1 Motion and force

Answers

Answers to in-text questions

1 **a)** **i)** This depends on your own journey. You should have given a vector answer with the magnitude equal to the "as the crow files" distance and the direction of your school from your home.

ii) Take a piece of string and use it to trace out your route to school. Lay the length of the journey in string against the map scale. This is the distance travelled.

b) **i)** The same magnitude as **(a)(i)** but the opposite direction.

ii) The same as **(a)(ii)**.

2 **a)** The total distance travelled = 5 + 2 + 5 + 2 = 14 m; the speed = $\frac{14}{42}$ = 0.33 m s^{-1}

b) The total displacement is zero, so the average velocity is zero.

3 Vector: Any **two** quantities that have a direction associated with them; for example, gravitational field, momentum.
Scalar: Any **two** quantities with no associated direction; for example, mass, energy.

4 **A**: Travelling at a constant speed of 5.0 m s^{-1};
B: Travelling at a constant speed of −3.0 m s^{-1};
C: First 2 s, constant speed of 5.0 m s^{-1} ; last 3 s, constant speed $\frac{10}{3}$ = 3.3 m s^{-1}

5 **a)** 20 minutes is 1200 s, so 26.4 km travelled.

b) Total distance = 26.4 + 35.0 = 61.4 km in 35 minutes (or 2100 s).

Average speed = $\frac{61400}{2100}$ = 29 m s^{-1} (to 2 sf)

6 **a)** 15 m s^{-1}

b) **i)** 0.75 m s^{-2} **ii)** −1.5 m s^{-2}

c) $\frac{1}{2}$ × 15 × 20 + 15 × 20 = 450 m

d) Final 10 s is a distance of 75 m, so total distance is 525 m and average speed = 10.5 m s^{-1} ≈ 11 m s^{-1}

7 **a)** A is faster than B, both at a constant speed; A travels at 1.8 m s^{-1}, B travels at 1.3 m s^{-1};
A travels 350 m, B travels 250 m, so A goes 100 m further.

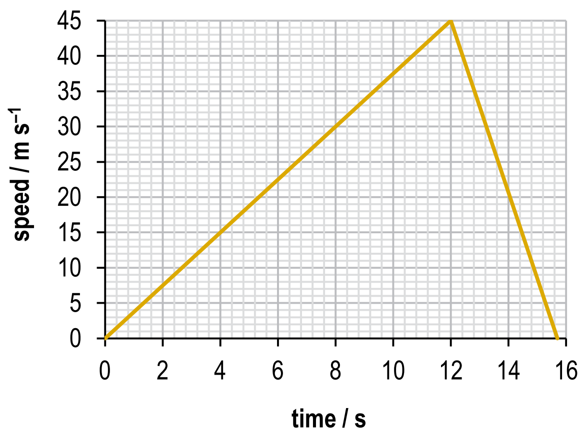
b) C has constant speed of 15 m s^{-1} and travels 300 m

c) D is increasing in speed, travels about half that of B.

8 **a)** **i)** $a = \frac{45 - 0}{12} = 3.8$ m s^{-2} **ii)** $s = 0 \times 12 + \frac{1}{2} \times 3.75 \times 12^2 = 270$ m

b) **i)** $0^2 = 45^2 + 2a \times 85$; $a = -\frac{45^2}{170} = -12$ m s^{-2} **ii)** $0 = 45 + (-12) \times t$; $t = \frac{-45}{-12} = 3.8$ s

8 **c)**



d) $\frac{1}{2} \times 45 \times 12 + \frac{1}{2} \times 45 \times 3.7 = 353 \approx 350$ m (2 sf)

9 **a)** **i)** 0.20 m s^{-2} **ii)** 90 m

b) **i)** −1.5 m s^{-2} **ii)** 6.0 s

10 **a)** 4.3 m s^{-2} from initial tangent at (0,0)

b) 23 squares ≡ 46 m (1 square = 2 m); 50 m to 1 sf

c) 20 m in last 2 s, so 30 m in first 4 s; $\frac{30}{4.0} = 7.5$ m s^{-1}

11 **a)** 2450 N **b)** 0 N **c)** 250 kg **d)** 330 N

12 **a)** Use $s = ut + \frac{1}{2}at^2$; $2.5 = 0 \times 5 + \frac{1}{2} \times a \times 5^2$; $a =$ 0.20 m s^{-2}

b) Weight force down plane = mg cos(60) = 22.1 N;
resultant force down plane = 4.5 × 0.20 = 0.90 N so friction must be 21.2 N

