Answers

Chapter 1 The force due to gravity

1.1 Newton's law of universal gravitation

WE 1.1.1 7.1×10^{-9} N **WE 1.1.2** 2.0×10^{20} N
WE 1.1.3 The acceleration of the Earth is 3.3×10^{5} times greater than the acceleration of the Sun.
WE 1.1.4 The equations give the same result to two significant figures.
WE 1.1.5 **a** 589 N **b** 774 N **c** 1.1×10^{3} N

1.1 Review

1 The force of attraction between any two bodies in the universe is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.
2 *r* is the distance between the centres of the two objects.
3 1.8×10^{21} N **4** 2.8×10^{-3} m s^{-2}
5 **a** 3.0×10^{16} N **b** 3.4×10^{22} N
c 0.000088% of the Sun–Earth force
6 The Moon has a smaller mass than the Earth.
7 3.5 m s^{-2} **8** 240 N
9 On Earth, weight is the gravitational force acting on an object near the Earth's surface whereas apparent weight is the contact force between the object and the Earth's surface. In an elevator accelerating upwards, the apparent weight of an object would be greater than its weight.
10 **a** 550 N **b** 490 N
11 299 N **12** D **13** D **14** A **15** B

1.2 Gravitational fields

WE 1.2.1 **a** See Reader+ **b** From strongest to weakest: B, C, A
WE 1.2.2 9.6 N kg^{-1} **WE 1.2.3** 9.75 N kg^{-1} **WE 1.2.4** 3.7 N kg^{-1}

1.2 Review

1 N kg^{-1} **2** 9.3 N kg^{-1} **3** It is one-ninth of the original.
4 **a** 5.67 N kg^{-1} **b** 1.48 N kg^{-1} **c** 0.56 N kg^{-1}
d 0.22 N kg^{-1}
5 0.0008 N kg^{-1} or 8×10^{-4} N kg^{-1}
6 Mercury: 3.7 N kg^{-1}
Saturn: 10.4 N kg^{-1}
Jupiter: 24.8 N kg^{-1}
7 2×10^{12} N kg^{-1}
8 The gravitational field strength at the poles is 1.4 times that at the equator.
9 3.4×10^{8} m **10** 10 Earth radii

1.3 Work in a gravitational field

WE 1.3.1 3.1×10^{3} MJ **WE 1.3.2** 5.2 m s^{-1} **WE 1.3.3** 5.2×10^{8} J
WE 1.3.4 5.4×10^{9} J

1.3 Review

1 C **2** *g* increases. **3** It will accelerate at an increasing rate.
4 A, B, C **5** 2.0×10^{12} J **6** 292 m s^{-1}
7 **a** *F* is between 9 N and 9.2 N. **b** 2.6×10^{6} m or 2600 km
8 **a** 8×10^{6} J **b** 1.9×10^{7} J **c** 2.7×10^{7} J
d 7348 m s^{-1} or 7.3 km s^{-1}
9 1.7×10^{9} J **10** 2.6×10^{11} J

Chapter 1 review

1 730 N **2** 3.78×10^{8} m **3** 2.1×10^{-7} m s^{-2}
4 **a** The forces are equal.
b The acceleration of Jupiter caused by the Sun is greater than the acceleration of the Sun caused by Jupiter.
5 3.7 m s^{-2} **6** **a** 460 N **b** 490 N
7 **a** 2.48×10^{4} N **b** 2.48×10^{4} N **c** 24.8 m s^{-2}
d 1.31×10^{-23} m s^{-2}
8 D **9** **a** D **b** B **c** C **d** A **e** D
10 The direction of the arrowhead indicates the *direction* of the gravitational force and the space between the arrows indicates the *magnitude* of the field. The field lines always point towards the source of the field.
11 9.76 N kg^{-1} **12** **a** 9.79 N kg^{-1} **b** 100.61%
13 **a** 11.1 N kg^{-1} **b** C **14** 16
15 **a** 3×10^{7} J **b** 4×10^{7} J **c** 2000 m s^{-1} or 2 km s^{-1}
d 3.5 N kg^{-1}
16 9 N kg^{-1} **17** D **18** C **19** 3.5×10^{9} J
20 No. Air resistance will play a major part as the satellite re-enters the Earth's atmosphere.

Chapter 2 Motion in a gravitational field

2.1 Inclined planes

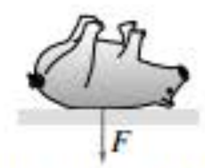
WE 2.1.1 **a** 285 N **b** 783 N **c** 3.4 m s^{-2}

2.1 Review

1 **a**

Force exerted on racquet by ball

b

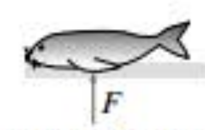


Force exerted on ground by pig

c

Force exerted on ground by wardrobe

d



Gravitational force of attraction that seal exerts on Earth

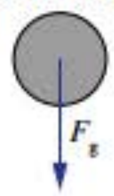
2 **a** A **b** C **c** 490 N up the hill. **d** 4.90 m s^{-2}
e Acceleration is not affected by mass if there is no friction.
3 A, B, D **4** A
5 **a** 849 N **b** 490 N **c** 4.90 m s^{-2}
6 **a** Ball 1: 0.888 N Ball 2: 1.78 N
b Ball 1: 4.14 m s^{-2} Ball 2: 4.14 m s^{-2}
c Ball 1: 0.335 N Ball 2: 0.670 N
d Ball 1: 9.21 m s^{-2} Ball 2: 9.21 m s^{-2}
e For (a) the normal force of ball 2 is double that of ball 1. This is because the normal force is directly proportional to mass. For (b) the two balls have the same acceleration, indicative of the fact that acceleration down an inclined plane depends on the angle of the plane, not the mass. Comparing (a) to (c) it can be seen that by increasing the angle of the inclined plane, the normal force acting on the two objects decreases as a function of the angle. You can think of this as the steeper the inclined plane, the closer the object is to free-fall and therefore apparent weightlessness ($F_N = 0$). Finally, comparing (b) to (d) it can be seen that increasing the angle of the inclined plane increases the acceleration of the objects; however, the acceleration of the two objects remains equal.

2.2 Projectiles launched horizontally

WE 2.2.1 **a** 2.47 s **b** 49.4 m
c 31.4 m s^{-1} at 50.4° below the horizontal
WE 2.2.2 9.74 m s^{-1}

2.2 Review

1 A, D **2** **a** 1.5 m **b** 7.35 m s^{-1} **c** 7.6 m s^{-1}
3 **a** 9.80 m s^{-2} down **b** 6.29 m s^{-1}
4 **a** 1.0 s **b** 20 m **c** 9.80 m s^{-2} down **d** 21.5 m s^{-1}
e 22.3 m s^{-1}
5 **a** 22.7 m s^{-1} **b** 45.6 m s^{-1} **6** B, C
7 The hockey ball travels further. A polystyrene ball is much lighter and is therefore more strongly affected by air resistance than the hockey ball.
8 **a** 0.64 s **b** 0.64 s **c** 3.2 m **9** **a** 54 m s^{-1}
b $\theta = 22°$
10 **a** 10 m s^{-1} forwards **b** 4.4 m s^{-1} down
c 10.9 m s^{-1} at 24° below the horizontal
d 0.45 s **e** 4.5 m **f**



