FORCES

AQA GCSE Physics | Topic 5.6

TEACHER EDITION

Contents

LESSON 1

Scalar and Vector Quantities

Do Now

1. Write down three physical quantities that can be measured in a physics experiment.

Answer: Any three from: time, mass, force, temperature, length, speed, energy.

2. A friend says a car is travelling at "60 mph". What extra piece of information would be useful when following directions on a map?

Answer: The direction of travel (e.g. north, or towards town centre). This makes it a velocity.

3. Which of the following need a direction to be fully described? Circle your answers: temperature | a push | mass | weight | the length of a room

Answer: A push and weight need a direction (they are vectors). Temperature, mass and length do not.

4. What do we mean when we say a quantity has a magnitude?

Answer: Magnitude means the size or amount of a quantity (how big it is).

Part 1 of 3 | Physical Quantities and Scalars

Key Information

A quantity is something that can be measured. Time, mass and force are all examples. 1

A scalar quantity has magnitude (size) only — no direction. 2

Examples of scalar quantities: distance, speed, energy, temperature, mass, time. 3

It is incorrect to give a scalar quantity a direction — scalars have no direction, so stating one is meaningless. 4

Questions

1. Define a scalar quantity.

(2 marks)

2. Give three examples of scalar quantities.

(2 marks)

3. Molly says "the mass of the parachutist is 75 kg towards the centre of the Earth". What is wrong with this statement? Why is it wrong?

(2 marks)

4. "Energy" is a scalar quantity. Explain why.

(2 marks)

Answers

1. A scalar quantity has magnitude (size) only — no associated direction.
2. Any three from: distance, speed, energy, temperature, mass, time.
3. Mass is a scalar quantity. It has magnitude only. Giving it a direction ("towards the centre of the Earth") is wrong because scalars do not have direction.
4. Energy is measured in joules — a size only. It has no direction, so it is a scalar.

Part 2 of 3 | Vector Quantities and Arrow Representation

Key Information

A vector quantity has both magnitude and direction. 1

Examples of vector quantities: displacement, velocity, force, acceleration, weight, momentum. 2

Vectors are represented by arrows. The arrow length represents magnitude; the arrow direction represents direction. 3

A free body diagram shows all forces acting on a single object as labelled arrows. 4

A scale diagram (vector diagram) draws vectors head-to-tail to find the resultant force. 5

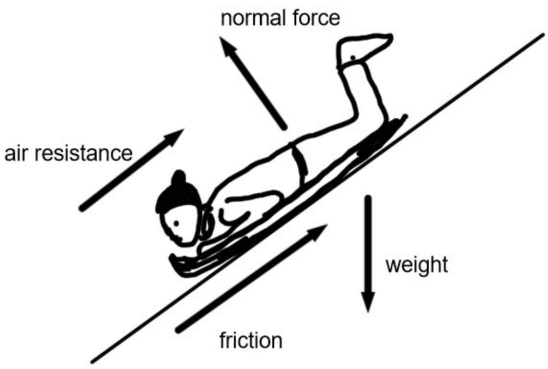


Fig 1.1 - Forces on a skier represented as vector arrows

Questions

5. Define a vector quantity.

(2 marks)

6. Give three examples of vector quantities.

(2 marks)

7. James says "the force of air resistance on the parachute is 50 N". What else must James include for a complete answer? Explain why this extra information is necessary.

(2 marks)

8. Look at Fig 1.1. Name the four vector quantities shown on the diagram.

(2 marks)

9. "Acceleration" is defined as "rate of change of velocity". Is acceleration a scalar or a vector quantity? Explain your reasoning.

(2 marks)

10. "Power" is defined as "rate of transfer of energy". Is power a scalar or a vector quantity? Explain your reasoning.

(2 marks)

Answers

5. A vector quantity has both magnitude and a specific direction.
6. Any three from: displacement, velocity, force, acceleration, weight, momentum.
7. James must state the direction (e.g. "upwards" or "opposing motion"). Force is a vector quantity — a direction must always be given for a complete description.
8. Normal force, air resistance, weight, friction.
9. Acceleration is a vector. Velocity is a vector; the rate of change of a vector must also have a direction.
10. Power is a scalar. Energy is a scalar; its rate of transfer has no direction.

Part 3 of 3 | Exam-Style Questions

EXAM QUESTION - Q1: Scalar and Vector Quantities (8 marks)

Mark allocations shown as (n) following AQA convention.

(a) State the difference between a scalar quantity and a vector quantity, giving one example of each.

(4)

(b) A car travels at a *speed* of 20 m/s and a *velocity* of 20 m/s north. Explain why these two statements give different information.

(2)

(c) A book rests on a table. The weight of the book is 6 N downwards. State the magnitude and direction of the normal contact force, and justify your answer using Newton's First Law.

(2)

Answers

(a) Scalar: magnitude only, e.g. speed/temperature/mass. (2) Vector: magnitude and direction, e.g. velocity/force/displacement. (2)

(b) Speed gives only how fast the car is moving (20 m/s). Velocity gives speed and direction (north), so provides more information. (2)

(c) Normal contact force = 6 N upwards. (1) Forces are balanced; resultant force = 0. (1) Newton's First Law: object at rest means resultant force = 0, so normal contact force equals weight in magnitude. (2 total = 2)

LESSON 2

Distance and Displacement

Do Now

1. Define a scalar quantity and give one example.

Answer: A scalar has magnitude only. Example: speed / mass / temperature.

2. Define a vector quantity and give one example.

Answer: A vector has magnitude and direction. Example: velocity / force / displacement.

3. Is force a scalar or a vector? Write one sentence to justify your answer.

Answer: Force is a vector — it has both a size (in N) and a direction in which it acts.

4. A sprinter runs 100 m along a straight track from start to finish. Is the distance run the same as the displacement? Explain.

Answer: Yes — the path is a straight line from start to finish so distance = displacement = 100 m.

Part 1 of 3 | Definitions

Key Information

Distance is a scalar quantity — the total length of the path travelled. 1

Displacement is a vector quantity — the straight-line distance from start to finish, including direction. 2

Example: an object travels from A to B (6 m upward), then B to C (1.5 m to the right), then C to D (4 m downward). 3

Distance = 6 + 1.5 + 4 = 11.5 m. 4

Displacement = 6.5 m to the right (straight-line from A to D). 5

Displacement is always less than or equal to distance. They are equal only when the path is a straight line in a single direction. 6

If an object returns to its starting point: displacement = 0 m, but distance is greater than 0. 7

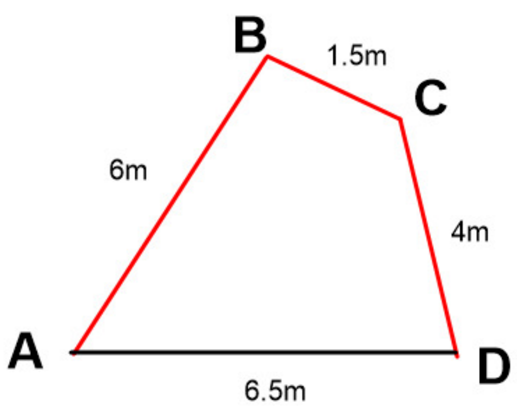


Fig 2.1 - Path A to B to C to D: distance = 11.5 m, displacement = 6.5 m

Questions

1. Describe the difference between distance and displacement.

(2 marks)

2. Which of distance and displacement is a vector quantity?

(1 mark)

3. True or false: for a moving object, displacement can equal distance but can never be greater. Explain your answer.

(2 marks)

4. Draw a diagram to illustrate the difference between distance and displacement for an object travelling along a curved path from A to B. Label both quantities.

(2 marks)

Answers

1. Distance: total length of path travelled (scalar, no direction). Displacement: straight-line distance from start to finish, with direction stated (vector).
2. Displacement is the vector quantity.
3. True. The straight-line distance from start to finish is always less than or equal to the actual path length (triangle inequality). They are equal only when the object travels in a straight line in one direction without turning back.
4. Diagram: a curved arrow labelled "distance" (longer path from A to B), and a straight arrow labelled "displacement" (shorter, direct from A to B). Both clearly labelled with direction for displacement.

Part 2 of 3 | Calculating Distance and Displacement

Key Information

To find distance: add up the lengths of every individual segment of the journey. 1

To find displacement: identify the start point and the end point; draw a straight line between them and state its length and direction. 2

For 2D paths: displacement = square root of (horizontal^2 + vertical^2) (Pythagoras' theorem). 3

Displacement is negative if the object ends up on the opposite side of the starting point from the defined positive direction. 4

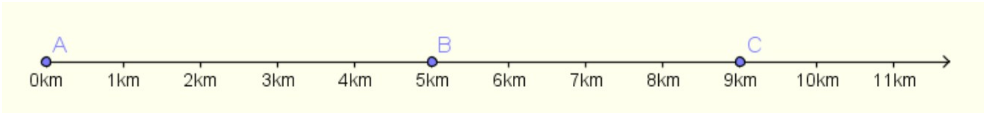


Fig 2.2 - Number line (km). A = 0 km, B = 5 km, C = 9 km

Questions

5. A car starts at A (0 km), travels to B (5 km), then to C (9 km), then back to B (5 km). a) What is the total distance travelled? b) What is the displacement of the car?

