

Physics 231: non-calculus introductory physics I

Section 003

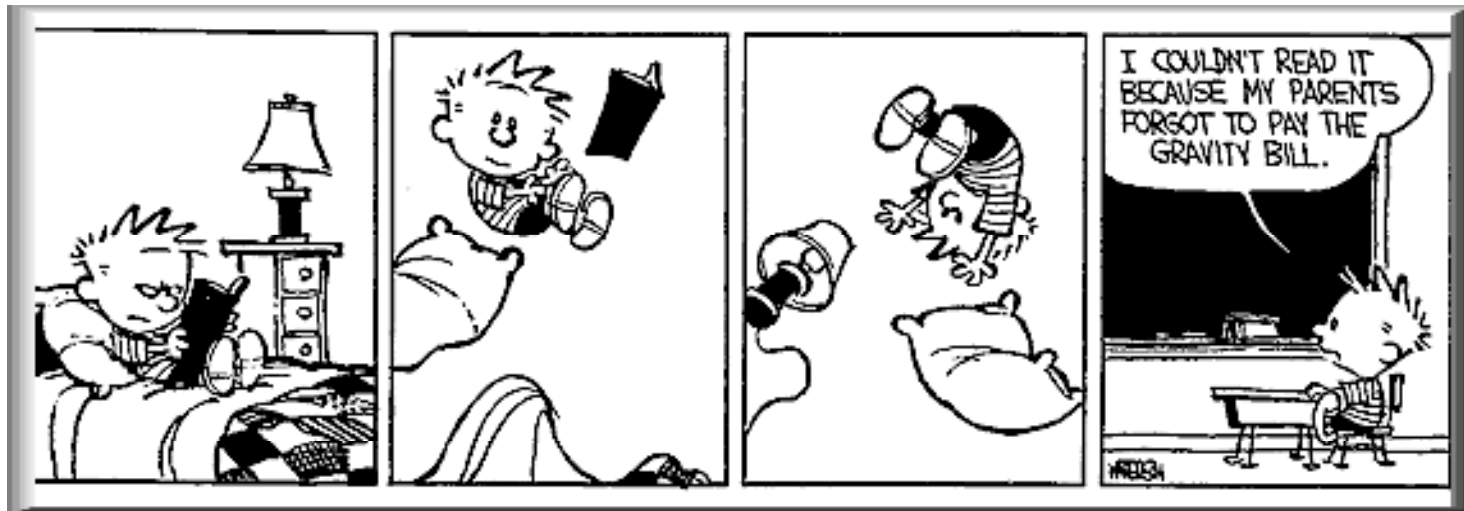
<http://www.pa.msu.edu/people/yuan/classes.htm>

Honors option:

- Serve two hours a week in the helproom (BPS 1248)
- must score 3.5 and above in all midterms

PHYSICS 231

Lecture 4: Vectors



Jumping fish

- A fish jumps out of the water with $v=5.0$ m/s straight up. At which point is its acceleration 0 m/s² (consider only the time after just leaving the water until just before reentering)?
 - A. On its way up
 - B. On its way down
 - C. At the highest point
 - D. Never

There is always acceleration due to gravity (-9.8 m/s²)

Know how to solve quadratic equations!!

important stuff

$$x(t) = x_0 + v_0 t + 0.5 a t^2$$
$$v(t) = v_0 + a t$$

free fall

$$y(t) = y_0 + v_0 t - 0.5 g t^2$$
$$v(t) = v_0 - g t$$

$g = 9.8 \text{ m/s}^2$ on earth

Vectors and Scalars

- **Scalar**: A quantity specified by its magnitude only
 - **Vector**: A quantity specified both by its magnitude and direction.
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- To distinguish a vector from a scalar quantity, it is usually written with an arrow above it, or in bold to distinguish it from a scalar.
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- Scalar: A
 - Vector: \vec{A} or \mathbf{A}

