2021 Sec 3 Physics Chapter 5 Kinematics

Answers to Examples and Exercises

5.1 Speed, velocity and acceleration

Examples 5.1.1

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
   (b) Maximum force = 20 N + 30 N = 50 N

4 (a) Minimum force = 30 N – 20 N = 10 N
   (b) 5.0 + 2.0 = 7.0 m s^{-1} towards the man

Example 5.1.2

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

Examples 5.1.3

1 (a) 5.0 m s^{-1}
   (b) 37° East of North (or 53° North of East) [$\tan \theta = ¾ \Rightarrow \theta = 37°$]

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 displacement will be zero and velocity is rate of change of displacement.

Examples 5.1.4

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

2. No. Although its magnitude (speed) is constant, its direction is continually changing.

Exercises

5.1 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□ + 4.0□) / (2.0 + 3.0) = 4.4 m s^{-1}

(b) 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}) | 5.0 s = 8.0 m s^{-2}

(b) average acceleration = (- 60 m s^{-1} - 20 m s^{-1}) | 5.0 s

= (- 80 m s^{-1}) | 5.0 s = -16 m s^{-2}

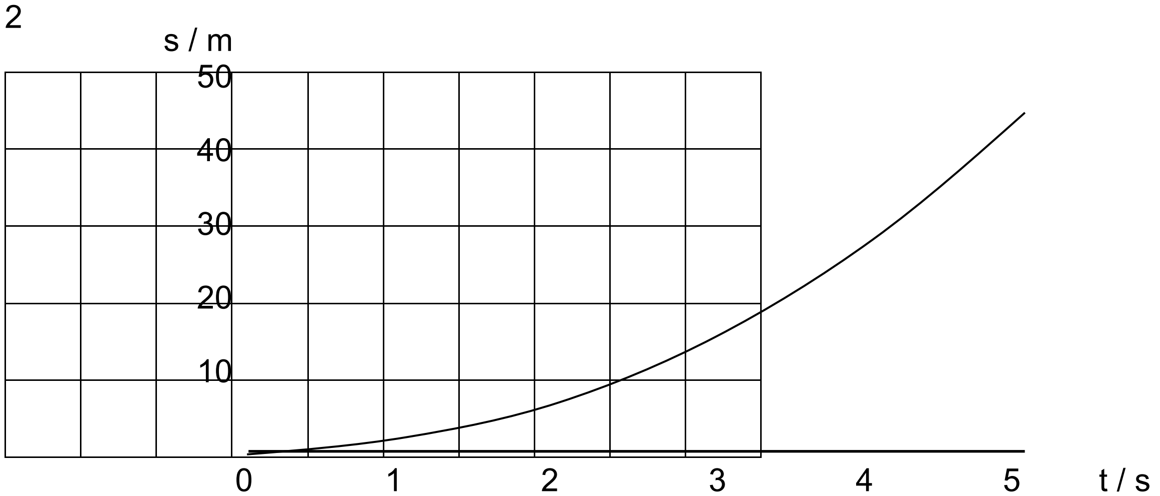
5.1.5 Problems on tabulated data

Example 5.1.5

1 (a) The car travels 1.0 m from t = 0.0 to 1.0 s; (6.0-1.0 = 5.0 m) from t = 1.0 to 2.0 s; (15.0-6.0 = 9.0 m) from t = 2.0 to 3.0 s; (28.0-15.0 = 13.0 m) from t = 3.0 to 4.0 s; (45.0-28.0 = 17.0 m) from t = 4.0 to 5.0 s. Since the distance travelled by the car per second is increasing, the <u>speed of the car is increasing</u>.

(b) Since the speed of the car is increasing from 1.0 m s^{-1} to 5.0 m s^{-1} to 9.0 m s^{-1} to 13.0 m s^{-1} to 17.0 m s^{-1}, at a constant rate of 4.0 m s^{-2}, the <u>acceleration is constant</u>.

2



Note:
v-t graph cannot be plotted directly from the data from the table.
v needs to be determined from the gradient of every suitable point on the s-t graph before v-t graph can be plotted.

Exercises

Problems on tabulated data

1 (a) Since the (magnitude of the) 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, the velocity of the car is decreasing.

