2026 Sec 3 Physics Chapter 5 Kinematics

Answers to Examples and Exercises

1 Speed, velocity and acceleration

Examples 1.1

1.

A	velocity	✓	**E**	force	✓
B	mass		**F**	temperature	
C	volume		**G**	energy	
D	weight	✓	**H**	density	

2. Most physical quantities have units, except those that are ratios (e.g. refractive index).

3 (a) 14 kg (b) 90 ^{0}C

4 Maximum force = 20 N + 30 N = 50 N
Minimum force = 30 N – 20 N = 10 N

Example 1.2

(a) 10 km (b) 4.24 km North-East

Examples 1.3

1 5.0 m s^{-1}
37° East of North (or 53° North of East) [tan θ = ¾ ➔ θ = 37°]

2 (a) Yes, since it covers the same distance per unit time.
(b) No, since the direction of motion in a circle is continually changing. As a vector, the magnitude and direction of velocity has to be constant for velocity to be constant.
(c) 2.0 m s^{-1}
(d) 0 m s^{-1} since the change in displacement will be zero and velocity is rate of change of displacement.

Examples 1.4

1. SI unit for acceleration = (SI unit for change in velocity) ÷ SI unit for change in time
= [m s^{-1}] ÷ [s] = m s^{-2}

2. Since the direction of velocity is continually changing, the velocity is continually changing. Therefore acceleration, the rate of change of velocity, is not zero.

Exercises

Speed, velocity and acceleration

1 (a) 3.0 + 2.0 + 3.0 = 8.0 m

(b) 2.0 m South

(c) Arrow to point from A to D, to denote the vector of the total displacement travelled.

(d) No. As long as an object moves, distance will increase.

(e) Average speed = total distance / total time = 8.0 / 10 = 0.80 m s^{-1}

(f) Average velocity = total displacement / total time = 2.0 / 10 = 0.20 m s^{-1}; direction = South.

2 time = 50.0 / 5.0 = 10 s

3 (a) average speed = $(3.0\pi + 4.0\pi) / (2.0 + 3.0) = 4.4\ m\ s^{-1}$

(b) magnitude of the average velocity = $(3.0 + 3.0 + 4.0 + 4.0) / (2.0 + 3.0) = 2.8\ m\ s^{-1}$

4 (a) average acceleration = $(v - u) / t = (60\ m\ s^{-1} - 20\ m\ s^{-1}) \div 5.0\ s = 8.0\ m\ s^{-2}$

(b) average acceleration = $(-60\ m\ s^{-1} - 20\ m\ s^{-1}) \div 5.0\ s$
$= (-80\ m\ s^{-1}) \div 5.0\ s = -16\ m\ s^{-2}$

1.5 Problems on motion data collected at a constant frequency

Example 1.5

(b) v is higher than u hence the speed is increasing
(Note: the spacing between consecutive dots increases when the speed is increasing)

Exercises

Problems on motion data collected at a constant frequency

1 (a) A (the end of the tape closest to the trolley)
(b) moving fastest: **BC**
(c) moving slowest: **DE**
(d) moving at constant speed: **BC / DE**
(e) moving with increasing speed / accelerating: **AB**
(f) moving with decreasing speed / decelerating: **CD**

Example 1.6

(b) The initial oil drops are on the left of the diagram, so **T** is decelerating since the distance between the oil drops are decreasing as **T** moves to the right.
(c) The oil is dripping at a constant rate.

Example 1.7

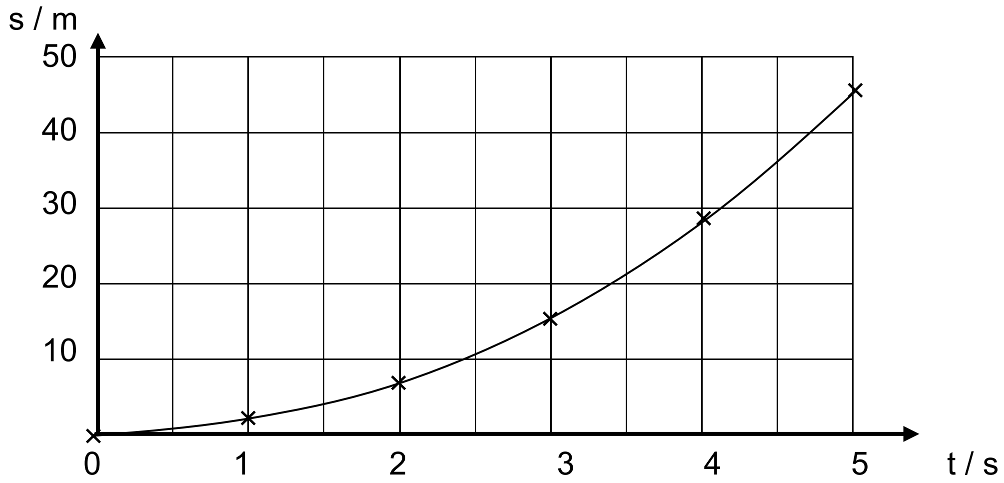
(a) Accelerating
(b) Distance of car from position to position 6 = 40.0 m
Time taken = 2.5 s
Average speed = 40.0/2.5 = 16 m s^{-1}

