

Answers

The questions, with the exception of those from past question papers, and all example answers that appear in this book were written by the authors. Cambridge Assessment International Education bears no responsibility for the example answers to questions taken from its past question papers which are contained in this publication.

Non-exact numerical answers should be given correct to three significant figures (or one decimal place for angles in degrees) unless a different level of accuracy is specified in the question. You should avoid rounding figures until reaching your final answer.

Chapter 1

? (Page 3)

v_y , the vertical component of velocity, is zero
 $\gamma = 0$

? (Page 5)

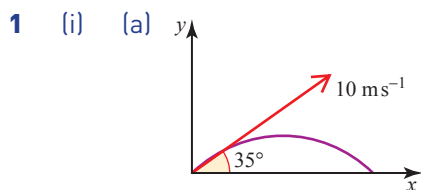
Yes for a parabolic path.

$$u_y - gt = 0 \text{ when } t = \frac{u_y}{g}$$

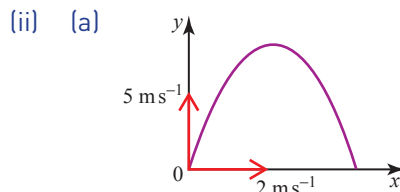
$$\text{and } u_y t - \frac{1}{2}gt^2 = 0 \text{ when } t = 2\frac{u_y}{g}.$$

The balls and the cannonball can be modelled as projectiles when there is no spin or wind and air resistance is negligible. Also a rocket with no power can be modelled as a projectile. The effects of air resistance are critical to the motion of the others, so they cannot be modelled as projectiles.

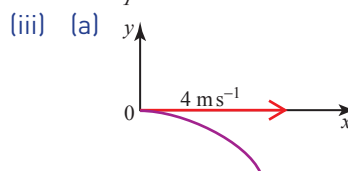
Exercise 1A (Page 5)



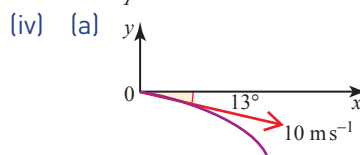
- (b) $u_x = 8.19 \text{ ms}^{-1}$
 $u_y = 5.74 \text{ ms}^{-1}$
 (c) $v_x = 8.19 \text{ ms}^{-1}$
 $v_y = 5.74 - 10t \text{ ms}^{-1}$
 (d) $x = 8.19t \text{ m}$
 $y = 5.74t - 5t^2 \text{ m}$



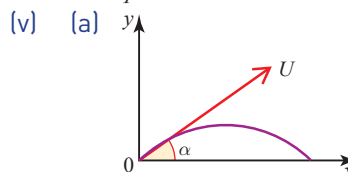
- (b) $u_x = 2 \text{ ms}^{-1}$
 $u_y = 5 \text{ ms}^{-1}$
 (c) $v_x = 2 \text{ ms}^{-1}$
 $v_y = 5 - 10t \text{ ms}^{-1}$
 (d) $x = 2t \text{ m}$
 $y = 5t - 5t^2 \text{ m}$



- (b) $u_x = 4 \text{ ms}^{-1}$
 $u_y = 0 \text{ ms}^{-1}$
 (c) $v_x = 4 \text{ ms}^{-1}$
 $v_y = -10t \text{ ms}^{-1}$
 (d) $x = 4t \text{ m}$
 $y = -5t^2 \text{ m}$

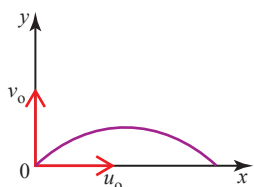


- (b) $u_x = 9.74 \text{ ms}^{-1}$
 $u_y = -2.25 \text{ ms}^{-1}$
 (c) $v_x = 9.74 \text{ ms}^{-1}$
 $v_y = -2.25 - 10t \text{ ms}^{-1}$
 (d) $x = 9.74t \text{ m}$
 $y = -2.25t - 5t^2 \text{ m}$



- (b) $u_x = U \cos \alpha \text{ m s}^{-1}$
 $u_y = U \sin \alpha \text{ m s}^{-1}$
 (c) $v_x = U \cos \alpha \text{ m s}^{-1}$
 $v_y = U \sin \alpha - gt \text{ m s}^{-1}$
 (d) $x = Ut \cos \alpha \text{ m}$
 $y = Ut \sin \alpha - \frac{1}{2}gt^2 \text{ m}$

(vi) (a)



- (b) $u_x = u_0 \text{ m s}^{-1}$
 $u_y = v_0 \text{ m s}^{-1}$
 (c) $v_x = u_0 \text{ m s}^{-1}$
 $v_y = v_0 - gt \text{ m s}^{-1}$
 (d) $x = u_0 t \text{ m}$
 $y = v_0 t - \frac{1}{2}gt^2 \text{ m}$

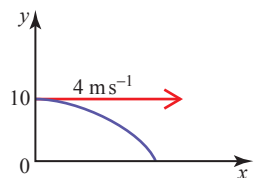
- 2 (i) (a) 1.5 s
 (b) 11.3 m
 (ii) (a) 0.5 s
 (b) 1.25 m

- 3 (i) (a) 4 s
 (b) 80 m
 (ii) (a) 0.866 s
 (b) 2.17 m

- 4 (i) $\frac{u_y^2}{2g}$
 (ii) $\frac{2u_y}{g}$
 (iii) $\frac{2u_x u_y}{g}$

Exercise 1B (Page 9)

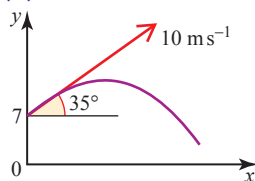
- 1 (i) (a)



- (b) $\begin{pmatrix} 4 \\ -10t \end{pmatrix} \text{ m s}^{-1}$

- (c) $\begin{pmatrix} 4t \\ 10 - 5t^2 \end{pmatrix} \text{ m}$

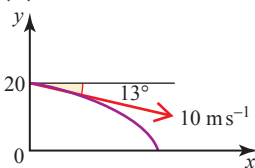
(ii) (a)



- (b) $\begin{pmatrix} 8.19 \\ 5.74 - 10t \end{pmatrix} \text{ m s}^{-1}$

- (c) $\begin{pmatrix} 8.19t \\ 7 + 5.74t - 5t^2 \end{pmatrix} \text{ m}$

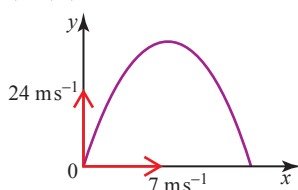
(iii) (a)



- (b) $\begin{pmatrix} 9.74 \\ -2.25 - 10t \end{pmatrix} \text{ m s}^{-1}$

- (c) $\begin{pmatrix} 9.74t \\ 20 - 2.25t - 5t^2 \end{pmatrix} \text{ m}$

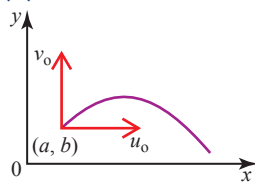
(iv) (a)