(b) The velocity for consecutive duration of 1 second is -10.0 m s^{-1}, -8.0 m s^{-1}, -6.0 m s^{-1}, -4.0 m s^{-1}, -2.0 m s^{-1} and 0 m s^{-1}. The change in velocity per second is constant at 2.0 m s^{-1} per second. Hence, the acceleration of the car is constant at 2.0 m s^{-2}.

5.1.6 Problems on motion data collected at a constant frequency

Example 5.1.6

(a) **PQ**: initial average $u = d_1 / t_1$ = 0.05 m / (3 x 1/ 60) s = 1.0 m s^{-1}

(b) **RS**: final average speed $v = d_2 / t_2$ = 0.30 m / (3 x 1/ 60) s = 6.0 m s^{-1}

(c) t = N x 1/60 = (1.5+3+1.5) x 1/60 = 6/60 = 0.10 s
average acceleration a = (v – u) / t = (6.0 – 1.0) / 0.10 = 50 m s^{-2}

Exercises

Problems on motion data collected at a constant frequency

1 (a) E
(b) moving fastest: **CD**
(c) moving slowest: **AB**
(d) moving at constant speed: **CD**
(e) moving with increasing speed / accelerating: **DE**
(f) moving with decreasing speed / decelerating: **BC**
(g) time interval represented by each space between two dots: 1/50 = 0.02 s.

(h) Hence, calculate the speed of **T** measured by portion **AB** of the tape.
Distance **AB** = 1.3 cm (measured from the hard copy)
Speed = 1.3 cm / (7 dot intervals x 0.02 s) = 9.3 cm s^{-1}

(i) Calculate the speed of **T** measured by portion **CD** of the tape.
Distance **CD** = 4.3 cm (measured from the hard copy)
Speed = 4.3 cm / (4 dot intervals x 0.02 s) = 54 cm s^{-1}

(j) Hence, calculate the average acceleration of T measured by portion BC of the tape.

Average a = (54 – 9.3) / (4 dot intervals x 0.02 s) = 559 cm s^{-2}

u is from CD and v from AB

Average a = (v – u) / t = (9.3 – 54)/t = - 559 = - 560 cm s^{-2} negative

2 (a) Accelerating (since the distance travelled per unit time between dots is increasing)

(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.