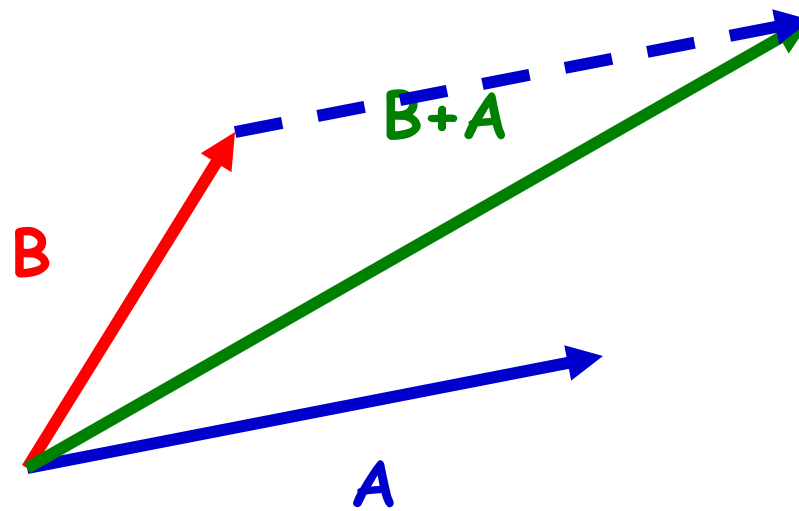
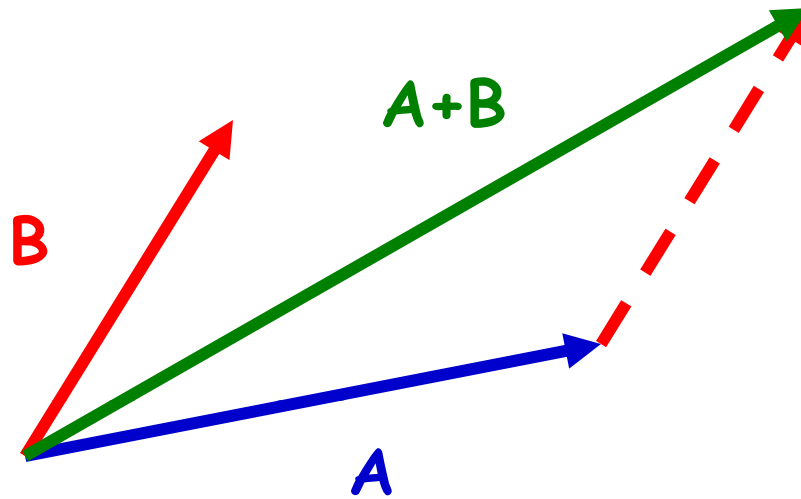
Question



- Are these two vectors the same?
- Are the lengths of these two vectors the same?

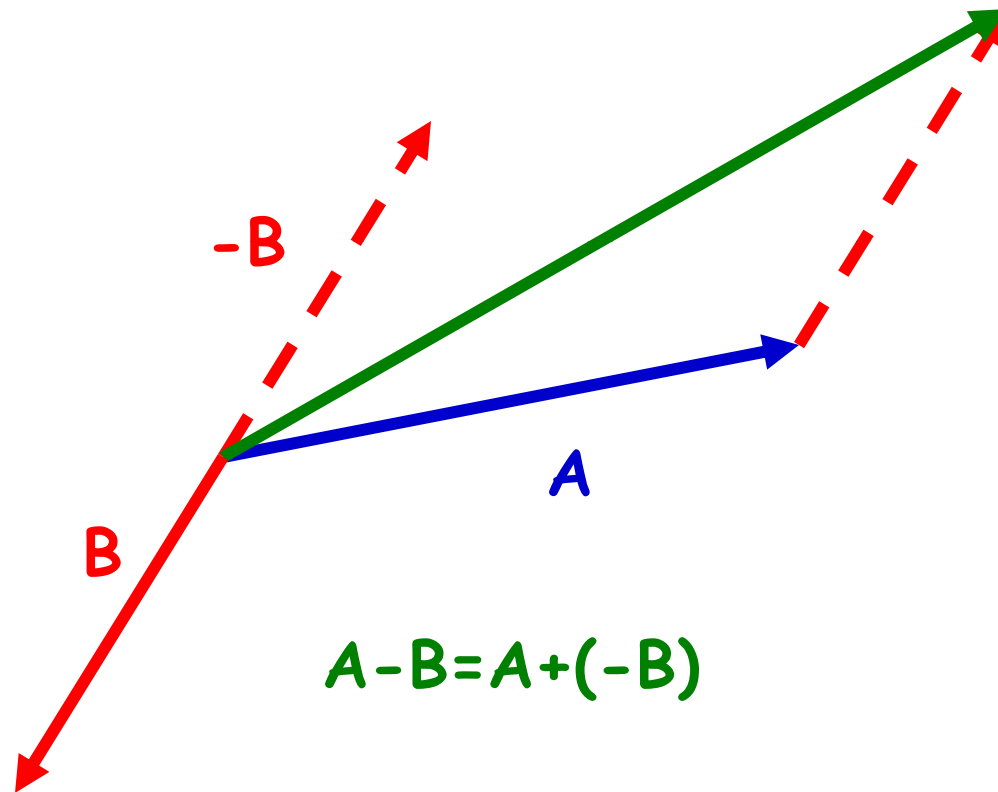
Two vectors are equal if both their length and direction are the same!

