Cambridge (CIE) IGCSE Physics

Your notes

Physical Quantities & Measurement Techniques

Contents

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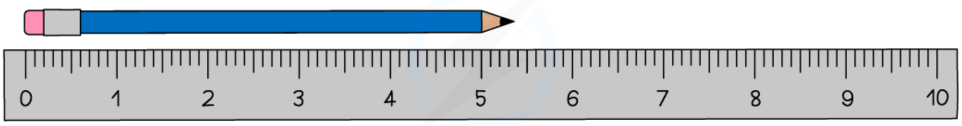
Your notes

Measuring length & volume

- When making measurements in physics, different instruments are used for different measurements

Measuring length

- Rulers can be used to measure small distances of a few centimetres (cm).
  - They are able to measure to the nearest millimetre (mm)



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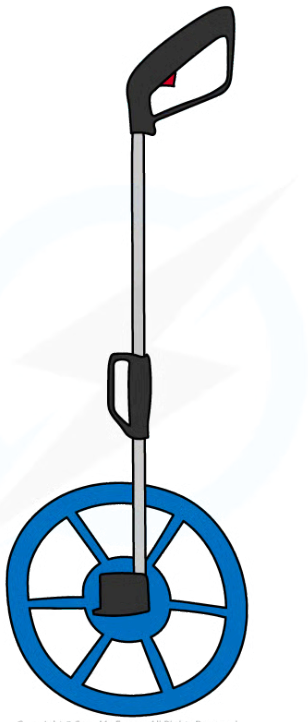
A ruler can measure lengths in cm or mm

- A **tape measure** is used to measure lengths of tens of centimetres
- A **trundle wheel** is used to measure lengths of tens of metres



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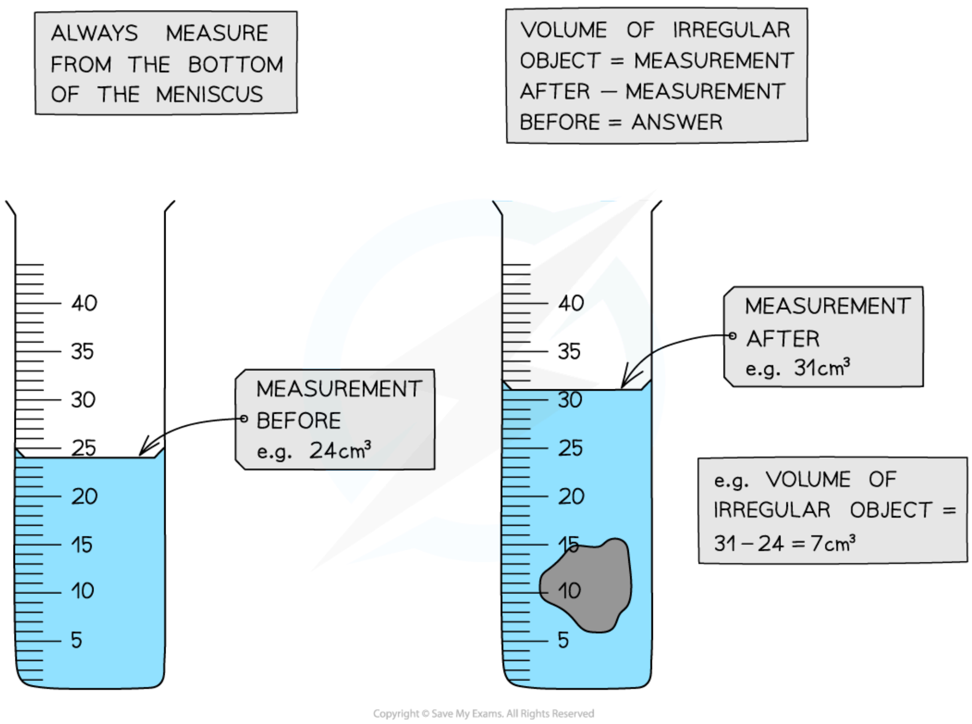
Trundle wheels can be used to measure larger distances