2 Graphical analysis of motion

2.3 Displacement vs Time Graph (s-t graph)

Example 2.1
(c) increasing gradient; increasing velocity
(d) decreasing gradient; decreasing velocity

Example 2.2
(a)

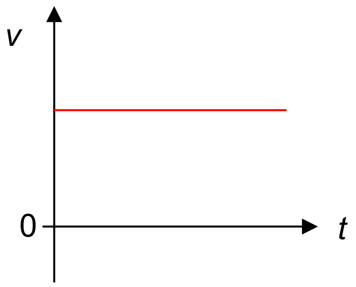
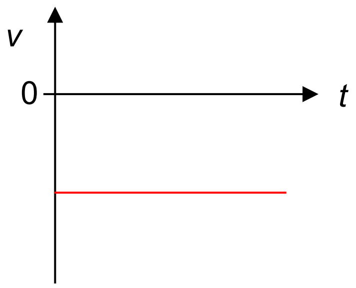


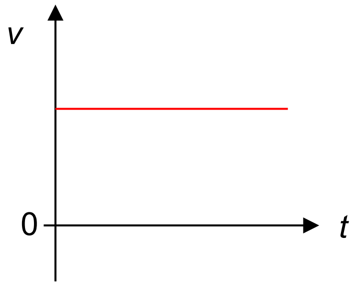
(b) Since the displacement travelled by the car per second (or gradient of s-t graph) is increasing, the velocity of the car is increasing.

t / s	0.0	1.0	2.0	3.0	4.0	5.0
s / m	0.0	1.0	6.0	15.0	28.0	45.0

+1.0 m +5.0 m +9.0 m +13.0 m +17.0 m

Example 2.3

v- t graph	**Qualitative description of velocity**
	The body moves in the positive direction with constant velocity.
	The body moves in the negative direction with constant velocity.

	The body moves in the positive direction with a constant velocity.

Examples 2.4

(a) distance = 4.5 km
(If question asked for the total distance the runner ran, then it would be 6.0 km.)

(b) time taken = 26.0 min

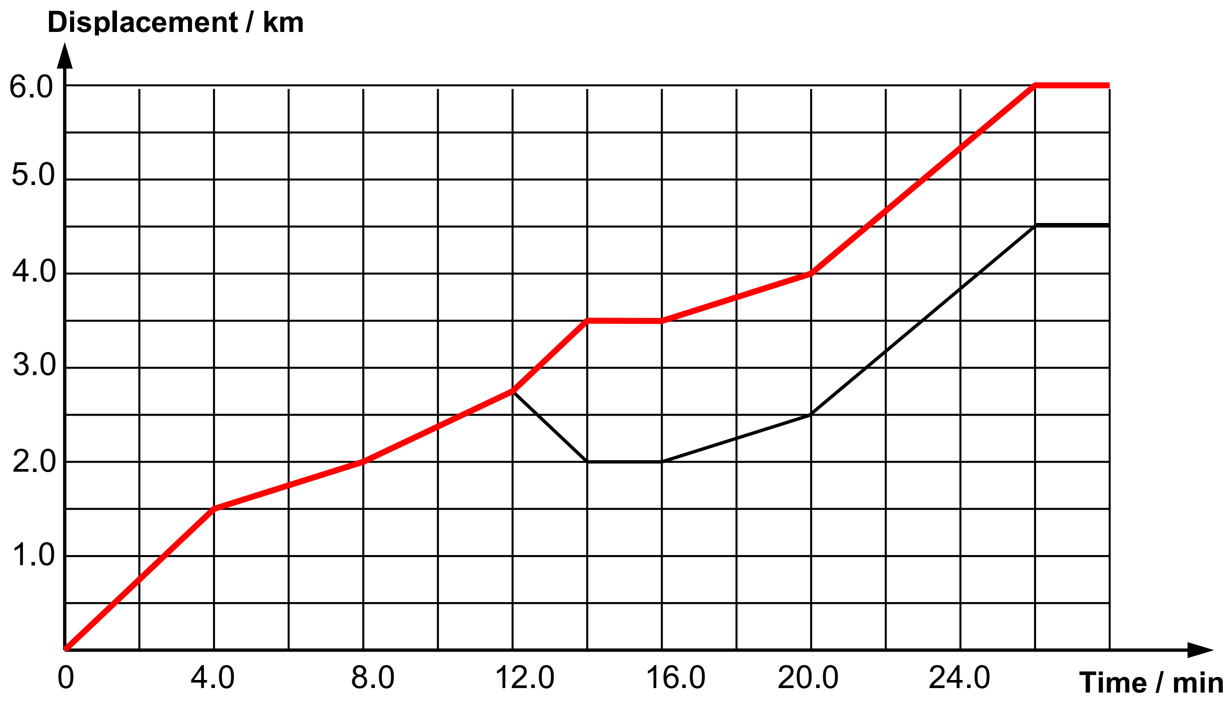
(c) average velocity = 4.5 km / (26.0 ÷ 60) hr = 10 km h^{-1}

