alone*

→ $a = g$, the *acceleration of gravity*

→ $g = 9.8 \text{ m/s}^2$

→ Important Kinematic Expressions

$$\gg y = y_0 + v_{0y}t - \frac{1}{2}gt^2$$

$$\gg v_y = v_{0y} - gt$$

$$\gg v_y^2 = v_{0y}^2 - 2g(y - y_0)$$

Free Fall, in 2-dimensions

- If you have free fall with both x and y motion, the motion in the x- and y-directions is **independent**
- Free fall with horizontal motion

$$\gg x = x_0 + v_{0x}t$$

No x acceleration!

$$\gg v_x = v_{0x}$$

$$\gg y = y_0 + v_{0y}t - \frac{1}{2}gt^2$$

$$\gg v_y = v_{0y} - gt$$

$$\gg v_y^2 = v_{0y}^2 - 2g(y - y_0)$$

Independence of x and y motion means they each do their own thing without the other caring about it

Tips for applying the kinematic equations

- Always pick a point (a particular x and t , or y and t) in the trajectory and apply kinematic equation(s) for that point.
- Commonly: Two unknowns after writing kinematic equations (e.g., maximum height reached by a ball and time it took to get there).
- Don't give up because the equations are hard. Use algebra to solve for unknowns. (Recall: you need 2 eqns to solve for 2 unknowns)

Example

A ball is thrown straight up with initial velocity of 15 m/s. How far above the point of release is the ball when its velocity is -10 m/s?

Method 1 (one step): Use $v_y^2 = v_{oy}^2 - 2g(y - y_o)$ and solve for y (y_o is 0 if you pick the origin where you threw ball).

Method 2 (two steps):

First use $v_y = v_{oy} - gt$ to find the **time** when $v_y = -10$ m/s

Then use $y = y_o + v_{oy}t - (1/2)gt^2$ to find **y** at that time.

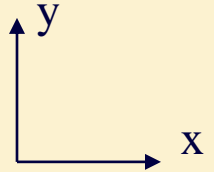
Clicker Q

A ball is thrown straight up in the air and returns to its initial position.

For the period of time that the ball is in the air, which of the following statements is true?

- A - Both average acceleration and average velocity are zero.
- B - Average acceleration is zero but average velocity is not zero.
- C - Average velocity is zero but average acceleration is not zero.
- D - Neither average acceleration nor average velocity are zero.

Free Fall Demo: Two Dropped Objects



Which will hit the ground first, the feather or the coin?

A) coin

B) Same

C) Feather

Clicker Q

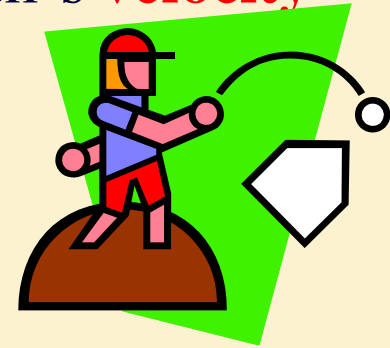
The **speed** of an object in free fall (neglect air resistance!)

- A. Always increases.
- B. Is constant.
- C. Always decreases.
- D. May increase or decrease or be constant.
- E. May increase or decrease but is never constant.

Free Fall Clicker Qs

Fred throws a ball 30 mph vertically upward.

Which of the following statements are true about the ball's **velocity** and **acceleration**. (Let up be the positive direction)



On the way up?

A) $v_y < 0$ B) $v_y = 0$ C) $v_y > 0$

A) $a_y < 0$ B) $a_y = 0$ C) $a_y > 0$

On the way down?

A) $v_y < 0$ B) $v_y = 0$ C) $v_y > 0$

A) $a_y < 0$ B) $a_y = 0$ C) $a_y > 0$

More Fred Clicker Q

Fred throws a ball 30 mph vertically upward and then catches it again at the same height he threw it from.

What is the **speed** of the ball just prior to catching it? (Neglect air resistance)

- 1) $v < 30$ mph 2) $v = 30$ mph 3) $v > 30$ mph

Fred's Free Fall Calculations

Fred throws a ball 30 m/s vertically upward.

What is the maximum height the ball reaches?

What is the speed at max height?

$v_y = 0 \text{ m/s}$ at maximum height.

- $v_y^2 = v_{oy}^2 - 2g\Delta y$

- $\Delta y = (v_y^2 - v_{oy}^2) / (-2g)$

- $= \frac{-(30)^2 \frac{\text{m}^2}{\text{s}^2}}{-2 \times 9.8 \frac{\text{m}}{\text{s}^2}}$

- $= 46 \text{ m.}$

Or, use: $v_{\text{top},y} = v_{oy} - gt$ to get t

Then $y = y_o + v_{oy}t - (1/2)gt^2$

Fred's Free Fall Calculations

Fred throws a ball 30 m/s vertically upward.