13 **a)** 72 N **b)** 51 N

14 **a)** 123 J **b)** 2.7 kJ

15 **a)** Take m to be 60 kg and h to be 1.0 m;
$E_k \approx mgh$ as all gpe energy is converted to kinetic energy; E_k = 590 J, so about 0.6 kJ.

b) Take speed limit to be 100 km per hour (about 30 m s^{-1}), mass of car about 1000 kg; $E_k \approx$ 0.5 MJ.

c) Take mass of bird to be 100 g and speed to be about 10 m s^{-1}; $E_k \approx$ 10 J

16 **a)** 270 J **b)** 130 J **c)** 270 J

17 **a)** 600 J **b)** 44 J **c)** 7.4%

18 **a)** 90 kg m s^{-1} to the left; 15 kg m s^{-1} to the right.

b) 75 kg m s^{-1} to the left.

c) Total mass is 15 kg; 5.0 m s^{-1} to the left.

19 **a)** $\dfrac{800 \times 8.0 + 1600 \times 0}{800 + 1600} = 2.7\ \text{m s}^{-1}$ **b)** Initial E_k = 25.6 kJ; final E_k = 8.5 kJ; so 17 kJ is lost.

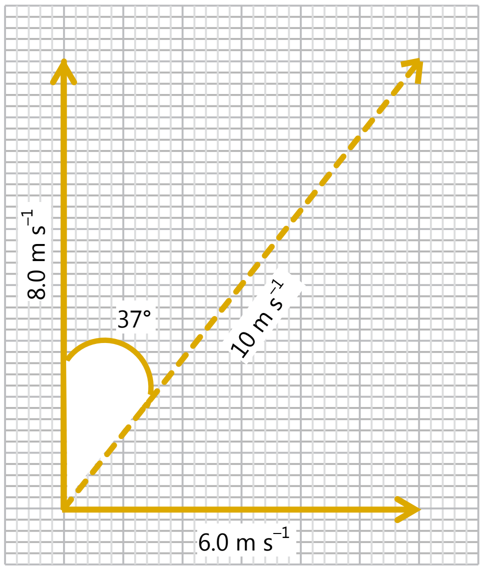
20 **a)** $\dfrac{5.0 \times 2.5 + 0.75 \times 0}{5.0 + 0.75} = 2.2\ \text{m s}^{-1}$

b) E_k immediately after blow = 14 J; this is all lost so frictional force = $\dfrac{\text{work done}}{\text{distance travelled}} = \dfrac{14}{0.075} \approx 190$ N

Answers to additional problems

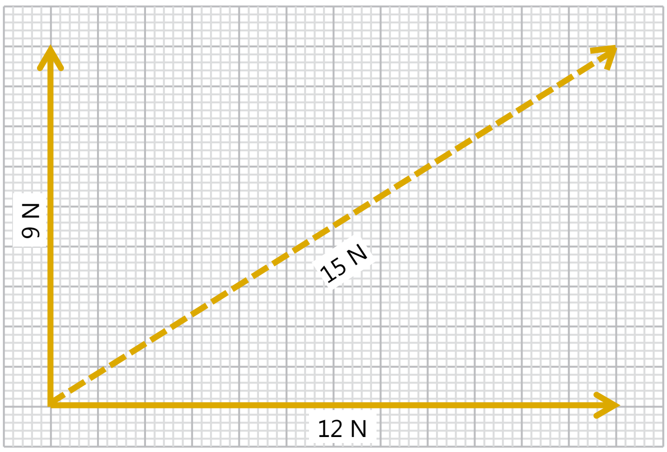
1 $\sqrt{8.0^2 + 6.0^2} = 10\ \text{m s}^{-1}$; $\tan^{-1}\left(\dfrac{30}{4.0}\right) = 37°$

