



Module 2 Foundations in Physics

Module 2: Foundations of physics

The aim of this module is to introduce important conventions and ideas that permeate the fabric of physics. Understanding of physical quantities, S.I. units,

scalars and vectors helps physicists to effectively communicate their ideas within the scientific community (HSW8, 11).



Module 2 – Foundations of physics

- 2.1 Physical quantities and units
- 2.2 Making measurements and analysing data
- 2.3 Nature of quantities

You are here! →

Module 3 – Forces and motion

- 3.1 Motion
- 3.2 Forces in action
- 3.3 Work, energy and power
- 3.4 Materials
- 3.5 Newton's laws of motion and momentum

Module 4 – Electrons, waves and photons

- 4.1 Charge and current
- 4.2 Energy, power and resistance
- 4.3 Electrical circuits
- 4.4 Waves
- 4.5 Quantum physics



2.3 Nature of Quantities

2.3.1 Scalars and vectors

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

- (a) scalar and vector quantities
- (b) vector addition and subtraction
- (c) vector triangle to determine the resultant of any two coplanar vectors
- (d) resolving a vector into two perpendicular components; $F_x = F \cos \theta$; $F_y = F \sin \theta$.



What are
scalar and
vector
quantities?



Scalar & Vector Quantities

- **Scalar Quantities**

- Have magnitude (size) but not direction
- Eg. Density, Temperature, Power, Distance, Speed.

- **Vector Quantities**

- Have magnitude (size) AND direction
- Eg. Velocity, Force, Current, Displacement, Acceleration.



Scalar Quantities

- Can be added/subtracted just like ordinary numbers.
 - **TAKE CARE** to make sure the units are the same though.
 - $23s + 4kg$ is meaningless.
- Can be multiplied/divided to produce another scalar quantity.
 - **TAKE CARE** to multiply/divide the units as well.



Some examples:

- Masses of 23kg and 12kg can be added to give a total of 35kg.
- 12J of energy are transferred over 24s. The power of the system is $12\text{J}/24\text{s} = 0.5\text{Js}^{-1} = 0.5\text{w}$.
 - **NOTE** the units have to be correctly divided as well.



