Oxford Resources for IB

Physics – 2023 Edition

Answers

Oxford Resources for IB

Physics – 2023 Edition

Answers

Theme A – Space, time and motion

A.1 – Kinematics

Practice questions – Page 11

1 **a.** 6.3 km

b. 4.5 km

c. 33°

2 **a.** distance = 24 cm, displacement = 21 cm

b. distance = 47 cm, displacement = 30 cm

Practice questions – Page 12

3 15 km h^{-1}

4 8.7 light years

Practice questions – Page 14

5 **a.** 45 km h^{-1}

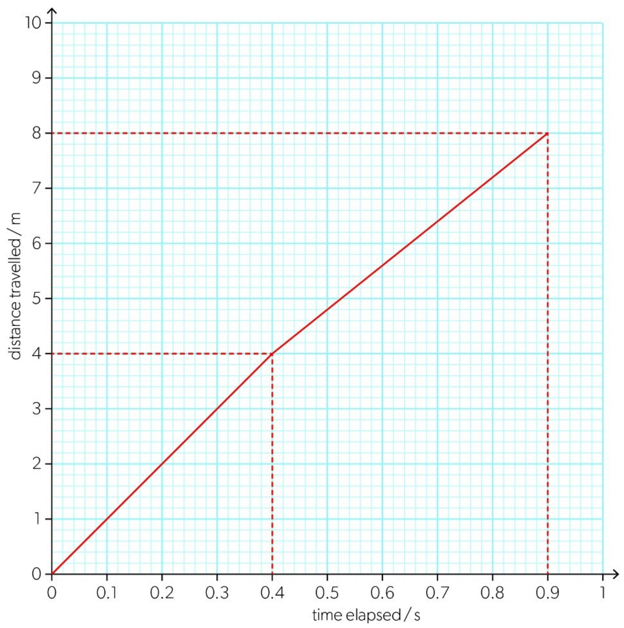
b. 800 m

c. 48 km h^{-1}

6 **a.** **i.** 0.40 s

ii. 8.0 m s^{-1}

b.



Practice questions – Page 16

7 **a.** **i.** approximately 6 m s^{-1}

ii. approximately 2 m s^{-1}

b. 1.9 m s^{-1}

8 **a.** 4.1 m s^{-1}

b. 2.6 m s^{-1}

Practice questions – Pages 21–22

9 C

10 A

11 A

12 B

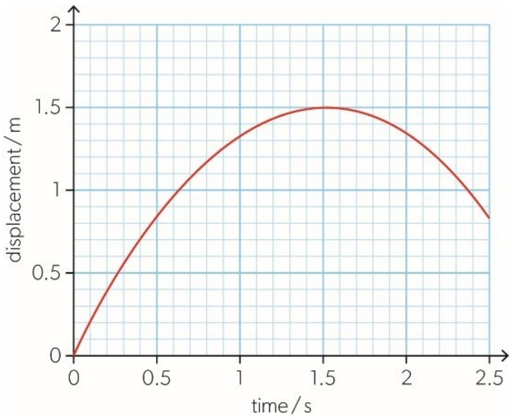
13 **a.** Decelerates from 0 to 1.5 s, changes the direction of motion at 1.5 s and accelerates in the opposite direction from 1.5 s to 2.5 s

b. **i.** −1.3 m s^{-2}

ii. 1.5 m

iii. Answer between 0.80 m and 0.85 m

c.



Practice questions – Page 25

14 **a.** 3.3 s

b. 2.5 m

15 **a.** 1.7 m s^{-2}

b. 1400 m

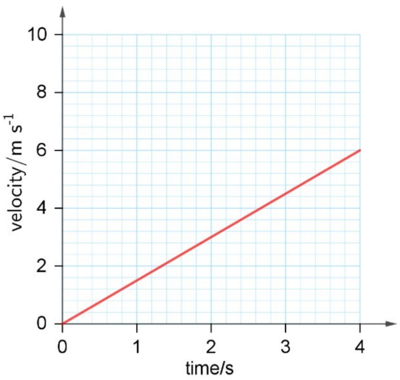
16 19 m s^{-1}

17 **a.** 31 m s^{-1} (110 km h^{-1})

b. 47 s

18 **a.** D

b.



Practice questions – Page 34

19 B

20 D

21 D

22 C

23 **a.** 8.8 m s^{-1}

b. 20 m s^{-1}

c. 26°

d. 4.0 m

24 19.8 m s^{-1}

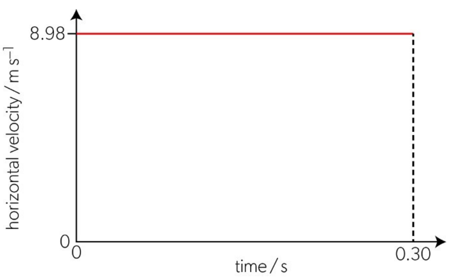
$$-0.25 = 9.0\sin 4.0° \times t - \frac{1}{2} \times 9.8t^2 \Rightarrow t = 0.299 \text{ s}$$

25 **a.**

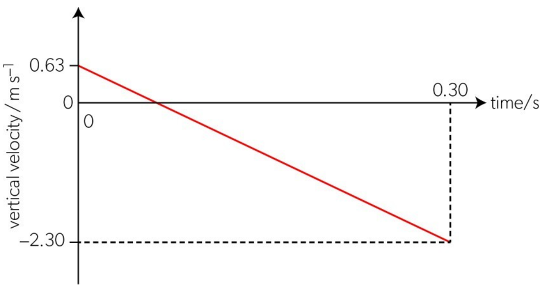
b. **i.** 2.7 m

ii. 9.3 m s^{-1}

c. **i.**



ii.



A.2 – Forces and momentum

Practice questions – Page 46–47

1 D

2 C

3 87 N

4 **a.** 11 kN

b. 1.0 s

5 **a.** 0.29 m s^{-1}

b. 1.2 m

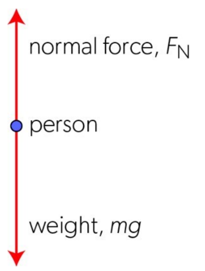
6 **a.** The force acts vertically so it only changes the vertical component of the velocity

b. **i.** 3.4 cm

ii. 15°

Practice questions – Page 52

7



a. 740 N

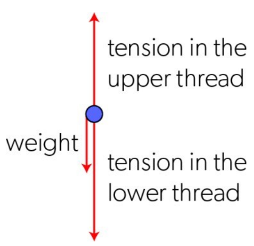
b. 890 N

Practice questions – Page 54

8 **a.** 38 N

b. The vertical component of tension is unchanged (is equal to half the weight of the object) and the horizontal component must increase if the overall force is to make a greater angle with the vertical. Tension in each thread increases so the threads are more likely to break.

9 **a.**



b. Upper thread: 3*Mg*, lower thread: 2*Mg*

10 **a.** **i.** 0.42 N

ii. 0.65 N

b. Moves away from the wall with a constant acceleration, in a straight line along the original direction of the thread.

Practice questions – Page 59

11 A

12 D

Practice questions – Page 61

13 A

14 **a.** 1.25 kg

b. The maximum mass of extra load that can be placed in the container is 5 kg, so the container will not sink.

Practice questions – Page 62

15 0.21 kg m^{-3}

16 **a.** 1.3×10^{-3} N

b. Increases by 8%

Practice questions – Page 67

17 **a.** 3.9 m s^{-2}

b. The maximum acceleration of the box that the static friction force can provide is $0.45g = 4.4$ m s^{-2}. This is greater than the actual acceleration so the box does not slide.

18 5.7 m s^{-1}

19 **a.** 0.069 m s^{-2}

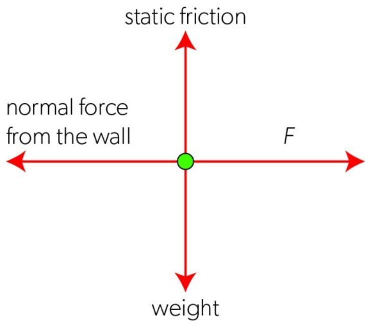
b. 5.1 N

c. 2.8 N

d. 0.15

20 **a.** 16 N

b.



c. 4.9 m s^{-2}

Practice questions – Page 72

21 B

22 C

23 A

24 **a.** Buoyancy and weight remain constant but the drag force in the oil increases with speed, at terminal velocity the net force is zero so the ball no longer accelerates

b. **i.** 2.6×10^{-3} N **ii.** 3.0×10^{-4} N

c. 0.73 m s^{-1}

Practice questions – Page 75

25 **a.** 300 m s^{-2}

b. 120 N

26 **a.** **i.** 0.36 N s

ii. 4.8×10^{-4} s

b. 4.3 cm

c. It assumes that the force on the pellet is constant which in reality may not be the case.

Practice questions – Page 77

27 B

28 D

29 **a.** **i.** 1.5 N

ii. 4.9 m s^{-1}

b. 13 N

Practice questions – Page 79

30 **a.** **i.** 10 kN

ii. 0.25 m s^{-2}

b. The thrust force is constant but the mass of the spacecraft decreases so the acceleration increases.

c. 420 m s^{-1}

d. 18 kg s^{-1}

Practice questions – Page 85

31 **a.** C

b. D

32 A

33 **a.** 8.0 m s^{-1}

b. 12 J

34 **a.** 210 m s^{-1}

b. **i.** 4.0×10^{5} m s^{-2} **ii.** 800 N

35 **a.** 3.0 m s^{-1}

b. K.E. before collision = K.E. after collision = 36 kJ

Practice questions – Page 88

36 **a.** 0.89 m s^{-1}, at 27° to the horizontal

b. KE decreases, inelastic collision

37 **a.** 60 m s^{-1}

b. 41.4°

Practice questions – Page 90

38 **a.** $0.97\ \mathrm{m\,s^{-1}}$

b. $1.6\ \mathrm{kg\,m\,s^{-1}}$ per second

c. The momentum of the water changes so a force is exerted on the water by the hose. From Newton's third law, an equal by opposite force is exerted by the exiting water on the hose. To keep the hose stationary, an external force has to be applied to balance the force exerted by the water.