10 m s^{-1} at N 37°E



2 24 m and 12 m

3 **a)**



b) **i)** Subtracting the vectors (forces acting in opposite directions)

ii) Adding the vectors (forces acting in the same direction)

4 **a)** Use $v = u + at$; $17 = 0 + 0.35t$; $t = 49$ s

b) Use $s = ut + \frac{1}{2}at^2$; $s = 0 \times 49 + 0.5 \times 0.35 \times 49^2 = 420$ m

c) $F = ma$; $F = 7000 \times 0.35 = 2.5$ kN

d) Resultant force decreases as speed increases so acceleration decreases as speed increases.

5 **a)** $3.5 \times 60 \times 60 = 12600$ s **b)** $\frac{42200}{12600} = 3.35$ m s^{-1}

6 **a)** **i)** Use $v = u + at$; $0 = 32 - 4.6t$; $t = 7.0$ s **ii)** That the acceleration is constant.

b) $F = ma$; $800 \times 4.6 = 3.7$ kN

7 Please refer to chapter 1 Motion and force where these distinctions are explained.

8 **a)** The gradient of the graph is the magnitude of g, so both gradients must be the same.

b) The first bounce occurs at A, so the velocity is now upwards (the opposite direction to the velocity from O to A) and is therefore negative.

c) Energy is lost at the first bounce.

d) **i)** $\frac{1}{2}mv^2 = mgh$; $v = \sqrt{2gh}$; $\sqrt{2 \times 9.81 \times 1.5} = 5.4$ m s^{-1} **ii)** $\sqrt{2 \times 9.81 \times 1.2} = 4.9$ m s^{-1}

9 **a)** Use $v^2 = u^2 + 2as$; $0^2 = 18^2 + 2 \times a \times 25$; $a = -6.5$ m s^{-2} **b)** $F = ma$; $950 \times 6.5 = 6.2$ kN

10 **a)** Use $v^2 = u^2 + 2as$; $0^2 = 28^2 + 2 \times a \times (5.5 + 5)$; $a = -65$ m s^{-2} **b)** $F = ma$; $65 \times 65 = 4.2$ kN

11 **a)** $F = ma$; $1100000 = 320000a$; $a = 3.4$ m s^{-2} **b)** $v = u + at$; $95 = 0 + 3.4t$; $t = 28$ s

c) $F = ma$; $F = 3.2 \times 10^5 \times (3.4 - 2.5) = 0.30$ MN **d)** $v^2 = u^2 + 2as$; $95^2 = 0^2 + 2 \times 2.5 \times s$; $s = -1.8$ km

e) By Newton's second law of motion: for constant velocity the drag force (friction) and the thrust from the engines must be equal in magnitude and opposite in direction; for constant height the upthrust from the wings must equal the weight of the aircraft in magnitude and be opposite in direction.

12 **a)** $55 \times 25 = 1.4$ kJ **b)** $60 \times 9.81 \times 2 = 1.2$ kJ **c)** 200 J

13 **a)** $1400 \times 9.81 \times 50 = 0.69$ MJ **b)** $\Delta E_k = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2} \times 1400 \times 28^2 - \frac{1}{2} \times 1400 \times 2.0^2 = 0.55$ MJ

c) Loss of energy = 0.69 – 0.55 = 0.14 MJ so average frictional force = $\frac{140000}{70} = 2.0$ kN

14 **a)** $P = F \times v$; $1.8 \times 10^4 = F \times 10$; $F = 1800$ N

b) **i)** Force of air resistance = 1800 – 250 = 1550 N

ii) 775 N

c) $P = F \times v$; $P = (775 + 250) \times 5.0 = 5.1 \times 10^3$ W

15 $P = \frac{W}{t}$; $35 = \frac{W}{90}$; W = 3.2 kJ; $E_{GPE} = mg\Delta h$; $3150 = 2.0 \times 9.81 \times \Delta h$; $\Delta h = 0.16$ km