IGCSE Physics 0625 · Topical Past Papers

Worked Solutions · Theory / Structured

PHYSICAL QUANTITIES & MEASUREMENT

Paper 2

Worked Solutions

Authored Solutions

Megalecture · Original Worked Solutions

Each question is solved from first principles with full working shown. Vector diagrams are described with calculated magnitudes and angles. All answers use SI units and show appropriate significant figures based on the data provided. This is owner's authorised material for IGCSE Physics 0625 study support.

Physical Quantities & Measurement — Paper 2

Overview: This document contains detailed worked solutions for all vector addition questions from the IGCSE Physics 0625 topical past paper on Physical Quantities & Measurement (Paper 2). Each question involves vector analysis, graphical methods, or component calculations. All solutions show complete working with final answers highlighted in boxes.

Method Notes: Vector problems are solved using the parallelogram law or triangle method. Magnitudes are calculated using Pythagoras' theorem; angles are found using trigonometry. Scale diagrams are described with precise scale ratios. All answers are given to 2–3 significant figures consistent with the precision of the given data.

1 Two Perpendicular Displacements (May/June 2010 P22)

Question: A journey consists of two displacements: 500 m north and 200 m east. Draw to scale a vector diagram showing both displacements and the resultant. Determine the magnitude and direction of the resultant displacement.

Solution:

(a) Vector Diagram Method

Scale: 1 cm : 100 m (or 1 cm ≡ 100 m)

Construction: Draw north arrow vertically: 500 m ÷ 100 m/cm = 5 cm. From the head of this vector, draw east arrow horizontally: 200 m ÷ 100 m/cm = 2 cm. Join the origin to the endpoint (resultant).

Calculation of Magnitude:

The two displacements are perpendicular (north and east), so use Pythagoras' theorem:

$$R = \sqrt{(500^2 + 200^2)}$$

$$R = \sqrt{(250\ 000 + 40\ 000)} = \sqrt{290\ 000}$$

$$R = 538\ m$$

Calculation of Direction:

Using tan(θ) = opposite / adjacent = 200 / 500 = 0.4

$$\theta = \arctan(0.4) = 21.8°$$

Direction: **21.8° east of north** (or 068° on compass bearings)

Size: 538 m (or 540 m to 2 s.f.)
Direction: 21.8° east of north (or E 21.8° N)

2 Boat Velocity Resultant (May/June 2014 P21)

Question: A boat has velocity 5.0 m/s in still water. The water flows at 2.0 m/s towards the north-east. Using a vector diagram, find the resultant velocity (magnitude and direction).

Solution:

Vector Addition by Parallelogram (or Triangle) Method

Scale: 1 cm : 1.0 m/s (or 1 cm ≡ 1 m/s)

Construction: Boat velocity = 5.0 m/s (assumed north for clarity, or from diagram). Draw as 5.0 cm arrow. Water velocity = 2.0 m/s north-east (45° from north). From origin, draw second vector as 2.0 cm at 45° from first. Complete the triangle by joining endpoints.

Calculation Setup:

If boat velocity is $\mathbf{v}_b$ = 5.0 m/s (direction T) and water velocity is $\mathbf{v}_w$ = 2.0 m/s at 45° (north-east):

Component method (assuming boat heads north, water flows NE at 45°):

$$v_x \text{ (east)} = 2.0 \times \cos(45°) = 2.0 \times 0.707 = 1.414 \text{ m/s}$$

$$v_y \text{ (north)} = 5.0 + 2.0 \times \sin(45°) = 5.0 + 1.414 = 6.414 \text{ m/s}$$

Resultant Magnitude:

$$R = \sqrt{(1.414^2 + 6.414^2)} = \sqrt{(2.0 + 41.1)} = \sqrt{43.1} = 6.6 \text{ m/s}$$

Resultant Direction:

$$\theta = \arctan(1.414 / 6.414) = \arctan(0.220) = 12.4° \text{ east of north}$$

Size of resultant velocity: 6.6 m/s
Direction: 12.4° east of north (or N 12.4° E)

3 Suspended Microphone Forces (Oct/Nov 2008 P2)

Question: A microphone of weight W = 6.0 N hangs from wire X. Wire Y (horizontal) pulls with tension T = 8.0 N. Using a vector diagram, find the magnitude and direction of the resultant of W and T.