Practice questions – Page 92

39 **a.** 29 kN

b. The volume of air passing the blades per second is Av so the mass per second is ρAv

c. $16\ \mathrm{m\,s^{-1}}$

d. $17\ \mathrm{m\,s^{-1}}$

40 **a.** 0.13 s

b. 0.8 m

Practice questions – Page 96

41 **a.** $1.99 \times 10^{-7}\ \mathrm{rad\,s^{-1}}$

b. $29.9\ \mathrm{km\,s^{-1}}$

42 **a.** $70\ \mathrm{rad\,s^{-1}}$

b. $11\ \mathrm{m\,s^{-1}}$

Practice questions – Page 97–98

43 C

44 **a.** $310\ \mathrm{km\,s^{-1}}$

b. $9.9 \times 10^{6}\ \mathrm{m\,s^{-2}}$

45 **a.** $0.21\ \mathrm{rad\,s^{-1}}$

b. 14 m

c. $0.63\ \mathrm{m\,s^{-2}}$

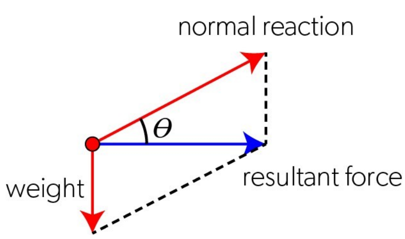
Practice questions – Page 103

46 **a.** $4.8\ \mathrm{rad\,s^{-1}}$

b. 1.3 s

47 890 m

48 **a.**



$$\frac{mg}{ma} = \tan\theta \Rightarrow a = \frac{g}{\tan\theta}$$

b.

c. **i.** 12 cm

ii. 6.3×10^{-2} N

d. The centripetal acceleration is constant:

$$\omega^2 r = \frac{g}{\tan\theta} = \text{const}$$

Decreasing the radius implies that the angular speed ω will be increasing.

Practice questions – Page 105

49 **a.** Lowest point, the tension here has a maximum value of:

$$m\frac{v^2}{r} + mg$$

b. **i.** 2.8 m s^{-1}

ii. 4.9 m s^{-1}

50 **a.** $N = m\left(g - \frac{v^2}{r}\right)$

b. **i.** 9.2 kN

ii. 83 km h^{-1}

A.3 – Work, energy and power

Practice questions – Page 111

1 **a.** 0.75 J

b. 0

c. −1.4 J

2 **a.** 830 m

b. 230 N

c. −190 kJ

Practice questions – Page 113

3 **a.** 1.28×10^5 J

b. **i.** 0.75 m s^{-2}

ii. −0.25 m s^{-2}

4 **a.** −15 J

b. 6.25 m

Practice questions – Page 115

5 D

6 D

7 **a.** 4.5 kN

b. **i.** 5.6×10^5 J

ii. 5.6×10^4 W

c. The driving force is constant but the speed increases, from $P = Fv$ the power must increase

Practice questions – Page 116

8 **a.** 160 kJ

b. 13.9 m s^{-1}

9 **a.** −2.2 J

b. 1.9 m s^{-1}

c. 2.1 m

Practice questions – Page 120–121

10 C

11 C

12 **a.** **i.** 1.44×10^6 J

ii. 1.28×10^6 J

b. The lift force is greater than weight so the helicopter accelerates.
The difference between parts **i.** and **ii.** represents the change in the kinetic energy of the helicopter.

c. 11 m s^{-1}

13 10.4 cm

14 **a.** Final KE = initial KE + loss of GPE, but the loss of GPE only depends on the height travelled and not on the initial angle.

b. 21.2 m s^{-1}

Practice questions – Page 123

15 C

16 B

17 **a.** **i.** 2.0 kN m^{-1}

ii. 0.90 J

b. 4.0 cm

18 **a.** **i.** 1.2 J

ii. 0.30 J

iii. 0.90 J

b. 690 N m^{-1}

c. 49 m s^{-2}, upwards

Practice questions – Page 125

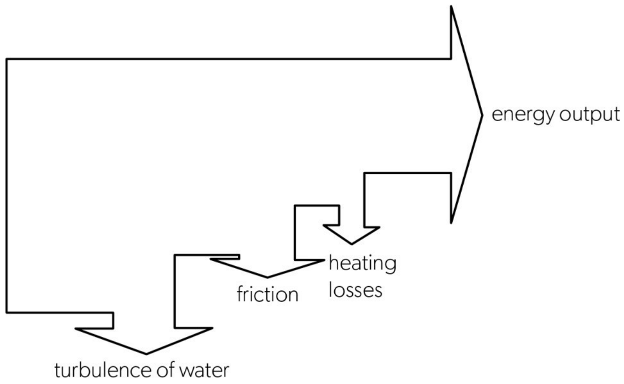
19 77%

20 2.4×10^5 J

Practice questions – Page 128

21 **a.** 53%

b.



A.4 – Rigid body mechanics

Practice questions – Page 133

1 **a.** 0.50 rad s^{-2}

b. 32 revolutions

2 **a.** 900 revolutions per minute

b. 150 revolutions

3 **a.** 1900 rad s^{-2}

b. 0.33 s

4 **a.** 9.5 rad s^{-2}

b. **i.** 4.2 s

ii. 2.7 s

Practice questions – Page 137

5 **a.** Ball A

b. Ball B

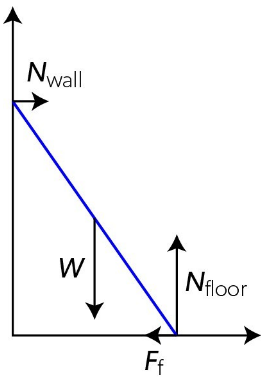
6 A

Practice questions – Page 139

7 **a.** 1.2 kg

b. 26 N

8 **a.**



b. 41 N

c. 0.35

9 **a.** 98 N

b. The vertical component of the tension is less than the weight of the rod hence the force from the wall must have a vertical component to hold the rod in translational equilibrium.

10 D

Practice questions – Page 142

11 B

12 **a.** 75 rad s^{-2}

b. 69 rad s^{-1}

c. 0.92 s

13 **a.** 15 N m

b. 110 N

14 **a.** 0.024 kg m^2

b. 21 revolutions

Practice questions – Page 147

15 **a.** 6.5 J

b. 5.4 m s^{-1}

16 9.5×10^5 N m

17 **a.** 2.6×10^{29} J

b. The assumption in part a. overestimates the moment of inertia hence the actual rotational energy is less than the answer in part **a**.

18 **a.** 170 J

b. 34 W

Practice questions – Page 149

19 B

20 **a.** 22 rad s^{-1}

b. −82 J

Practice questions – Page 154

21 **a.** 4.0 N m s

b. 4800 rpm

22 **a.** 6.5×10^{-4} N m s

b. 4.4×10^{-2} N m

23 **a.** 25 rad s^{-1}

b. The torque is zero so the turntable is in rotational equilibrium

c. 28 revolutions

d. The impulse applied between 8 and 10 s is equal but opposite to the impulse applied between 0 and 1 s.

Practice questions – Page 157–158

24 B

25 **a.** 0.43 m s^{-2}

b. See worked example 23

c. 3.5°

26 **a.** Tension in the thread

b. Hint: consider Newton's second law in the translational and rotational form

c. 1.63 m s^{-2}

d. 1.96 J

27 **a.** 2.4×10^{5} J

b. 0.040. Exactly 4% of the total KE of the car is the rotational energy of the wheels.

A.5 – Galilean and special relativity

Practice questions – Page 174

1 **a.** $x' = 12.1$ km, $t' = 0.131$ ms

b. $x' = 40.4$ km, $t' = 0.183$ ms

2 $x = 610$ km, $ct = 690$ m (2 s.f.)

Practice questions – Page 175

3 **a.** 0.9 m

b. 3.8 ns

4. **a.** Hint: (distance according to spacecraft) = (relative speed) × (5.0 years)

b. 0.66c

Practice questions – Page 177

5 **a.** 0.25c

b. 0.27c

6 **a.** 0.40c

b. 0.81c

Practice questions – Page 180

7 5.0×10^{-11} s

8 **a.** $0.966c$

b. 29.0 m

Practice questions – Page 191–192

9 **a.** **i.** A **ii.** B

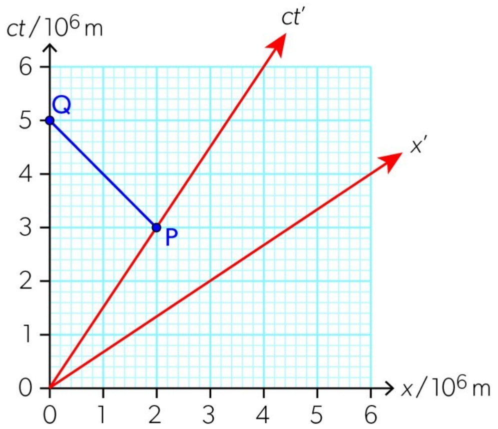
b. **i.** B **ii.** A

10 C

11 D

12 **a.** $\frac{2}{3}c$

b.