3 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}

5.2 Graphical analysis of motion

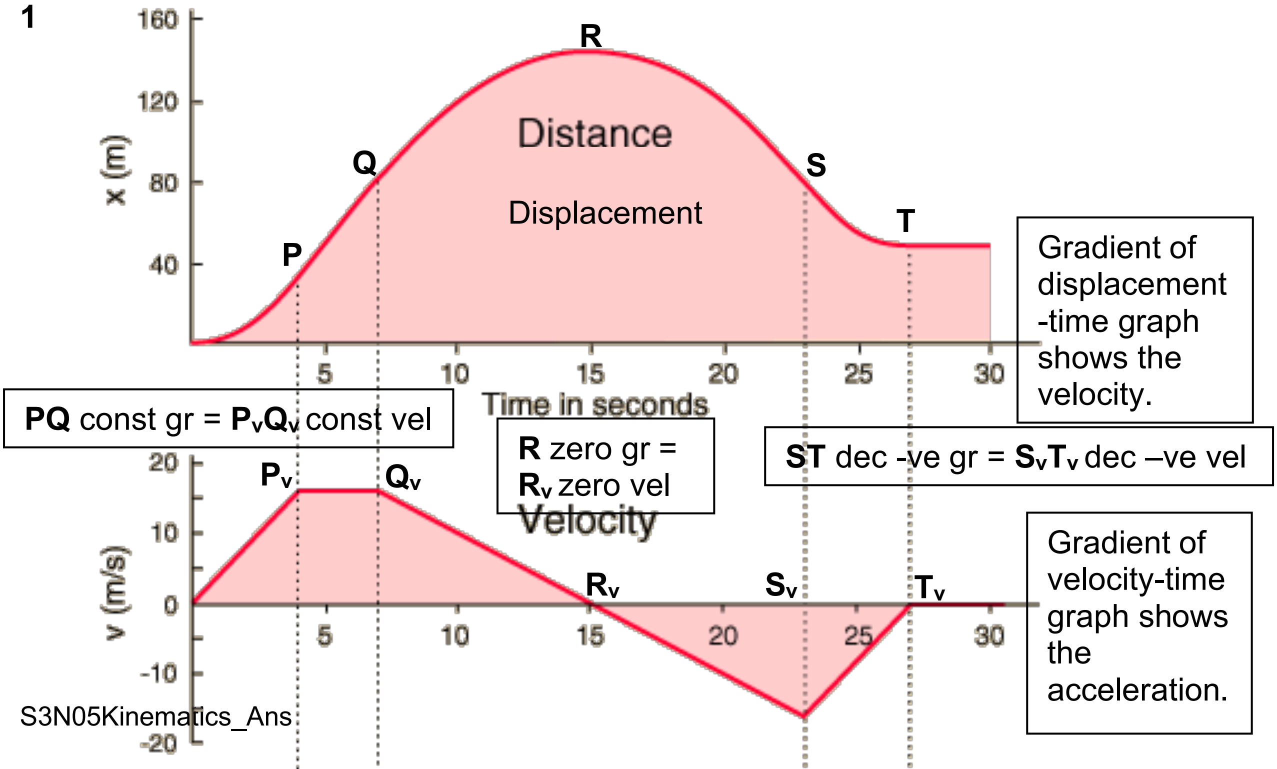
Displacement vs Time Graph

Examples 5.2.1

1. The body starts at the origin and moves in the positive direction with constant velocity.
2. The body starts at a positive displacement from the origin and moves in the negative direction with constant velocity ending at the origin.
3. The body starts at a negative displacement from the origin and moves in the negative direction with a constant negative velocity ending further away from the origin.
4. The body starts at a negative displacement from the origin and moves in the positive direction with constant velocity ending at the origin.

Example 5.2.2

1



t / s	0 to 4	4 to 7	7 to 15	15 to 23	23 to 27	27 to 30
Description of motion	Object moves with constant acceleration of 3.8 m s^{-2} from rest to 15 ms^{-1}.	Object moves with constant velocity of 15 m s^{-1} (zero acceleration)	Object moves with constant acceleration of -1.9 m s^{-2} from 15 m s^{-1} to rest.	Object moves with constant acceleration of – 1.9 m s^{-2} from rest to -15 m s^{-1}.	Object moves with constant acceleration of 5.0 m s^{-2} from -15 m s^{-1} to rest.	Object is not moving.

2. (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

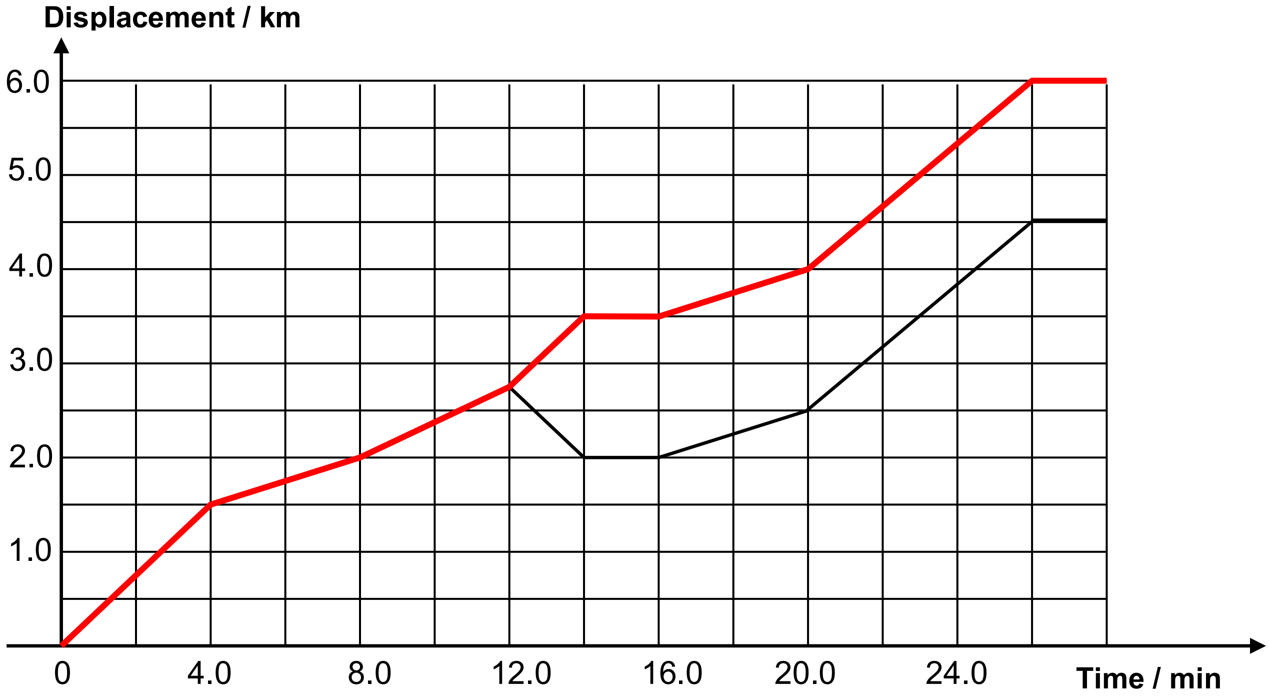
(c) average velocity = 4.5 km / (26.0 ÷ 60) hr = 10 km h^{-1}