(3 marks)

6. a) What is the displacement from B to A? b) What is the distance from B to A?

(2 marks)

Answers

5a) A to B = 5 km, B to C = 4 km, C to B = 4 km. Total distance = 13 km.
5b) Start = 0 km (A), finish = 5 km (B). Displacement = 5 km to the right.
6a) Displacement from B to A = 5 km to the left (or -5 km).
6b) Distance from B to A = 5 km.

Part 3 of 3 | Exam-Style Questions

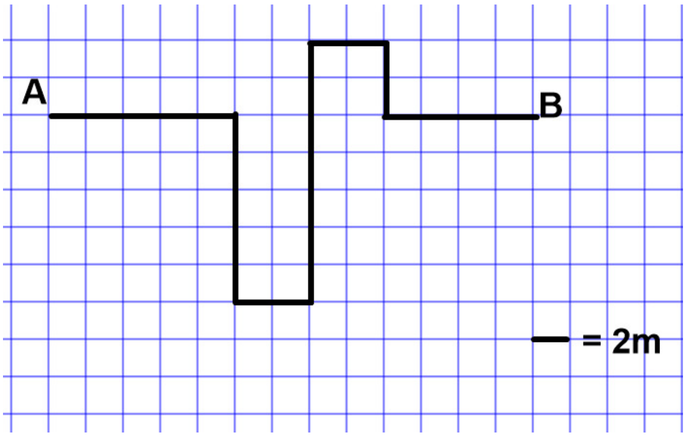


Fig 2.3 - Grid for questions below. Each small square = 2 m.

EXAM QUESTION - Q2: Distance and Displacement (7 marks)

Mark allocations shown as (n) following AQA convention.

(a) Using Fig 2.3: find (i) the distance travelled from A to B and (ii) the displacement from A to B.

(2)

(b)(i) A sprinter runs one complete lap of a 400 m track and returns to the starting line. State the total distance travelled.

(1)

(b)(ii) State the displacement of the sprinter at the end of the lap.

(1)

(b)(iii) Explain why the distance and displacement are different in this case.

(2)

Answers

(a)(i) Count path squares and multiply by 2 m. Distance is approximately 14 m. (1)

(a)(ii) Straight-line from A to B = 10 m to the right (5 squares x 2 m). (1)

(b)(i) 400 m. (1)

(b)(ii) 0 m. (1)

(b)(iii) Distance is the total length of the path along the track (400 m). Displacement is the straight-line distance from start to finish — the sprinter returns to the starting point so start and end positions are the same, giving displacement = 0 m. (2)

LESSON 3

Distance, Displacement and Speed

Do Now

1. What is the difference between distance and displacement?

Answer: Distance is the total path length (scalar). Displacement is the straight-line distance from start to finish with direction (vector).

2. A car drives 4 km east then 3 km north. What is the total distance driven? What is the magnitude of the displacement from start to finish?

Answer: Distance = 4 + 3 = 7 km. Displacement = sqrt(4^2 + 3^2) = 5 km.

3. A person walks to school along a winding path (2.1 km) then walks back home along the same path. What is their total distance? What is their displacement when they arrive back home?

Answer: Total distance = 2.1 + 2.1 = 4.2 km. Displacement = 0 km (returns to start).

4. Write down the units for: (a) distance (b) time (c) speed.

Answer: (a) metres (m) (b) seconds (s) (c) metres per second (m/s or m s^-1).

Part 1 of 3 | Speed and Velocity - Definitions

Key Information

Speed is the rate of change of distance. It is a scalar quantity (magnitude only). 1

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

distance = speed × time (rearranged) 2

Units: m/s. Typical values: walking approx. 1.5, cycling approx. 6, car approx. 30, sound approx. 330 m/s. 3

Velocity is the rate of change of displacement. It is a vector quantity (magnitude and direction). 4

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

displacement = velocity × time (rearranged) 5

Velocity must always state direction, e.g. "12 m/s to the right" or "12 m/s upward". 6

$$\mathbf{v} = \frac{\mathbf{d}}{\mathbf{t}}$$

$$\mathbf{d} = \mathbf{v} \times \mathbf{t}$$

$$\mathbf{t} = \frac{\mathbf{d}}{\mathbf{v}}$$

Questions

1. What is the difference between speed and velocity?

(1 mark)

2. An object travels 25 m to the right in 10 s. Find its velocity.

(2 marks)

3. A hot air balloon travels 125 m upward in 50 s. Find its velocity.

(2 marks)

4. A diver travels 640 m downward during a 16 s dive. Find their velocity.

(2 marks)

5. A rocket travels at 150 m/s upward for 30 s. Find its displacement, stating the direction.

(2 marks)

6. An insect crawls for 180 s at 0.25 m/s to the left. Find its displacement.

(2 marks)

7. A car travels at 24 m/s to the right for 58 s. Find its displacement.

(2 marks)

8. A car travelling at 2.75 m/s covers a displacement of 185 m. Calculate the time taken.

(2 marks)

9. A rocket travelling at 240 m/s reaches a displacement of 15 000 m. Find the time taken.

(2 marks)

10. A snail travels at 0.08 m/s and reaches a displacement of 0.2 m. Find the time taken.

(2 marks)

Answers

1. *Speed is scalar (magnitude only). Velocity is vector (magnitude and direction).*
2. *v = 25 / 10 = 2.5 m/s to the right*
3. *v = 125 / 50 = 2.5 m/s upward*
4. *v = 640 / 16 = 40 m/s downward*
5. *d = 150 x 30 = 4 500 m upward*
6. *d = 0.25 x 180 = 45 m to the left*
7. *d = 24 x 58 = 1 392 m to the right*
8. *t = 185 / 2.75 = 67.3 s*
9. *t = 15 000 / 240 = 62.5 s*
10. *t = 0.2 / 0.08 = 2.5 s*

Part 2 of 3 | Further Practice

Questions

11. An object travels 35 m to the right in 40 s. Find its velocity.

(2 marks)

12. A hot air balloon travels 325 m upward in 59 s. Find its velocity.

(2 marks)

13. A diver travels 645 m downward in 12 s. Find their velocity.

(2 marks)

14. A rocket travels at 350 m/s upward for 20 s. Find its displacement.

(2 marks)

15. An insect crawls for 380 s at 0.75 m/s to the left. Find its displacement.

(2 marks)

16. An object travels at 34 m/s to the right for 48 s. Find its displacement.

(2 marks)

17. An object travelling at 3.75 m/s covers 196 m. Calculate the time taken.

(2 marks)

18. A rocket at 170 m/s reaches a displacement of 46 000 m. Find the time taken.

(2 marks)

19. A snail travels at 0.02 m/s and reaches a displacement of 0.4 m. Find the time taken.

(2 marks)

Answers

11. 35 / 40 = 0.875 m/s to the right
12. 325 / 59 = 5.51 m/s upward
13. 645 / 12 = 53.75 m/s downward
14. 350 x 20 = 7 000 m upward
15. 0.75 x 380 = 285 m to the left
16. 34 x 48 = 1 632 m to the right
17. 196 / 3.75 = 52.3 s
18. 46 000 / 170 = 270.6 s
19. 0.4 / 0.02 = 20 s

Part 3 of 3 | Exam-Style Questions

EXAM QUESTION - Q3: Velocity and Speed Calculations (9 marks)

Mark allocations shown as (n) following AQA convention.

(a)(i) A cyclist travels 1 200 m north in 3 minutes. Calculate the speed of the cyclist. Give the unit.

(3)

(a)(ii) State the velocity of the cyclist.

(1)

(b) A car travels at 30 m/s for 2 hours. Calculate the total distance travelled. Give your answer in km.

(3)

(c)(i) A swimmer completes a 50 m length in 38 s, then turns and swims back 50 m in 40 s. Calculate the average speed for the whole swim.

(2)

(c)(ii) State the total displacement at the end of both lengths. Explain your answer.

(2)

Answers

(a)(i) t = 3 x 60 = 180 s. speed = 1 200 / 180 = 6.67 m/s (3)
(a)(ii) velocity = 6.67 m/s north (1)
(b) t = 2 x 3 600 = 7 200 s. d = 30 x 7 200 = 216 000 m = 216 km (3)
(c)(i) Total distance = 100 m, total time = 78 s. speed = 100 / 78 = 1.28 m/s (2)
(c)(ii) Displacement = 0 m. The swimmer returns to the starting point so the start and end positions are the same; displacement = 0. (2)

LESSON 4

Velocity and Acceleration

Do Now

1. State the formula for speed and rearrange it to make time the subject.

Answer: speed = distance / time. Rearranged: time = distance / speed.

