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PEARSON EDEXCEL A LEVEL PHYSICS (9PH0) — ORIGINAL PRACTICE QUESTIONS

Topic 2: Mechanics

A Level Physics — Original Practice Set

Written by GuideMyGrades — original questions in the style of Pearson Edexcel A Level Physics

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Contents

This booklet contains original practice questions written by GuideMyGrades for A Level Physics Topic 2: Mechanics, modelled on the style, structure, command words and difficulty of genuine Pearson Edexcel papers. It is organised by numbered sub-topic (2.1, 2.2, 2.3...), each broken down further into lettered sections. Sub-topic 2.1 covers motion graphs, beginning with a short foundational review of distance-time and displacement-time graphs, before moving on to velocity-time graphs in depth. Each section opens with a fully worked example, followed by two practice questions of increasing difficulty. None of the questions are taken from or adapted from any real past paper — the content, numbers and contexts are original. Further sub-topics will be added to this booklet over time.

Question Paper

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Mark Scheme

Topic 2: Mechanics

A Level Physics — Original Practice Set



Topic 2: Mechanics — Question Paper

Original questions written by GuideMyGrades in the style of Pearson Edexcel A Level Physics (9PH0). Not from a real past paper. Click ANSWER (top right of each question) to jump to its mark scheme.

2.1 Distance, Velocity & Acceleration-time Graphs

GCSE Recap

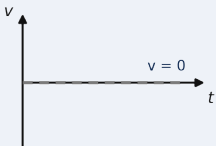
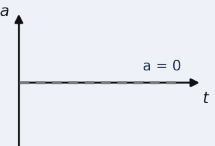
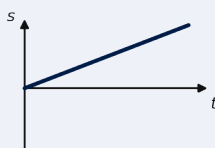
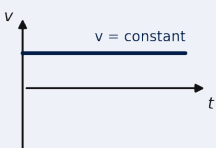
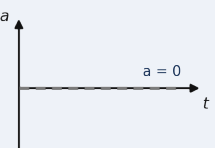
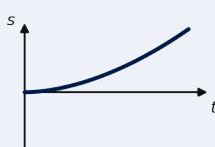
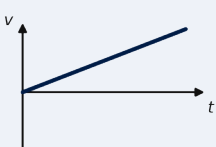
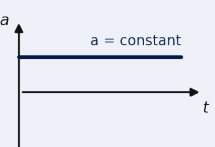
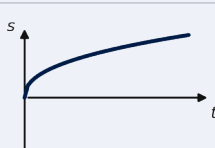
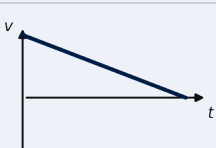
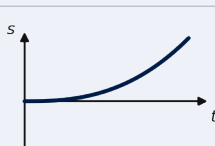
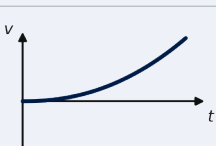
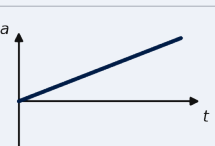
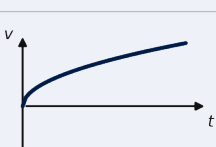
A quick shape-vocabulary refresher before velocity-time graphs — skip ahead to Section A if you're already confident reading motion graphs.



GCSE RECAP

Reading the Shape of a Motion Graph

The same six motions recur throughout. Read down a row to see how ONE motion looks across all three graphs — s , v and a .

Description	Displacement, s $s = \text{area under } v\text{-}t \text{ graph}$	Velocity, v $v = \text{gradient of } s\text{-}t \text{ graph}$	Acceleration, a $a = \text{gradient of } v\text{-}t \text{ graph}$
Object at rest ($v = 0$) <i>"constant displacement"</i>			
Constant velocity ($a = 0$)			
Constant acceleration <i>"increasing velocity at a constant rate"</i>			
Constant deceleration <i>"decreasing velocity at a constant rate"</i>			
Increasing acceleration <i>"increasing velocity at an increasing rate"</i>			
Decreasing acceleration <i>"increasing velocity at a decreasing rate"</i>			



A. Distance-Time Graphs

MEMORISE THIS

Gradient (and Area) on a Distance-Time Graph

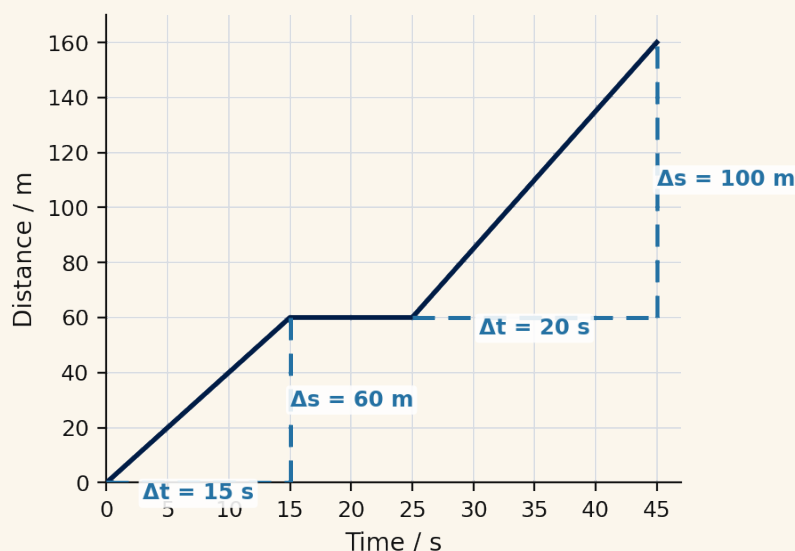
A distance-time graph never slopes downward: distance travelled can only increase or stay the same, even if the object changes direction. (Contrast a displacement-time graph, where the line CAN fall — see Section B.)

On a distance-time graph...	...this represents
The gradient	Speed (m s^{-1}) — always ≥ 0 , since distance never decreases
The area between the line and the time axis	Not a standard physical quantity in this specification (unlike a velocity-time graph, where area = displacement — see Section C)

WORKED EXAMPLE

Gradient = Speed

The distance-time graph below shows a cyclist's ride, including a stop at a red light. Use the graph to find (i) the cyclist's speed during the first 15 s, and (ii) the cyclist's speed between 25 s and 45 s.



■ gradient → speed

Solution

- (i) The first 15 s is a straight line rising from 0 to 60 m, so its **gradient** = (change in distance) ÷ (change in time) = $(60 - 0) / 15 = 4.0 \text{ m s}^{-1}$.
- Between 15 s and 25 s the line is flat (zero gradient) — the cyclist is stopped at the red light.
- (ii) Between 25 s and 45 s, the **gradient** = $(160 - 60) / (45 - 25) = 100 / 20 = 5.0 \text{ m s}^{-1}$.

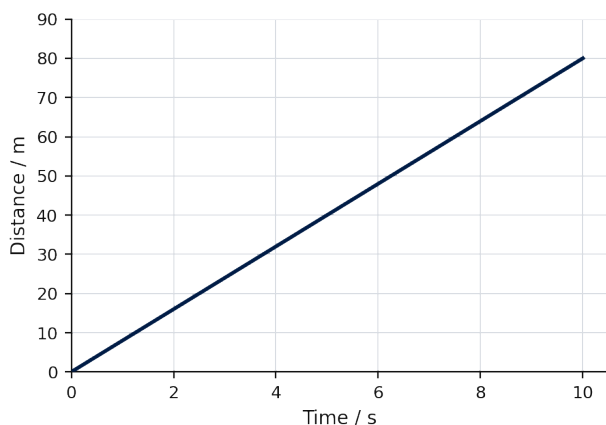
speed (first 15 s) = 4.0 m s^{-1} speed (25–45 s) = 5.0 m s^{-1}



1.

ANSWER ›

The distance-time graph below shows a delivery van's short trip along a straight road.



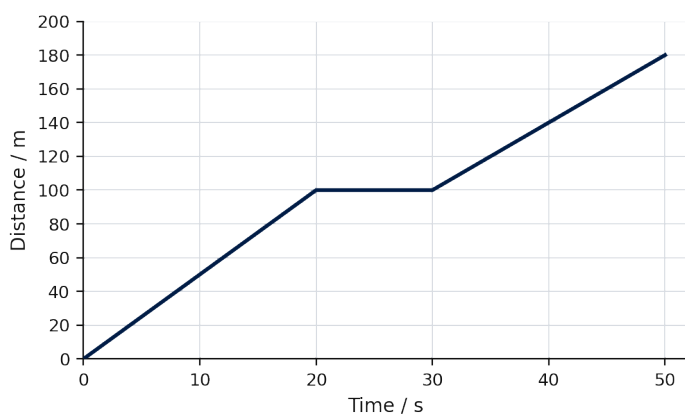
(a) Calculate the speed of the van.

(Total for Question 1 = 2 marks)

2.

ANSWER ›

The distance-time graph below shows a jogger's run, including a water break.



(a) Calculate the jogger's speed during the first 20 s.

(b) Calculate the jogger's speed between 30 s and 50 s.

[2]

(Total for Question 2 = 4 marks)



B. Displacement-Time Graphs

MEMORISE THIS

Gradient (and Area) on a Displacement-Time Graph

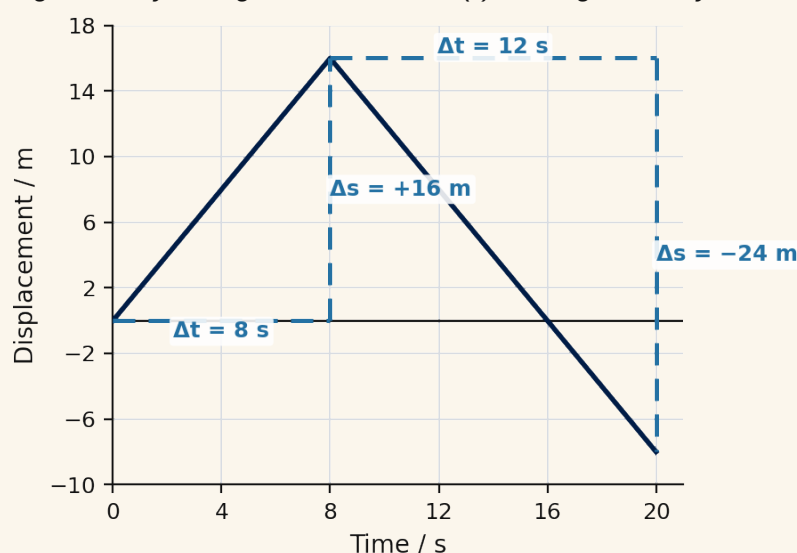
Unlike distance, displacement is a vector — it can be positive, negative or zero, so a displacement-time graph CAN slope downward. A negative gradient means the object is moving back towards, or past, its starting point.

On a displacement-time graph...	...this represents
The gradient	Velocity (m s^{-1}) — the sign shows the direction of travel
The area between the line and the time axis	Not a standard physical quantity in this specification

WORKED EXAMPLE

Gradient = Velocity

The displacement-time graph below shows a dog's movement along a straight path relative to its owner, where a positive displacement means in front of the owner. Use the graph to find (i) the dog's velocity during the first 8 s, and (ii) the dog's velocity between 8 s and 20 s.



■ gradient → velocity

Solution

- (i) The first 8 s is a straight line rising from 0 to 16 m, so its **gradient** = $(16 - 0) / 8 = +2.0 \text{ m s}^{-1}$, positive, so the dog is moving away from its owner.
- (ii) Between 8 s and 20 s, the **gradient** = $(-8 - 16) / (20 - 8) = -24 / 12 = -2.0 \text{ m s}^{-1}$, negative, so the dog is moving back towards, then past, its owner. By $t = 20 \text{ s}$ its displacement is -8 m (8 m behind the owner) — something a distance-time graph could never show.

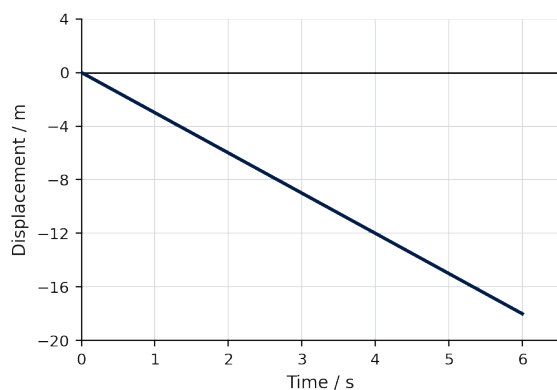
velocity (0–8 s) = $+2.0 \text{ m s}^{-1}$ velocity (8–20 s) = -2.0 m s^{-1}



3.

ANSWER ›

The displacement-time graph below shows a remote-control car's motion along a straight track, where a positive displacement means to the right of its start point.



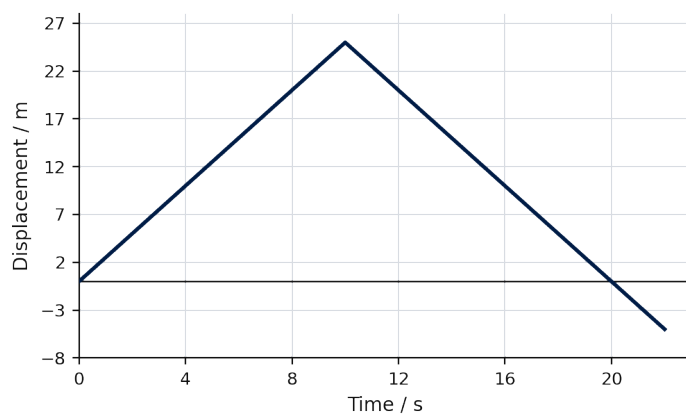
(a) Calculate the velocity of the car.

(Total for Question 3 = 2 marks)

4.

ANSWER ›

The displacement-time graph below shows a swimmer's position in a pool relative to the wall they pushed off from, during a length and back.



(a) Calculate the swimmer's velocity during the first 10 s.

(b) Calculate the swimmer's velocity between 10 s and 22 s.

[2]

(Total for Question 4 = 4 marks)



WORKED EXAMPLE**Plotting a Displacement-Time Graph From a Description**

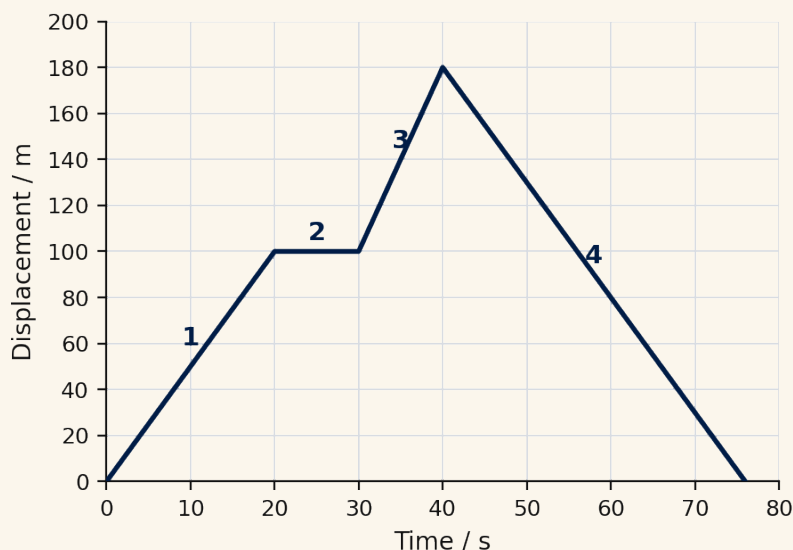
A cyclist's journey away from and back to home is described below. Plot her displacement-time graph on gridded axes, using a positive displacement to mean away from home.

Stage 1 (0–20 s): cycles away from home at a steady speed, reaching 100 m.

Stage 2 (20–30 s): stops for a rest (stays at 100 m).

Stage 3 (30–40 s): continues away from home, now at a faster steady speed, reaching 180 m.

Stage 4 (40–76 s): cycles straight back home at a steady speed.

**Solution**

- Each stage is a STEADY speed (or a stop), so it's a STRAIGHT line — plot just the point at the END of each stage, then join consecutive points with a ruler: $(0, 0) \rightarrow (20, 100) \rightarrow (30, 100) \rightarrow (40, 180) \rightarrow (76, 0)$.
- Stage 1** (constant velocity, away): straight line, positive gradient, $0 \rightarrow 100$ m.
- Stage 2** (stationary): FLAT line at 100 m — no gradient, not moving.
- Stage 3** (constant velocity, away, faster): straight line, steeper positive gradient than Stage 1, $100 \rightarrow 180$ m.
- Stage 4** (constant velocity, returning): straight line, NEGATIVE gradient (heading back towards home), $180 \rightarrow 0$ m.

A straight-line graph is built stage by stage — plot the (time, displacement) point at the END of each stage first, THEN join them up; never try to draw the whole line in one go.



5.

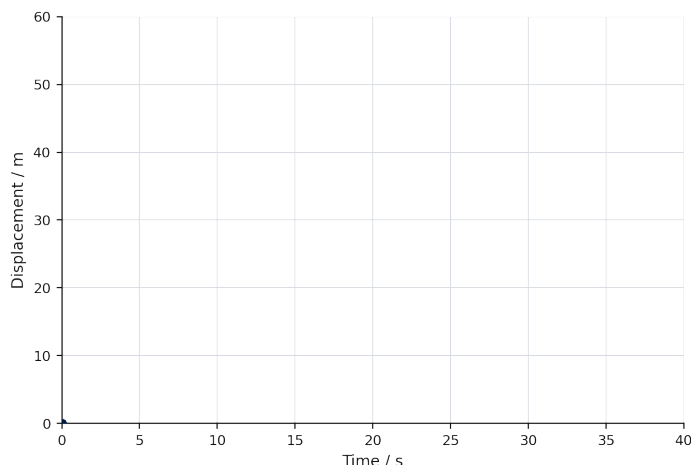
ANSWER ›

A dog walker's displacement from home is described below (positive = away from home). Plot the displacement-time graph on the blank axes provided.

Stage A (0–15 s): walks away from home at a steady speed, reaching 30 m.

Stage B (15–25 s): stops to let the dog sniff a lamppost (stays at 30 m).

Stage C (25–40 s): continues away from home at a steady speed, reaching 60 m.



(a) Plot the displacement-time graph for the whole walk on the axes provided.

(b) Calculate the dog walker's velocity during Stage C (25 s to 40 s).

[2]

(Total for Question 5 = 5 marks)

6.

ANSWER ›

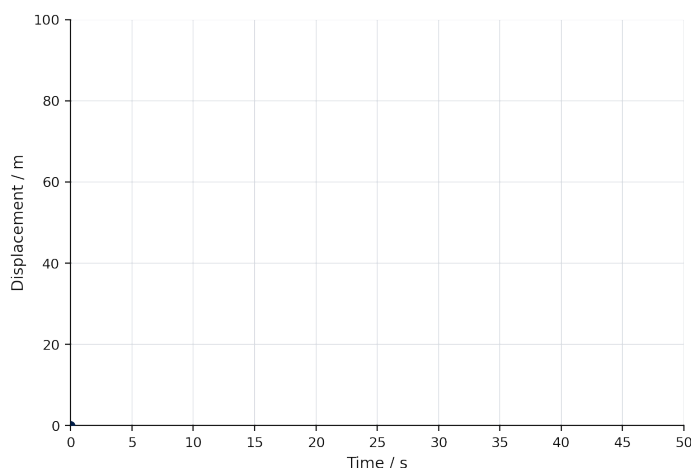
A delivery drone's displacement from its base is described below (positive = away from base). Plot the displacement-time graph on the blank axes provided.

Stage 1 (0–10 s): flies away from base at a steady speed, reaching 40 m.

Stage 2 (10–18 s): hovers to release a parcel (stays at 40 m).

Stage 3 (18–30 s): continues away from base at a steady speed, reaching 100 m.

Stage 4 (30–50 s): flies straight back to base at a steady speed.



(a) Plot the displacement-time graph for the whole flight on the axes provided.



(b) State what is happening to the drone's displacement during Stage 2, and suggest what the drone is doing.

[1]

(Total for Question 6 = 5 marks)

C. Gradient = Acceleration, Area = Displacement

MEMORISE THIS

Gradient & Area on a Velocity-Time Graph

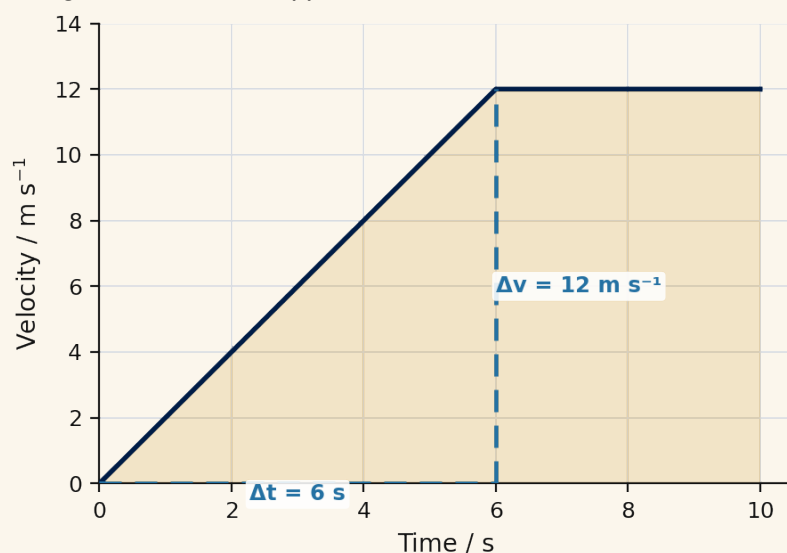
If a graph has several straight sections, split it into simple shapes -- triangles, rectangles, trapezia -- and add (or subtract, for time below the axis) the areas for the total displacement.

On a velocity-time graph...	...this represents
The gradient	Acceleration (m s^{-2})
The area between the line and the time axis	Displacement — or distance travelled, if the object never changes direction (m)

WORKED EXAMPLE

Gradient = Acceleration, Area = Displacement

A cyclist's velocity-time graph is shown below. Use the graph to find (i) the cyclist's acceleration during the first 6 s, and (ii) the total distance travelled in the 10 s shown.



■ gradient → acceleration ■ area → distance

Solution

- (i) The first 6 s is a straight line rising from 0 to 12 m s^{-1} , so its **gradient** = (change in v) ÷ (change in t) = $(12 - 0) / (6 - 0) = 2.0 \text{ m s}^{-2}$.
- (ii) The **area** under the whole graph splits into a triangle (0–6 s) and a rectangle (6–10 s).
- Triangle: $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 6 \times 12 = 36 \text{ m}$. Rectangle: $\text{base} \times \text{height} = 4 \times 12 = 48 \text{ m}$.



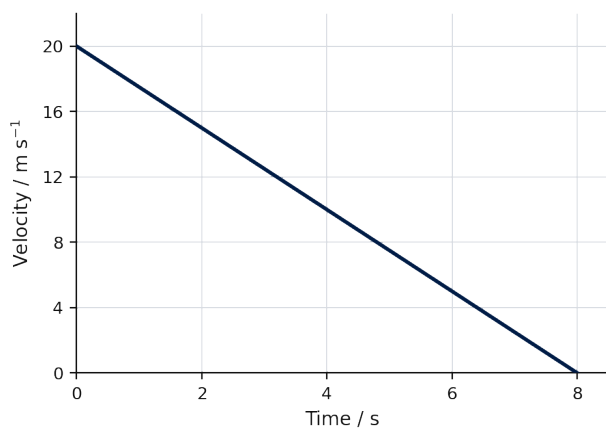
4. Total distance = $36 + 48 = 84 \text{ m}$.

acceleration = 2.0 m s^{-2} distance = 84 m

7.

ANSWER ›

The velocity-time graph below shows a car braking to a stop.



(a) Show that the car's deceleration is 2.5 m s^{-2} .

(b) Calculate the distance the car travels while it is braking.

[2]

.....

.....

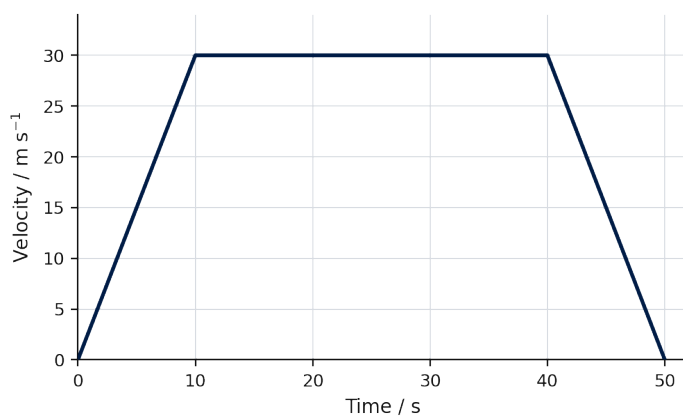
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(Total for Question 7 = 4 marks)

8.

ANSWER ›

The velocity-time graph below shows a train's journey between two stations.



(a) Calculate the train's acceleration during the first 10 s.

(b) Calculate the train's deceleration during the last 10 s shown.

[2]

.....

.....

.....

(c) Calculate the total distance travelled by the train over the 50 s shown.

[3]

.....

.....

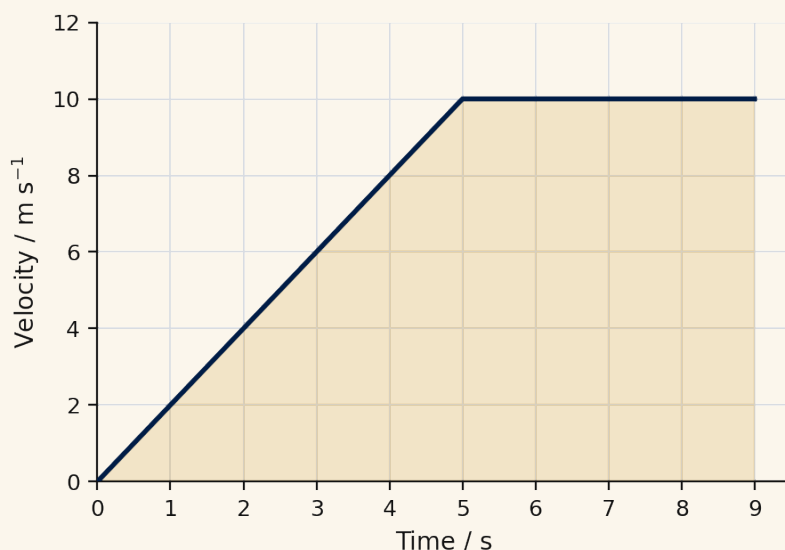
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(Total for Question 8 = 7 marks)

WORKED EXAMPLE**Distance Travelled: the Area-Formula Method**

The velocity-time graph below shows a rowing boat's short sprint, accelerating uniformly before holding a steady speed. Calculate the total distance travelled.



■ area → distance

Solution

1. This graph has two straight sections, and each needs a different shape formula for its **area**: a sloped section (0–5 s) and a horizontal section (5–9 s).
2. Sloped section → a **triangle**: area = $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 5 \times 10 = 25 \text{ m}$.
3. Horizontal section → a **rectangle**, NOT a triangle: area = base $\times$ height = $4 \times 10 = 40 \text{ m}$.
4. Total **distance** = $25 + 40 = 65 \text{ m}$.

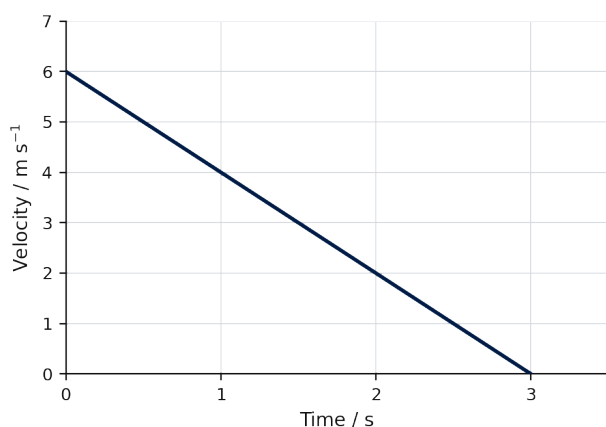
distance = 65 m



9.

ANSWER ›

The velocity-time graph below shows a skateboarder decelerating to a stop.



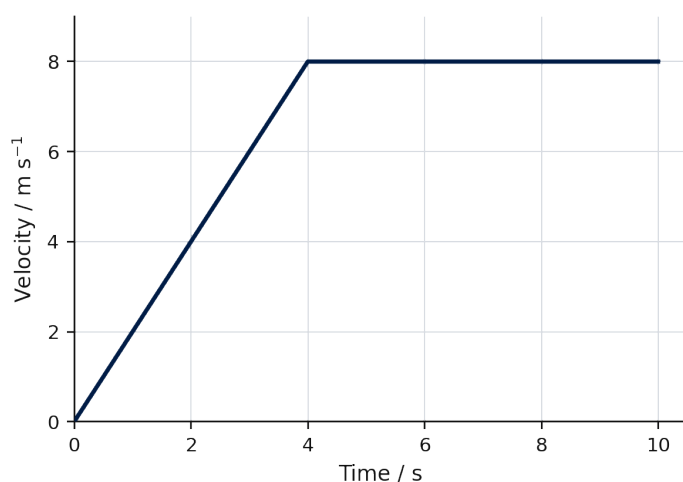
(a) Calculate the distance travelled by the skateboarder as they decelerate.

(Total for Question 9 = 2 marks)

10.

ANSWER ›

The velocity-time graph below shows a forklift truck accelerating, then moving at a constant speed to place a pallet.



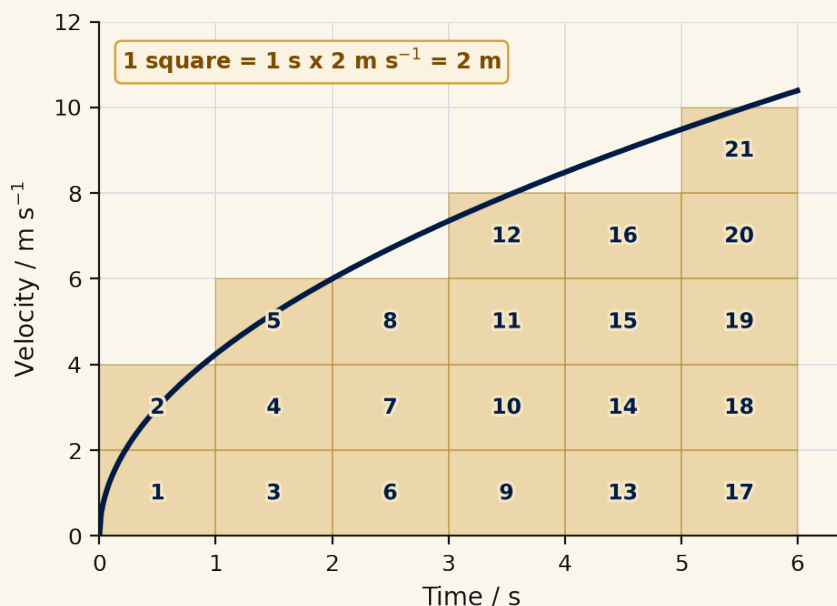
(a) Calculate the total distance travelled by the forklift truck.

(Total for Question 10 = 3 marks)



WORKED EXAMPLE**Distance Travelled: the Counting-Squares Method (Curved Graphs)**

The velocity-time graph below shows a jet-ski accelerating away from a jetty; its rate of acceleration decreases as its speed builds up. Estimate the total distance travelled in the first 6 s by counting the grid squares under the curve.