- (b) $\begin{pmatrix} 7 \\ 24 - 10t \end{pmatrix} \text{ m s}^{-1}$

- (c) $\begin{pmatrix} 7t \\ 24t - 5t^2 \end{pmatrix} \text{ m}$

(v) (a)

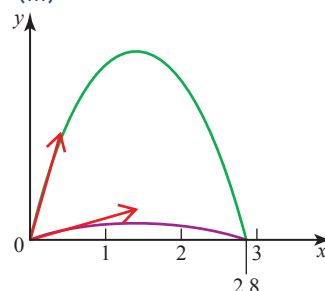


- (b) $\begin{pmatrix} u_0 \\ v_0 - gt \end{pmatrix} \text{ m s}^{-1}$

- (c) $\begin{pmatrix} a + u_0 t \\ b + v_0 t - \frac{1}{2}gt^2 \end{pmatrix} \text{ m}$

- 2 (i) (a) 1.47 s
 (b) 25.8 m
 (ii) (a) 0.3 s
 (b) 10.5 m

- 3 (i) 2.8 m
 (ii) 2.8 m
 (iii)



4 $T = \frac{u \sin \theta + \sqrt{u^2 \sin^2 \theta + 2gh}}{g} \text{ s};$

$$R = \frac{u^2 \sin \theta \cos \theta}{g} + \frac{u \cos \theta}{g} \sqrt{u^2 \sin^2 \theta + 2gh} \text{ m}$$

? (Page 14)

They land together because u , s and a in the vertical direction are the same for both.

Exercise 1C (Page 15)

- 1 (i) 17.3, 10 m s⁻¹
 (ii) 0, -10 m s⁻²
 (iii) 34.6 m
 (iv) 1 s
 (v) 5 m
 2 (i) 25.3 m
 (ii) 4.5 s
 (iii) 175 m

3 (i) 41.0, 28.7 ms⁻¹

(ii)

<i>t</i>	0	1	2	3	4	5	6
<i>x</i>	0	41	82	123	164	205	246
<i>y</i>	0	24	37	41	35	18	-7.9

(iii)



(iv) 41.1 m, 235 m

(v) The ball is a particle, no spin, no air resistance so acceleration = g

4 (i) 17.2, 8.03 ms⁻¹

(ii) 1.61 s

(iii) 27.7 m

(iv) 0.803 s

(v) 3.22 m

(vi) 2.58 m, No

5 (i) 10.3, 14.7 ms⁻¹

(ii) 2.91 s

(iii) Into the goal

(iv) No, the height of the ball is 6.39 m above the ground when it passes above the goalkeeper.

6 (i) 44.7 s

(ii) 13.4 km

(iii) 539 ms⁻¹

(iv) 56.1°

7 (i) 76.5 m

(ii) 65.4 m

(iii) 47.7 ms⁻¹, 61.8° to the horizontal.

8 $\cos \theta = \frac{24}{25}$, $\sin \theta = \frac{7}{25}$; $x_q = 24$ when $t = 0.5$, $y_q = 50 \times 0.5 \times \frac{7}{25} - 5 \times 0.5^2 = 5.75$, $y_p = 7 - 5 \times 0.5^2 = 5.75$

9 (i) 41.0 ms⁻¹

(ii) $x = 30.7$ m $y = 42.0$ m

10 (i) 2.02 s

(ii) No! Vertical displacement of the ball after 2.02 s would be -0.2 m, which means that the ball would have hit the ground before it reached the goalposts.

(iii) 21.8 ms⁻¹

11 (i) 0.467 s

(ii) 0.632 s

(iii) 25.7 ms⁻¹

(iv) 29.1 ms⁻¹

12 (i) Yes the range is 68.9 m

(ii) 33.0 ms⁻¹

13 20 ms⁻¹; 17.9 ms⁻¹

14 (i) (a) 34.6 m

(b) 39.4 m

(c) 40 m

(d) 39.4 m

(e) 34.6 m

(ii) $80 \sin \alpha \cos \alpha = 80 \cos(90^\circ - \alpha) \sin(90^\circ - \alpha)$

(iii) 57.9°

(iv) + 0.297 m; 0.311 cm. The lower angle is slightly more accurate.

15 (i) 26.3 ms⁻¹

(ii) 27.6 ms⁻¹

(iii) $26.4 \text{ ms}^{-1} < u < 27.2 \text{ ms}^{-1}$

16 25.2 m

? (Page 19)

$\begin{pmatrix} 20 \\ 30 \end{pmatrix} \text{ ms}^{-1}$, (0, 6), 10 ms⁻²

Exercise 1D (Page 19)

1 (i) $y = \frac{5}{16}x^2$

(ii) $y = 6 + 0.4x - 0.2x^2$

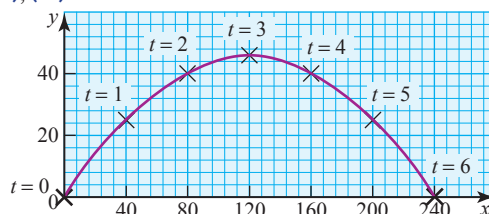
(iii) $y = -14 + 17x - 5x^2$

(iv) $5y = 29 + 12x - x^2$

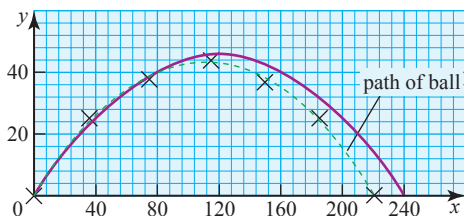
(v) $y = 2x - \frac{gx^2}{2u^2}$

2 (i) $x = 40t$

(iii), (iv)



3 (i) $y = \frac{3}{4}x - \frac{1}{320}x^2$
 (ii)



Air resistance would reduce x .

(iii) Yes, horizontal acceleration $= -0.5 \text{ m s}^{-2}$

4 (ii) 11.7 m s^{-1} ; 31.0°

? (Page 22)

The projectile is a particle and there is no air resistance or wind, so that the only force acting on the projectile is the gravitational force which acts in the y -direction. The particle is projected from the origin.