2. An object travels 240 m in 12 s at constant speed. Calculate its speed.

Answer: speed = 240 / 12 = 20 m/s.

3. What is the difference between speed and velocity? Give an example to illustrate the difference.

Answer: Speed is scalar (magnitude only). Velocity is vector (magnitude + direction). Example: 30 m/s is a speed; 30 m/s north is a velocity.

4. A cyclist travels at 6 m/s east for 30 s. Calculate her displacement and state the direction.

Answer: displacement = 6 x 30 = 180 m east.

Part 1 of 3 | Defining Acceleration

Key Information

Acceleration is the rate of change of velocity. Unit: m/s^2. 1

Since velocity is a vector, all of the following count as acceleration: 2

Speeding up (increasing speed) 3

Slowing down — also called deceleration (negative acceleration) 4

Turning a corner (changing direction at constant speed) 5

An acceleration always requires a resultant (net) force — Newton's Second Law. 6

Typical accelerations: car approx. 3, motorbike approx. 5, free fall (Earth) = 10, space shuttle approx. 29 (all in m/s^2). 7

Questions

1. Define "acceleration" and state its unit.

(2 marks)

2. Explain why applying the brakes in a moving car causes the car to accelerate. What change is made to the velocity?

(2 marks)

3. Explain why a bouncing ball is accelerating at the moment it hits the ground. What change is made to the velocity?

(2 marks)

4. Explain why the Moon orbiting the Earth is accelerating, even though its speed is roughly constant.

(2 marks)

5. What is the relationship between resultant force and acceleration?

(1 mark)

Answers

1. *Acceleration is the rate of change of velocity. Unit: m/s^2.*
2. *The brakes apply a resultant force opposing the direction of motion. This reduces the car's speed (velocity decreases) — a negative acceleration / deceleration.*
3. *At the moment of impact the ball's velocity changes direction (downward to upward). A change in direction is a change in velocity, so there is a very large acceleration over a very short time.*
4. *The Moon travels in a circle so its direction of motion changes continuously. A change in direction is a change in velocity (velocity is a vector), so the Moon is always accelerating. The centripetal force is provided by gravity.*
5. *A resultant (net) force causes acceleration. F = m x a: acceleration is proportional to force and inversely proportional to mass.*

Part 2 of 3 | The Acceleration Formula

Key Information

$$\text{acceleration} = \frac{\Delta\text{velocity}}{\Delta\text{time}}$$

$$a = \frac{v_f - v_i}{t}$$

$\Delta v = a \times t$ (rearranged) 1

If an object slows down, the change in velocity is negative, giving a negative value for acceleration (deceleration). 2

$$\mathbf{a} = \frac{\Delta \mathbf{v}}{\mathbf{t}}$$

$$\Delta \mathbf{v} = \mathbf{a} \times \mathbf{t}$$

$$\mathbf{t} = \frac{\Delta \mathbf{v}}{\mathbf{a}}$$

Questions

6. An object accelerates from 5 m/s to 10 m/s in 20 s. Calculate the acceleration.

(2 marks)

7. An object starts at 0.2 m/s and increases its speed to 12.5 m/s over a period of 5 s. Find the acceleration.

(2 marks)

8. What acceleration takes an object from 20 m/s to 8 m/s in 3 s?

(2 marks)

9. An object decelerates from 100 m/s to 75 m/s in 5 s. Calculate the deceleration.

(2 marks)

10. Find the deceleration of an object that goes from 45 m/s to 13 m/s in 12 s.

(2 marks)

11. An object decelerates from 48 m/s to 3 m/s in 30 s. Calculate the deceleration.

(2 marks)

12. An object starts from rest and reaches 14 m/s in 3.5 s. Find the acceleration.

(2 marks)

13. An object accelerates from rest to 105 m/s in 55 s. Calculate the acceleration.

(2 marks)

14. An object travelling at 35 m/s slows to rest in 70 s. Find the deceleration.

(2 marks)

15. An object comes to rest from 12 m/s in 2.5 s. Find the deceleration.

(2 marks)

16. An object at 58 m/s comes to rest in 4 s. Find the deceleration.

(2 marks)

17. How long does it take an object with deceleration 2 m/s^2 to reduce speed from 10 m/s to 4 m/s?

(2 marks)

18. How long does it take an object with acceleration 4.3 m/s^2 to speed up from 9 m/s to 85 m/s?

(2 marks)

19. An object with acceleration 0.45 m/s^2 accelerates from rest to 3 m/s. How long does this take?

(2 marks)

20. For an object with acceleration 6 m/s^2, calculate the change in velocity over 15 s.

(2 marks)

21. For an object with acceleration -18 m/s^2, calculate the change in velocity over 76 s.

(2 marks)

22. For an object with acceleration 0.9 m/s^2, calculate the change in velocity over 200 s.

(2 marks)

Answers

6. change in v = 10 - 5 = 5. a = 5 / 20 = 0.25 m/s^2
7. change in v = 12.5 - 0.2 = 12.3. a = 12.3 / 5 = 2.46 m/s^2
8. change in v = 8 - 20 = -12. a = -12 / 3 = -4 m/s^2
9. change in v = 75 - 100 = -25. a = -25 / 5 = -5 m/s^2
10. change in v = 13 - 45 = -32. a = -32 / 12 = -2.67 m/s^2
11. change in v = 3 - 48 = -45. a = -45 / 30 = -1.5 m/s^2
12. change in v = 14 - 0 = 14. a = 14 / 3.5 = 4 m/s^2
13. a = 105 / 55 = 1.91 m/s^2
14. change in v = 0 - 35 = -35. a = -35 / 70 = -0.5 m/s^2
15. a = -12 / 2.5 = -4.8 m/s^2
16. a = -58 / 4 = -14.5 m/s^2
17. change in v = 4 - 10 = -6. t = 6 / 2 = 3 s
18. change in v = 85 - 9 = 76. t = 76 / 4.3 = 17.7 s
19. t = 3 / 0.45 = 6.67 s
20. change in v = 6 x 15 = 90 m/s
21. change in v = -18 x 76 = -1 368 m/s
22. change in v = 0.9 x 200 = 180 m/s

Part 3 of 3 | Exam-Style Questions

EXAM QUESTION - Q4: Acceleration (8 marks)

Mark allocations shown as (n) following AQA convention.

(a)(i) A train accelerates from rest to 55 m/s in 220 s. Calculate the acceleration of the train.

(2)

(a)(ii) Describe what is meant by deceleration.

(1)

(b)(i) A skydiver jumps from an aircraft. Their velocity is 0 m/s at the moment of jumping. After 6 s they reach 60 m/s downward. Calculate the acceleration during this time.

(2)

(b)(ii) The skydiver opens a parachute and slows from 60 m/s to 8 m/s in 10 s. Calculate the deceleration.

(2)

(b)(iii) The skydiver later reaches terminal velocity. Explain what terminal velocity means and why it occurs.

(3)

Answers

(a)(i) a = (55 - 0) / 220 = 0.25 m/s^2 (2)

(a)(ii) Deceleration is negative acceleration — a decrease in velocity/speed. (1)

(b)(i) a = (60 - 0) / 6 = 10 m/s^2 downward (2)

(b)(ii) a = (8 - 60) / 10 = -52 / 10 = -5.2 m/s^2 (deceleration = 5.2 m/s^2) (2)

(b)(iii) Terminal velocity is the maximum constant velocity reached when the driving force (weight downward) equals the resistive force (air resistance/drag upward), giving a zero resultant force. With no resultant force there is no acceleration, so velocity remains constant. (3)

LESSON 5

Distance-Time Graphs

Do Now

1. State the formula for acceleration and write down its unit.

Answer: a = change in v / time (or a = Dv/t). Unit: m/s^2.

2. A motorbike accelerates from 0 to 24 m/s in 8 s. Calculate the acceleration.

Answer: a = (24 - 0) / 8 = 3 m/s^2.

3. On any graph, what does the gradient (steepness of the line) tell us?

Answer: The gradient tells us the rate of change of the y-axis quantity with respect to the x-axis quantity.

4. Describe the motion of an object with zero acceleration. Give two examples.

Answer: Zero acceleration means constant velocity (constant speed in a straight line). Examples: a car on a motorway at steady 70 mph; a book sitting still on a table.