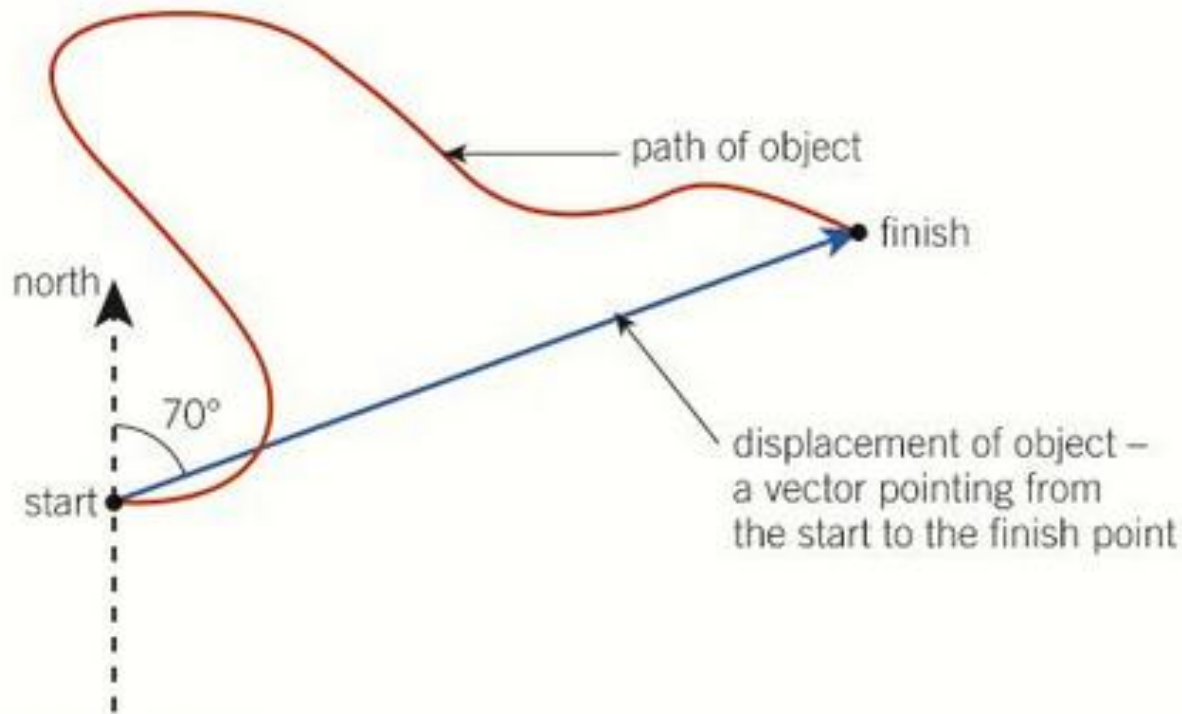
Vector Quantities

- Have direction as well as magnitude.
 - Eg. Force – you need to know which direction the force is acting.
 - Eg. Displacement – you need to know in which direction an object has travelled.
- When adding vectors we need to also add the directions.



Distance and displacement

Distance and displacement are both measured in m, but distance is a scalar quantity and displacement is a vector quantity. This is illustrated in Figure 2.

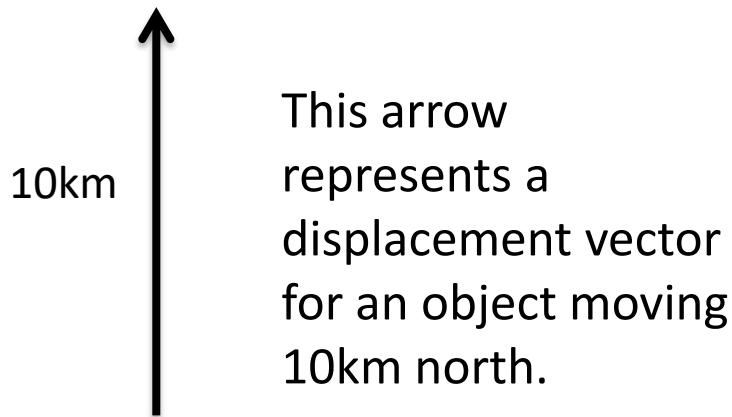


▲ **Figure 2** Distance travelled is the length of the red path, whereas the magnitude of the displacement is the length of the blue arrow and the direction of the displacement is 70° off due north



How to represent vectors

- The easiest way is to represent them as arrows.
 - Length of the arrow indicates magnitude.
 - Direction of the arrow shows direction of vector.



How would we show the object moving 5km south?

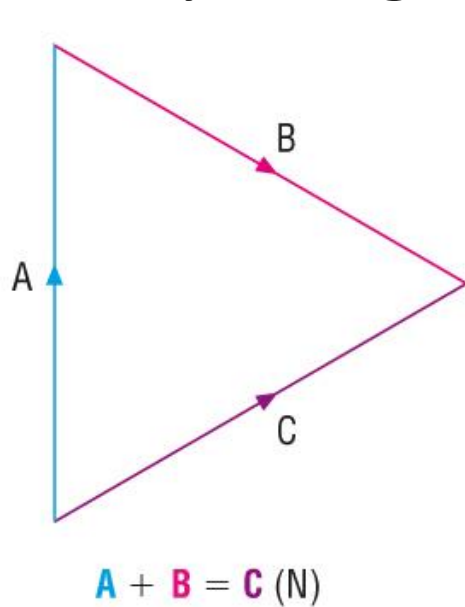
What would the total displacement be?

What about the total distance travelled?