Measuring volume

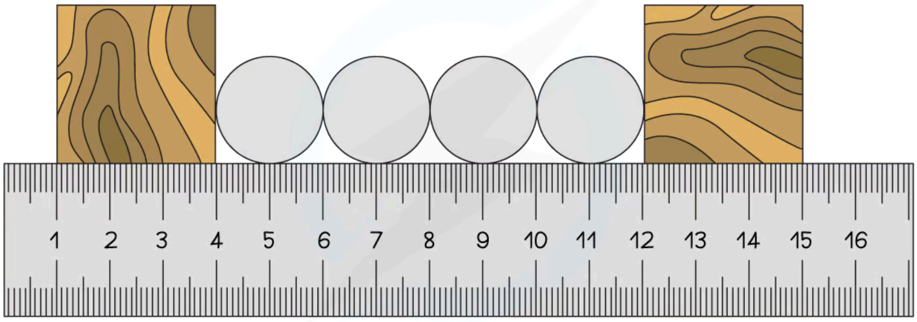
- **Measuring cylinder** are used to measure the volume of liquids
  - By measuring the **change in volume**, a measuring cylinder can also be used to determine the volume of an irregular shape



Measuring cylinders can be used to determine the volume of a liquid or an irregular shaped solid

Worked Example

The diagram shows four identical ball-bearings placed between two blocks on a steel ruler.



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Calculate the diameter of one ball-bearing.

Answer:

Step 1: Measure the length of all four ball-bearings

- The blocks mark the edges of the first and last ball bearings
- The blocks make it easier to measure the length of all four ball-bearings

$$\text{total length} = 12 - 4$$

$$\text{total length} = 8 \text{ cm}$$

Step 2: Find the diameter by dividing the total length by the number of ball-bearings

$$\text{diameter} = \frac{\text{total length}}{\text{number of ball bearings}}$$

$$\text{diameter} = \frac{8}{4}$$

$$\text{diameter} = 2 \text{ cm}$$

Examiner Tips and Tricks

Two measurements can be considered equal within the limits of experimental accuracy if their values are within 10% of each other

Measuring time

- In physics, stop-clocks and stopwatches are usually used to measure **time intervals**
- An important factor when measuring time intervals is **human reaction time**
  - The standard human reaction time for an alert person is **0.25 s**

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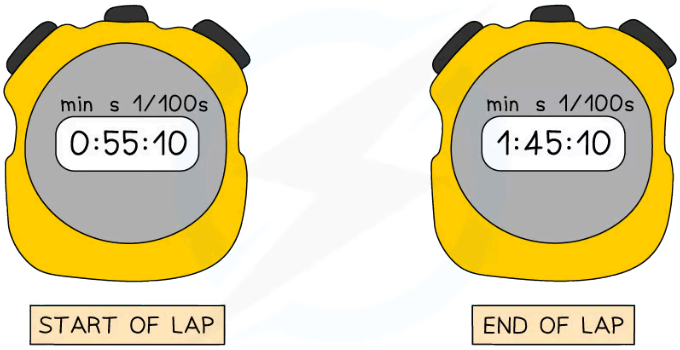
- This can have a significant impact upon measurements when the measurements involved are very short

Your notes

Worked Example

A stopwatch is used to measure the time taken for a runner to complete a lap of a 400 m track.

The images below give the readings on the stopwatch at the start and the end of the lap.



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Calculate how long it took the runner to complete the lap. Give your answer in seconds.

Answer:

Step 1: Identify the start time for the lap

- The stopwatch was already at 0:55:10 when the runner started the lap
- Start time = **55.10 seconds (s)**

Step 2: Identify the finish time for the lap

- The stopwatch reads 1:45:10 at the end of the lap
- Finish time = **1 minute and 45.10 s**

Step 3: Convert the finish time into seconds

$$1 \text{ minute} = 60 \text{ seconds}$$

$$\text{finish time} = 60 \text{ s} + 45.10 \text{ s}$$

$$\text{finish time} = 105.10 \text{ s}$$

Step 4: Calculate the total time taken to complete the lap

$$\text{total time} = \text{finish time} - \text{start time}$$

$$\text{total time} = 105.10 \text{ s} - 55.10 \text{ s}$$

$$\text{total time} = 50 \text{ s}$$

Examiner Tips and Tricks

You will sometimes find that information is given in the question that is not actually needed in the calculation.