Exercise 1E (Page 23)

1 (i) $(21.2t, 21.2t - 5t^2)$
 (ii) $t = \frac{x}{21.21...} \Rightarrow y = x - \frac{1}{90}x^2$
 (iii) 8.89
 (iv) 30 or 60

2 (i) $y = 1.5 + x \tan 14^\circ - \frac{5}{100}(1 + \tan^2 14^\circ)x^2$
 (ii) 6.90 m

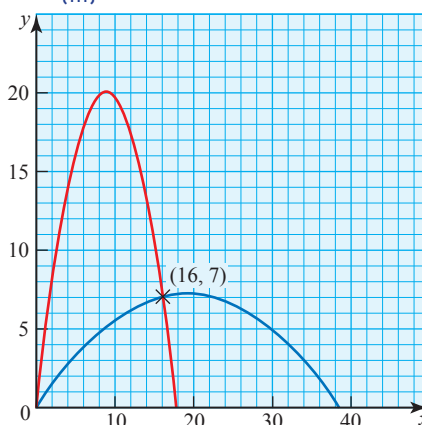
3 (i) $y = 2.5 + x \tan 5^\circ - \frac{5}{625}(1 + \tan^2 5^\circ)x^2$
 (ii) 23.7 m
 (iii) Yes, $y = 2.38 \text{ m}$ when $x = 12$

4 (i) $y = 1 + 0.700 - \frac{7.45}{u^2}x^2$
 (ii) $u > 7.81 \text{ m s}^{-1}$
 (iii) $u < 8.50 \text{ m s}^{-1}$

5 (i) 1 m, (25, 0)
 (ii) 10 m
 (iii) 0.6 s
 (iv) $u_x = 25 \text{ m s}^{-1}$, 1 s
 (v) 25.7 m s^{-1}

6 (ii) When $\tan \theta = \frac{3}{4}$, OA = 38.4 m
 When $\tan \theta = \frac{17}{4}$,
 OA = 17.8 m

(iii)



7 (i) $x = 12.5t\sqrt{2}$, $y = 12.5t\sqrt{2} - 5t^2$
 (ii) 57.5 m

8 (i) $x = 5t$; $y = 5t^2 \Rightarrow y = 0.2x^2$
 (ii) $x = 8.85 \text{ m}$, speed $= 18.4 \text{ m s}^{-1}$

9 56.3° , 18.6 m s^{-1}

10 (ii) 1.8, 0.6
 (iii) 22.5 m when $\tan \alpha = 1.2$
 (iv) 5.72 m

11 (ii) 39.2° , 72.6°

12 (i) $2 + 10t \sin \theta - 5t^2 = 0$
 $\Rightarrow t = \sin \theta + \sqrt{\sin^2 \theta + 0.4}$
 $\Rightarrow t = \sqrt{\frac{1-c}{2}} + \sqrt{\frac{9-5c}{10}}$
 (ii) $R = 5\sqrt{1-c^2} + \sqrt{5(9+4c-5c^2)}$
 (iii) $R = 11.83$ compared to $R = 11.7$
 for $\theta = 45^\circ$

Chapter 2

? (Page 28)

It is possible to produce a very large turning moment with a very small force if the perpendicular distance from the force to the pivot is large. This is explained on pages 28 and 29.

? (Page 31)

The tool shown in Figure 2.8(ii) can produce a large turning moment but you have to turn your hands through a large circle (greater distance).

The tool shown in Figure 2.8(i) produces a smaller turning moment, but once the wheel nut is loose it is quicker to use this to unwind the nut.

? (Page 38)

You produce equal and opposite couples using friction between one hand and the lid and between the other hand and the jar so that they turn in opposite directions.

Pressing increases the normal reactions and hence the maximum friction possible.

Exercise 2A (Page 38)

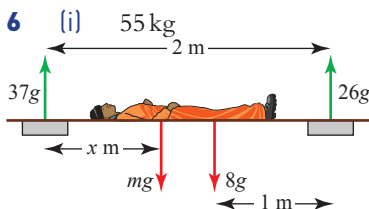
- 1 (i) 15 Nm
(ii) -22 Nm
(iii) 18 Nm
(iv) -28 Nm

- 2 (i) 2.1 Nm
(ii) 6.16 Nm
(iii) 0.1 Nm
(iv) 0.73 Nm

- 3 29.2 N, 20.8 N

- 4 (i) 1250 N, 1250 N
(ii) 1479 N, 1821 N

- 5 96.5 N, 138.5 N

- 6 (i) 
(ii) 0.8 m

- 7 (i) $P = 275 \text{ N}$, $Q = 1475 \text{ N}$
(ii) $P = 25 \text{ N}$, $Q = 1725 \text{ N}$

- (iii) If child sits 0.95 m from the adult, $P = 0$ and the bench is on the point of tipping about B unless A is anchored to the ground.
(iv) The bench tips about B if A is not anchored.

- 8 (i) 300 N at A , 150 N at B
(ii) 50 N at A , 900 N at B
(iii) zero
(iv) $\frac{2}{3} \text{ m}$

- 9 (i) $(1.5 \times 10^5 - 5 \times 10^3 x) \text{ N}$;
 $(10^5 + 5 \times 10^3 x) \text{ N}$
(ii) its centre of mass
(iii) The reaction force at each support is a constant 15000 N.

- 10 6 grams; $9\frac{1}{3} \text{ cm}$

- 11 $20\frac{5}{7} \text{ kg}$

- 12 (i) 7510 N, 350 N
(ii) no, when couple step onto left hand end of bridge, anticlockwise moments = 862.5 Nm and clockwise moments = 750 Nm, so bridge would tip
(iii) 36 kg

- 13 2 N upwards, 9 m to the left of A .

- 14 (i) $R_C = 7692 \text{ N}$,
 $R_D = 2308 \text{ N}$
(ii) 5
(iii) 800 N

- 15 (i) 3600 N
(ii) 0.00169 m s^{-2}
(iii) 101 N

? (Page 47)

No, the system is symmetrical providing the rod is uniform.

Exercise 2B (Page 49)

- 1 (i) 6 Nm
(ii) -10.7 Nm
(iii) 23.0 Nm
(iv) 0
(v) -4.24 Nm
(vi) 4.24 Nm

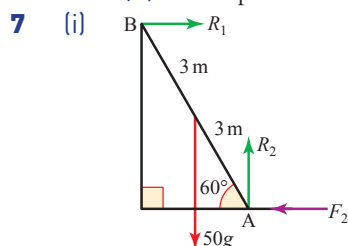
- 2 David and Hannah
(by radius $\times 0.0275 \text{ Nm}$)

- 3 (i) 5920 kg
(ii) 4532 sec θ kg

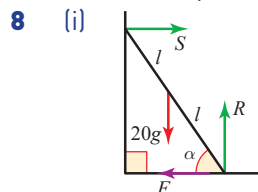
- 4 (i) 43.3 N
(ii) 28.1 N
(iii) 30.7 N

- 5 (i) $T \cos 30^\circ$, $T \sin 30^\circ$
(iii) -30 Nm
(v) 8.04 N, 15.4 N
(vi) (a) 33.7°
(b) 3.23 m

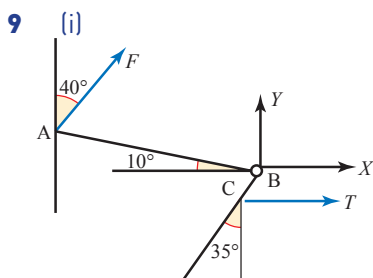
- 6 (i) 1434 N
(ii) 651 N, 1644 N
(iv) (a) jib stays put, $T = 0$
(b) A drops

- 7 (i) 

- (ii) 0
(iii) 144 N
(iv) 144 N, $\mu \geq 0.289$

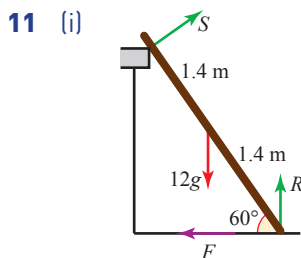
- 8 (i) 

- (a) (ii) 57.7 N, 57.7 N, 200 N
(iii) 0.289
(b) (ii) 100 N, 100 N, 200 N
(iii) 0.5



- (ii) 162 N
(iii) 61.7 N

- 10 (ii) $1.60 \times 10^6 \text{ Nm}$ (to 3 s.f.)
(iii) 6830 N, 3830 N



- (ii) 26.0 N, 105 N
(iii) 0.51
(iv) 2.25 m

- 12 (i) 60°
(ii) 14.4 N at 76.1° to the horizontal.