(d) Between 12.0 and 14.0 min

(e) time taken = 2.0 min

(f) Between 0.0 and 4.0 min

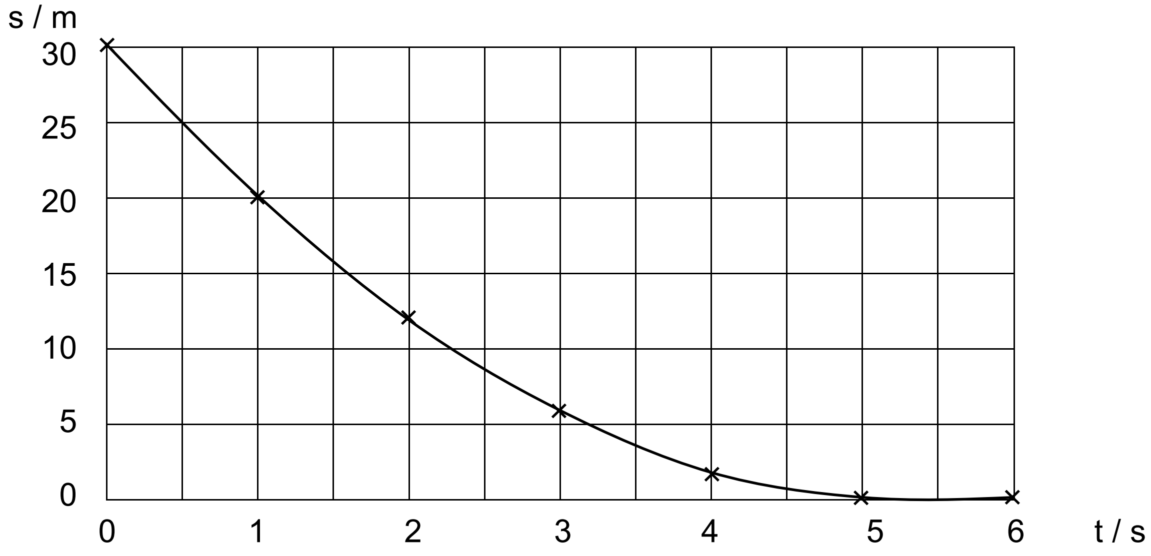
(g) Red line as drawn below



Exercises

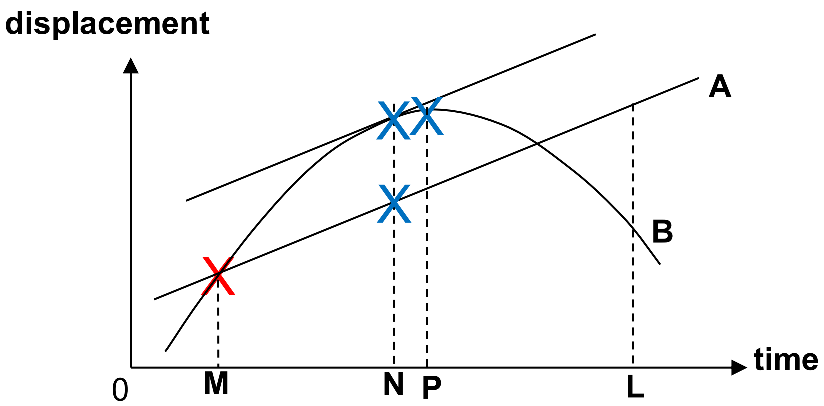
Displacement vs Time Graph (s-t graph)

1 (a)



(b) Since the (magnitude of the) <u>displacement travelled by the car per second</u> (or gradient of s-t graph) <u>is decreasing</u>, the <u>velocity of the car is decreasing</u>.
(The magnitude of the change in displacement of the car for consecutive 1 s intervals decreases from 10.0 m, 8.0 m, 6.0 m, 4.0 m, 2.0 m to 0 m)

2 (a), (b)