(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

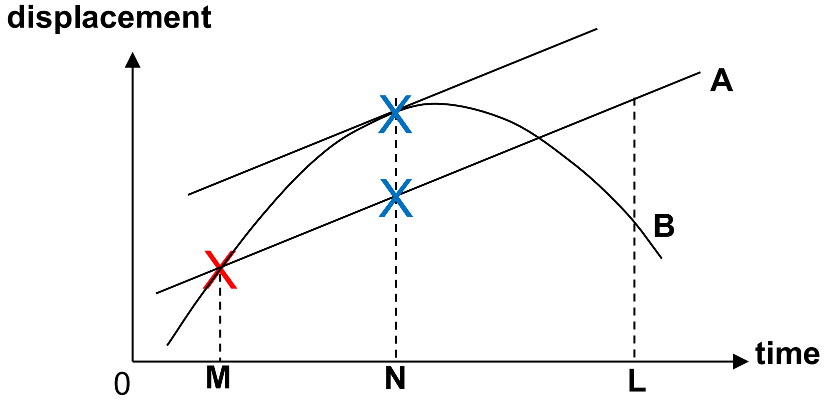


3. The object moves with constant acceleration of 2.5 m s^{-2} from -5.0 m s^{-1} to rest in 2.0 s, then from rest to 10.0 m s^{-1} in another 4.0 s.

   the acceleration is in the* ***positive* *direction. Although the speed has decreased in the first 2 seconds, but the velocity has increased! (-5.0 to 0!)*
   **Example for this graph: tossing a ball up in the air*

5.2 Graphical analysis of motion

1 (a)



(b) **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**.

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

2 (a) At **O** and **R**
(b) (i) Btw **P** and **Q** (ii) Btw **Q** and **R**
(c) Distance = area under the graph = ½ (7.0 + 12.0) (20.0) = 190 m
(d) acceleration = 20.0 / 3.0 = 6.7 m s^{-2} (2 s.f.)
(e) acceleration = -20.0 / 2.0 = - 10 m s^{-2}

(f) 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.

(g) (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 25 s - area under the graph between 25 to 45 s = zero