- 13 (i) $MX=0.2\text{m}$, $XC=0.8\text{m}$
(ii) $\arctan(0.05)=2.86^\circ$
(iii) 1456.5 N, 1664.6 N

- 14 $\tan \theta = \frac{1}{2} \tan \phi$

- 15 (ii) 0.328

So total anticlockwise moments equal total clockwise moments and hence the rod balances.

Exercise 3A (Page 60)

- 1 (i) 0.2 m right of O
(ii) 0
(iii) 0.72 m left of O
(iv) 1.19 m right of O
(v) 0.275 m right of O
(vi) 0.36 m right of O
(vii) 0.923 m left of O
(viii) 0.471 m right of O
- 2 2.18 m from 20 kg child
- 3 4.17 cm (towards the 60 kg mass)
- 4 4680 km (to 3 s.f.)
- 5 0.917 m
- 6 3.33 mm from centre
- 7 2.95 cm
- 8 1.99 kg
- 9 42 kg
- 10 $\frac{m_2 l}{(m_1 + m_2)}$ from m_1 end
- 11 (i) 3.35 m from centre line, tips over
(ii) 4.55 tonnes
(iii) $L(l-d) < Md + C(a+d)$,
 $C(a-d) < Md$
(iv) $\frac{2Mad}{(l-d)(a-d)}$

Exercise 3B (Page 70)

- 1 (i) (2.3, -0.3)
(ii) (0, 1.75)
(iii) $(\frac{1}{24}, \frac{1}{6})$
(iv) (-2.7, -1.5)
- 2 (5, $6\frac{1}{3}$)
- 3 (i) (20, 60)
(ii) (30, 65)
(iii) (30, 60)

- 4 23.1 cm
- 5 (i) (1.5, -1.5)
(ii) (1.5, -2.05)
- 6 (i) (3, 2)
(ii) $(1\frac{1}{6}, 1\frac{1}{6})$
(iii) (1.6, 1.6)

- 7 (i) 0.2 cm below O
(ii) 9.1°

- 8 24.4°

- 9 (i) $(a, 2\frac{5}{6}a)$
(ii) 2.36°
(iii) 2m

- 10 8.78 cm from the base on the axis of symmetry

- 11 (ii) (a) 4.8 N
(b) 1.29 N

- 12 (ii) 3.04° ; arc

- 14 $(-1, \frac{4}{\pi})$

- 15 (i) (a) $\left(\frac{4m+M}{8m+4M}\right)h$
(b) $\frac{h}{2} \left(\frac{M\alpha^2 + m}{M\alpha + m}\right)$

? (Page 75)

It is likely to topple. Toppling depends on relative mass of upstairs and downstairs passengers.

? (Page 76)

1st box will slide, 2nd box will topple.
2nd box is more comparable to the bus.

? (Page 76)

R cannot act outside the surfaces in contact so there is a resultant moment about the edge E.

Chapter 3

? (Page 56)

Yes, centre of mass vertically below P.

? (Page 59)

Taking moments about a point

1 $\frac{2}{15}$ from A:

$$4 \times 1\frac{2}{15} + 5 \times \frac{2}{15} = 6 \times \frac{13}{15}$$

$$\frac{26}{5} = \frac{26}{5}$$

? (Page 79)

Yes, when $\mu = 0.5$ and $\alpha = 26.6^\circ$

Exercise 3C (Page 79)

- 1 (i) 2.8gN
(ii) 3.5gN
(iii) slide
- 2 (i) $P = 2\mu g = 20\mu\text{N}$
(ii) $0.6\text{gN} = 6\text{N}$
(iii) $\mu < 0.3$
(iv) $\mu > 0.3$
- 3 (i) 14.0°
(ii) 18.4°
(iii) sliding
- 4 It slides.
- 5 (a) (i) 22.5 N
(ii) 22.0 N
(iii) topples
(b) (i) 22.8 N
(ii) 25.9 N
(iii) slides.
(iv) 63.4° , 22.4 N
- 6 (i) (a) $50\text{ cm} \times 20\text{ cm}$
(b) $20\text{ cm} \times 10\text{ cm}$
(ii) The shortest side is perpendicular to the plane of the slope for maximum likelihood of sliding.
(iii) (a) $\mu < 0.2$
(b) $\mu > 5$
- 7 (ii) $F = \mu(120 - P\cos\theta)$ and $F = P\sin\theta$
(iii) vertically upwards on edge AB
(v) $\mu < \tan\theta$
- 8 (ii) 37.5 N
(iii) $\mu \geq 0.625$
- 9 (i) (28, 60)
(ii) (52, 60)
(iii) (64, 60)
(iv) 40 cm

- 10 (i) (a) (10, 2.5)
(b) (12.5, 5)
(c) (15, 7.5)
(d) (17.5, 10)
(e) (20, 12.5)
(ii) 5
(iii) $(9 + n, 2.5n)$, 11
(iv) 102.5 cm
- 11 (i) 49.4°
(ii) 1.2 m
(iii) 0.944 m
- 12 (i) stays put
(ii) topples over

Chapter 4**? (Page 86)**

Accept any suitable objects that move in circular paths.

Forces that pull them towards the centre of the circle.

The gravitational pull of the earth on the moon causes the moon to circle the earth.

It moves off at a tangent.

Not if they are travelling fast enough.

Exercise 4A (Page 89)

- 1 (i) 8.2 rad s^{-1}
(ii) 4.7 rad s^{-1}
(iii) 3.5 rad s^{-1}
- 2 2865 rpm
- 3 (i) (a) 0.0333 rpm
(b) $0.00349\text{ rad s}^{-1}$
(ii) 0.267 m s^{-1}
- 4 32.5 rad s^{-1}
- 5 (i) 50 rad s^{-1}
(ii) 150 rad s^{-1}
- 6 (i) 3820 rpm
(ii) 2080 rpm

- 7 (i) $1.99 \times 10^{-7}\text{ rad s}^{-1}$
(ii) $7.27 \times 10^{-5}\text{ rad s}^{-1}$
(iii) 465 m s^{-1}
(iv) 1530 km h^{-1}
- 8 2.29:1
- 9 (i) 61.7 J
(ii) points on a large object would travel with different speeds
- 10 (i) minute hand: $2.09 \times 10^{-3}\text{ m s}^{-1}$, hour hand: $1.16 \times 10^{-4}\text{ m s}^{-1}$
(ii) 18:1 the radius is also involved
- 11 (i) 4.91 m
(ii) 12.3 m s^{-1}
- 12 (i) $\mathbf{v} = 2\cos t\mathbf{i} - 2\sin t\mathbf{j} - \frac{1}{2}\mathbf{k}$
(ii) 2.06 m s^{-1}
(iii) 2 m s^{-2} horizontally towards the vertical axis, making an angle of $\frac{\pi}{4}$ with both the $\mathbf{i}$ and $\mathbf{j}$ axes.