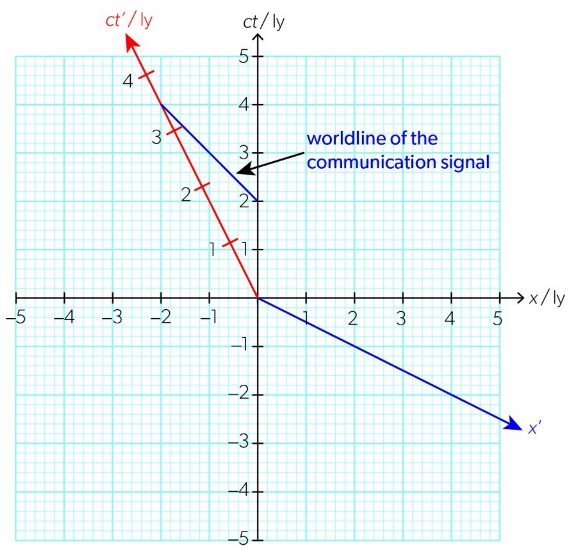
c. **i.** $\frac{2.24 \times 10^6 \text{ m}}{c} = 7.45 \times 10^{-3}$ s

ii. $ct' = 6.71 \times 10^6$ m, $x' = -4.47 \times 10^6$ m

d. **i.** 4.47×10^6 m

ii. 2.00×10^6 m

13 **a.**



b. **i.** approximately 3.5 years

ii. 4 years

c. $x' = 0$, $ct' = 3.46$ ly

End-of-theme questions – Pages 194–195

1 **a.** **i.** 150 N

ii. 4800 W

b. **i.** 0.187 s

ii. The height of the ball decreases by 1.63 m during 0.187 s so the height at the net is 1.2 m.

iii. 64.4 m s^{-1}

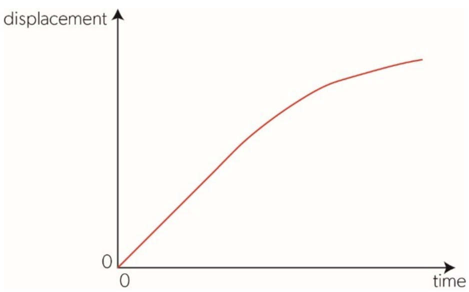
2 **a.** **i.** Hint: elastic energy is the sum of the kinetic and gravitational potential energies of the ice block at C.

ii. 4.9 m s^{-1}

b. **i.** There is zero net force on the block, hence there is constant velocity.

ii. There is a component of weight acting down the slope so the speed decreases.

c.



d. 640 N

3 **a.** **i.** zero

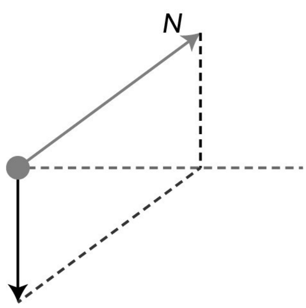
ii. the blades exert a downward force on the air, so the air exerts an equal and opposite force on the blades

iii. 8.1 m s^{-1}

b. 4.6 m s^{-2}

4 **a.** **i.** towards the centre of the circle (horizontally to the right)

ii.



iii. The horizontal component of N provides the centripetal force, so $F = N\cos\theta$.

In the vertical direction, $mg = F\sin\theta$. Combining the equations gives the result.

b. 13 m s^{-1}

c. No, because there is no force to balance the weight.

d. 2.0 m-

5 **a.** The torque is 100 N m so the acceleration $\alpha = \frac{\tau}{I} = 0.22$ rad s^{-2}

b. **i.** 1.7 rad s^{-1}

ii. 750 kg m^2 rad s^{-1}

c. 1.3 rad s^{-1}

d. **i.** moment of inertia will decrease and angular momentum will be constant, so the speed will increase ($L = I\omega$).

ii. 131 J

6 **a.** has the same value in all inertial frames

b. **i.** 504 m^2

ii. 7.5×10^{-8} s

c. B measures the proper time, the time is dilated according to A due to its motion relative to B

Oxford Resources for IB

Physics – 2023 Edition

Answers

Theme B – The particulate nature of matter

B.1 – Thermal energy transfers

Practice questions – Page 202

1 **a.** Resistivity of a metal

b. Measure your property from (a) at 0 °C in ice-water mixture, measure the property at 100 °C in boiling water. Plot both data points on graph of property versus temperature. Draw a straight line between them. Measure property at intermediate unknown temperature and read off temperature from graph.

Practice questions – Page 204

2 A

3 B

Practice questions – Page 209

4 **a.** The molecules of each liquid initially have a different average kinetic energy. During intermolecular collisions, energy is transferred from fast moving molecules of one liquid to slow moving molecules of the other liquid. As a result, the molecular energy is averaged, and the mixture approaches an equilibrium temperature.

b. B

5 D

6 460 J kg^{-1} K^{-1}

7 380 J kg^{-1} K^{-1}

8 **a.** 85.0 °C

b. $\frac{1}{66} \approx 0.015$

9 **a.** 130 s

b. 310 W

10 1200 W

Practice questions – Page 213

11 The specific heat capacity of water is large. So, in winter, the rate of cooling of the water is slow, as larger amounts of energy must be transferred from the water compared to the land. The specific heat capacity of the air (which largely carries the energy away) is constant so the lakes cool slower.

12 **a.** 17 kJ
b. 200 g
c. A mixture of water and ice at 0 °C

13 **a.** 0.13 kg
b. 0.11 kg

14 9.7 s

15 **a.** 76 g
b. 66 kJ kg^{-1}
c. Increases at a lower rate than for t < 10 s

Practice questions – Page 219

16 **a.** 3.1 kW m^{-2}
b. 58 W m^{-2}

17 **a.** 38 W
b. 6.8 g

Practice questions – Page 220–221

18 **a.** 130 W
b. 382 W m^{-1} K^{-1}

19 **a.** around 0.044−0.045 K s^{-1}
b. 9.2−9.4 W
c. 0.11 W m^{-1} K^{-1}

Practice questions – Page 229

20 T_{min} = 4100 K, T_{max} = 7300 K

21 **a.** 2000 K
b. 1400 nm

22 **a.** 180 °C
b. 11 W

Practice questions – Page 231

23 8.6×10^{-8} W m^{-2}

24 5.5×10^{17} m

25 **a.** $4P$
b. $\sqrt[4]{0.25} \times T \approx 0.71T$

B.2 – Greenhouse effect

Practice questions – Page 235

1 350 K

2 0.84

3 **a.** 31 W, absorbed by the cube

b. 2.9×10^{-3} K s^{-1}

c. There are additional ways of transferring energy between the cube and the environment e.g. thermal conduction.

Practice questions – Page 236

4 $$\left(\frac{1.0167}{0.9833}\right)^2 = 1.069$$

The intensity received in January is greater by 6.9% than in July.

5 2.2 kW

Practice questions – Page 240

6 300 W m^{-2}

7 0.25

8 24

Practice questions – Page 243

9 The radiation emitted from the Earth's surface is mostly in the infrared range, and hence can be absorbed by the molecules of greenhouse gases in the atmosphere. The gases re-emit this radiation in all directions, partly back towards the surface.

10 The symmetric mode does not cause the positive and negative charges to be displaced relative to each other within a molecule. Hence, the molecule oscillating in this mode is unlikely to interact with the electric field of the wave. The opposite is true for the anti-symmetric mode.

Practice questions – Page 251

11 **a.** Increase by 1.2 K

b. Water has a lower albedo and absorbs more energy than sea ice, leading to a further increase in the temperature. This is known as positive feedback loop. Clouds have a greater albedo than the surface and so reduce the average intensity reaching the surface, countering the effect of warming. This is an example of negative feedback.

12 **a.** 390 W m^{-2}

b. E.g. evaporation of surface water, thermal conduction to the air above the surface.

c. 104 W m^{-2}

B.3 – Gas laws

Practice questions – Page 254

1 1.7 MPa

2 **a.** 50 kPa

b. 0.10 mm

Practice questions – Page 256

3 Gold: 3.67×10^{22}

Copper: 3.79×10^{22}

About 3% more of copper atoms than gold.

4 1.6×10^{15} molecules

5 0.02 μg

Practice questions – Page 261

6 C

7 D

8 **a.** 1.2×10^{5} Pa

b. 0.17 g

9 **a.** 8.2×10^{-2} mol

b. 9.4×10^{4} Pa

c. 49 N

10 **a.** 3×10^{-7} mol

b. 25 million particles

Practice questions – Page 267

11 These estimates assume a room of dimensions 4.5 m × 3 m × 3 m.

a. 40 m^3

b. 10^{27}

c. 0.1 m^3

12 **a.** 1.5×10^{-21} J

b. 20%

13 In an inelastic collision, energy is removed from the moving particles and transferred away to the environment. The effective temperature of the particles would decrease as they lose kinetic energy and slow down. The assumption of elasticity is very good.

Practice questions – Page 268

14 1300 m s^{-1}

15 483 m s^{-1}

16 2300 m s^{-1}

17 **a.** 0.44 kg m^{-3}

b. 410 m s^{-1}

c. 44 g mol^{-1}

Practice questions – Page 269

18 **a.** 0.047 mol

b. **i.** 1.9 × 10^{-3} kg

ii. 310 J kg^{-1} K^{-1}

19 **a.** 3.76 × 10^{23}

b. 10.3 K

B.4 – Thermodynamics

Practice questions – Page 276

1 D

2 **a.** 0

b. 53 K

3 26 J

4 **a.** **i.** 5.0 J

ii. −2.0 J, energy removed from the gas

b. 5.0 J

Practice questions – Page 279

5 **a.** 7.2 × 10^{-3} mol

b. **i.** 2.0 × 10^{-4} m^3

ii. 400 K

iii. 15 J

6 **a.** −40 J

b. 330 K

c. −60 J

Practice questions – Page 282–283

7 **a.**

	***Q* / J**	**Δ*U* / J**	***W* / J**
AB	**0**	**970**	−970
BC	**−1570**	−1570	**0**
CA	1000	**600**	**400**

b. 570 J

8 **a.** 4.55×10^5 Pa

b. 200 K

9 **a.** 3.10×10^{-4} m^3

b. The change in temperature is proportional to the change in the internal energy. The internal energy increases because the work is done on the gas and no energy is transferred.

c. 174 J (work done by the gas)

d. 75 J

e. 435 J

Practice questions – Page 285

10 **a.** 8.2 kJ

b. 0.71

c. 1000 °C (1270 K)