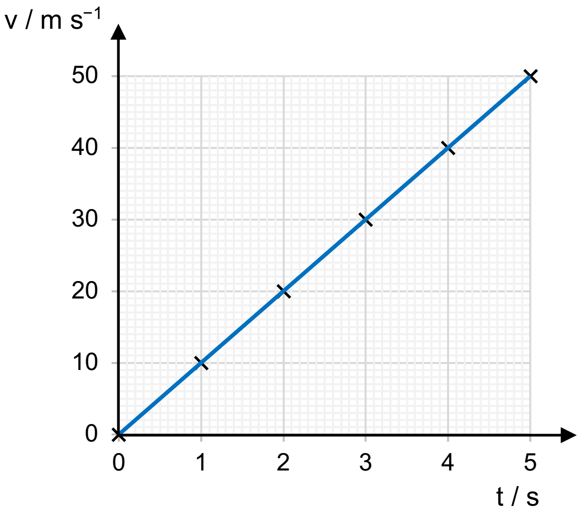


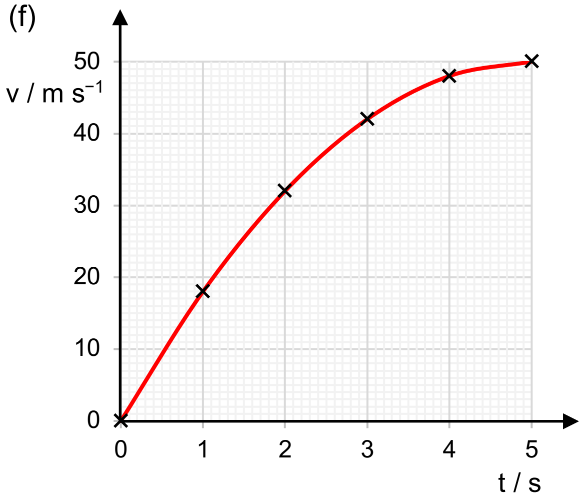
(c) **B** is moving faster as the magnitude of the gradient of the displacement-time graph represents the magnitude of the velocity and it is steeper for **B** at time **L**.

(d) Since the gradient represents the velocity, the velocities of the cars are the same at time **N** as their gradients are the same.

2.4 Velocity vs Time Graph (v-t graph)

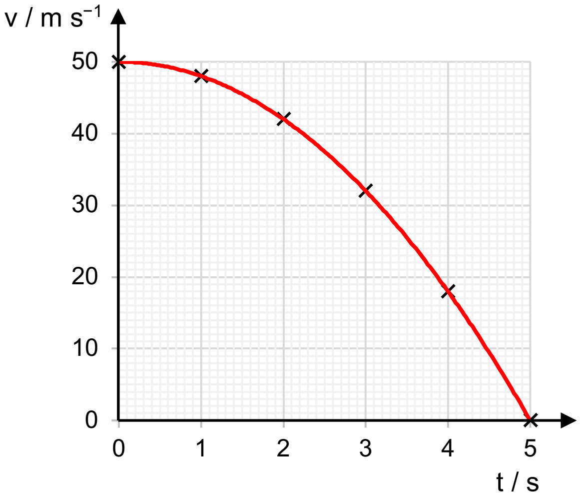
<table>
<tr><th colspan="2">Example 2.5</th></tr>
<tr><td></td><td>(b) Graph: The gradient of v-t graph is zero

Motion: The velocity of the body is constant or the body moves with zero acceleration.</td></tr>
<tr><td>(c)

</td><td>(d) Graph: The magnitude of velocity decreases and the gradient is constant.
Motion: The velocity of the body decreases at a constant rate, or the body moves with constant deceleration</td></tr>
<tr><td>(e)
Graph: The magnitude of velocity increases and the gradient is increasing.

Motion: The velocity of the body increases at an increasing rate, or the body moves with increasing acceleration</td><td>(f)


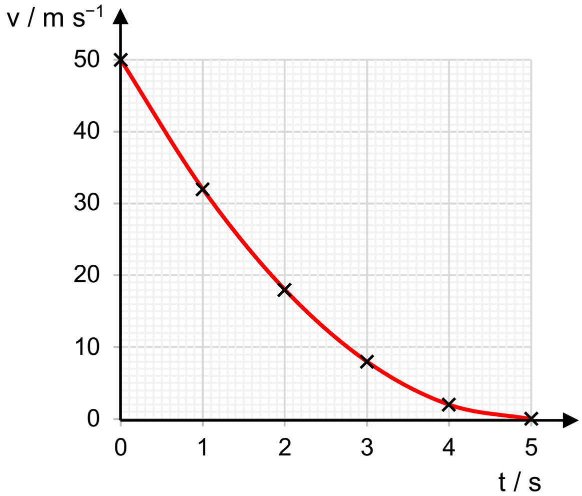
Graph: The magnitude of velocity increases and the gradient is decreasing
Motion: The velocity of the body increases at a decreasing rate, or the body moves with decreasing acceleration</td></tr>
</table>

(g)



<u>Graph</u>: The magnitude of velocity decreases and the gradient is increasing
<u>Motion</u>: The velocity of the body decreases at an increasing rate, or the body moves with increasing deceleration

(h)



<u>Graph</u>: The magnitude of velocity decreases and the gradient is decreasing
<u>Motion</u>: The velocity of the body decreases at a decreasing rate, or the body moves with decreasing deceleration

Example 2.6

(a) 2.0 seconds (when velocity is zero)