Activity 4.1 (Page 98)

When you turn fast enough, the coin flies off the card. When the card is tilted it stays put at higher angular speeds.

? (Page 100)

See Example 4.5 and the text that follows.

? (Page 102)

To prevent the car from sliding down the slope.

Resolving perpendicular to the slope: $R - mg\cos\alpha = m\frac{v^2}{r}\sin\alpha$ and parallel to the slope: $mg\sin\alpha - F = m\frac{v^2}{r}\cos\alpha$

If there is no slipping then $F < \mu R$ and substituting for F and R gives

$$mg\sin\alpha - m\frac{v^2}{r}\cos\alpha < \mu \left(mg\cos\alpha + m\frac{v^2}{r}\sin\alpha \right)$$

which eventually reduces to

$$\sqrt{gr \left(\frac{\sin \alpha - \mu \cos \alpha}{\cos \alpha + \mu \sin \alpha} \right)} < v$$

To prevent the car from sliding up the slope, the equation of motion along the slope is

$$mg \sin \alpha + F = m \frac{v^2}{r} \cos \alpha$$

Then substituting for R and F in $F < \mu R$ reduces to

$$v < \sqrt{gr \left(\frac{\sin \alpha + \mu \cos \alpha}{\cos \alpha - \mu \sin \alpha} \right)}$$

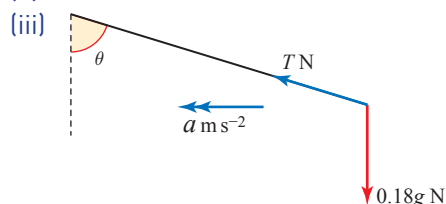
Exercise 4B (Page 103)

- 1 (i) Neither, both have $\omega = 0.75 \text{ rad s}^{-1}$.
(ii) No because they have the same angular speed.
(iii) 13.5 m s^{-2} , 11.25 m s^{-2}
(iv) towards the centre for circular motion
- 2 (i) (a) neither coin slips
(b) B slips, A doesn't
(c) both coins slip
(ii) (a) neither coins slips
(b) A slips, B doesn't
(c) both coins slip
Any coin slips when $m\omega^2 r > \mu mg$, so slipping does not depend on the mass of the coin.
- 3 (i) The car accelerates because direction of motion changes
(ii) 11.25 m s^{-2}
(iii) 2250 N
- 4 (i) True for fixed seats
(ii) False, as $v = r\omega$ so speed depends on r .
(iii) False, as $a = r\omega^2$ so acceleration depends on r .
- 5 (i) (a) 0.5 rad s^{-1}
(b) 1 m s^{-2}
(c) 60 N towards centre
(ii) skater is particle
- 6 B exerts a greater force on clothes in the drum because it generates a greater acceleration
- 7 (i) (a) $\frac{(2.00 \times 10^7)}{\sqrt{r}}$
(b) $\pi r^{\frac{3}{2}} \times 10^{-7} \text{ s}$
(ii) $T^2 = \pi^2 \times 10^{-14} r^3$
(iii) $4.23 \times 10^7 \text{ m}$

- 8 (i) 263 N
(ii) The weight of the sphere is very small compared with the tension in the string.
(iii) 23.1 m s^{-1}
- 9 (i) $5.72 \times 10^{-3} \text{ m s}^{-2}$
(ii) $1.78 \times 10^{30} \text{ kg}$ (length of year = 365 days)
(iii) any planet in this orbit would have the same period whatever its mass

- 10 (i) An upwards vertical force is required to balance weight. If the string were horizontal, there would be no component of tension acting upwards.

(ii) 12.6 rad s^{-1}



(iv) $T \sin \theta = m r \omega^2 = 0.18 \times 0.8 \sin \theta \times (4\pi)^2$;
 $T \cos \theta = m g = 1.8$

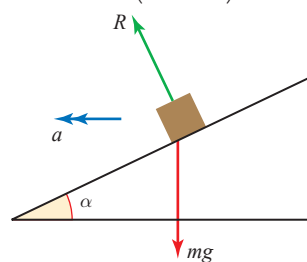
(vi) 22.7 N

- 11 (i) 72 km h^{-1} (20 m s^{-1})
(ii) 6.6 km h^{-1} (1.84 m s^{-1}) faster

- 12 (i) 6400 N
(a) The car is about to skid on a bend.
(b) The car is accelerating or braking and is about to skid.

(ii) 112 km h^{-1} (31 m s^{-1})

(iii)



(iv) $R \sin \alpha = \frac{mv^2}{r}$, $R \cos \alpha = mg$

(vi) 10.6° or 0.185 rad

- 13 (i) 1.86 m s^{-1}
(ii) 5.37 rad s^{-1}

- 14 (i) $T_{PQ} = 4 \text{ N}$, $T_{BQ} = 3 \text{ N}$
(ii) 13.4 N , 26.6°

- 15 (i) $M = 0.6m$
(ii) 5.77 rad s^{-1}

- 16 (ii) 2.83 m s^{-1}
(iii) 1.33 s

- 17 (ii) $6T_1 + 8T_2 = 30$; $T_1 = 0.714 \text{ N}$, $T_2 = 3.21 \text{ N}$

? (Page 113)

No, see next section 'The breakdown of circular motion'.

Activity 4.2 (Page 114)

If the string breaks the object will fly off at a tangent to the circle. If a rod were used rather than a string, the motion would be the same for A and B. For C, when a string is used, the object leaves the circle and falls in a parabola. On a rod, it swings back as a pendulum.

? (Page 117)

For a string, the particle remains in circular motion if $T = m\omega^2 r - mg \cos \alpha > 0$.

A particle travelling on the outside of a circle remains in circular motion if $R = mg \cos \beta - m\omega^2 r > 0$ so for circular motion to continue, ω is bounded above and below by these two equations.