Vector addition



$$A+B=B+A$$

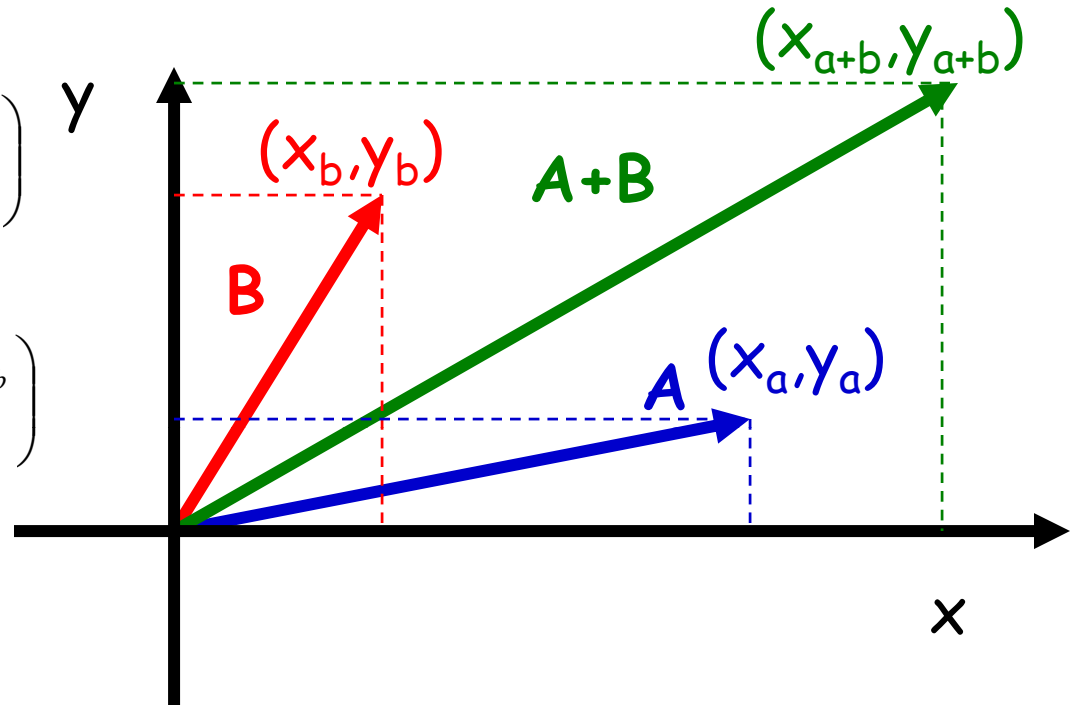
Vector subtraction



Vector operations in equations

$$\begin{pmatrix} X_{a+b} \\ Y_{a+b} \end{pmatrix} = \begin{pmatrix} X_a \\ Y_a \end{pmatrix} + \begin{pmatrix} X_b \\ Y_b \end{pmatrix} = \begin{pmatrix} X_a + X_b \\ Y_a + Y_b \end{pmatrix}$$

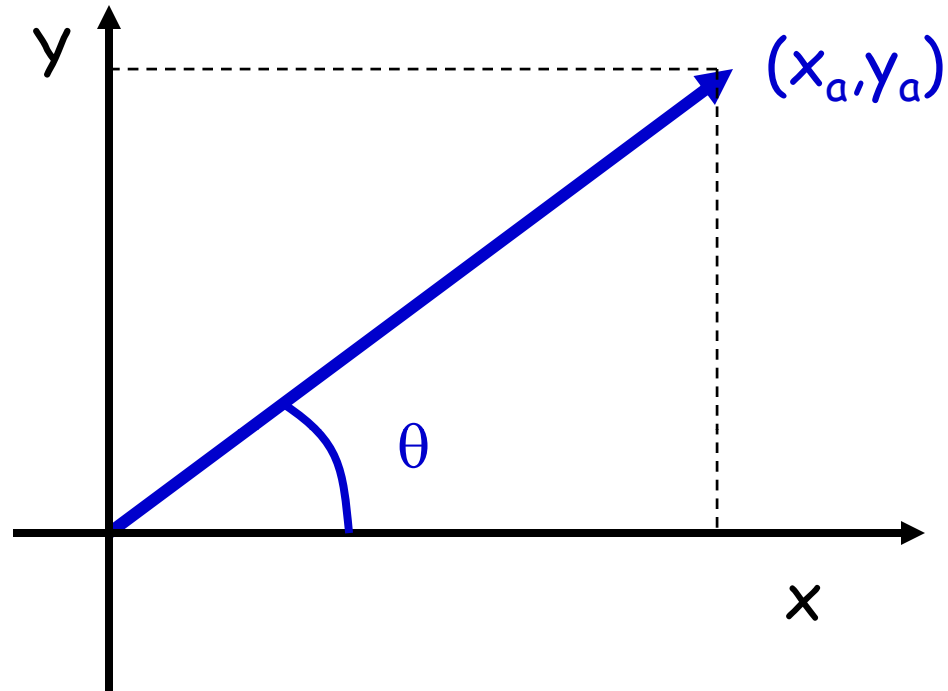
$$\begin{pmatrix} X_{a-b} \\ Y_{a-b} \end{pmatrix} = \begin{pmatrix} X_a \\ Y_a \end{pmatrix} - \begin{pmatrix} X_b \\ Y_b \end{pmatrix} = \begin{pmatrix} X_a - X_b \\ Y_a - Y_b \end{pmatrix}$$