11 **a.** **i.** AB

ii. CD

b. **i.** 2.40 kJ

ii. 1.44 kJ

12 By reducing T_c to about 30 °C

Practice questions – Page 289–290

13 **a.** **i.** 2.7×10^5 Pa

ii. 832 K

iii. 175 J

b. **i.** 56.0 J

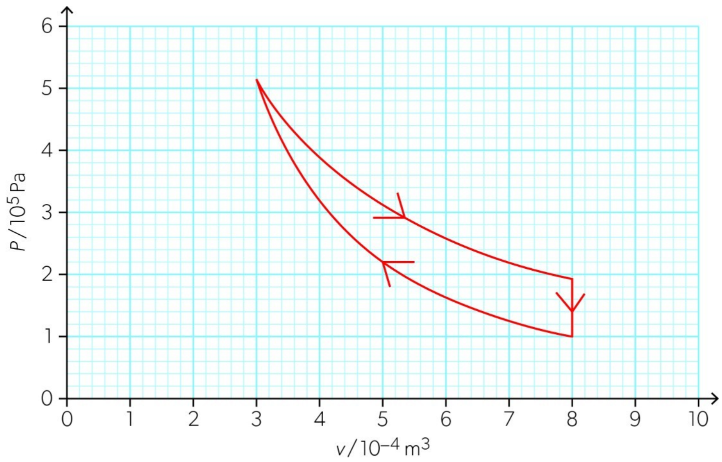
ii. 0.320

14 **a.** **i.** 5.1×10^5 Pa

ii. 615 K

b. 1.9×10^5 Pa

c.



d. 0.27

B.5 – Current and circuits

Practice questions – Page 301

1 **a.** 16 C

b. 1.0×10^{20}

2 75 minutes

Practice questions – Page 304

3 5.1×10^{8} J

4 **a.** 1.1×10^{4} C

b. 2.0 hours

Practice questions – Page 306

5 C

6 **a.** 2.1 kW

b. 9.1 A

7 **a.** 36 A

b. 500 km

c. 5.75 kW

d. 18 hours

Practice questions – Page 309

8 **a.** 6.6 A

b. 1.5 kW

9 **a.** 0.67 A

b. 6.8 Ω

c. 13 C

Practice questions – Page 314

10 D

11 **a.** 880 Ω

b. **i.** 0.26 A

ii. 60 W

12 **a.** 0.17 Ω

b. 2.6×10^{-8} Ω m

13 1.6 mm

14 1.8×10^{-6} Ω m

Practice questions – Page 319

15 **a.** 220 Ω

b. 150 Ω

16 **a.** current = 30 mA, p.d. = 3.0 V

b. current = 22 mA, p.d. = 2.2 V

17 **a.** **i.** 0.40 A

ii. 3.0 Ω

iii. 4.0 A

b. The current in each of the nine remaining lamps is unchanged, the current in the ammeter is the sum of the individual currents in all lamps so it decreases by 10%.

18 **a.** **i.** 2.0 V

ii. 1.0 V

b. 50 Ω

Practice questions – Page 323

19 **a.** 4.13 μA

b. 41.3 mV

c. **i.** 80.6 Ω **ii.** 0.496 mA

20 A

21 From 0.30 A to zero

Practice questions – Page 324

22 8.9 V

23 **a.** 65 Ω

b. 230 V

c. 1.2 mm

24 270 W

25 C

26 D

Practice questions – Page 327

27 **a.** 2.0 Ω

b. 4.5 V

28 B

29 **a.** 9.0 V

b. 1.2 Ω

c. 17 Ω

End-of-theme questions – Pages 330–331

1 **a.**

$$I = \frac{\sigma A T^4}{4\pi d^2} = \frac{5.67\times10^{-8}\times\left(7.0\times10^{8}\right)^2\times5800^4}{\left(1.5\times10^{11}\right)^2} = 1397\ \text{W m}^{-2}$$

b. Transmitted intensity = 0.7 × 1400 = 980 W m^{-2}. The exposed surface is ¼ of the total surface so the average intensity is

$$\frac{980}{4} = 245 \text{ W m}^{-2}$$

c. 256 K

2 **a.** Intensity = $5.67 \times 10^{-8} \times 289^4 = 396$ W m^{-2}

b. The oceans emit short-wave infrared radiation that is absorbed by greenhouse gases in the atmosphere and re-emitted in all directions, partly back towards oceans.

c. **i.** 104 W m^{-2}

ii. E.g. evaporation, thermal conduction to the air above the ocean.

3 **a.** **i.** 2.3×10^6 J kg^{-1}

ii. All of the added energy is used to increase the intermolecular potential energy of the molecules; the temperature is related to the average kinetic energy so remains constant.

b. 86 °C

c. **i.**

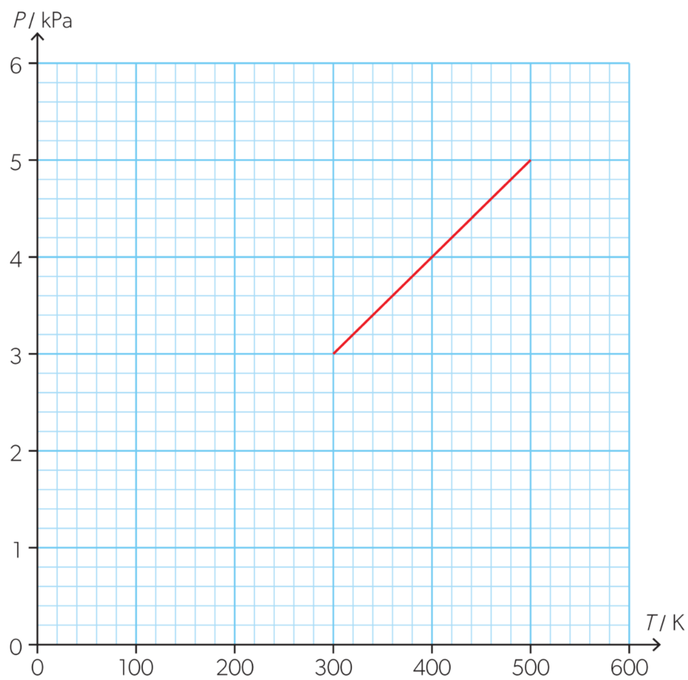
$$R = \frac{V^2}{P} = \frac{220^2}{1600} = 30.25\ \Omega$$

ii. 3200 W

4 **a.** The total random kinetic energy of the particles of the gas.

b. **i.** 3.0×10^3 Pa

ii.



c. The average kinetic energy depends on the temperature only and must be the same for both gases since their temperature is the same.

5 **a.** **i.**

$$\frac{250 \times 10^3}{1.5^{\frac{5}{3}}} = 127 \text{ kPa}$$

ii. 1.31

b. **i.** 940 J

ii. Thermal energy is removed from the gas hence *S* decreases.

iii. The total entropy of the system and the surroundings is the same or increased, and the 2nd law is not violated.

6 **a.** When there is a current in the cell, the potential drops across the internal resistance.

b. 7.2 Ω

c. 0.12

7 **a.** 5.4×10^{-3} m

b. 38 lamps

c. E.g. the brightness of each lamp stays the same when adding more lamps in parallel; the p.d. across each lamp is the operating value in the parallel arrangement but not in series.

8 **a.** Current is not directly proportional to the potential difference, so the resistance of X is not constant.

b. 85 Ω

c. 0.080 W

Oxford Resources for IB

Physics – 2023 Edition

Answers

Theme C – Wave behaviour

C.1 – Simple harmonic motion

Practice questions – Page 371

1 A

2 1.7 ms

3 **a.** 2.5 Hz

b. 3.0 cm

Practice questions – Page 376–377

4 B

5 **a.** 1.8 s

b. 1.4 m

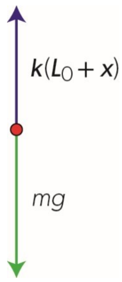
6 **a.** 1.2 s

b. 1.8 N

7 12 N m^{-1}

8 **a.** 0.17 m

b.



c. $kL_0 = mg$, hence F = (spring force) – (weight) = $k(L_0 + x) - mg = kx$

d. The equation of motion is $ma = -kx$ which is the same as for the horizontal system, hence the period is the same.

e. 0.83 s

Practice questions – Page 381–382

9 **a.** **i.** 8.0 ms **ii.** 12 ms

b. **i.** −4.2 m s^{-1} **ii.** 5.6 m s^{-1}

c. 2.3×10^3 m s^{-2}

10 **a.** 2.5 s

b. 4.8 cm

c. 2.8 cm

11 **a.** 1.4 Hz

b. $1.1\ \mathrm{m\ s^{-1}}$

c. $0.92\ \mathrm{m\ s^{-1}}$

Practice questions – Page 384

12 **a.** $x_0 = 3.0$ cm, $\omega = 26\ \mathrm{rad\ s^{-1}}$

$$\phi = -\frac{\pi}{3} \approx -1.0\ \mathrm{rad}$$

b. $79\ \mathrm{cm\ s^{-1}}$

c. $v = 39\ \mathrm{cm\ s^{-1}}$, $a = 1.8 \times 10^3\ \mathrm{cm\ s^{-2}}$

13 **a.** 12.6 s

b. $3.24\ \mathrm{cm\ s^{-1}}$

Practice questions – Page 386

14 **a.** 0.19 J

b. 0.99 J

15 **a.** $0.41\ \mathrm{m\ s^{-1}}$

b. **i.** 1.5 s **ii.** $12\ \mathrm{N\ m^{-1}}$

16 **a.** 15.1 J

b. 0.259 m

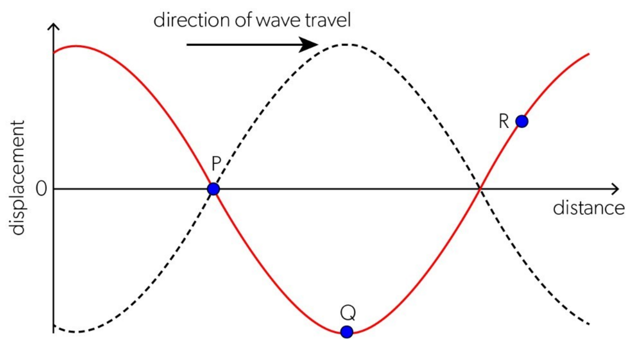
17 C

C.2 – Wave model

Practice questions – Page 396

1 **a.** P: positive, Q: zero, R: negative

b.