? (Page 118)

(i) and (iv)

Exercise 4C (Page 120)

- 1 (i) (A) 4 m s^{-2}
(B) 40 m s^{-2}
(ii) (a) A yes, B No
(b) A no, B yes
(c) A no, B yes
(d) A yes, B yes
- 2 (A) (i) $22m \text{ J}$
(ii) complete revolutions;
 4.90 m s^{-1}
(iii) (a) $74m \text{ N}$
towards O

- (b) $14m \text{ N}$
towards O
- (B) (i) $18m \text{ J}$
(ii) stops; 1.8 m
(iii) (a) $18m \text{ N}$
towards O
(b) $9m \text{ N}$ away
from O
- (C) (i) $4.83m \text{ J}$
(ii) stops, 0.48 m
(iii) (a) $6.66m \text{ N}$
away from O
(b) $9.66m \text{ N}$
away from O

- 3 (ii) $2mg$

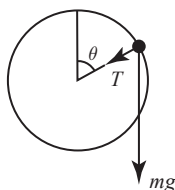
- 4 (ii) $R = \frac{mv^2}{a} + mg \cos \theta$
 $v^2 = u^2 - 2ga(1 - \cos \theta)$
 $= ga(1 + 2 \cos \theta)$
 $\Rightarrow R = mg(1 + 3 \cos \theta)$

- 5 (i) $0.186mg \text{ J}$
(iv) 0.598 m
(v) No, it leaves the track

- 6 (ii) $3mg$

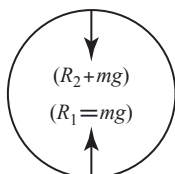
- 7 (i) 8 J , 6.40 m s^{-1}
(ii) $\sqrt{9 + 1.6g(1 - \cos \theta)}$
(iii) (a) 0.625 N
(b) 30.625 N

(iv)



$$T = 15.63 - 15 \cos \theta, \\ g \sin \theta$$

- 8 (i) 83.1 m s^{-1} , 53.9 m s^{-1}
(ii) 69 m s^{-2} , 29 m s^{-2}
(iii)



$$R_1 = 5530 \text{ N}, \\ R_2 = 1330 \text{ N}$$

- (iv) He would fail to complete the loop
(v) 138 m

- 9 (i) Almost zero speed at the top of the loop not sufficient
(ii) 20 m
(iii) It stops below the centre and returns to C; 8 m
- 10 (i) 12.2 m s^{-1} , 44 kph
(ii) Traffic used to travel more slowly.
(iii) Increase the radius by making the approaches less steep.

- 11 (i) cons. of energy
 $\Rightarrow \frac{1}{2} \times 300 \times 20^2$
 $= 300g \times 15 + \frac{1}{2} \times 300v^2$
 $v = 10 \text{ m s}^{-1}$
(ii) 13.3 m s^{-2} ; $R = 1000 \text{ N}$, force from the track is downwards, so could operate
(iii) 23.3 m s^{-2} ; 8.66 m s^{-2} ; 24.9 m s^{-2} , 39.6°

- 12 (i) $v^2 = gl(2 \cos \theta - 1)$
(iii) $2mg$ when $\theta = 0$

Chapter 5

? (Page 127)

Use energy considerations. See Activity 5.1 at the end of the chapter.

Exercise 5A (Page 132)

- 1 (i) 50 N , 250 N
(ii) 100 N , $33\frac{1}{3} \text{ N}$
(iii) 1 N , 5 N
- 2 (i) 20 N
(ii) 20 N
(iii) Tension required to double the length is the same. There is a 20 N force at the fixed end in part (i).

- 3** (i) 0.03 N
(ii) 0.0375 m
(iii) 0.08 N
- 4** (i) 5 N
(ii) 75 N
(iii) 0.625 kg
- 5** (i) 30 N
(ii) 3 kg
(iii) Spring has already become fully compressed with fewer than seven blocks are stacked, so adding a seventh will make no difference to the spring.

6 $-40 \text{ N} < \text{force} < 80 \text{ N}$

7 $\frac{\lambda a}{\lambda - ma\omega^2}$

Exercise 5B (Page 136)

- 1** (i) [a] 60 N
[b] 0.04 m
(ii) 2400 N; double that of the original strings (could be two strings together)
- 2** (i) 12000 N
(ii) 12000 N
(iii) 0.05 m
(iv) 0.02 m
- 3** (i) 7000 N
(ii) 4000 N
- 4** (i) [a] 198 N
[b] 654 N
(ii) 118%
(iii) 51.6 m
- 5** (i) $(0.3 - x) \text{ m}$
(ii) $16x \text{ N}$, $25(0.3 - x) \text{ N}$
(iii) 0.183
- 6** (i) $2.2 - h \text{ m}$, $h - 1.2 \text{ m}$
(ii) $44 - 20h \text{ N}$, $30h - 36 \text{ N}$
(iii) 1.2
(iv) 20 N, 0 N
- 7** (i) $\frac{l_0}{\lambda} mg \sin \alpha$
(ii) [a] $\frac{l_0}{\lambda} mg (\mu \cos \alpha + \sin \alpha)$
[b] $\frac{l_0}{\lambda} mg (\sin \alpha - \mu \cos \alpha)$
- 8** 1.3 m
- 9** (ii) 0.313 m

- (iii) No; an elastic band is unlikely to pass smoothly over a peg.

- 10** (i) 1.3 N
(ii) 15.6 N
- 11** (i) 0.35 m, 0.35 m
(ii) 17.5 N

Exercise 5C (Page 144)

- 1** (i) 0.1 J
(ii) 0.001 J
(iii) 0.4 J
(iv) 0 J
- 2** (i) 4 J
(ii) 0.25 J
(iii) 1 J
(iv) 0.0625 J
- 3** (i) 0.75 J
(ii) 5.48 m s^{-1}
- 4** (i) 0.006 67 J
(ii) 0.577 m s^{-1}
- 5** (i) $5 \times 10^4 \text{ J}$
(ii) 7.07 m s^{-1}
(iii) 1.29 m
(iv) $7.07 \times 10^4 \text{ N}$, 35.4 m s^{-2}
(v) Truck moves back along the rail at 5 m s^{-1} if other forces ignored.
- 6** 0.433 m, 0.0674 m
- 8** (i) 26 N, 7 N
(ii) 20 m s^{-2}
(iii) 0.933 m
- 9** (i) $AP = 1.3 \text{ m}$
(ii) 9.17 m s^{-1}
- 10** (i) 12 N, 24 N
(iii) 7.5 m s^{-2}
(iv) 0.5 m

Exercise 5D (Page 149)

- 1** (i) $5h^2 \text{ J}$
(ii) $0.2gh \text{ J}$
(iii) 0.4
- 2** $2l_0$
- 3** $l_0 \left(1 + \frac{mg}{\lambda} \right)$

4 (ii) 0.13 m

5 0.466 m

6 (i) 1 J

(iii) 0.2 m

7 (i) 0.11 m

(ii) 0.15 m

8 $4gml_0 = \frac{1}{2} \times \frac{\lambda}{l_0} \times (3l_0)^2 \Rightarrow \lambda = \frac{8}{9}mg$

$\Rightarrow T_{\max} = \frac{8mg}{9l_0} \times 3l_0 = \frac{8mg}{3}$

9 (i) Equating energies: $\frac{1}{2}mu^2 = mgl_0$ gives the required result

(ii) $ma = mg - \frac{\lambda}{l_0}x$

(iii) $v \frac{dv}{dx} = g - \frac{\lambda x}{ml_0}$

(iv) $v = \sqrt{2gl_0 + 2gx - \frac{\lambda}{ml_0}x^2}$

(v) $x = 0$. The string is about to become slack with the particle going upwards.