Part 1 of 3 | Key Rules for Distance-Time Graphs

Key Information

A distance-time graph has time on the x-axis and distance on the y-axis. 1

$$\textbf{Speed = gradient of the line} = \frac{\Delta\text{distance}}{\Delta\text{time}}$$

A steeper gradient means a higher speed. 2

A horizontal (flat) line (gradient = 0) means the object is stationary. 3

A downward slope means the object is moving back towards the starting point. 4

A curved line means the speed is changing — the object is accelerating or decelerating. 5

Example: an object that travels 40 m in 5 s has speed = 40 / 5 = 8 m/s. 6

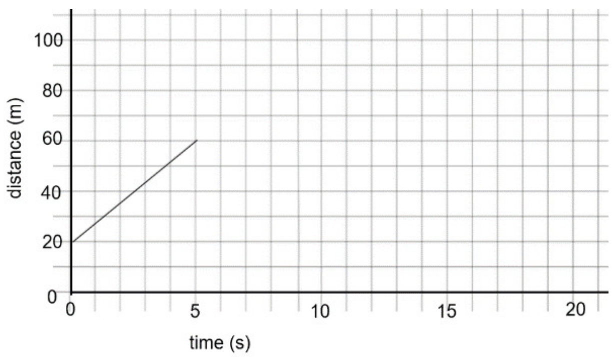


Fig 5.1 - 40 m in 5 s; speed = 8 m/s

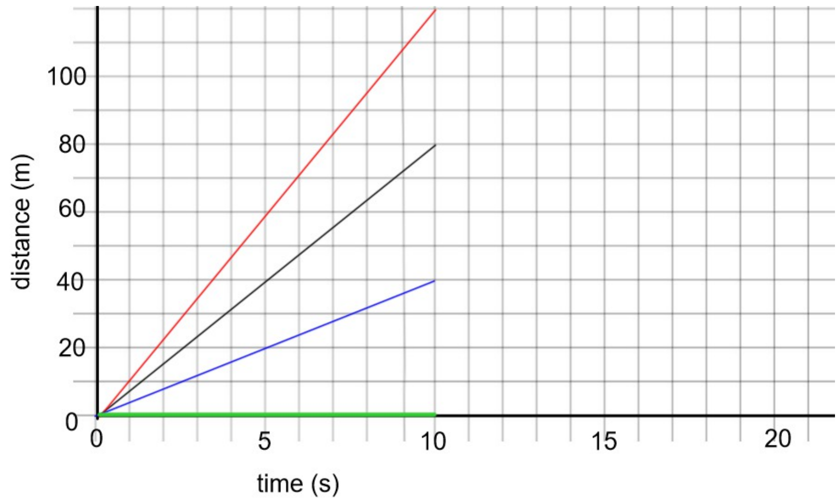


Fig 5.2 - Steeper gradient = higher speed

Questions

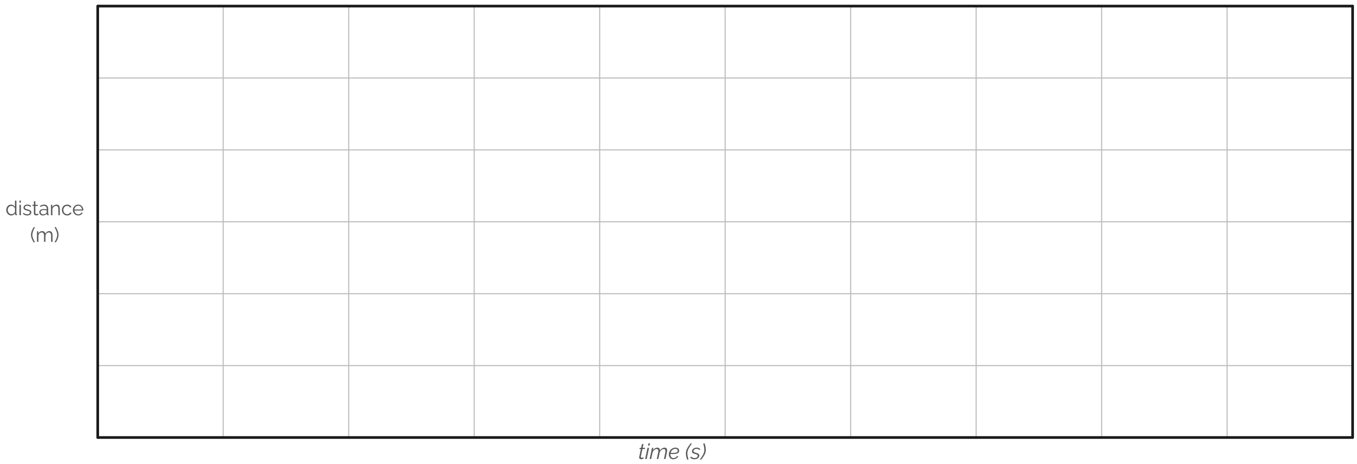
1. What does the gradient of a distance-time graph represent?

(1 mark)

2. What does a horizontal (flat) line on a distance-time graph tell us about the object's motion?

(1 mark)

3. Using the blank axes below, draw lines to show the motion of objects travelling at: a) 60 m in 5 s b) 100 m in 5 s c) 20 m in 5 s

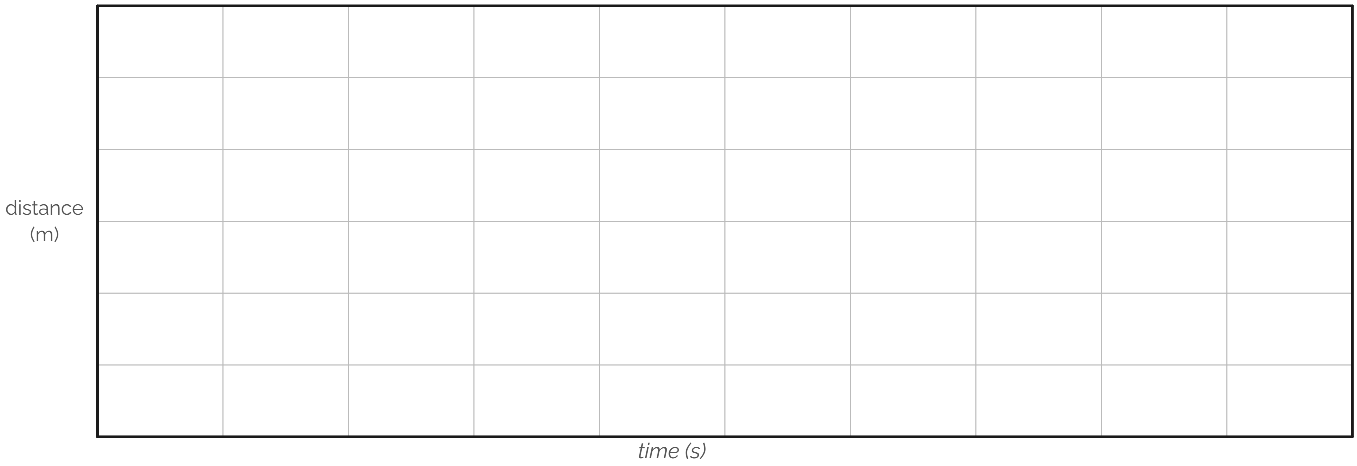


Blank axes for Q3. Time axis: 0-10 s. Distance axis: 0-100 m.

d) Calculate the speed of each object in Q3.

(3 marks)

4. Using a second set of blank axes, draw lines for objects travelling at: a) 10 m in 10 s b) 100 m in 10 s c) 40 m in 10 s



Blank axes for Q4. Time axis: 0-10 s. Distance axis: 0-100 m.

d) Calculate the speed of each object in Q4.

(3 marks)

Answers

1. *The speed of the object.*
2. *The object is stationary (speed = 0).*

3d) a) 60 / 5 = 12 m/s b) 100 / 5 = 20 m/s c) 20 / 5 = 4 m/s

4d) a) 10 / 10 = 1 m/s b) 100 / 10 = 10 m/s c) 40 / 10 = 4 m/s

Part 2 of 3 | Reading Speed from a Graph

Key Information

To read speed from a distance-time graph: choose two points on the line that are easy to read from the grid. 1

$$\text{speed} = \frac{d_2 - d_1}{t_2 - t_1}$$

If the line does not start at the origin, use the change in distance, not the total distance value on the y-axis. 2