■ numbered squares → distance

Solution

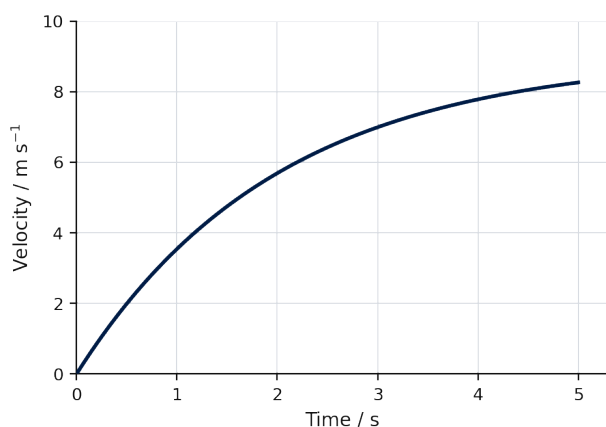
1. The line is curved, so it cannot be split into simple triangles or rectangles — instead, count the grid squares that lie under the curve.
2. Each grid square represents $1 \text{ s} \times 2 \text{ m s}^{-1} = 2 \text{ m}$ of distance, as highlighted on the graph.
3. Counting a square whenever at least half of it lies under the curve, and numbering them in order as shown above, gives a running total of 21 squares.
4. Total distance $\approx 21 \times 2 \text{ m} = 42 \text{ m}$.

distance $\approx 42 \text{ m}$



11.**ANSWER ›**

The velocity-time graph below shows a paraglider's speed during the first 5 s after launching off a hill.

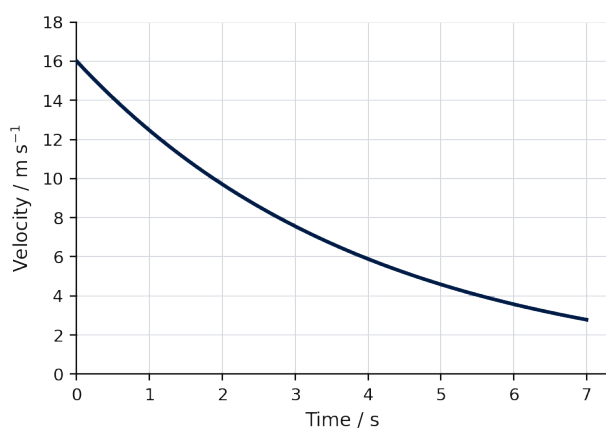


(a) Estimate the distance travelled by the paraglider in the first 5 s, by counting the grid squares under the curve.

(Total for Question 11 = 2 marks)

12.**ANSWER ›**

The velocity-time graph below shows a canoe slowing down after the paddler stops paddling, over the first 7 s.



(a) Estimate the distance travelled by the canoe in the first 7 s, by counting the grid squares under the curve.

(Total for Question 12 = 2 marks)



D. Acceleration-Time Graphs

MEMORISE THIS

Gradient & Area on an Acceleration-Time Graph

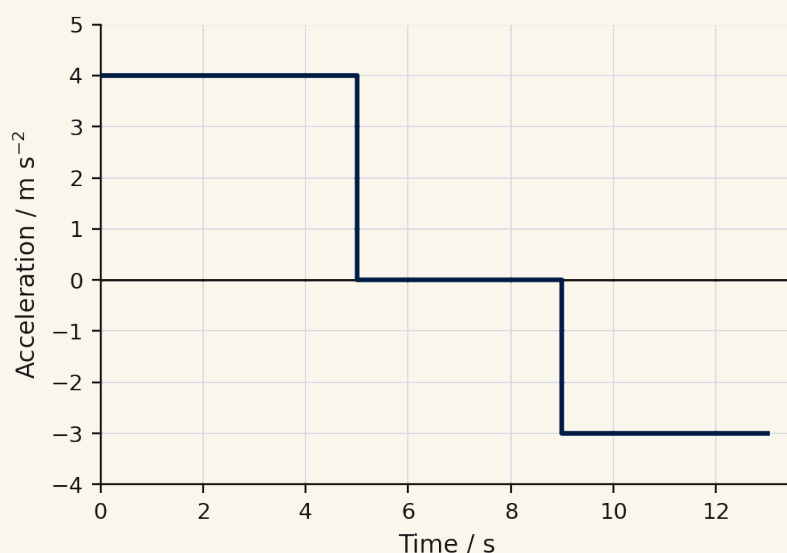
- **Gradient** (rate of change of acceleration) — NOT required by this specification.
- **Area** under the line — works just like the other two graphs (see table below).

On an acceleration-time graph...	...this represents
The gradient	Not examined in this specification
The area between the line and the time axis	Change in velocity, δv (m s^{-1}) — negative if the section of line is below the axis

WORKED EXAMPLE

Area = Change in Velocity

The acceleration-time graph below shows a rocket sled's acceleration during a 13 s test run. Use the graph to find (i) the change in velocity during the first 5 s, and (ii) the overall change in velocity over the full 13 s.



■ area → change in velocity

Solution

- (i) 0–5 s: $a = 4 \text{ m s}^{-2}$ (**accelerating**), so **area** = base $\times$ height = $5 \times 4 = 20 \text{ m s}^{-1}$.
- 5–9 s: $a = 0$ (line on the axis) — **constant velocity**, no contribution to δv .
- (ii) 9–13 s: $a = -3 \text{ m s}^{-2}$ (rectangle **BELOW** the axis, **decelerating**), so **area** = $4 \times (-3) = -12 \text{ m s}^{-1}$ (negative, since slowing down).
- Total $\delta v = 20 + 0 + (-12) = 8 \text{ m s}^{-1}$ over the full 13 s.

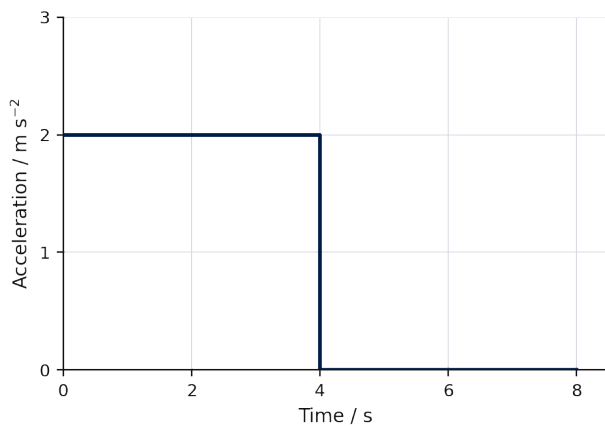
δv (first 5 s) = 20 m s^{-1} δv (whole 13 s) = 8 m s^{-1}



13.

ANSWER ›

The acceleration-time graph below shows a lift's acceleration as it sets off from the ground floor.



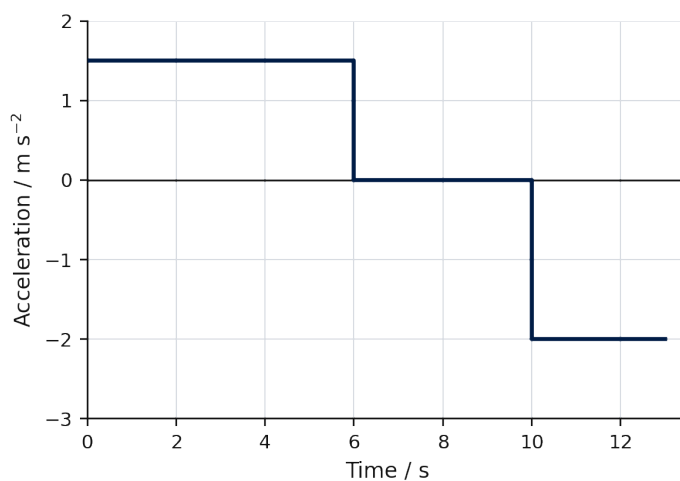
(a) Use the graph to calculate the increase in the lift's velocity during the first 4 s.

(Total for Question 13 = 2 marks)

14.

ANSWER ›

The acceleration-time graph below shows a train's acceleration as it leaves one station and brakes into the next.



(a) Calculate the change in the train's velocity during the first 6 s.

(b) Calculate the change in the train's velocity during the braking phase (10 s to 13 s).

[2]

(Total for Question 14 = 4 marks)



E. Linking the Graphs: How to Describe Each Shape

MEMORISE THIS

Describing the Shape of a Line: What Each Shape Means

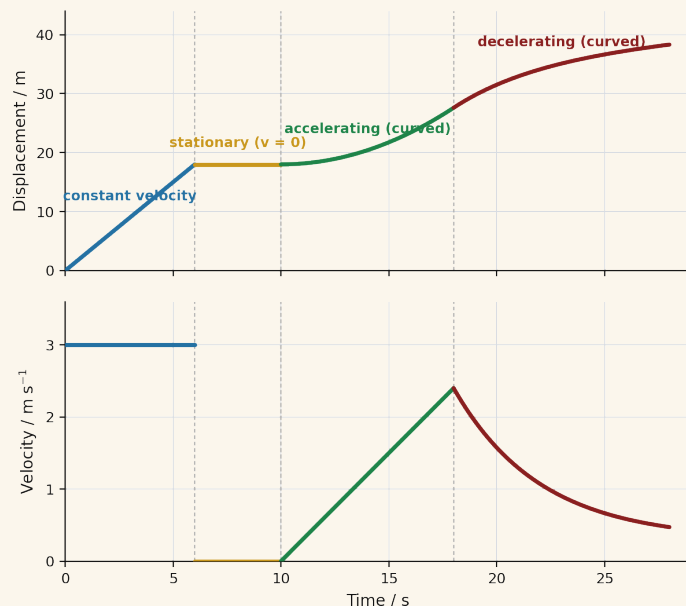
The same four shapes turn up on distance-time, displacement-time AND velocity-time graphs — only what the gradient represents changes (speed, velocity or acceleration — see the MEMORISE THIS boxes in Sections A–C). Read a shape once, and you can describe it on any of the three graph types.

Shape of the line	What it means
Straight, sloped line	Constant gradient — whatever the gradient represents is constant (e.g. constant speed on a distance-time graph, constant acceleration on a velocity-time graph)
Straight, horizontal line (flat, gradient = 0)	Zero rate of change — the quantity on the y-axis is not changing (e.g. stationary, on a distance/displacement-time graph; constant velocity, on a velocity-time graph)
Curve getting steeper (concave up)	Increasing gradient — accelerating (speeding up)
Curve levelling off / flattening while still rising (concave down)	Decreasing gradient — decelerating (slowing down)

WORKED EXAMPLE

Linking a Displacement-Time Graph to Its Velocity-Time Graph

The top graph below shows a scooter rider's displacement during a 28 s journey along a straight cycle path. The bottom graph shows the SAME rider's velocity over the SAME 28 s. Each coloured section covers the same time interval on both graphs — use this to see exactly how the shape of the top graph creates the shape of the bottom graph.



■ constant velocity ■ stationary ($v = 0$) ■ accelerating (curved) ■ decelerating (curved)

Solution

- 0–6 s:** the displacement graph is a straight, sloped line, so its gradient (velocity) is **constant**. This shows up on the velocity graph as a flat horizontal line at $v = 3.0 \text{ m s}^{-1}$.
- 6–10 s:** the displacement graph is flat (zero gradient) — the rider has stopped. This shows up on the velocity graph as a flat line sitting exactly on the time axis, $v = 0$.



3. **10–18 s**: the displacement graph curves upward, getting steeper — its gradient (velocity) is **increasing**, i.e. the rider is accelerating. On the velocity graph this is a straight line rising from 0 to about 2.4 m s^{-1} : since the acceleration itself is constant here, the VELOCITY graph is straight even though the DISPLACEMENT graph is curved.

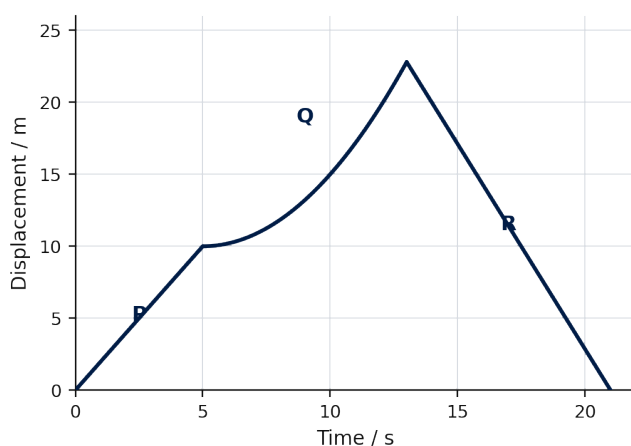
4. **18–28 s**: the displacement graph is still rising but now levels off — its gradient (velocity) is **decreasing**, i.e. the rider is decelerating. On the velocity graph this is a curve falling from about 2.4 m s^{-1} , approaching a steady, slower speed.

The gradient of the displacement-time graph at any instant equals the height of the velocity-time graph at that same instant — true everywhere on the two graphs, section by section.

15.

ANSWER ›

The displacement-time graph below shows a delivery drone's test flight in a straight line above a runway, over 21 s, where a positive displacement means moving away from its launch point.



(a) Describe the shape of the line, and what it shows about the drone's motion, during section P (0–5 s).

(b) Describe the shape of the line, and what it shows about the drone's motion, during section Q (5–13 s).

[2]

(c) Describe the shape of the line, and what it shows about the drone's motion, during section R (13–21 s).

[2]

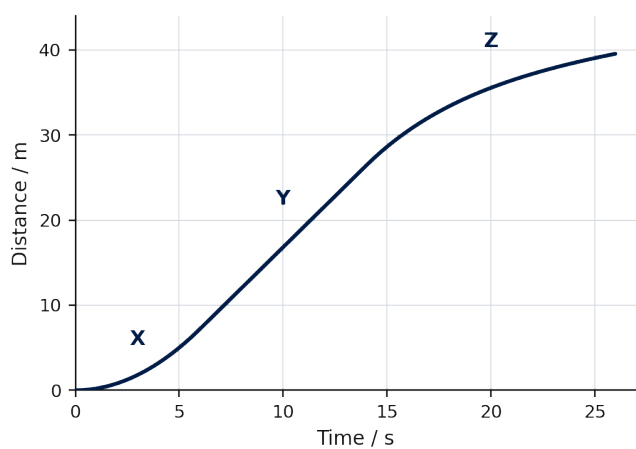
(Total for Question 15 = 6 marks)



16.

ANSWER ›

The distance-time graph below shows the distance climbed by a mountain biker riding up a short, steep section of trail, over 26 s.



(a) Describe the shape of the line, and what it shows about the biker's motion, during section X (0–6 s).

(b) Describe the shape of the line, and what it shows about the biker's motion, during section Y (6–14 s).

[2]

(c) Describe the shape of the line, and what it shows about the biker's motion, during section Z (14–26 s).

[2]

(Total for Question 16 = 6 marks)



F. Linking All Three Graphs: Displacement, Velocity & Acceleration

The three graph types aren't independent of each other — they're three different views of the SAME motion. The worked examples below stack all three graphs for one motion at a time, with matching colours, so you can see exactly how a feature on one graph creates a feature on the other two.

MEMORISE THIS

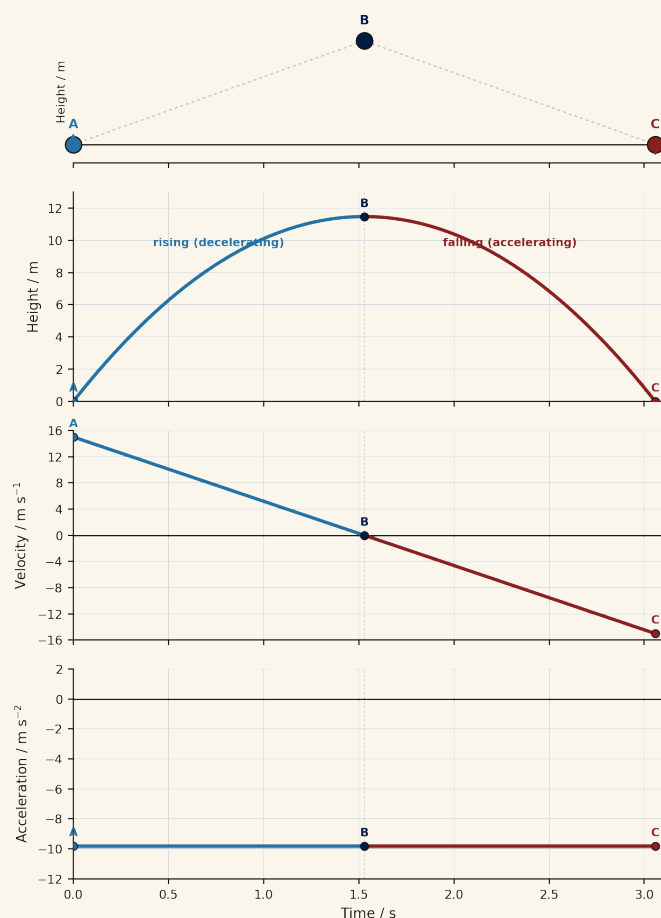
Real Bouncing Balls Lose Energy at Every Bounce

- A PERFECTLY elastic bounce would return the ball to its original height, forever — real balls never do this.
- Each bounce converts some **kinetic energy** to heat and sound, and loses some to deformation of the ball and floor.
- Evidence on the diagram: peak height gets LOWER each bounce, AND the time between bounces gets SHORTER.

WORKED EXAMPLE

A Ball Thrown Straight Up and Caught

A ball is thrown straight up at 15 m s^{-1} and caught again at the same height 3.06 s later. The graphs below show its height, velocity and acceleration for the whole flight (taking $g = 9.81 \text{ m s}^{-2}$, and ignoring air resistance).



■ rising (decelerating) ■ falling (accelerating)



Solution

1. **0–1.53 s (rising)**: curve getting LESS steep (decreasing gradient) — **decelerating**. Matches v-t: straight line, $+15 \text{ m s}^{-1} \rightarrow 0$ (**momentarily stationary** at the very top).
2. **1.53–3.06 s (falling)**: curve getting MORE steep — **accelerating**. v-t carries on as the SAME straight line, now negative, down to -15 m s^{-1} .
3. a-t graph: one flat line at -9.81 m s^{-2} for the WHOLE flight — gravity never switches off. Only the DESCRIPTION changes: 'decelerating' while $v > 0$, 'accelerating' once $v < 0$ (see Section G).

One constant acceleration ($a = -9.81 \text{ m s}^{-2}$) $\rightarrow$ curved s-t graph, straight v-t graph, flat a-t graph — all three, at the same time.

17.**ANSWER ›**

A ball is thrown vertically upwards and returns to the thrower's hand. Choose the correct answer to each of the following. Write the letter of your chosen answer on the line provided.

- (a) Which row correctly gives the ball's velocity and acceleration at the very top of its flight [1]
(ignoring air resistance)?

- A. velocity = 0, acceleration = 0
- B. velocity = 0, acceleration = g, downwards
- C. velocity = maximum, acceleration = 0
- D. velocity = 0, acceleration = g, upwards

- (b) Which of the following correctly describes the ball's acceleration throughout the WHOLE [1]
flight (ignoring air resistance)?

- A. Zero throughout
- B. Constant, directed downwards throughout, including at the top
- C. Downwards while rising, upwards while falling
- D. Increases as the ball rises, then decreases as it falls

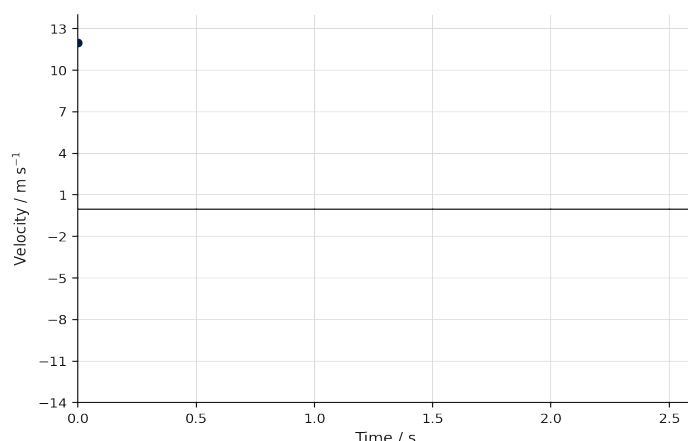
(Total for Question 17 = 2 marks)

18.**ANSWER ›**

A ball is thrown vertically upwards at 12 m s^{-1} from ground level, and returns to the ground 2.45 s later ($g = 9.81 \text{ m s}^{-2}$, air resistance ignored, upward taken as positive).

- (a) State the ball's velocity at the instant it returns to the ground. [1]





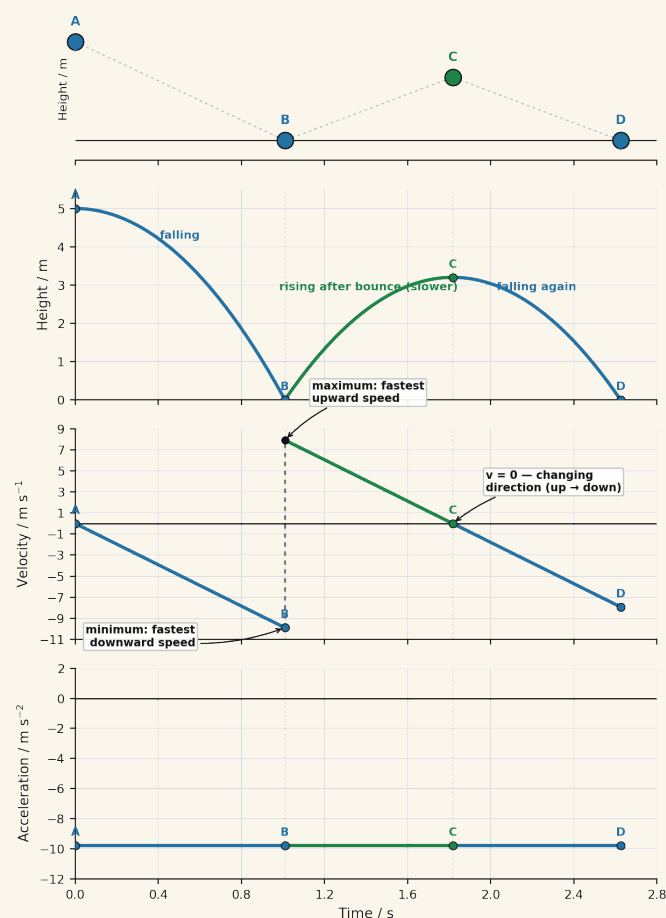
(b) On the blank axes provided, sketch the velocity-time graph for the ball's whole flight. Label the velocity axis at $t = 0$ and at $t = 2.45$ s, and mark the time at which the ball is at its highest point.

(Total for Question 18 = 4 marks)

WORKED EXAMPLE

A Ball Dropped and Bounced Once

A ball is dropped from rest at a height of 5 m. It bounces once, losing 20% of its speed at the bounce, and is caught when it lands again. The graphs below show its height, velocity and acceleration throughout ($g = 9.81 \text{ m s}^{-2}$, air resistance ignored).



■ falling ■ rising after the bounce

Solution

- 0–1.01 s (accelerating, gaining speed): falls from 5 m, speeding up — impact speed -9.90 m s^{-1} .



2. Bounce ($t = 1.01$ s): velocity reverses almost instantly, $-9.90 \rightarrow +7.92 \text{ m s}^{-1}$ (dashed grey line). NOT back to $+9.90$: 20% of speed (and energy) lost.
3. **1.01–1.82 s (decelerating on the way up, momentarily stationary at the top)**: rises to only 3.20 m (well below the 5 m drop height), then falls again — accelerating once more — landing at the same reduced speed it bounced away with (7.92 m s^{-1}).
4. a-t graph unaffected by the bounce (flat -9.81 m s^{-2} throughout) — the brief huge acceleration DURING contact is too short to show at this scale.

Losing speed at the bounce ($9.90 \rightarrow 7.92 \text{ m s}^{-1}$) means a lower bounce height ($5 \text{ m} \rightarrow 3.20 \text{ m}$) — energy lost in the bounce.

19.

ANSWER ›

A ball is dropped from rest and bounces on a hard floor, losing some speed at each bounce. Choose the correct answer to each of the following. Write the letter of your chosen answer on the line provided.

(a) Which best describes the ball's acceleration during the very brief instant of contact with the floor? [1]

- A. Zero
- B. Equal to g , downwards, same as during the fall
- C. Very large, directed upwards — much greater than g
- D. Very large, directed downwards

(b) In a real (non-ideal) repeated bounce, which is true? [1]

- A. Each bounce reaches the same height as the last, but takes less time
- B. Each bounce reaches a LOWER height than the last, AND takes less time than the last
- C. Each bounce reaches a lower height than the last, but takes the same time
- D. Each bounce reaches a HIGHER height than the last, as energy builds up

(Total for Question 19 = 2 marks)

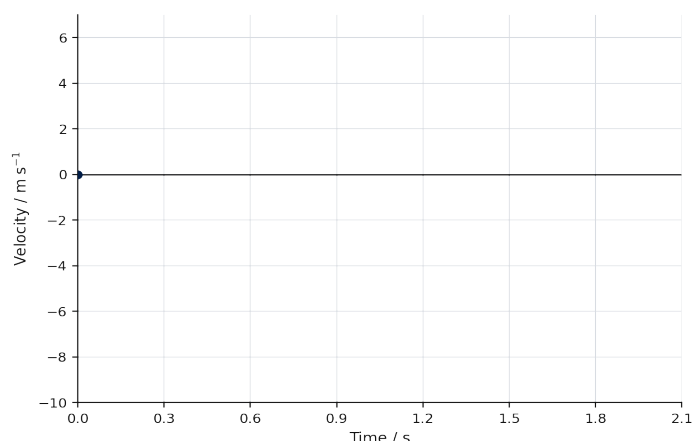
20.

ANSWER ›

A ball is dropped from rest at a height of 4 m onto a hard floor. It bounces once, losing 40% of its speed at the bounce, before being caught when it lands a second time ($g = 9.81 \text{ m s}^{-2}$, air resistance ignored, upward taken as positive).

(a) Calculate the ball's speed the instant before it hits the floor. [2]





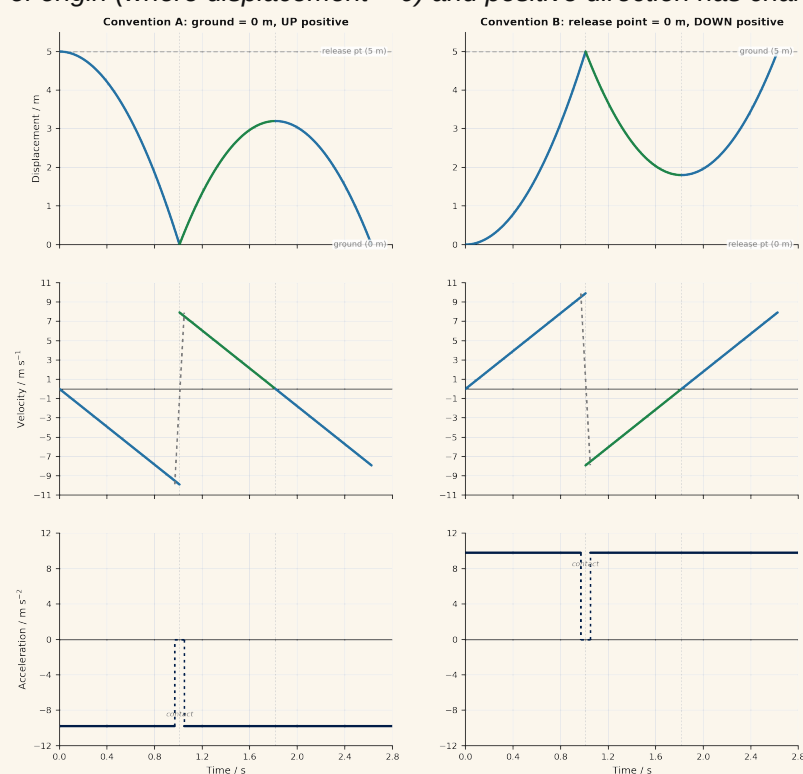
(b) On the blank axes provided, sketch the velocity-time graph for the ball's motion from release to the second landing. Mark the value you found in part (a), and the rebound speed, on your sketch.

(Total for Question 20 = 5 marks)

WORKED EXAMPLE

Same Motion, Different-Looking Graph: It Depends on Your Origin

Both sets of graphs below show the EXACT SAME single-bounce motion above — only the choice of origin (where displacement = 0) and positive direction has changed.



■ falling ■ rising after the bounce

Solution

- Convention A** (ground = 0, UP+): s starts at +5 m, drops to 0 (impact), rises to +3.20 m (bounce peak — momentarily stationary, $v = 0$), drops to 0 again. v is negative (accelerating) while falling, positive (decelerating) while rising.
- Convention B** (release point = 0, DOWN+): s starts at 0, rises to +5 m (impact), drops to +1.80 m (bounce peak), rises to +5 m again — the exact mirror of Convention A. v is positive while falling, negative while rising.



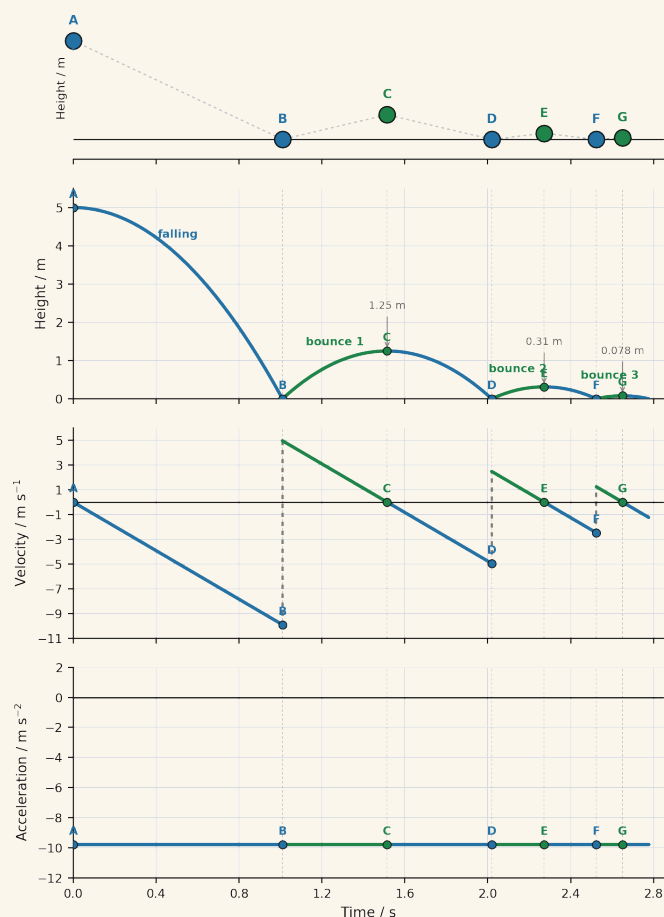
3. Same ball, same motion, same numbers — but a DIFFERENT-shaped graph, because displacement (unlike distance) always depends on a chosen origin and positive direction.
4. a-t graphs (bottom row): ONE constant value throughout each convention (-9.81 m s^{-2} for A, $+9.81 \text{ m s}^{-2}$ for B) — gravity never switches off. The dotted 'contact' bridge just marks where the real, much larger, contact acceleration briefly happens, off this scale.

There is no single 'correct' displacement-time graph for a motion — only a graph that's correct FOR A GIVEN origin and positive direction. Always check that choice before reading values off one.

WORKED EXAMPLE

A Ball Dropped and Bounced Repeatedly

The same ball is now dropped from 5 m and allowed to keep bouncing, losing half its speed at EVERY bounce. The graphs below show the first three bounces.



■ falling ■ rising after a bounce

Solution

- Each bounce: half the speed it arrived with → peak height is a QUARTER of the last ($\text{height} \propto \text{speed}^2$): $5 \text{ m} \rightarrow 1.25 \text{ m} \rightarrow 0.31 \text{ m} \rightarrow 0.078 \text{ m}$.
- Time between bounces shrinks the same way — 1.01 s, 0.50 s, 0.25 s, 0.13 s — the bounce arcs on the v-t graph get narrower each time.

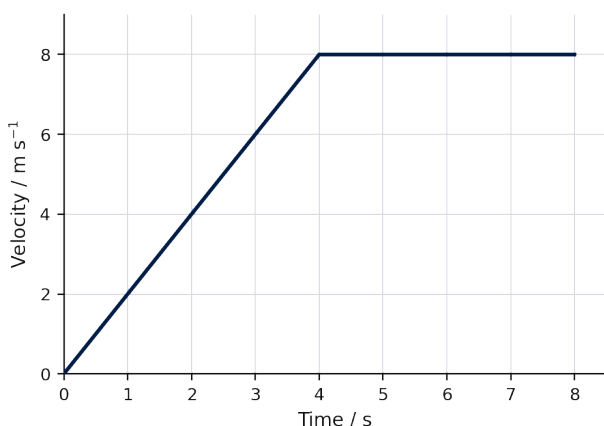
3. Idealised model: bounces continue forever, infinitely close together. In reality, friction and air resistance bring the ball to rest within a few bounces.