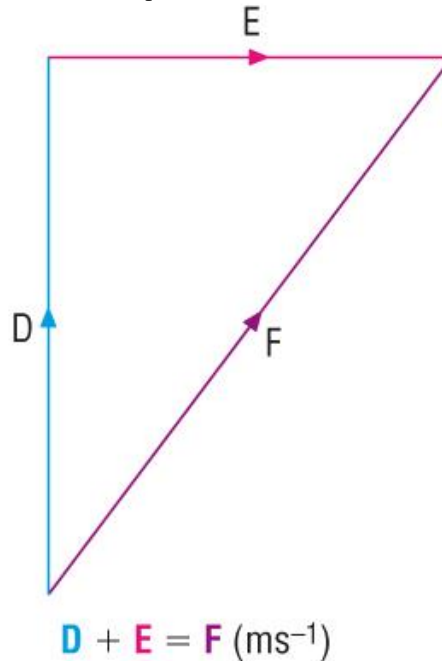


Adding Vectors

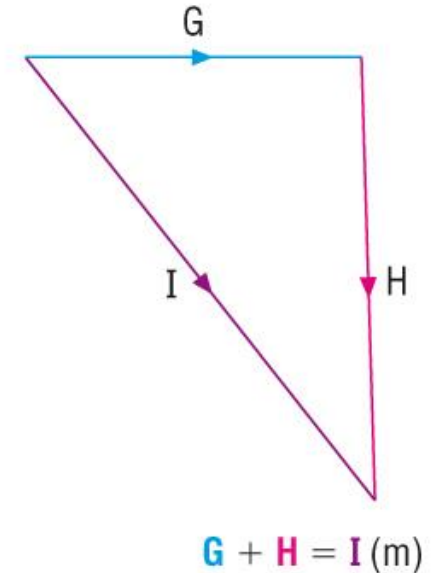
- The resultant of two vectors can be shown easily using these representations:



Adding forces $A + B$ gives a resultant force of C .



Adding velocities $D + E$ gives a resultant velocity of F .

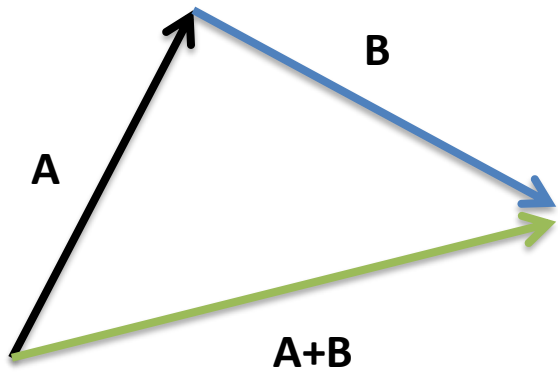


Adding displacements $G + H$ gives a resultant displacement of I .

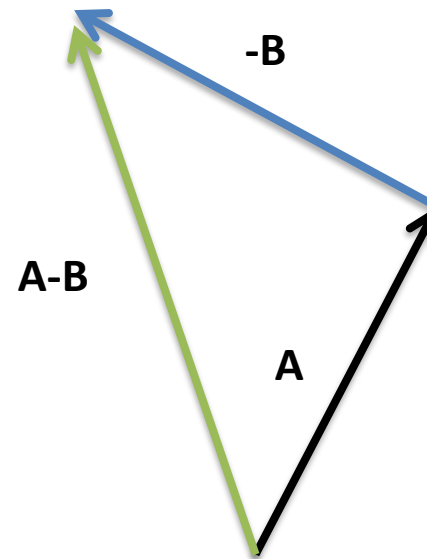


Subtracting Vectors

If vector $A + B = C$



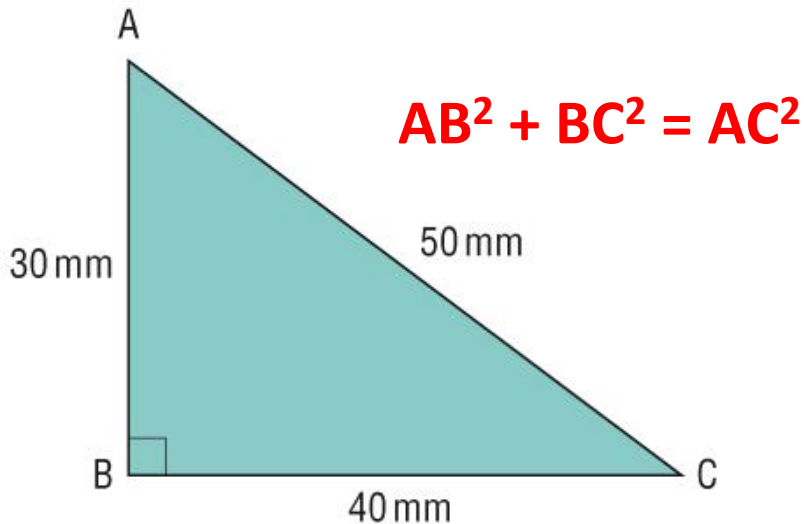
vector A minus vector B
can be shown if you add
minus B to A .