2 **a.** 10 mm

b. S; the particles immediately to the left of S are displaced towards it, and so are the particles immediately to the right of S.

c. Q: −10 mm, R: zero, S: +10 mm

3 D

4 **a.** 16.7 Hz

b. π

c. 30 cm

Practice questions – Page 398

5 **a.** 8.0 ms

b. 0.24 m

6 **a.** 0.44 m

b. 0.22 m

7 20 m s^{-1}

Practice questions – Page 400

8 370 m s^{-1}

9 **a.** At 100 Hz the timer cannot measure processes shorter than 10 ms but the expected time of travel between the microphones is about 5.3 ms.

b. At 5 kHz the resolution of the timer is 0.2 ms so the expected percentage uncertainty of time measurement is

$$\frac{0.2}{5.3} \times 100 \approx 4\%$$

If the percentage error of the distance between the microphones is not greater than 1%, then the overall uncertainty of 5% can be achieved.

Practice questions – Page 405

10 20 cm, microwaves

11 4.6×10^{14} Hz

12 390 000 km

C.3 – Wave phenomena

Practice questions – Page 413

1 **a.** 1.13

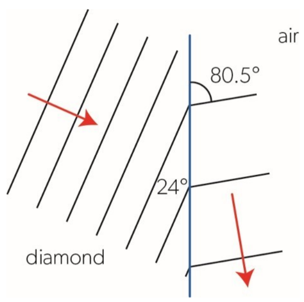
b. 22°

2 **a.** 2.42

b. 186 nm

c. **i.** 80.5°

ii.



Practice questions – Page 415

3 **a.** 50°

b. 30°

c. The angle of incidence on AB will be 90 – 30 = 60°, which is greater than the critical angle.

d. 57°

4 13°

Practice questions – Page 417

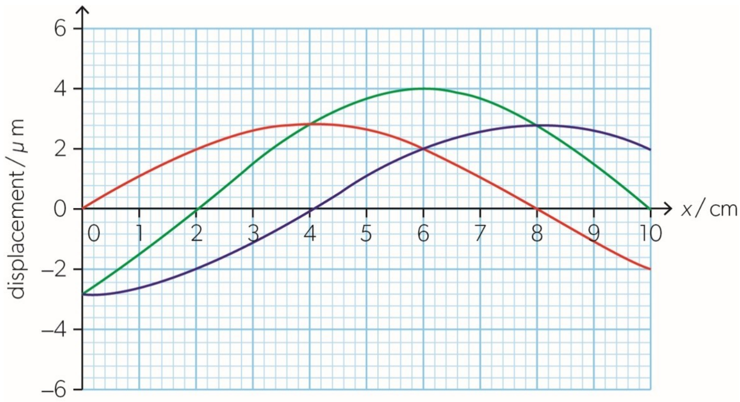
5 B

6 **a.** −2.8 μm

b. **i.** 2.0 cm, 10 cm **ii.** 6.0 cm

c. 4.0 μm

d.



Practice questions – Page 423

7 **a.** 8.0×10^{-3} rad

b. 19 mm

8 C

9 B

Practice questions – Page 427

10 **a.** 592 nm

b. 2.25 mm

11 **a.** The path difference between the waves arriving at the screen from both slits is a half-integer multiple of the wavelength, so destructive interference occurs.

b. 0.25 mm

12 C

Practice questions – Page 430

13 **a.** 0.26 mm

b. 1.3 mm

14 A

Practice questions – Page 434

15 **a.** 300

b. 11

c. 45.2°

16 a. 60°

b. 555 nm

C.4 – Standing waves and resonance

Practice questions – Page 441

1 a. 8.0 cm

b. 30 cm

c. 0.10 s

Practice questions – Page 445

2 a. 500 m s^{-1}

b. 52 cm

3 a. 950 Hz

b. π

4 D

5 B

6 2800 m s^{-1}

Practice questions – Page 449

7 352 m s^{-1}

8 a. 340 Hz, 680 Hz

b. 170 Hz, 510 Hz

9 a. the wavelength is only determined by the length of the pipe, so it remains unchanged (ignoring minute effects of thermal expansion).

b. for a given wavelength, the frequency is proportional to the speed of sound so it will increase with the temperature.

C.5 – Doppler effect

Practice questions – Page 461

1 Maximum 880 Hz, minimum 820 Hz

2 25 m s^{-1}

3 D

Practice questions – Page 462

4 a. 820 Hz

b. 21 m s^{-1}

5 88.9 kHz

Practice questions – Page 465

6 a. 0.012c, moving away

b. 533.3 nm

7 2.94 MHz

Practice questions – Page 469

8 0.42 nm

9 **a.** 12 GHz

b. 18 kHz

10 **a.** the speed of blood cells is much less than the speed of ultrasound, so both the incident and the reflected beam will experience approximately the same frequency shift of *u*/*v*.

b. 9.9 cm s^{-1}

End-of-theme questions – Pages 470–471

1 **a.** Path difference is 1.8 m which is a half-integer multiple of the wavelength of 0.40 m.

b. There will be a series of four maxima and minima of sound between P and Q, and one more maximum detected at Q.

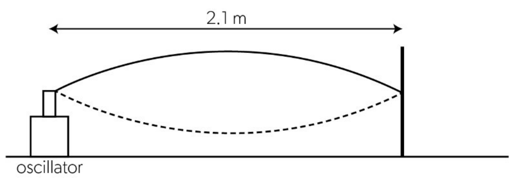
c. **i.** The microphone is moving away from the stationary source so the speed of sound relative to the microphone is less, and the microphone will cross fewer wavefronts in unit time.

ii. 2.00 m s^{-1}

2 **a.** **i.** 250 m s^{-1} **ii.** 830 Hz

b. Q has a larger magnitude of acceleration, because it has a larger displacement and the acceleration is proportional to displacement.

c.



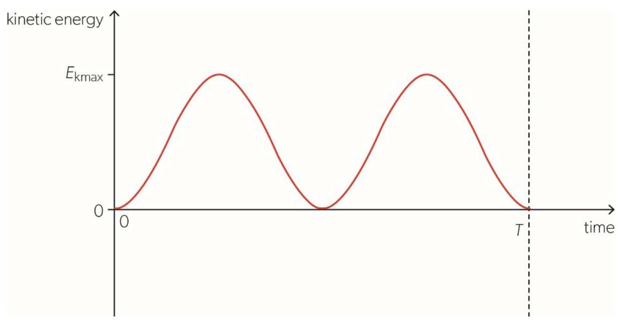
3 **a.** Because the vertical force on the cylinder is proportional to displacement.

b. From the defining equation of SHM:

$$\omega^2 = -\frac{a}{x} = -\frac{F}{mx} = \frac{\rho A g}{m}$$

$$\omega = \sqrt{\frac{1.03\times10^3 \times 2.29\times10^{-1} \times 9.8}{118}} = 4.43 \text{ rad s}^{-1}$$

c. **i.**



ii. 71.4 J

4 **a.** 5.7 m s^{-2}

b. 2.6°

c. 1.4 m

d. **i.** 1400 Hz **ii.** 0.24 m

5 **a.** 560 nm

b. **i.** The interference pattern will be modulated by single slit diffraction, so the intensity of the maxima will decrease away from the central maximum.

ii. The angular position of this point is 0.01867 rad which coincides with the first minimum of the diffraction envelope.

Oxford Resources for IB

Physics – 2023 Edition

Answers

Theme D – Field

D.1 – Gravitational fields

Practice questions – Page 480

1 **a.** 6.9×10^{-9} N

b. 0.66 m

2 **a.** 1.6×10^{14} kg

b. 6.8×10^{-9} m s^{-2}

Practice questions – Page 481

3 0.997

4 32 km

5 B

Practice questions – Page 485

6 D

7 2.0 days

8 3.5×10^{11} m

Practice questions – Page 487

9 **a.** 6.4×10^{23} kg

b. 2.3×10^{7} m

10 7.08×10^{3} s (approximately 2 hours)

Practice questions – Page 493

11 **a.** 1.2×10^{9} J

b. 0.58 m s^{-2}

12 **a.** 3.0×10^{7} J

b. around 5500 to 6000 km

Practice questions – Page 452

13 **a.** $\sqrt{1.5} \simeq 1.22$

$-\frac{1}{3}E$

b.

14 **a.** 4.2×10^{10} J

b. 5.8×10^{7} J

15 **a.** $8\ m\ s^{-1}$

b. 8×10^{16} kg

Practice questions – Page 501

16 $4.2 \times 10^{4}\ m\ s^{-1}$

17 **a.** 2.1×10^{10} J

b. $1.1 \times 10^{4}\ m\ s^{-1}$

c. 1.9×10^{10} J

D.2 – Electric and magnetic fields

Practice questions – Page 510

1 **a.** 15 nC

b. **i.** 0.20 mN

ii. 0.39 mN

2 **a.** 3.0 N

b. 78 mm

Practice questions – Page 512

3 **a.** $1.0 \times 10^{21}\ N\ C^{-1}$

b. 160 N

4 -3.3×10^{-9} C

5 1.5 m

Practice questions – Page 514

6 **a.** $1.6 \times 10^{7}\ N\ C^{-1}$, to the left

b. 81 mN, to the right

7 A

8 D

Practice questions – Page 519

9 **a.** $67\ kV\ m^{-1}$

b. −60 nC

10 **a.** $80\ kV\ m^{-1}$

b. 1.6 kV

Practice questions – Page 525

11 $2.0 \times 10^{5}\ V\ m^{-1}$, vertically downwards

12 **a.** 6e

b. 8 electrons

Practice questions – Page 532

13 **a.** −2.9 V

b. **i.** $+3.7 \times 10^{-9}$ J

ii. -2.6×10^{-9} J

c. **i.** $+7.5 \times 10^{-9}$ J

ii. -5.2×10^{-9} J. Negative work indicates that the potential energy of the system decreases.