Shrinking peak heights AND shrinking bounce times are both evidence of energy loss — see the MEMORISE THIS box above.

21.

ANSWER ›

The velocity-time graph below shows a go-kart's speed over an 8 s interval.



(a) For the interval 0–4 s, describe the shape of the corresponding displacement-time graph, and the shape of the corresponding acceleration-time graph.

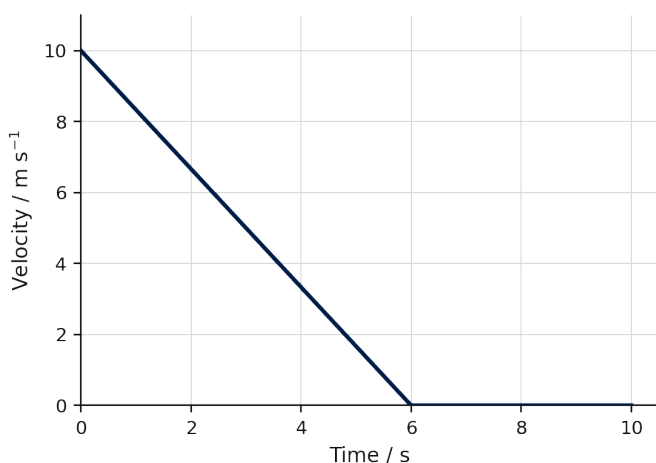
(b) For the interval 4–8 s, describe the shape of the corresponding displacement-time graph, and the shape of the corresponding acceleration-time graph. [2]

(Total for Question 21 = 4 marks)

22.

ANSWER ›

The velocity-time graph below shows a sled's speed as it slides to a stop over a 10 s interval.



(a) For the interval 0–6 s, describe the shape of the corresponding displacement-time graph, and the shape of the corresponding acceleration-time graph.

(b) For the interval 6–10 s, describe the shape of the corresponding displacement-time graph, and the shape of the corresponding acceleration-time graph. [2]



(Total for Question 22 = 4 marks)

G. Describing & Interpreting Motion, Including a Change of Direction

MEMORISE THIS

Reading the Sign of Velocity & Gradient

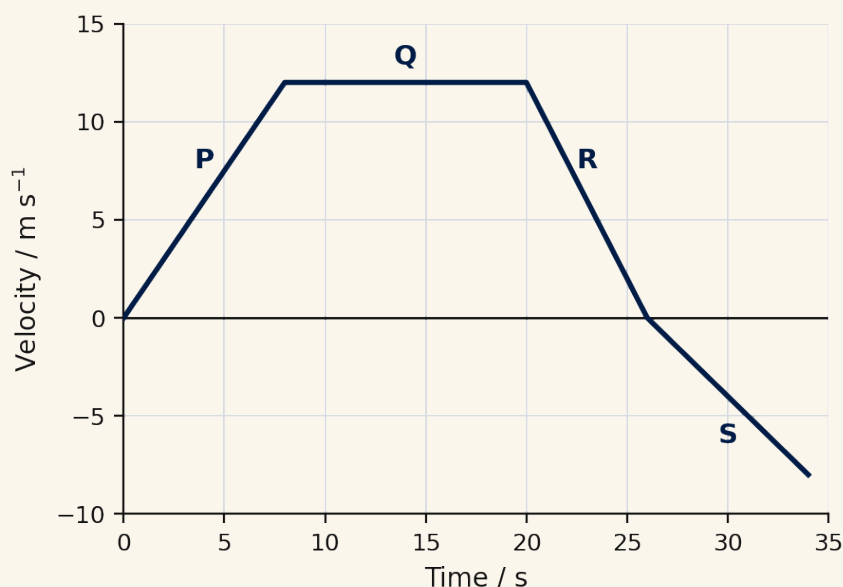
Common mistake: a negative gradient does NOT always mean 'decelerating'. If the velocity is already negative, a negative gradient means the object is speeding up in the negative direction. Always compare the gradient's sign to the velocity's sign, not to zero.

Feature	What it means
$v > 0$	Moving in the positive direction
$v = 0$	Instantaneously at rest (only truly 'stationary' if v stays at 0 for a period of time)
$v < 0$	Moving in the negative (reverse) direction
Gradient has the same sign as v	Speeding up
Gradient has the opposite sign to v	Slowing down

WORKED EXAMPLE

Describing Motion From a Velocity-Time Graph

The graph below shows the velocity of a delivery drone during a 34 s flight test, in a straight line, where a positive velocity means moving away from its launch pad. Describe the motion occurring in each of the four labelled sections.



Solution

- P** (0–8 s): velocity rises steadily from 0 to 12 m s^{-1} — a constant positive gradient, so this is uniform acceleration. The drone speeds up, moving away from the pad.
- Q** (8–20 s): velocity is constant at 12 m s^{-1} — zero gradient, but velocity $\neq 0$, so the drone is moving at a steady speed, not stationary.



3. **R** (20–26 s): velocity falls steadily from 12 to 0 m s^{-1} — a constant negative gradient while v is still positive, so this is uniform deceleration. The drone is momentarily at rest at the very end of R ($t = 26$ s).

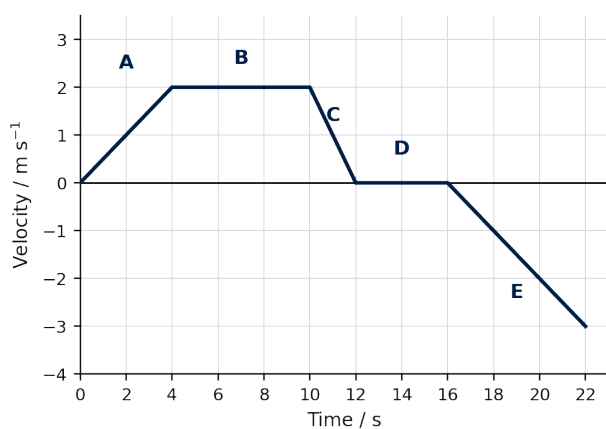
4. **S** (26–34 s): velocity becomes negative, falling from 0 to -8 m s^{-1} . The gradient is still negative, but now so is v — matching signs mean the drone is speeding up again, this time moving back towards the pad (the reverse direction).

P: speeding up (+) Q: constant velocity R: slowing down, momentarily at rest at 26 s S: speeding up in reverse

23.

ANSWER ›

The velocity-time graph below shows a lift's motion over 22 s, where a positive velocity means moving upwards. Describe the motion of the lift during each of the five labelled sections.



(a) Section A (0–4 s).

(b) Section B (4–10 s).

[1]

(c) Section C (10–12 s).

[2]

(d) Section D (12–16 s).

[1]

(e) Section E (16–22 s).

[2]

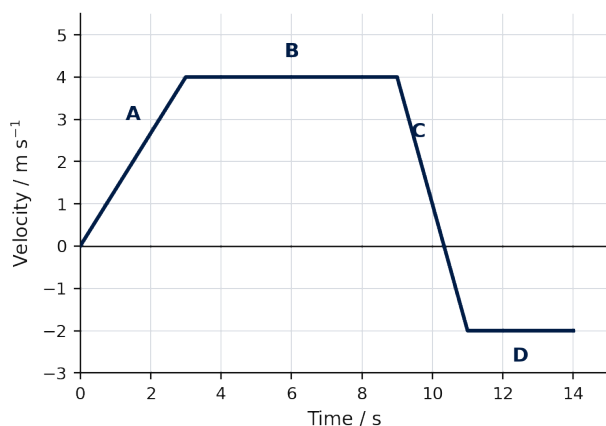
(Total for Question 23 = 8 marks)



24.

ANSWER >

The velocity-time graph below shows a delivery robot moving along a corridor over 14 s, where a positive velocity means moving towards the delivery point.



(a) Describe the robot's motion during section A (0–3 s).

(b) Describe the robot's motion during section B (3–9 s).

[1]

(c) Describe the robot's motion during section C (9–11 s), and calculate the time at which the robot is instantaneously at rest.

[3]

(d) Describe the robot's motion during section D (11–14 s).

[1]

(Total for Question 24 = 7 marks)



H. Non-Uniform Motion: Tangents & Estimating the Area Under a Curve

MEMORISE THIS

Non-Uniform Motion: Tangents & Area Under a Curve

When a velocity-time graph is curved, the velocity changes non-uniformly, so a single straight-line gradient or simple triangle/rectangle area no longer applies.

Instantaneous acceleration at a point = gradient of the **tangent** to the curve there — draw the tangent, then treat it as a straight line (rise $\div$ run).

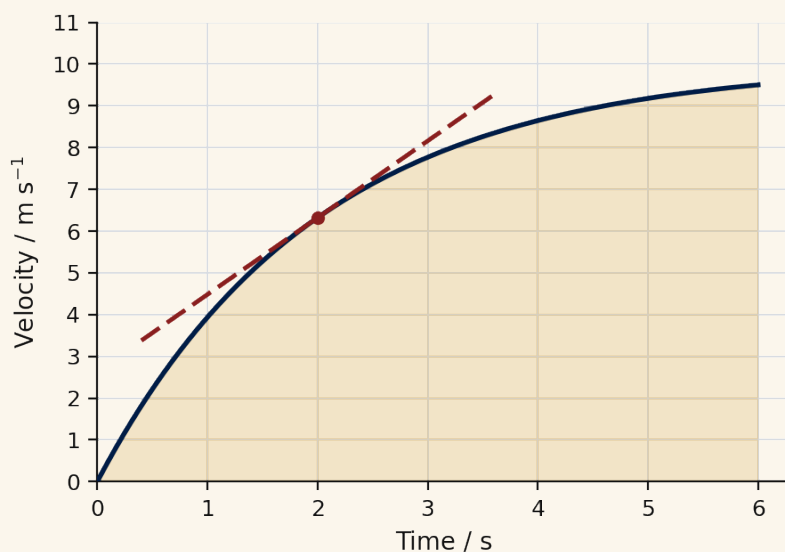
Displacement over an interval = **area under the curve** over that interval, estimated by counting grid squares or splitting it into thin strips (trapezia) and summing them.

Both methods involve reading a graph, so mark schemes accept a range of answers around the true value, not one exact number.

WORKED EXAMPLE

Instantaneous Gradient & Estimating Area Under a Curve

The curved velocity-time graph below shows a sprinter accelerating out of the blocks. A tangent has been drawn to the curve at $t = 2$ s. Use the graph to find (i) the sprinter's acceleration at $t = 2$ s, and (ii) the distance the sprinter covers in the first 6 s.



■ tangent at $t = 2$ s ■ shaded area $\rightarrow$ distance

Solution

- (i) Read two convenient points that lie on the **tangent line**, e.g. (0.4 s, 3.4 m s⁻¹) and (3.6 s, 9.2 m s⁻¹).
- Gradient = (change in v) $\div$ (change in t) = $(9.2 - 3.4) / (3.6 - 0.4) \approx 1.8 \text{ m s}^{-2}$ (accept any answer in the range 1.6–2.0 m s⁻², since this comes from reading a graph).
- (ii) Count the grid squares covered by the **shaded area** under the curve between $t = 0$ and $t = 6$ s (each 1 s $\times$ 1 m s⁻¹ square represents 1 m).
- This gives a total of approximately **41 squares**, i.e. $\approx 41 \text{ m}$ (accept any answer in the range 38–44 m).

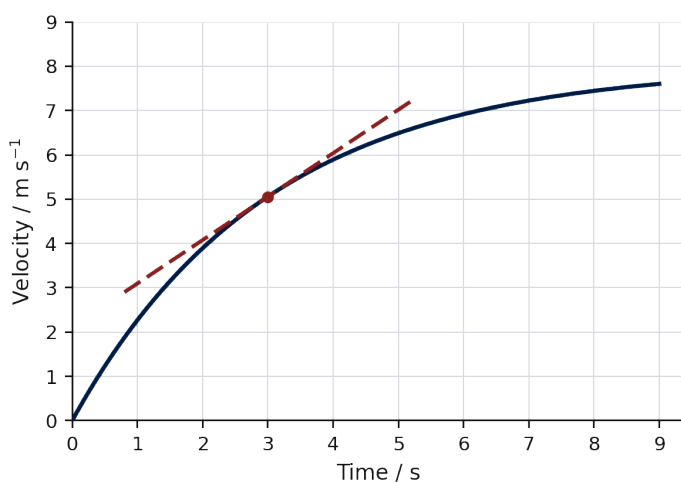
acceleration at $t = 2$ s $\approx 1.8 \text{ m s}^{-2}$ (range 1.6–2.0) distance in first 6 s $\approx 41 \text{ m}$ (range 38–44)



25.

ANSWER ›

The curved velocity-time graph below shows a motorbike accelerating away from a junction. A tangent has been drawn to the curve at $t = 3$ s.



(a) Use the tangent shown to estimate the motorbike's acceleration at $t = 3$ s.

(b) Estimate the distance travelled by the motorbike in the first 9 s.

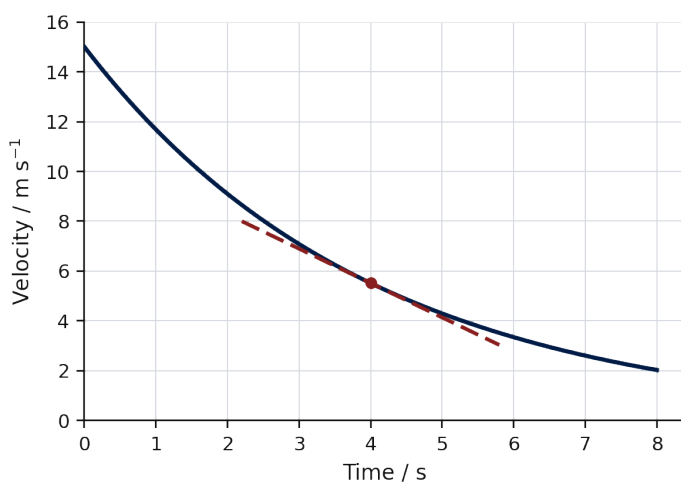
[2]

(Total for Question 25 = 4 marks)

26.

ANSWER ›

The curved velocity-time graph below shows a go-kart slowing down after its engine cuts out, with resistive forces acting on it. A tangent has been drawn to the curve at $t = 4$ s.



(a) Use the tangent shown to estimate the magnitude of the go-kart's deceleration at $t = 4$ s.

(b) Estimate the distance travelled by the go-kart in the first 8 s.

[2]



(Total for Question 26 = 4 marks)

I. Terminal Velocity: The Parachutist Problem

MEMORISE THIS

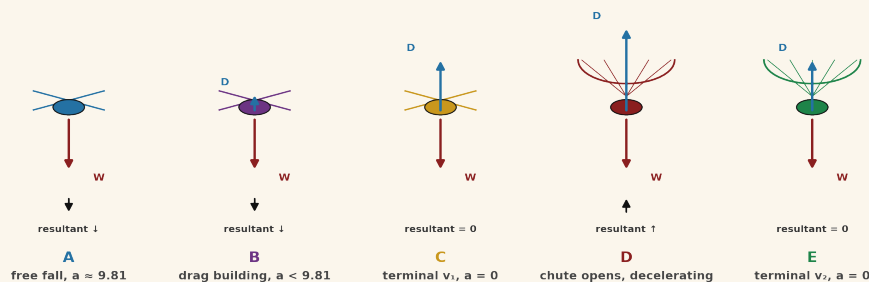
What Is Terminal Velocity?

- The instant an object begins to fall freely, drag is negligible — the only force acting is weight, so **acceleration $\approx g = 9.81 \text{ m s}^{-2}$** .
- As speed increases, **drag** (air resistance) increases too — this makes the resultant force (and so the acceleration) get smaller, even though it's still accelerating.
- Terminal velocity**: reached once drag = weight, so $\Sigma F = 0$.
- $\Sigma F = 0 \rightarrow$ (Newton's 2nd law) **$a = 0 \text{ m s}^{-2}$** $\rightarrow$ velocity constant.
- One fall can have TWO terminal velocities if something changes partway (e.g. parachute opens) — drag suddenly exceeds weight, giving a resultant force UPWARDS (deceleration), until a new, lower terminal velocity is reached.

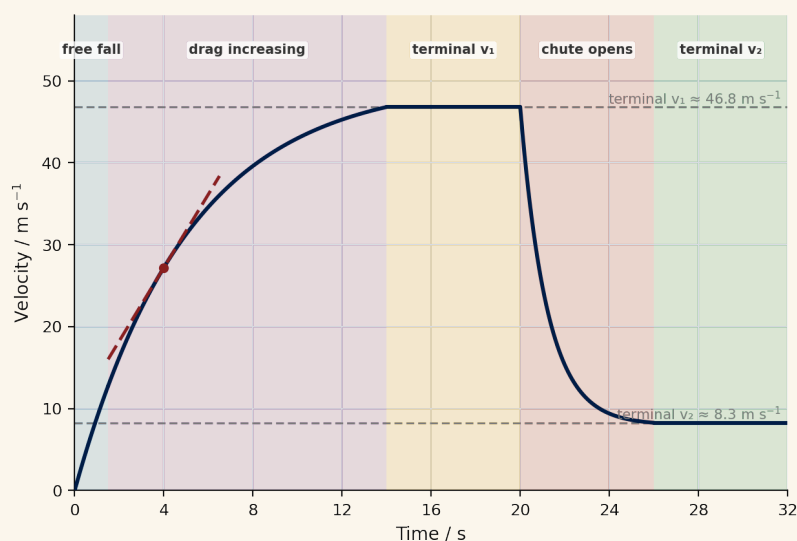
WORKED EXAMPLE

Terminal Velocity: Before and After the Parachute Opens

The velocity-time graph below shows a skydiver's velocity during a 32 s fall, from the moment they jump to the moment they land under an open parachute (downward taken as positive). Use the graph and the free-body diagrams to (i) describe the forces acting in each of the five highlighted stages, and (ii) use the tangent shown to estimate the skydiver's acceleration at $t = 4 \text{ s}$.



The five stages, A-E, matching the graph below (W = weight, D = drag).



Solution

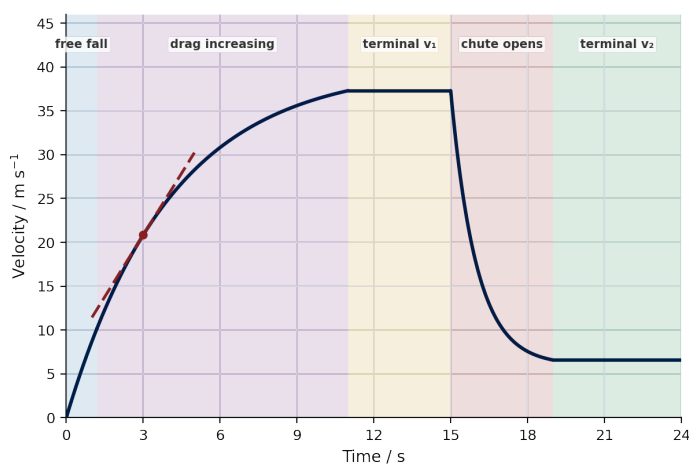
- A — Free fall** (just jumped): drag is negligible, so weight is the ONLY force, giving resultant = W (down), $a \approx 9.81 \text{ m s}^{-2}$.
- B — Drag increasing**: as speed builds, drag grows but is still less than weight — resultant force still downwards, but smaller, so $a < 9.81 \text{ m s}^{-2}$ (curve flattens).
- C — Terminal v_1** : drag has grown to equal weight, so $\Sigma F = 0$, $a = 0 \text{ m s}^{-2}$, constant velocity $\approx 47 \text{ m s}^{-1}$.
- D — Chute opens**: drag jumps to MORE than weight, so ΣF is now UPWARDS and the skydiver decelerates rapidly.
- E — Terminal v_2** : drag has fallen back to equal weight (at this lower speed), so $\Sigma F = 0$ once more, $a = 0 \text{ m s}^{-2}$, new constant velocity $\approx 8.3 \text{ m s}^{-1}$.
- (ii) Tangent at $t = 4 \text{ s} \rightarrow$ acceleration $\approx 4.5 \text{ m s}^{-2}$ (accept 4.0–4.9, reading off a graph).

Terminal velocity stages: $a = 0 \text{ m s}^{-2}$ ($\Sigma F = 0$). Acceleration at $t = 4 \text{ s} \approx 4.5 \text{ m s}^{-2}$ (range 4.0–4.9).

27.

ANSWER >

The velocity-time graph below shows a different skydiver's fall, from the moment they jump to the moment their parachute has fully opened and settled (the same five stages as the worked example, colour-matched).



(a) Use the tangent shown to estimate the skydiver's acceleration at $t = 3 \text{ s}$.



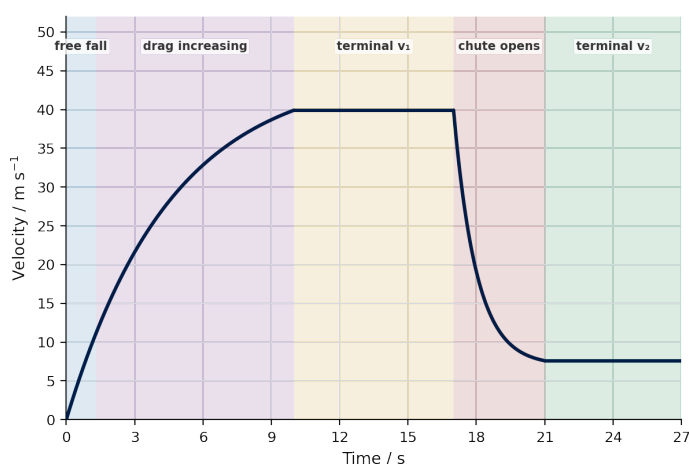
- (b) Estimate the distance fallen while the skydiver is at the first terminal velocity (11 s to 15 s). [2]

(Total for Question 27 = 4 marks)

28.

ANSWER >

The velocity-time graph below shows a third skydiver's fall, under a larger parachute that brings them to a slower, safer landing speed (the same five stages as the worked example, colour-matched).



- (a) Estimate the distance fallen while the skydiver is at the first terminal velocity (10 s to 17 s).

- (b) State the resultant force acting on the skydiver while at the second (lower) terminal velocity, from $t = 21$ s onwards, and explain your answer. [2]

(Total for Question 28 = 4 marks)



2.2 Equations of Uniformly Accelerated Motion (SUVAT)

A. The Four SUVAT Equations & Choosing the Right One

MEMORISE THIS

The Four SUVAT Equations

u = initial velocity, v = final velocity, a = acceleration, s = displacement, t = time -- all four equations assume **CONSTANT** acceleration. Each omits one of the five quantities: identify the one you don't need, then pick the matching equation.

Equation	Leaves out
$v = u + at$	s
$s = ut + \frac{1}{2}at^2$	v
$v^2 = u^2 + 2as$	t
$s = \frac{1}{2}(u + v)t$	a

WORKED EXAMPLE

Choosing the Right SUVAT Equation

A cyclist accelerates uniformly from rest to 8.0 m s^{-1} over a distance of 40 m. Calculate (i) her acceleration, and (ii) the time taken.

Solution

- Known: $u = 0$ (from rest), $v = 8.0 \text{ m s}^{-1}$, $s = 40 \text{ m}$. Want a ; t is unknown and not needed for (i), so use the equation that omits t : $v^2 = u^2 + 2as$.
- (i) $8.0^2 = 0^2 + 2 \times a \times 40 \rightarrow 64 = 80a \rightarrow a = 0.80 \text{ m s}^{-2}$.
- (ii) a is now known, so switch to the equation that omits s : $v = u + at$.
- $8.0 = 0 + 0.80 \times t \rightarrow t = 10 \text{ s}$.

acceleration = 0.80 m s^{-2} time = 10 s

29.

ANSWER >

A sprinter starts from rest and accelerates uniformly at 3.0 m s^{-2} for 4.0 s.

(a) Calculate her velocity at $t = 4.0 \text{ s}$.

[2]

(b) Calculate the distance she covers in this time.

[2]

(Total for Question 29 = 4 marks)



30.

ANSWER ›

A train travelling at 20 m s^{-1} brakes uniformly and comes to rest after travelling 250 m.

(a) Calculate the train's deceleration.

[2]

(b) Calculate the time taken for the train to stop.

[2]

(Total for Question 30 = 4 marks)

B. Applying SUVAT Vertically: Free Fall & Vertical Motion

MEMORISE THIS

Using SUVAT for Free Fall & Vertical Motion

- Free fall (ignoring air resistance) is just SUVAT with $a = g = 9.81 \text{ m s}^{-2}$, ALWAYS directed downwards.
- Choose a positive direction FIRST (downwards for a drop, upwards for a throw) and apply it consistently to every quantity.
- If up is positive, a thrown object has negative acceleration: it decelerates rising, is momentarily at rest at the top ($v = 0$), then accelerates back down.

WORKED EXAMPLE

A Stone Dropped From a Bridge

A stone is dropped from rest from a bridge and hits the water 2.5 s later ($g = 9.81 \text{ m s}^{-2}$, air resistance ignored, downwards positive). Calculate (i) its speed on impact, and (ii) the height of the bridge above the water.

Solution

- $u = 0$ (dropped from rest), $a = g = +9.81 \text{ m s}^{-2}$, $t = 2.5 \text{ s}$.
- (i) $v = u + at = 0 + (9.81 \times 2.5) = \mathbf{24.5 \text{ m s}^{-1}}$.
- (ii) $s = ut + \frac{1}{2}at^2 = 0 + (0.5 \times 9.81 \times 2.5^2) = \mathbf{30.7 \text{ m}}$.

impact speed = 24.5 m s^{-1} height of bridge = 30.7 m

31.

ANSWER ›

A ball is thrown vertically downwards from a tall building with an initial speed of 5.0 m s^{-1} ($g = 9.81 \text{ m s}^{-2}$, taking downwards as positive).

(a) Calculate the ball's speed after falling for 3.0 s.

[2]



(b) Calculate the distance fallen in this time.

[2]

(Total for Question 31 = 4 marks)

32.

ANSWER ›

A stone is thrown vertically upwards at 12 m s^{-1} from the edge of a cliff ($g = 9.81 \text{ m s}^{-2}$, taking upwards as positive).

(a) Calculate the maximum height reached above the point of release.

[3]

(b) Calculate the time taken to reach this maximum height.

[2]

(Total for Question 32 = 5 marks)



2.3 Scalars, Vectors & Resolving Vectors

A. Scalars vs Vectors & Adding Perpendicular Vectors

MEMORISE THIS

Scalars vs Vectors

A scalar has magnitude only. A vector has BOTH magnitude and direction.

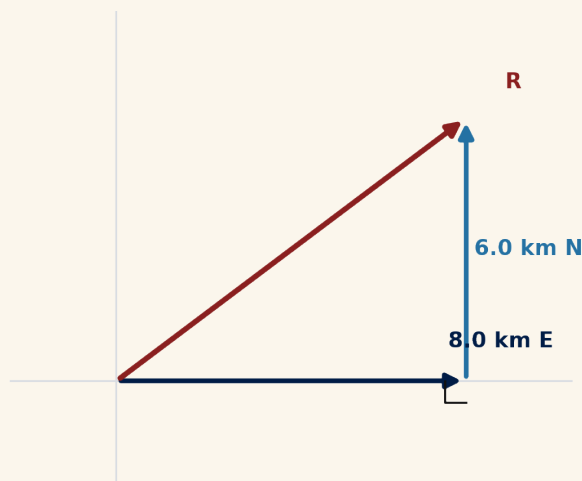
- Two perpendicular vectors combine into a resultant via **Pythagoras** (magnitude) and **tan** (direction), forming a right-angled triangle.

Scalars	Vectors
distance, speed, mass, energy, time, temperature, density	displacement, velocity, acceleration, force, momentum, weight

WORKED EXAMPLE

Adding Two Perpendicular Vectors

A hiker walks 8.0 km due east, then 6.0 km due north. Calculate the magnitude and direction of her resultant displacement.



Solution

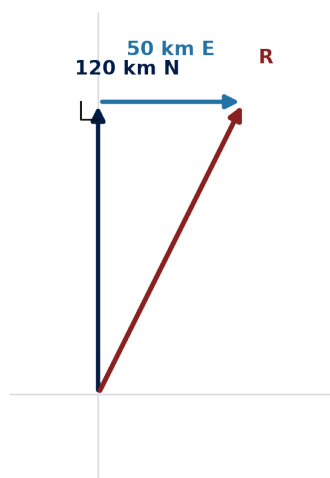
- The two displacements are perpendicular, forming a right-angled triangle with resultant R as the hypotenuse.
- Magnitude: $R = \sqrt{(8.0^2 + 6.0^2)} = \sqrt{(64 + 36)} = \sqrt{100} = 10 \text{ km}$.
- Direction: $\tan \theta = \text{opposite} / \text{adjacent} = 6.0 / 8.0 \rightarrow \theta = \tan^{-1}(0.75) = 36.9^\circ \text{ north of east}$.

resultant displacement = 10 km, at 36.9° north of east

33.

ANSWER ›

A light aircraft flies 120 km due north, then 50 km due east.



(a) Calculate the magnitude of the aircraft's resultant displacement.

(b) Calculate the direction of the resultant displacement, relative to north.

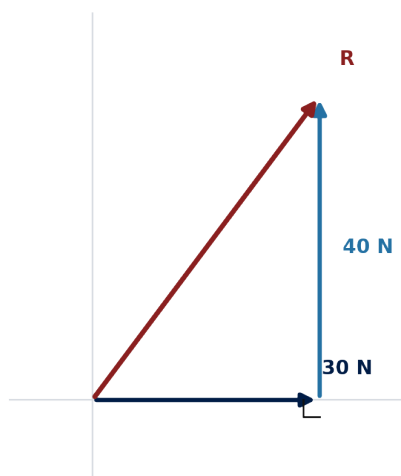
[2]

(Total for Question 33 = 4 marks)

34.

ANSWER ›

Two forces act on a hook: 30 N to the right and 40 N vertically upward.



(a) Calculate the magnitude of the resultant force.

(b) Calculate the angle the resultant makes with the 30 N force.

[2]

(Total for Question 34 = 4 marks)

B. Resolving a Vector Into Components

MEMORISE THIS

Resolving a Vector Into Components

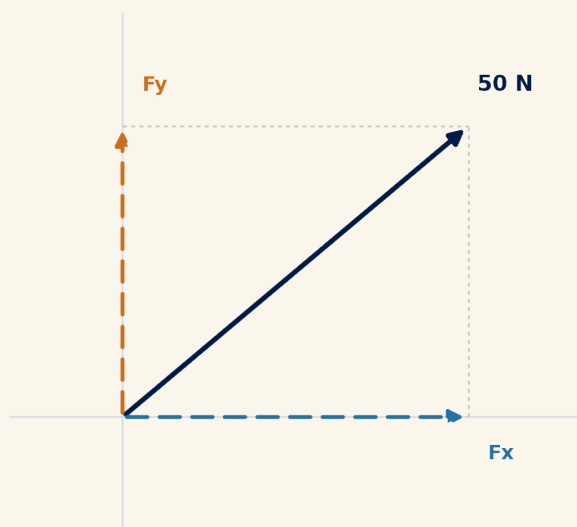
Any vector can be split into two perpendicular components, usually horizontal and vertical.

Component	Formula (θ measured from the horizontal)
Horizontal	$F_x = F \cos\theta$
Vertical	$F_y = F \sin\theta$

WORKED EXAMPLE

Resolving a Force Into Components

A force of 50 N acts at 40° above the horizontal. Calculate its horizontal and vertical components.