2.3 Projectiles launched obliquely

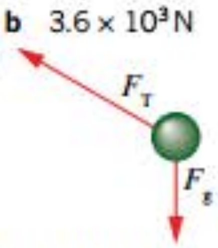
WE 2.3.1 **a** 6.11 m s^{-1} horizontally to the right **b** 0.25 m **c** 0.45 s
WE 2.3.2 **a** 2.25 m s^{-1} to the right **b** 0.366 m
c 3.50 m s^{-1} at 50.0° below the horizontal

2.3 Review

1 B **2** 45° **3** **a** 8.83 m s^{-1} **b** 0.989 m
4 **a** 13.6 m s^{-1} **b** 6.34 m s^{-1} **c** 9.80 m s^{-2} down **d** 13.6 m s^{-1}
5 **a** 4.0 m s^{-1} **b** 6.9 m s^{-1} **c** 0.70 s **d** 3.9 m **e** 4.0 m s^{-1}
6 **a** 24.2 m s^{-1} **b** 24.2 m s^{-1} **c** 24.2 m s^{-1}
7 **a** 14.0 m s^{-1} **b** 4.20 m s^{-1} **c** 5.60 m s^{-1} down
8 24.8 m s^{-1} **9** 69.2 m **10** C **11** 16.2 m s^{-1}

2.4 Circular motion in a horizontal plane

WE 2.4.1 7.5 km h^{-1}
WE 2.4.2 **a** 521 m s^{-2} **b** 3.6×10^3 N
WE 2.4.3 **a** 1.53 m **b**



c 2.34 N towards the left **d** 3.05 N

2.4 Review

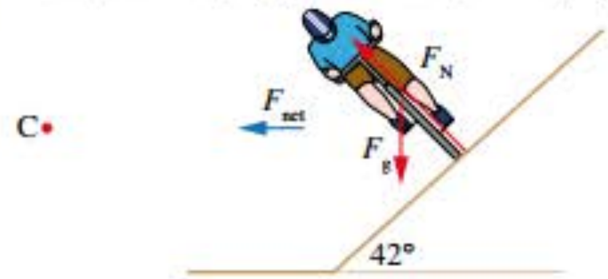
1 B **2** 0.2 s **3** A, D
4 **a** 8.0 m s^{-1} **b** 8.0 m s^{-1} south **c** 7.0 m s^{-2} west
5 8.4×10^3 N west **6** **a** 8.0 m s^{-1} north **b** east
7 The force needed to give the car a larger centripetal acceleration will eventually exceed the maximum frictional force that could act between the tyres and the road surface. At this time, the car would skid out of its circular path.
8 **a** 2.67 m s^{-2}
b The skater has an acceleration, so forces are unbalanced.
c 135 N
9 **a** 28 s **b** 5.0 N **10** **a** 0.5 s **b** 10 m s^{-1}
c 125 m s^{-2} **d** 310 N
11 **a** 1.2 m
b The forces are her weight acting vertically and the tension in the rope acting along the rope towards the top of the maypole.
c Acceleration is directed towards point B, the centre of her circular path.
d 170 N towards B **e** 2.6 m s^{-1}

2.5 Circular motion on banked tracks

WE 2.5.1 **a** 590 N towards the centre of the circle **b** 17 m s^{-1}

2.5 Review

1 towards the centre of the circle
2 The architect could make the banking angle larger or increase the radius of the track.
3 It will travel higher up the banked track because the greater speed means that a greater radius is required in the circular path.
4 friction, normal, weight, balanced, normal, weight
5



6 48 km h^{-1}
7 **a** 640 N
b On a horizontal track, F_N is equal and opposite to the weight force, so $F_N = mg = 539$ N. This is less than the normal force on the banked track (643 N).
8 47° **9** **a** 4.9 kN **b** 22°
10 A greater radius will make the car travel higher up the banked track. The driver would have to turn the front wheels slightly towards the bottom of the bank.

2.6 Circular motion in a vertical plane

WE 2.6.1 **a** 4.85 m s^{-1} **b** 15.6 N up **c** 3.70 m s^{-1}
d 6.73 N down

2.6 Review

1 **a** It is constant in magnitude.
b at the bottom of its path
c at the top of its path
d at the bottom of its circular path
2 3.8 m s^{-1}
3 **a** weight force from gravity and the normal force from the road
b 1280 N (or 1.3×10^3 N)
c Yes. When the car is moving over a hump, the normal force on the driver is less than her weight *mg*. Her apparent weight is given by the normal force that is acting and so the driver feels lighter at this point.
d 36 km h^{-1}
4 **a** 31.4 m s^{-1} **b** 19.9 m s^{-1} **c** 8300 N down
5 12.1 m s^{-1} **6** 196 N down **7** 31.3 m s^{-1}
8 188 m s^{-1} **9** **a** 18 m s^{-2} up **b** 1530 N up
10 **a** 9.80 m s^{-2} down **b** 2.2 m s^{-1}
11 **a** 3.6×10^3 N down **b** 1.3×10^3 N up **c** 7.0 m s^{-1}

2.7 Satellite motion

WE 2.7.1 3.08×10^3 m s^{-1}
WE 2.7.2 **a** 6.70×10^5 km **b** 1.90×10^{27} kg **c** 8.20 km s^{-1}

2.7 Review

1 C **2** D
3 **a** 0.22 m s^{-2} **b** 506 N (or 510 N to 2 significant figures)
4 15.6 days

Chapter 2 review

1 B **2** **a** 4.9 m s^{-2} **b** $0.87F_g$
3 **a** 4.9 m s^{-2} **b** 4.9 m s^{-1}
4 **a** 236 N
b 8.88 m s^{-2} down the ramp **c** 506 N down the ramp
d 9.4 m s^{-1} **e** 506 N up the ramp

5 **a** 508 N **b** 137 N

c The reaction to the force of the slide on the teenager due to friction is the force of the teenager on the slide.

d The reaction of the weight force on the teenager is the force of gravitational attraction from the teenager on the Earth.

6 **a** 2.5 m **b** 9.80 m s^{-2} downwards

7 **a** 10 m s^{-1} **b** 4.4 m s^{-1} **c** 11 m s^{-1} (speed only so no direction required)

8 **a** 10.3 m s^{-1} **b** 12.3 m s^{-1} **c** 8.9 m

9 Tait is correct.

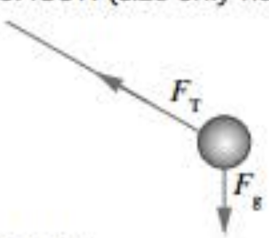
10 **a** 1.8 J **b** 1.96 J **c** 8.7 m s^{-1}

11 392 J **12** **a** 33.0 J **b** 33.0 J **c** 21.4 m

13 **a** 3.70 m s^{-1} **b** 17.1 m s^{-2} towards the centre of the circle

c 0.430 N (size only needed)

14 **a**



b 0.49 N

15 **a** 2.5 m s^{-2} towards the centre of the circle

b The centripetal force is created by the friction between the tyres and the ground.

16 **a** 1.02×10^3 m s^{-1} **b** 1.99×10^{20} N

17 3.40×10^{-2} m s^{-2}

18 **a** 10 m s^{-1} south **b** 10 m s^{-1}

c 13 s **d** 5.0 m s^{-2} west **e** 7.5×10^3 N west

19 A **20** **a** 15.7 m s^{-1}

b A frictional force will be acting up the plane.

c 740 N

d No. Once Joe's speed is greater than the design speed, there will be friction contributing to his centripetal acceleration. He would need to speed up and overcome this friction before he slid off the track.