Solution:

Vector Addition (Perpendicular Forces)

Scale: 1 cm : 2.0 N (or 1 cm ≡ 2 N)

Construction: Weight W acts vertically downward: 6.0 N ÷ 2 N/cm = 3.0 cm (down). Tension T acts horizontally: 8.0 N ÷ 2 N/cm = 4.0 cm (to the right). Complete the vector triangle by drawing the resultant from origin to endpoint.

Calculation of Magnitude (Perpendicular Vectors):

$$R = \sqrt{(W^2 + T^2)} = \sqrt{(6.0^2 + 8.0^2)} = \sqrt{(36 + 64)} = \sqrt{100}$$

$$R = 10 \text{ N}$$

Direction from Vertical (or Horizontal):

$$\tan(\theta) = T / W = 8.0 / 6.0 = 1.333$$

$$\theta = \arctan(1.333) = 53.1°$$

This is 53.1° from the vertical (downward), towards the horizontal direction (right).

Magnitude: 10 N (or 10.0 N)
Direction: 53.1° from the vertical (below the horizontal)

4 Parachutist Velocity with Wind (Oct/Nov 2012 P21)

Question: A parachutist falls vertically at 6.5 m/s and simultaneously moves horizontally at 4.5 m/s due to wind. Using a graphical method, determine the resultant velocity. Provide scale and diagram.

Solution:

Vector Addition (Perpendicular Velocities)

Scale: 1 cm : 1.0 m/s (or 1 cm ≡ 1 m/s)

Diagram Construction:

- Draw vertical arrow downward: 6.5 m/s → 6.5 cm (down)
- From its head, draw horizontal arrow: 4.5 m/s → 4.5 cm (to the right)
- Draw resultant from origin to endpoint

Calculation of Resultant Magnitude:

Vertical and horizontal components are perpendicular:

$$R = \sqrt{(v_{vertical}^2 + v_{horizontal}^2)}$$

$$R = \sqrt{(6.5^2 + 4.5^2)} = \sqrt{(42.25 + 20.25)} = \sqrt{62.5}$$

$$R = 7.9 \text{ m/s}$$

Direction:

$$\theta = \arctan(4.5 / 6.5) = \arctan(0.692) = 34.7° \text{ from vertical}$$

Size of velocity: 7.9 m/s
Scale: 1 cm : 1.0 m/s

5 Traffic Lights on Cable (Oct/Nov 2013 P22)

Question: A traffic light (weight 240 N) hangs from an inclined metal cable. A horizontal chain pulls with tension 140 N. Using a scale diagram, find the resultant force on the traffic lights.

Solution:

(a) Force Arrows on Diagram:

- **(i) Tension in horizontal chain:** Arrow pointing horizontally to the right (direction of applied force).
- **(ii) Weight:** Arrow pointing vertically downward.

(b) Scale Diagram and Resultant Calculation:

Scale: 1 cm : 40 N (or 1 cm ≡ 40 N)

Construction:

- Weight W = 240 N: 240 ÷ 40 = 6.0 cm (downward)
- Horizontal tension T = 140 N: 140 ÷ 40 = 3.5 cm (horizontal)
- These forces are perpendicular. Complete the parallelogram/triangle.
- Measure or calculate the resultant.

Calculation of Resultant Magnitude:

$$R = \sqrt{(W^2 + T^2)} = \sqrt{(240^2 + 140^2)}$$

$$R = \sqrt{(57\ 600 + 19\ 600)} = \sqrt{77\ 200}$$

$$R = 277.8\ \text{N} \approx 280\ \text{N (to 2 s.f.)}$$

Direction:

$$\theta = \arctan(140 / 240) = \arctan(0.583) = 30.3^\circ \text{ from vertical}$$

Scale: 1 cm : 40 N
Resultant Force: 278 N (or 280 N to 2 s.f.)

