Physics Year 11

Term 1 Week 2

Scalars and Vectors

Scalar and Vector Quantities

A **scalar quantity** has a magnitude (size) only.

A **vector quantity** has both magnitude and direction.

When stating a vector quantity both magnitude and direction must be given.

Both distance, ***d***, and displacement, ***s***, are measured in metres, but distance is a scalar quantity and displacement is a vector quantity,

i.e. displacement can be described as the distance travelled in a particular direction from the starting point.

The distance and displacement for the same journey can be very different. Consider, for example, a runner on a 400 m circular track. At the end of the race he has covered a distance of 400 m but as he has arrived back at his starting point his final displacement is zero.

Velocity and Speed

Both speed and velocity have the symbol ***v*** and are measured in metres per second, m s^{-1}.

Speed is a scalar quantity and has magnitude only and can be described as the distance covered in unit time.

Velocity is a vector quantity and has both magnitude and direction. It can be described as the speed in a particular direction and is equal to the displacement per unit time.

$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad \text{velocity} = \frac{\text{displacement}}{\text{time}}$$

Scalar or Vector

All variables can be classified as vector or scalar quantities:

Scalar
distance
speed
time
mass
energy
power

Vector
displacement
velocity
acceleration
force
momentum
impulse

Working Out Vector Quantities

Vector quantities have to be added up vectorially, i.e. the directions have to be taken into account.

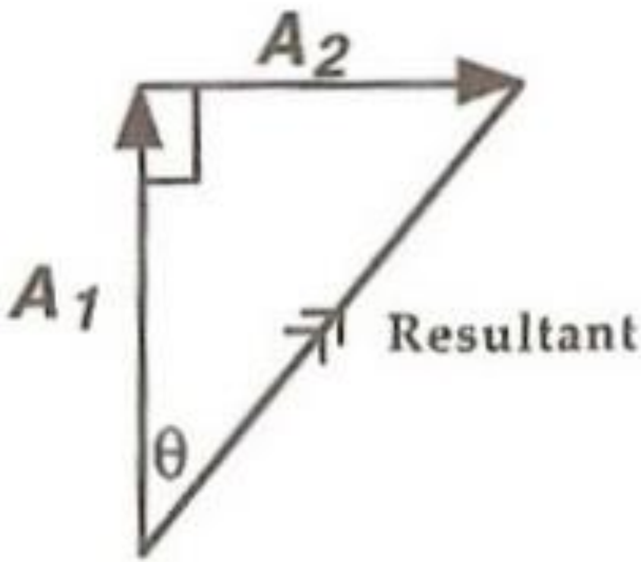
The overall effect due to a number of vectors is called the **resultant**, e.g. several displacements in varying directions will give a final resultant displacement from the start.

The direction of the individual vectors must be taken into account when calculating the resultant by scale diagram (*or by calculation*).

The resultant of two vectors, A_1 and A_2, can be found by drawing a **vector triangle**. The vectors are added 'nose to tail', i.e. the second vector, A_2, is drawn starting where the first vector, A_1, finishes:

Pythagoras' Theorem

If the two vectors are at right angles then ***Pythagoras' theorem*** *can be used to calculate the resultant:*



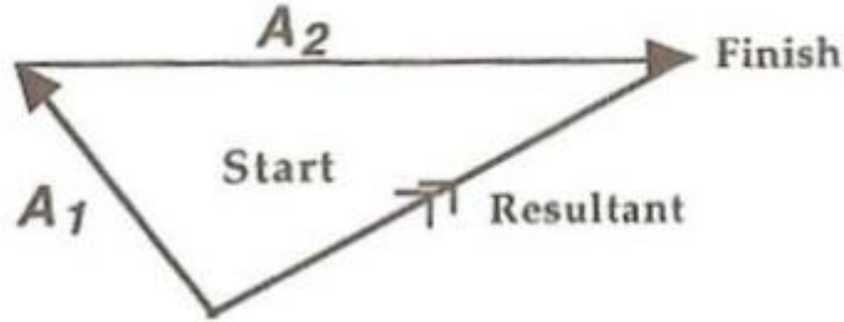
The magnitude of the resultant vector is given by:

$$|\text{Resultant}| = \sqrt{(A_1)^2 + (A_2)^2}$$

Direction is given by calculating θ:

$$\tan\theta = \frac{A_2}{A_1}$$

Vector Diagram

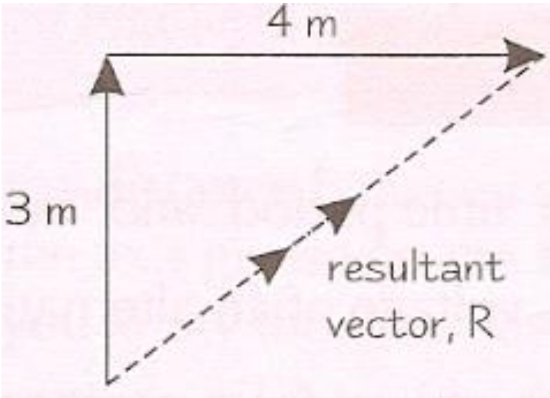


Each vector has to be drawn in the correct direction and to a suitable scale. The resultant is the line joining the first unconnected tail to the last unconnected head. The magnitude of the resultant is found by measuring the length and using the scale in reverse. The direction is given by measuring a suitable angle from the diagram.