Example:

$$\begin{pmatrix} X_{a+b} \\ Y_{a+b} \end{pmatrix} = \begin{pmatrix} 5 \\ 2 \end{pmatrix} + \begin{pmatrix} -3 \\ 2 \end{pmatrix} = \begin{pmatrix} 2 \\ 4 \end{pmatrix}$$

The length of a vector and its components



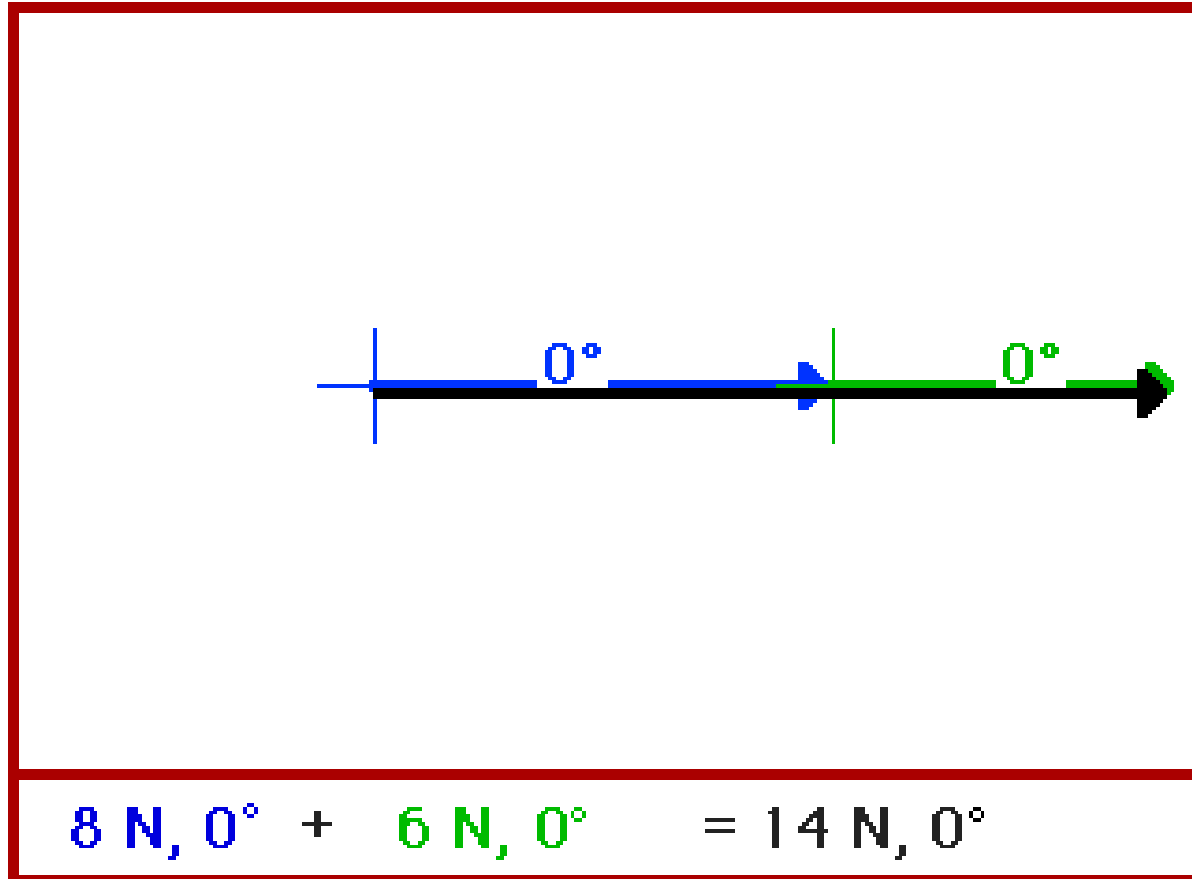
Length of vector (use pythagorean theorem): $l = \sqrt{x_a^2 + y_a^2}$

$$x_a = l \cos \theta$$

$$y_a = l \sin \theta$$

$$\tan \theta = y_a / x_a$$

vector addition



Question

A man walks 5 km/h. He travels 12 minutes to the east, 30 minutes to the south-east and 36 minutes to the north.