14 **a.** -4.9×10^{-4} J

b. $+4.9 \times 10^{-4}$ J

15 **a.** 120 V

b. 240 V m^{-1}

Practice questions – Page 539

16 **a.** C

b. D

17 A

D.3 – Motion in electromagnetic fields

Practice questions – Page 544

1 A

2 C

Practice questions – Page 549

3 **a.** 7.5×10^{-5} N m^{-1}

b. zero

4 1.8×10^{-5} N, to the left

Practice questions – Page 552

5 5.2×10^{6} m s^{-1}

6 **a.** 1.0×10^{4} m s^{-1}

b. 7.3×10^{3} m s^{-1}

Practice questions – Page 555

7 **a.** positive

b. $$q = \frac{mv}{BR}$$

8 B

9 **a.** 1.9 cm

b. 9.6×10^{5} m s^{-1}

Practice questions – Page 558

10 **a.** 1.13×10^5 m s^{-1}

b. 28.3 kV m^{-1}

11 **a.** 9.05×10^4 m s^{-1}

b. 1.17×10^{-26} m s^{-1}

12 D

D.4 – Induction

Practice questions – Page 566

1 **a.** 0.10 A

b. **i.** 0.40 V

ii. 3.3 m s^{-1}

iii. 40 mW

2 0.19 V

Practice questions – Page 573

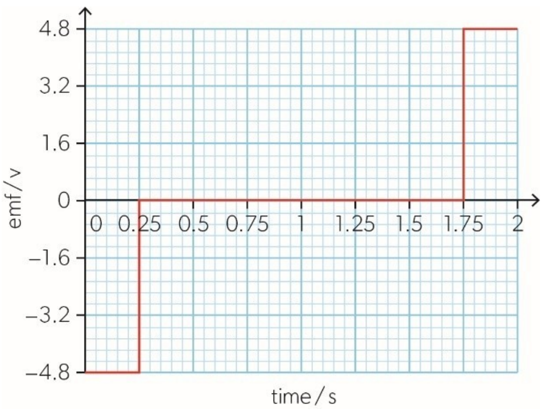
3 **a.** 1.4×10^{-3} Wb

b. 17 mV

c. 7.2 mJ

4 **a.** 0.75 T

b.



c. 0.32 m s^{-1}

d. **i.** anti-clockwise

ii. clockwise

e. 23 W

5 B

6 D

Practice questions – Page 580

7 **a.** 0.90 W

b. 0.15 A

c. 0.21 A

8 **a.** 31 W

b. 18 V

9 C

End-of-theme questions – Pages 584–585

1 **a.** The velocity of the planet is constantly changing, and its acceleration is directed towards the centre of the orbit, so there must be a force directed towards the centre.

b. 8.8×10^{23} N

c. **i.** $$V = -\frac{6.67\times10^{-11}\times8.0\times10^{24}}{9.1\times10^{6}} - \frac{6.67\times10^{-11}\times3.2\times10^{30}}{4.4\times10^{10}} = -4.9\times10^{9}\ \text{J kg}^{-1}$$

ii. 9.9×10^{4} m s^{-1}

2 **a.** **i.** gravitational attraction of Mars

ii. the force is perpendicular to the velocity

b. **i.** The centripetal acceleration is provided by the gravitational force so

$$\frac{GM}{R^2} = \frac{v^2}{R} = \frac{(2\pi R/T)^2}{R}$$

which leads to

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$$

ii. 6.4×10^{23} kg

c. 7.4×10^{24} kg

3 **a.** $$E = \frac{kq}{r^2} = \frac{8.99\times10^{9}\times6.0\times10^{-3}}{0.4^2} = 3.37\times10^{8}\ \text{N C}^{-1}$$

b. **i.** $5.9\times10^{19}\ \text{m s}^{-2}$

ii. The electron moves away from the point charge with decreasing acceleration and increasing speed.

4 **a.** Initially, the magnetic force is directed to the left. This is perpendicular to the velocity of the proton so its direction of motion will change but not the speed. The force will remain constant in magnitude and provide the centripetal acceleration.

b. **i.** $$qvB = \frac{mv^2}{R}\text{, hence } R = \frac{mv}{qB} = \frac{1.67\times10^{-27}\times2.0\times10^{6}}{1.6\times10^{-19}\times0.35} = 0.060\ \text{m}$$

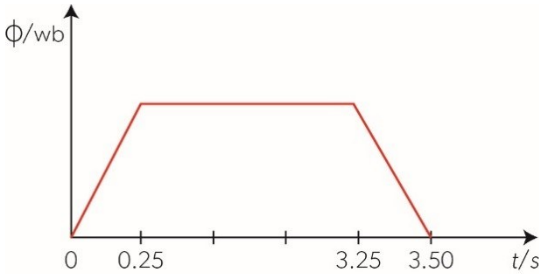
ii. 1.9×10^{-7} s

c. The change in the kinetic energy is equal to the work done by the net force; in this case the force is perpendicular to the velocity so the work done is zero.

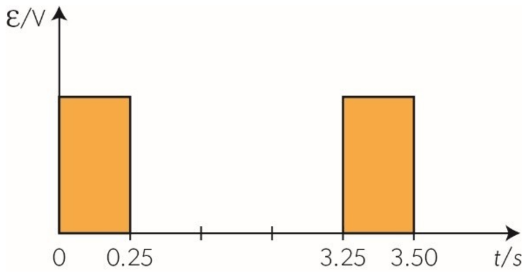
$$v = \frac{70}{3.5} = 20 \text{ cm s}^{-1}$$

5 **a.**

b. **i.**



ii.



c. **i.** 0.80 V

ii. 1.3 N

d. **i.** $E = fvt$ = 1.3 × 0.20 × 0.50 = 0.13 J

ii. 1.9×10^{-2} K

$$Q = \frac{VR}{k} = \frac{3.4 \times 10^5 \times 0.48}{8.99 \times 10^9} = 18.2\,\mu\text{C}$$

6 **a.**

b. **i.** electrons leave the small sphere, making it positively charged.

ii. q_1 = 12 μC, q_2 = 6.0 μC

7 **a.** The magnet gets closer to the ring so the magnetic field at the position of the ring is increasing.

b. Diagram showing an arrow going anticlockwise.

c. The induced magnetic field is upwards, so the force in the magnet is repulsive.

Oxford Resources for IB

Physics – 2023 Edition

Answers

Theme E – Nuclear and quantum

E.1 – Structure of the atom

Practice questions – Page 597

1 128

2 **a.** 12 fm

b. 26 MeV

Practice questions – Page 601

3 **a.** **i.** 1550 nm

ii. 258 nm

b. from −2.30 eV to −6.30 eV

4 **a.** 2.10528 eV and 2.10315 eV

b. 2.13×10^{-3} eV

Practice questions – Page 610

5 **a.** As the spectrum is a series of lines these energy states must be discrete not continuous.

b. The wavelengths absorbed/emitted by the gas are unique to the atoms in the sample. By matching the wavelengths to known spectra the atomic species in the sample can be identified.

6 **a.** 3

b. arrow from −2.74 eV to −5.01 eV

c. $$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^{-6}}{-2.74 + 5.01} = 546\,\text{nm}$$

7 **a.** 3.14×10^{-19} J

b. 8.0×10^{15} photons

8 **a.** B

b. **i.** $n = 3$

ii. 2.4×10^{-19} J

iii. Use the following

$$f = \frac{E_3 - E_1}{h}$$

where E_3 and E_1 should be calculated using Bohr's formula for energy levels.

c. $n = 5$

E.2 – Quantum physics

Practice questions – Page 618

1 **a.** 1.0×10^{15} Hz

b. **i.** 1.4×10^{-19} J **ii.** 5.5×10^{5} m s^{-1}

c. **i.** unchanged **ii.** increases

2 **a.** 7.3×10^{5} m s^{-1}

b. 330 nm

3 **a.** 2.6 eV

b. 1.1 V

Practice questions – Page 624

4 **a.** 1.7 keV

b. 3.6×10^{-12} m

c. 120°

5 **a.** incident: 6.2×10^{-11} m, scattered: 6.6×10^{-11} m

b. 1.2 keV

6 **a.** The particle model suggests that the energy of a photon is directly proportional to its frequency. A scattered X-ray has a smaller frequency (longer wavelength) and therefore smaller energy than the incident X-radiation. Typical processes for a wave model (e.g., scattering, diffraction) do not involve a wavelength shift. Compton modelled the interaction between an X-ray photon and a free electron using a mechanical collision process. His theoretical predictions were confirmed by the data that he collected. This showed that the photons were interacting as particles, not waves. Therefore, this observation supports the particle model.

b. 160°

c. 4.8×10^{-23} N s

Practice questions – Page 627

7 **a.** 1.0×10^{-15} m

b. 3.9×10^{-11} m

8 8×10^{-2} eV

E.3 – Radioactive decay

Practice questions – Page 634

1 **a.** ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$

b. 146

2 **a.** ${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}\alpha$

b. 93 keV

Practice questions – Page 635

3 Electron ($^{\ 0}_{-1}\beta$) and electron antineutrino ($\bar{\nu}_e$).

4 $^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{1}\beta^{+} + \nu_e$

Practice questions – Page 642

5 **a.** **i.** 0.137005 u **ii.** 127.6 MeV

b. **i.** 0.543708 u **ii.** 506.5 MeV

c. **i.** 1.756788 u **ii.** 1.636 GeV

6 **a.** 1.1×10^{12} J

b. 300 MWh

Practice questions – Page 645

7 **a.** 7.976 MeV

b. 8.732 MeV

c. 7.868 MeV

8 **a.** 4.3 MeV

b. 632 keV

Practice questions – Page 652

9 **a.** 3 days

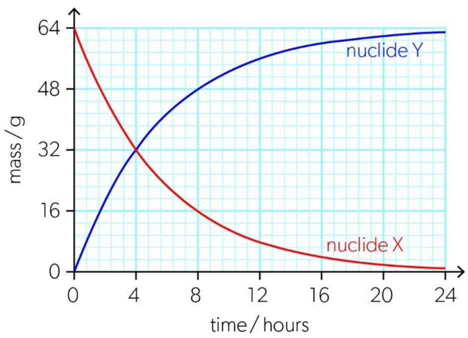
b. $0.031A_0$

c. 12 days

10 **a.** 56 g

b. 24 hours

c.