Example

Jemima goes for a walk. She walks 3 m North and 4 m East. She has walked 7 m but she isn't 7 m from her starting point. Find the magnitude and direction of her displacement.

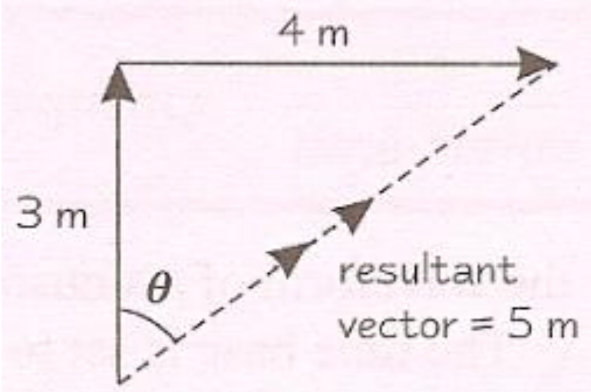
First, draw the vectors **tip-to-tail**. Then draw a line from the **tail** of the first vector to the **tip** of the last vector to give the **resultant**:



$R^2 = 3^2 + 4^2 = 25$

So $R = 5$ m

Now find the **bearing** of Jemima's new position from her original position.

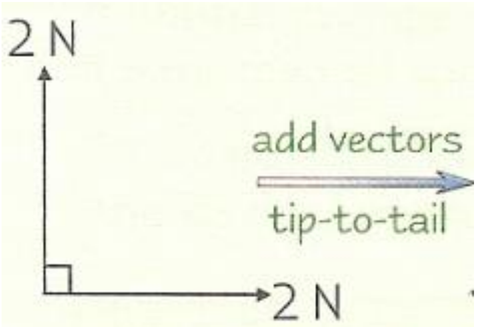


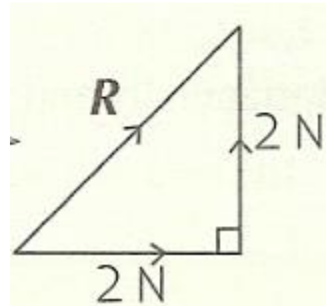
$\tan \theta = 4 / 3$

$\theta = 53.1°$

SOH CAH TOA.

Resultant Forces or Velocities



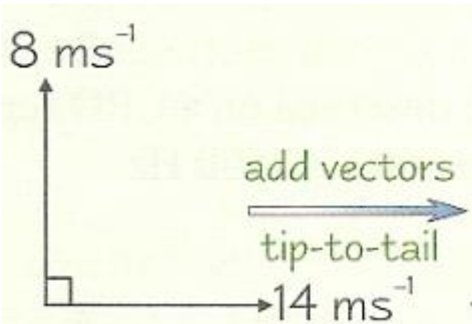


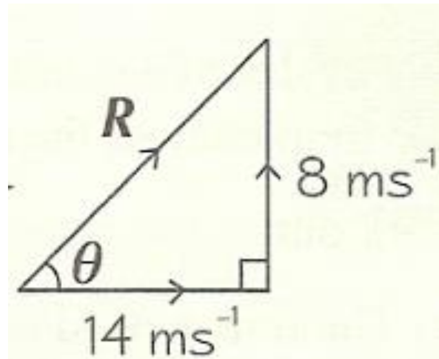
You know the resultant force is at 45° to the horizontal

$$\boldsymbol{R}^2 = 2^2 + 2^2 = 8$$

which gives $\boldsymbol{R} = 2.83$ N at 45° to the horizontal.

Example





$$R^2 = 14^2 + 8^2 = 260$$

$$R = 16.1 \text{ ms}^{-1}$$

$$\tan \theta = 8/14 = 0.5714$$

$$\theta = 29.7°$$

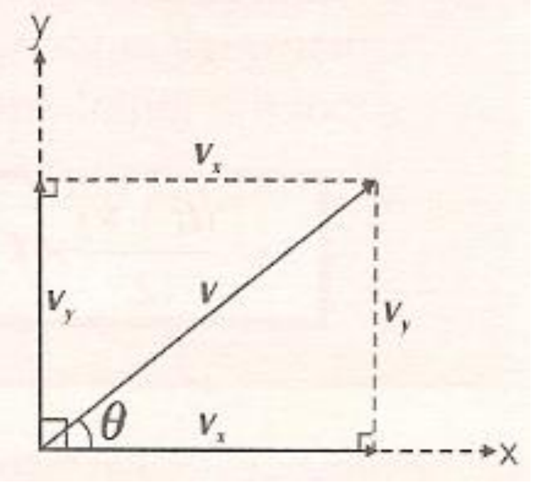
Vector into Horizontal and Vertical Components

Resolving a vector v into horizontal and vertical components

You get the **horizontal** component v_x like this:

$$\cos\theta = v_x / v$$

$$v_x = v\cos\theta$$



...and the **vertical** component v_y like this:

$$\sin\theta = v_y / v$$

$$v_y = v\sin\theta$$

Example

Charley's amazing floating home is travelling at a speed of 5 ms^{-1} at an angle of 60° up from the horizontal. Find the vertical and horizontal components.

The **horizontal** component v_x is:

$v_x = v \cos\theta = \mathbf{5 \cos 60°} = 2.5\ ms^{-1}$

The vertical component v_y is:

$v_y = v \sin\theta = \mathbf{5 \sin 60°} = 4.33\ ms^{-1}$