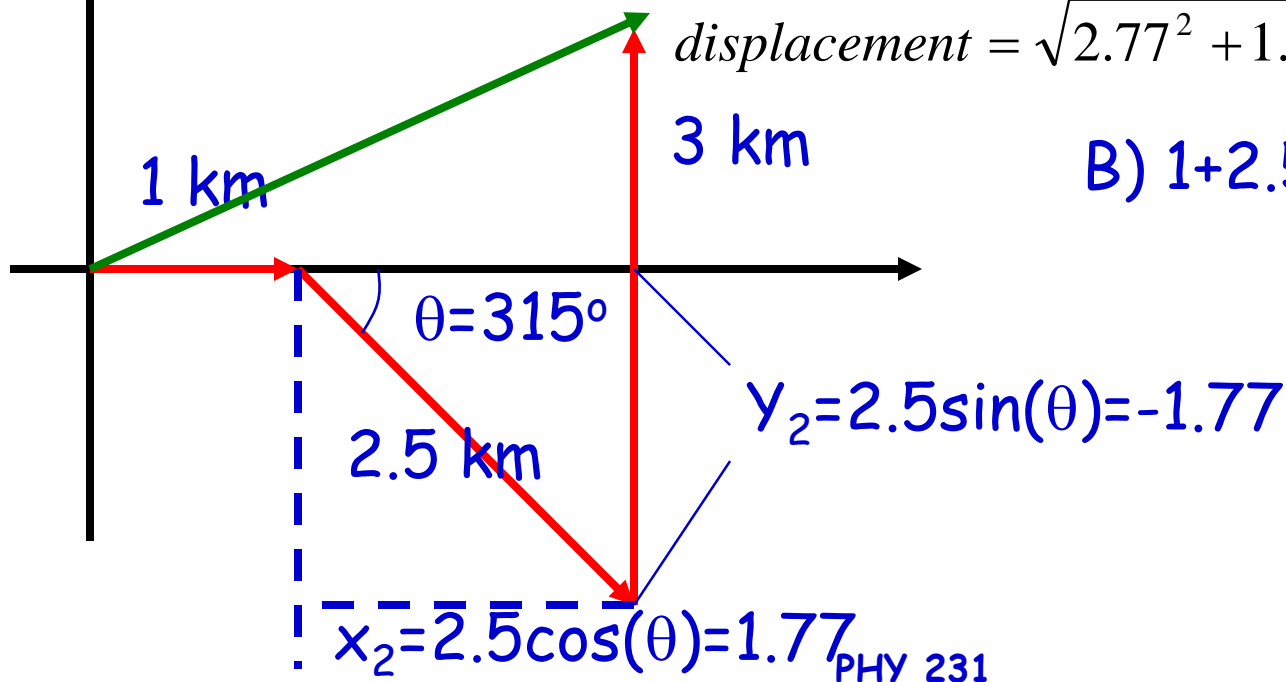
A) What is the displacement of the man?

B) What is the total distance he walked?

$$A) \begin{pmatrix} X_{1+2+3} \\ Y_{1+2+3} \end{pmatrix} = \begin{pmatrix} X_1 + X_2 + X_3 \\ Y_1 + Y_2 + Y_3 \end{pmatrix} = \begin{pmatrix} 1 + 1.77 + 0 \\ 0 - 1.77 + 3 \end{pmatrix} = \begin{pmatrix} 2.77 \\ 1.23 \end{pmatrix}$$

