EXAM PAPERS PRACTICE

Boost your performance and confidence with these topic-based exam questions

Practice questions created by actual examiners and assessment experts

Detailed mark scheme

Suitable for all boards

Designed to test your ability and thoroughly prepare you

4.1 Scalars & Vectors

PHYSICS

AQA A Level Revision Notes

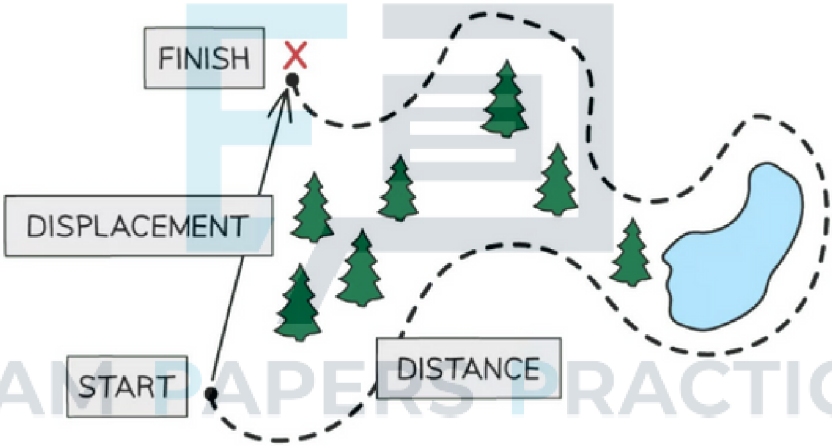
4.1 Scalars & Vectors

CONTENTS

4.1.1 Scalars & Vectors
4.1.2 Resolving Vectors

Scalars & Vectors

- A **scalar** is a quantity which **only** has a magnitude (size)
- A **vector** is a quantity which has **both** a magnitude and a direction
- For example, if a person goes on a hike in the woods to a location which is a couple of miles from their starting point
  - As the crow flies, their **displacement** will only be a few miles but the **distance** they walked will be much longer



Displacement is a vector while distance is a scalar quantity

- **Distance** is a scalar quantity because it describes how far an object has travelled overall, but not the direction it has travelled in
- **Displacement** is a vector quantity because it describes how far an object is from where it started and in what direction
- Some common scalar and vector quantities are shown in the table below:

Scalars and Vectors Table

SCALARS	VECTORS
DISTANCE	DISPLACEMENT
SPEED	VELOCITY
MASS	ACCELERATION
TIME	FORCE
ENERGY	MOMENTUM
VOLUME	
DENSITY	
PRESSURE	
ELECTRIC CHARGE	
TEMPERATURE	

Exam Tip

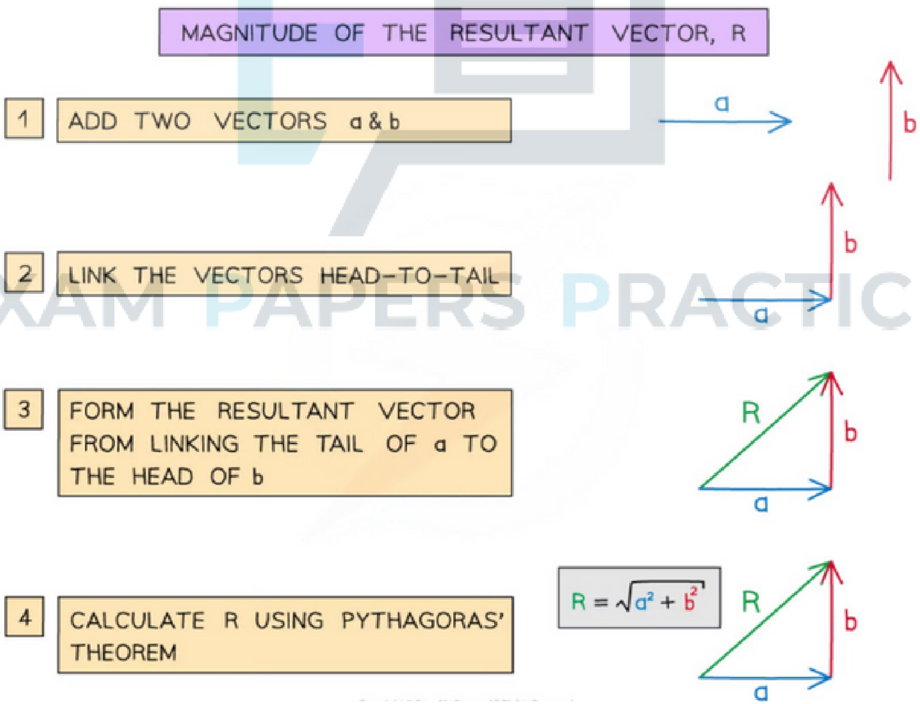
Do you have trouble figuring out if a quantity is a vector or a scalar? Just think - can this quantity have a minus sign? For example - can you have negative energy? No. Can you have negative displacement? Yes!