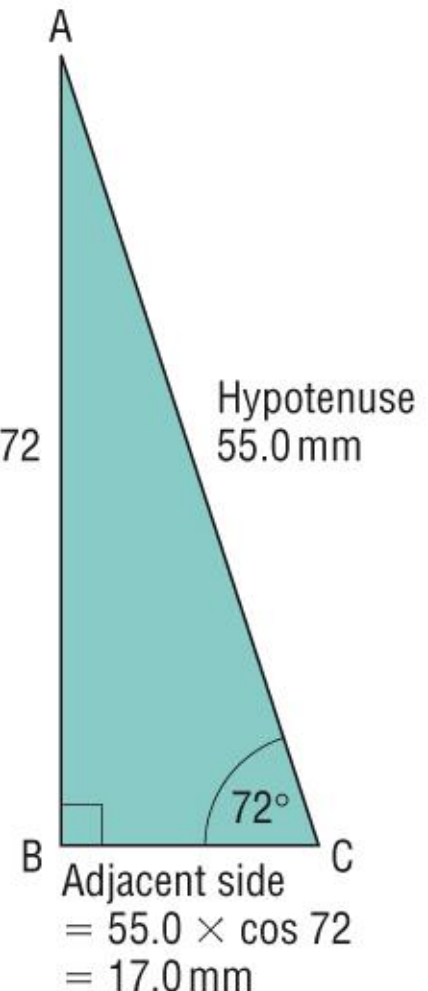


Calculating the resultant of perpendicular vectors

- When vectors are arranged at right angles to each other, the vector triangle is a right angled triangle.
 - Pythagoras and trigonometry can therefore be used to calculate the resultant.