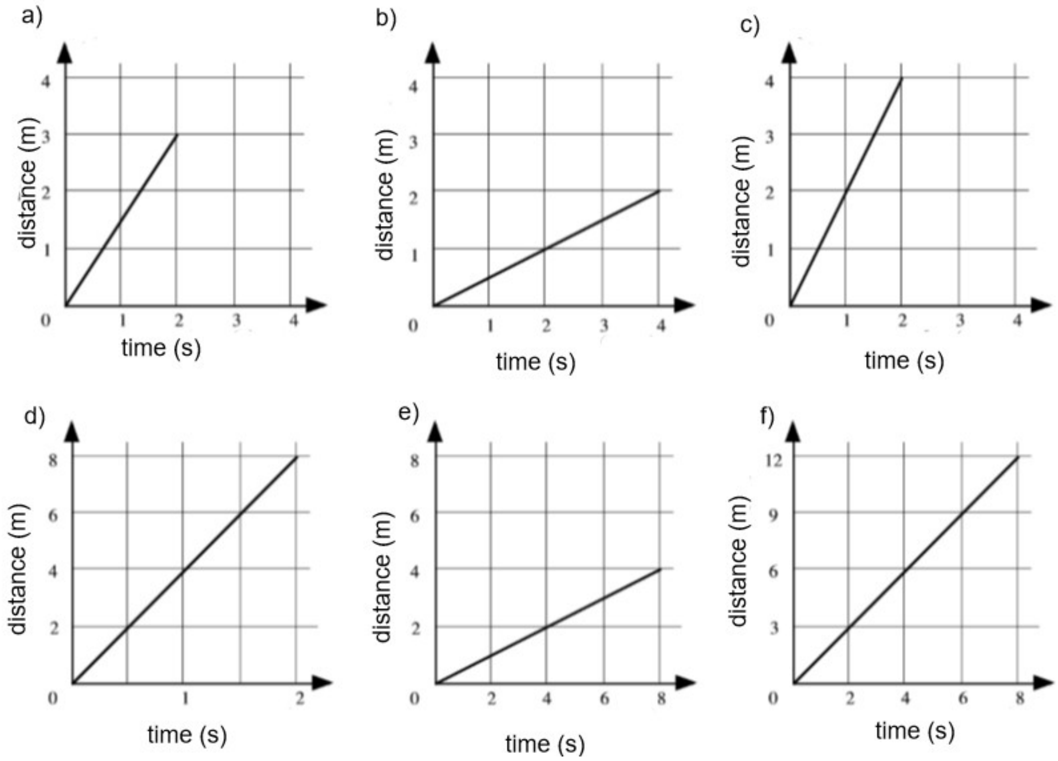


Fig 5.3 - Questions 5a-f: find the speed of each object

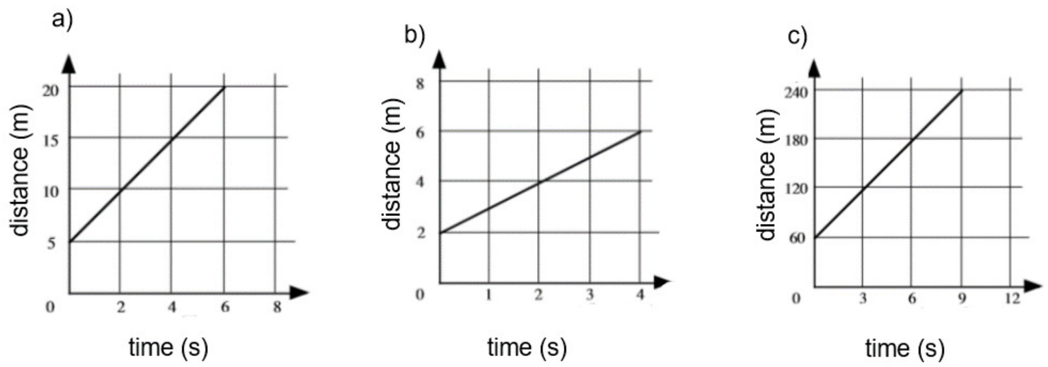


Fig 5.4 - Questions 6a-c: find the speed of each object

Questions

5. Using Fig 5.3, find the speed of each object (a-f).

(6 marks)

6. Using Fig 5.4, find the speed of each object (a-c).

(3 marks)

Answers

5a) gradient = 3 / 4 = 0.75 m/s
5b) gradient = 3 / 4 = 0.75 m/s (same gradient, different start)
5c) gradient = 4 / 2 = 2 m/s
5d) gradient = 8 / 2 = 4 m/s
5e) gradient = 8 / 8 = 1 m/s
5f) gradient = 12 / 8 = 1.5 m/s
6a) gradient = 20 / 8 = 2.5 m/s
6b) gradient = 6 / 4 = 1.5 m/s
6c) gradient = 240 / 12 = 20 m/s

Part 3 of 3 | Curved Graphs and Exam-Style Questions

Key Information

A curved distance-time graph means speed is changing — the object is accelerating. 1

A curve bending upward (becoming steeper) indicates positive acceleration (speeding up). 2

A curve bending downward (becoming flatter) indicates negative acceleration (slowing down). 3

To find instantaneous speed at a given time: draw a tangent to the curve at that point, then calculate the gradient of the tangent (change in d / change in t). 4

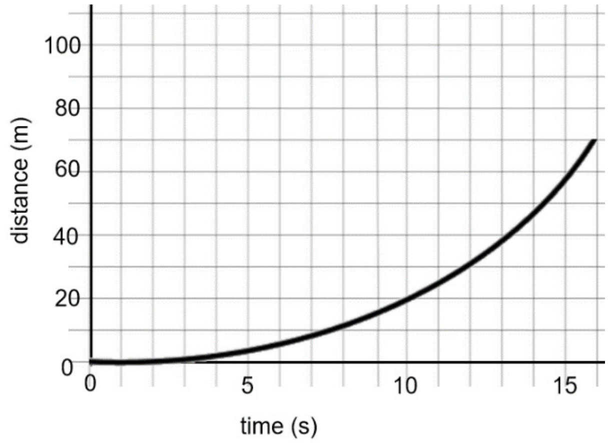
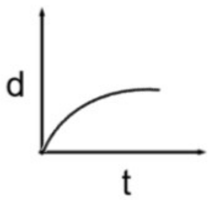


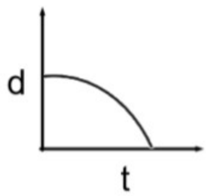
Fig 5.5 - Positive acceleration: curve becomes steeper over time

Questions

7-10. For each sketch graph below, state: (i) positive or negative acceleration? (ii) is the object moving forwards or backwards?

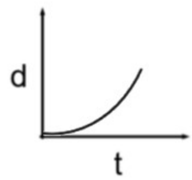


Graph 7



Graph 8

Graph 9



Graph 10

(4 marks)

Answers

7. Negative acceleration, moving forwards (curve bends downward).
8. Negative acceleration, moving forwards.
9. Negative acceleration, moving backwards (distance decreasing).
10. Positive acceleration, moving forwards (curve bends upward).

11. Explain how we find the instantaneous speed of an object from a curved distance-time graph.

(2 marks)

12. Describe the motion shown by a straight line with a negative gradient on a distance-time graph. What does the gradient tell us?

(2 marks)

EXAM QUESTION - Q5: Distance-Time Graphs (5 marks)

Mark allocations shown as (n) following AQA convention.

(a) A straight line on a distance-time graph slopes downward. Describe the motion of the object.

(2)

(b) A curved line on a distance-time graph becomes progressively flatter. Describe the motion of the object.

(2)

(c) An object travels 80 m in the first 10 s, then remains stationary for 5 s, then returns to the starting point in 8 s. Sketch the distance-time graph and calculate the speed during each phase.

(5)

Answers

7. Negative acceleration / deceleration (curve becomes flatter). Moving forwards.
8. Negative acceleration / deceleration. Moving forwards.
9. Negative acceleration / deceleration. Moving backwards (distance is decreasing).
10. Positive acceleration (curve becomes steeper). Moving forwards.
11. Draw a straight tangent line to the curve at the required point. Calculate the gradient of the tangent: speed = change in d / change in t.
12. The object is moving back towards the starting point at constant speed. The gradient gives the speed (take the magnitude; the negative sign indicates direction is reversed).
Exam (a) The object is moving back towards the starting point at constant speed. (2)
Exam (b) The object is decelerating (slowing down) while moving forwards. (2)
Exam (c) Phase 1: speed = 80 / 10 = 8 m/s. Phase 2: speed = 0 m/s (stationary). Phase 3: speed = 80 / 8 = 10 m/s (returning). (5)

LESSON 6

Velocity-Time Graphs

Do Now

1. On a distance-time graph, what does the gradient of the line represent?

Answer: The gradient represents the speed of the object.

2. An object travels 80 m in 10 s at constant speed. Calculate its speed and describe what its distance-time graph looks like.

Answer: speed = 80 / 10 = 8 m/s. Graph: straight diagonal line from origin, rising to 80 m at t = 10 s.

3. On a distance-time graph, what does a horizontal (flat) line tell us about the object's motion?

Answer: A horizontal line means the object is stationary (speed = 0).

4. A car travels at 15 m/s for 20 s then stops. Calculate the total distance travelled.

Answer: distance = 15 x 20 = 300 m.