Combining Vectors

- **Vectors** are represented by an arrow
  - The arrowhead indicates the **direction** of the vector
  - The length of the arrow represents the **magnitude**
- Vectors can be combined by **adding** them to produce the resultant vector
  - The resultant vector is sometimes known as the 'net' vector (eg. the net force)
- There are two methods that can be used to add vectors
  - **Calculation** – if the vectors are perpendicular
  - **Scale drawing** – if the vectors are not perpendicular

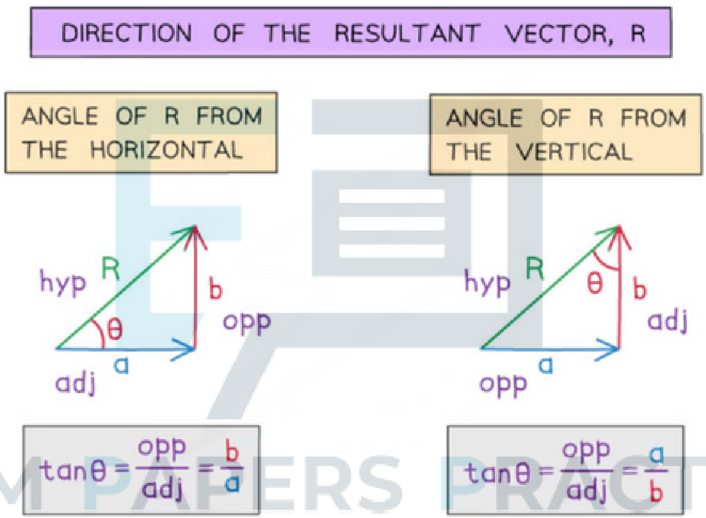
Vector Calculation

- Vector calculations will be limited to two vectors at right angles
- This means the combined vectors produce a right-angled triangle and the magnitude (length) of the resultant vector is found using **Pythagoras' theorem**



The magnitude of the resultant vector is found by using Pythagoras' Theorem

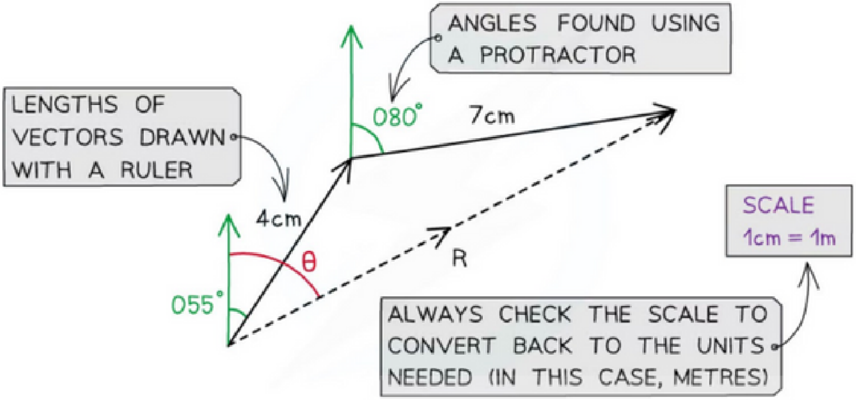
- The direction of the resultant vector is found from the angle it makes with the horizontal or vertical
  - The question should imply which angle it is referring to (ie. Calculate the angle from the x-axis)
- Calculating the angle of this resultant vector from the horizontal or vertical can be done using **trigonometry**
  - Either the sine, cosine or tangent formula can be used depending on which vector magnitudes are calculated