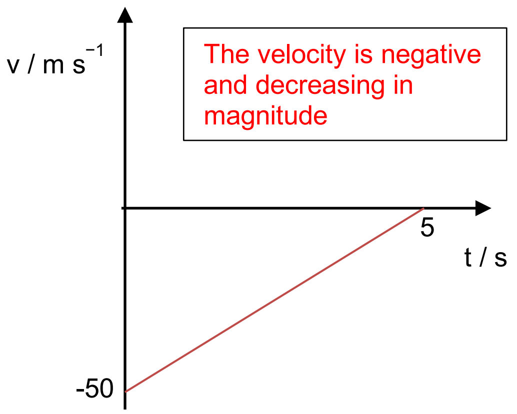
(b) From t = 0 s to t = 6.0 s, the acceleration is constant at 2.5 m s^{-2}.
From t = 0 s to t = 2.0 s, the object moves in the negative direction, slowing down from a speed of 5.0 m s^{-1} to an instantaneous rest at t = 2.0 s (constant deceleration)
From t = 2.0 s to t = 6.0s, it speeds up in the positive direction to a speed of 10.0 m s^{-1} at t = 6.0 s. (constant acceleration)

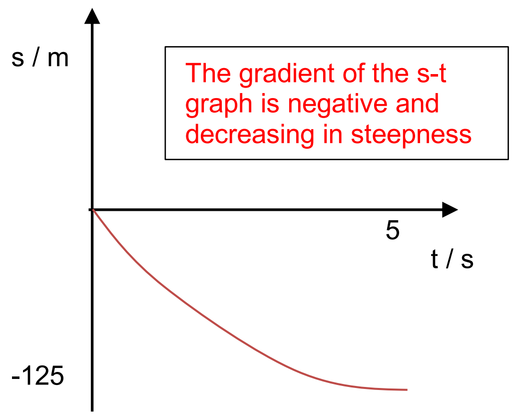
(c) Displacement = – ½ (2.0)(5.0) + ½ (6.0 – 2.0)(10.0) = 15 m

Exercises

Velocity vs Time Graph (v-t graph)

1 (a)





(b) The car moves in the negative direction with the speed decreasing at a constant rate of 10 m s^{-2} (or constant deceleration). It comes to rest at t = 5 s.

2 (a) (i) At **O** and **R** **(ii)** Between **P** and **Q** **(iii)** Between **Q** and **R**

(b) Distance = area under the graph = ½ (7.0 + 12.0) (20.0) = 190 m

(c) acceleration = 20.0 / 3.0 = 6.7 m s^{-2} (2 s.f.)

(d) acceleration = -20.0 / 2.0 = - 10 m s^{-2}

(e) The speed-time graph would be identical. Since there was no change in the direction of travel of the car, there was no change in the sign of the velocity values. Hence all the velocity values are the same as the speed values.

(f) (i) If his reaction time is 0.50s, mark clearly on the graph above with an '**X**' to indicate the instant when he first saw the child.

(ii) Distance travelled before the car comes to a complete stop = distance under the graph between 9.5 s to 12.0 s = ½ (0.5 + 2.5) (20.0) = 30 m
The car would not hit the child.

3 (a) 4.0 cm s^{-1}

(b) Displacement = area under the graph between 0 to 15 s − area under the graph between 15 to 45 s = ½ (5+15)(2.0) – ½ (25+10)(4.0) = −50 cm

(c)

interval	**direction of motion**	**speeding up or slowing down**
t = 10 s to *t* = 15 s	rightwards	Slowing down (decelerating)
t = 15 s to *t* = 25 s	leftwards (Note: v is negative)	Speeding up (accelerating) (Note: magnitude of v is increasing)
t = 25 s to *t* = 40 s	leftwards (Note: v is negative)	Slowing down (decelerating) (magnitude of v is decreasing

4 (a) The area under the graph for car **B** is greater than that for car **A**.

(b) Both cars must have travelled the same distance for the same time when **A** overtakes **B**.
Area under the graph for **A** = Area under the graph for **B**

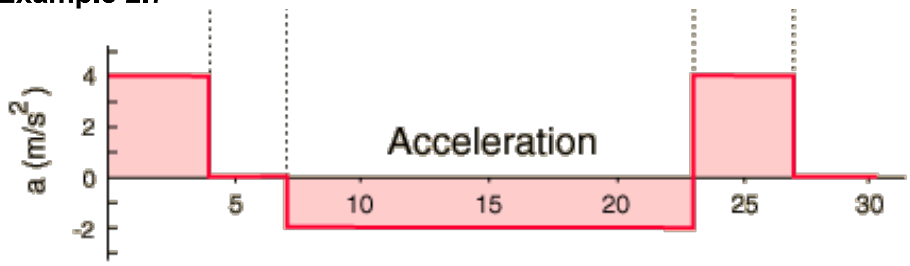
½ x t x v = 28 x t

v = 56 m s^{-1}

(c) a = (v – u) / t = 56/t = 8.0, time taken, t = 7.0 s
(d) Car **A** must still reach 56 m s^{-1} to overtake car **B** as the distance moved **to** overtake **B** is still the same but it will take a shorter time as car **A** will reach 56 m s^{-1} in a shorter time.