How long does it take to reach its maximum height?

$$\checkmark v_y = v_{0y} - gt$$

$$\checkmark t = \frac{v_y - v_{0y}}{a}$$

$$\checkmark = \frac{0 - 30 \frac{\text{m}}{\text{s}}}{-9.8 \frac{\text{m}}{\text{s}^2}}$$

$$\checkmark = 3.1 \text{ seconds}$$

How long does it take the ball to make the complete round trip?

More free fall clicker Qs

Dennis and Carmen are standing on the edge of a cliff.

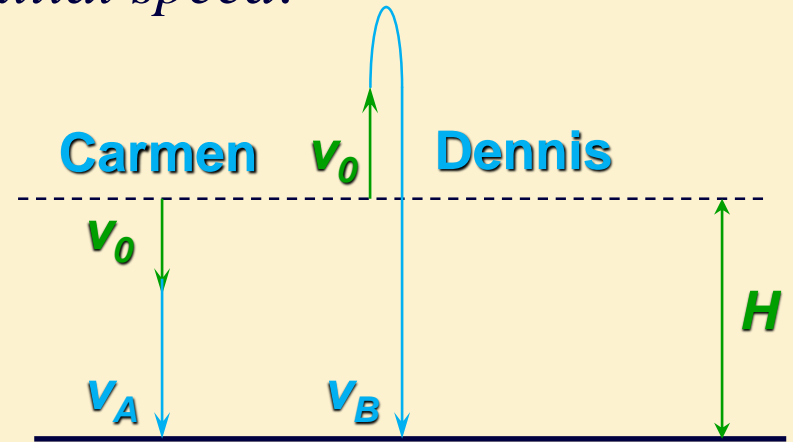
Dennis throws a basketball vertically upward.

At the same time Carmen throws a basketball vertically downward.

Both balls are thrown with the *same initial speed*.

Whose ball hits the ground first?

- A. Dennis' ball
- B. Carmen's ball
- C. Same



$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$\text{Dennis: } 0 = H + v_{0y}t - \frac{1}{2}gt^2$$

$$\text{Carmen: } 0 = H - v_{0y}t - \frac{1}{2}gt^2$$

More free fall clicker Qs

Dennis and Carmen are standing on the edge of a cliff.

Dennis throws a basketball vertically upward.

At the same time Carmen throws a basketball vertically downward.

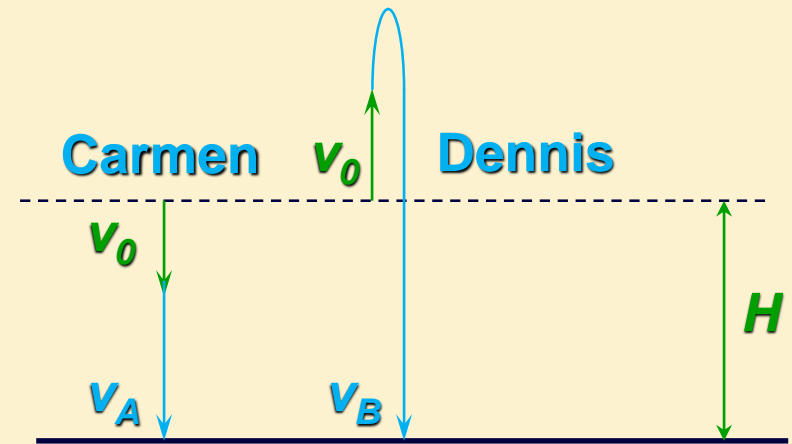
Both balls are thrown with the *same initial speed*.

Whose ball is moving fastest when it hits the ground?

A. Dennis' ball

B. Carmen's ball

C. Same



Free Fall Facts:

- ✓ Remember: $a_y = -g$.
- ✓ Velocity becomes more and more negative if object is dropped from rest.
- ✓ If $v_y > 0$, speed decreases.
- ✓ If $v_y \leq 0$ speed increases.