The direction of vectors is found by using trigonometry

Scale Drawing

- When two vectors are not at right angles, the resultant vector can be calculated using a scale drawing
  - **Step 1:** Link the vectors head-to-tail if they aren't already
  - **Step 2:** Draw the resultant vector using the triangle or parallelogram method
  - **Step 3:** Measure the length of the resultant vector using a ruler
  - **Step 4:** Measure the angle of the resultant vector (from North if it is a bearing) using a protractor



A scale drawing of two vector additions. The magnitude of resultant vector R is found using a rule and its direction is found using a protractor

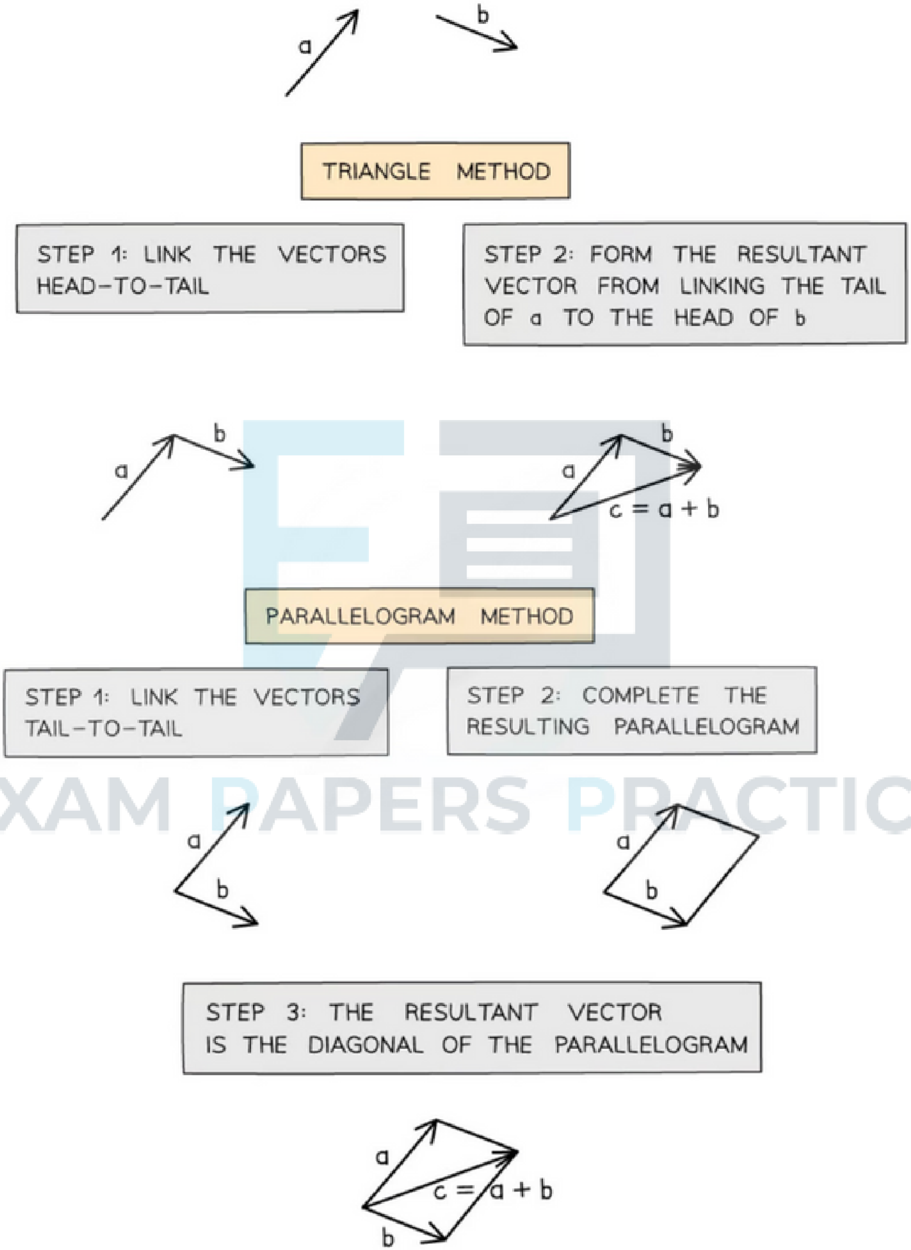
- Note that with scale drawings, a scale may be given for the diagram such as 1 cm = 1 km since only limited lengths can be measured using a ruler
- The final answer is always converted back to the units needed in the diagram
  - Eg. For a scale of 1 cm = 2 km, a resultant vector with a length of 5 cm measured on your ruler is actually 10 km in the scenario