(vi) $m \frac{dv}{dt} = g; v = g(t - T) - \sqrt{2gl_0}$
for $T < t < T + 2\sqrt{\frac{2l_0}{g}}$

10 (i) $\arccos\left(\frac{g}{\omega^2 l}\right)$

(ii) $\arccos\left(\frac{g(\lambda - m\omega^2 l_0)}{\omega^2 l_0 \lambda}\right)$

11 (ii) 0.2

(iii) -3.27 m s^{-2}

12 (i) 3.61 m s^{-1}

(ii) The particle moves 0.9 m upwards from lowest point (0.3 m while string is taut and 0.6 m while it is slack), so with constant acceleration $-g$.

13 (i) 1.22 m

(ii) 6 m s^{-1}

(iii) 60 m s^{-2}

14 (ii) 0.05 m

(ii) 0.508

15 (i) $2\left(\frac{\lambda}{3.6}\right) \times 0.3 \times \frac{0.75}{1.95} = 0.5 \times 10$

$\Rightarrow \lambda = 78 \text{ N}$

(ii) 14.2 m s^{-1}

Activity 5.1 (Page 153)

(i) 90.8 kg

(ii) 41.4 m

(iii) 3.2 m

(iv) 21.3 m s^{-2}

Chapter 6

2 (Page 155)

The forces are air resistance near to the surface of the Earth and the Moon, and the gravitational forces due to the Earth and the Moon.

It will reach a point that is $\frac{47}{52}$ of the distance from the Earth to the Moon.

2 (Page 160)

Because the acceleration is not constant, and that formula can only be used for motion with constant acceleration.

Exercise 6A (Page 162)

1 In these answers, k is an arbitrary constant.

(i) $s = \frac{1}{2}v + k$

(ii) $v = ke^{2t}$

(iii) $v = -\frac{2}{3}\cos 3t + k$

(iv) $v = \frac{1}{t+k}$

(v) $v = ke^{-s}$

(vi) $v = \pm \sqrt{4s(1-s) + k}$

(vii) $s = -\frac{1}{3}\ln k(3v+2)$

(viii) $s = \frac{1}{2}\ln(1+v^2) + k$

2 (i) $\frac{16}{3}$

(ii) $\pm \frac{1}{2}$

(iii) $\pm \sqrt{2\ln 2}$ or ± 1.177

(iv) $7\frac{1}{2}$

(v) $\frac{\pi}{4}$ or 0.785

(vi) $\frac{1}{3}\ln \frac{5}{2}$ or 0.305

- (vii) $\frac{1}{2}\ln 3$ or 0.549
 (viii) $\frac{1}{2}\ln \frac{4}{3}$ or 0.144
- 3** (i) $v \frac{dv}{ds} = \frac{1}{v+2}$
 (iii) $\frac{dv}{dt} = \frac{1}{v+2}$
 (v) $s = -2t + \frac{1}{3}(4+2t)^{\frac{3}{2}} - \frac{8}{3}$
- 4** (ii) 2.85 m
 (iii) 7.14 ms^{-1}
- 5** (ii) 1.35 s
- 6** (i) $t = 2.75 \text{ s}$
 (ii) $OP = 4.51 \text{ m}$
- 7** (ii) 2.32
- 8** (i) Greatest speed when $x = 3\frac{1}{3}$,
 $\sqrt{\frac{50}{3}} = 4.082\dots$
 (ii) 6.67 m
- 9** (ii) 1.26 s
- 10** (i) $60 \frac{dv}{dt} = 150 - 12v \Rightarrow 5 \frac{dv}{dt} = 12.5 - v$
 (ii) $\ln(12.5 - v) = -0.2t \Rightarrow v = 12.5 - e^{-0.2t}$
 (iii) $x = 12.5t + 5e^{-0.2t} - 5$
- 11** (i) $\frac{dv}{dx} = -\frac{1}{3}\left(\frac{v+30}{v}\right) \Rightarrow a = -\frac{1}{3}(v+30)$
 (ii) $0.1v \text{ N}$
 (iii) $3\ln \frac{5}{3} = 1.53 \text{ s}$
- 12** (i) $0.25v \frac{dv}{dx} = -(5-x)$
 (ii) $x = 5(1 - e^{-2t}) < 5$ for all t
- 13** (ii) $v = 2000(1 - e^{-0.005t})$
 (iii) 124 m
- 14** (ii) $\frac{2U^{\frac{3}{2}}}{3k}$
- 15** (i) 1.00 s
 (ii) 7.98 m
 (iii) $v = 8(1 - e^{-1.25t})$
 (iv) $x = 8t - 6.4(1 - e^{-1.25t})$. It takes it 1.70 s to reach ground level, from solving $8t - 6.4(1 - e^{-1.25t}) = 7.98$ numerically.

Chapter 7

? (Page 167)

See the text that follows in section 7.1 'Impulse'.

? (Page 168)

Using $v = u + at$ with

$$t = 0.1 \Rightarrow 20 = -10 + 0.1a$$

$$\Rightarrow a = 300 \Rightarrow F = 0.06 \times 300 = 18 \text{ N}$$

$$t = 0.015 \Rightarrow a = 30 \div 0.015 = 2000$$

$$\Rightarrow F = 0.06 \times 2000 = 120 \text{ N}.$$

Average means it stays the same over the time period.

? (Page 170)

Cricket ball: momentum is 6 Ns; kinetic energy is 120 J

Train: momentum is 200 Ns; kinetic energy is 1 J

Probably better to be hit by an object with higher speed and lower momentum.

Exercise 7A (Page 171)

- 1** (i) 500 Ns
 (ii) 20 000 Ns
 (iii) $2.8 \times 10^8 \text{ Ns}$
 (iv) $2 \times 10^{-22} \text{ Ns}$
- 2** (i) 18 200 Ns
 (ii) 0.002 25 Ns
 (iii) 3 Ns
 (iv) 10 Ns
- 3** (i) 15 N
 (ii) 20 m
 (iii) 20 ms^{-1}
 (iv) 300 J; work done by force = K.E. gain
 (v) 30 Ns; impulse = mom. gain
- 4** (i) [a] $0.2v - 0.2 \times 5$
 $= 20 \times 0.1 \Rightarrow v = 15 \text{ ms}^{-1}$
 [b] $v = 5 + \left(\frac{20}{0.2}\right) \times 0.1 \text{ ms}^{-1}$
 $= 15$
 (ii) They give the same answer

- 5 (i) 1.2 N s upwards
(ii) 2 s
(iii) 0
(iv) 1.2 N s

- 6 (i) 2.125 N s
(ii) (a) 21.25 N
(b) 42.5 N
(iii) smaller impulse exerted on your hands as cushioning increases the time taken for the ball to stop

- 7 (i) (a) 11 880 N s
(b) 99 000 N
(c) 11 gms^{-2}
(ii) Crumple zones increase the collision time and therefore reduce the force exerted on the people in the car.