11 8.03 days

12 B

Practice questions – Page 656

13 **a.** 4 count s^{-1}

b. 5 count s^{-1}

14 60 count $minute^{-1}$

Practice questions – Page 660

15 **a.** 2.86×10^{8} Bq

b. 244 days

c. 4.30 μg

16 **a.** 5.7×10^{-3} s

b. 50 Bq

Practice questions – Page 661

17 **a.** 1.55×10^{-7} s

b. 51.9 days

c. 170 days

18 **a.** 1.4×10^{-11} s

b. 37000 s^{-1}

E.4 – Fission

Practice questions – Page 671

1 **a.** 2.8×10^{-11} J

b. 7.9×10^{-4}

c. 5.3 kg

2 **a.** 3

b. 188 MeV

E.5 – Fusion and stars

Practice questions – Page 682

1 3 × 2.573 – 2 × 1.112 = 5.495 MeV

2 **a.** 3.27 MeV

b. 7.84×10^{13} J

3 4.8 MeV

4 **a.** 6.1×10^{11} kg

b. 4.3×10^{9} kg

Practice questions – Page 686

5 **a.** $6.3L_{\odot}$

b. main sequence star

6 $10R_{\odot}$

7 D

Practice questions – Page 693

8 **a.** Mu Columbae has more hydrogen in the core than the Sun but its rate of fusion is much higher, so hydrogen fusion processes will stop much earlier than in the Sun.

b. The Sun will fusion helium into carbon in the red giant stage but will not reach temperatures high enough for fusion of heavier elements. Mu Columbae is likely to become a supergiant star, fusing heavier elements than helium until it develops an iron core.

c. The mass of the Sun is less than the Chandrasekhar limit so its final evolutionary stage will be white dwarf. Mu Columbae will undergo supernova explosion and its remnant mass may be greater than the Oppenheimer-Volkoff limit, leading to a formation of a black hole.

9 **a.** Relatively small radius and luminosity, relatively large surface temperature and density

b. The inward gravitational forces are balanced by electron degeneracy pressure.

c. White dwarfs do not undergo fusion and the energy they radiate comes from residual thermal energy of the star.

Practice questions – Page 697

10 **a.** The stellar parallax method is only suitable for stars relatively close to Earth where the angles are measurable using present technology. When the method is used from the Earth's surface parallax is further limited by dust and convection currents in the atmosphere. Measurements carried out from satellites extend the range considerably.

b. **i.** 3.5×10^{17} kg

ii. 6.5×10^{28} W

c. 4300 K

d. 1.7×10^{10} m

11 **a.** 5.5×10^{5} AU

b. 0.37 arc-second

c. 1.1×10^{-7} W m^{-2}

12 **a.** 35.9 ly

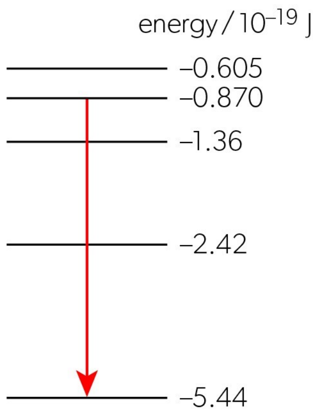
b. $14L_{\odot}$

c. The luminosity and radius of a star lead to the surface temperature. This gives the position on the HR diagram and its mass. It is the mass that gives an indication of the future evolution of the star whether to white dwarf, neutron star or black hole.

End-of-theme Questions – Pages 698–699

1 **a.** 4.6×10^{-19} J

b.



2 **a.** **i.** Centripetal force is equal to the electrical force, hence

$$\frac{2ke^2}{r^2} = \frac{mv^2}{r}$$

Algebraical rearrangement of the equation gives the result.

ii. $E_k = \frac{ke^2}{r}$ and $E_p = -\frac{2ke^2}{r}$

The total energy is the sum $E_k + E_p$

iii. The total energy decreases so, because of the equation derived in **ii.**, the radius must also decrease.

b. **i.** $n = 3$, $v = 1.44 \times 10^6$ m s^{-1}

$$\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times1.44\times10^6} = 5.05\times10^{-10}\text{ m}$$

ii. 2.99 ≈ 3

3 **a.** $^{18}_{9}\text{F} \rightarrow {}^{18}_{8}\text{O} + {}^{0}_{1}\beta^+ + {}^{0}_{0}\nu$

b. **i.** 630 keV

ii. The decay energy is the same for every decaying nucleus but it is divided between the beta particle and the neutrino in a probabilistic way.

c. **i.** 110 minutes

ii. 1.05×10^{-4} s^{-1}

iii. 0.24 mg

4 **a.** $^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\alpha$

b. **i.** Fusion involves positively charged particles that must have high enough kinetic energy to overcome Coulomb repulsion. Kinetic energy of the particles increases with temperature.

ii. Energy is released when binding energy per nucleon increases, which happens when light nuclei undergo fusion or heavy nuclei undergo fission.

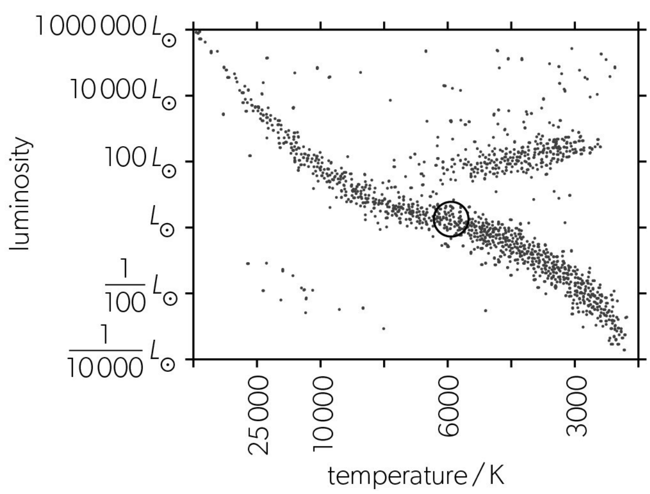
iii. 160 MeV

5 **a.** **i.** $T = \frac{2.9\times10^{-3}}{490\times10^{-9}} = 5900\text{ K}$

ii. 2.2

iii. $1.2L_\odot$

b. **i.**



ii. main sequence star

Oxford Resources for IB

Physics – 2023 Edition

Answers

Tools for Physics

Mathematical tools for physics

Practice questions – Page 338

1 12 m s^{-1}

2 109 cm^3

3 0.116 A

4 The force acting on the girl from the ground is equal to change in pressure over change in time. Estimate both the time the girl takes to land and her mass. Her landing speed comes from a *suvat* equation and your guess at a safe height for a wall.

5 The density of common construction materials is roughly about 2000 kg m^{-3}. Either estimate the dimensions of the walls, floors and so on or estimate the number of bricks or blocks used in the construction and the weight of each block. Do you have to consider the weight of any steel used in the construction? Are the internal furnishings important in the estimate?

6 Estimate the number of characters on the average page. Count a few lines to estimate the number of characters on the average line. Multiply the number of pages by your estimate of characters/page. Some characters (capitals etc) require two depressions. Decide whether it is important to include this.

7 Review the dimensions of each building in your school and estimate the area of each building. Do not forget to allow for buildings with more than one floor. Will stairs make a difference to your estimate?

8 Open the lid of a grand piano or look at a photograph of the interior of the instrument. Divide the strings into three groups: the lowest frequencies with one string, the middle frequencies with two and the high frequencies with three. Estimate an average string length for each group. Estimate the number of strings per group. Hence the total estimate length of string. You could go on to suggest whether the mass of the metal of the strings is significant in estimating the mass of the instrument.