- There are two methods that can be used to combine vectors: the **triangle method** and the **parallelogram method**
- To combine vectors using the triangle method:
  - **Step 1:** link the vectors head-to-tail
  - **Step 2:** the resultant vector is formed by connecting the tail of the first vector to the head of the second vector

- To combine vectors using the parallelogram method:
  - **Step 1:** link the vectors tail-to-tail
  - **Step 2:** complete the resulting parallelogram
  - **Step 3:** the resultant vector is the diagonal of the parallelogram

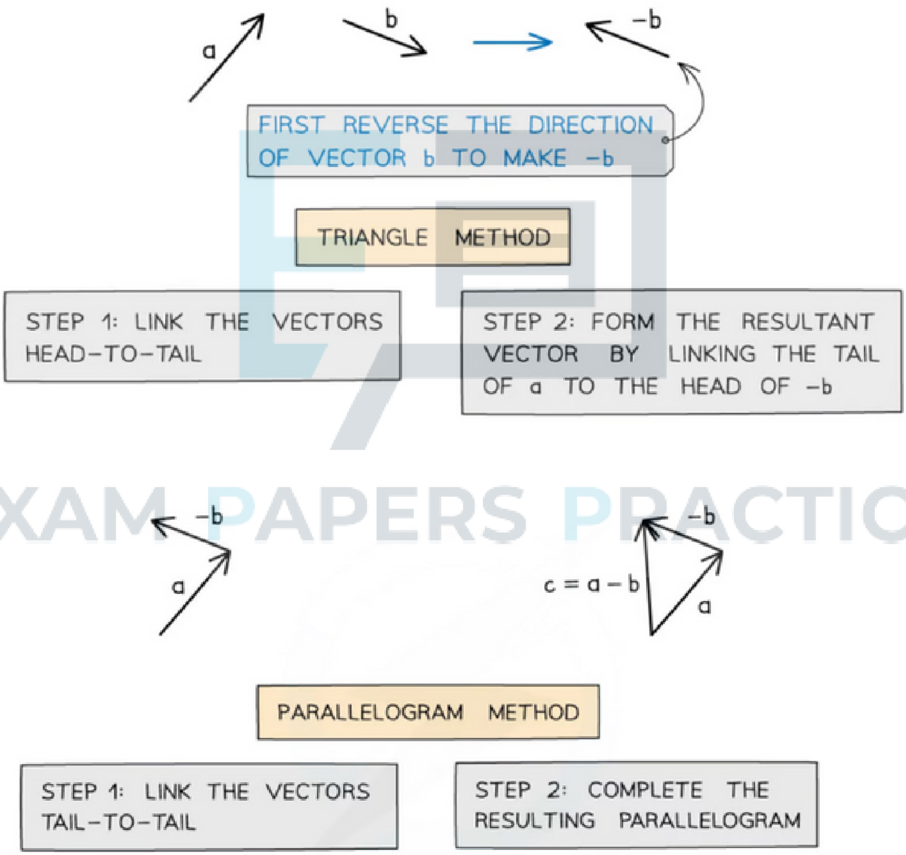
Vector Addition

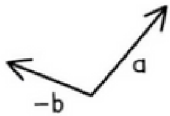
? Draw the vector c = a + b

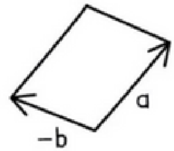

a
b
TRIANGLE METHOD
STEP 1: LINK THE VECTORS HEAD-TO-TAIL
STEP 2: FORM THE RESULTANT VECTOR FROM LINKING THE TAIL OF a TO THE HEAD OF b
a
b
a
b
c = a + b
PARALLELOGRAM METHOD
STEP 1: LINK THE VECTORS TAIL-TO-TAIL
STEP 2: COMPLETE THE RESULTING PARALLELOGRAM
a
b
a
b