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

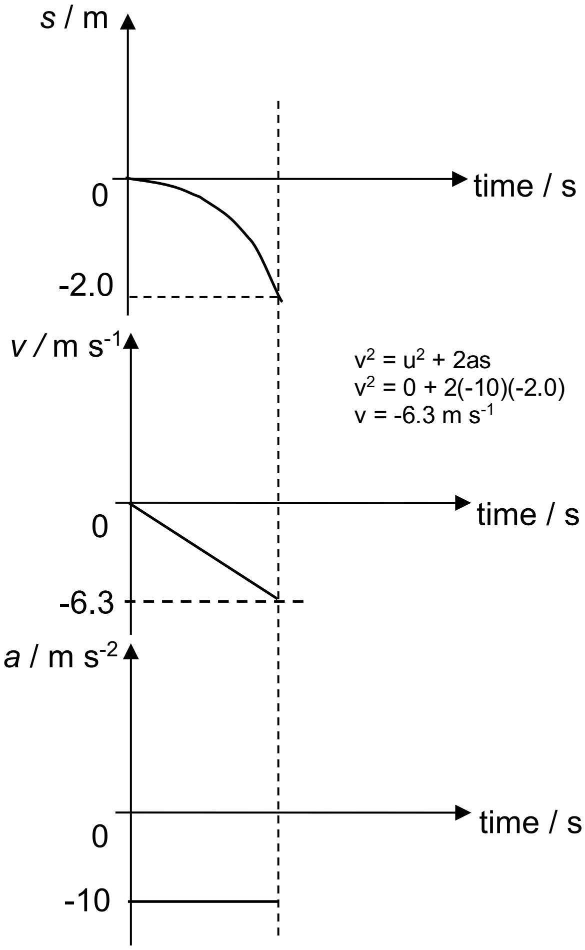
(b) Both cars must have travelled the same distance for the same time when **A** overtakes **B**.
Area under the graph for **A** = Area under the graph for **B**
½ x t x v = 28 x t v = 56 m s^{-1}

(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.

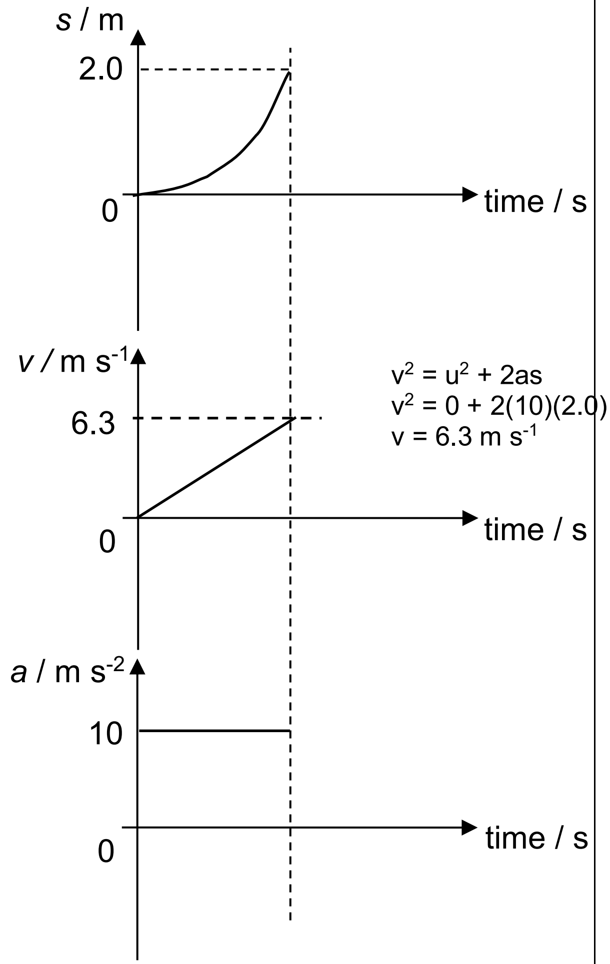
5.3 Free-fall

Example 5.3.1

(i) upwards positive



(ii) downwards positive



Exercises

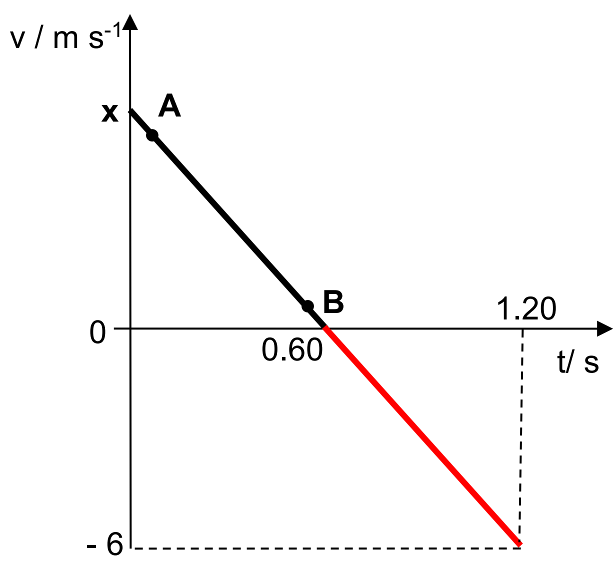
1 (a) the sign convention : up is positive

(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}.