Vectors

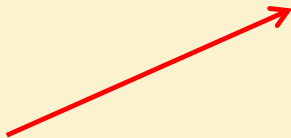
- Vector:
 - A quantity that has:
 - size (called magnitude)
 - direction
- In physics lots of quantities are vectors such as:
 - velocity
 - acceleration
 - forces

Vectors

- We represent vectors with arrows.
 - ➔ The length of the arrow is the magnitude of the vector
 - ➔ The direction is shown by which way the arrow points

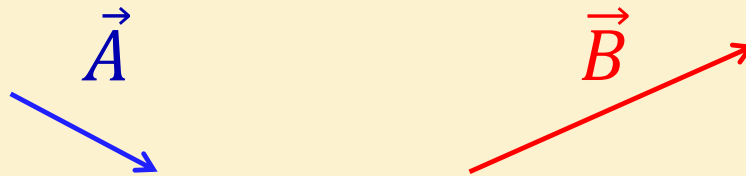


- Rules for dealing with vectors:
 - ➔ You can move a vector in space and it is the same vector, as long as you do not change:
 - » the magnitude (length of the arrow)
 - » the direction
 - ➔ These two red vectors are the same.

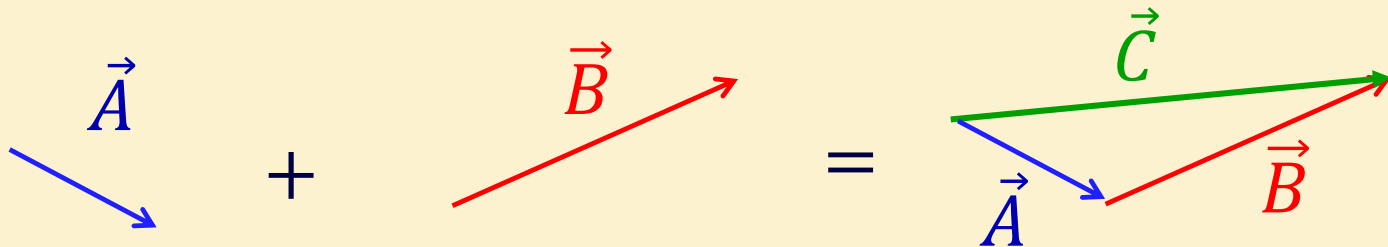


Adding and subtracting vectors

- To add two vectors, put the tail of the second vector at the tip of the first vector, and draw the sum from the tail of the first vector to the tip of the second.

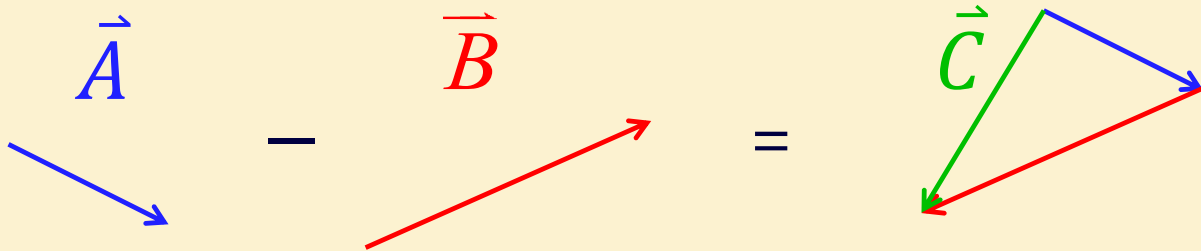


- Let's perform $\vec{A} + \vec{B} = \vec{C}$:

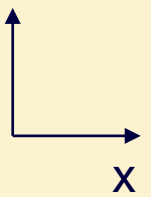


Subtracting Vectors

- To subtract vectors:
 - add the negative of the vector you are subtracting.
 - The negative of a vector has the same length but points in the opposite direction.



Swimmer Example: Velocity is a Vector



Ann needs to swim across a river.

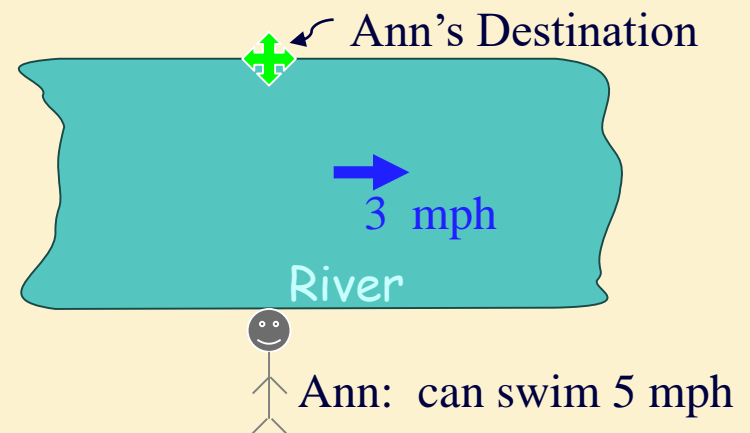
Ann can swim 5 mph with *respect to the water*.