2.5 Comparisons between s-t, v-t and a-t graphs

Example 2.7



Section	A	B	C	D	E	F
s / m	increasing at an increasing rate	increasing at a constant rate	increasing at a decreasing rate	decreasing at an increasing rate	decreasing at a decreasing rate	constant
v / m s^{-1}	• moving in the positive direction • speed increases at a constant rate	• moving in the positive direction • constant speed	• moving in the positive direction • speed decreases to zero at a constant rate	• moving in the negative direction • speed increases at a constant rate	• moving in the negative direction • speed decreases to zero at a constant rate	• at rest • zero velocity
a / m s^{-2}	constant positive acceleration (accelerating)	zero acceleration	constant negative acceleration (decelerating)	constant negative acceleration (accelerating)	constant positive acceleration (decelerating)	Zero acceleration

(Note: when v and a are in the same direction, the object speeds up / accelerates. When v and a are in opposite directions, the object slows down / decelerate)

3 Free-fall

Amanda:

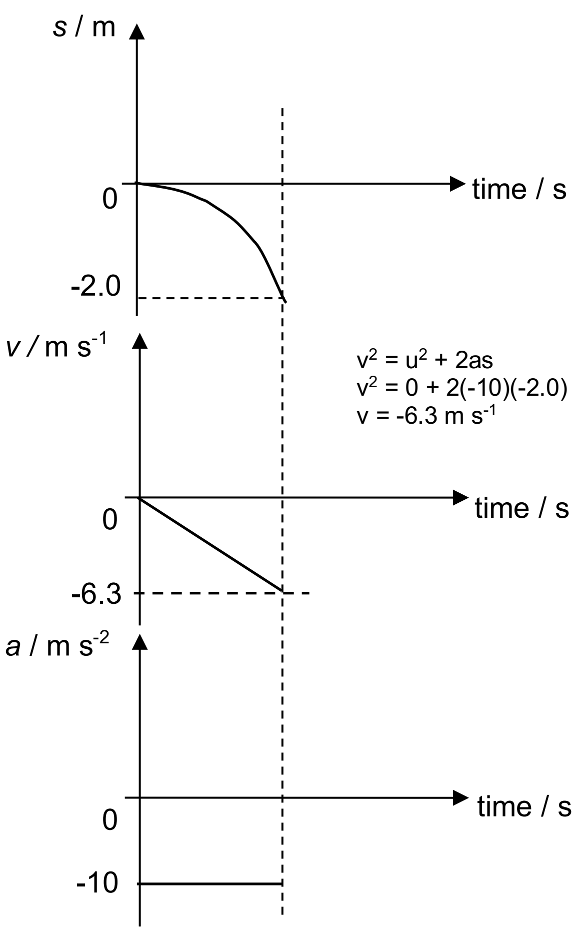
- At time t = 0 s, velocity is upward as ball is moving upwards.
- However, acceleration is downward due to gravity.
- Since velocity and acceleration are in *opposite* directions, ball's speed will decrease.

Ben:

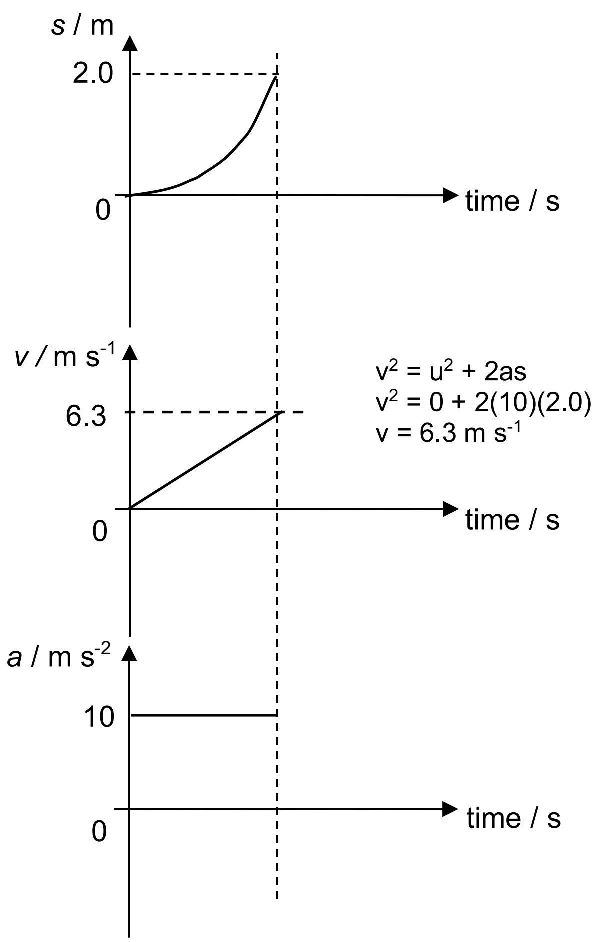
- At time t = 3 s, velocity is zero as the ball stops momentarily at that change in direction.
- However, its acceleration is still downward due to gravity. Velocity is still *changing*, so the ball will not hang in mid-air forever. Just before 3 s, it was still moving upwards, and just after 3 s, it will be moving downwards!