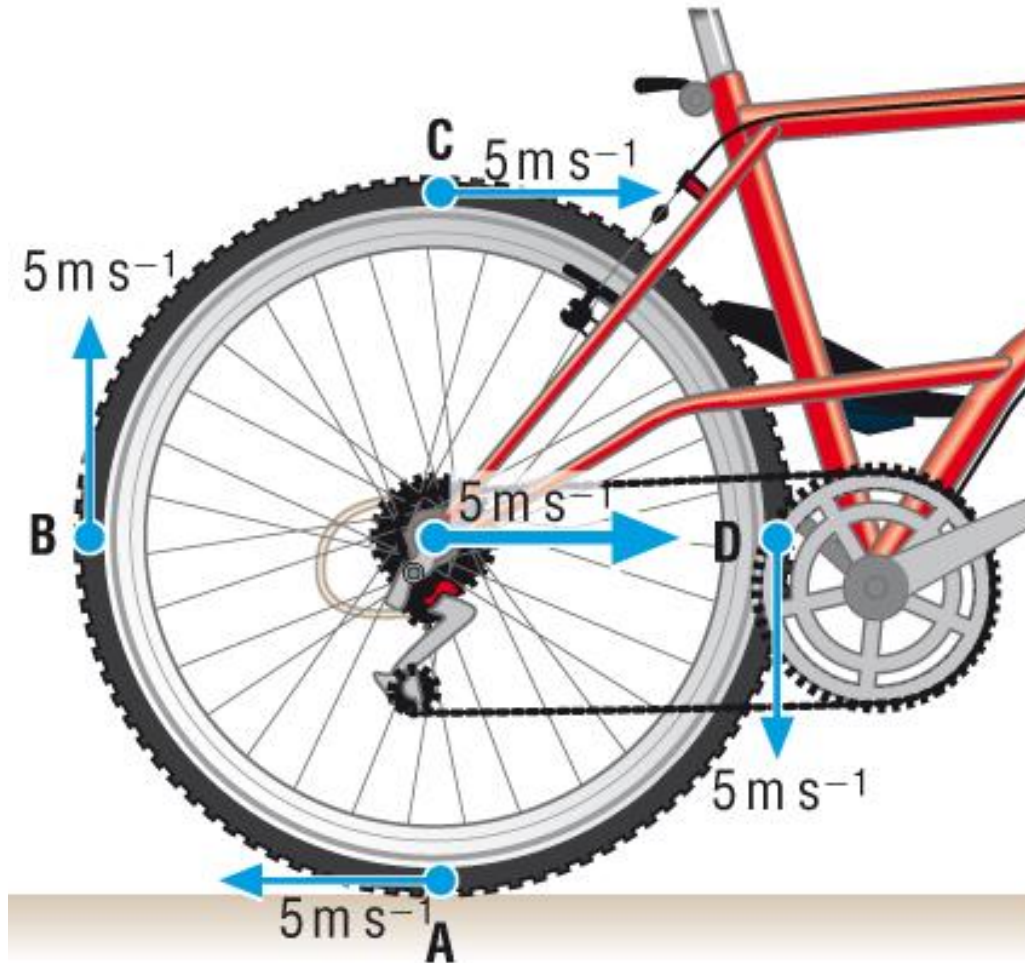


$$\begin{aligned}\text{Opposite side} &= 55.0 \times \sin 72 \\ &= 52.3 \text{ mm}\end{aligned}$$





Draw vector diagrams to show the resultant velocities of the 4 points on the wheel (A, B, C & D)