21 **a** **i** 365 N up **ii** 615 N up **b** D

22 The forces are the force of gravity (weight) and the normal force from the base of the bucket on the water. Both act downwards. The acceleration of the water is towards the centre of the circle, i.e. downwards, and is greater than the acceleration due to gravity.

23 D **24** D **25** A

26 11.2*T*

27 **a** 0.0540 m s^{-2} **b** 4.38×10^3 m s^{-1} **c** 5.89 days

28 **a** 0.315 N kg^{-1} **b** 344 m s^{-1}

Chapter 3 Equilibrium of forces

3.1 Torque

WE 3.1.1 39.5 N m anticlockwise

WE 3.1.2 Yes. The minimum perpendicular distance required is 62.1 cm.

WE 3.1.3 17.1 N m clockwise **WE 3.1.4** 17.1 N m clockwise

3.1 Review

1 A **2** B

3 5.00 N m in the direction in which the spanner is being turned.

4 0.289 m **5** D **6** 1.5×10^4 N m **7** 1.34 m

8 38.6 N m **9** 0.595 N m **10** 56.5 N m

11 0.750 m **12** 9.38 N m clockwise

3.2 Equilibrium of forces

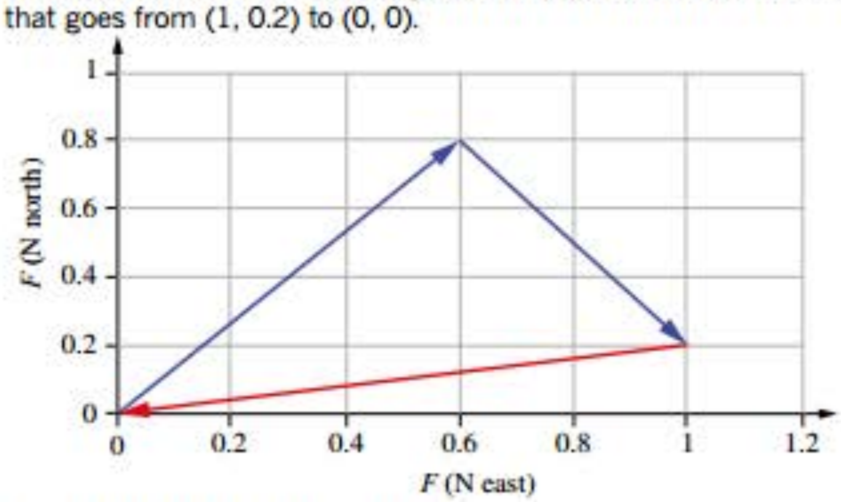
WE 3.2.1 2.9×10^4 N up **WE 3.2.2** 8490 N

3.2 Review

1 D **2** D **3** 3.48 N upwards **4** 0.765 kg

5 29.4 N **6** 911 N

7 The force that causes the trolley to be in equilibrium is the force that goes from (1, 0.2) to (0, 0).



8 Cable A: 1130 N or 1.13×10^3 N

Cable B: 565 N

9 5.25 kg **10** 2120 N

3.3 Static equilibrium

WE 3.3.1 **a** 1.96 N up **b** 0.300 m or 30.0 cm

WE 3.3.2 Around reference point Y (the position of the boy), the clockwise torque due to the girl's position on the plank is equal to the anticlockwise torque due to the pivot's action on the plank. So the plank is in rotational equilibrium.

WE 3.3.3 555 N

WE 3.3.4 36.8 N downwards on the beam

WE 3.3.5 52.0 N

3.3 Review

1 C **2** 0.750 m **3** B **4** 0.889 m

5 340 N **6** 2990 N **7** 9.8×10^3 N

8 downwards **9** 980 N

Chapter 3 review

1 D **2** B **3** C, D **4** 3.60 N m

5 86.5 N m

6 Stability refers to the ability of an object to restore its original static equilibrium after being slightly displaced by an outside force.

An object is in unstable equilibrium if the smallest displacement is sufficient to produce a force or torque that continue to make it move away from equilibrium.

An object is in stable equilibrium if the object returns to its original position once the outside force is removed.

An object is in neutral equilibrium if small outside forces don't create any unbalanced forces or torques to move the object further. The object remains in its new equilibrium position.

7 The 75.0 cm spanner; the longer the lever arm the less force is needed.

8 33.8 N m

9 **a** the spindle of the tap; about 3 cm

b front wheel axle of the wheelbarrow; 1 m (handle plus barrow through to the axle)

c the end of the tweezers, usually a few centimetres

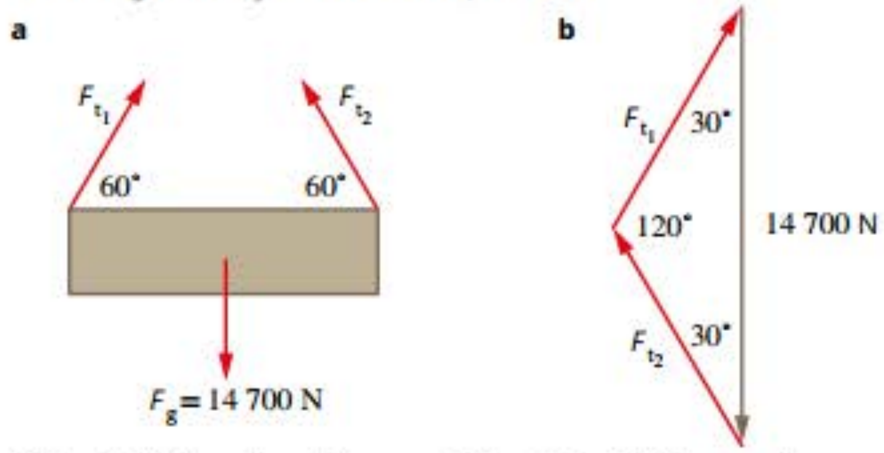
d the point of contact between screwdriver and the rim of the tin, 15–30 cm being the length of the screwdriver

10 4.9×10^5 N m

11 The crane must have a counterweight providing a torque in the opposite direction.

12 A, B, D

13 Diagram (a) shows the forces acting on the beam. Diagram (b) shows these forces added as a vector diagram (head to tail) illustrating that they are in static equilibrium.



14 8.49×10^3 N in each cable 15 2.9×10^4 N upwards
16 109 N upwards 17 848 N 18 $F_L = 141$ N, $F_R = 123$ N
19 15.5 cm from the model of the Sun