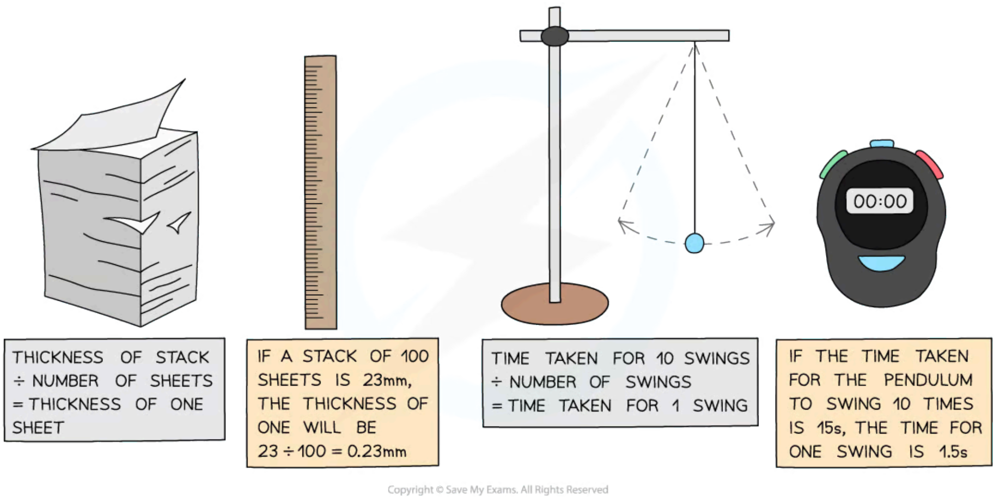
In this worked example, you were told that the track the runner is running on is 400 m. This had nothing to do with the calculation the question asked you to perform.

This is a common method for making a question seem more difficult. Don't let it catch you out.

Multiple readings

- In physics, **multiple readings** of measurements are often taken to reduce the impact of measurement errors

Taking multiple measurements in physics



- The measurement of the thickness of a single sheet of paper is so small that it would be very difficult to get an **accurate** answer
  - However, measuring the thickness of **100 sheets** of paper can be done much more accurately
  - **Dividing** the answer by 100 then gives an accurate figure for the **average** thickness of **one sheet**
- Measuring the time period of a simple pendulum would incur a human reaction time error at the start of the measurement **and** at the end of the measurement
- If the measurement is small, the uncertainty in the measurement is huge

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- Therefore, **multiple readings** can be taken to reduce the uncertainty of the measurement
  - The time taken for **10 swings** of the pendulum can be measured
  - **Dividing** the answer by 10 gives a more **accurate** figure for the **average** time taken for **one swing**
- A **fiducial marker** can be used when measuring oscillations
  - A fiducial marker is a **visual reference point** such as a line or a dot
  - The marker is added to the point at which the **measurement is taken**, such as the **equilibrium position** of an oscillating pendulum
  - This makes it easier to see when the pendulum passes this point, **reducing** the **error** in **starting** and **stopping** the timer

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Scalar & vector quantities

Extended tier only

- All quantities can be one of two types:
  - A **scalar**
  - A **vector**

Scalars

- Scalar quantities have only a **magnitude**
  - **Mass** is an example of a scalar quantity because it has magnitude **without direction**
  - **Energy** and **volume** are also examples of scalar quantities

Vectors

- Vector quantities have both **magnitude** and **direction**
  - **Weight** is an example of a vector quantity because it is a **force** and therefore has both **magnitude** and **direction**
  - **Acceleration** and **momentum** are also examples of vector quantities

Distance and displacement

- **Distance** is a measure of how far an object has travelled, **regardless of direction**
  - Distance is the total length of the path taken
  - Distance, therefore, has a **magnitude** but **no direction**
  - So, distance is a **scalar** quantity
- **Displacement** is a measure of how far it is between two points in space, **including the direction**
  - Displacement is the **length** and **direction** of a **straight line** drawn from the starting point to the finishing point
  - Displacement, therefore, has a **magnitude** and a **direction**
  - So, displacement is a **vector** quantity

What is the difference between distance and displacement?