■ $F_x = F \cos\theta$ ■ $F_y = F \sin\theta$

Solution

- Horizontal: $F_x = F \cos\theta = 50 \times \cos 40^\circ = \mathbf{38.3 \text{ N}}$.
- Vertical: $F_y = F \sin\theta = 50 \times \sin 40^\circ = \mathbf{32.1 \text{ N}}$.
- Check: $\sqrt{(38.3^2 + 32.1^2)} = \sqrt{(1467 + 1030)} \approx 50 \text{ N} \checkmark$, confirming the components recombine to the original force.

$F_x = 38.3 \text{ N}$ $F_y = 32.1 \text{ N}$

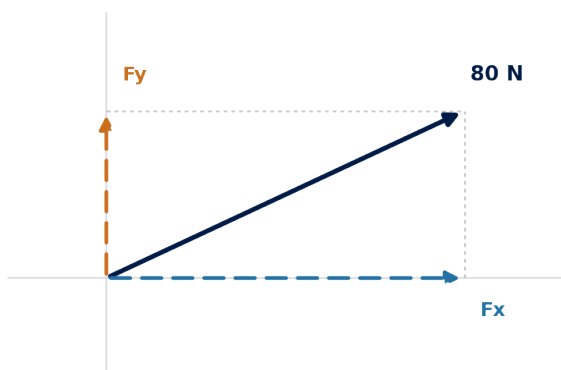


35.

ANSWER ›

A rope pulls a sledge with a tension of 80 N, at 25° above the horizontal.

(a) Calculate the horizontal component of the tension.



(b) Calculate the vertical component of the tension.

[2]

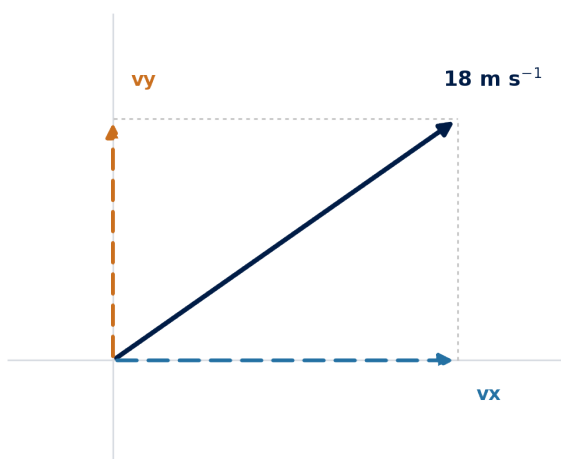
(Total for Question 35 = 4 marks)

36.

ANSWER ›

A ball is kicked with a velocity of 18 m s^{-1} , at 35° above the horizontal.

(a) Calculate the horizontal component of the ball's velocity.



(b) Calculate the vertical component of the ball's velocity.

[2]

(Total for Question 36 = 4 marks)



C. Adding Vectors by Calculation (Non-Perpendicular)

MEMORISE THIS

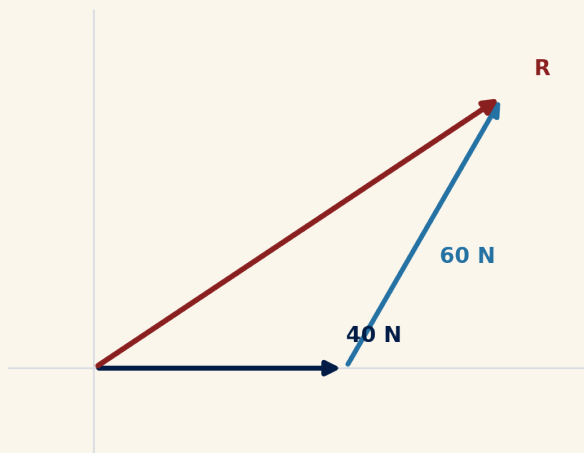
Adding Non-Perpendicular Vectors by Calculation

- Resolve EACH vector into horizontal and vertical components first.
- Add the horizontal components together, and the vertical components together, separately.
- Recombine the totals with Pythagoras (magnitude) and tan (direction), as in Section A.

WORKED EXAMPLE

Adding Two Vectors at an Angle to Each Other

Two forces act on a ring: 40 N horizontal, and 60 N at 60° above the horizontal. Calculate the magnitude and direction of the resultant force.



Solution

1. Resolve each force into components. 40 N is horizontal: $F_x = 40$, $F_y = 0$. 60 N: $F_x = 60\cos 60^\circ = 30$, $F_y = 60\sin 60^\circ = 52.0$.
2. Total horizontal: $40 + 30 = 70$ N. Total vertical: $0 + 52.0 = 52.0$ N.
3. Magnitude: $R = \sqrt{70^2 + 52.0^2} = \sqrt{4900 + 2700} = \mathbf{87.2 \text{ N}}$.
4. Direction: $\theta = \tan^{-1}(52.0 / 70) = \mathbf{36.6^\circ \text{ above the } 40 \text{ N force}}$.

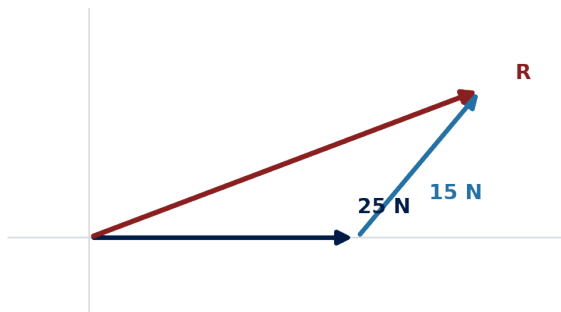
resultant force = 87.2 N, at 36.6° above the 40 N force

37.

ANSWER ›

Two forces act on an object: 25 N due east, and 15 N at 50° north of east.

(a) Calculate the magnitude of the resultant force.



(b) Calculate the direction of the resultant force, relative to east.

[2]

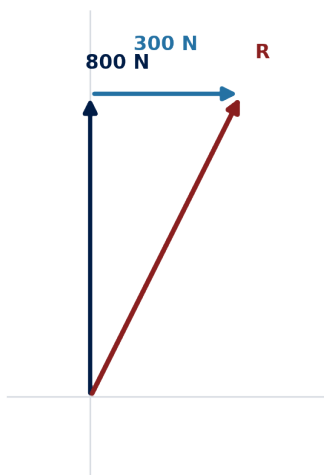
(Total for Question 37 = 5 marks)

38.

ANSWER ›

A boat's engine produces a thrust of 800 N due north, while the current exerts 300 N due east on the hull.

(a) Calculate the magnitude of the resultant force on the boat.



(b) Calculate the direction of the resultant force, relative to north.

[2]

(Total for Question 38 = 4 marks)



2.4 Projectile Motion

A. Horizontal Projection (Launched Off a Height)

MEMORISE THIS

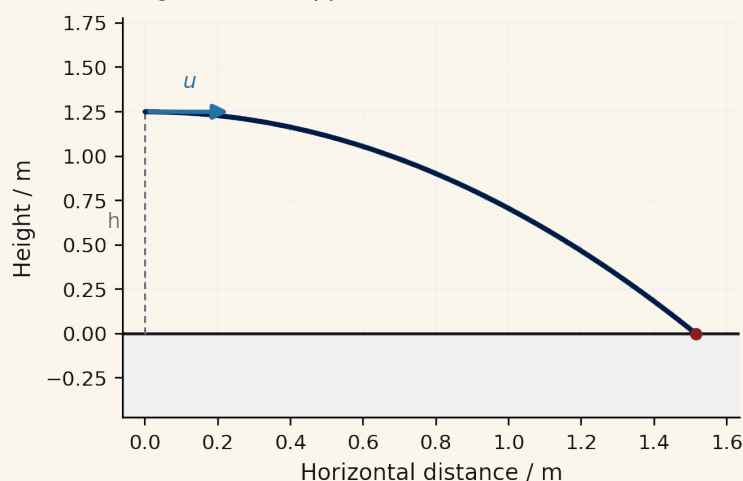
Horizontal & Vertical Motion Are Independent

- Horizontal and vertical motion happen at the SAME time but don't affect each other (ignoring air resistance).
- Horizontal:** no horizontal force, so velocity is CONSTANT: speed = distance / time.
- Vertical:** free fall, $a = g = 9.81 \text{ m s}^{-2}$; use ordinary SUVAT.
- TIME OF FLIGHT depends only on the vertical drop: find it first from the vertical SUVAT equation, then use it in the horizontal equation.

WORKED EXAMPLE

A Ball Rolling Off a Table

A ball rolls off a table 1.25 m high with a horizontal velocity of 3.0 m s^{-1} . Calculate (i) the time taken to reach the ground, and (ii) the horizontal distance travelled.



Solution

- (i) Vertical motion only: $s = ut + \frac{1}{2}at^2$, with $u = 0$, $a = g = 9.81$, $s = 1.25 \text{ m}$.
- $1.25 = 0 + (0.5 \times 9.81 \times t^2) \rightarrow t^2 = 0.2548 \rightarrow t = 0.505 \text{ s}$.
- (ii) Horizontal motion only: constant velocity, so distance = speed $\times$ time = $3.0 \times 0.505 = 1.51 \text{ m}$.

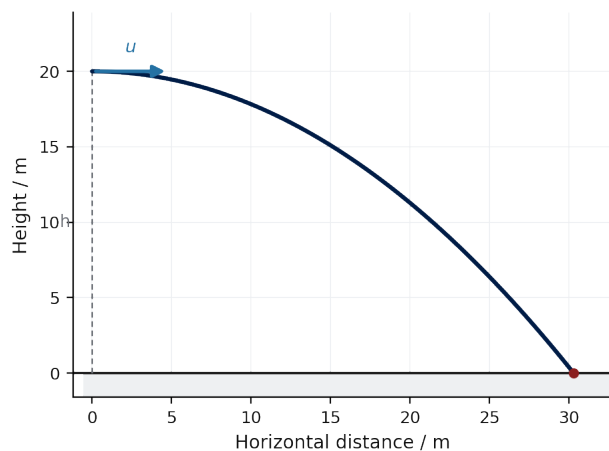
time of flight = 0.505 s | horizontal distance = 1.51 m



39.

ANSWER ›

A stone is thrown horizontally from the top of a 20 m cliff with a speed of 15 m s^{-1} .



(a) Calculate the time taken for the stone to hit the ground.

(b) Calculate the horizontal distance travelled by the stone.

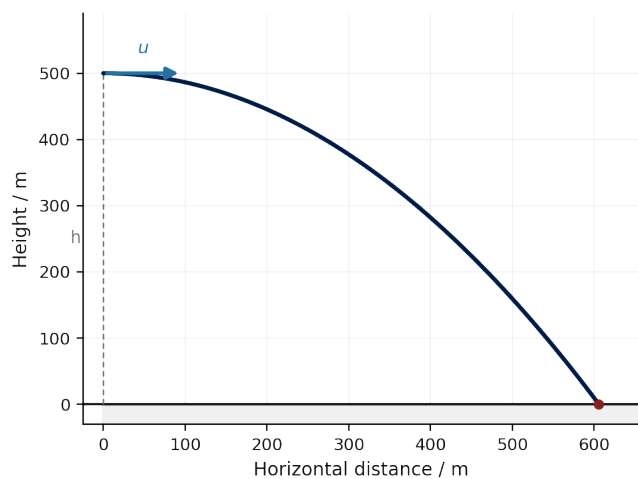
[2]

(Total for Question 39 = 4 marks)

40.

ANSWER ›

A plane flying horizontally at a height of 500 m, at a speed of 60 m s^{-1} , drops a supply package.



(a) Calculate the time taken for the package to reach the ground.

(b) Calculate the horizontal distance between the drop point and the package's landing point.

[2]

(Total for Question 40 = 4 marks)



B. Projectiles Launched at an Angle

MEMORISE THIS

Projectiles Launched at an Angle

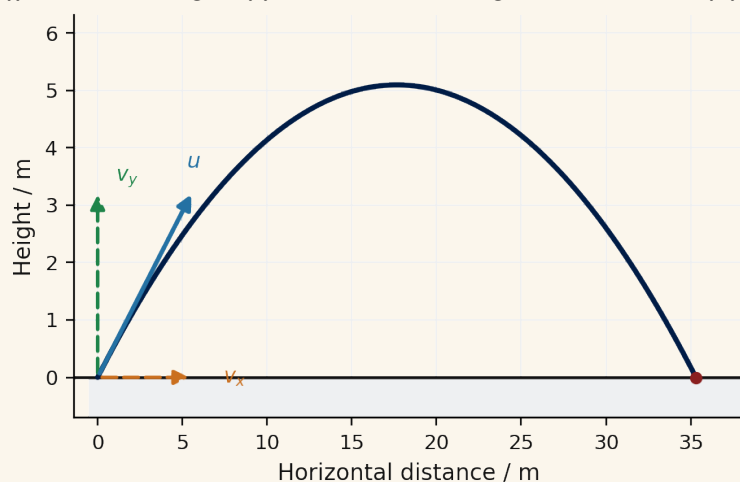
Resolve launch velocity u into components first (Topic 2.3, Section B), then treat horizontal and vertical motion separately, as in Section A.

Quantity (launch & landing at the SAME height)	Formula
Horizontal component	$u_x = u \cos\theta$
Vertical component	$u_y = u \sin\theta$
Time of flight	$t = 2u_y / g$
Maximum height	$h_{\max} = u_y^2 / (2g)$
Horizontal range	$\text{range} = u_x \times t$

WORKED EXAMPLE

A Ball Kicked at an Angle

A ball is kicked with a velocity of 20 m s^{-1} at 30° above the horizontal, from level ground. Calculate (i) the time of flight, (ii) the maximum height reached, and (iii) the horizontal range.



■ u = launch velocity

Solution

- Resolve: $u_x = 20\cos 30^\circ = 17.3 \text{ m s}^{-1}$, $u_y = 20\sin 30^\circ = 10.0 \text{ m s}^{-1}$.
- (i) Time of flight: $t = 2u_y / g = (2 \times 10.0) / 9.81 = \mathbf{2.04 \text{ s}}$.
- (ii) Maximum height: $h_{\max} = u_y^2 / (2g) = 10.0^2 / (2 \times 9.81) = \mathbf{5.10 \text{ m}}$.
- (iii) Range = $u_x \times t = 17.3 \times 2.04 = \mathbf{35.3 \text{ m}}$.

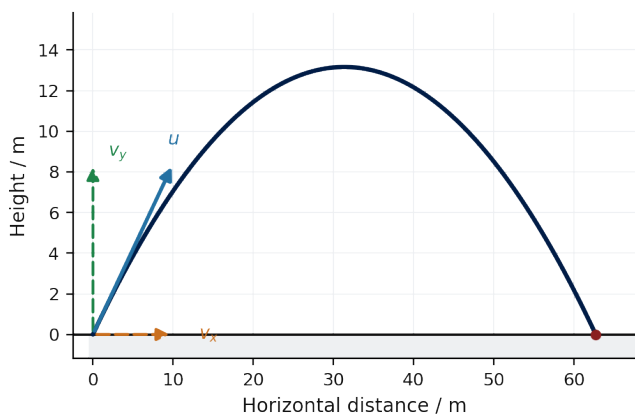
time of flight = 2.04 s | max height = 5.10 m | range = 35.3 m



41.

ANSWER ›

A javelin is thrown at 25 m s^{-1} , at 40° above the horizontal, and lands at the same height it was thrown from.



(a) Calculate the javelin's time of flight.

(b) Calculate the horizontal range achieved.

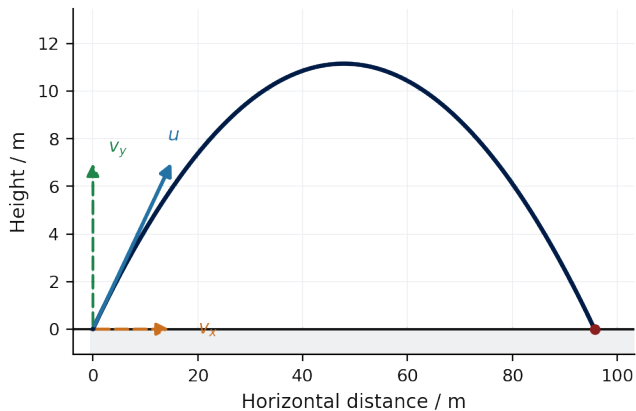
[2]

(Total for Question 41 = 5 marks)

42.

ANSWER ›

A golf ball is struck at 35 m s^{-1} , at 25° above the horizontal.



(a) Calculate the maximum height reached by the ball.

(b) Calculate the horizontal range of the ball (it lands at the same height it was struck from).

[3]

(Total for Question 42 = 6 marks)



C. Projectiles Launched at an Angle From a Height

MEMORISE THIS

Projectiles Launched at an Angle From a Height

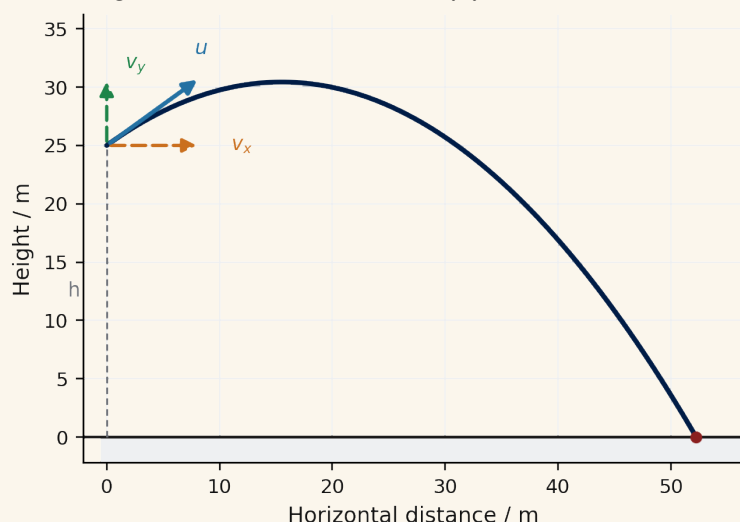
$s = u_y t - \frac{1}{2}gt^2$ (up positive). When launch and landing heights differ, $s \neq 0$, so $t = 2u_y/g$ no longer applies: solve the quadratic instead.

- Landing BELOW the launch point (e.g. a cliff or bridge): $s = -h$ (the drop) when it lands. Substitute into $s = u_y t - \frac{1}{2}gt^2$ and solve the quadratic for t .
- Maximum height above the LAUNCH point is still $u_y^2 / (2g)$; add the launch height h to get the height above the ground/river/field: $h_{\max} = h + u_y^2 / (2g)$.
- The projectile keeps travelling horizontally at constant u_x throughout, even as it falls back past the launch height to the ground below.

WORKED EXAMPLE

A Projectile Launched at an Angle From a Cliff

A ball is thrown from the top of a cliff, 25 m above the sea, with a velocity of 18 m s^{-1} at 35° above the horizontal. Calculate (i) the maximum height above the sea reached by the ball, (ii) the total time of flight until it hits the sea, and (iii) the horizontal distance travelled.



Solution

- Resolve: $u_x = 18\cos 35^\circ = 14.7 \text{ m s}^{-1}$, $u_y = 18\sin 35^\circ = 10.3 \text{ m s}^{-1}$.
- (i) Extra height above the launch point $= u_y^2 / (2g) = 10.3^2 / (2 \times 9.81) = 5.43 \text{ m}$; $h_{\max} = 25 + 5.43 = 30.4 \text{ m}$ above the sea.
- (ii) Time of flight: taking up as positive, $s = -25 \text{ m}$ when it lands: $-25 = 10.3t - 4.905t^2 \rightarrow 4.905t^2 - 10.3t - 25 = 0 \rightarrow t = [10.3 + \sqrt{(10.3)^2 + 4 \times 4.905 \times 25}] / (2 \times 4.905) = 3.54 \text{ s}$.
- (iii) Range $= u_x \times t = 14.7 \times 3.54 = 52.2 \text{ m}$.

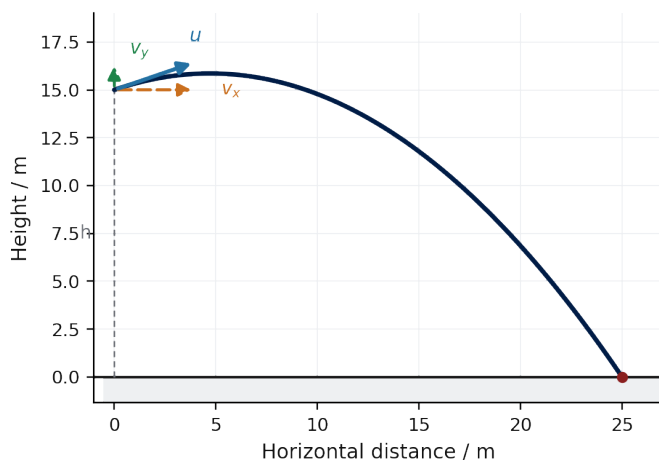
max height $\approx 30.4 \text{ m}$ above the sea; time of flight $\approx 3.54 \text{ s}$; horizontal distance $\approx 52.2 \text{ m}$



43.

ANSWER ›

A stone is thrown from a bridge, 15 m above a river, with a velocity of 12 m s^{-1} at 20° above the horizontal.



(a) Show that the vertical component of the stone's initial velocity is 4.10 m s^{-1} .

(b) Calculate the maximum height of the stone above the river.

[2]

(c) Calculate the total time of flight and the horizontal distance travelled before the stone hits the water.

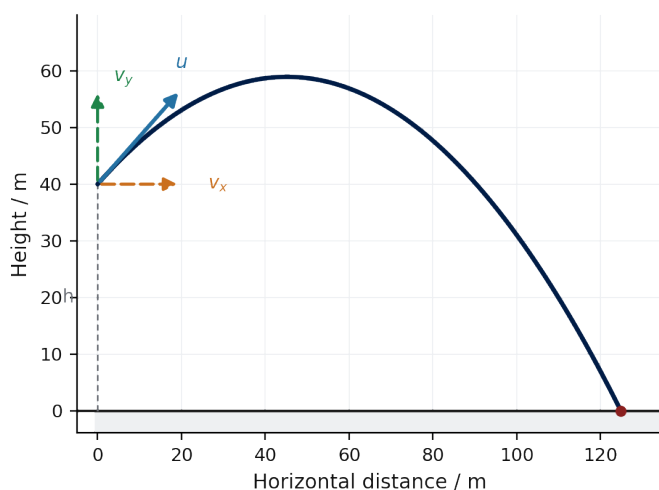
[4]

(Total for Question 43 = 7 marks)

44.

ANSWER ›

A drone is launched from the top of a hill, 40 m above a flat field, with a velocity of 30 m s^{-1} at 40° above the horizontal, before its motor fails and it falls freely.



(a) Calculate the horizontal and vertical components of the launch velocity.

(b) Calculate the maximum height reached above the field.

[2]



- (c) Calculate the total time of flight and the horizontal distance travelled before the drone lands in the field. [4]

(Total for Question 44 = 8 marks)

D. Projectiles Hitting a Raised Target

MEMORISE THIS

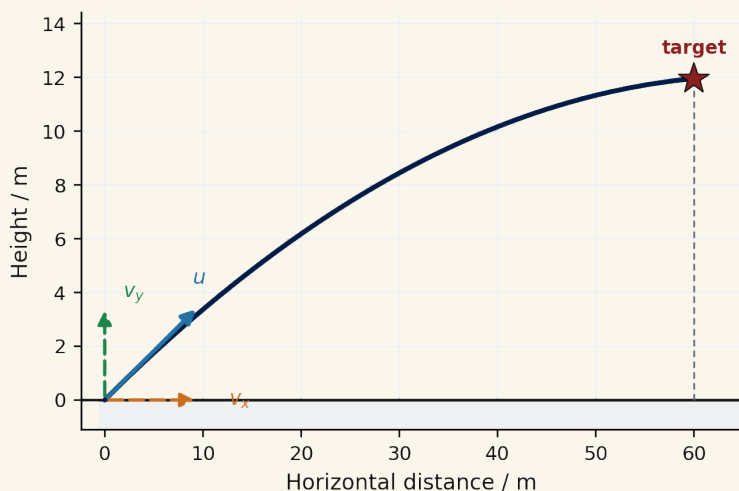
Projectiles Hitting a Raised Target

- To check whether a projectile reaches a target at horizontal distance x_t , first find the time to get there: $t = x_t / u_x$ (horizontal motion is unaffected by the target).
- Then find the projectile's height at that instant: $y = u_y t - \frac{1}{2}gt^2$ (up positive, from the launch point), and compare to the target's height to see whether it's hit, cleared, or missed.
- A target ABOVE the ground is only reached if the projectile is still in flight at that time: check t is less than the total time of flight.

WORKED EXAMPLE

Does the Arrow Clear the Wall?

An archer fires an arrow at 45 m s^{-1} , at 20° above the horizontal, towards a castle wall 60 m away. Show that the arrow reaches the wall at a height of 12.0 m, and state whether it clears a wall of height 12.0 m.



Solution

- Resolve: $u_x = 45 \cos 20^\circ = 42.3 \text{ m s}^{-1}$, $u_y = 45 \sin 20^\circ = 15.4 \text{ m s}^{-1}$.
- Time to reach the wall: $t = x / u_x = 60 / 42.3 = 1.42 \text{ s}$.
- Height at that time: $y = u_y t - \frac{1}{2}gt^2 = (15.4 \times 1.42) - (0.5 \times 9.81 \times 1.42^2) = 21.8 - 9.88 = 12.0 \text{ m}$.



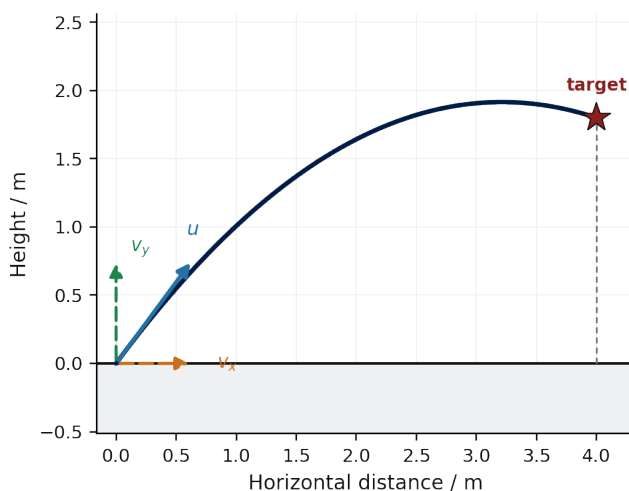
4. Since $y = 12.0$ m equals the wall's height, the arrow JUST clears (grazes) the top.

height at the wall ≈ 12.0 m; the arrow just clears it

45.

ANSWER >

A ball is thrown at 8.0 m s^{-1} , at 50° above the horizontal, towards a target ring 4.0 m away.



(a) Calculate the horizontal and vertical components of the ball's initial velocity.

(b) Calculate the time taken for the ball to travel the 4.0 m horizontal distance to the ring.

[2]

(c) Calculate the height of the ball at this time, and state whether it passes through the ring if the ring is mounted 1.80 m above the ground.

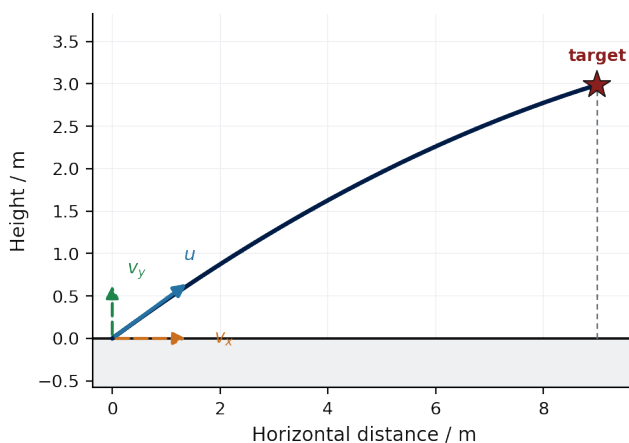
[3]

(Total for Question 45 = 7 marks)

46.

ANSWER >

A football is kicked at 20 m s^{-1} , at 25° above the horizontal, towards a wall 9.0 m away.



(a) Calculate the time taken for the ball to reach the wall.



(b) Calculate the height of the ball when it reaches the wall.

[2]

(c) The wall is 2.5 m high. State, with a reason, whether the ball goes over the wall.

[2]

(Total for Question 46 = 6 marks)



2.5 Forces, Free-Body Diagrams & Newton's Laws

A. Triangle of Forces: Checking Equilibrium

MEMORISE THIS

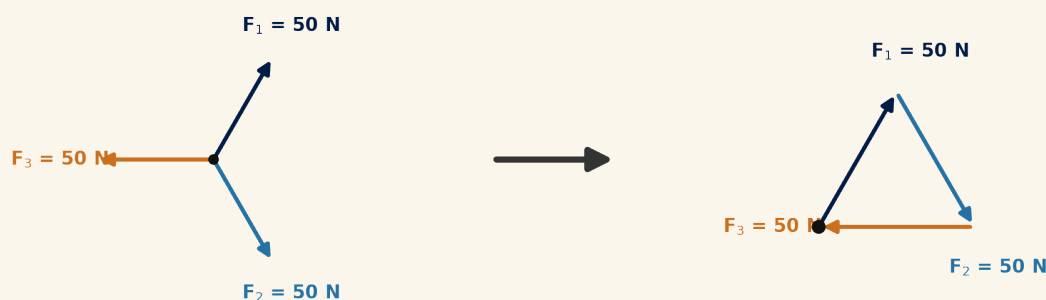
The Triangle (Polygon) of Forces

- Redraw the forces **tip to tail** (the head of one vector joins the tail of the next), keeping each one's own length and direction.
- If the vectors form a **closed shape** (the last one's tip lands back on the first one's tail), the forces are balanced and the object is in **equilibrium**: $\Sigma \mathbf{F} = \mathbf{0}$.
- If they do NOT close up, the gap left over IS the resultant force, and the object is NOT in equilibrium: $\Sigma \mathbf{F} \neq \mathbf{0}$.
- This works for any number of forces, not just two.

WORKED EXAMPLE

Checking Equilibrium With a Triangle of Forces

Three forces act on a ring, as shown on the left below. By redrawing them tip to tail (right), determine whether the ring is in equilibrium.



Closed loop — object IS in equilibrium

Solution

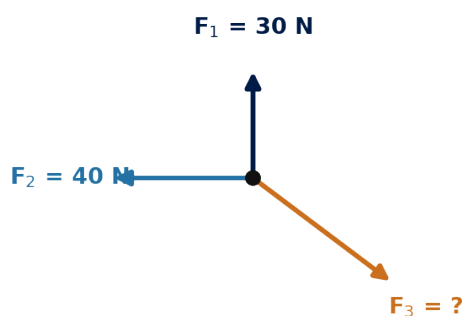
1. Redraw F_1 , then from its tip draw F_2 , then from its tip draw F_3 — each keeping its own length and direction unchanged.
2. The three vectors form a **closed triangle**: the tip of F_3 lands back exactly on the tail of F_1 .
3. A closed vector diagram means the forces have **no resultant**.

closed triangle $\rightarrow \Sigma \mathbf{F} = \mathbf{0} \rightarrow$ the ring IS in equilibrium

47.

ANSWER ›

Three forces act at a single point on a ring: $F_1 = 30\text{ N}$ vertically upward, $F_2 = 40\text{ N}$ horizontally to the left, and F_3 , acting as shown below.



- (a) By drawing a vector diagram, placing the forces tip to tail in the order F_1 , F_2 , F_3 , show that the diagram forms a closed triangle. [3]

- (b) State what this closed triangle tells you about the resultant force on the ring. [1]

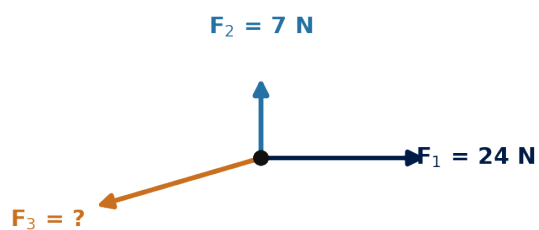
(Total for Question 47 = 4 marks)



48.

ANSWER ›

Three forces act at a point: $F_1 = 24\text{ N}$ horizontally, $F_2 = 7\text{ N}$ vertically upward, and F_3 , acting as shown below.



(a) Show, by calculation, that the resultant of F_1 and F_2 has a magnitude of 25 N .