6 Two Tugboats Pulling a Ship (Oct/Nov 2017 P22)

Question: Two tugboats each exert a force of 49 kN on a ship. The forces are directed at 20° on each side of a central line (40° between them). Using a graphical method, find the resultant force.

Solution:

Vector Addition (Symmetric Forces)

Scale: 1 cm : 10 kN (or 1 cm ≡ 10 kN)

Diagram Construction:

- Draw first force 49 kN: 49 ÷ 10 = 4.9 cm at 20° to the right of the central axis.
- Draw second force 49 kN: 4.9 cm at 20° to the left of the central axis.
- By symmetry, these forces form a V-shape opening along the central line.
- The resultant points along the central axis (vertical component) and the horizontal components cancel.

Analytical Calculation:

Each force has magnitude 49 kN, separated by angle 20° + 20° = 40° total angle between them.

Component along central axis (for each):

$$F_{central} = 49 \times \cos(20°) = 49 \times 0.9397 = 46.05 \text{ kN}$$

Total resultant (both forces contribute equally along the axis):

$$R = 2 \times 46.05 = 92.1 \text{ kN} \approx 92 \text{ kN}$$

Alternative (Parallelogram Law): Using the law of cosines with angle 40° between vectors:

$$R^2 = 49^2 + 49^2 + 2(49)(49)\cos(40°)$$

$$R^2 = 2401 + 2401 + 4802 \times 0.766 = 4802 + 3678 = 8480$$

$$R = 92.1 \text{ kN}$$

Scale: 1 cm : 10 kN
Resultant: 92 kN (along the central line, perpendicular to the V-shape)

7 Bus on Inclined Slope (Oct/Nov 2010 P22)

Question: A bus (weight 32 000 N) is pushed up a 10° slope at constant speed. The passengers push with force 17 000 N parallel to the slope. Using a graphical method, determine the resultant of the weight and push force. Provide magnitude and direction.

Solution:

Vector Addition Setup:

Scale: 1 cm : 4000 N (or 1 cm ≡ 4 kN)

Forces to combine:

- **Weight:** 32 000 N vertically downward
- **Push force:** 17 000 N parallel to the slope (up the slope)
- **Angle between them:** 90° + 10° = 100° (since push is at 10° to horizontal, weight is vertical)

Diagram Construction:

- Draw weight: 32 000 ÷ 4000 = 8.0 cm downward (vertically)
- From its head, draw push force: 17 000 ÷ 4000 = 4.25 cm at 10° above horizontal (parallel to slope)
- Complete the triangle from origin to endpoint. Measure resultant length.

Calculation of Resultant (Using Law of Cosines):

Angle between weight (down) and push (along slope at 10°) = 100°

$$R^2 = 32000^2 + 17000^2 + 2(32000)(17000)\cos(100°)$$

$$R^2 = 1\ 024\ 000\ 000 + 289\ 000\ 000 + 2(32000)(17000)(-0.1736)$$

$$R^2 = 1\ 313\ 000\ 000 - 188\ 582\ 400 = 1\ 124\ 417\ 600$$

$$R = 33\ 533\ \text{N} \approx 33.5\ \text{kN (or 34 kN to 2 s.f.)}$$

Direction Calculation:

Using the sine rule or component analysis. The resultant points downward and to the left (perpendicular to slope, approximately).

Direction: approximately 10° to the left of vertical (normal to the slope surface)

Scale: 1 cm : 4000 N
Size of resultant: 33 500 N (or 34 kN to 2 s.f.)
Direction: Perpendicular to the slope (normal to the surface)

8 Vector vs. Scalar & Aeroplane Force Resultant (Oct/Nov 2015 P21)

Question: (a) Define vector vs. scalar quantities and give examples. (b) An aeroplane has weight 160 kN and an upward force of 320 kN at 30° to the horizontal. Using a scale of 1 cm : 40 kN, find the resultant force's magnitude and direction.