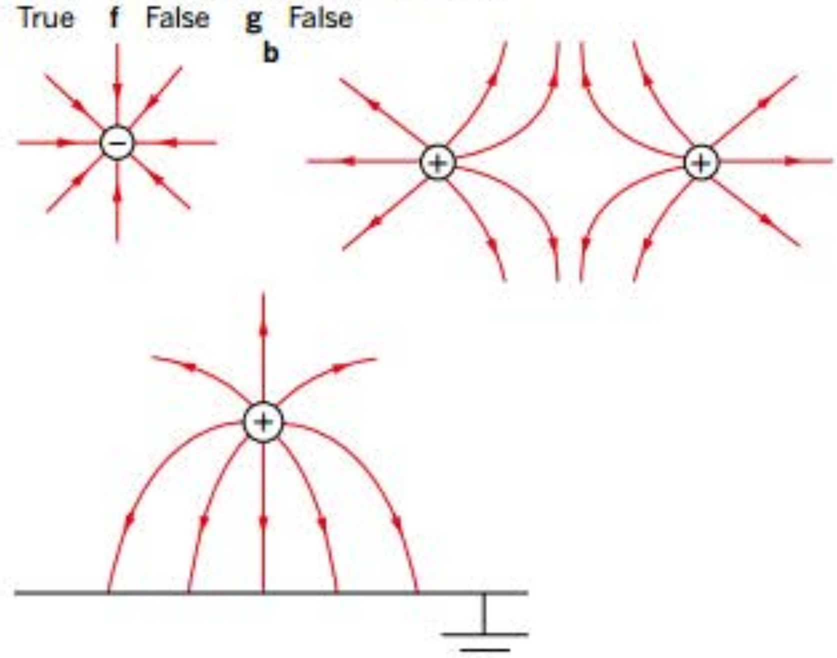
Chapter 4 Electric fields

4.1 Electric fields

WE 4.1.1 5.62×10^{-4} N C^{-1}

4.1 Review

1 C **2** B
3 **a** True **b** False **c** False **d** True **e** True **f** False **g** False
4 **a** **b** **c**



5 1.25×10^{-2} N **6** 1.39 mC **7** 5.72×10^{11} m s^{-2}

4.2 Coulomb's law

WE 4.2.1 6.32×10^{-4} N repulsion
WE 4.2.2 $q_1 = +6.35 \times 10^{-10}$ C, $q_2 = -6.35 \times 10^{-10}$ C
WE 4.2.3 8.0×10^5 N C^{-1} away from the charge or to the right

4.2 Review

1

Force	q_1 charge	q_2 charge	Action
a positive	positive	positive	repulsion
b negative	negative	positive	attraction
c positive	negative	negative	repulsion
d negative	positive	negative	attraction

2 D **3** -8.22×10^{-8} N **4** 1.1×10^7 N C^{-1}
5 9000 N **6** 1.435 m
7 **a** double, repel **b** quadruple, repel **c** double, attract **d** quadruple, repel
8 37 N **9** 1.97×10^{13} electrons

4.3 Work done in an electric field

WE 4.3.1 2.16×10^{-18} J on the field

4.3 Review

1 1200 V **2** 20 electrons
3 **a** Work is done by the field. **b** No work is done. **c** Work is done on the field. **d** No work is done. **e** Work is done on the field. **f** Work is done by the field.
4 **a** 1.09×10^{-19} J **b** Work is done on the field.
5 2.23×10^{-6} C

Chapter 4 review

1 0.0225 N **2** D
3 The electrical potential is defined as the work done per unit charge to move a charge from infinity to a point in the electric field. The electrical potential at infinity is defined as zero. When you have two points in an electric field (E) separated by a distance (d) that is parallel to the field, the potential difference V is then defined as the change in the electrical potential between these two points.
4 25 V **5** C **6** field, charged particle
7 4.17×10^{-18} J **8** 2×10^{-14} N
9 **a** quarter , repel **b** quadruple, repel **c** halve, attract
10 5.42×10^4 m s^{-1} **11** 0.045 N **12** 45.8 m
13 $+1.63 \times 10^{-4}$ C **14** 7.9×10^{-6} N
15 **a** 8.80×10^{-14} N upwards **b** 24.8 V **c** 3.96×10^{-15} J
16 **a** 1.80×10^5 N attraction **b** -5.5×10^{-6} C per sphere **c** 5.98×10^3 N repulsion
17 **a** 1.28×10^{-15} J **b** 8.00×10^3 V
18 6.80×10^{-6} N

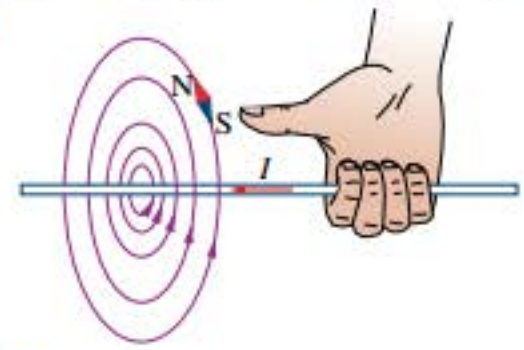
Chapter 5 Magnetic field and force

5.1 The magnetic field

WE 5.1.1 anticlockwise around the wire
WE 5.1.2 2.67×10^{-5} T

5.1 Review

1 B **2** A **3** C **4** C
5



6 A
7 **a** A = east, B = south, C = west, D = north
b A = west, B = north, C = east D = south
8 2.25 A **9** 62.5 A **10** 1.91 cm

5.2 Forces on charged objects

WE 5.2.1 4.8×10^{-22} N
WE 5.2.2 out of the screen (towards you)

5.2 Review

1 D
2 **a** south (S) **b** path C **c** It remains constant. **d** path A **e** particles with no charge, e.g. neutrons
3 D **4** 0 N **5** 4.8×10^{-24} N south
6 $2F$ north
7 Charged particles experience a force from the magnetic field that is perpendicular to the particle's velocity, constantly accelerating the charged particle towards the centre. Thus the magnetic force provides the centripetal force.
8 10.0 m s^{-1} **9** 0.0500 T
10 It would need to be halved

5.3 The force on a conductor

WE 5.3.1 2.5×10^{-3} N per metre of power line
WE 5.3.2 vertically downwards
WE 5.3.3 **a** 0 N **b** 1.0×10^{-3} N out from Santa's house
WE 5.3.4 1.6×10^{-7} N m clockwise

5.3 Review

1 No force will apply. **2** 0.4 N upwards
3 **a** 0.18 N downwards **b** Same as (a). **4** 0.1 N
5 Current flows into brush P and around the coil from V to X to Y to W. So force on side VX is down, force on side YW is up, so rotation is anticlockwise.
6 D **7** **a** down the page **b** up the page
8 anticlockwise
9 **a** down the page **b** up the page
c Zero torque acts as the forces are trying to pull the coil apart rather than turn it. The force is parallel to the coil, rather than perpendicular to it.
10 C

Chapter 5 review

1 east—away from the north pole of the left-hand magnet
2 west—away from the north pole of the right-hand magnet
3 The point is equidistant from the two magnets so resulting field would be zero.
4 *B*, into the page **5** 3*B*, into the page
6 zero **7** 1.50 cm **8** 20 µT **9** 75 A
10 D **11** **a** palm **b** fingers **c** thumb
12 equal to, into **13** 2.78 A
14 **a** 5.0×10^{-9} N into the page
b 2.0×10^{-3} N into the page
15 9.6×10^{-15} N **16** The force is downwards.
17 The east–west line because it runs perpendicular to the Earth's magnetic field.
18 2.0×10^{-4} N north **19** A
20 1.0×10^{-2} N into the page **21** 1.0×10^{-2} N out of the page
22 0 N **23** anticlockwise **24** D
25 2.0×10^{-4} N m
26 It reverses the direction of the current in the coil every half turn, to keep the coil rotating in the same direction.