STEP 3: THE RESULTANT VECTOR IS THE DIAGONAL OF THE PARALLELOGRAM
a
c = a + b
b

Vector Subtraction

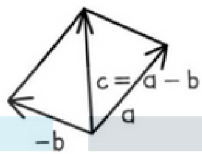
Draw the vector c = a - b







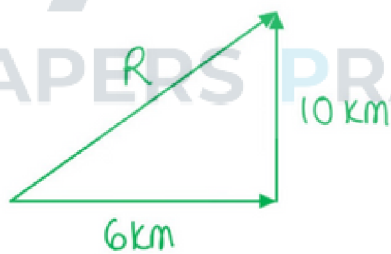
STEP 3: THE RESULTANT VECTOR IS THE DIAGONAL OF THE PARALLELOGRAM



Worked Example

A hiker walks a distance of 6 km due east and 10 km due north. Calculate the magnitude of their displacement and its direction from the horizontal

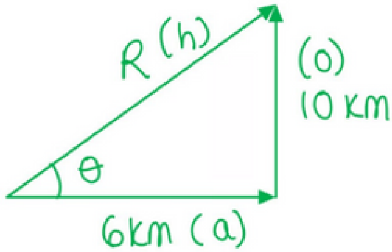
Step 1: Draw a vector diagram



Step 2: Calculate the magnitude of the resultant vector using Pythagoras' Theorem

$$R = \sqrt{6^2 + 10^2}$$

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



$$\tan(\theta) = \frac{\text{opposite}}{\text{adjacent}} = \frac{10}{6}$$

$$\theta = \tan^{-1}\left(\frac{10}{6}\right) = 59^\circ$$

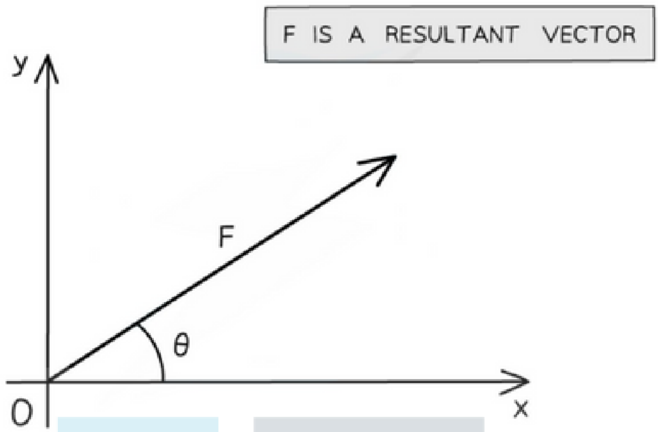
Exam Tip

Pythagoras' Theorem and trigonometry are consistently used in vector addition, so make sure you're fully confident with the maths here!