[2]

(b) Given that $F_3 = 25\text{ N}$, explain why the three forces are in equilibrium.

[2]

(Total for Question 48 = 4 marks)



B. Triangle of Forces: Non-Equilibrium & the Resultant

MEMORISE THIS

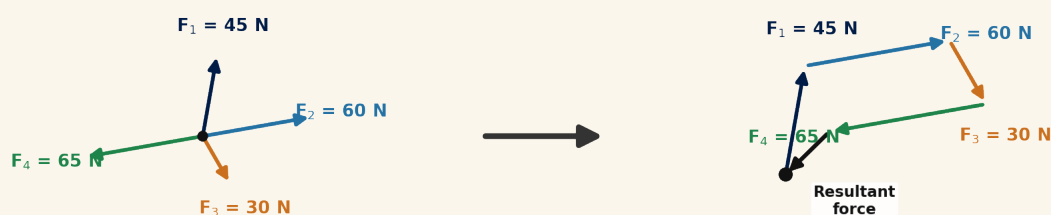
Non-Equilibrium: The Resultant Is the Missing Side

- If the forces, drawn tip to tail, do NOT form a closed shape, the gap between the start of the first vector and the end of the last IS the resultant force: **R**.
- **R** is found by drawing (or calculating) the single vector that closes the diagram, from the tail of the first force to the tip of the last.
- The **equilibrant** is the extra force that would bring the object into equilibrium: equal in magnitude to R, opposite in direction: $\mathbf{F}_{\text{equilibrant}} = -\mathbf{R}$.

WORKED EXAMPLE

Identifying Non-Equilibrium and Finding the Resultant

Four forces act on a boat's mooring ring: $F_1 = 45\text{ N}$, $F_2 = 60\text{ N}$, $F_3 = 30\text{ N}$ and $F_4 = 65\text{ N}$, in the directions shown below. By drawing them tip to tail, show that the ring is NOT in equilibrium.



Gap left — object is NOT in equilibrium

Solution

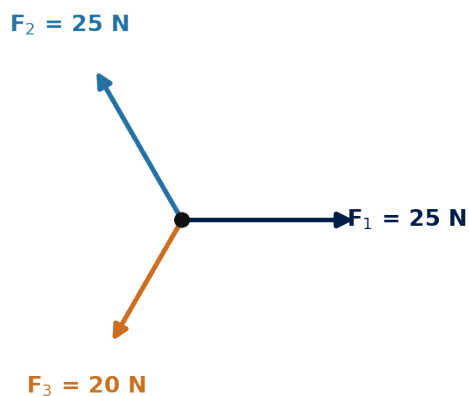
1. Redraw F_1 , F_2 , F_3 , F_4 tip to tail, in order, each keeping its own length and direction.
2. The tip of F_4 does NOT return to the tail of F_1 — there is a clear gap, so $\Sigma \mathbf{F} \neq \mathbf{0}$ and the ring is NOT in equilibrium. The gap itself IS the resultant force, **R**.

open (non-closed) diagram $\rightarrow \Sigma \mathbf{F} \neq \mathbf{0} \rightarrow$ the ring is NOT in equilibrium

49.

ANSWER >

Three forces act at a point: $F_1 = 25\text{ N}$ horizontally, $F_2 = 25\text{ N}$ at 120° to F_1 , and $F_3 = 20\text{ N}$ at 240° to F_1 , as shown below.



- (a) By drawing the forces tip to tail, show that the point is NOT in equilibrium, then draw in the resultant force needed to close the diagram. [2]

- (b) By scale drawing (or calculation), estimate the magnitude and direction of the resultant force. [3]

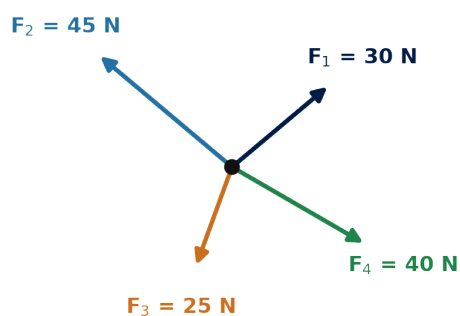
(Total for Question 49 = 5 marks)
--



50.

ANSWER ›

Four forces act at a point: $F_1 = 30\text{ N}$ at 40° above the horizontal, $F_2 = 45\text{ N}$ at 140° , $F_3 = 25\text{ N}$ at 250° , and $F_4 = 40\text{ N}$ at 330° , as shown below.



- (a) By drawing the forces tip to tail, show that the point is NOT in equilibrium, then draw in the resultant force needed to close the diagram. [2]

- (b) By scale drawing (or calculation), estimate the magnitude and direction of the resultant force. [3]

(Total for Question 50 = 5 marks)
--



C. Scale Diagrams for Resultant Forces

MEMORISE THIS

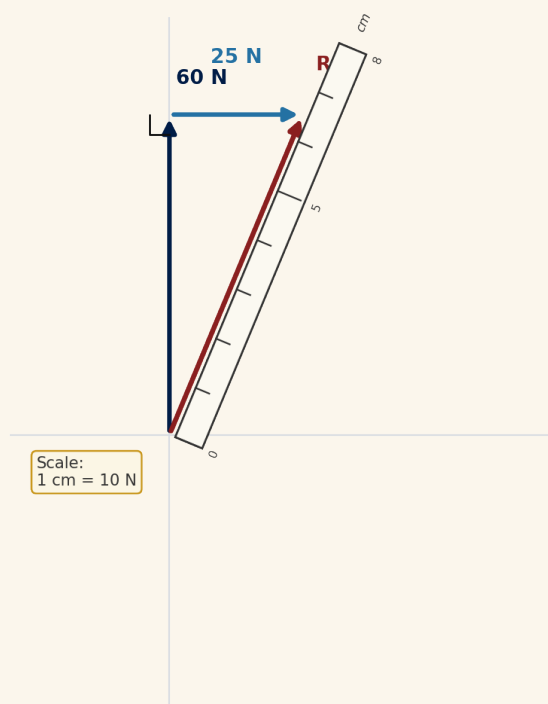
Finding a Resultant by Scale Drawing

- Choose a sensible scale (e.g. 1 cm = 10 N) so the diagram fits neatly on the page.
- Using a ruler and protractor, draw the first force as an accurately measured, accurately angled line.
- From its tip, draw the second force tip to tail, to the same scale.
- The resultant is the line from the START of the first force to the END of the last: measure its length (convert back using the scale) and its angle (with a protractor).

WORKED EXAMPLE

Finding a Resultant by Scale Drawing

A force of 60 N acts vertically and a force of 25 N acts horizontally on the same point. Using a scale of 1 cm = 10 N, find the magnitude of the resultant force, and check your scale drawing by calculation.



Solution

1. Draw the 60 N force vertically, to scale — a line 6.0 cm long (1 cm = 10 N).
2. From its tip, draw the 25 N force horizontally, to scale — a line 2.5 cm long.
3. The resultant, R, is the line from the start of the 60 N force to the end of the 25 N force. Measuring it gives $R \approx 6.5$ cm, i.e. $R \approx 65$ N.
4. Check by calculation (Pythagoras, since the two forces are perpendicular): $R = \sqrt{60^2 + 25^2} = \sqrt{4225} = 65.0$ N ✓ matches the scale drawing.

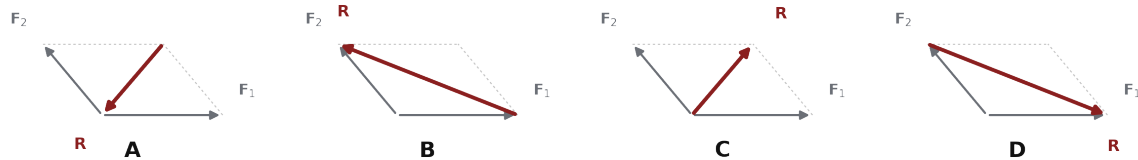
resultant ≈ 65 N (found by scale drawing, confirmed by calculation)



51.

ANSWER >

Two forces, $F_1 = 50 \text{ N}$ and $F_2 = 40 \text{ N}$, act on the same point, with F_2 at 130° to F_1 . Four students have each drawn a vector diagram to find the resultant force, R , by placing the forces tip to tail — but only ONE diagram is correct.



(a) State which diagram, A, B, C or D, correctly shows the resultant force R . [1]

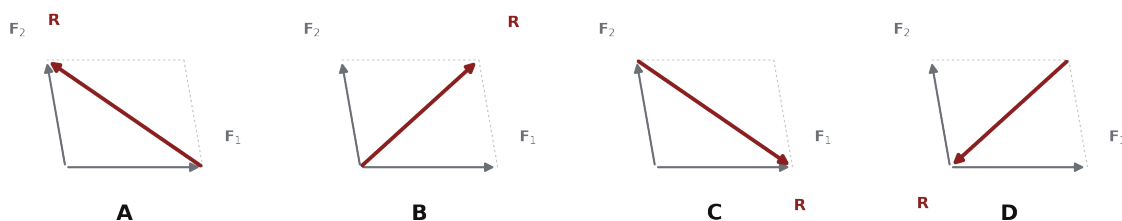
(b) Explain what is wrong with ONE of the other three diagrams. [2]

(Total for Question 51 = 3 marks)

52.

ANSWER >

Two forces, $F_1 = 45 \text{ N}$ and $F_2 = 35 \text{ N}$, act on the same point, with F_2 at 100° to F_1 . Four possible vector diagrams for the resultant force, R , are shown below.



(a) State which diagram, A, B, C or D, correctly shows the resultant force R . [1]

(b) Explain what is wrong with ONE of the other three diagrams. [2]

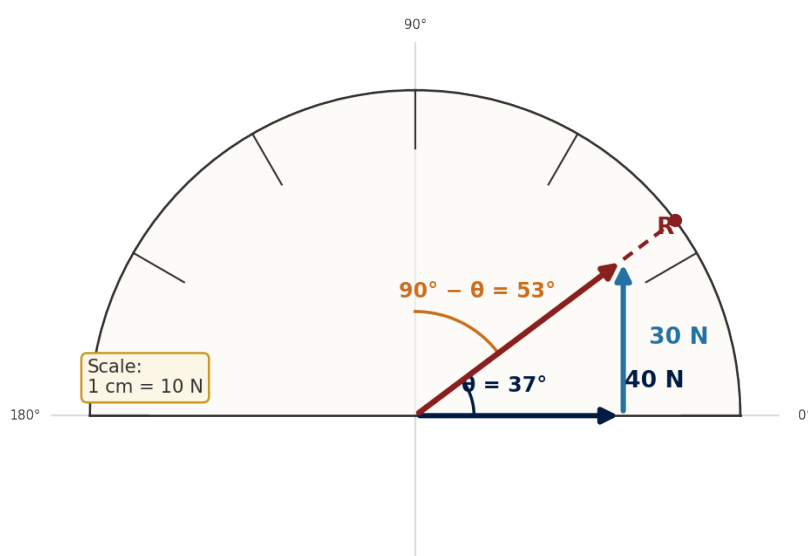
(Total for Question 52 = 3 marks)



53.

ANSWER >

A force of 40 N acts due East and a force of 30 N acts due North on the same point, as shown. Using a scale of 1 cm = 10 N, draw a scale diagram to find the resultant force, R.



(a) By scale drawing, find the magnitude of R.

[2]

(b) By protractor, find the angle R makes with the horizontal (the 40 N force).

[2]

(c) Hence, WITHOUT taking a further measurement, state the angle R makes with the vertical.

[1]

(Total for Question 53 = 5 marks)



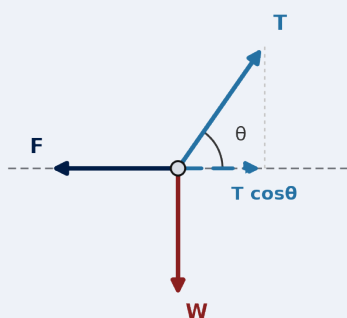
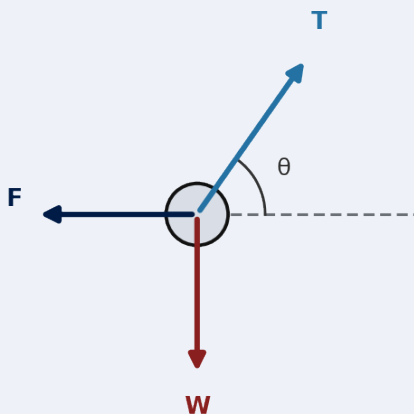
D. Resolving Forces in Equilibrium

MEMORISE THIS

Resolving at an Angle: Which One Is Sin, Which Is Cos?

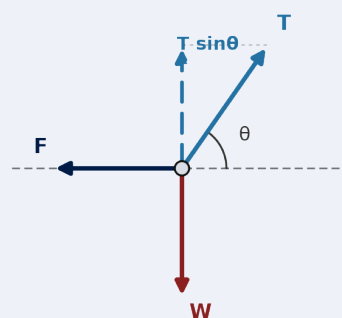
in equilibrium: $\Sigma F_x = 0$ and $\Sigma F_y = 0$, the forces in EVERY direction must sum to zero

- A pendulum bob is held in equilibrium by a horizontal force F . Weight W acts down, and tension T pulls towards the point of attachment at angle θ ABOVE the horizontal.
- Memorise it this way:** if the hypotenuse (T) goes THROUGH the angle, that component is $T \cos \theta$; if it goes AGAINST the angle (perpendicular to it), that component is $T \sin \theta$.
- Horizontal component of T : T goes THROUGH the angle θ , so horizontal component of $T = T \cos \theta$.
- Vertical component of T : T goes AGAINST the angle θ , so vertical component of $T = T \sin \theta$.
- Here: the horizontal component of T balances F ($\Sigma F_x = 0$: $F = T \cos \theta$), and the vertical component of T balances W ($\Sigma F_y = 0$: $T \sin \theta = W$).



Horizontal component picked out

$$\Sigma F_x = 0: F = T \cos \theta$$



Vertical component picked out

$$\Sigma F_y = 0: T \sin \theta = W$$

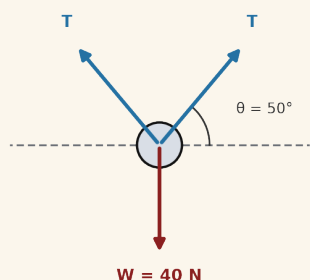
Isolating each component in turn: left, horizontal ($\Sigma F_x = 0$); right, vertical ($\Sigma F_y = 0$).

WORKED EXAMPLE

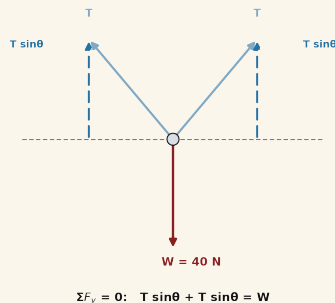
Resolving Tension Into Horizontal & Vertical Components



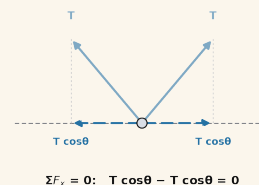
A picture frame of weight 40 N hangs in equilibrium from two strings attached to the same hook. Each string makes an angle of 50° with the horizontal, as shown. Calculate the tension, T , in each string.



Both strings at 50° to the horizontal.



Vertical component of T , on BOTH strings: together support W .



Horizontal component of T , on BOTH strings: cancel.

Solution

- T is the hypotenuse of each string's own right-angled triangle, measured from the horizontal: horizontal component = $T \cos 50^\circ$; vertical component = $T \sin 50^\circ$.
- How do we get the vertical component of T ?** Each string contributes $T \sin 50^\circ$ upwards. With $\Sigma F_y = 0$, the two strings' vertical components together must support the whole weight: $2 \times T \sin 50^\circ = W$.
- How do we get the horizontal component of T ?** Each string contributes $T \cos 50^\circ$, but pointing in OPPOSITE directions. With $\Sigma F_x = 0$: $T \cos 50^\circ - T \cos 50^\circ = 0$ ✓ (confirms the frame doesn't swing sideways).
- $2 \times T \times 0.766 = 40 \rightarrow 1.532T = 40 \rightarrow T = 26.1 \text{ N}$.

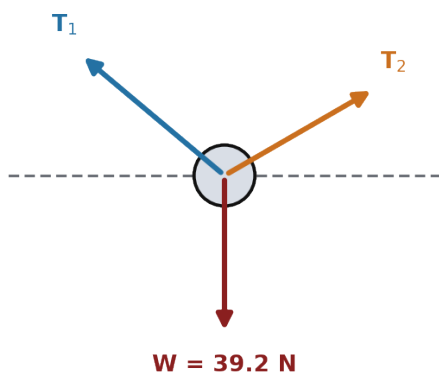
tension in each string = 26.1 N

54.

ANSWER >

A mass of 4.0 kg (weight 39.2 N) hangs in equilibrium from two wires attached to a horizontal ceiling. One wire, tension T_1 , makes 40° with the horizontal; the other, tension T_2 , makes 30° with the horizontal, as shown.

(a) By resolving horizontally, write T_1 in terms of T_2 (no need to solve fully yet).



(b) By resolving vertically and substituting your answer to (a), calculate T_2 , and hence T_1 . [3]

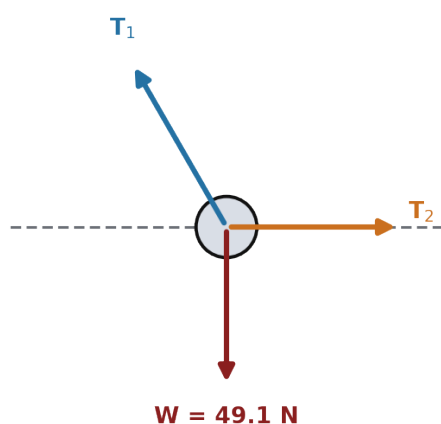
(Total for Question 54 = 5 marks)

55.

ANSWER ›

A ring is held in equilibrium by two tensions, T_1 and T_2 , and a weight of 49.1 N hanging directly below it, as shown. T_1 acts at 60° above the horizontal; T_2 acts horizontally.

(a) By resolving vertically, calculate T_1 .



(b) By resolving horizontally, calculate T_2 . [2]

(Total for Question 55 = 4 marks)

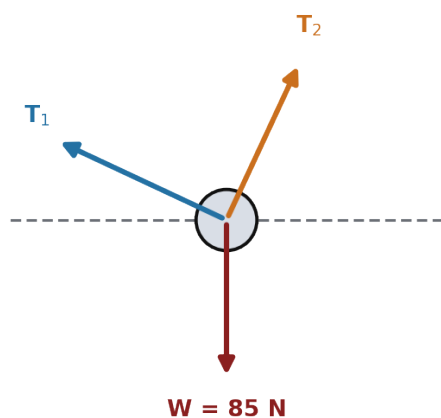


56.

ANSWER ›

A road sign of weight 85 N is supported in equilibrium by two cables attached to the same point on the sign: T_1 at 25° above the horizontal, and T_2 at 65° above the horizontal, as shown.

(a) By resolving horizontally, show that $T_1 = 0.466 T_2$.



(b) By resolving vertically and substituting, calculate T_2 , and hence T_1 .

[3]

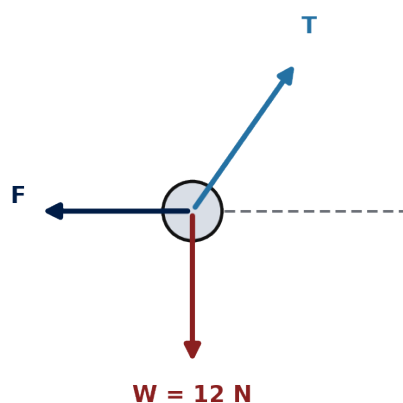
(Total for Question 56 = 5 marks)
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57.

ANSWER ›

A pendulum bob of weight 12 N is held in equilibrium by a horizontal force F and a string of tension T , at 55° above the horizontal, as shown.

(a) Calculate the tension, T , in the string.



(b) Calculate the horizontal force, F .

[2]

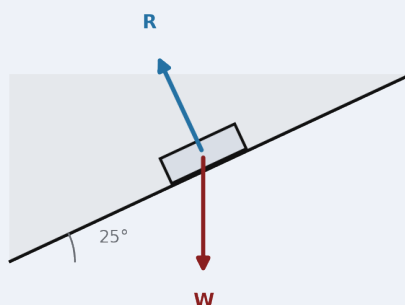
(Total for Question 57 = 4 marks)

E. Balanced Forces on a Slope

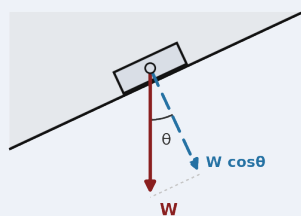
MEMORISE THIS

Balanced Forces on a Slope (Incline)

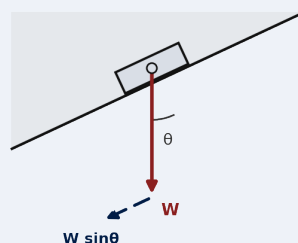
- Resolve the object's weight, W , into two components RELATIVE TO THE SLOPE: $W \cos \theta$ perpendicular INTO the slope, balanced by the normal contact force, R ; and $W \sin \theta$ down the slope, balanced by friction, F , if the object is in equilibrium.
- Memorise it this way, with W as the 'hypotenuse':** θ sits between W (straight down) and the perpendicular-into-the-slope direction. W goes THROUGH the angle towards the perpendicular, so that component is $W \cos \theta$. W goes AGAINST the angle (down the slope), so that component is $W \sin \theta$.
- Perpendicular to the slope (equilibrium): $R = W \cos \theta$.
- Parallel to the slope (equilibrium, no sliding): $F = W \sin \theta$.
- θ is the same angle as the incline itself — weight always acts straight down, so resolving it relative to a tilted slope always brings in the slope angle θ .



The real forces on the object: normal contact force R (perpendicular to the slope) and weight W (straight down). Nothing has been resolved yet.



Perpendicular component picked out
 $\perp$ to slope: $R = W \cos \theta$

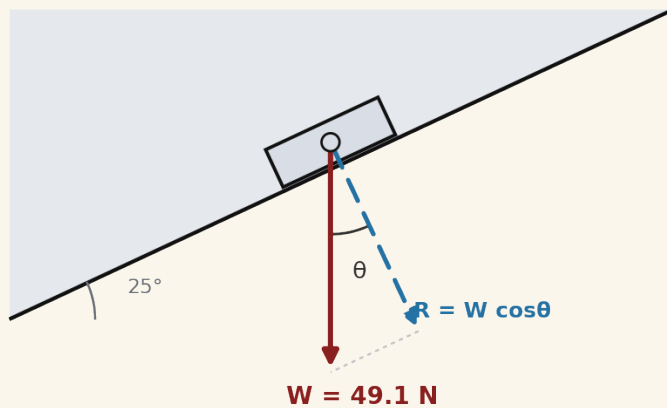


Down-the-slope component picked out
 $\parallel$ to slope: $F = W \sin \theta$

Take W and split it into a triangle: resolving straight-down W relative to the slope gives its two components. Left, perpendicular to the slope ($R = W \cos \theta$); right, down the slope ($F = W \sin \theta$).

WORKED EXAMPLE**Resolving Weight on a Slope**

A 5.0 kg crate rests in equilibrium on a slope inclined at 25° to the horizontal, as shown. Calculate (i) the normal contact force, R , and (ii) the frictional force, F_r , acting on the crate.



$$R = 49.1 \times \cos 25^\circ = 44.5 \text{ N}$$

W goes THROUGH the angle θ here, so $R = W \cos \theta$. F_r uses the same triangle, taken the other way: W goes AGAINST θ , so $F_r = W \sin \theta$.

Solution

1. $W = mg = 5.0 \times 9.81 = 49.1 \text{ N}$.
2. (i) R is the component of W PERPENDICULAR to the slope. Dropping W down to complete the triangle (see diagram), W goes THROUGH the angle θ , so $R = W \cos \theta = 49.1 \times \cos 25^\circ = 49.1 \times 0.9063 = 44.5 \text{ N}$.
3. (ii) F_r is the component of W PARALLEL to (down) the slope — the same triangle, taken the other way. W goes AGAINST the angle θ here, so $F_r = W \sin \theta = 49.1 \times \sin 25^\circ = 49.1 \times 0.4226 = 20.7 \text{ N}$.

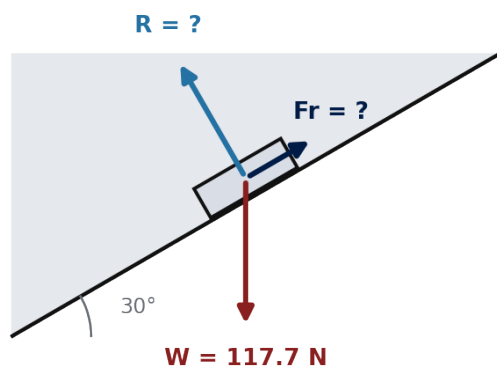
$R = 44.5 \text{ N}$; friction (up the slope) $F_r = 20.7 \text{ N}$

58.

ANSWER ›

A 12 kg box rests in equilibrium on a rough slope inclined at 30° to the horizontal, as shown.

(a) Calculate the weight of the box.



(b) Calculate the normal contact force, R , acting on the box.

[2]

(c) Calculate the frictional force, F , acting on the box.

[2]

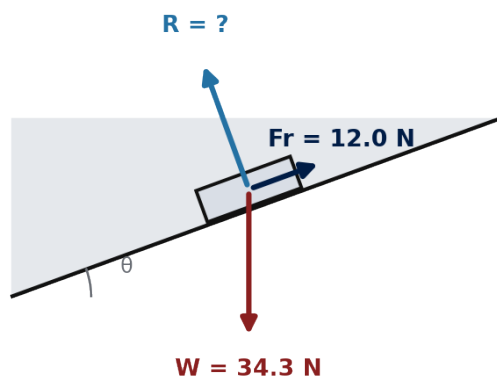
(Total for Question 58 = 5 marks)

59.

ANSWER ›

A 3.5 kg parcel rests in equilibrium on a slope, as shown. The friction force acting on it is 12.0 N.

(a) Show that the weight of the parcel is 34.3 N.



(b) By using $F = W \sin \theta$, calculate the angle θ of the slope.

[3]

(c) Calculate the normal contact force, R , acting on the parcel.

[2]

(Total for Question 59 = 6 marks)

F. Newton's Second Law: $F = ma$

MEMORISE THIS

Newton's Second Law

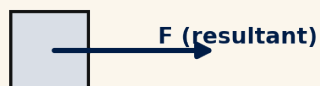
$F = ma$: resultant force = mass $\times$ acceleration (units: $N = kg\ m\ s^{-2}$)

- F must be the RESULTANT (net, unbalanced) force — if several forces act, add/subtract them first: $F = \Sigma F$.
- A bigger resultant force gives a bigger acceleration (for the same mass); a bigger mass gives a smaller acceleration (for the same resultant force).

WORKED EXAMPLE

Finding the Resultant Force From an Acceleration

A 1200 kg car accelerates uniformly from rest to $24\ m\ s^{-1}$ in 8.0 s. Calculate (i) its acceleration, and (ii) the resultant force needed to produce this acceleration.



Solution

- (i) $a = (v - u) / t = (24 - 0) / 8.0 = 3.0\ m\ s^{-2}$.
- (ii) $F = ma = 1200 \times 3.0 = 3600\ N$.

acceleration = $3.0\ m\ s^{-2}$ | resultant force = 3600 N



60.**ANSWER >**

A resultant force of 2500 N acts on an 800 kg go-kart, initially at rest.

(a) Calculate the go-kart's acceleration.

[2]

(b) Calculate the go-kart's velocity after 5.0 s.

[2]

(Total for Question 60 = 4 marks)

61.**ANSWER >**

A resultant force of 8.0 N acts on a 0.50 kg ball, initially at rest.

(a) Calculate the ball's acceleration.

[2]

(b) Calculate the distance the ball travels in the first 2.0 s.

[2]

(Total for Question 61 = 4 marks)



G. Weight & Newton's Third Law

MEMORISE THIS

Weight & Newton's Third Law

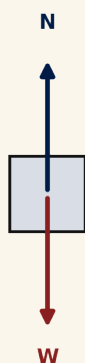
$W = mg$: weight (a force, in newtons) is not the same thing as mass (in kilograms)

- **Newton's third law:** every force has a partner force that is equal in size, opposite in direction, of the SAME TYPE, and acts on a DIFFERENT object, at the same instant.
- **COMMON MISTAKE:** an object's weight and the normal contact force on it are NOT a third-law pair. They act on the SAME object (just happen to be equal, in equilibrium), and are different TYPES of force (gravitational vs contact).
- A true third-law pair to 'the table pushes the book up' is 'the book pushes the table down': same size, opposite direction, same type (contact), but acting on the OTHER object.

WORKED EXAMPLE

Weight and a True Third-Law Pair

A 5.0 kg box rests on a table ($g = 9.81 \text{ m s}^{-2}$). Calculate (i) the box's weight, and (ii) state the Newton's third law pair to the normal contact force the table exerts on the box.



Solution

1. (i) $W = mg = 5.0 \times 9.81 = \mathbf{49.1 \text{ N}}$.
2. (ii) The third-law pair to 'the table pushes the box up' (N) is '**the box pushes the table down**', **with an equal force of 49.1 N** — same type (contact), same size, opposite direction, acting on the table instead of the box.
3. Note: N and W are NOT a third-law pair, even though $N = W$ here — they both act on the BOX, and are different types of force (contact vs gravitational).

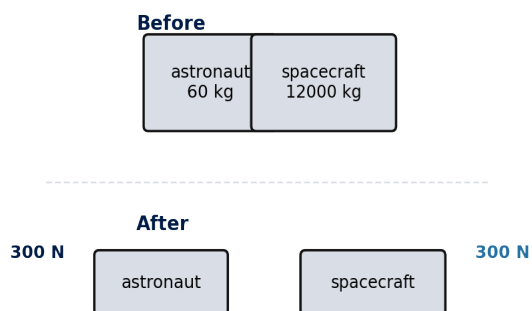
weight = 49.1 N; third-law pair to N = the box pushing down on the table with 49.1 N



62.

ANSWER ›

An astronaut of mass 60 kg pushes off a 12 000 kg spacecraft with a force of 300 N, in deep space.



(a) Calculate the astronaut's acceleration.

(b) State the size and nature of the force acting on the spacecraft as a result, and name the law that predicts it.

[2]

(c) Calculate the spacecraft's acceleration.

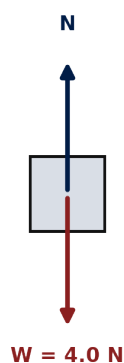
[2]

(Total for Question 62 = 6 marks)

63.

ANSWER ›

A book of weight 4.0 N rests in equilibrium on a table.



(a) Calculate the normal contact force the table exerts on the book.

(b) State the Newton's third law pair to this normal contact force, naming both the size and direction of the force, and the object it acts on.

[2]

(Total for Question 63 = 4 marks)



2.6 Core Practical 1: Determining g by Free Fall

A. Determining g From a Displacement-Time-Squared Graph

MEMORISE THIS

Core Practical 1: Determining g by Free Fall

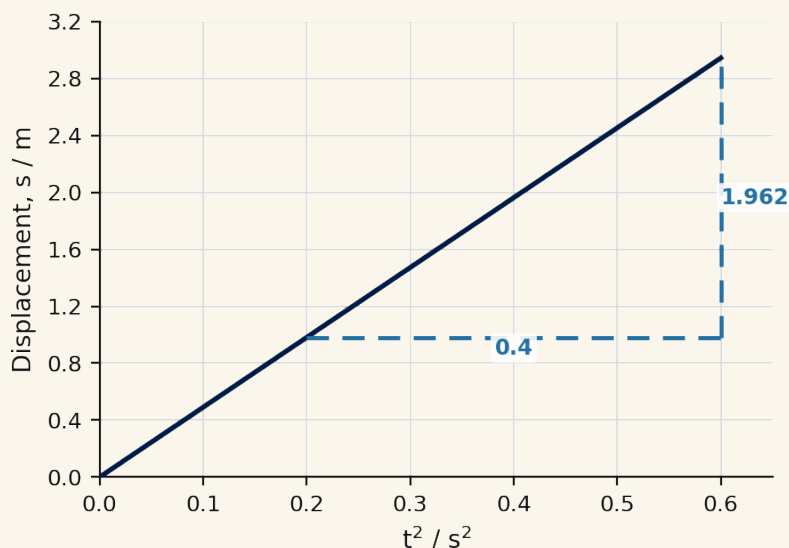
$s = ut + \frac{1}{2}at^2$, with $u = 0$ for an object released from rest, gives $s = \frac{1}{2}gt^2$.