The river flows 3 mph East (i.e. from Ann's left to Ann's right).

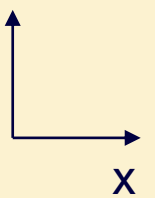
At what angle should Ann swim to end directly to the other side of the river?

Clicker Q: Step 1: In which direction should Ann swim?

- a) toward her left
- b) toward her right
- c) straight across



Swimmer Example: Velocity is a Vector



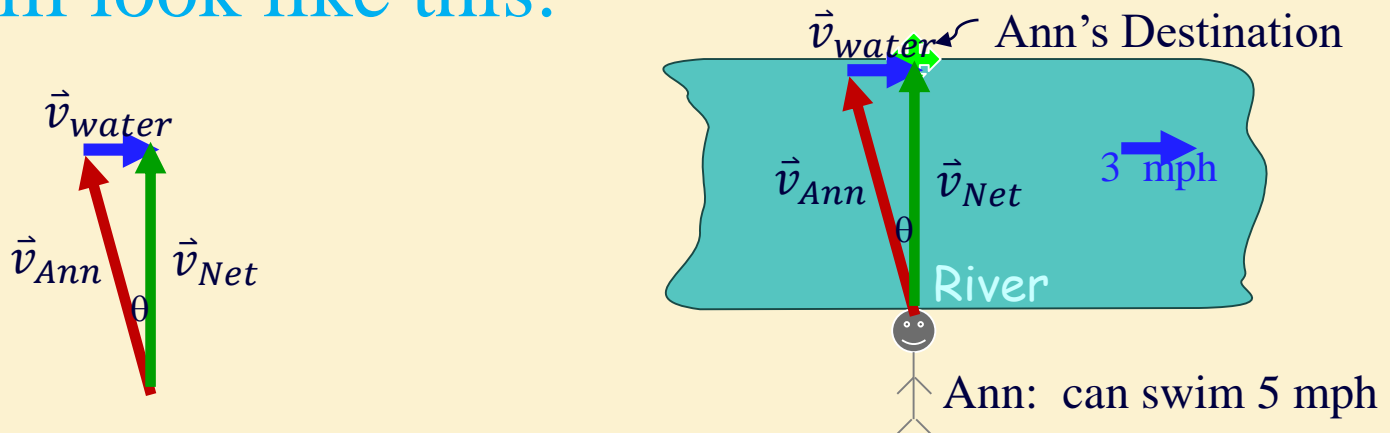
Ann needs to swim across a river.

Ann can swim 5 mph with *respect to the water*.

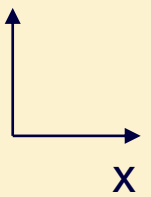
The river flows 3 mph East (i.e. from Ann's left to Ann's right).

At what angle should Ann swim to end directly to the other side of the river?

Step 2: The vector diagram for Ann's swim will look like this:



Swimmer Example: Velocity is a Vector



Ann needs to swim across a river.

Ann can swim 5 mph with *respect to the water*.

The river flows 3 mph East (i.e. from Ann's left to Ann's right).

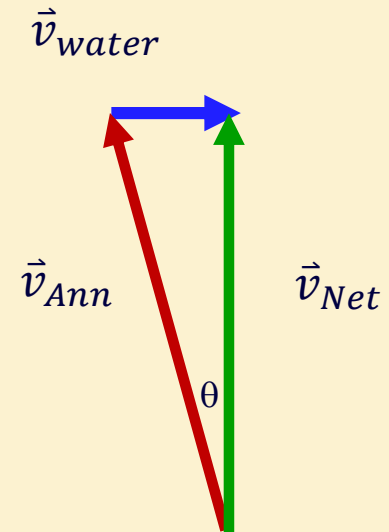
At what angle should Ann swim to end directly to the other side of the river?

Step 3: Find θ :