Part 1 of 3 | Key Rules - Do Not Confuse with Distance-Time Graphs

Key Information

A velocity-time graph has time on the x-axis and velocity on the y-axis. 1

Do not confuse velocity-time graphs with distance-time graphs — they look similar but give completely different information. 2

A horizontal line on a v-t graph means constant velocity (zero acceleration). The object may still be moving. 3

A line at v = 0 means the object is stationary. 4

A positive gradient (sloping upward) means the object is accelerating. 5

A negative gradient (sloping downward) means the object is decelerating. 6

The gradient of a velocity-time graph equals the acceleration. 7

The area under a velocity-time graph equals the distance travelled. 8

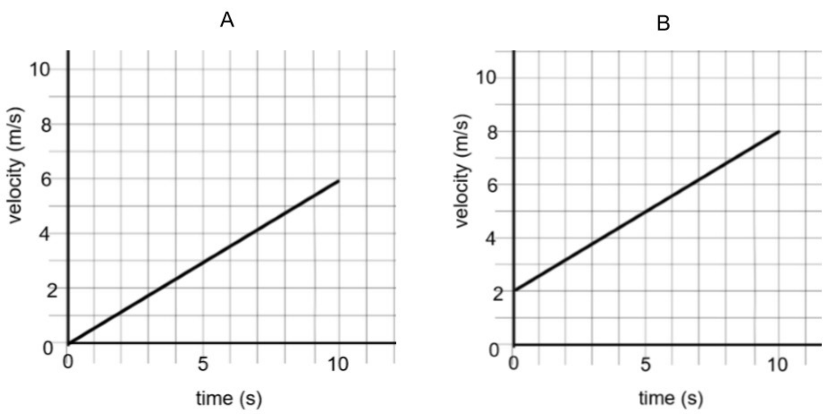
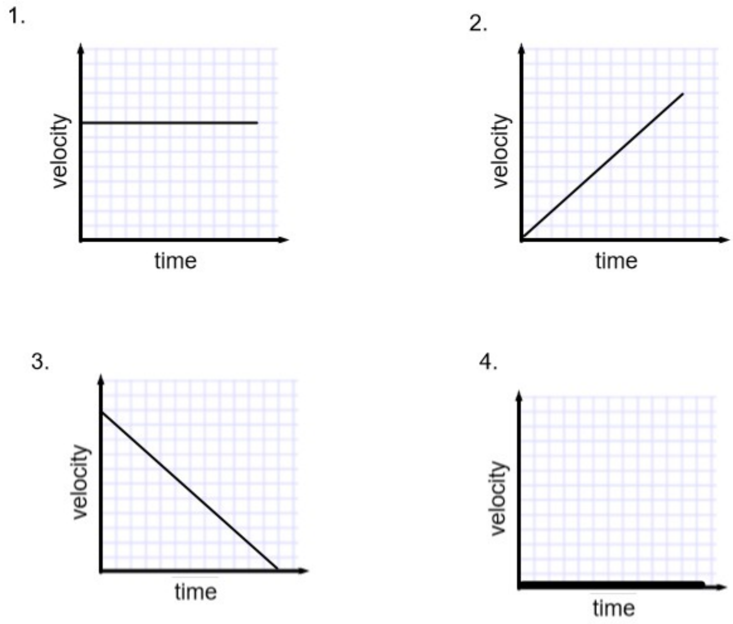


Fig 6.1 - Two objects with the same acceleration but different starting velocities (Graph A and B)

Questions

1-4. State what each of the following graphs shows (acceleration / constant velocity / deceleration / stationary):



Graphs 1-4: state the motion type for each

(4 marks)

Answers

Graph 1: Deceleration — velocity decreasing (negative gradient).
Graph 2: Deceleration — velocity decreasing.
Graph 3: Constant velocity — horizontal line (zero gradient).
Graph 4: Acceleration — velocity increasing (positive gradient).
Graph 5: Deceleration — velocity decreasing to zero.
Graph 6: Stationary — line sits at v = 0.

Part 2 of 3 | Finding Acceleration from the Gradient

Key Information

The gradient of a velocity-time graph equals the acceleration. 1

$$\text{acceleration} = \frac{\Delta \text{velocity}}{\Delta \text{time}}$$

$$a = \frac{v_f - v_i}{t}$$

Always use the change in velocity (final minus initial), not just the final velocity value. 2

Example 1: v goes 0 2 m/s in 10 s a = 2 / 10 = 0.2 m/s^2. 3

Example 2: v goes 2 8 m/s in 10 s a = (8−2) / 10 = 0.6 m/s^2. 4

Example 3 (deceleration): v goes 6 0 m/s in 10 s a = (0−6) / 10 = −0.6 m/s^2. 5

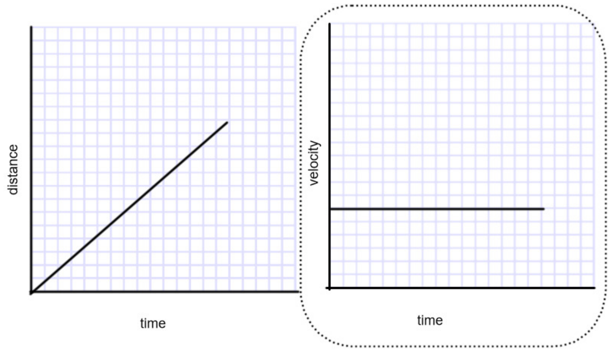


Fig 6.2 - Worked example: finding acceleration from gradient

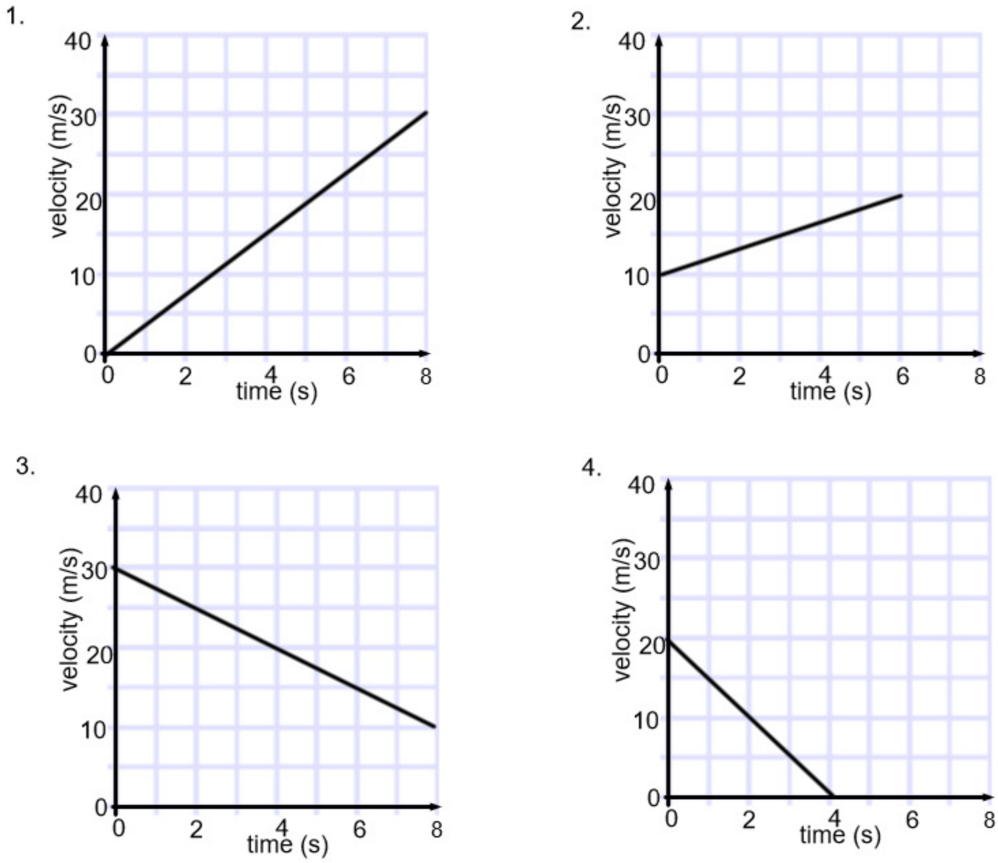
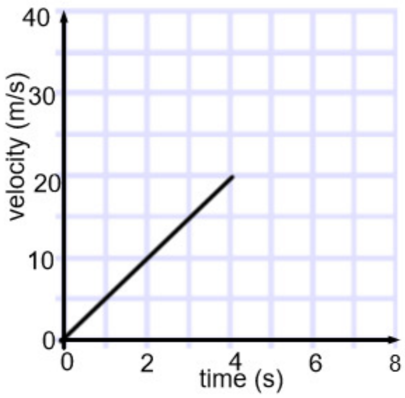


Fig 6.3 - Graphs 1-4: find the acceleration of each object (Questions 5-8)

5.