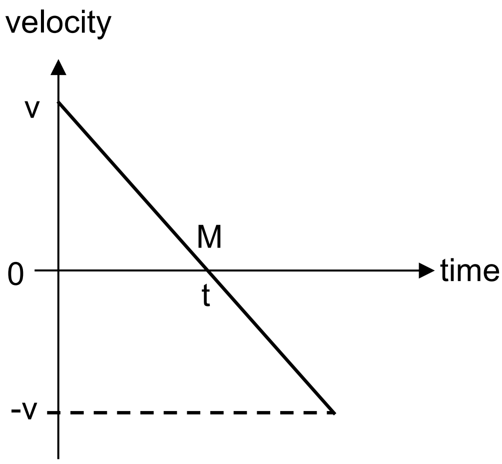


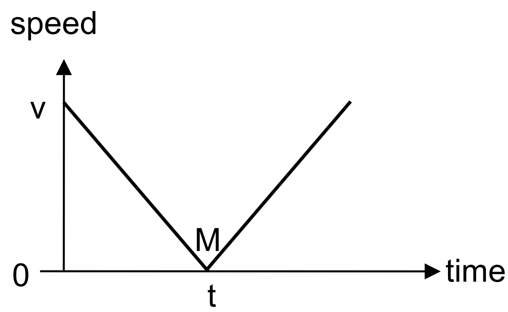
2 (a) sign convention: up is positive

(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.

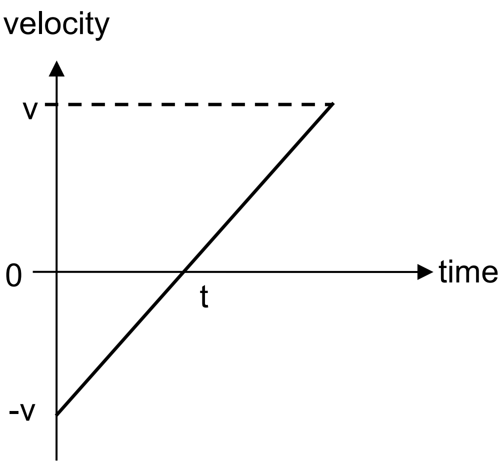
(c) acceleration = 10 m s^{-2}

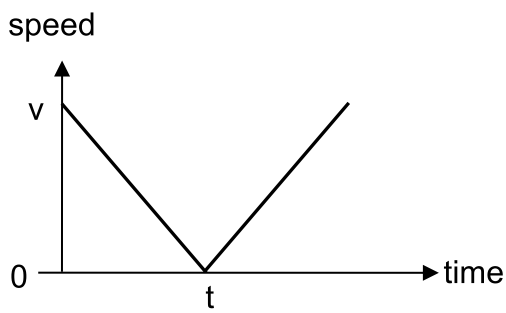
(d)



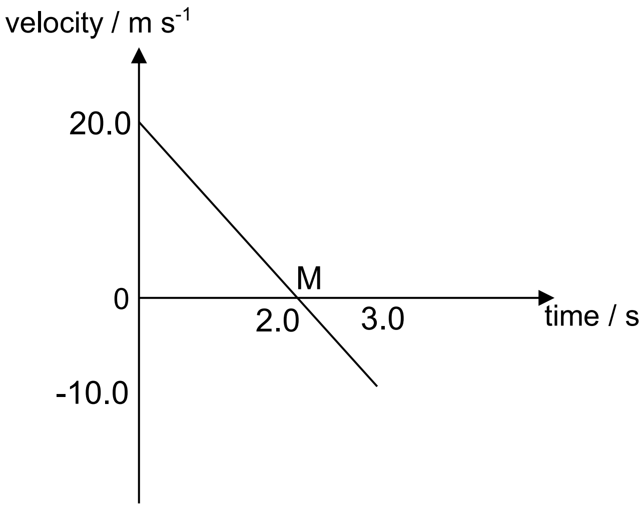


(e)





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.

Challenge Yourself!