Solution (Part a):

(a)(i) Vector vs. Scalar Definition:

Vector quantity: A physical quantity that has both magnitude (size) and direction. It cannot be fully described by a number alone; direction is essential.

Scalar quantity: A physical quantity that has magnitude only, with no direction. It is completely described by a number and appropriate unit.

(a)(ii) Examples:

- **Vector quantity (other than force):** Velocity (e.g., 25 m/s north), displacement, acceleration
- **Scalar quantity (other than mass):** Speed (e.g., 25 m/s), distance, time, temperature

Solution (Part b):

(b) Aeroplane Force Resultant:

Scale: 1 cm : 40 kN (given)

Vector Diagram Construction:

- **Weight:** 160 kN vertically downward → 160 ÷ 40 = 4.0 cm (down)
- **Upward force:** 320 kN at 30° to horizontal → 320 ÷ 40 = 8.0 cm at 30° above horizontal
- Complete triangle: join origin to endpoint. Measure resultant.

Calculation of Magnitude (Law of Cosines):

Angle between weight (downward) and upward force (30° above horizontal) = 90° + 30° = 120°

$$R^2 = 160^2 + 320^2 + 2(160)(320)\cos(120°)$$

$$R^2 = 25\ 600 + 102\ 400 + 2(160)(320)(-0.5)$$

$$R^2 = 128\ 000 - 51\ 200 = 76\ 800$$

$$R = 277.1\ N \approx 277\ N\ (\text{Convert: } 277\ N = 0.277\ kN;\ \text{or work in kN directly})$$

$$R = 277\ kN \text{ or } \approx 280\ kN \text{ to 2 s.f. (Check: units in kN} \rightarrow R \approx 0.277 \times 1000 = 277\ N\text{? Scale error; recalc...)}$$

$$\mathbf{R = \sqrt{76\ 800} = 277\ kN\ (recalculated\ in\ kN)}$$

Direction (Using component method for clarity):

Horizontal component (F_x): 320 × cos(30°) = 320 × 0.866 = 276.9 kN (to the right)

Vertical component (F_y): 320 × sin(30°) − 160 = 160 − 160 = 0 kN

Resultant is purely horizontal: **277 kN horizontally forward**

Verification: When the vertical component of the upward force (320 sin 30° = 160 kN) equals the weight (160 kN), they cancel, leaving only the horizontal component (320 cos 30° ≈ 277 kN).

Size of resultant force: 277 kN (or 280 kN to 2 s.f.)
Direction of resultant force: Horizontal (forward / parallel to the initial direction of the 30° force)

Summary of Methods

Vector Addition Techniques

- **Graphical (Parallelogram or Triangle):** Draw vectors to scale, complete the parallelogram, and measure or calculate the resultant.
- **Component Method:** Resolve each vector into perpendicular components (horizontal & vertical), sum components, then recombine using Pythagoras' theorem.
- **Trigonometry (Perpendicular Vectors):** If vectors are perpendicular, $R = \sqrt{(A^2 + B^2)}$; direction = $\arctan(B/A)$.
- **Law of Cosines (Angled Vectors):** $R^2 = A^2 + B^2 + 2AB\cos(\theta)$, where θ is the angle between the vectors.

Key Reminders for Paper 2 Questions

- **Always show the scale:** e.g., "1 cm ≡ 10 N" or "1 cm : 100 m".
- **Label forces/displacements:** Ensure arrows and components are clearly marked on diagrams.
- **Use significant figures:** Match the precision of given data (typically 2–3 s.f.).
- **Direction conventions:** Specify direction relative to a reference (vertical, horizontal, north, east, etc.) or as a bearing.
- **Verify answers:** Check that magnitudes and angles make physical sense; use component decomposition as verification.