Handling data and modelling physics

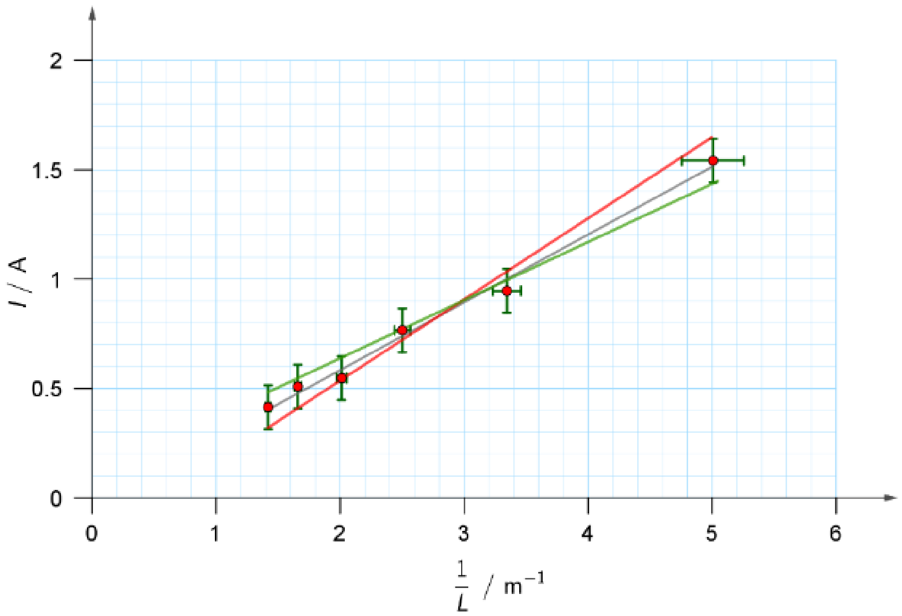
Practice questions – Page 360

1 **a** The model predicts that I is directly proportional to $1/L$. The line of best fit is straight and passes through the origin when extrapolated (within experimental uncertainties), so the data are consistent with the model.

$$k = \text{gradient} = \frac{1.5 - 0.40}{5.0 - 1.4} = 0.31\ \text{A m}$$

b

c One possibility is shown below.



d Max gradient = 0.37 A m, min gradient = 0.27 A m

$$\Delta k = \frac{0.37 - 0.27}{2} = 0.05\ \text{A m}$$

k = (0.31 ± 0.05) A m

Oxford Resources for IB

Physics – 2023 Edition

Answers

Extended response questions – Pages 700–701

Question 1

a. The equation assumes constant acceleration. From the graph, the net force is changing with time hence the acceleration is changing, too.

b. i. The peak force is about 120 N so the maximum acceleration is

$$\frac{F}{m} = \frac{120}{75} = 1.6\ \text{m s}^{-2}$$

ii. The area under the graph represents the impulse delivered to the bicycle. The area is approximately 24 grid squares, and each grid square is 20 N s. Area = 24 × 20 = 480 N s.

$$m\Delta v = \Delta p \Rightarrow \Delta v = \frac{\Delta p}{m} = \frac{480}{75} = 6.4\ \text{m s}^{-1}$$

The final speed of the bicycle is 6.4 m s^{-1}.

c. i. Power output $V \times I = 42 \times 6.2 = 260$ W.

ii. The difference between the emf and the terminal p.d. is equal to the potential drop on the internal resistance r.

$$48 - 42 = 6.2r\text{, hence } r = \frac{48-42}{6.2} = 0.97\ \Omega$$

iii. The increase in the gravitational PE during the entire ride is 75 × 9.8 × 420 = 3.1 × 10^5 J

The rate of change is therefore

$$\frac{3.1 \times 10^5}{40 \times 60} = 130\ \text{W}$$

iv. Useful power output is only 50% of the power transferred from the battery, so there are undesired energy losses. Possible mechanisms include work done against air resistance and other frictional forces, and mechanical inefficiency of the motor and gearing.

d. The gravitational field strength decreases with the square of the distance from the centre of the Earth. The relative change during the ride is

$$\frac{\Delta g}{g} = \frac{\frac{1}{R^2} - \frac{1}{(R+h)^2}}{\frac{1}{R^2}}$$

where R = 6370 km is the radius of the Earth and h = 0.420 km is the gain in height. The calculation gives

$$\frac{\Delta g}{g} = 1.3 \times 10^{-4} = 0.013\%$$

The field strength changes by a hundredth of a percent, so by all practical means it can be considered constant.

e. **i.** The work done by the brakes is equal to the change in the kinetic energy of the bicycle:

$$\Delta E_k = \frac{1}{2} \times 75 \times \left(\frac{25}{3.6}\right)^2 = 1.8 \times 10^3 \text{ J}$$

This in turn is equal to the thermal energy transferred to the brakes. The increase in temperature is therefore

$$\Delta T = \frac{\Delta E_k}{mc} = \frac{1.8 \times 10^3}{0.300 \times 850} = 7.1 \text{ K}$$

ii. The calculation assumes that thermal energy accumulates in brakes during deceleration, which is not realistic as brake rotors are moving parts exposed to air and part of the energy will be transferred to the air before the bicycle stops. On the other hand, the rotors are not heated uniformly across their volume and the temperature of the surface in immediate contact with the pads may temporarily rise much more than the calculation suggests.

The solution ignores the work done on the bicycle by other forces, e.g. air resistance or the component of weight parallel to the road, if braking takes part on a slope.

Question 2

a. **i.** Spectral lines are observed when an atom absorbs or emits a photon of energy corresponding to the wavelength of the line, and the energy of the atom changes by the amount equal to the energy of the photon. Since spectral lines have discrete wavelengths, the energy of the atom can only change between a set of specific energy values, known as atomic energy levels.

ii. The photon with the greatest energy is the one with the shortest wavelength, 501.6 nm.

$$E = \frac{hc}{\lambda} = \frac{1.99 \times 10^{-25}}{501.6 \times 10^{-9}} = 3.97 \times 10^{-19} \text{ J}$$

b. **i.** The difference between the emitted and observed wavelength is due to relative motion of the star and the observer on the Earth. The observed wavelength is periodically above and below the laboratory wavelength, so the star periodically moves towards and away from the observer. This can be explained as orbital motion of the star around another body in a binary system.

ii. Use the Doppler effect formula:

$$v = \frac{\Delta\lambda}{\lambda} c = \frac{588.7 - 587.6}{587.6} \times 3 \times 10^8 = 5.6 \times 10^5 \text{ m s}^{-1}$$

c. **i.** The surface temperature is related to the peak wavelength of the black-body spectrum by Wien's displacement law.

$$T = \frac{2.9 \times 10^{-3}}{340 \times 10^{-9}} = 8500 \text{ K}$$

ii. The distance in parsec is the reciprocal of the parallax angle in arc-second:

$$d = \frac{1}{6.5 \times 10^{-3}} = 154 \text{ pc.}$$

Conversion to light years is straightforward: $d = 154 \times 3.26 = 500 \text{ ly}$

iii. The intensity of radiation coming from the star, as measured on the Earth.

iv. The apparent brightness together with the distance to the star can be used to determine the luminosity L of the star. Since the absolute temperature of the star is known, its total surface area A can be estimated from the Stefan–Boltzmann law, $A = \frac{L}{\sigma T^4}$. Assuming that the star can be modelled as a sphere, its radius can be calculated from the surface area.

d. i. Kepler's laws are a consequence of the law of gravitation and other laws of mechanics. We believe that these fundamental laws are the same throughout the observable Universe, so they allow us to make detailed predictions of the same type as to the orbital motion of planets in other stellar systems.

ii. Kepler's third law, in its generalized form, links three quantities: orbital radius and period of a planet, and the mass of the central star. The radius of the orbit can be determined from this law if, in addition to the orbital period, we have an independent estimate of the mass of the star.

Question 3

a. A collision in which the total mechanical energy of the system is unchanged.

b. i. The momentum gained by stone B is equal but opposite to the change in momentum of stone A. We first calculate the *x*- and *y*-components of *p*, then the magnitude.

$$p_x = 0.10 \times 1.6 - 0.10 \times 1.0 \times \cos 60° = 0.11 \text{ N s}$$

$$p_y = 0.10 \times 1.0 \times \sin 60° = 8.7 \times 10^{-2} \text{ N s}$$

$$p = \sqrt{p_x^2 + p_y^2} = 0.14 \text{ N s}$$

ii. The change in momentum of the stones is equal to the impulse transferred between them.

$$\text{Force} = \frac{\text{impulse}}{\text{time}} = \frac{0.14}{4.0 \times 10^{-4}} = 350 \text{ N}$$

iii. The kinetic energy lost by stone A is

$$\frac{1}{2} \times 0.10 \left(1.6^2 - 1.0^2\right) = 7.8 \times 10^{-2} \text{ J}$$

The kinetic energy gained by stone B is

$$\frac{0.14^2}{2 \times 0.20} = 4.9 \times 10^{-2} \text{ J}$$

which is less than energy change of stone A, hence the collision is not elastic.

c. In the particle model, the incident X-ray photon transfers some of its energy to a recoil electron. The energy of the photon decreases hence the wavelength increases.

d. **i.** We use the Compton scattering equation:

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos 60^\circ) = 1.2\times10^{-12}\ \text{m}$$

ii. The momentum of the electron-photon system is conserved hence the initial momentum of the electron is equal to the change in momentum of the scattered photon, which can be determined if the energy or the wavelength of the photon is known.

iii. The energy of the recoil electron is equal to the energy change of the photon,

$$\frac{hc}{\lambda_i} - \frac{hc}{\lambda_f} = \frac{1.24\times10^{-6}}{1.0\times10^{-10}} - \frac{1.24\times10^{-6}}{1.0\times10^{-10}+1.2\times10^{-12}} = 147\ \text{eV}$$

e. **i.** The centripetal force equation is

$$\frac{m_e v^2}{r} = evB$$

Rearranging for r gives

$$r = \frac{m_e v}{eB}$$

The speed v of the electron can be calculated from the kinetic energy:

$$\frac{1}{2}m_e v^2 = 147\times1.6\times10^{-19} \Rightarrow v = 7.2\times10^6\ \text{m s}^{-1}$$

The radius of the path is

$$r = \frac{9.11\times10^{-31}\times7.2\times10^6}{1.6\times10^{-19}\times2.0\times10^{-3}} = 2.0\ \text{cm}$$

ii.

$$\frac{v}{c} = \frac{7.2\times10^6}{3.0\times10^8} = 0.024$$

The ratio v/c is much less than one, so the electron's speed is much less than the speed of light. Relativistic effects become important when $v/c > 0.2$.

f. The change in photon's wavelength is constant at a given scattering angle. The wavelength of the incident photon is now shorter, so the same increase in the wavelength in absolute terms corresponds to a greater percentage increase. The proton undergoes a greater relative change in energy, and so a greater percentage of the energy is now transferred to the electron.

g. Radioactive decay can be modelled as repeatedly rolling a large number of dice and removing all dice that land with a particular number upwards. This provides a visual link to an invisible phenomenon and illustrates the random nature of the radioactive decay.

Analogy between gravitational and electric fields allows to apply the results obtained in one area to the other.