Chapter 6 Magnetic field and emf

6.1 Induced emf in a conductor moving in a magnetic field

WE 6.1.1 No, emf = 0.695 V. This is a very small emf and would not be dangerous.
WE 6.1.2 0.500 m s^{-1}
WE 6.1.3 6.02×10^{-4} V

6.1 Review

1 A **2** 0.0144 V or 1.44×10^{-2} V **3** 0.842 m s^{-1}
4 0.100 m **5** 0 V **6** 0.500 V **7** 3.13×10^{-4} V
8 0.624 V **9** 0.614 V **10** 0.0542 V, 0.668 V

6.2 Induced emf from a changing magnetic flux

WE 6.2.1 8.00×10^{-5} Wb
WE 6.2.2 **a** 5.00×10^{-4} Wb **b** 5.00×10^{-3} V
WE 6.2.3 1000 turns

6.2 Review

1 0 Wb **2** 1.30×10^{-5} Wb **3** 1.20×10^{-6} Wb
4 Zero flux **5** 3.00×10^{-5} V **6** 4.00×10^{-3} V
7 2.00 V **8** 6.00×10^{-3} V **9** 0.0100 m^2
10 0.125 s

6.3 Lenz's law

WE 6.3.1 clockwise when viewed from above
WE 6.3.2 **(i)** through the solenoid from Y to X (through the meter from X to Y)
(ii) no induced emf or current
(iii) through the solenoid from X to Y (through the meter from Y to X)
WE 6.3.3 anticlockwise

6.3 Review

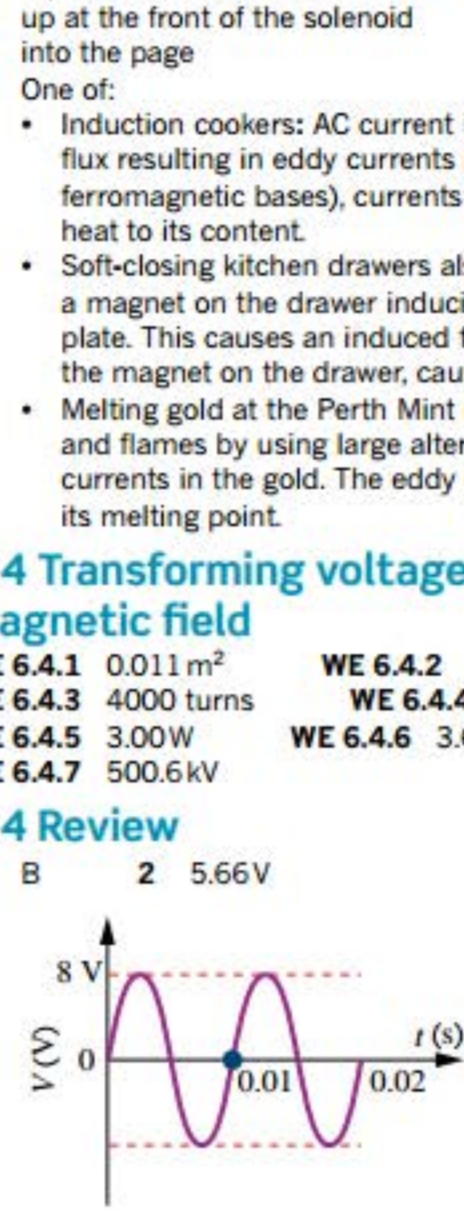
1 C **2** **a** A **b** A
3 **a** anticlockwise
b Any combination of:
1 strength of the magnet
2 speed of the magnet
3 area/diameter of the ring
4 orientation of the ring
5 type of copper making up the ring
6 resistance of the circuit containing the coil.
4 Lenz's law states that an induced current is created, which produces flux to oppose the change in flux. As the copper wire accelerates through the magnetic field, the induced opposing magnetic field produces a repulsive upwards force that reduces the net force acting on the wire. When the upwards magnetic force is equal to the downwards gravitation force, there is no net force and a constant terminal velocity is reached.
5 The compass will oscillate freely above the glass but damping will occur over the aluminium due to induced eddy currents in the aluminium that create a field to oppose the change of flux, according to Lenz's law.
6 top end **7** anticlockwise
8 up at the front of the solenoid
9 into the page
10 One of:
- Induction cookers: AC current in coil produced changing flux resulting in eddy currents in metal pans (best with ferromagnetic bases), currents will heat up pan which transfers heat to its content.
- Soft-closing kitchen drawers also use eddy currents created by a magnet on the drawer inducing an eddy current in a metal plate. This causes an induced field that opposes the motion of the magnet on the drawer, causing it to slow down as it closes.
- Melting gold at the Perth Mint is done without the need for fuel and flames by using large alternating voltages that create eddy currents in the gold. The eddy currents heat the gold to beyond its melting point.

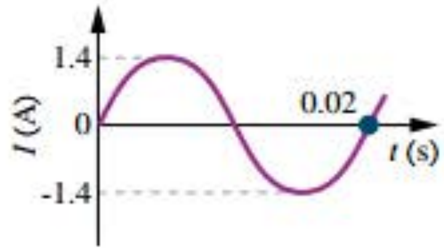
6.4 Transforming voltage using changing magnetic field

WE 6.4.1 0.011 m^2 **WE 6.4.2** 2000 W
WE 6.4.3 4000 turns **WE 6.4.4** 0.0125 A
WE 6.4.5 3.00 W **WE 6.4.6** 3.60×10^5 W or 0.360 MW
WE 6.4.7 500.6 kV

6.4 Review

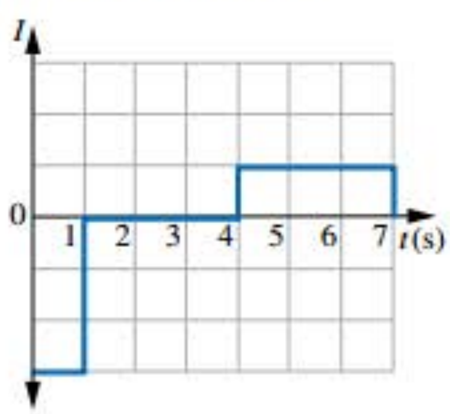
1 B **2** 5.66 V
3



4 

5 D **6** 40 turns
7 **a** $P_1 = P_2$ **b** $\frac{I_2}{I_1} = \frac{N_1}{N_2}$
8 **a** 80.0 V **b** 16.0 W **c** 0.200 A **9** 400 W
10 **a** 5000 A **b** 100 − 10 = 90 kV

Chapter 6 review

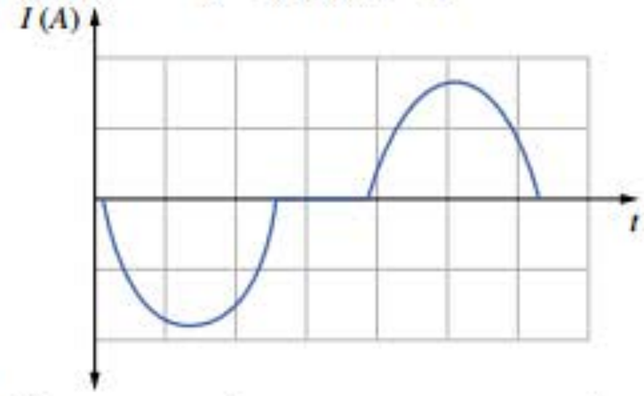
1 3.20×10^{-6} Wb
2 The magnetic flux decreases from 3.20×10^{-6} Wb to 0 after one-quarter of a turn. Then it increases again to 3.20×10^{-6} Wb through the opposite side of the loop after half a turn. Then it decreases to 0 again after three-quarters of a turn. After a full turn it is back to 3.20×10^{-6} Wb again.
3 C
4 The student must induce an emf of 1.00 V in the wire by somehow changing the magnetic flux through the coil at an appropriate rate. A change in flux can be achieved by changing the strength of the magnetic field or by changing the area of the coil. The magnetic field can be changed by changing the position of the magnet relative to the coil. The area can be changed by changing the shape of the coil or by rotating the coil relative to the magnetic field. See Reader+ for fully worked solution.
5 B **6** 30.0 W **7** 3.54 A
8 **a** 3.20×10^{-3} V **b** clockwise
9 **a** 0.0402 V
b from Y to X; clockwise around the coil when viewed from above
10 **a** 4.00×10^{-3} V or 4.00 mV **b** from X to Y
11 1.60×10^{-3} V or 1.60 mV
12 