From the triangle, we know: $\sin\theta = v_{\text{water}}/v_{\text{Ann}} = 3/5$

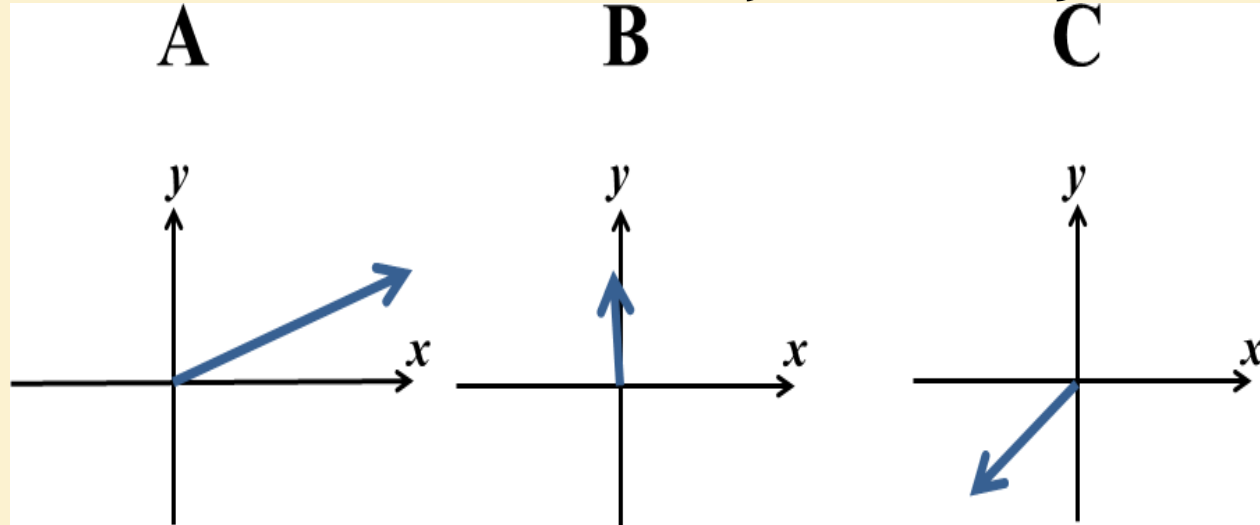
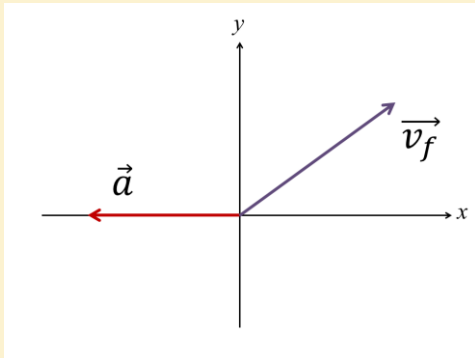
So solve for θ : $\theta = \arcsin(3/5) = 36.9^\circ$

How would you go about finding the green vector, which is Ann's velocity relative to the ground?



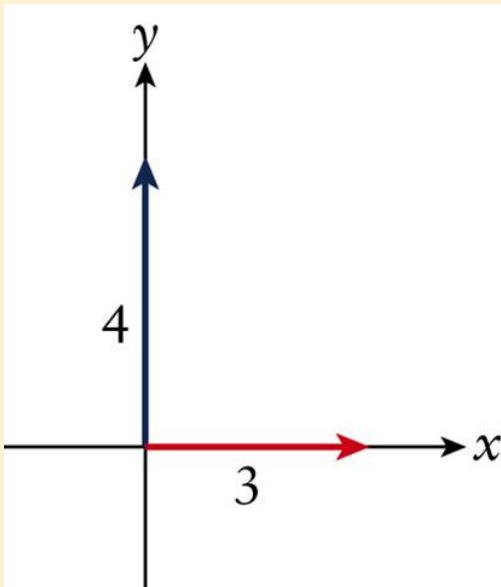
Checkpoint 3, Q3

An object experiences a constant acceleration and attains a velocity as shown in the figure below. Which of the following vectors best corresponds to the initial velocity of the object?

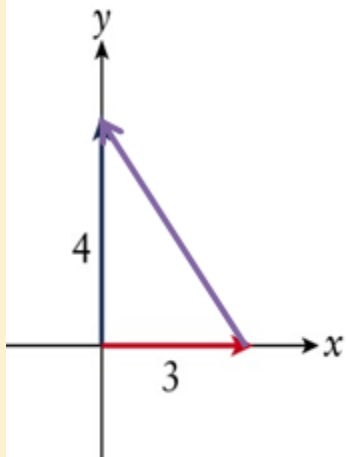


Checkpoint 3, Q1

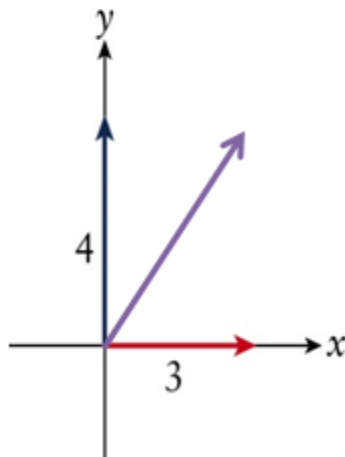
If these two vectors are added together, which drawing represents the resultant vector?



A



B



C