Example 3.1

(i) upwards positive



(ii) downwards positive



Exercises

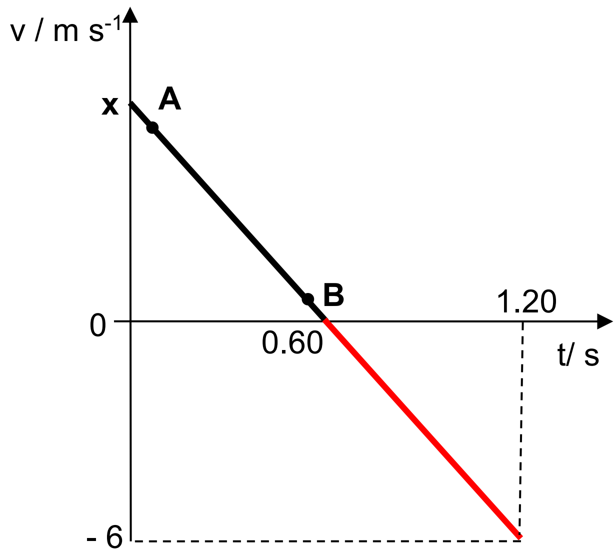
1 (a) the sign convention : up is positive

(b) Ball at A is moving faster than when it is at B. At both instants, the ball is moving upwards and the acceleration acting on the ball is the same.

(c) a = (v – u) / t ➔ -10 = (0 – x) / 0.60
x = 6.0 m s^{-1}

(d) Maximum height = ½ x 0.60 x 6.0 = 1.8 m

(e) Complete the graph to show the motion of the ball as it falls back down to its initial position at t = 1.20 s and v = -6 m s^{-1}.

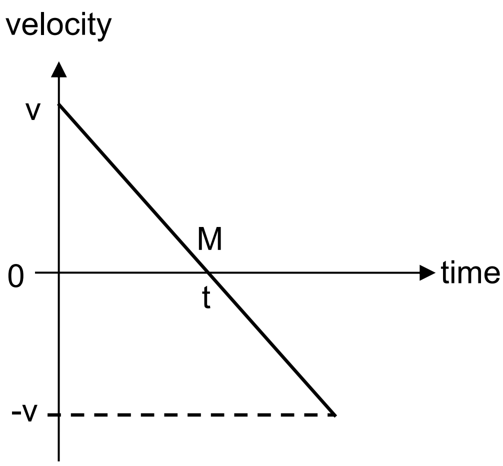


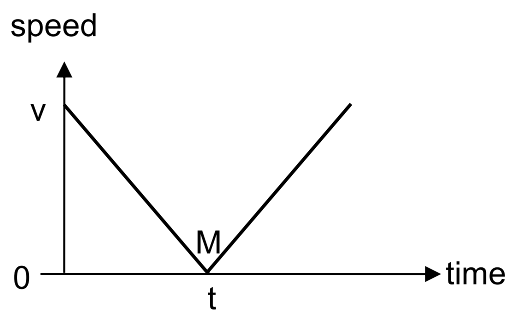
2 (a) sign convention: up is positive

(b) Since velocity is a vector quantity, the sign of the velocity will be reversed when the direction of motion is reversed. The velocity after time t is negative as the ball travels in the opposite direction i.e. down compared to the direction before time t which is up. Speed is a scalar quantity so it only has magnitude, which means all speed values are positive.

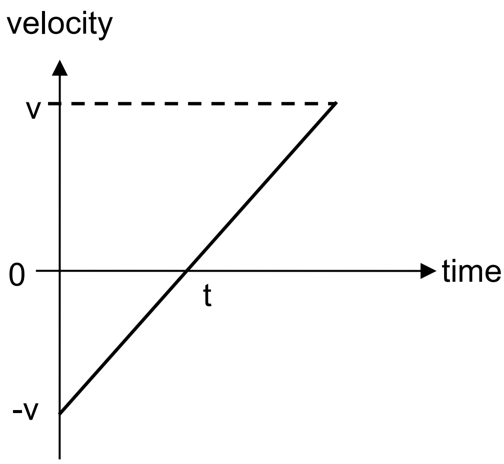
(c) acceleration = 10 m s^{-2}

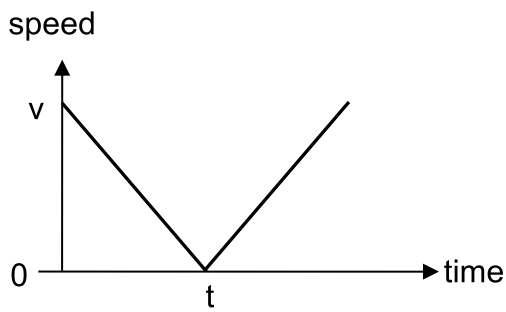
(d)