4 (a) acceleration = (v – u) / t = 30/3.05 = 9.8 m s^{-2}

(b) height = area under graph = ½ x 3.05 x 30 = 46 m

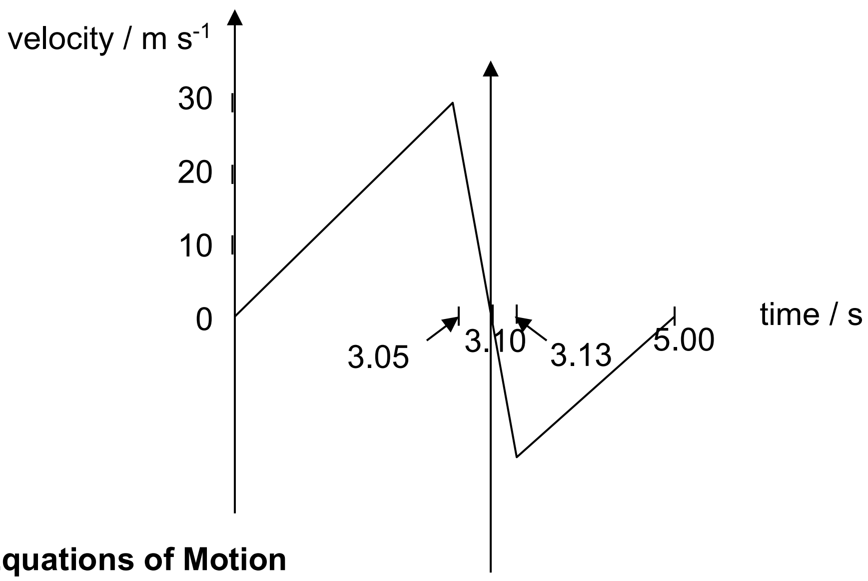
(c) **AB**: Speed increases from 0 to 30 m/s at a constant acceleration.

BC: Ball touches the ground at 3.05 s and becomes squashed to come to a complete stop at 3.10 s.

CD: Ball regains its normal shape from 3.10 s to 3.13 s and leaves the ground with a speed of 20 m/s.

DE: Ball rises above the ground and slows down to a stop at 5.00 s when it is at the maximum height.

(d) The velocity-time graph is shown below.



5.4 Four Equations of Motion

Examples 5.4.1

1 .

Displacement:

Initial velocity: 10 m/s

Final velocity: 30 m/s

Acceleration:

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

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

2.

s:

u: 0 m/s

v:

a: 10 m/s^2

$s = ut + \frac{1}{2} at^2$

$0 = (0 \times 4.0) + \frac{1}{2} (10) (4.0^2)$

$s = 80$ m

3

s:

u: 40 m/s

v: 0 m/s

a: -10 m/s^2

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

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

$s = 80$ m

Exercises

5.4 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

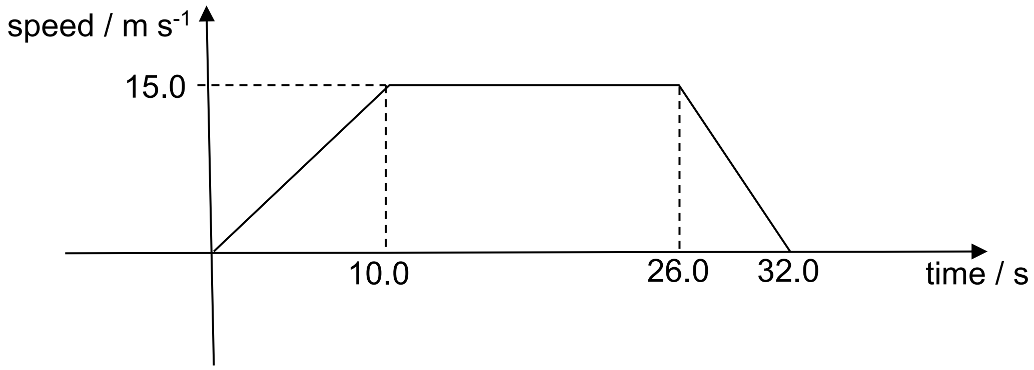
v = 53 m/s

(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.

$s = ut + \frac{1}{2}at^2$ $-20.0 = 30.0\,t + \frac{1}{2}(-10)t^2$

$t = 6.6\ s$