- A graph of s (y-axis) against t^2 (x-axis) is a STRAIGHT LINE through the origin, since $s = \frac{1}{2}g \times t^2$ matches $y = mx$ (gradient $m = \frac{1}{2}g$).
- Plotting s against t^2 , rather than s against t , gives a straight line, so a single best-fit line through ALL the data points averages out random error better than reading g from any one timing.
- Method: release a ball from rest, record time t to fall a measured height s , and repeat for several values of s . Plot s against t^2 , draw a best-fit line, then find its gradient with a large gradient triangle.
- Since gradient = $\frac{1}{2}g$, the final step is simply **$g = 2 \times \text{gradient}$** .

WORKED EXAMPLE

Finding g From a Best-Fit Line

The graph below shows displacement, s , against t^2 for a ball released from rest and timed falling different distances. Use the gradient triangle shown to determine the acceleration due to gravity, g .



Solution

1. Read the gradient triangle: base = 0.4 s^2 , height = 1.962 m .
2. gradient = height / base = $1.962 / 0.4 = 4.905 \text{ m s}^{-2}$.
3. Since gradient = $\frac{1}{2}g$: $g = 2 \times \text{gradient} = 2 \times 4.905 = 9.81 \text{ m s}^{-2}$.

gradient = 4.905 m s^{-2} | $g = 9.81 \text{ m s}^{-2}$



64.

ANSWER ›

A student plots s against t^2 for a free-fall timing experiment. The best-fit line through their data has a gradient of 4.85 m s^{-2} .

(a) Determine the student's experimental value of g .

[2]

(b) The accepted value of g is 9.81 m s^{-2} . Calculate the percentage difference between the student's value and this accepted value.

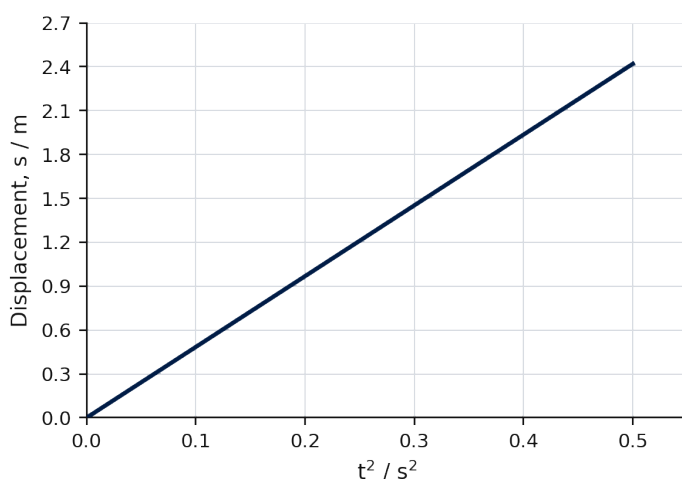
[2]

(Total for Question 64 = 4 marks)

65.

ANSWER ›

The graph below shows a student's s against t^2 data, with the best-fit line drawn from the origin to (0.50, 2.42), where s is in metres and t^2 in s^2 .



(a) Use the graph to calculate the gradient of the best-fit line.

(b) Use your answer to part (a) to determine the student's experimental value of g .

[2]

(Total for Question 65 = 4 marks)



2.7 Momentum & Conservation of Momentum

A. Momentum & Impulse

MEMORISE THIS

Momentum & Impulse

$p = mv$: momentum, in kg m s^{-1} (equivalently N s), a VECTOR quantity

- **Impulse** = force $\times$ time = change in momentum: $F\delta t = \delta p = m(v - u)$.
- Impulse and momentum are vectors: use a consistent sign convention (+/–). A change of direction (e.g. a ball bouncing back) still counts as a change in velocity.
- Rearranging gives Newton's second law's general form, $F = \delta p / \delta t$: resultant force = RATE OF CHANGE of momentum.
- For a given change in momentum, a LONGER contact time means a SMALLER average force (and vice versa), which is why crumple zones, airbags and landing mats work.

WORKED EXAMPLE

Impulse and Force From a Bounce

A 0.15 kg cricket ball travelling at 20 m s^{-1} is struck by a bat and returns along the same line at 25 m s^{-1} . The ball is in contact with the bat for $5.0 \times 10^{-3} \text{ s}$. Taking the ball's initial direction as positive, calculate (i) the impulse on the ball, and (ii) the average force exerted by the bat.

Before

20 m/s

0.15 kg

After

25 m/s

0.15 kg

Solution

- (i) Impulse = $\delta p = m(v - u) = 0.15 \times (-25 - 20) = 0.15 \times (-45) = -6.75 \text{ N s}$ (magnitude 6.75 N s , direction reversed).
- (ii) $F = \delta p / \delta t = -6.75 / (5.0 \times 10^{-3}) = -1350 \text{ N}$ (magnitude 1350 N , acting back towards the bowler).

impulse = 6.75 N s (direction reversed) | average force = 1350 N



66.

ANSWER ›

A golf club strikes a stationary 0.046 kg golf ball, giving it a velocity of 65 m s^{-1} . The club is in contact with the ball for $5.0 \times 10^{-4} \text{ s}$.

Before

0.046 kg

at rest

After

0.046 kg

65 m/s

(a) Calculate the impulse given to the ball.

(b) Calculate the average force exerted on the ball by the club.

[2]

(Total for Question 66 = 4 marks)

67.

ANSWER ›

A 900 kg car travelling at 15 m s^{-1} is brought to rest by braking, in a time of 2.5 s.

Before

900 kg

15 m/s

After

900 kg

at rest

(a) Calculate the car's change in momentum.

(b) Calculate the average braking force on the car.

[2]

(Total for Question 67 = 4 marks)



B. Conservation of Momentum: Collisions & Explosions

MEMORISE THIS

Conservation of Momentum

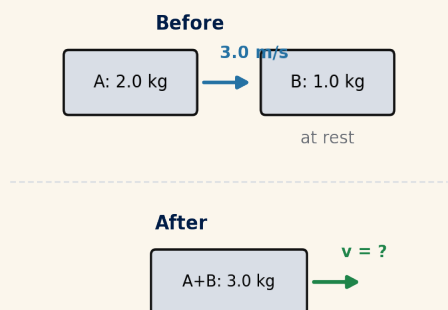
$\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$: in a closed system with no external resultant force, total momentum before = total momentum after

- Applies to BOTH collisions (objects come together) AND explosions (a stationary object splits apart), from Newton's third law: equal and opposite forces, for equal times, give equal and opposite momentum changes.
- Take one direction as positive, the other negative, and stay consistent for every object, before and after.
- **Inelastic collision**: objects stick together (or deform), moving with a common final velocity. Kinetic energy is NOT conserved (some becomes heat/sound/deformation), but momentum always is.
- **Explosion**: total momentum starts at zero (system at rest), so the parts fly apart with momenta equal in size and opposite in direction.

WORKED EXAMPLE

Two Trolleys Colliding and Sticking Together

Trolley A, of mass 2.0 kg, moves at 3.0 m s^{-1} and collides with a stationary trolley B, of mass 1.0 kg. The trolleys stick together on impact. Calculate their common velocity immediately after the collision.



Solution

1. Momentum before = momentum after (conservation of momentum).
2. Momentum before = $(2.0 \times 3.0) + (1.0 \times 0) = 6.0 \text{ kg m s}^{-1}$.
3. After the collision, the combined mass is $2.0 + 1.0 = 3.0 \text{ kg}$, moving at v : $6.0 = 3.0 \times v \rightarrow v = 2.0 \text{ m s}^{-1}$, in trolley A's original direction.

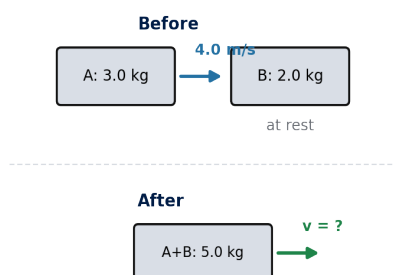
common velocity after collision = 2.0 m s^{-1}



68.

ANSWER ›

Trolley A, of mass 3.0 kg, moves at 4.0 m s^{-1} and collides with a stationary trolley B, of mass 2.0 kg. The trolleys stick together on impact.



(a) Calculate the total momentum of the system before the collision.

(b) Calculate the common velocity of the trolleys immediately after the collision.

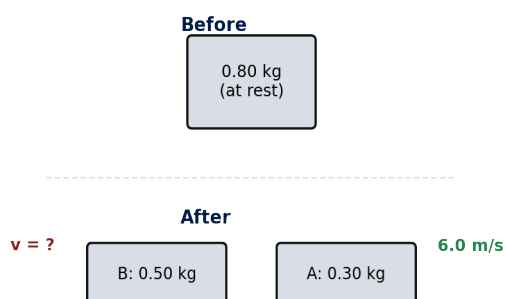
[2]

(Total for Question 68 = 3 marks)

69.

ANSWER ›

A stationary 0.80 kg trolley, fitted with a spring-loaded plunger, splits into two parts when the plunger is released: part A, of mass 0.30 kg, moves off at 6.0 m s^{-1} to the right; part B, of mass 0.50 kg, recoils to the left.



(a) Explain why the total momentum of the system must be zero both before and immediately after the plunger is released.

(b) Calculate the velocity of part B after the explosion.

[2]

(Total for Question 69 = 4 marks)



C. Elastic & Inelastic Collisions

MEMORISE THIS

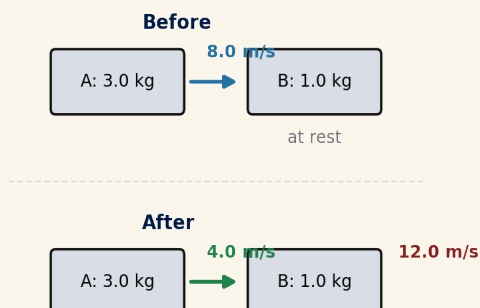
Elastic & Inelastic Collisions

- Momentum is ALWAYS conserved in a collision (an isolated system) — but kinetic energy is only conserved if the collision is ELASTIC.
- **Elastic collision:** total KE before = total KE after (no energy is transferred to heat, sound or deformation). Truly elastic collisions are rare on an everyday scale, but common between atoms, molecules and subatomic particles.
- **Inelastic collision:** total KE after is LESS than total KE before — some KE is transferred to other forms. Objects that stick together (Section B) are a special case: PERFECTLY inelastic, losing the maximum KE possible while still conserving momentum.
- To test which type a collision is: first find any unknown velocity using conservation of momentum (as before), THEN calculate ΣKE before and ΣKE after SEPARATELY and compare them.

WORKED EXAMPLE

Testing Whether a Collision Is Elastic

A 3.0 kg trolley moving at 8.0 m s^{-1} collides with a stationary 1.0 kg trolley. After the collision, the 3.0 kg trolley continues in the same direction at 4.0 m s^{-1} , and the 1.0 kg trolley moves off in the same direction at 12.0 m s^{-1} . Determine, showing your working, whether the collision is elastic.



Solution

1. Momentum should be conserved in ANY collision — check: before = $3.0 \times 8.0 = 24.0 \text{ kg m s}^{-1}$; after = $(3.0 \times 4.0) + (1.0 \times 12.0) = 12.0 + 12.0 = 24.0 \text{ kg m s}^{-1}$. Momentum IS conserved, as expected.
2. To test for elastic/inelastic, calculate the total KE separately before and after.
3. KE before = $\frac{1}{2} \times 3.0 \times 8.0^2 = \mathbf{96 \text{ J}}$ (the 1.0 kg trolley starts at rest, so contributes no KE).
4. KE after = $(\frac{1}{2} \times 3.0 \times 4.0^2) + (\frac{1}{2} \times 1.0 \times 12.0^2) = 24 + 72 = \mathbf{96 \text{ J}}$.
5. Since KE before = KE after ($96 \text{ J} = 96 \text{ J}$), no kinetic energy has been lost: the collision is **ELASTIC**.

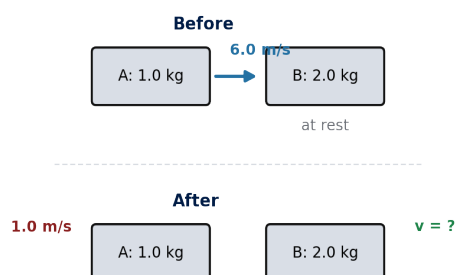
KE before = KE after = 96 J → the collision is elastic



70.

ANSWER ›

A 1.0 kg ball moving at 6.0 m s^{-1} collides with a stationary 2.0 kg ball. After the collision, the 1.0 kg ball rebounds (reverses direction) at 1.0 m s^{-1} , as shown. Take the 1.0 kg ball's original direction as positive.



(a) By conservation of momentum, calculate the velocity of the 2.0 kg ball immediately after the collision.

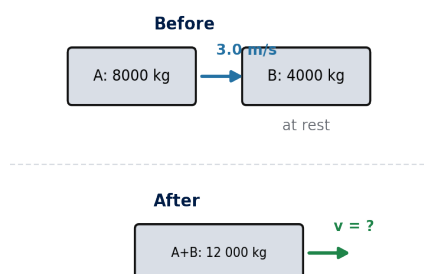
(b) By calculating the total kinetic energy before and after the collision, determine whether the collision is elastic or inelastic. [3]

(Total for Question 70 = 6 marks)

71.

ANSWER ›

A railway truck, A, of mass 8000 kg, moving at 3.0 m s^{-1} , collides with a stationary truck, B, of mass 4000 kg. The trucks couple together on impact and move off with a common velocity.



(a) Calculate the common velocity of the trucks immediately after coupling.

(b) Calculate the kinetic energy lost in the collision. [3]

(Total for Question 71 = 5 marks)



D. Momentum in Two Dimensions

MEMORISE THIS

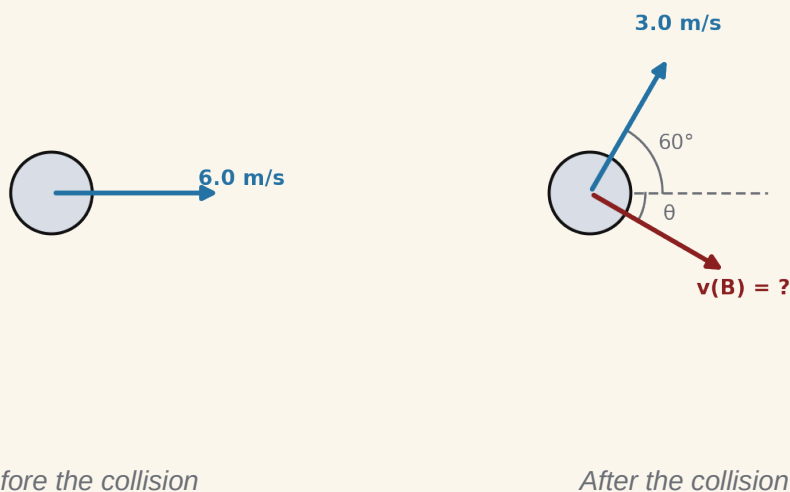
Momentum in Two Dimensions

- Momentum is a VECTOR, so conservation of momentum must hold SEPARATELY in each direction: resolve every velocity into components parallel and perpendicular to a chosen reference direction first (Topic 2.3).
- $\Sigma p_{\text{parallel, before}} = \Sigma p_{\text{parallel, after}}$ and, independently, $\Sigma p_{\text{perp, before}} = \Sigma p_{\text{perp, after}}$
- Once you have the missing object's momentum components, combine them with Pythagoras for magnitude and $\tan^{-1}$ for direction, exactly as for any other vector.
- A 2D explosion FROM REST still has zero total momentum in every direction, but a moving object splitting apart only needs its momentum components to balance — the fragments don't have to fly off along a single line.

WORKED EXAMPLE

Conservation of Momentum in Two Dimensions

Ball A, of mass 2.0 kg, moves at 6.0 m s^{-1} and collides with a stationary ball B, of mass 3.0 kg. After the collision, ball A moves off at 3.0 m s^{-1} , deflected 60° from its original direction, as shown. Calculate the velocity of ball B (magnitude and direction).



Solution

- Momentum is conserved SEPARATELY parallel to A's original direction, and perpendicular to it.
- Before: $p_{\parallel} = 2.0 \times 6.0 = 12.0 \text{ kg m s}^{-1}$; $p_{\perp} = 0$.
- After ball A: $p_{\parallel} = 2.0 \times 3.0 \times \cos 60^\circ = 3.0 \text{ kg m s}^{-1}$; $p_{\perp} = 2.0 \times 3.0 \times \sin 60^\circ = 5.20 \text{ kg m s}^{-1}$.
- Parallel: $12.0 = 3.0 + p_{B\parallel} \rightarrow p_{B\parallel} = 9.0 \text{ kg m s}^{-1}$.
- Perpendicular: $0 = 5.20 + p_{B\perp} \rightarrow p_{B\perp} = -5.20 \text{ kg m s}^{-1}$ (opposite side to ball A's deflection).
- $|p_B| = \sqrt{(9.0)^2 + (5.20)^2} = \sqrt{108} = 10.4 \text{ kg m s}^{-1}$.
- $v_B = p_B / m_B = 10.4 / 3.0 = 3.46 \text{ m s}^{-1}$, at $\tan^{-1}(5.20 / 9.0) = 30.0^\circ$ to A's original direction, on the opposite side to A's deflection.

$v(B) = 3.46 \text{ m s}^{-1}$, at 30.0° to A's original direction (opposite side to A's deflection)

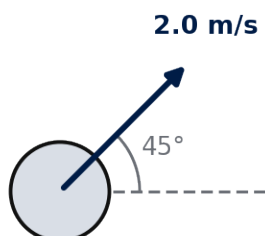


72.

ANSWER ›

A ball of mass 1.0 kg , moving at 4.0 m s^{-1} , collides with a stationary ball, also of mass 1.0 kg . After the collision, the first ball moves off at 2.0 m s^{-1} , deflected 45° from its original direction, as shown.

(a) Calculate the components of the second ball's momentum parallel and perpendicular to the first ball's original direction.



(b) Calculate the speed and direction of the second ball after the collision.

[3]

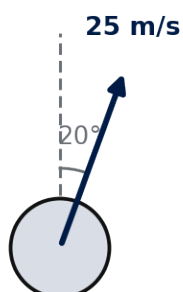
(Total for Question 72 = 6 marks)



73.

ANSWER >

A firework shell, of mass 0.60 kg , is moving straight up at 20 m s^{-1} when it explodes into two fragments of equal mass, 0.30 kg each. Immediately after the explosion, one fragment moves off at 25 m s^{-1} , at 20° to the shell's original (vertical) direction, as shown.



(a) Calculate the vertical and horizontal components of the momentum of the second fragment.

(b) Calculate the speed and direction of the second fragment.

[3]

(Total for Question 73 = 6 marks)

2.8 Moments & Equilibrium

A. Moments & the Principle of Moments

MEMORISE THIS

Conditions for Equilibrium

- For an object in COMPLETE equilibrium (no translation AND no rotation), THREE conditions must all hold at once: $\Sigma F_x = 0$, $\Sigma F_y = 0$, and $\Sigma M = 0$ (sum of moments about ANY point).
- The first two follow from Newton's first law; the third, the principle of moments, is what stops rotation even when the forces themselves balance.
- Forces can balance yet the object still rotates if $\Sigma M \neq 0$, e.g. a 'couple': two equal, opposite, parallel forces not acting through the same point.

MEMORISE THIS

Moments & the Principle of Moments

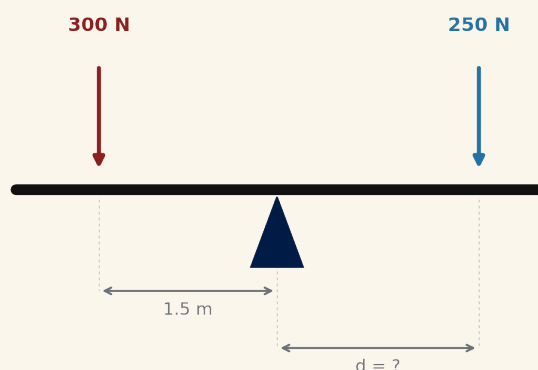
$M = Fx$: moment of a force about a point = force $\times$ perpendicular distance from the pivot to the force's line of action (units: N m)

- A moment is CLOCKWISE or ANTICLOCKWISE; always state which, or use a consistent sign convention.
- Principle of moments:** for equilibrium, $\Sigma M_{\text{clockwise}} = \Sigma M_{\text{anticlockwise}}$ about any point.
- The distance used must be PERPENDICULAR to the force's line of action; if a force acts at an angle to the beam, resolve it first (Topic 2.3) or use the perpendicular component of the distance.

WORKED EXAMPLE

Balancing a Seesaw

A child of weight 300 N sits 1.5 m from the pivot of a seesaw. Calculate the distance from the pivot at which a second child, of weight 250 N, must sit on the other side for the seesaw to balance. (Diagram not drawn to scale.)



Solution

- By the principle of moments: **anticlockwise moment** = **clockwise moment**.
- $300 \times 1.5 = 250 \times d$.

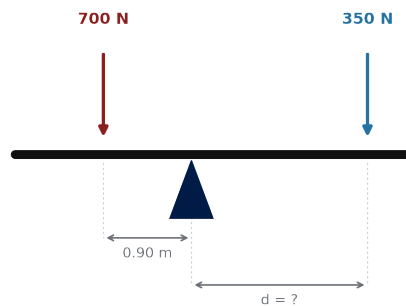
$$3. 450 = 250d \rightarrow d = 1.8 \text{ m.}$$

distance from pivot = 1.8 m

74.

ANSWER ›

A parent of weight 700 N sits 0.90 m from the pivot of a seesaw.



(a) State the principle of moments.

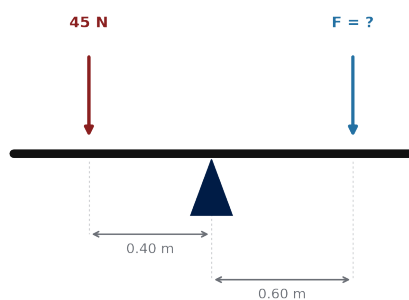
(b) Calculate the distance from the pivot at which a child of weight 350 N must sit on the other side, for the seesaw to balance. [2]

(Total for Question 74 = 3 marks)

75.

ANSWER ›

A downward force of 45 N acts 0.40 m from the pivot of a light beam.



(a) Calculate the moment of this force about the pivot.

(b) Calculate the force, F, that must act 0.60 m from the pivot on the other side, for the beam to balance. [2]

(Total for Question 75 = 4 marks)

B. Centre of Gravity & Non-Uniform Beams

MEMORISE THIS

Centre of Gravity & Non-Uniform Beams

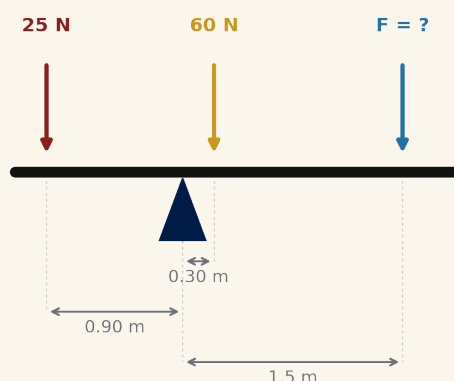
centre of gravity = the single point at which an object's entire weight can be considered to act

- For a UNIFORM beam, rod, ruler or plank, the centre of gravity is at its exact midpoint.
- For a NON-UNIFORM beam, the centre of gravity is NOT at the midpoint; its position must be given or found experimentally (e.g. where the beam balances on a single pivot).
- When a beam rests on a pivot, include its own WEIGHT (acting at its centre of gravity) in the moments equation, unless the pivot IS the centre of gravity, in which case its perpendicular distance is zero and it contributes NO moment.

WORKED EXAMPLE

A Non-Uniform Beam With Its Own Weight Included

A non-uniform plank of weight 60 N is balanced on a pivot. Its centre of gravity lies 0.30 m from the pivot, and a 25 N weight hangs 0.90 m from the pivot on the opposite side. Calculate the extra downward force, F , that must be applied 1.5 m from the pivot (on the same side as the centre of gravity) to keep the plank horizontal and in equilibrium.



■ 25 N — hanging weight ■ 60 N — plank's own weight, at its centre of gravity

Solution

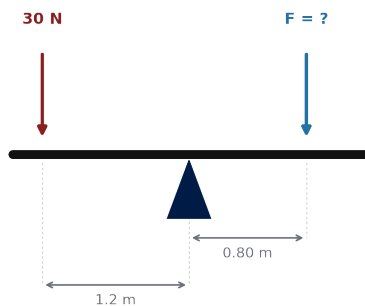
1. **Anticlockwise moment** (25 N weight): $25 \times 0.90 = 22.5 \text{ N m}$.
2. **Clockwise moment** (plank's own weight, acting at its centre of gravity): $60 \times 0.30 = 18 \text{ N m}$.
3. For equilibrium, the extra clockwise moment needed from F is: $22.5 - 18 = 4.5 \text{ N m}$.
4. $F \times 1.5 = 4.5 \rightarrow F = 3.0 \text{ N}$.

extra downward force required = 3.0 N

76.

ANSWER ›

A uniform beam of length 4.0 m and weight 40 N is balanced on a pivot placed at its centre (i.e. at its centre of gravity). A 30 N weight hangs 1.2 m from the pivot.



(a) Explain why the beam's own weight contributes no moment about the pivot in this case.

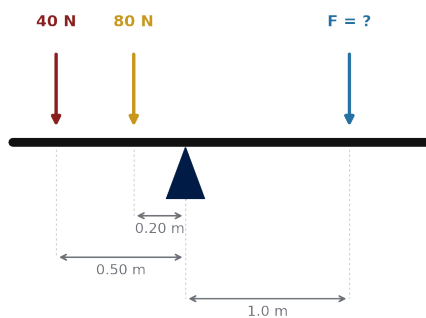
(b) Calculate the force, F , that must act 0.80 m from the pivot on the other side, for the beam to balance. [2]

(Total for Question 76 = 4 marks)

77.

ANSWER ›

A non-uniform beam of weight 80 N is pivoted at a point 0.50 m from end A. Its centre of gravity lies 0.20 m from the pivot, on the opposite side to end A. A 40 N weight hangs from end A.



(a) Calculate the moment of the 40 N weight about the pivot.

(b) Calculate the extra force, F , required 1.0 m from the pivot (on the same side as the centre of gravity) to hold the beam in equilibrium. [3]

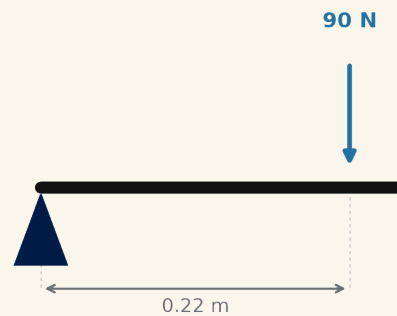
(Total for Question 77 = 5 marks)

C. Moments in Everyday Levers

WORKED EXAMPLE

Moments in Practice: A Spanner

A mechanic applies a force of 90 N perpendicular to a spanner, 0.22 m from the nut it is turning. Calculate (i) the moment applied to the nut, and (ii) the new moment if a pipe extends the spanner's effective length to 0.40 m, with the mechanic now applying a smaller force of 60 N at this greater distance.



Solution

1. (i) $M = Fx = 90 \times 0.22 = \mathbf{19.8 \text{ N m}}$.
2. (ii) $M = Fx = 60 \times 0.40 = \mathbf{24.0 \text{ N m}}$.
3. Even though the force is **SMALLER**, the moment is **LARGER**: the extra distance outweighs the reduced force. This is why a longer lever (or extension pipe) makes a nut easier to turn.

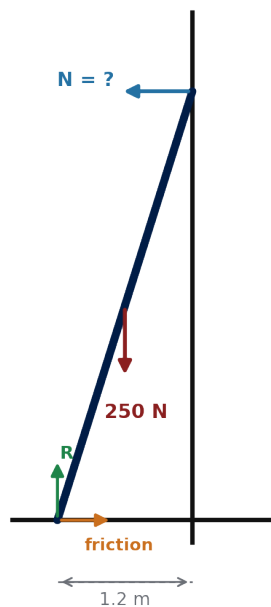
(i) 19.8 N m (ii) 24.0 N m



78.

ANSWER ›

A uniform ladder of weight 250 N and length 4.0 m leans against a smooth (frictionless) vertical wall, its foot on rough ground 1.2 m from the wall's base, as shown. Since the wall is smooth, it exerts only a horizontal force, N , on the ladder.



(a) Show that the top of the ladder is 3.82 m above the ground.

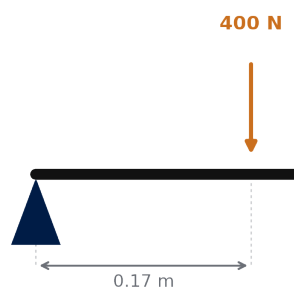
(b) By taking moments about the foot of the ladder, calculate N , the horizontal force exerted by the wall. [4]

(Total for Question 78 = 6 marks)

79.

ANSWER ›

A cyclist pushes down on a bicycle pedal with a force of 400 N, applied perpendicular to the 0.17 m crank arm, as shown.



(a) Calculate the moment (torque) applied to the crank.

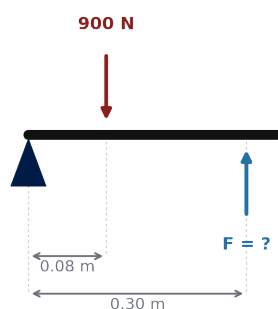
(b) State and explain what would happen to the moment if the cyclist used a longer crank arm but applied the same force. [2]

(Total for Question 79 = 4 marks)

80.

ANSWER >

A model of a dinosaur's jaw treats it as a rigid lever, pivoted at the jaw joint. A jaw-closing muscle exerts a force of 900 N, perpendicular to the jaw, 0.08 m from the joint. The bite force acts at the tip of the jaw, 0.30 m from the joint, as shown.



(a) By taking moments about the jaw joint, calculate the resulting bite force at the tip of the jaw.

(b) Explain, in terms of moments, why the bite force is smaller than the muscle force.

[2]

(Total for Question 80 = 5 marks)

D. Stability & Toppling

MEMORISE THIS

Stability & Toppling

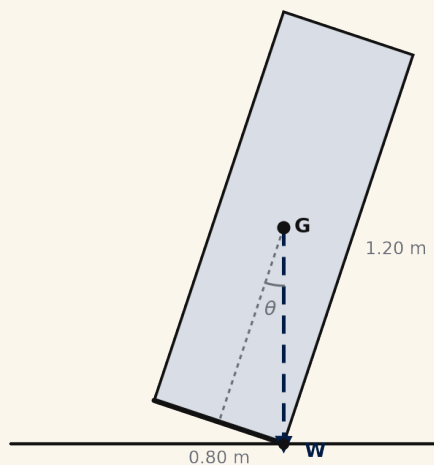
- An object topples over when the **LINE OF ACTION** of its weight (a vertical line straight down from its centre of gravity) falls **OUTSIDE** its base.
- While the line of action still falls **WITHIN** the base, the normal contact force and weight form a restoring couple that tips the object back — it stays stable.
- An object is made **MORE** stable by **LOWERING** its centre of gravity and/or **WIDENING** its base, since both increase the tilt angle needed before the line of action reaches the edge of the base.
- At the critical (about to topple) angle, the line of action passes exactly through the pivot edge of the base: **$\tan \theta = (\text{half the base width}) / (\text{height of the centre of gravity above the base})$** .