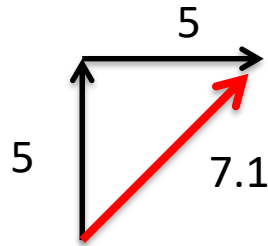
Answers

A



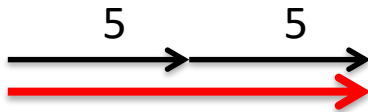
Resultant = 0 ms^{-1}

B



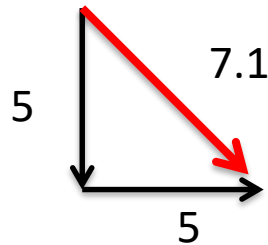
Resultant = 7.1 ms^{-1}

C

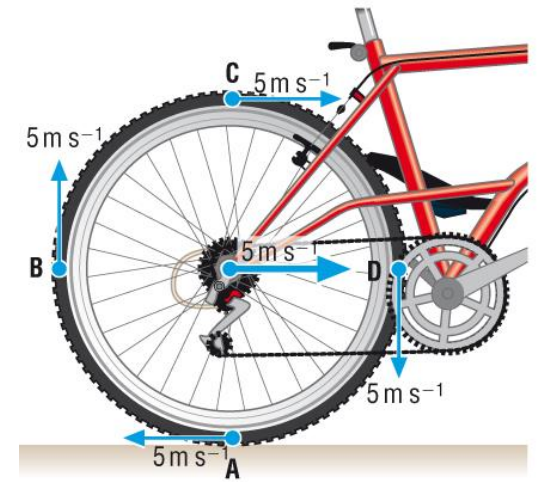


Resultant = 10 ms^{-1}

B



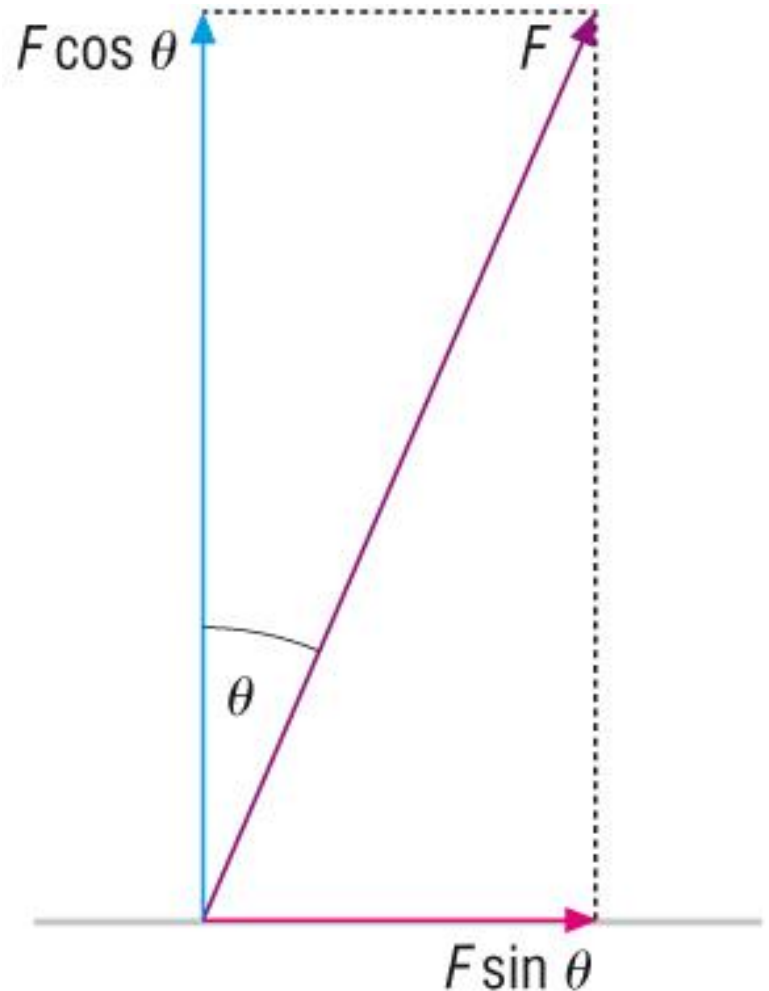
Resultant = 7.1 ms^{-1}





Resolving Vectors

- The opposite process to producing a resultant vector from perpendicular vectors.
- **ie. Creating two perpendicular vectors from a single vector.**

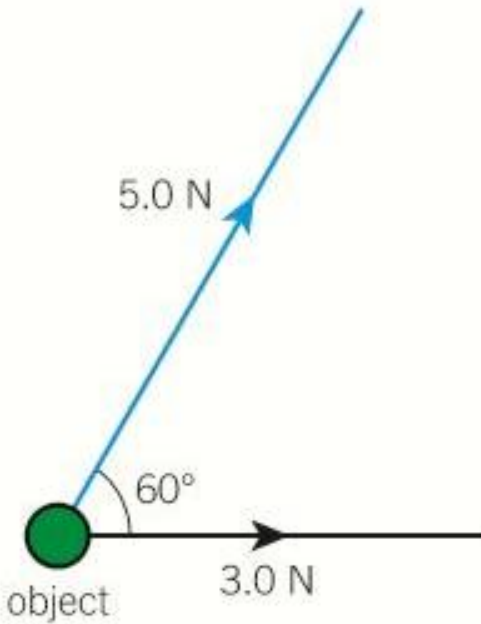




What
techniques can I
use to find a
resultant
vector?



What is the magnitude and direction of the resultant?



$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Three possible methods:

1. Draw a scale diagram
 - Use a protractor
2. Use the cosine and sine rules.
 - Remember these?
3. Resolve both vectors into x and y directions then add up the x coordinates and then the y coordinates.



Geek Joke:

- What do you get if you cross a mosquito and a rock climber?
- Nothing – you cannot multiply a vector with a scalar.



2.3 Nature of Quantities (review)

2.3.1 Scalars and vectors

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

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(a) State the difference between vector and scalar quantities.

.....
.....
(1 mark)

(b) State **one** example of a vector quantity (other than force) and **one** example of a scalar quantity.

vector quantity

scalar quantity

(2 marks)

(c) A 12.0 N force and a 8.0 N force act on a body of mass 6.5 kg at the same time.
For this body, calculate

(i) the maximum resultant acceleration that it could experience,

.....
.....

(ii) the minimum resultant acceleration that it could experience.



(4 marks)



Q2 Jan

- (a) vector quantities have direction (as well as magnitude)
and scalar quantities do not ✓
- (b) vector: e.g. velocity, acceleration, momentum ✓
scalar: e.g. mass, temperature, energy ✓
- (c)(i) addition of forces $(12 + 8)$ ✓
(use of $F = ma$ gives) $a = \frac{(12 + 8)}{6.5} = 3.1 \text{ m s}^{-2}$ ✓ (3.08 m s^{-2})
- (ii) subtraction of forces $(12 - 8)$ ✓
 $a = \frac{(12 - 8)}{6.5} = 0.62 \text{ m s}^{-2}$ ✓ (0.615 m s^{-2})