4.1.2 Resolving Vectors

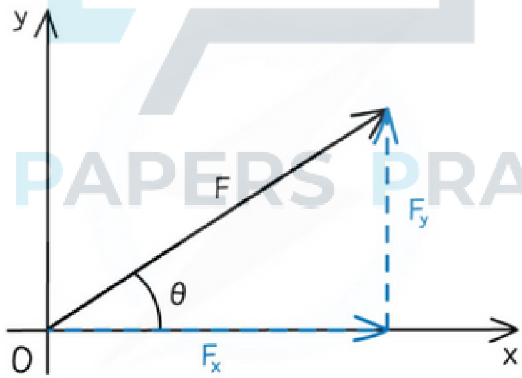
Resolving Vectors

- Two vectors can be represented by a single **resultant vector**
  - Resolving a vector is the opposite of adding vectors
- A single resultant vector can be resolved
  - This means it can be represented by **two** vectors, which in combination have the same effect as the original one
- When a single resultant vector is broken down into its **parts**, those parts are called **components**
- For example, a force vector of magnitude F and an angle of θ to the horizontal is shown below



The resultant force F at an angle θ to the horizontal

- It is possible to **resolve** this vector into its **horizontal** and **vertical** components using trigonometry

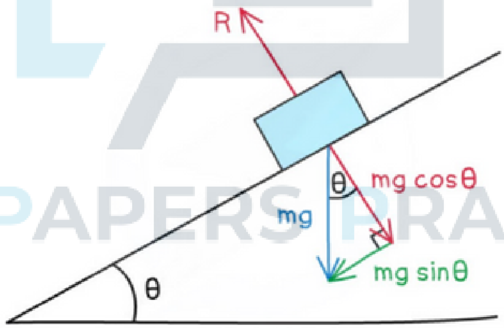


The resultant force F can be split into its horizontal and vertical components

- For the **horizontal** component, $F_x = F\cos\theta$
- For the **vertical** component, $F_y = F\sin\theta$

Forces on an Inclined Plane

- Objects on an inclined plane is a common scenario in which vectors need to be resolved
  - An inclined plane, or a slope, is a flat surface tilted at an angle, θ
- Instead of thinking of the component of the forces as horizontal and vertical, it is easier to think of them as **parallel** or **perpendicular** to the slope
- The **weight** of the object is vertically downwards and the **normal** (or reaction) force, *R* is always vertically up from the object
- The weight *W* is a vector and can be split into the following components:
  - *W* cos (θ) perpendicular to the slope
  - *W* sin (θ) parallel to the slope
- If there is no friction, the force *W* sin (θ) causes the object to move down the slope
- The object is not moving perpendicular to the slope, therefore, the normal force *R* = *W* cos (θ)



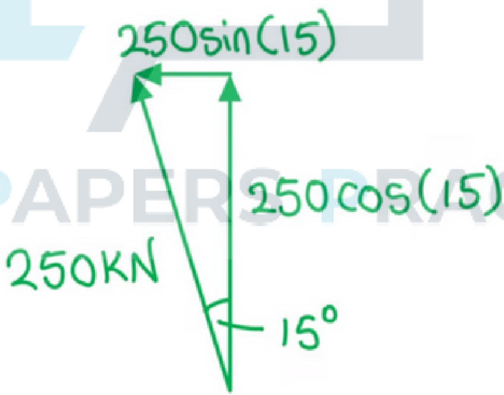
The weight vector of an object on an inclined plane can be split into its components parallel and perpendicular to the slope

Worked Example

A helicopter provides a lift of 250 kN when the blades are tilted at 15° from the vertical.

Calculate the horizontal and vertical components of the lift force.