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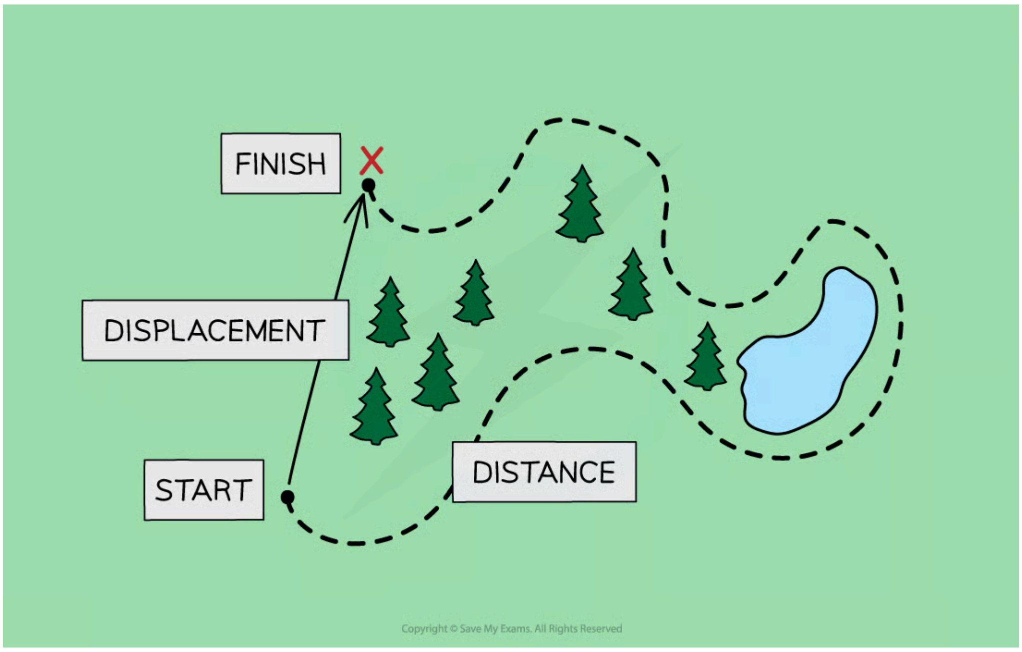

Displacement is a vector quantity, while distance is a scalar quantity

- When a student travels to school, there will probably be a **difference** between the **distance** they travel and their **displacement**
  - The **overall distance** they travel includes the total lengths of all the roads, including any twists and turns
  - The **overall displacement** of the student would be a straight line between their home and school, regardless of any obstacles, such as buildings, lakes or motorways, along the way

Speed and velocity

- **Speed** is a measure of the **distance** travelled by an object per unit time, **regardless of the direction**
  - The speed of an object describes how fast it is moving, but **not** the direction it is travelling in
  - Speed, therefore, has **magnitude** but **no direction**
  - So, speed is a **scalar** quantity
- **Velocity** is a measure of the **displacement** of an object per unit time, **including the direction**
  - The velocity of an object describes how fast it is moving **and** which direction it is travelling in
  - An object can have a **constant speed** but a **changing velocity** if the object is **changing direction**
  - Velocity, therefore, has **magnitude and direction**

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- So, velocity is a **vector** quantity

Examples of scalars & vectors

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- The table below lists some common examples of scalar and vector quantities
- Corresponding scalars and their vector counterparts are aligned in the table where applicable

Table of scalars and vectors

Scalar	Vector
distance	displacement
speed	velocity
mass	weight
	force
	acceleration
	momentum
	electric field strength
energy	
volume	
density	
temperature	
power	

Worked Example

An instructor is in charge of training junior astronauts. For one of their sessions, they would like to explain the difference between mass and weight.