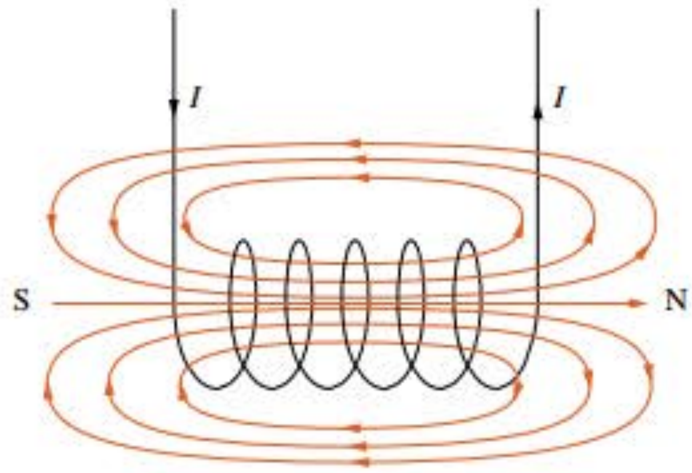
Either the graph shown or its inversion is correct.
13 1.00 A **14** 10 turns **15** A
16 **a** 18.0 V **b** 375 W **17** option C
18 8.91 V
19 Doubling the frequency doubles the rms emf, since the rate of change of flux is doubled.
20 Any two of:
- Using a DC power supply means that the voltage cannot be stepped up or down with transformers.
- There will be significant power loss along the 8 Ω power lines.
- There could be damage to any appliances operated in the shed that are designed to operate on 240 V AC and not on 240 V DC.

21 As the coil area is reduced, the flux into the page will decrease. To oppose this, the induced current will try to increase the flux again in the same direction. Using the right-hand grip rule the direction of the induced current will be clockwise.
22 AB and CD **23** 15.0 A **24** 9970 V
25 450 W **26** This results in a 30% power loss—a bad idea!
27 anticlockwise **28** B
29 **a** 40 turns **b** 0.141 A **c** 24.0 W **d** A
30 4.00×10^7 W or 40.0 MW
31 B. A is incorrect because the *V* in the formula indicates the voltage drop in the transmission lines; it does not refer to the voltage being transmitted.

Unit 3 review

Section 1: Short response

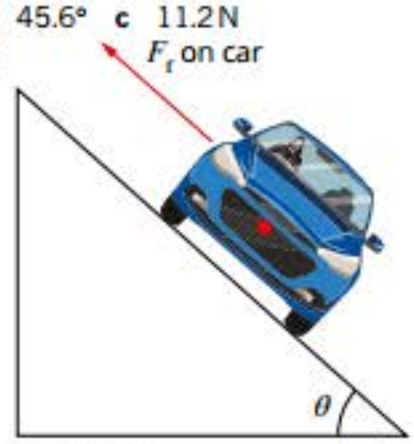
1 3.22×10^{-6} N **2** 4340 days
3 **a** 8.28 m s^{-1} **b** 4.58×10^2 J
4 **a** 35.0 m s^{-1} at 40.0° down from horizontal. **b** 42.6 m s^{-1}
5 2.57 N **6** 9.38×10^{-2} m
7 

8 **a** 

b increasing the current flowing through the coil
increasing the number of turns in the coil
placing a bar of iron inside the coil
c Currents are in opposite directions, so the two magnetic fields will be in opposite directions, so they will attract each other.

Section 2: Problem solving

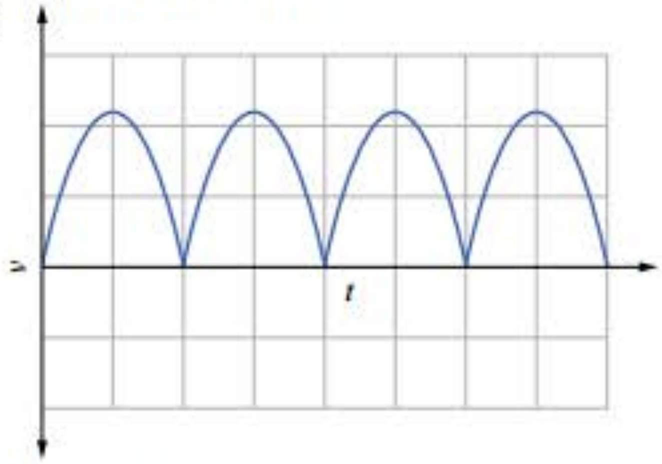
9 **a** 

b 45.6° **c** 11.2 N
d 

e 3.83 m s^{-1}
10 **a** A geostationary orbit is the orbit of a satellite around Earth for which the period of the orbit is exactly one day, and so appears to be stationary in the sky.
b 3.58×10^7 m **c** 3.88×10^3 m s^{-1} **d** 15 m

11 a 1.80×10^{-2} N upwards

b



c 24.0×10^{-3} V

d Slip rings allow the coil to maintain constant contact with the circuit, and so will have current flowing in a constant direction. Side AB will experience an upwards force, causing the coil to rotate clockwise. Once the coil has rotated by 180°, the side CD will be where AB previously was; however, the current will be flowing in the opposite direction, since the coil has flipped. Side CD will then experience a downwards force. The coil will then oscillate back and forth between each position until it likely reaches an equilibrium position turned halfway.

12 a With more appliances on, the amount of current required would increase, increasing the power loss in the transmission line as $P_{loss} = I^2R$. This power loss would cause a significant drop in potential across the transmission lines according to $\Delta V = IR$.

b $V_{house} = 42.0$ V, $P_{house} = 672$ W

c At the generator end, a step-up transformer is needed, with a turns ratio of 1:20 to convert 250V up to 5000V.
At the house end of the line, a step-down transformer is needed, with an approximate turns ratio of 20:1 to convert the approximately 5000V down to 250V again.

d 0.800A **e** 10.4V **f** 8.32W **g** 4989.6V **h** 3991.7W

i Without transformers: efficiency = 16.8%
With transformers: efficiency = 99.8%.

j With a higher transmission voltage, there is a corresponding decrease in current in the transmission lines. As $P_{loss} = I^2R$, any decrease in current has a significant effect on the power loss.