$$\text{displacement} = \sqrt{2.77^2 + 1.23^2} = 3.03$$

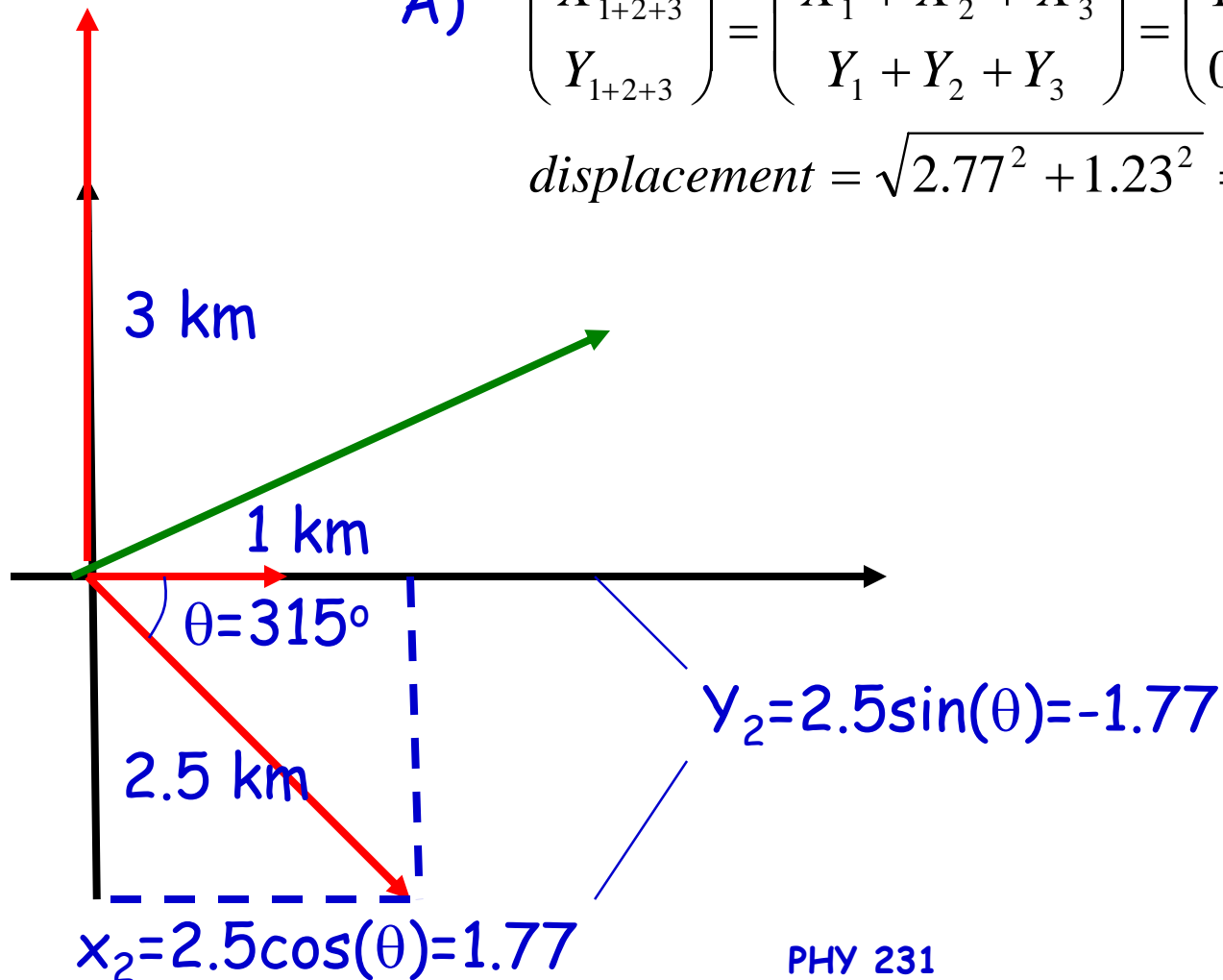
$$B) 1 + 2.5 + 3 = 6.5 \text{ km}$$



Another view

$$A) \begin{pmatrix} X_{1+2+3} \\ Y_{1+2+3} \end{pmatrix} = \begin{pmatrix} X_1 + X_2 + X_3 \\ Y_1 + Y_2 + Y_3 \end{pmatrix} = \begin{pmatrix} 1 + 1.77 + 0 \\ 0 - 1.77 + 3 \end{pmatrix} = \begin{pmatrix} 2.77 \\ 1.23 \end{pmatrix}$$