Your notes

Suggest how the instructor should explain the difference between mass and weight, using definitions of scalars and vectors in your answer.

Answer:

Step 1: Recall the definitions of a scalar and vector quantity

- Scalars are quantities that have only a magnitude
- Vectors are quantities that have both magnitude and direction

Step 2: Identify which quantity has magnitude only

- Mass is a quantity with magnitude only
- So mass is a scalar quantity
- The instructor might explain to their junior astronauts that their mass will not change as their location in the Universe changes

Step 3: Identify which quantity has magnitude and direction

- Weight is a quantity with magnitude and direction (it is a force)
- So weight is a vector quantity
- The instructor might explain that their weight, the force on them due to gravitational field strength, will vary depending on their location. For example, the force of weight acting on them would be less on the Moon than it is on Earth

Examiner Tips and Tricks

Make sure you are comfortable with the differences between **similar** scalars and vectors.

The most commonly confused pairings tend to be:

- distance and displacement
- speed and velocity
- weight and mass

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Calculations with vectors

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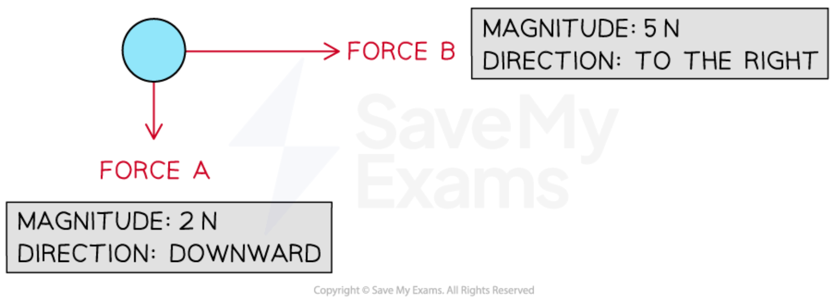
- **Vectors** can be drawn using **vector diagrams**

Vector diagrams

- **Vectors** are represented by an arrow
  - The **length** of the arrow represents the **magnitude**
  - The **direction** of the arrow indicates the **direction**
  - the **scale** of the arrows should be **proportional** to the relative magnitudes of the forces
    - an arrow for a 4 N force should be twice as long as an arrow for a 2 N force

Vector diagram of two forces acting on an object



The length of the arrows are proportional to the magnitude of the forces, and show the direction that forces act in

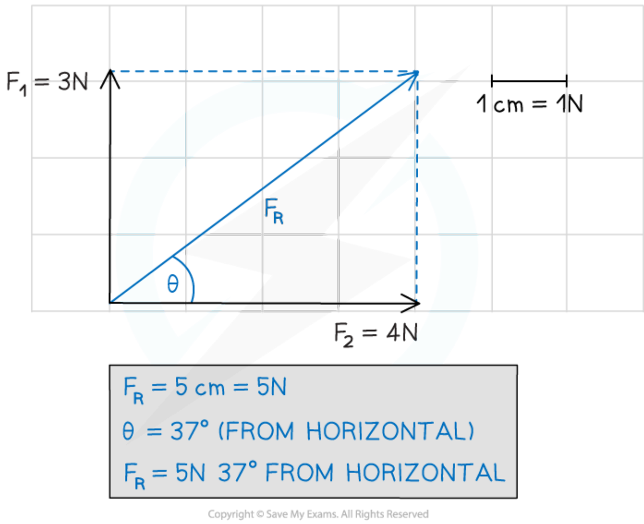
Calculating vectors graphically

- Vector diagrams can be used to combine vectors
- Vectors at **right angles** to one another can be **combined** into one **resultant vector**
  - The resultant vector will have the combined effect of the two original vectors
  - For example, a resultant force vector will have the combined effect of two component forces
- **Component** vectors are sometimes drawn with a dotted line and a **subscript** indicating horizontal or vertical
  - A force F, for example, may have two components:

- F_V is the vertical component of the force F
- F_H is the horizontal component of force F