Section 3: Comprehension

13 a The Doppler spectroscopy method relies on detecting the Doppler shift of the star in order to determine its velocity, so the star must be moving either towards or away from Earth. Thus, a side view will be best because it has all of the star's velocity in the radial direction towards Earth. A top view would give no information about the velocity of the star.

b i In a general stellar system in which the plane of the system is not exactly side-on to Earth, some of the velocity of the star will be perpendicular to the line-of-sight of an astronomer. This velocity is undetectable to observers on Earth. Therefore, the radial velocity detected will only be one component of the total velocity of a star, and its true velocity will be greater than this detected velocity. From the formula $\frac{M_{planet}}{v_{star}} = \frac{M_{star}}{v_{planet}}$, it can be seen that the mass of the planet, $M_{planet} = \frac{v_{star}M_{star}}{v_{planet}}$, is directly proportional to the velocity of the star. Since observations from Earth using this method provide only a lower bound for the star's velocity, they will only provide a lower bound for the planet's mass, with the true quantity determined by the star's true velocity.

ii In order to observe the transit of a planet in front of its local star, the star system must be side-on to observers on Earth. In light of the answers to the previous two questions, one would expect the measurement of the star's velocity to be close to its true velocity, and therefore for these mass calculations to be accurate.

c 2.39×10^{24} kg

Chapter 7 Wave–particle duality and the quantum theory

7.1 Properties of waves in two dimensions

WE 7.1.1 1.52
WE 7.1.2 1.62×10^8 m s^{-1}
WE 7.1.3 28.2°
WE 7.1.4 The light speed is increasing, therefore the angle is refracted way from the normal, as in Figure 7.1.10 on page 236. There will be a significant change in angle and corresponding increase in wavelength.
WE 7.1.5 24.4°

7.1 Review

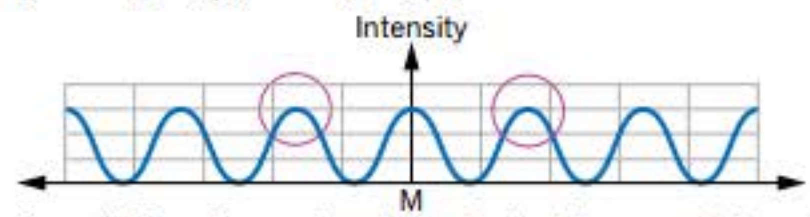
1 **a** wave model **b** wave model **c** particle model
2 C **3** slower than **4** 2.17×10^8 m s^{-1}
5 1.31 **6** 35.3° **7** b and c **8** D
9 Polarisation is a phenomenon in which transverse waves are restricted in their direction of vibration. Polarisation can only occur in transverse waves and cannot occur in longitudinal waves. Since light can be polarised, it must be a transverse wave.

7.2 Interference: Further evidence for the wave model of light

WE 7.2.1 550 nm

7.2 Review

1 D **2** C, D **3** A, D
4



5 Up until Young's experiment, most scientists supported a particle or 'corpuscular' model of light. Young's experiment demonstrated interference patterns, which are characteristic of waves. This led to scientists abandoning the particle theory and supporting a wave model of light.
6 **a** increase **b** decrease **c** increase
7 2610 nm or 2.61×10^{-6} m
8 **a** destructive **b** constructive **c** destructive
9 1400 nm **10** 455 nm

7.3 Electromagnetic waves

WE 7.3.1 5.0×10^{14} Hz

7.3 Review

1 B **2** D **3** D
4 X-rays, visible light, infrared radiation, FM radio waves
5 **a** 4.57×10^{14} Hz **b** 5.09×10^{14} Hz **c** 6.17×10^{14} Hz **d** 7.56×10^{14} Hz
6 0.07% **7** 500 nm **8** 4.3 m
9 1.5×10^{18} Hz **10** 0.122 m

7.4 Light quanta: Blackbody radiation and the photoelectric effect

WE 7.4.1 2.4×10^{-19} J **WE 7.4.2** 1.5 eV
WE 7.4.3 5.0 eV **WE 7.4.4** 2.08 eV

7.4 Review

1 **a** False **b** False **c** True **d** True **e** False
2 1 Molecules vibrate at fixed frequencies or energies.
2 To change energy levels, a molecule needs to absorb or emit a photon of exactly the right energy difference between two levels.
3 **a** 3.03×10^{-19} J **b** 3.38×10^{-19} J **c** 4.09×10^{-19} J **d** 5.01×10^{-19} J
4 In the photoelectric effect, a metal surface may become positively charged if light shining on it causes electrons to be released.

5 **a** True **b** False **c** True
6 **a** 4.1 eV **b** 4.6 eV **c** 6.2 eV
7 D **8** 0.066 eV **9** 0.25 eV **10** C, D
11 **a** True **b** False **c** True **d** True
12 1.68 eV

7.5 Atomic spectra

WE 7.5.1 103 nm, Lyman series
WE 7.5.2 A photon of 6.7 eV corresponds to the energy required to promote an electron from the ground state to the second excited state ($n = 1$ to $n = 3$). The photon may be absorbed.
A photon of 5.0 eV cannot be absorbed.
A photon of 11.0 eV may ionise the mercury atom. The ejected electron will leave the atom with 0.6 eV of kinetic energy.
WE 7.5.3 3.40 eV, 366 nm, ultraviolet

7.5 Review

1 The electrons in a sample become excited when the substance is heated or an electric current flows through it. As the electrons return to their ground state, a photon is emitted.
2 4.0×10^{-19} J **3** 3.0×10^{-6} m
4 **a** light-emitting diode
b light amplification by stimulated emission of radiation
5 675 nm **6** 12.75 eV **7** 9.74×10^{-8} m or 97.4 nm
8 It could not explain high-energy orbits of multi-electron atoms, the continuous emission spectrum of solids and the two close spectral lines in hydrogen that are revealed at high resolution.
9 –0.54 eV
10 The energy difference between $n = 1$ and $n = 3$ is 6.7 eV. An electron from the electron beam will promote the atomic electron from $n = 1$ to $n = 3$ and lose 6.7 eV. It will then exit the atom with an energy of 0.3 eV.
A photon has exactly 7 eV of energy and needs to give up all of its energy, therefore it cannot promote the electron and will pass straight through.

7.6 The quantum nature of light and matter

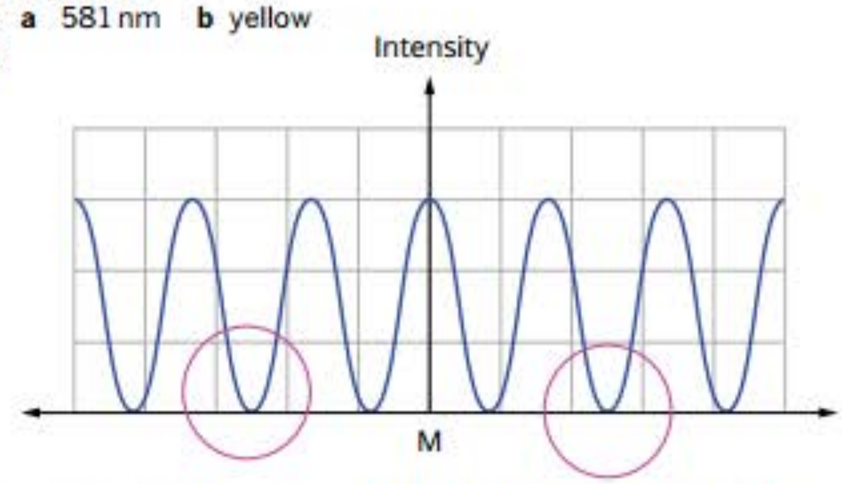
WE 7.6.1 5.7×10^{-13} m **WE 7.6.2** 1.0×10^{-36} m
WE 7.6.3 0.17 nm **WE 7.6.4** 1.47×10^{-27} kg m s^{-1}

7.6 Review

1 7.3×10^{-10} m **2** 1.8×10^{5} m s^{-1} **3** B
4 **a** 3.5×10^{-11} m **b** 2.1×10^{7} m s^{-1}
5 The wavelength of a cricket ball is so small that its wave-like behaviour could not be seen by a cricket player.
6 1.32×10^{5} m s^{-1}
7 $\lambda = \frac{h}{\sqrt{2qVm}}$ **8** $p = \frac{h}{\lambda}$
9 An electron microscope can resolve images in finer detail than an optical microscope because a high-speed electron has a shorter wavelength than a light wave.
10 De Broglie proposed a model in which electrons were viewed as matter waves with wavelengths that formed standing waves within an atomic orbit circumference. A bowed violin string forms standing waves between the bridge of the violin and the violinist's finger.