$$\text{displacement} = \sqrt{2.77^2 + 1.23^2} = 3.03$$

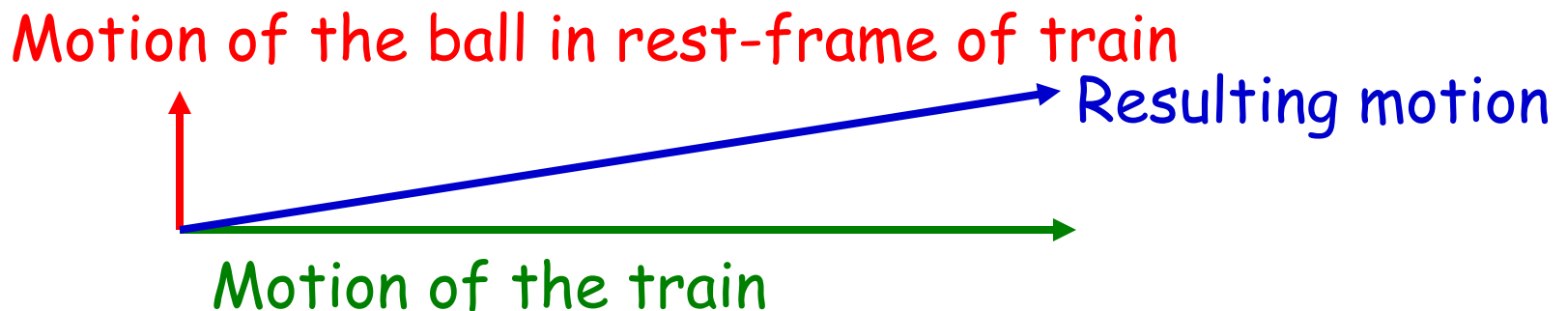


$$\begin{aligned} \theta &= 360^\circ - 45^\circ \\ &= 315^\circ \end{aligned}$$

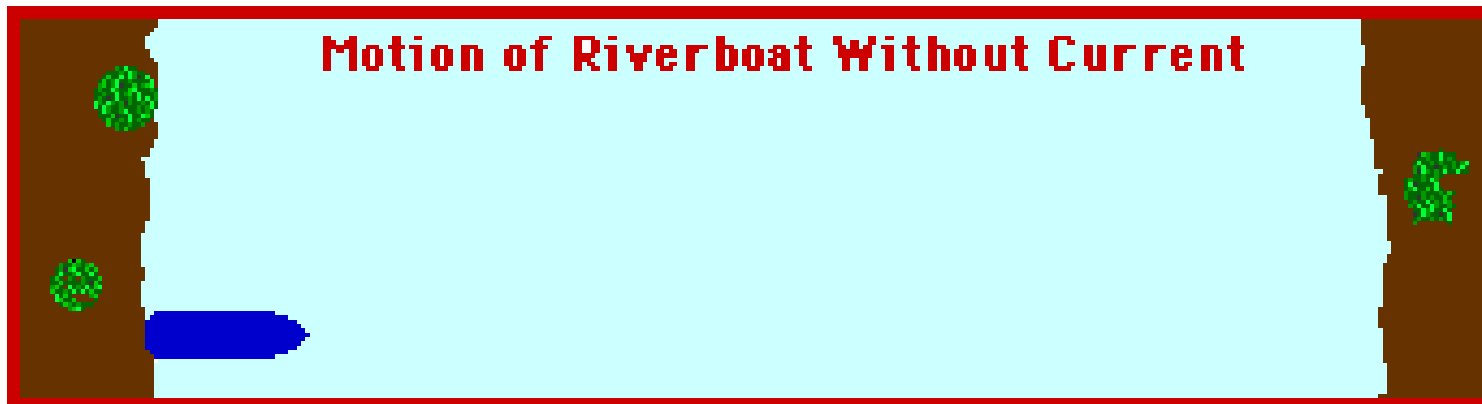
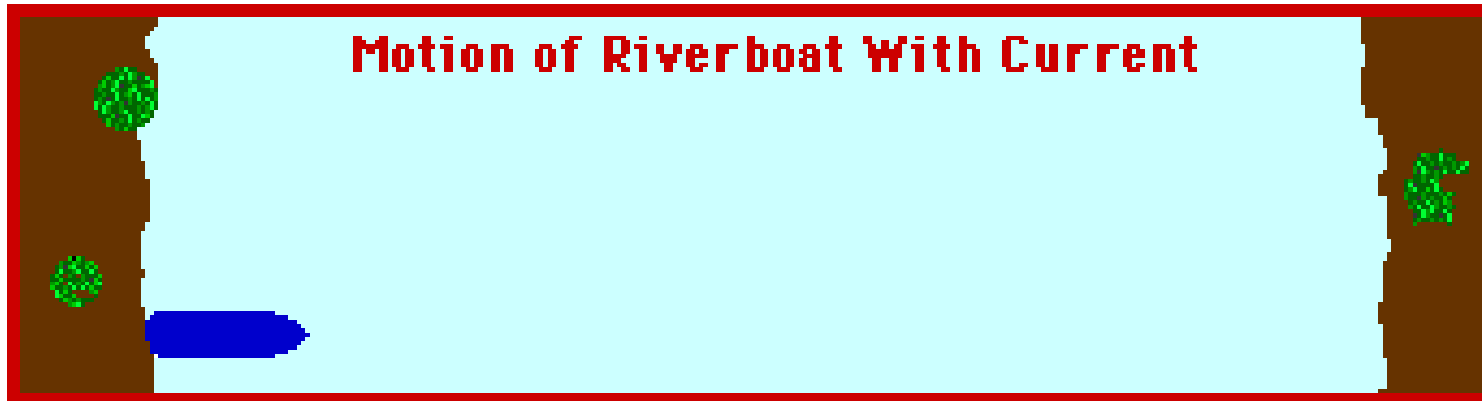
Relative motion