- To calculate vectors graphically means carefully producing a scale drawing with all lengths and angles correct
  - This should be done using a sharp **pencil**, **ruler** and **protractor**
- Follow these steps to carry out calculations with vectors on graphs

1. Choose a **scale** which fits the page
   - For example, use 1 cm = 10 m or 1 cm = 1 N, so that the diagram is around 10 cm high
2. Draw the vectors at **right angles** to one another
3. Complete the rectangle
4. Draw the **resultant vector** diagonally from the origin
5. Carefully **measure the length** of the resultant vector
6. Use the scale factor to calculate the **magnitude**
7. Use the protractor to measure the **angle**



Vectors can be measured or calculated graphically using scaled vector diagrams

Combining vectors by calculation

- In this method, a vector diagram is still essential but it does **not** need to be exactly to scale
- The vector diagram can take the form of a sketch, as long as the resultant side, component sides are clearly labelled

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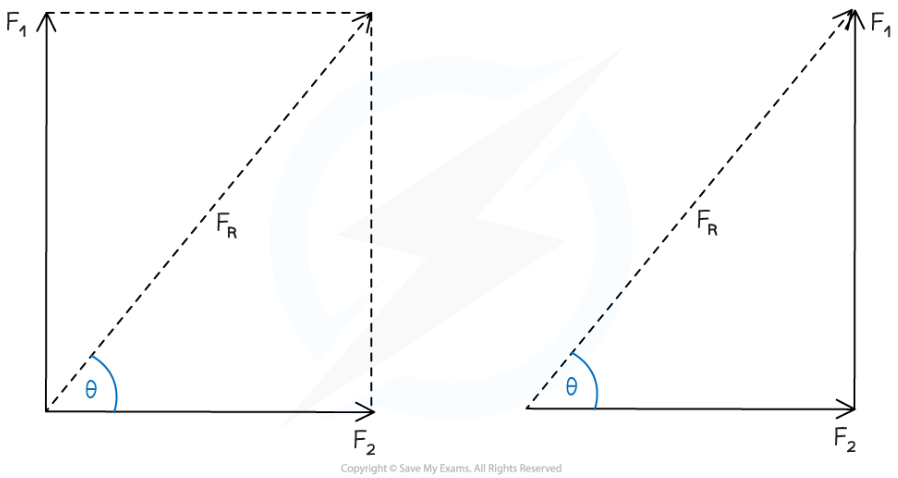
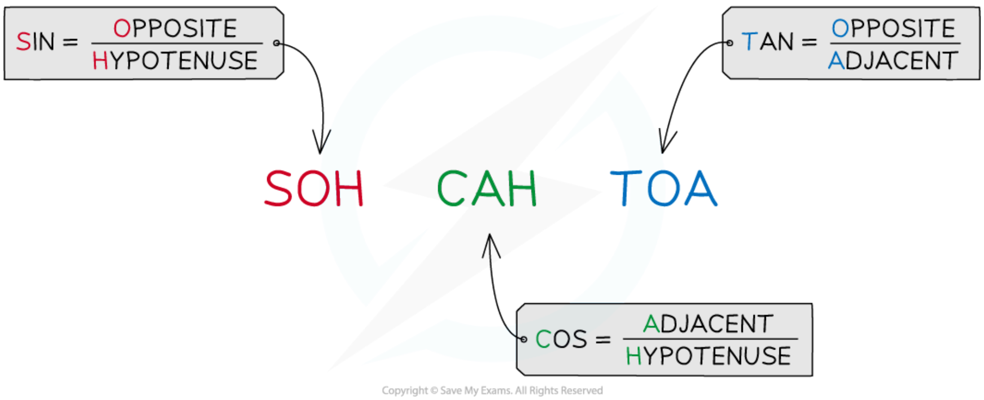
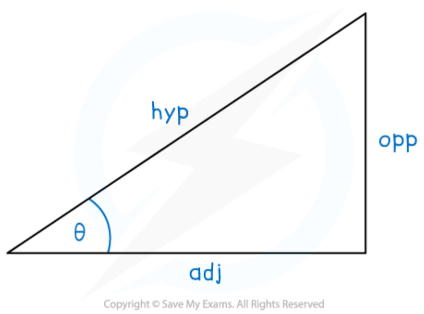