WORKED EXAMPLE

Finding the Critical Tilt Angle

A packing crate is 0.80 m wide and its centre of gravity is 1.20 m above the ground, at the midpoint of its width, as shown. The crate is slowly tilted onto one bottom edge. Calculate the maximum angle, θ , it can be tilted through before it topples over.





Solution

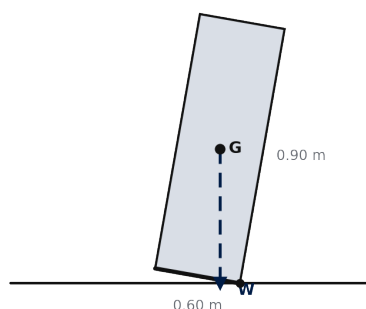
1. Before the crate is tilted, its weight acts straight down the crate's OWN centre line (dashed grey) — from G to M, the midpoint of the base — a distance of 0.40 m (half the 0.80 m width) horizontally from the pivot, and 1.20 m below G.
2. As the crate tilts by an angle θ , this dashed line is fixed TO the crate, so it tilts WITH it — the angle between it and the TRUE vertical (the actual line of action of the weight, shown in red once critical) is also θ .
3. The crate is on the point of toppling exactly when this true-vertical line of action passes through the pivot edge of the base (shown) — i.e. when the dashed line and the red line meet AT the pivot, making θ the angle inside the right-angled triangle G-M-pivot.
4. In that triangle: $\tan \theta = (\text{half the base width}) / (\text{height of G above the base}) = (0.80 / 2) / 1.20 = 0.40 / 1.20$.
5. $\tan \theta = 0.333 \rightarrow \theta = 18.4^\circ$.

maximum tilt before toppling = 18.4°

81.

ANSWER >

A filing cabinet is 0.60 m wide and its centre of gravity is 0.90 m above the floor, at the midpoint of its width, as shown.



- (a) State the condition, in terms of the line of action of the cabinet's weight, for it to be on the point of toppling over.

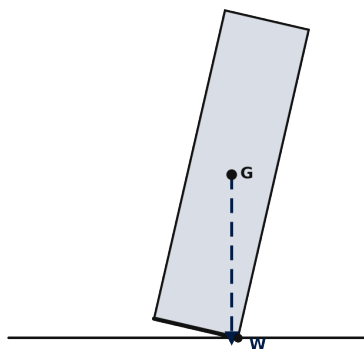
- (b) Calculate the maximum angle the cabinet can be tilted through before it topples over. [3]

(Total for Question 81 = 4 marks)

82.

ANSWER ›

A single-decker bus and a double-decker bus have the same wheelbase (the same base width between their wheels), but the double-decker's centre of gravity is higher above the ground, as shown.



- (a) Explain, in terms of the line of action of the weight, why the double-decker bus is more likely to topple over when cornering than the single-decker bus.

- (b) State two design changes that would make the double-decker bus more stable. [2]

(Total for Question 82 = 4 marks)



2.9 Work, Energy & Power

A. Work Done

MEMORISE THIS

Work Done

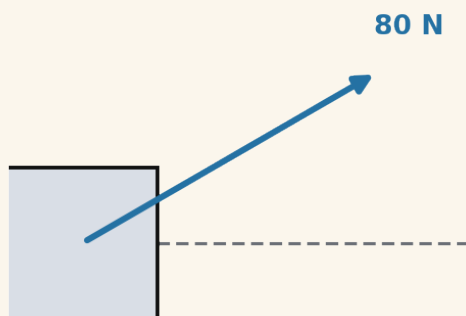
work done, $W = Fs \cos\theta$, where θ is the angle between the force and the direction of motion (units: joules, $J = N\ m$)

- Work is a SCALAR quantity: it has no direction, even though force and displacement do.
- If the force acts in the SAME direction as the motion, $\theta = 0^\circ$ and $\cos\theta = 1$, so $W = Fs$.
- If the force acts PERPENDICULAR to the motion, $\theta = 90^\circ$ and $\cos\theta = 0$: that force does ZERO work, however large (e.g. the normal contact force on a sliding object does no work).
- Work done ON an object equals the energy TRANSFERRED to it: the key link between work and energy.

WORKED EXAMPLE

Work Done by a Force at an Angle

A rope pulls a sledge with a force of $80\ N$ at 30° above the horizontal. The sledge moves $12\ m$ horizontally. Calculate the work done by the rope.



Solution

1. $W = Fs \cos\theta = 80 \times 12 \times \cos 30^\circ$.
2. $= 960 \times 0.866$.
3. $= 831\ J$.

work done by the rope = 831 J

83.

ANSWER ›

A horizontal force of 200 N pulls a box 5.0 m across a floor, in the direction of the force.

(a) Calculate the work done by the force.



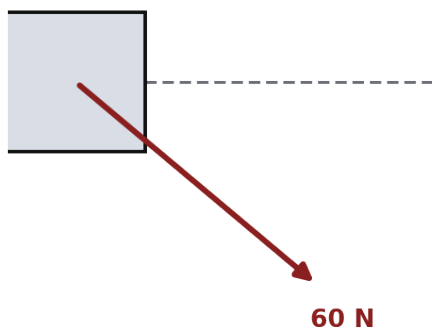
(Total for Question 83 = 2 marks)

84.

ANSWER ›

A gardener pushes a lawnmower with a force of 60 N, directed at 40° below the horizontal. The lawnmower moves 10 m horizontally.

(a) Calculate the work done by the pushing force.



(b) State the angle θ if the mower instead moved 10 m perpendicular to the force, and explain what this means for the work done.

[2]

(Total for Question 84 = 4 marks)

B. Kinetic & Gravitational Potential Energy; Conservation of Energy

MEMORISE THIS

Kinetic & Gravitational Potential Energy

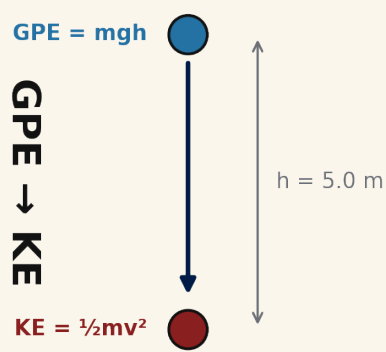
- **Conservation of energy:** energy cannot be created or destroyed, only transferred between stores, so the total energy of a closed system is constant.
- For an object falling freely (air resistance ignored), loss in GPE = gain in KE: $mg\delta h = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$. The mass cancels if starting from rest, giving $v = \sqrt{2g\delta h}$.

Energy store	Formula
Kinetic energy (KE)	$E_k = \frac{1}{2}mv^2$
Gravitational potential energy (GPE)	$E_p = mgh$

WORKED EXAMPLE

Falling From Rest: GPE to KE

A 2.0 kg ball is dropped from rest from a height of 5.0 m. Using conservation of energy (ignoring air resistance), calculate the ball's speed just before it hits the ground.



Solution

1. Loss in GPE = gain in KE (conservation of energy, no air resistance).
2. $mgh = \frac{1}{2}mv^2 \rightarrow 2.0 \times 9.81 \times 5.0 = 0.5 \times 2.0 \times v^2$.
3. $98.1 = v^2 \rightarrow v = 9.90 \text{ m s}^{-1}$.

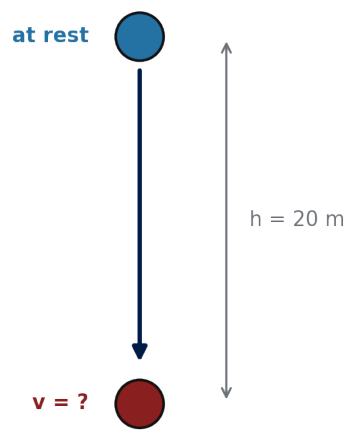
speed just before impact = 9.90 m s^{-1}



85.**ANSWER ›**

A 0.50 kg stone is dropped from rest from a height of 20 m. Ignore air resistance.

(a) Calculate the loss in gravitational potential energy of the stone as it falls.



(b) Use conservation of energy to calculate the stone's speed just before it hits the ground. [2]

(Total for Question 85 = 4 marks)

86.**ANSWER ›**

A 1500 kg car increases its speed from 10 m s^{-1} to 25 m s^{-1} .

(a) Calculate the increase in the car's kinetic energy. [3]

(Total for Question 86 = 3 marks)



C. Power & Efficiency

MEMORISE THIS

Power & Efficiency

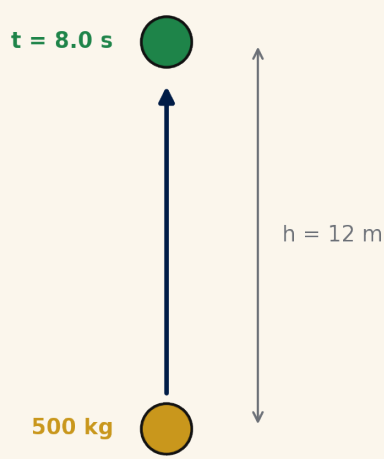
power = work done (or energy transferred) / time taken, $P = W / t$ (units: watts, $W = J\ s^{-1}$)

- For a force moving at constant velocity, power can also be found from $P = Fv$.
- **Efficiency** = (useful energy output / total energy input) $\times 100\%$, or equivalently (useful power output / total power input) $\times 100\%$.
- Efficiency can NEVER exceed 100%: some energy is always transferred to non-useful stores (usually heating the surroundings), by conservation of energy.

WORKED EXAMPLE

Power Output of a Crane

A crane lifts a 500 kg load at a constant velocity through a height of 12 m in a time of 8.0 s. Calculate (i) the work done against gravity, and (ii) the useful power output of the crane.



Solution

- (i) $W = mgh = 500 \times 9.81 \times 12 = \mathbf{58\ 860\ J}$ (58.9 kJ).
- (ii) $P = W / t = 58860 / 8.0 = \mathbf{7360\ W}$ (7.36 kW).

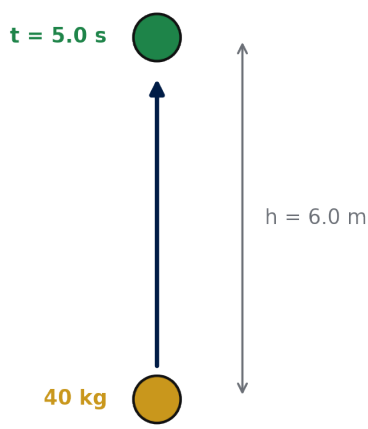
work done = 58.9 kJ | power output = 7.36 kW

87.

ANSWER ›

An electric motor raises a 40 kg crate at a constant velocity through a height of 6.0 m in 5.0 s.

(a) Calculate the work done against gravity.



(b) Calculate the useful power developed by the motor.

[2]

(Total for Question 87 = 4 marks)

88.

ANSWER ›

An engine has a total power input of 2.5 kW and a useful power output of 1.8 kW.

(a) State the formula for efficiency in terms of power input and power output.

[1]

(b) Calculate the efficiency of the engine.

[2]

(Total for Question 88 = 3 marks)

D. Energy Transfer: Motors on Ramps

MEMORISE THIS

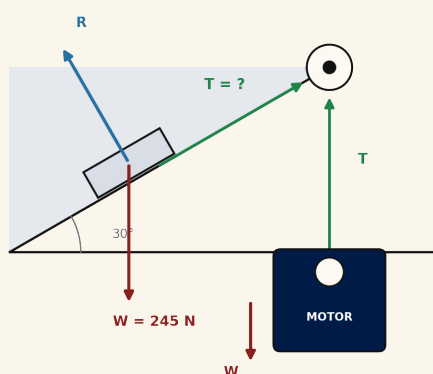
Energy Transfer: Motors on Ramps

- A motor pulling a load up a ramp at **CONSTANT** velocity is in equilibrium along the ramp: resolve parallel to the slope as in Topic 2.5: $T = W \sin\theta$ (smooth ramp) or $T = W \sin\theta + F_r$ (rough ramp, friction F_r acting down the slope).
- Work done by the motor = $W_{\text{motor}} = T \times d$, where d is the distance travelled along the ramp.
- By conservation of energy, this work is transferred entirely to GPE (smooth ramp) or split between GPE and heat from friction (rough ramp): $W_{\text{motor}} = \delta E_p + W_{\text{friction}}$.

WORKED EXAMPLE

Work Done by a Motor Pulling a Load up a Smooth Ramp

A motor pulls a 25 kg crate up a smooth ramp inclined at 30° to the horizontal, at a constant velocity, using a cable parallel to the ramp. Calculate (i) the tension, T , in the cable, and (ii) the work done by the motor in pulling the crate a distance of 4.0 m up the ramp.



Solution

- $W = mg = 25 \times 9.81 = 245 \text{ N}$.
- (i) Parallel to the ramp, equilibrium (constant velocity): $T = W \sin\theta = 245 \times \sin 30^\circ = 245 \times 0.5 = \mathbf{122.5 \text{ N}}$.
- (ii) $W_{\text{motor}} = T \times d = 122.5 \times 4.0 = \mathbf{490 \text{ J}}$.
- Check: since the ramp is smooth, all the work should equal the gain in GPE: $\delta E_p = mgd \sin\theta = 245 \times 4.0 \times 0.5 = 490 \text{ J} \checkmark$.

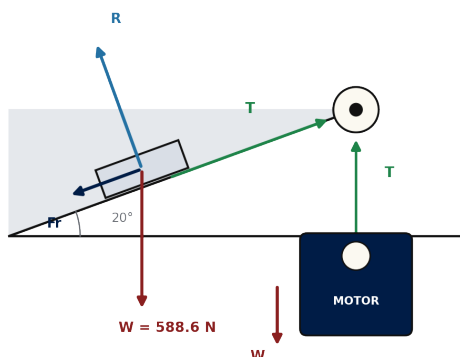
tension = 122.5 N; work done by the motor = 490 J

89.

ANSWER ›

A motor pulls a 60 kg crate up a rough ramp inclined at 20° to the horizontal, at a constant velocity, using a cable parallel to the ramp. The frictional force acting on the crate is 85 N.

(a) Calculate the weight of the crate.



(b) By resolving parallel to the ramp, calculate the tension, T , in the cable.

[3]

(c) Calculate the work done by the motor in pulling the crate 6.0 m up the ramp, and show that this is consistent with the energy transferred to GPE and to friction.

[4]

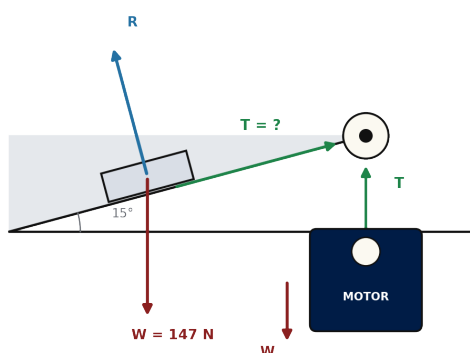
(Total for Question 89 = 8 marks)

90.

ANSWER ›

A motor pulls a 15 kg toolbox up a smooth ramp inclined at 15° to the horizontal, at a constant velocity, using a cable parallel to the ramp.

(a) Calculate the weight of the toolbox.



(b) By resolving parallel to the ramp, calculate the tension in the cable.

[2]



(c) Calculate the work done by the motor in pulling the toolbox 3.0 m up the ramp.

[2]

(Total for Question 90 = 5 marks)

E. Energy Transfer: Loops & Roller Coasters

MEMORISE THIS

Energy Transfer: Loops & Roller Coasters

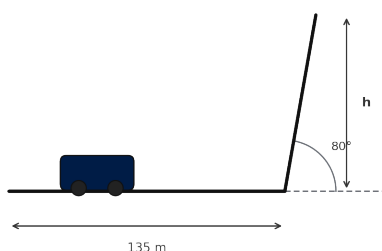
$\frac{1}{2}mu^2 + mgh_A = \frac{1}{2}mv^2 + mgh_B$: conservation of energy between any two points A and B on a smooth track (no friction/air resistance)

- TRACK SHAPE doesn't matter, only the HEIGHTS of the two points, since gravity is a conservative force (work done against it depends only on height gained, not on path taken).
- If the car starts from rest, $u = 0$, and the equation simplifies to $mgh_A = \frac{1}{2}mv^2 + mgh_B$: the mass cancels, so speed at a given height doesn't depend on the car's mass.

91.

ANSWER ›

A 500 kg rollercoaster cart does 500 kJ of work during the acceleration phase as it accelerates from rest through a distance of 135 m. The coaster then enters a smooth ramp inclined at 80° to the horizontal, as shown, and coasts freely (no further engine work) up the ramp.



(a) Assuming the coaster accelerates at a constant rate, use the work-energy theorem to determine the maximum velocity it reaches.

(b) By conservation of energy, determine the maximum height, h , the rollercoaster reaches up the ramp.

[3]

(c) Determine the time taken for the rollercoaster to reach this height.

[3]

(Total for Question 91 = 8 marks)



Topic 2: Mechanics — Mark Scheme

Mark scheme for the original questions above, written by GuideMyGrades. Click [QUESTION](#) to jump back.

2.1 Distance, Velocity & Acceleration-time Graphs

A. Distance-Time Graphs

Question 1

[QUESTION](#)

Question Number	Answer	Mark
1(a)	speed = gradient = (change in distance) ÷ (change in time) = 80 / 10	M1
	= 8.0 m s ⁻¹	A1
	Total for Question 1	2

Question 2

[QUESTION](#)

Question Number	Answer	Mark
2(a)	speed = gradient = (change in distance) ÷ (change in time) = 100 / 20	M1
	= 5.0 m s ⁻¹	A1
2(b)	speed = (180 – 100) / (50 – 30) = 80 / 20	M1
	= 4.0 m s ⁻¹	A1
	Total for Question 2	4

B. Displacement-Time Graphs

Question 3

[QUESTION](#)

Question Number	Answer	Mark
3(a)	velocity = gradient = (change in displacement) ÷ (change in time) = (–18 – 0) / 6	M1
	= –3.0 m s ⁻¹	A1
	Total for Question 3	2

Question 4

[QUESTION](#)

Question Number	Answer	Mark
4(a)	velocity = 25 / 10	M1



	$= +2.5 \text{ m s}^{-1}$ (positive, moving away from the wall)	A1
4(b)	velocity $= (-5 - 25) / (22 - 10) = -30 / 12$	M1
	$= -2.5 \text{ m s}^{-1}$ (negative, moving back towards and past the wall)	A1
	Total for Question 4	4

Question 5

◀ QUESTION

Question Number	Answer	Mark
5(a)	straight line, positive gradient, from (0, 0) to (15, 30)	B1
	flat line from (15, 30) to (25, 30)	B1
	straight line, positive gradient, from (25, 30) to (40, 60)	B1
5(b)	velocity $= (60 - 30) / (40 - 25) = 30 / 15$	M1
	$= +2.0 \text{ m s}^{-1}$	A1
	Total for Question 5	5

Question 6

◀ QUESTION

Question Number	Answer	Mark
6(a)	straight line, positive gradient, from (0, 0) to (10, 40)	B1
	flat line from (10, 40) to (18, 40)	B1
	straight line, positive gradient, from (18, 40) to (30, 100)	B1
	straight line, negative gradient, from (30, 100) back to (50, 0)	B1
6(b)	displacement stays constant (flat line, not moving) — e.g. hovering while it releases/delivers the parcel	B1
	Total for Question 6	5

C. Gradient = Acceleration, Area = Displacement

Question 7

◀ QUESTION

Question Number	Answer	Mark
7(a)	deceleration $= (\text{change in } v) \div (\text{change in } t) = (0 - 20) / 8$	M1
	$= -2.5 \text{ m s}^{-2}$, i.e. a deceleration of 2.5 m s^{-2}	A1



7(b)	distance = area under the graph = $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 8 \times 20$	M1
	= 80 m	A1
	Total for Question 7	4

Question 8

◀ QUESTION

Question Number	Answer	Mark
8(a)	acceleration = (change in v) ÷ (change in t) = $30 / 10$	M1
	= 3.0 m s^{-2}	A1
8(b)	deceleration = (change in v) ÷ (change in t) = $(0 - 30) / 10 = -3.0$, i.e. a deceleration of 3.0 m s^{-2}	M1
	(magnitude) = 3.0 m s^{-2}	A1
8(c)	splits the graph into a triangle (0–10 s), a rectangle (10–40 s), and a triangle (40–50 s)	M1
	triangle areas = $\frac{1}{2} \times 10 \times 30 = 150 \text{ m}$ (each); rectangle area = $30 \times 30 = 900 \text{ m}$	M1
	total distance = $150 + 900 + 150 = 1200 \text{ m}$	A1
	Total for Question 8	7

Question 9

◀ QUESTION

Question Number	Answer	Mark
9(a)	distance = area of triangle = $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 3 \times 6$	M1
	= 9 m	A1
	Total for Question 9	2

Question 10

◀ QUESTION

Question Number	Answer	Mark
10(a)	splits the graph into a triangle (0–4 s) and a rectangle (4–10 s)	M1
	triangle area = $\frac{1}{2} \times 4 \times 8 = 16 \text{ m}$; rectangle area = $6 \times 8 = 48 \text{ m}$	M1
	total distance = $16 + 48 = 64 \text{ m}$	A1
	Total for Question 10	3



Question 11

◀ QUESTION

Question Number	Answer	Mark
11(a)	valid method shown, e.g. counting whole and part grid squares under the curve	M1
	answer in the range 25–32 m (true value ≈ 28 m)	A1
	Total for Question 11	2

Question 12

◀ QUESTION

Question Number	Answer	Mark
12(a)	valid method shown, e.g. counting whole and part grid squares under the curve	M1
	answer in the range 48–58 m (true value ≈ 53 m)	A1
	Total for Question 12	2

D. Acceleration-Time Graphs

Question 13

◀ QUESTION

Question Number	Answer	Mark
13(a)	change in velocity = area under graph = base $\times$ height = 4×2	M1
	= 8.0 m s^{-1}	A1
	Total for Question 13	2

Question 14

◀ QUESTION

Question Number	Answer	Mark
14(a)	change in velocity = area under graph = base $\times$ height = 6×1.5	M1
	= 9.0 m s^{-1}	A1
14(b)	change in velocity = area under graph = $3 \times (-2)$	M1
	= -6.0 m s^{-1} (i.e. a decrease of 6.0 m s^{-1})	A1
	Total for Question 14	4



E. Linking the Graphs: How to Describe Each Shape

Question 15

◀ QUESTION

Question Number	Answer	Mark
15(a)	Straight line, constant positive gradient — constant velocity (uniform motion)	B1
	the drone moves away from the launch point at a steady 2 m s^{-1}	B1
15(b)	Curved line getting steeper — an increasing (positive) gradient, so accelerating	B1
	the drone speeds up from rest to about 3.2 m s^{-1} by $t = 13 \text{ s}$, still moving away from the launch point	B1
15(c)	Straight line, constant negative gradient — constant velocity, but now in the reverse direction	B1
	the drone returns towards the launch point at a steady speed, arriving back at displacement = 0 at $t = 21 \text{ s}$	B1
	Total for Question 15	6

Question 16

◀ QUESTION

Question Number	Answer	Mark
16(a)	Curved line getting steeper — an increasing gradient, so accelerating	B1
	the biker speeds up from rest to 2.4 m s^{-1} by $t = 6 \text{ s}$	B1
16(b)	Straight line — constant gradient, so constant speed	B1
	the biker climbs at a steady 2.4 m s^{-1}	B1
16(c)	Curved line levelling off — a decreasing gradient, so decelerating	B1
	the biker slows from 2.4 m s^{-1} , approaching a much slower, steadier pace by $t = 26 \text{ s}$ (distance is still increasing, so the biker never fully stops)	B1
	Total for Question 16	6

F. Linking All Three Graphs: Displacement, Velocity & Acceleration

Question 17

◀ QUESTION

Question Number	Answer	Mark
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17(a)	B — velocity = 0, acceleration = g downwards (momentarily at rest, but gravity never switches off)	B1
17(b)	B — constant, downwards throughout, including at the top (gravity acts continuously; the resultant force is never zero during the flight)	B1
	Total for Question 17	2

Question 18

◀ QUESTION

Question Number	Answer	Mark
18(a)	-12 m s^{-1} (same magnitude as the throw speed, opposite direction — the flight is symmetrical)	B1
18(b)	single straight line, constant negative gradient, from (0, +12) to (2.45, -12)	B1
	line correctly labelled $+12 \text{ m s}^{-1}$ at $t = 0$ and -12 m s^{-1} at $t = 2.45 \text{ s}$	B1
	line crosses $v = 0$ at $t = 1.22 \text{ s}$ (accept 1.1–1.3 s), correctly marked as the highest point	B1
	Total for Question 18	4

Question 19

◀ QUESTION

Question Number	Answer	Mark
19(a)	C — very large, directed upwards (the floor's contact force reverses the ball's motion almost instantly — far greater than g)	B1
19(b)	B — lower height AND less time at every bounce (both are evidence of energy lost at each bounce)	B1
	Total for Question 19	2

Question 20

◀ QUESTION

Question Number	Answer	Mark
20(a)	$v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 4}$	M1
	$= 8.86 \text{ m s}^{-1}$ (accept 8.7–9.0)	A1
20(b)	straight line, constant negative gradient, from (0, 0) down to -8.86 m s^{-1} (accept -8.7 to -9.0) at the bounce, labelled	B1
	sudden (near-vertical) jump UP at the bounce, to $+5.3 \text{ m s}^{-1}$ (accept $+5.0$ to $+5.6$), labelled — 60% of the impact speed	B1



	straight line continuing down from the rebound value, back through $v = 0$, to landing — same gradient magnitude as the first line	B1
	Total for Question 20	5

Question 21

◀ QUESTION

Question Number	Answer	Mark
21(a)	Displacement-time: a curve getting steeper (concave up), since the velocity is increasing	B1
	Acceleration-time: a horizontal line ABOVE the time axis (constant positive acceleration)	B1
21(b)	Displacement-time: a straight, sloped line, since the velocity is constant	B1
	Acceleration-time: a horizontal line ON the time axis ($a = 0$, since velocity isn't changing)	B1
	Total for Question 21	4

Question 22

◀ QUESTION

Question Number	Answer	Mark
22(a)	Displacement-time: a curve levelling off (concave down, still rising), since the velocity is positive but decreasing	B1
	Acceleration-time: a horizontal line BELOW the time axis (constant negative acceleration/deceleration)	B1
22(b)	Displacement-time: a horizontal (flat) line, since the sled is stationary and not travelling any further	B1
	Acceleration-time: a horizontal line ON the time axis ($a = 0$)	B1
	Total for Question 22	4

G. Describing & Interpreting Motion, Including a Change of Direction**Question 23**

◀ QUESTION

Question Number	Answer	Mark
23(a)	Uniform acceleration (constant positive gradient)	B1
	speeding up from rest to 2 m s^{-1} over the first 4 s, moving upwards	B1



23(b)	Constant velocity of 2 m s^{-1} (zero gradient, $v \neq 0$, so moving — not stationary)	B1
23(c)	Uniform deceleration (constant negative gradient)	B1
	slowing from 2 m s^{-1} to rest over 2 s; the lift comes to a complete stop at $t = 12 \text{ s}$	B1
23(d)	Stationary — velocity = 0 for the whole interval (e.g. the doors are open at a floor)	B1
23(e)	Uniform acceleration in the negative direction (gradient and v both negative once moving)	B1
	the lift moves off downwards and speeds up to 3 m s^{-1} over 6 s	B1
	Total for Question 23	8

Question 24

◀ QUESTION

Question Number	Answer	Mark
24(a)	Uniform acceleration from rest (constant positive gradient)	B1
	speeds up to 4 m s^{-1} over the first 3 s, moving towards the delivery point	B1
24(b)	Constant velocity of 4 m s^{-1}	B1
24(c)	Uniformly decelerating; velocity falls from 4 m s^{-1} , reaching zero partway through this section, then becomes negative — the robot reverses direction and begins moving back the way it came, speeding up in that direction	B1
	gradient of section C = $(-2 - 4) / (11 - 9) = -3 \text{ m s}^{-2}$; reads/interpolates the time at which the line crosses $v = 0$	M1
	$t \approx 10.3 \text{ s}$ (accept 10.2–10.5 s)	A1
24(d)	Constant velocity of -2 m s^{-1} — continues moving away from the delivery point at a steady speed	B1
	Total for Question 24	7

H. Non-Uniform Motion: Tangents & Estimating the Area Under a Curve

Question 25

◀ QUESTION

Question Number	Answer	Mark
25(a)	reads two points on the tangent line and calculates its gradient (rise $\div$ run)	M1
	answer in the range $0.8\text{--}1.2 \text{ m s}^{-2}$ (true value $\approx 0.98 \text{ m s}^{-2}$)	A1



25(b)	valid method shown, e.g. counting grid squares, or splitting the area into strips/trapezia and summing them	M1
	answer in the range 45–53 m (true value ≈ 49 m)	A1
	Total for Question 25	4

Question 26

◀ QUESTION

Question Number	Answer	Mark
26(a)	reads two points on the tangent line and calculates its gradient (rise $\div$ run)	M1
	answer in the range 1.1–1.6 m s ⁻² (true value ≈ 1.38 m s ⁻²)	A1
26(b)	valid method shown, e.g. counting grid squares, or splitting the area into strips/trapezia and summing them	M1
	answer in the range 47–57 m (true value ≈ 52 m)	A1
	Total for Question 26	4

I. Terminal Velocity: The Parachutist Problem**Question 27**

◀ QUESTION

Question Number	Answer	Mark
27(a)	reads two points on the tangent line and calculates its gradient (rise $\div$ run)	M1
	answer in the range 4.2–5.2 m s ⁻² (true value ≈ 4.7 m s ⁻²)	A1
27(b)	distance = area under graph = base $\times$ height $\approx 4 \times 37$	M1
	answer in the range 135–160 m (true value ≈ 149 m)	A1
	Total for Question 27	4

Question 28

◀ QUESTION

Question Number	Answer	Mark
28(a)	distance = area under graph = base $\times$ height $\approx 7 \times 40$	M1
	answer in the range 260–295 m (true value ≈ 279 m)	A1
28(b)	resultant force = 0 N	B1
	because the velocity is constant (terminal velocity) — the forces are balanced, so air resistance (drag) must equal weight	B1



	Total for Question 28	4
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2.2 Equations of Uniformly Accelerated Motion (SUVAT)

A. The Four SUVAT Equations & Choosing the Right One

Question 29

[◀ QUESTION](#)

Question Number	Answer	Mark
29(a)	$v = u + at = 0 + (3.0 \times 4.0)$	M1
	$= 12 \text{ m s}^{-1}$	A1
29(b)	$s = ut + \frac{1}{2}at^2 = 0 + (0.5 \times 3.0 \times 4.0^2)$	M1
	$= 24 \text{ m}$	A1
	Total for Question 29	4

Question 30

[◀ QUESTION](#)

Question Number	Answer	Mark
30(a)	$v^2 = u^2 + 2as: 0^2 = 20^2 + 2 \times a \times 250$	M1
	$a = -0.80 \text{ m s}^{-2}$, i.e. a deceleration of 0.80 m s^{-2}	A1
30(b)	$v = u + at: 0 = 20 + (-0.80 \times t)$	M1
	$t = 25 \text{ s}$	A1
	Total for Question 30	4

B. Applying SUVAT Vertically: Free Fall & Vertical Motion

Question 31

[◀ QUESTION](#)

Question Number	Answer	Mark
31(a)	$v = u + at = 5.0 + (9.81 \times 3.0)$	M1
	$= 34.4 \text{ m s}^{-1}$	A1
31(b)	$s = ut + \frac{1}{2}at^2 = (5.0 \times 3.0) + (0.5 \times 9.81 \times 3.0^2)$	M1
	$= 59.1 \text{ m}$	A1
	Total for Question 31	4



Question 32

◀ QUESTION

Question Number	Answer	Mark
32(a)	at maximum height, $v = 0$; $v^2 = u^2 + 2as$: $0^2 = 12^2 + (2 \times (-9.81) \times s)$	M1
	$s = 144 / 19.62$	M1
	$= 7.34 \text{ m}$	A1
32(b)	$v = u + at$: $0 = 12 + (-9.81 \times t)$	M1
	$t = 1.22 \text{ s}$	A1
	Total for Question 32	5