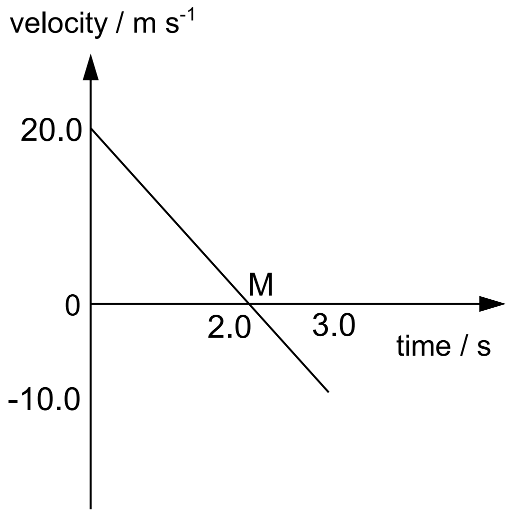


(e)





3 (a) Refer to the diagram



(b) **h** = (½ x 2.0 x 20.0) + (½ x 1.0 x -10.0) = 15 m

(c) On the time-axis of the graph above, mark the instant with letter **M** at which the ball is at its highest position.

4 Four Equations of Motion

Examples 4.1

1 .

Displacement:

Initial velocity: 10 m/s

Final velocity: 30 m/s

Acceleration:

Time taken: 5.0 s

$s = (u + v)/2 \times t$

$= (10 + 30)/2 \times 5.0 = 100$ m

2.

s:

u: 0 m/s

v:

a: 10 m/s^2

t: 4.0 s

Take down as positive.

$s = ut + ½ at^2$

$0 = (0 \times 4.0) + ½ (10) (4.0^2)$

$s = 80$ m

3

s:

u: 40 m/s

v: 0 m/s

a: -10 m/s^2

t:

Take up as positive.

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

$0 = 40^2 + 2(-10)s$

$s = 80$ m

Exercises

Four Equations of Motion

1 **(a)** Take the upwards direction as positive
Assume g = 10 m/s^2

$s = ut + ½ at^2$

$-100 = 40t + ½ (-10) t^2$
$t = -2.0$ s (inadmissible) or $+10$ s

Time taken is 10 s

(b) $v^2 = u^2 + 2as$
$v^2 = 40^2 + 2(-10) (-100)$

$v = -60$ m/s or $+60$ m/s

velocity is - 60 m/s since it is downward

2 $s = ut + ½ at^2$
$s = 0 + ½ (10) (5.0^2)$

$s = 125$ m

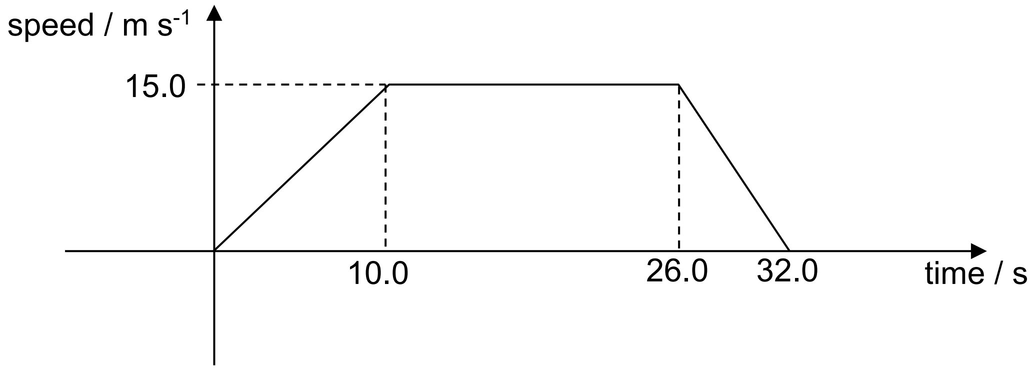
3 (a) average speed = 250 / 8.0 = 31 m/s

(b) s = (u + v)/2 x t
250 = (10.0 + v) / 2 x8.0
v = 53 m/s

(c) 52.5 = 10.0 + a(8.0)
a = 5.3 m/s^2

4

(a)



Total distance = ½ (16.0 + 32.0) x 15.0 = 360 m

(b) Since the equations of motion can only be used when the acceleration is constant, it must be applied separately for the 0 s – 10.0 s, 10.0 s – 26.0 s and 26.0 s – 32.0 s.

We apply s = (u + v)/2 x t.

[(0 + 15.0)/2 x 10.0] + [(15.0 + 15.0)/2 x 16.0] + [(15.0 + 0)/2 x 6.0]
= 75 + 240 + 45 = 360 m

5 (a) the time taken to reach the maximum height and

Take the upwards direction as +
Assume *g* = 10 m/s^2
At the maximum height, the velocity is zero. v = u + at 0 = 30.0 + (-10) t t = 3.0 s

(b) the total time taken to reach the ground.

s = ut + ½ at^2 ➔ -20.0 = 30.0 t + ½ (-10)t^2

t = 6.6 s