Using a vector diagram to resolve two force vectors F_1 and F_2 into a resultant force vector F_R

- When the magnitude of only one vector is known, **and** the angle is known, then **trigonometry** can be used to find the magnitude of the missing vector
  - The mnemonic '**soh-cah-toa**' can used to remember the trigonometric functions





Trigonometry can be used when the magnitude of one vector and the angle is known

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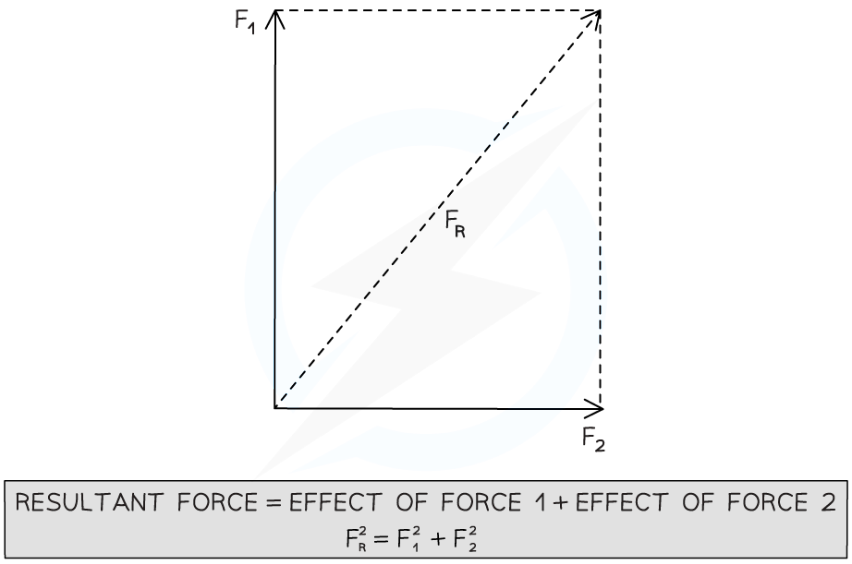
- When the magnitudes of two of the vectors are known, then **Pythagoras' theorem** can be used to find the magnitude of the missing vector

Your notes



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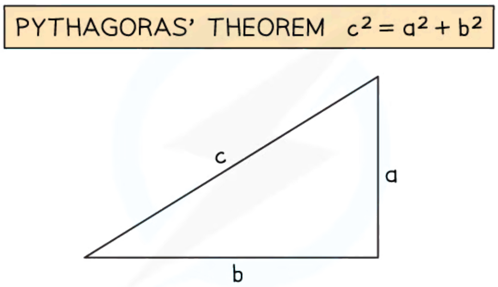

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Pythagoras's theorem can be used when the magnitudes of two of the three vectors are known