2.3 Scalars, Vectors & Resolving Vectors

A. Scalars vs Vectors & Adding Perpendicular Vectors

Question 33

◀ QUESTION

Question Number	Answer	Mark
33(a)	$R = \sqrt{(120^2 + 50^2)} = \sqrt{(14400 + 2500)} = \sqrt{16900}$	M1
	$= 130 \text{ km}$	A1
33(b)	$\theta = \tan^{-1}(50 / 120)$	M1
	$= 22.6^\circ \text{ east of north}$	A1
	Total for Question 33	4

Question 34

◀ QUESTION

Question Number	Answer	Mark
34(a)	$R = \sqrt{(30^2 + 40^2)} = \sqrt{(900 + 1600)} = \sqrt{2500}$	M1
	$= 50 \text{ N}$	A1
34(b)	$\theta = \tan^{-1}(40 / 30)$	M1
	$= 53.1^\circ$	A1
	Total for Question 34	4

B. Resolving a Vector Into Components

Question 35

◀ QUESTION



Question Number	Answer	Mark
35(a)	$F_x = F \cos\theta = 80 \times \cos 25^\circ$	M1
	$= 72.5 \text{ N}$	A1
35(b)	$F_y = F \sin\theta = 80 \times \sin 25^\circ$	M1
	$= 33.8 \text{ N}$	A1
	Total for Question 35	4

Question 36

◀ QUESTION

Question Number	Answer	Mark
36(a)	$v_x = v \cos\theta = 18 \times \cos 35^\circ$	M1
	$= 14.7 \text{ m s}^{-1}$	A1
36(b)	$v_y = v \sin\theta = 18 \times \sin 35^\circ$	M1
	$= 10.3 \text{ m s}^{-1}$	A1
	Total for Question 36	4

C. Adding Vectors by Calculation (Non-Perpendicular)

Question 37

◀ QUESTION

Question Number	Answer	Mark
37(a)	$F_x = 25 + (15 \times \cos 50^\circ) = 25 + 9.64 = 34.6 \text{ N}$	M1
	$F_y = 15 \times \sin 50^\circ = 11.5 \text{ N}$	M1
	$R = \sqrt{(34.6^2 + 11.5^2)} = 36.5 \text{ N}$	A1
37(b)	$\theta = \tan^{-1}(11.5 / 34.6)$	M1
	$= 18.4^\circ \text{ north of east}$	A1
	Total for Question 37	5

Question 38

◀ QUESTION

Question Number	Answer	Mark
38(a)	$R = \sqrt{(800^2 + 300^2)} = \sqrt{730000}$	M1



	= 854 N	A1
38(b)	$\theta = \tan^{-1}(300 / 800)$	M1
	= 20.6° east of north	A1
	Total for Question 38	4

2.4 Projectile Motion

A. Horizontal Projection (Launched Off a Height)

Question 39

[QUESTION](#)

Question Number	Answer	Mark
39(a)	$s = ut + \frac{1}{2}at^2$: $20 = 0 + (0.5 \times 9.81 \times t^2)$	M1
	$t = 2.02 \text{ s}$	A1
39(b)	distance = speed $\times$ time = 15×2.02	M1
	= 30.3 m	A1
	Total for Question 39	4

Question 40

[QUESTION](#)

Question Number	Answer	Mark
40(a)	$s = ut + \frac{1}{2}at^2$: $500 = 0 + (0.5 \times 9.81 \times t^2)$	M1
	$t = 10.1 \text{ s}$	A1
40(b)	distance = speed $\times$ time = 60×10.1	M1
	= 606 m	A1
	Total for Question 40	4

B. Projectiles Launched at an Angle

Question 41

[QUESTION](#)

Question Number	Answer	Mark
41(a)	$u_y = 25 \times \sin 40^\circ = 16.1 \text{ m s}^{-1}$	M1
	$t = 2u_y / g = (2 \times 16.1) / 9.81$	M1
	= 3.28 s	A1



41(b)	$u_x = 25 \times \cos 40^\circ = 19.2 \text{ m s}^{-1}$; range = $u_x \times t = 19.2 \times 3.28$	M1
	= 62.8 m	A1
	Total for Question 41	5

Question 42

◀ QUESTION

Question Number	Answer	Mark
42(a)	$u_y = 35 \times \sin 25^\circ = 14.8 \text{ m s}^{-1}$	M1
	$h_{\max} = u_y^2 / (2g) = 14.8^2 / (2 \times 9.81)$	M1
	= 11.2 m	A1
42(b)	$u_x = 35 \times \cos 25^\circ = 31.7 \text{ m s}^{-1}$; $t = 2u_y / g = 3.01 \text{ s}$	M1
	range = $u_x \times t = 31.7 \times 3.01$	M1
	= 95.6 m	A1
	Total for Question 42	6

C. Projectiles Launched at an Angle From a Height

Question 43

◀ QUESTION

Question Number	Answer	Mark
43(a)	$u_y = 12 \times \sin 20^\circ = 4.10 \text{ m s}^{-1}$	B1
43(b)	$h_{\max} = 15 + u_y^2 / (2g) = 15 + 4.10^2 / (2 \times 9.81)$	M1
	= 15.9 m	A1
43(c)	$4.905t^2 - 4.10t - 15 = 0$	M1
	$t = [4.10 + \sqrt{(4.10^2 + 4 \times 4.905 \times 15)}] / (2 \times 4.905) = 2.22 \text{ s}$	M1
	range = $u_x \times t = (12 \cos 20^\circ) \times 2.22 = 11.3 \times 2.22$	M1
	= 25.0 m	A1
	Total for Question 43	7

Question 44

◀ QUESTION

Question Number	Answer	Mark
44(a)	$u_x = 30 \cos 40^\circ = 23.0 \text{ m s}^{-1}$	M1



	$u_y = 30\sin 40^\circ = 19.3 \text{ m s}^{-1}$	A1
44(b)	$h_{\max} = 40 + u_y^2 / (2g) = 40 + 19.3^2 / (2 \times 9.81)$	M1
	$= 59.0 \text{ m}$	A1
44(c)	$4.905t^2 - 19.3t - 40 = 0$	M1
	$t = [19.3 + \sqrt{(19.3^2 + 4 \times 4.905 \times 40)}] / (2 \times 4.905) = 5.43 \text{ s}$	M1
	$\text{range} = u_x \times t = 23.0 \times 5.43$	M1
	$= 124.9 \text{ m}$	A1
	Total for Question 44	8

D. Projectiles Hitting a Raised Target

Question 45

◀ QUESTION

Question Number	Answer	Mark
45(a)	$u_x = 8.0\cos 50^\circ = 5.14 \text{ m s}^{-1}$	M1
	$u_y = 8.0\sin 50^\circ = 6.13 \text{ m s}^{-1}$	A1
45(b)	$t = x / u_x = 4.0 / 5.14$	M1
	$= 0.778 \text{ s}$	A1
45(c)	$y = u_y t - \frac{1}{2}gt^2 = (6.13 \times 0.778) - (0.5 \times 9.81 \times 0.778^2)$	M1
	$= 4.77 - 2.97 = 1.80 \text{ m}$	M1
	$y = 1.80 \text{ m}$ equals the ring's height, so the ball passes through the ring	A1
	Total for Question 45	7

Question 46

◀ QUESTION

Question Number	Answer	Mark
46(a)	$u_x = 20\cos 25^\circ = 18.1 \text{ m s}^{-1}$	M1
	$t = x / u_x = 9.0 / 18.1 = 0.497 \text{ s}$	A1
46(b)	$u_y = 20\sin 25^\circ = 8.45 \text{ m s}^{-1}$; $y = u_y t - \frac{1}{2}gt^2 = (8.45 \times 0.497) - (0.5 \times 9.81 \times 0.497^2)$	M1
	$= 4.20 - 1.21 = 2.99 \text{ m}$	A1
46(c)	$2.99 \text{ m} > 2.5 \text{ m}$	B1



	so the ball clears the wall (with about 0.5 m to spare)	B1
	Total for Question 46	6

2.5 Forces, Free-Body Diagrams & Newton's Laws

A. Triangle of Forces: Checking Equilibrium

Question 47

[◀ QUESTION](#)

Question Number	Answer	Mark
47(a)	resultant of F_1 and F_2 (perpendicular): $\sqrt{(30^2 + 40^2)} = \sqrt{2500} = 50$ N	M1
	$F_3 = 50$ N, equal in magnitude and opposite in direction to this resultant, so drawn tip to tail the three vectors return exactly to the start	M1
	closed triangle formed	A1
47(b)	$\Sigma F = 0$, so the ring is in equilibrium	B1
	Total for Question 47	4

Question 48

[◀ QUESTION](#)

Question Number	Answer	Mark
48(a)	resultant of F_1 , F_2 (perpendicular) = $\sqrt{(24^2 + 7^2)} = \sqrt{625}$	M1
	= 25 N	A1
48(b)	F_3 is equal in magnitude and opposite in direction to the resultant of F_1 and F_2	B1
	so, drawn tip to tail, the three forces form a closed triangle: $\Sigma F = 0$	B1
	Total for Question 48	4

B. Triangle of Forces: Non-Equilibrium & the Resultant

Question 49

[◀ QUESTION](#)

Question Number	Answer	Mark
49(a)	the three vectors, drawn tip to tail, do NOT form a closed shape — there is a gap between the tail of F_1 and the tip of F_3 : $\Sigma F \neq 0$	M1
	the missing side, drawn from the tail of F_1 to the tip of F_3 , is the resultant, R	A1
49(b)	$\Sigma F_x = 25 + 25\cos 120^\circ + 20\cos 240^\circ = 25 - 12.5 - 10.0 = 2.5$ N	M1



	$\Sigma F_y = 25\sin 120^\circ + 20\sin 240^\circ = 21.7 - 17.3 = 4.3 \text{ N}$	M1
	$R = \sqrt{(2.5^2 + 4.3^2)} = 5.0 \text{ N}$ at $\theta = 60^\circ$ above the horizontal (accept scale-drawing answers in the range 4.5–5.5 N, 55–65°)	A1
	Total for Question 49	5

Question 50

◀ QUESTION

Question Number	Answer	Mark
50(a)	the four vectors, drawn tip to tail, do NOT form a closed shape — there is a gap between the tail of F_1 and the tip of F_4 : $\Sigma \mathbf{F} \neq \mathbf{0}$	M1
	the missing side, drawn from the tail of F_1 to the tip of F_4 , is the resultant, R	A1
50(b)	$\Sigma F_x = 30\cos 40^\circ + 45\cos 140^\circ + 25\cos 250^\circ + 40\cos 330^\circ = 23.0 - 34.5 - 8.6 + 34.6 = 14.6 \text{ N}$	M1
	$\Sigma F_y = 30\sin 40^\circ + 45\sin 140^\circ + 25\sin 250^\circ + 40\sin 330^\circ = 19.3 + 28.9 - 23.5 - 20.0 = 4.7 \text{ N}$	M1
	$R = \sqrt{(14.6^2 + 4.7^2)} = 15.3 \text{ N}$ at $\theta = 17.9^\circ$ above the horizontal (accept scale-drawing answers in the range 14–17 N, 15–22°)	A1
	Total for Question 50	5

C. Scale Diagrams for Resultant Forces

Question 51

◀ QUESTION

Question Number	Answer	Mark
51(a)	C	B1
51(b)	any ONE valid explanation, e.g. A shows R pointing in the wrong direction (reversed); B and D show the wrong diagonal of the parallelogram — not the one found by placing the vectors tip to tail	B2
	Total for Question 51	3

Question 52

◀ QUESTION

Question Number	Answer	Mark
52(a)	B	B1



52(b)	any ONE valid explanation, e.g. A shows R in the wrong direction (reversed); C and D show the wrong diagonal of the parallelogram, not the tip-to-tail one	B2
	Total for Question 52	3

Question 53

◀ QUESTION

Question Number	Answer	Mark
53(a)	correct scale drawing (6.0 cm $\perp$ 4.0 cm), R measured as 5.0 cm	M1
	R = 50 N (accept 48–52 N by scale drawing; exact: $\sqrt{(40^2 + 30^2)} = 50$ N)	A1
53(b)	protractor correctly lined up against the horizontal (the 40 N force)	M1
	angle to horizontal $\approx 37^\circ$ (accept 35° – 39° ; exact: $\tan^{-1}(30/40) = 36.9^\circ$)	A1
53(c)	$90^\circ - 37^\circ = 53^\circ$ (no new measurement needed — the angle to the vertical is always the COMPLEMENT of the angle to the horizontal)	B1
	Total for Question 53	5

D. Resolving Forces in Equilibrium

Question 54

◀ QUESTION

Question Number	Answer	Mark
54(a)	horizontal ($\Sigma F_x = 0$): $T_1 \cos 40^\circ = T_2 \cos 30^\circ$	M1
	$T_1 = T_2 \times (\cos 30^\circ / \cos 40^\circ) = 1.13 T_2$	A1
54(b)	vertical ($\Sigma F_y = 0$): $T_1 \sin 40^\circ + T_2 \sin 30^\circ = 39.2$	M1
	substituting: $(1.13 T_2 \times \sin 40^\circ) + T_2 \sin 30^\circ = 39.2 \rightarrow 1.23 T_2 = 39.2$	M1
	$T_2 = 32.0$ N, so $T_1 = 1.13 \times 32.0 = 36.2$ N	A1
	Total for Question 54	5

Question 55

◀ QUESTION

Question Number	Answer	Mark
55(a)	vertical ($\Sigma F_y = 0$): $T_1 \sin 60^\circ = W = 49.1$	M1
	$T_1 = 49.1 / \sin 60^\circ = 56.7$ N	A1
55(b)	horizontal ($\Sigma F_x = 0$): $T_2 = T_1 \cos 60^\circ$	M1



	$= 56.7 \times \cos 60^\circ = 28.3 \text{ N}$	A1
	Total for Question 55	4

Question 56[◀ QUESTION](#)

Question Number	Answer	Mark
56(a)	horizontal ($\Sigma F_x = 0$): $T_1 \cos 25^\circ = T_2 \cos 65^\circ$	M1
	$T_1 = T_2 \times (\cos 65^\circ / \cos 25^\circ) = 0.466 T_2$	A1
56(b)	vertical ($\Sigma F_y = 0$): $T_1 \sin 25^\circ + T_2 \sin 65^\circ = 85$; substituting: $(0.466 T_2 \times \sin 25^\circ) + T_2 \sin 65^\circ = 85 \rightarrow 1.103 T_2 = 85$	M1
	$T_2 = 77.1 \text{ N}$	M1
	$T_1 = 0.466 \times 77.1 = 35.9 \text{ N}$	A1
	Total for Question 56	5

Question 57[◀ QUESTION](#)

Question Number	Answer	Mark
57(a)	vertical ($\Sigma F_y = 0$): $T \sin 55^\circ = W = 12$	M1
	$T = 12 / \sin 55^\circ = 14.7 \text{ N}$	A1
57(b)	horizontal ($\Sigma F_x = 0$): $F = T \cos 55^\circ$	M1
	$= 14.7 \times \cos 55^\circ = 8.4 \text{ N}$	A1
	Total for Question 57	4

E. Balanced Forces on a Slope**Question 58**[◀ QUESTION](#)

Question Number	Answer	Mark
58(a)	$W = mg = 12 \times 9.81 = 118 \text{ N}$	B1
58(b)	$R = W \cos 30^\circ = 117.7 \times \cos 30^\circ$	M1
	$= 102 \text{ N}$	A1
58(c)	$F = W \sin 30^\circ = 117.7 \times \sin 30^\circ$	M1
	$= 58.9 \text{ N}$	A1

	Total for Question 58	5
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Question 59[◀ QUESTION](#)

Question Number	Answer	Mark
59(a)	$W = mg = 3.5 \times 9.81 = 34.3 \text{ N}$	B1
59(b)	$F = W \sin\theta: 12.0 = 34.3 \times \sin\theta$	M1
	$\sin\theta = 12.0 / 34.3 = 0.350$	M1
	$\theta = 20.5^\circ$	A1
59(c)	$R = W \cos\theta = 34.3 \times \cos 20.5^\circ$	M1
	$= 32.1 \text{ N}$	A1
	Total for Question 59	6

F. Newton's Second Law: $F = ma$ **Question 60**[◀ QUESTION](#)

Question Number	Answer	Mark
60(a)	$a = F / m = 2500 / 800$	M1
	$= 3.13 \text{ m s}^{-2}$	A1
60(b)	$v = u + at = 0 + (3.13 \times 5.0)$	M1
	$= 15.6 \text{ m s}^{-1}$	A1
	Total for Question 60	4

Question 61[◀ QUESTION](#)

Question Number	Answer	Mark
61(a)	$a = F / m = 8.0 / 0.50$	M1
	$= 16 \text{ m s}^{-2}$	A1
61(b)	$s = ut + \frac{1}{2}at^2 = 0 + (0.5 \times 16 \times 2.0^2)$	M1
	$= 32 \text{ m}$	A1
	Total for Question 61	4



G. Weight & Newton's Third Law

Question 62

◀ QUESTION

Question Number	Answer	Mark
62(a)	$a = F / m = 300 / 60$	M1
	$= 5.0 \text{ m s}^{-2}$	A1
62(b)	300 N, in the opposite direction (pushing the spacecraft away from the astronaut)	B1
	Newton's third law	B1
62(c)	$a = F / m = 300 / 12000$	M1
	$= 0.025 \text{ m s}^{-2}$	A1
	Total for Question 62	6

Question 63

◀ QUESTION

Question Number	Answer	Mark
63(a)	equilibrium, so $N = W$	M1
	$= 4.0 \text{ N}$	A1
63(b)	the book pushes down on the table	B1
	with an equal force of 4.0 N, acting on the table (not on the book)	B1
	Total for Question 63	4

2.6 Core Practical 1: Determining g by Free Fall

A. Determining g From a Displacement-Time-Squared Graph

Question 64

◀ QUESTION

Question Number	Answer	Mark
64(a)	$g = 2 \times \text{gradient} = 2 \times 4.85$	M1
	$= 9.70 \text{ m s}^{-2}$	A1
64(b)	% difference = $ 9.70 - 9.81 / 9.81 \times 100$	M1
	$= 1.12\%$	A1
	Total for Question 64	4



Question 65

◀ QUESTION

Question Number	Answer	Mark
65(a)	gradient = $2.42 / 0.50$	M1
	= 4.84 m s^{-2}	A1
65(b)	$g = 2 \times \text{gradient} = 2 \times 4.84$	M1
	= 9.68 m s^{-2}	A1
	Total for Question 65	4

2.7 Momentum & Conservation of Momentum

A. Momentum & Impulse

Question 66

◀ QUESTION

Question Number	Answer	Mark
66(a)	impulse = $\delta p = m(v - u) = 0.046 \times (65 - 0)$	M1
	= 2.99 N s	A1
66(b)	$F = \delta p / \delta t = 2.99 / (5.0 \times 10^{-4})$	M1
	= 5980 N	A1
	Total for Question 66	4

Question 67

◀ QUESTION

Question Number	Answer	Mark
67(a)	$\delta p = m(v - u) = 900 \times (0 - 15)$	M1
	= $-13\,500 \text{ N s}$ (magnitude $13\,500 \text{ N s}$)	A1
67(b)	$F = \delta p / \delta t = 13500 / 2.5$	M1
	= 5400 N	A1
	Total for Question 67	4

B. Conservation of Momentum: Collisions & Explosions

Question 68

◀ QUESTION



Question Number	Answer	Mark
68(a)	$p = (3.0 \times 4.0) + (2.0 \times 0) = 12 \text{ kg m s}^{-1}$	B1
68(b)	$12 = (3.0 + 2.0) \times v \rightarrow v = 12 / 5.0$	M1
	$= 2.4 \text{ m s}^{-1}$	A1
	Total for Question 68	3

Question 69

◀ QUESTION

Question Number	Answer	Mark
69(a)	momentum before = 0, as the trolley is at rest (stationary system)	B1
	momentum is conserved (no external resultant force), so total momentum after must also be zero	B1
69(b)	$(0.30 \times 6.0) + (0.50 \times (-v)) = 0 \rightarrow 1.8 = 0.50v$	M1
	$v = 3.6 \text{ m s}^{-1}$, to the left	A1
	Total for Question 69	4

C. Elastic & Inelastic Collisions

Question 70

◀ QUESTION

Question Number	Answer	Mark
70(a)	$1.0 \times 6.0 = (1.0 \times (-1.0)) + 2.0v \rightarrow 6.0 = -1.0 + 2.0v$	M1
	$2.0v = 7.0$	M1
	$v = 3.5 \text{ m s}^{-1}$ (same direction as the 1.0 kg ball's original motion)	A1
70(b)	$\text{KE before} = \frac{1}{2} \times 1.0 \times 6.0^2 = 18.0 \text{ J}$	M1
	$\text{KE after} = (\frac{1}{2} \times 1.0 \times 1.0^2) + (\frac{1}{2} \times 2.0 \times 3.5^2) = 0.5 + 12.25 = 12.75 \text{ J}$	M1
	since $\text{KE after} < \text{KE before}$ ($12.75 \text{ J} < 18.0 \text{ J}$), the collision is inelastic	A1
	Total for Question 70	6

Question 71

◀ QUESTION

Question Number	Answer	Mark
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71(a)	$8000 \times 3.0 = (8000 + 4000) \times v \rightarrow v = 24000 / 12000$	M1
	$= 2.0 \text{ m s}^{-1}$	A1
71(b)	$\text{KE before} = \frac{1}{2} \times 8000 \times 3.0^2 = 3.6 \times 10^4 \text{ J}$	M1
	$\text{KE after} = \frac{1}{2} \times 12000 \times 2.0^2 = 2.4 \times 10^4 \text{ J}$	M1
	$\text{KE lost} = 3.6 \times 10^4 - 2.4 \times 10^4 = 1.2 \times 10^4 \text{ J}$	A1
	Total for Question 71	5

D. Momentum in Two Dimensions

Question 72

◀ QUESTION

Question Number	Answer	Mark
72(a)	parallel: $p = (1.0 \times 4.0) - (1.0 \times 2.0 \times \cos 45^\circ) = 4.0 - 1.41$	M1
	$= 2.59 \text{ kg m s}^{-1}$	A1
	perpendicular: $p = 0 - (1.0 \times 2.0 \times \sin 45^\circ) = -1.41 \text{ kg m s}^{-1}$	A1
72(b)	$ p = \sqrt{(2.59^2 + 1.41^2)} = \sqrt{8.68} = 2.95 \text{ kg m s}^{-1}$	M1
	$v = 2.95 \text{ m s}^{-1}$ (mass = 1.0 kg)	A1
	$\theta = \tan^{-1}(1.41 / 2.59) = 28.6^\circ$, on the opposite side to the first ball's deflection	A1
	Total for Question 72	6

Question 73

◀ QUESTION

Question Number	Answer	Mark
73(a)	vertical: $p = (0.60 \times 20) - (0.30 \times 25 \times \cos 20^\circ) = 12.0 - 7.05$	M1
	$= 4.95 \text{ kg m s}^{-1}$	A1
	horizontal: $p = 0 - (0.30 \times 25 \times \sin 20^\circ) = -2.57 \text{ kg m s}^{-1}$	A1
73(b)	$ p = \sqrt{(4.95^2 + 2.57^2)} = \sqrt{31.1} = 5.58 \text{ kg m s}^{-1}$	M1
	$v = 5.58 / 0.30 = 18.6 \text{ m s}^{-1}$	A1
	$\theta = \tan^{-1}(2.57 / 4.95) = 27.4^\circ$, on the opposite side of the vertical to the first fragment	A1
	Total for Question 73	6



2.8 Moments & Equilibrium

A. Moments & the Principle of Moments

Question 74

[◀ QUESTION](#)

Question Number	Answer	Mark
74(a)	$\Sigma M_{\text{clockwise}} = \Sigma M_{\text{anticlockwise}}$ (about the same point), for an object in equilibrium	B1
74(b)	$700 \times 0.90 = 350 \times d \rightarrow d = 630 / 350$	M1
	$= 1.8 \text{ m}$	A1
	Total for Question 74	3

Question 75

[◀ QUESTION](#)

Question Number	Answer	Mark
75(a)	$M = Fx = 45 \times 0.40$	M1
	$= 18 \text{ N m}$	A1
75(b)	$F \times 0.60 = 18 \rightarrow F = 18 / 0.60$	M1
	$= 30 \text{ N}$	A1
	Total for Question 75	4

B. Centre of Gravity & Non-Uniform Beams

Question 76

[◀ QUESTION](#)

Question Number	Answer	Mark
76(a)	the beam's weight acts at its centre of gravity, which is exactly at the pivot	B1
	so its perpendicular distance from the pivot is zero, giving a moment of zero	B1
76(b)	$30 \times 1.2 = F \times 0.80 \rightarrow F = 36 / 0.80$	M1
	$= 45 \text{ N}$	A1
	Total for Question 76	4

Question 77

[◀ QUESTION](#)

Question Number	Answer	Mark
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77(a)	$M = 40 \times 0.50$	M1
	$= 20 \text{ N m}$	A1
77(b)	clockwise moment from beam's weight $= 80 \times 0.20 = 16 \text{ N m}$	M1
	extra clockwise moment needed $= 20 - 16 = 4 \text{ N m}$; $F \times 1.0 = 4$	M1
	$F = 4 \text{ N}$	A1
	Total for Question 77	5

C. Moments in Everyday Levers

Question 78

[◀ QUESTION](#)

Question Number	Answer	Mark
78(a)	$\text{height}^2 = 4.0^2 - 1.2^2 = 16 - 1.44 = 14.56$	M1
	$\text{height} = \sqrt{14.56} = 3.82 \text{ m}$	A1
78(b)	anticlockwise moment (weight, acting at the ladder's centre of gravity, 0.60 m horizontally from the foot) $= 250 \times 0.60 = 150 \text{ N m}$	M1
	clockwise moment (N, horizontal, perpendicular distance = the ladder's height) $= N \times 3.82$	M1
	$150 = N \times 3.82$	M1
	$N = 39.3 \text{ N}$	A1
	Total for Question 78	6

Question 79

[◀ QUESTION](#)

Question Number	Answer	Mark
79(a)	$M = Fx = 400 \times 0.17$	M1
	$= 68 \text{ N m}$	A1
79(b)	the moment would increase	B1
	because $M = Fx$, and x (the perpendicular distance) has increased while F stays the same	B1
	Total for Question 79	4

Question 80

[◀ QUESTION](#)


Question Number	Answer	Mark
80(a)	$M_{\text{muscle}} = M_{\text{bite}} : 900 \times 0.08 = F_{\text{bite}} \times 0.30$	M1
	$F_{\text{bite}} = 72 / 0.30$	M1
	$= 240 \text{ N}$	A1
80(b)	the muscle acts much closer to the pivot (0.08 m) than the bite point does (0.30 m)	B1
	so, for the moments to be equal, the bite force must be smaller than the muscle force in the same ratio (0.08 / 0.30)	B1
	Total for Question 80	5

D. Stability & Toppling

Question 81

[◀ QUESTION](#)

Question Number	Answer	Mark
81(a)	the line of action of the weight passes exactly through the pivot edge of the base	B1
81(b)	$\tan \theta = (0.60 / 2) / 0.90 = 0.30 / 0.90$	M1
	$\tan \theta = 0.333$	M1
	$\theta = 18.4^\circ$	A1
	Total for Question 81	4

Question 82

[◀ QUESTION](#)

Question Number	Answer	Mark
82(a)	the double-decker's centre of gravity is higher, so for the same base width a smaller tilt angle is needed to move the line of action of the weight beyond the base	B1
	once the line of action falls outside the base (beyond the wheels), the bus topples over	B1
82(b)	lower the centre of gravity (e.g. mount heavier components, such as the engine or batteries, lower down)	B1
	widen the base (the track width between the wheels)	B1
	Total for Question 82	4



2.9 Work, Energy & Power

A. Work Done

Question 83

[◀ QUESTION](#)

Question Number	Answer	Mark
83(a)	$W = Fs = 200 \times 5.0$	M1
	$= 1000 \text{ J}$	A1
	Total for Question 83	2

Question 84

[◀ QUESTION](#)

Question Number	Answer	Mark
84(a)	$W = Fs \cos\theta = 60 \times 10 \times \cos 40^\circ$	M1
	$= 460 \text{ J}$	A1
84(b)	$\theta = 90^\circ$	B1
	$\cos 90^\circ = 0$, so the work done would be zero	B1
	Total for Question 84	4

B. Kinetic & Gravitational Potential Energy; Conservation of Energy

Question 85

[◀ QUESTION](#)

Question Number	Answer	Mark
85(a)	$\delta GPE = mgh = 0.50 \times 9.81 \times 20$	M1
	$= 98.1 \text{ J}$	A1
85(b)	$98.1 = \frac{1}{2} \times 0.50 \times v^2 \rightarrow v^2 = 392.4$	M1
	$v = 19.8 \text{ m s}^{-1}$	A1
	Total for Question 85	4

Question 86

[◀ QUESTION](#)

Question Number	Answer	Mark
86(a)	$\delta Ek = \frac{1}{2}m(v^2 - u^2) = 0.5 \times 1500 \times (25^2 - 10^2)$	M1



	$= 0.5 \times 1500 \times 525$	M1
	$= 393\,750 \text{ J} \approx 394 \text{ kJ}$	A1
	Total for Question 86	3

C. Power & Efficiency

Question 87

QUESTION

Question Number	Answer	Mark
87(a)	$W = mgh = 40 \times 9.81 \times 6.0$	M1
	$= 2354 \text{ J}$	A1
87(b)	$P = W / t = 2354 / 5.0$	M1
	$= 471 \text{ W}$	A1
	Total for Question 87	4

Question 88

QUESTION

Question Number	Answer	Mark
88(a)	efficiency = (useful power output / total power input) $\times$ 100%	B1
88(b)	efficiency = $(1.8 / 2.5) \times 100$	M1
	$= 72\%$	A1
	Total for Question 88	3

D. Energy Transfer: Motors on Ramps

Question 89

QUESTION

Question Number	Answer	Mark
89(a)	$W = mg = 60 \times 9.81 = 588.6 \text{ N}$	B1
89(b)	$T = W \sin\theta + F_r$	M1
	$= (588.6 \times \sin 20^\circ) + 85 = 201.3 + 85$	M1
	$= 286.3 \text{ N}$	A1
89(c)	$W_{\text{motor}} = T \times d = 286.3 \times 6.0 = 1720 \text{ J}$	M1
	$\delta E_p = mgd \sin\theta = 588.6 \times 6.0 \times \sin 20^\circ = 1210 \text{ J}$	M1



	work against friction = $F_r \times d = 85 \times 6.0 = 510 \text{ J}$	A1
	$1210 + 510 = 1720 \text{ J} \checkmark$, matching W_{motor}	A1
	Total for Question 89	8

Question 90

◀ QUESTION

Question Number	Answer	Mark
90(a)	$W = mg = 15 \times 9.81 = 147 \text{ N}$	B1
90(b)	$T = W \sin 15^\circ = 147 \times \sin 15^\circ$	M1
	$= 38.1 \text{ N}$	A1
90(c)	$W_{\text{motor}} = T \times d = 38.1 \times 3.0$	M1
	$= 114 \text{ J}$	A1
	Total for Question 90	5

E. Energy Transfer: Loops & Roller Coasters

Question 91

◀ QUESTION

Question Number	Answer	Mark
91(a)	work-energy theorem: $W = \delta KE \rightarrow 500\,000 = \frac{1}{2} \times 500 \times v^2$	M1
	$v^2 = 2000 \rightarrow v = 44.7 \text{ m s}^{-1}$	A1
91(b)	energy conservation (smooth ramp, comes to rest at max height): $\frac{1}{2}mv^2 = mgh$	M1
	$h = v^2 / (2g) = 2000 / (2 \times 9.81)$	M1
	$= 101.9 \text{ m} (\approx 102 \text{ m})$	A1
91(c)	deceleration along the ramp = $g \sin \theta = 9.81 \times \sin 80^\circ = 9.65 \text{ m s}^{-2}$	M1
	$v = u - at$, with $v = 0$: $t = u / a = 44.7 / 9.65$	M1
	$= 4.63 \text{ s}$	A1
	Total for Question 91	8