Step 1: Draw a vector triangle of the resolved forces



Step 2: Calculate the vertical component of the lift force

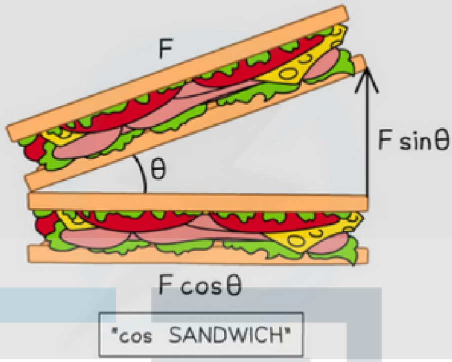
$$\text{Vertical} = 250 \times \cos(15) = 242 \text{ kN}$$

Step 3: Calculate the horizontal component of the lift force

$$\text{Horizontal} = 250 \times \sin(15) = 64.7 \text{ kN}$$

Exam Tip

If you're unsure as to which component of the force is cos θ or sin θ, just remember that the cos θ is always the adjacent side of the right-angled triangle AKA, making a 'cos sandwich'

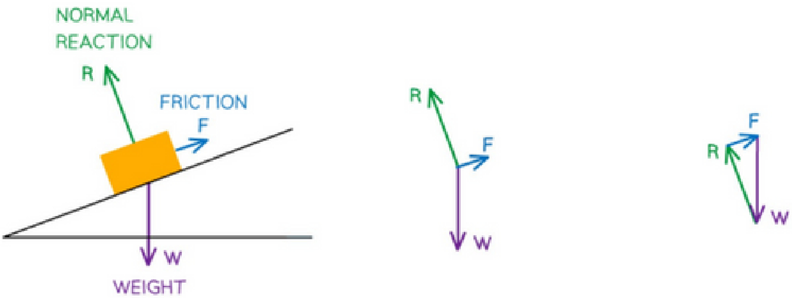


Equilibrium

- Coplanar forces can be represented by vector triangles
- Forces are in equilibrium if an object is either
  - At rest
  - Moving at **constant** velocity

- In equilibrium, coplanar forces are represented by **closed** vector triangles
  - The vectors, when joined together, form a closed path
- The most common forces on objects are
  - Weight
  - Normal reaction force
  - Tension (from cords and strings)
  - Friction
- The forces on a body in equilibrium are demonstrated below:

A VEHICLE IS AT REST ON A SLOPE AND HAS THREE FORCES ACTING ON IT TO KEEP IT IN EQUILIBRIUM

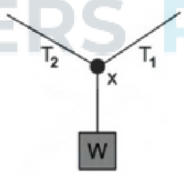


STEP 1:	STEP 2:	STEP 3:
DRAW ALL THE FORCES ON THE FREE-BODY DIAGRAM	REMOVE THE OBJECT AND PUT ALL THE FORCES COMING FROM A SINGLE POINT	REARRANGE THE FORCES INTO A CLOSED VECTOR TRIANGLE. KEEP THE SAME LENGTH AND DIRECTION

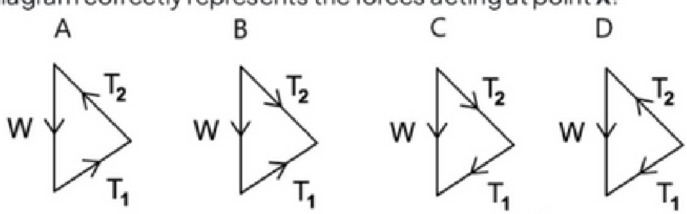
Three forces on an object in equilibrium form a closed vector triangle

Worked Example

A weight hangs in equilibrium from a cable at point **X**. The tensions in the cables are T_1 and T_2 as shown.



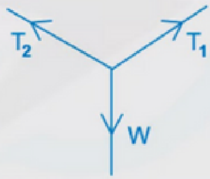
Which diagram correctly represents the forces acting at point **X**?



ANSWER: A

STEP 1

IDENTIFY THE DIRECTION OF ALL THE FORCES



STEP 2

ARRANGE THESE INTO A VECTOR TRIANGLE KEEPING THE SAME MAGNITUDE AND DIRECTIONS

STEP 3

ENSURE THE DIRECTION OF THE VECTORS FORM A CLOSED PATH

Exam Tip

The diagrams in exam questions about this topic could ask you to draw to scale, so make sure you have a ruler handy!