Chapter 7 review

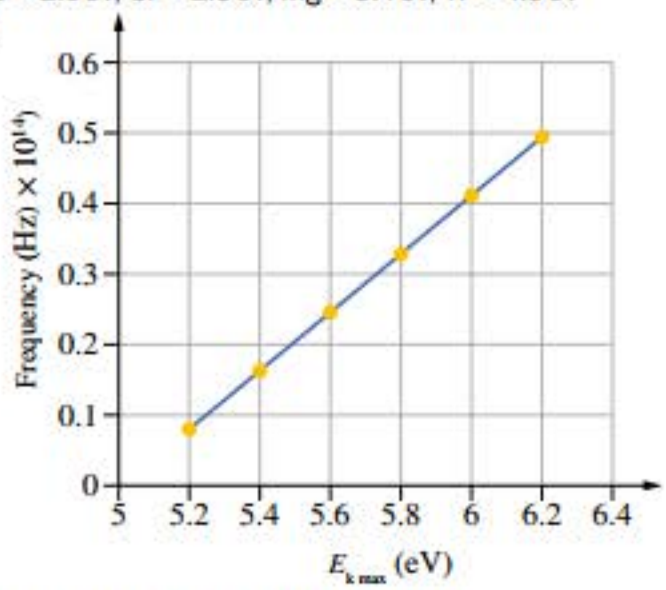
1 A
2 The diffraction pattern for green light would be more spread out.
3 D
4 The light reflected from water and snow is partially polarised. Snowboarders and sailors would benefit from wearing polarising sunglasses as these will absorb the polarised glare from the snow or water respectively.
5 2.25×10^{8} m s^{-1} **6** increases, away from
7 A: incident ray
B: normal
C: reflected ray
D: boundary between media
E: refracted ray
8 2.1×10^{8} m s^{-1} **9** $a = 25.4°$, $b = 25.4°$, $c = 28.9°$
10 **a** 32.0° **b** 53.7° **c** 21.7° **d** 1.97×10^{8} m s^{-1}
11 **a** 19.5° **b** 19.1° **c** 0.4° **d** 1.96×10^{8} m s^{-1}
12 **a** 49.8° **b** 40.5° **c** 27.6°
13 B, D, A, C
14 **a** 581 nm **b** yellow
15



16 radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays
17 **a** microwaves **b** infrared waves
c X-rays, radio waves (in MRI), infrared radiation, visible light, UV and gamma radiation
18 490 m
19 Young performed his famous experiment in 1803, in which he observed an interference pattern for light. Young shone monochromatic light on a pair of narrow slits. Light passed through the slits and formed a pattern of bright and dark lines/fringes/bands on a screen. He compared this to interference patterns he had observed, and identified that these lines corresponded to regions of constructive and destructive interference. This could only be explained by considering light to be a wave.
20 A microwave oven is tuned to produce electromagnetic waves with a frequency of 2.45 GHz. This is the resonant frequency of water molecules. When food is bombarded with radiation at this frequency, the water molecules within the food start to vibrate. The energy of the water molecules is then transferred to the rest of the food, heating it up.
21 2.5 eV **22** 8.0×10^{-19} J **23** photoelectrons
24 1.2×10^{15} Hz **25** 2.9 eV **26** 1.95 eV

27 Rb = 2.1 eV, Sr = 2.5 eV, Mg = 3.4 eV, W = 4.5 eV

28 **a**



b 4.1×10^{-15} eV s **c** 5.0×10^{14} Hz

d No. The frequency of red light (4.41×10^{14} Hz) is below the threshold frequency for rubidium, so no photoelectrons will be emitted.

29 **a** 4.78 keV

b The electrons have a de Broglie wavelength that is similar to the wavelength of the X-rays. This is evidence for the dual nature of light and matter.

c 2.6×10^{-24} kg m s^{-1}

30 **a** The detector observed a sequence of maximum and minimum intensities.

b As the electron beam is diffracted, the electrons are exhibiting wave-like behaviour. Electrons are not light but, like light, a beam of electrons can be diffracted.

31 Energy levels in an atom cannot assume a continuous range of values but are restricted to certain discrete values, i.e. the levels are quantised.

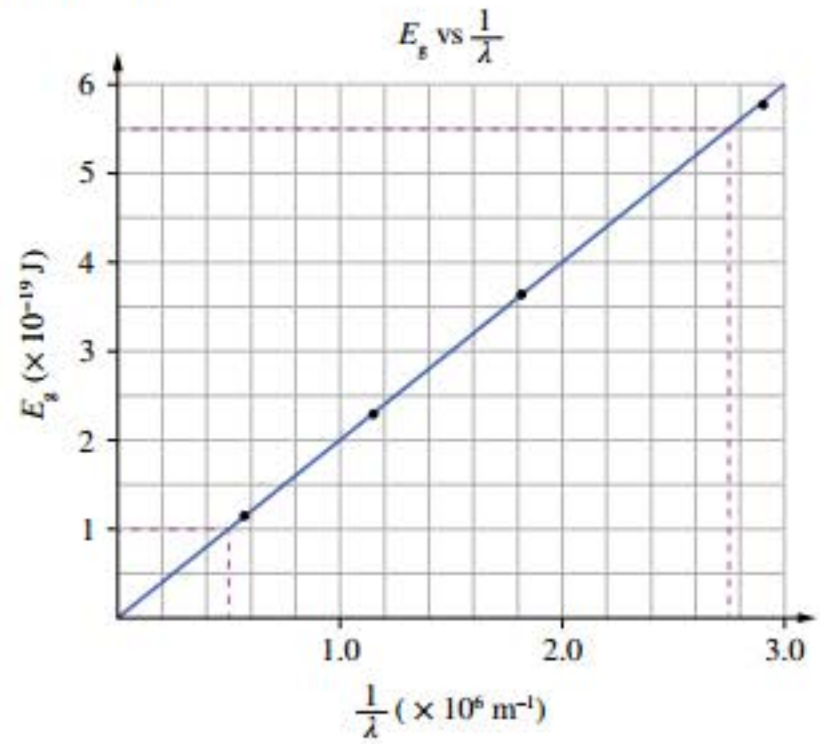
32 2.92×10^{15} Hz

33 Bohr's work on the hydrogen atom convinced many scientists that a particle model was needed to explain the way light behaves in certain situations. It built significantly on the work of Planck and Einstein.

34 The emission spectrum of hydrogen appears as a series of coloured lines. The absorption spectrum of hydrogen appears as a full visible spectrum with a number of dark lines. The colours missing from the absorption spectrum match the colours that are visible in the emission spectrum.

35 As the filament heats up, the free electrons in the tungsten atoms collide, accelerate and emit photons. A wide range of photon wavelengths are emitted due to a wide range of different collisions (some weak, some strong).

36 6.7×10^{-34}



37 B **38** 1.7×10^{-35} m

39 No—the wavelength of the bullet is many times smaller than the radius of an atom. Significant diffraction only occurs when wavelength and gap (or object) size are approximately equal, i.e. when $\lambda \geq w$.

40 For the product of the uncertainty in position and the uncertainty in momentum to remain constant then as the uncertainty in position is decreased, the uncertainty in momentum would increase.

41 It is likely that the photon would knock the electron off course and hence the electron's position would be subject to greater uncertainty.