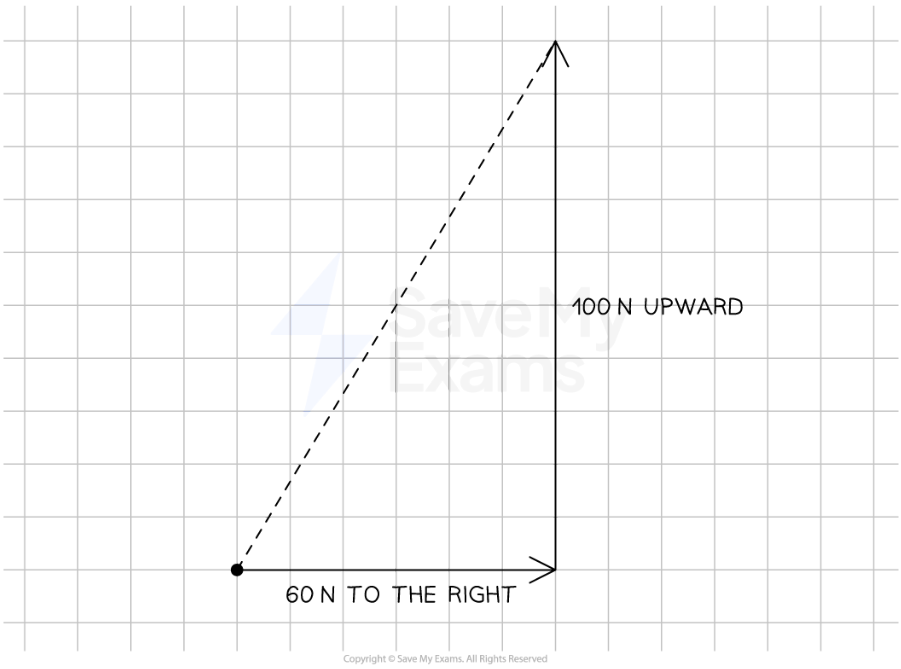
Worked Example

A force acts on an object with 60 N to the right. A second force of 100 N acts on the same object in the upward direction.

Calculate the resultant force acting on the object.

Answer:

Step 1: Draw a vector diagram



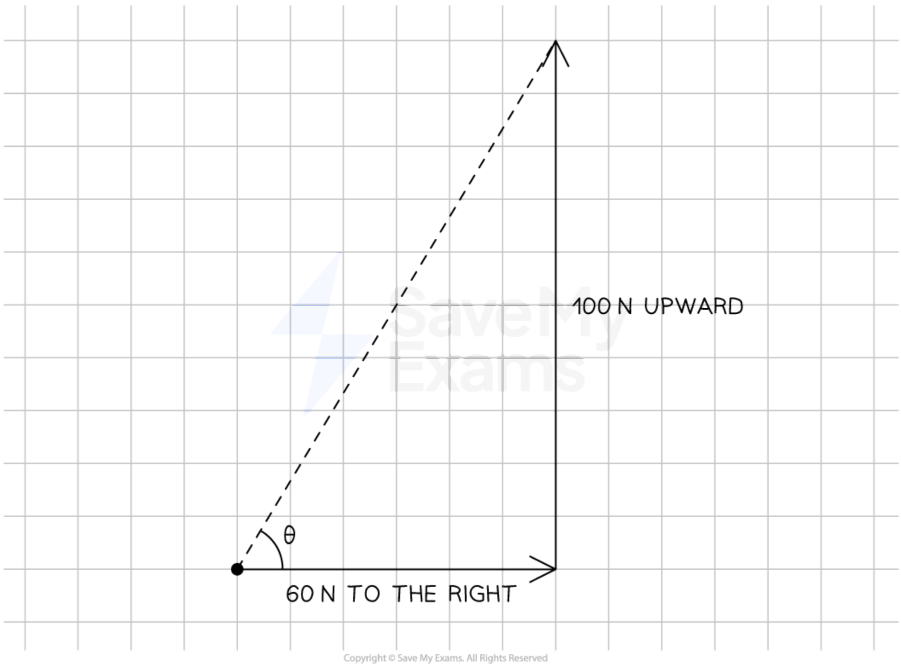
Step 2: Calculate the magnitude of the resultant force using Pythagoras' theorem

$$F = \sqrt{60^2 + 100^2}$$

$$F = \sqrt{13\,600}$$

$$F = 117 \text{ N}$$

Step 3: Calculate the direction of the resultant vector using trigonometry



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$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan\theta = \frac{100}{60}$$

$$\theta = \tan^{-1}\left(\frac{100}{60}\right) = 59°$$

Step 4: State the final answer, complete with magnitude and direction

$$F = 117 \text{ N at } 59° \text{ from the horizontal}$$

Your notes

Examiner Tips and Tricks

If the question specifically asks you to use the calculation or graphical method, you must solve the problem as asked. However, if the choice is left up to you then any correct method will lead to the correct answer.

The graphical method sometimes feels easier than calculating, but once you are confident with trigonometry and Pythagoras you will find calculating quicker and more accurate.