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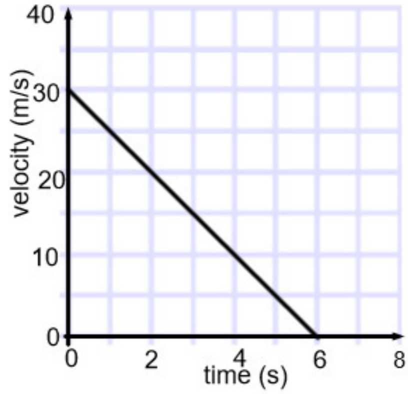

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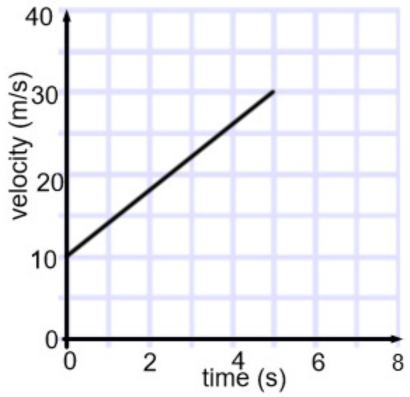

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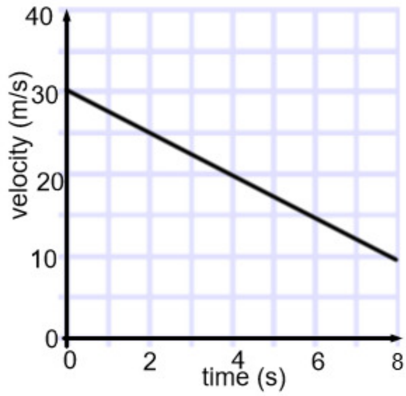


Fig 6.4 - Graphs 5-8: find the acceleration of each object (Questions 9-12)

Questions

5. Using Fig 6.3: find the acceleration of object 1.

(2 marks)

6. Using Fig 6.3: find the acceleration of object 2.

(2 marks)

7. Using Fig 6.3: find the acceleration of object 3.

(2 marks)

8. Using Fig 6.3: find the acceleration of object 4.

(2 marks)

9. Using Fig 6.4: find the acceleration of object 5.

(2 marks)

10. Using Fig 6.4: find the acceleration of object 6.

(2 marks)

11. Using Fig 6.4: find the acceleration of object 7.

(2 marks)

12. Using Fig 6.4: find the acceleration of object 8.

(2 marks)

Answers

5. change in v = 30 - 10 = 20, t = 8 s. a = 20 / 8 = 2.5 m/s^2
6. change in v = 20 - 10 = 10, t = 8 s. a = 10 / 8 = 1.25 m/s^2
7. change in v = 15 - 30 = -15, t = 8 s. a = -15 / 8 = -1.875 m/s^2
8. change in v = 0 - 20 = -20, t = 4 s. a = -20 / 4 = -5 m/s^2
9. change in v = 25 - 10 = 15, t = 6 s. a = 15 / 6 = 2.5 m/s^2
10. change in v = 0 - 30 = -30, t = 6 s. a = -30 / 6 = -5 m/s^2
11. change in v = 30 - 10 = 20, t = 4 s. a = 20 / 4 = 5 m/s^2
12. change in v = 10 - 30 = -20, t = 8 s. a = -20 / 8 = -2.5 m/s^2

Part 3 of 3 | Area Under the Graph and Exam-Style Questions

Key Information

Area under a velocity-time graph = distance travelled. 1

Rectangle section: area = base x height = time x velocity = distance. 2

Triangle section (v starts or ends at zero): area = (1/2) x base x height. 3

Trapezium: area = (1/2) x (v_1 + v_2) x t. 4

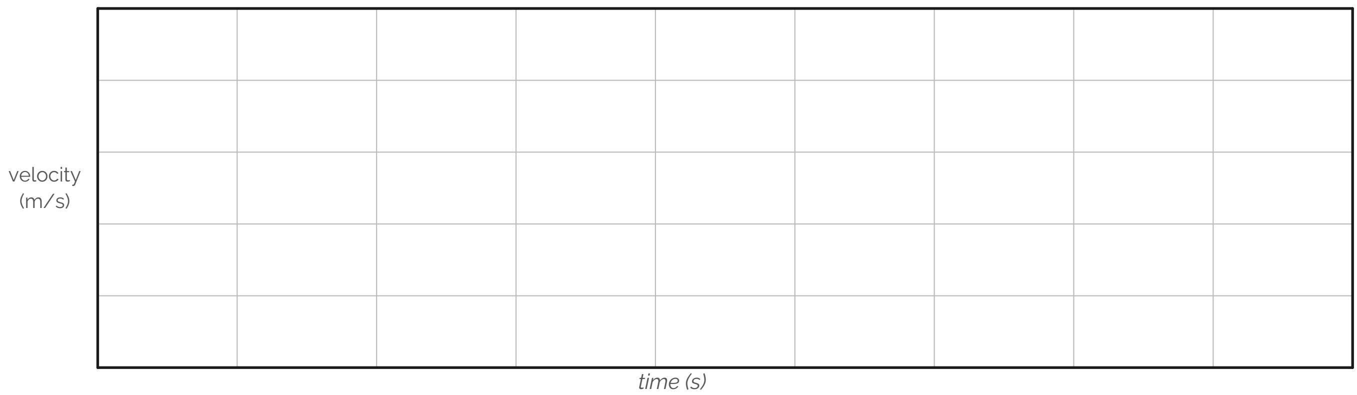
For complex shapes: break into rectangles and triangles, then add the areas. 5

EXAM QUESTION - Q6: Velocity-Time Graphs (14 marks)

Mark allocations shown as (n) following AQA convention.

(a)(i) A car accelerates uniformly from rest to 20 m/s in 10 s, then travels at 20 m/s for a further 30 s, then decelerates uniformly to rest in 5 s. Sketch the velocity-time graph for this motion on the axes below.

(2)



Blank velocity-time axes for Q(a)(i).

(a)(ii) Calculate the acceleration of the car during the first 10 s.

(2)

(a)(iii) Calculate the total distance travelled.

(3)

(b)(i) An object accelerates uniformly from rest to 30 m/s in 8 s. Calculate the acceleration.

(2)

(b)(ii) Calculate the distance travelled during the 8 s.

(2)

(c) Explain how the velocity-time graph for a falling object dropped from rest would change as the object approaches terminal velocity.

(3)

Answers

(a)(i) Graph: straight line up from (0,0) to (10,20); horizontal at 20 from t=10 to t=40; straight line down from (40,20) to (45,0). (2)

(a)(ii) a = (20 - 0) / 10 = 2 m/s^2 (2)

(a)(iii) Area = triangle + rectangle + triangle = (1/2 x 10 x 20) + (30 x 20) + (1/2 x 5 x 20) = 100 + 600 + 50 = 750 m (3)

(b)(i) a = 30 / 8 = 3.75 m/s^2 (2)

(b)(ii) area = 1/2 x 8 x 30 = 120 m (2)

(c) Initially the graph has a steep positive gradient (large acceleration). As speed increases, air resistance increases. The gradient decreases. When air resistance = weight, resultant force = 0, gradient = 0; the graph becomes horizontal — terminal velocity reached. (3)

LESSON 7

$v^2 = u^2 + 2as$

Do Now

1. Write the formula a = Dv / t and rearrange it to make Dv the subject.

Answer: Dv = a x t.

2. A car accelerates from 10 m/s to 34 m/s in 6 s. Calculate the acceleration.

Answer: a = (34 - 10) / 6 = 24 / 6 = 4 m/s^2.

3. On a velocity-time graph, what does the area under the line represent?

Answer: The area under a velocity-time graph equals the distance travelled.

4. A cyclist decelerates from 12 m/s to rest. Deceleration = 3 m/s^2. How long to stop?

Answer: t = Dv / a = (0 - 12) / (-3) = 4 s.

Part 1 of 3 | The Equation and Identifying Variables

Key Information

The equation $v^2 = u^2 + 2as$ links four quantities:

v = final velocity (m/s)

u = initial velocity (m/s)

a = acceleration (m/s^2)

s = displacement (m)

This formula is provided on the AQA formula sheet.

Use this equation when the time t is not known.

Object starting from rest: u = 0. Object slowing to a stop: v = 0.

$$v^2 = u^2 + 2as$$

Questions

Section A - Identify u, v, a, s and state which quantity is unknown.

1. "Find the final velocity of an object whose initial velocity is 9 m/s, acceleration 7.8 m/s^2, over a displacement of 80 m."

(2 marks)

2. "An object has acceleration 7 m/s^2. After travelling 500 m, it has reached a velocity of 280 m/s. Find its initial velocity."

(2 marks)

3. "An object has acceleration 0.8 m/s^2. Over 2 500 m, what must the initial velocity be for the object to reach 560 m/s?"

(2 marks)

Section B - Substitute values into $v^2 = u^2 + 2as$ and solve. Show all working.