- 8 (i) 5.48 ms^{-1}
(ii) 110 N s
(iii) 110 N s
(iv) 548 N

- 9 (i) +30 000 N s
(ii) -15 000 N s
(iii) -45 000 N s
(iv) the impulse
(v) 450 000 N

- 10 (i) 12 800 N s
(ii) 5.12 ms^{-1}

Exercise 7B (Page 174)

- 1 (i) 10 ms^{-1}
(ii) Van: -28 000 N s; Car 28 000 N s
- 2 (i) 2.22 ms^{-1}
(ii) 0.8 ms^{-1}
- 3 1476 ms^{-1}
- 4 2.5 ms^{-1}
- 5 3.72 ms^{-1}

Exercise 7C (Page 179)

- 1 (i) $\frac{2}{3}$
(ii) 1.44 ms^{-1}
(iii) $\frac{3}{4}$
(iv) 3.2 ms^{-1}

- 2 (i) 0.3
(ii) 0
(iii) 0.95
(iv) 1

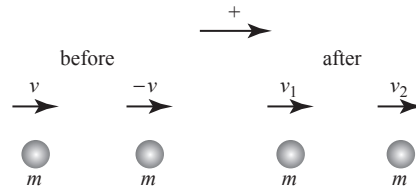
- 3 (i) 0.8
(ii) 1.62 N s
(iii) 2.43 J

- 4 (i) 4.47 ms^{-1}
(ii) 4.02 ms^{-1}
(iii) 0.900
(iv) 0.152 J
(v) 0.152 J
(vi) 0.656 m

- 5 (a) (ii) 2.5 ms^{-1} , 3.5 ms^{-1}
(iii) 3.75 J
(b) (ii) -0.5 ms^{-1} ; 2.5 ms^{-1}
(iii) 33.75 J
(c) (ii) 1.2 ms^{-1} ; 1.2 ms^{-1}
(iii) 4.8 J
(d) (ii) -1 ms^{-1} ; 2 ms^{-1}
(iii) 0 J
(e) (ii) -0.5 ms^{-1} ; 1 ms^{-1}
(iii) 2.25 J
(f) (ii) 2 ms^{-1} ; 4 ms^{-1}
(iii) 96 J

- 6 (i) 1 ms^{-1}
(ii) 0.2
(iii) 450 N s
(iv) 900 J

- 7 (i) 20 ms^{-1}
(ii) 0.75
(iii) 1750 N s
(iv) 4375 J
(v) a low one; more kinetic energy absorbed and impact force is less

- 8 (i)
- 
- (ii) $-ev, ev$

- (iv) Kinetic energy cannot be gained during a collision, which would be the case if $e > 1$.

9 $\frac{13}{32} \text{ ms}^{-1}, \frac{15}{32} \text{ ms}^{-1}, \frac{9}{8} \text{ ms}^{-1}$

10 $-\frac{47}{16} \text{ ms}^{-1}, \frac{7}{16} \text{ ms}^{-1}$

11 (i) $\sqrt{\frac{2h}{g}}, \sqrt{2hg}$

(ii) $e^2 h$

(iii) he^{2n}

(iv) $\sqrt{\left(\frac{2h}{g}\right)}(1+2e), \left(\sqrt{\frac{2h}{g}}\right)(1+2e+\dots+2e^{n-1})$

(vi) $h\left(\frac{1+e^2}{1-e^2}\right)$

12 $v_A = \frac{1}{2}(1-e)u; v_B = \frac{1}{4}(1-e^2)u;$

$v_C = \frac{1}{4}(1+e)^2 u$

2 (Page 183)

When $e = 0$, the ball does not rebound and moves only along the plane. All the kinetic energy from the motion perpendicular to the plane is lost. When $e = 1$, the collision is perfectly elastic and there is no loss in kinetic energy.

Exercise 7D (Page 184)

1 (i) $\begin{pmatrix} 3.76 \\ 0.684 \end{pmatrix} \text{ ms}^{-1}$

(ii) $\begin{pmatrix} 7.66 \\ 0.643 \end{pmatrix} \text{ ms}^{-1}$

(iii) $\begin{pmatrix} u \cos \alpha \\ 0.8u \sin \alpha \end{pmatrix} \text{ ms}^{-1}$

2 (i) 1.58 N s in **j** direction;

(ii) 1.58 N s in **-j** direction;

(iii) 3.10 J

3 (i) 0.453 N s in **j** direction

(ii) 0.453 N s in **-j** direction

(iii) 0.512 J

4 (i) $mu \sin \alpha$ N s

(ii) $\frac{1}{2}mu^2 - \frac{1}{2}mu^2 \cos^2 \alpha = \frac{1}{2}mu^2 \sin^2 \alpha$

6 (i) time of flight = $\frac{2u_y}{g}$; range = $\frac{2u_x u_y}{g}$

(ii) $0.6 R$

(iii) $0.6^n \times R$

(iv) $2.38R$

7 (i) 3.54 ms^{-1}

(ii) 3.22 ms^{-1} at 18.3° to the plane

(iii) 0.526 J

8 (i) $\begin{pmatrix} 2.5 \\ -4 \end{pmatrix} \text{ ms}^{-1}$

(ii) 1 m

(iii) 1.4 m

(iv) 2×0.7^n

(v) 7

9 (i) at 24.8° to cushion after first impact; at 60° to cushion after second impact

(ii) 1.6 ms^{-1}

(iii) at β to first cushion with $\tan \beta = e \tan \alpha$, at $90^\circ - \alpha$ to second cushion, which is same as α to the first cushion and hence direction is reversed; speed is reduced by e .

10 (i) $\tan \theta = \frac{eu \cos \theta}{u \sin \theta} \Rightarrow \tan^2 \theta = e = \frac{7}{25}$

(ii) $(1-e^2) \cos^2 \theta = \left[1 - \left(\frac{7}{25}\right)^2\right] \left[\frac{1}{1 + \frac{7}{25}}\right] = \frac{18}{25}$

Exercise 7E (Page 190)

1 $1.58 \text{ ms}^{-1}, 3.16 \text{ ms}^{-1}; 116.6^\circ, 63.4^\circ$

2 $0.872u, 0.4u, 83.4^\circ, 0^\circ$

3 $\frac{1}{4}u, \frac{5}{4}u, 0^\circ, 53.1^\circ$

4 $0.901u, 0.901u, 106.1^\circ, 73.9^\circ$

5 0.2

6 80.5°

7 Loss in K.E. for direct impact = $mu^2(1-e^2)$

Loss in K.E. in oblique impact = $\frac{3}{4}mu^2(1-e^2)$

8 (i) $\frac{1}{2}u; u$

(ii) A: $1.80u$ at 73.9° ; B: $u\sqrt{2}$ at 45°

(iii) $\frac{1}{4}mu^2$

9 (iii) The contact between the two discs is smooth.