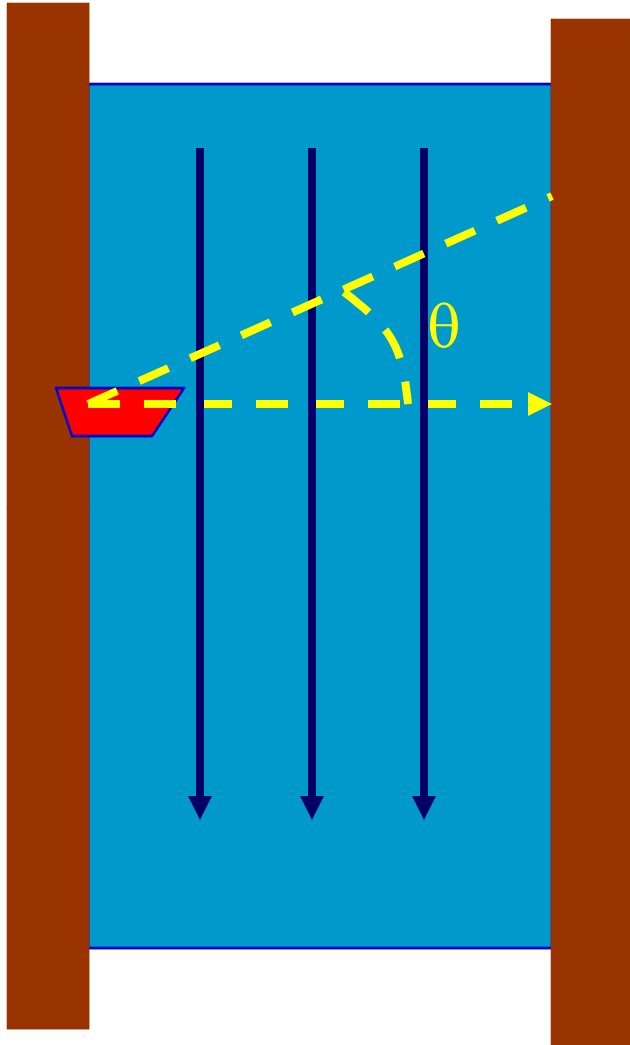
Motion is relative to a frame!

A woman in a train moving 50 m/s throws a ball straight up with a velocity of 5 m/s . A second person watches the train pass by and sees the woman through a window. What is the motion of the ball seen from the point of view from the man outside the train?



Boat crossing the river





Question

A boat is trying to cross a 1-km wide river in the shortest way (straight across). Its maximum speed (in still water) is 10 km/h. The river is flowing with 5 km/h.

1) At what angle θ does the captain have to steer the boat to go straight across?

A) 30° B) 45° C) 0° D) -45°

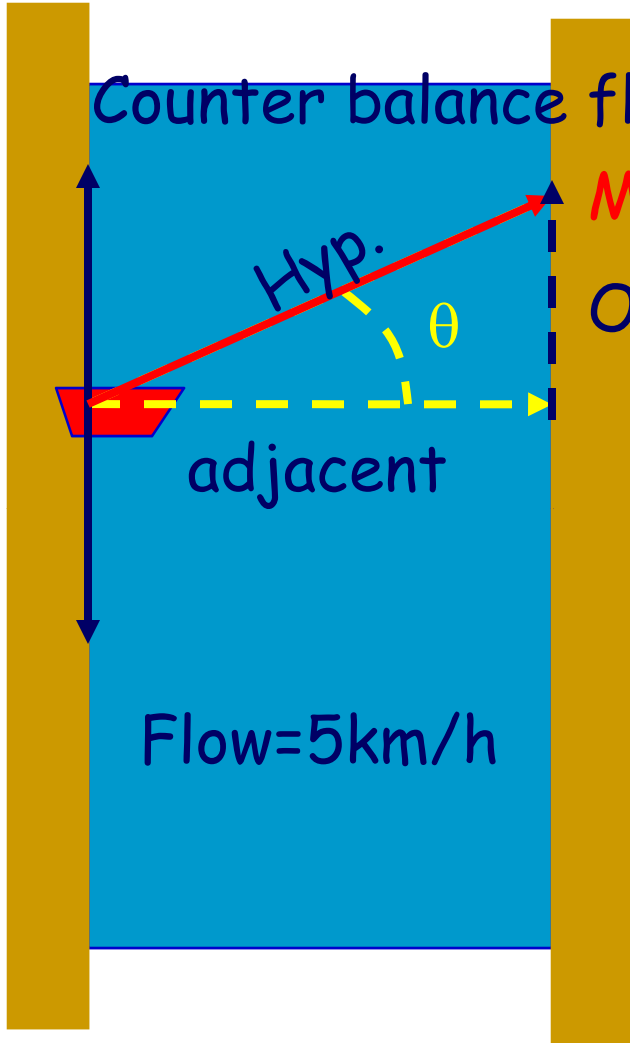
2) How long does it take for the boat to cross the river?

A) 6 min B) 6.9 min C) 12 min D) 1 h

3) If it doesn't matter at what point the boat reaches the other side, at what angle should the captain steer to cross in the fastest way?

A) 30° B) 45° C) 0° D) -45°

Answer



Maximum $v=10$ km/h

Opp. 1) $\sin\theta = \text{opposite/hypotenuse}$
 $= 5/10 = 0.5$
 $\theta = \sin^{-1}0.5 = 30^\circ$

2) $\tan\theta = \text{opposite/adjacent}$
 $\tan 30^\circ = 0.577 = 5/\text{velocity}_{\text{hor}}$
 $\text{velocity}_{\text{hor}} = 8.66$ km/h
 $\text{time} = (1 \text{ km}) / (8.66 \text{ km/h}) =$
 $0.115 \text{ h} = 6.9 \text{ min}$

3) 0° (the horizontal component of the velocity is then maximum.)

plane in the wind