4. $v = 10$ m/s, $u = 3$ m/s, $a = 2.5$ m/s^2, $s = ?$

(2 marks)

5. $v = ?$, $u = 4$ m/s, $a = 3.8$ m/s^2, $s = 31$ m

(2 marks)

6. $v = 40$ m/s, $u = ?$, $a = 4.1$ m/s^2, $s = 100$ m

(2 marks)

Answers

1. u = 9, a = 7.8, s = 80, v = ? --> v^2 = 81 + 1 248 = 1 329 --> v = 36.5 m/s
2. v = 280, a = 7, s = 500, u = ? --> 78 400 = u^2 + 7 000 --> u^2 = 71 400 --> u = 267.2 m/s
3. v = 560, a = 0.8, s = 2 500, u = ? --> 313 600 = u^2 + 4 000 --> u^2 = 309 600 --> u = 556.4 m/s
4. 100 = 9 + 5s --> 5s = 91 --> s = 18.2 m
5. v^2 = 16 + 235.6 = 251.6 --> v = 15.86 m/s
6. 40^2 = u^2 + 2(4.1)(100) --> 1 600 = u^2 + 820 --> u^2 = 780 --> u = 27.9 m/s

Part 2 of 3 | Rearranging - Finding v, u, a and s

Key Information

$v = \sqrt{(u^2 + 2as)}$

$u = \sqrt{(v^2 - 2as)}$

$$a = \frac{v^2 - u^2}{2s}$$

$$s = \frac{v^2 - u^2}{2a}$$

Questions

Section C - Find v (final velocity).

7. $u = 2$, $a = 30$, $s = 45$, find v.

(2 marks)

8. $u = 40$, $a = 6.8$, $s = 230$, find v.

(2 marks)

9. $u = 650$, $a = 1\,300$, $s = 490$, find v.

(2 marks)

10. An object has initial velocity 3 m/s, acceleration 4.8 m/s^2, and travels 24 m. Find v.

(2 marks)

11. An object has initial velocity 25 m/s, acceleration 0.5 m/s^2, and travels 200 m. Find v.

(2 marks)

12. An object has initial velocity 0.2 m/s, acceleration 1.9 m/s^2, and travels 140 m. Find v.

(2 marks)

Section D - Find u (initial velocity).

13. $v = 135.7$, $a = 22.1$, $s = 100$, find u.

(2 marks)

14. $v = 655$, $a = 25$, $s = 239$, find u.

(2 marks)

15. v = 0.64, a = 0.21, s = 0.31, find u.

(2 marks)

16. An object has acceleration 3.1 m/s^2. After 700 m it reaches 207 m/s. Find u.

(2 marks)

17. An object has acceleration 2.1 m/s^2. After 900 m it reaches 607 m/s. Find u.

(2 marks)

18. An object has acceleration 1.8 m/s^2. After 1 600 m it reaches 560 m/s. Find u.

(2 marks)

Answers

7. v^2 = 4 + 2 700 = 2 704 --> v = 52 m/s
8. v^2 = 1 600 + 3 128 = 4 728 --> v = 68.8 m/s
9. v^2 = 422 500 + 1 274 000 = 1 696 500 --> v = 1 302.5 m/s
10. v^2 = 9 + 230.4 = 239.4 --> v = 15.5 m/s
11. v^2 = 625 + 200 = 825 --> v = 28.7 m/s
12. v^2 = 0.04 + 532 = 532.04 --> v = 23.1 m/s
13. u^2 = 135.7^2 - 2(22.1)(100) = 18 414 - 4 420 = 13 994 --> u = 118.3 m/s
14. u^2 = 655^2 - 2(25)(239) = 429 025 - 11 950 = 417 075 --> u = 645.8 m/s
15. u^2 = 0.64^2 - 2(0.21)(0.31) = 0.4096 - 0.1302 = 0.2794 --> u = 0.529 m/s
16. u^2 = 207^2 - 2(3.1)(700) = 42 849 - 4 340 = 38 509 --> u = 196.2 m/s
17. u^2 = 607^2 - 2(2.1)(900) = 368 449 - 3 780 = 364 669 --> u = 603.9 m/s
18. u^2 = 560^2 - 2(1.8)(1 600) = 313 600 - 5 760 = 307 840 --> u = 554.8 m/s

Part 3 of 3 | Finding a and s; Deceleration; Exam Questions

Key Information

$$a = \frac{v^2 - u^2}{2s}$$

$$s = \frac{v^2 - u^2}{2a}$$

For deceleration: v < u, so $v^2 - u^2$ is negative a is negative. 1

Object from rest (u = 0): $v^2 = 2as$ 2

$$a = \frac{v^2}{2s}$$

$$s = \frac{v^2}{2a}$$

Object stopping (v = 0): $0 = u^2 + 2as$ 3

$$s = \frac{-u^2}{2a}$$

(note: a is negative here) 4

Questions

Section E - Find a (acceleration).

19. v = 560, u = 352, s = 28. Find a.

(2 marks)

20. v = 28.3, u = 15.1, s = 0.7. Find a.

(2 marks)

21. v = 1 560, u = 1 550, s = 145. Find a.

(2 marks)

22. An object goes from 12 m/s to 63 m/s over a displacement of 125 m. Find a.

(2 marks)

Section F - Find s (displacement).

23. u = 2, v = 3, a = 0.25. Find s.

(2 marks)

24. u = 6, v = 30, a = 4. Find s.

(2 marks)

25. u = 20, v = 300, a = 18. Find s.

(2 marks)

Section G - Deceleration and special cases (u = 0 or v = 0).

26. v = 20, u = 30, s = 5. Find a.

(2 marks)

27. u = 4 m/s, v = 3 m/s, a = -0.25 m/s^2. Find s.

(2 marks)

28. An object accelerates from rest to 5 m/s with a = 0.9 m/s^2. Find s.

(2 marks)

29. An object starts from rest, a = 5 m/s^2, and travels s = 15 m. Find v.

(2 marks)

30. An object starts from rest and reaches v = 165 m/s over s = 30 m. Find a.

(2 marks)

31. An object slows to rest with a = -20 m/s^2 over s = 60 m. Find u.

(2 marks)

32. A car travelling at 35 m/s comes to rest over s = 10.2 m. Find a.

(2 marks)

33. A stone enters the ground at 1.3 m/s and experiences a = -135 m/s^2. Calculate the distance the stone penetrates into the ground.

(2 marks)

EXAM QUESTION - Q7: $v^2 = u^2 + 2as$ (10 marks)

Mark allocations shown as (n) following AQA convention.

(a) State the names and symbols of the four quantities in the equation $v^2 = u^2 + 2as$, giving the unit for each.

(4)

(b)(i) A car travelling at 30 m/s applies its brakes and comes to rest over a distance of 45 m. Calculate the deceleration of the car.

(3)

(b)(ii) State one assumption you made in your calculation in (b)(i).

(1)

(c)(i) A ball is dropped from rest and falls freely under gravity (g = 10 m/s^2). Calculate the velocity of the ball after it has fallen 20 m.

(3)

(c)(ii) Calculate the velocity of the ball after it has fallen 80 m.

(2)

Answers

Section E answers:

19. $(560^2 - 352^2) / (2 \times 28) = 189\,696 / 56 = 3\,387$ m/s²

20. $(28.3^2 - 15.1^2) / (2 \times 0.7) = 572.9 / 1.4 = 409$ m/s²

21. $(1\,560^2 - 1\,550^2) / (2 \times 145) = 31\,100 / 290 = 107.2$ m/s²

22. $(63^2 - 12^2) / (2 \times 125) = 3\,825 / 250 = 15.3$ m/s²

Section F answers:

23. (9 - 4) / (2 x 0.25) = 5 / 0.5 = 10 m

24. (900 - 36) / (2 x 4) = 864 / 8 = 108 m

25. (90 000 - 400) / (2 x 18) = 89 600 / 36 = 2 489 m

Section G answers:

26. (400 - 900) / (2 x 5) = -500 / 10 = -50 m/s²

27. (9 - 16) / (2 x -0.25) = -7 / -0.5 = 14 m

28. u = 0: $s = v^2 / (2a) = 25 / 1.8 = 13.9$ m

29. u = 0: $v^2 = 2(5)(15) = 150$ --> v = 12.25 m/s

30. u = 0: $a = 165^2 / (2 \times 30) = 27\,225 / 60 = 453.75$ m/s²

31. v = 0: $u^2 = -2(-20)(60) = 2\,400$ --> u = 49.0 m/s

32. v = 0: $a = -35^2 / (2 \times 10.2) = -1\,225 / 20.4 = -60.1$ m/s²

33. v = 0: $s = -1.3^2 / (2 \times -135) = 1.69 / 270 = 0.00626$ m (6.3 mm)

Exam (a) v = final velocity (m/s), u = initial velocity (m/s), a = acceleration (m/s²), s = displacement (m). (1 each = 4)

Exam (b)(i) v = 0, u = 30, s = 45. 0 = 900 + 2a(45) --> 90a = -900 --> a = -10 m/s² (3)

Exam (b)(ii) The deceleration is uniform (constant) throughout. (1)

Exam (c)(i) u = 0, a = 10, s = 20. $v^2 = 0 + 2(10)(20) = 400$ --> v = 20 m/s (3)

Exam (c)(ii) $v^2 = 2(10)(80) = 1\,600$ --> v = 40 m/s (2)