

Exam-style question answers and commentaries

Chapter 1

Answers to question 1

ANSWER A

a f ✗

e This is the inverse of a base quantity, but it is not a base quantity. Mark: 0/1

b i kg m s^{-2} ✓

e The student has correctly identified the base units from which the newton is derived. Mark: 1/1

ii Rearranging the equation gives:

$$\mu = \frac{T}{f^2 2L}$$

in units $\mu = \frac{\text{N}}{\text{s}^{-2} \text{m}}$

$$= \frac{\text{kg m s}^{-2}}{\text{s}^{-2} \text{m}}$$

$$= \text{kg} \text{ ✗}$$

e This is a good effort, but the student has failed to recognise that the $2L$ needed to be squared. Mark: 0/1

ANSWER B

a L only ✓

e L is the only base unit so the student scores this mark. Mark: 1/1

b i T is measured in newtons; the base units coming from $F = ma$, giving kg m s^{-2} ✓

e This is an excellent answer, with the student showing how they worked out the base units. Mark: 1/1

ii Rearranging the equation gives:

$$\mu = \frac{T}{f^2 4L^2}$$

in units $\mu = \frac{\text{N}}{\text{s}^{-2} \text{m}}$

$$= \frac{\text{kg m s}^{-2}}{\text{s}^{-2} \text{m}}$$

$$= \text{kg m}^{-1} \text{ ✓}$$

e The answer is clearly set out and correctly worked through. Mark: 1/1

Answers to question 2

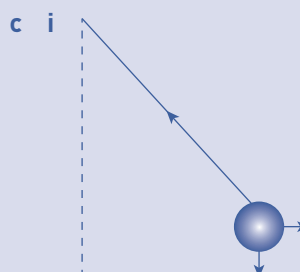
ANSWER A

a A vector quantity has direction as well as magnitude ✓✗.

e The student recognises the nature of a vector, but does not finish the explanation by stating that a scalar has magnitude but no direction. Mark: 1/2

b Weight = $10 \times 50 = 500 \text{ N}$ ✗✗

e At this level, it is mandatory to use three significant figures for the acceleration of free fall. The student also fails to convert the mass into kilograms. Mark: 0/2



e The student has identified the directions of the forces but has omitted to label them. Mark: 2/3

ii $T \cos 30 = W$
 $T = \frac{W}{\cos 30} = \frac{500}{0.866} = 580 \text{ N} \checkmark\checkmark$
 iii $F = W \sin 30 \times$
 $= 500 \times 0.5 = 250 \text{ N} \times$

- e** The first calculation is correct, allowing error carried forward from part b. The second calculation should recognise that the horizontal force would be equal to the horizontal component of the tension, not the weight, which has horizontal component zero. Mark: 2/4

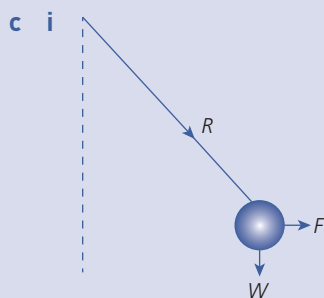
ANSWER B

- a** A scalar quantity has magnitude only whereas a vector quantity has direction as well as magnitude $\checkmark\checkmark$.

- e** This is a good and complete answer. Mark: 2/2

- b** $\text{Weight} = 9.81 \times 50 \times 10^{-3} = 0.49 \text{ N} \checkmark\checkmark$

- e** This is a good answer, with clear working. Mark: 2/2



- e** This is a reasonable effort. However, the tension force on the bob acts in the opposite direction. Mark: 2/3

ii $T \cos 30 = W$
 Therefore:
 $T = \frac{W}{\cos 30} = \frac{0.49}{0.866} = 0.57 \text{ N} \checkmark\checkmark$
 iii $F = T \sin 30$
 $= 0.57 \times 0.5 = 0.29 \text{ N} \checkmark\checkmark$

- e** Both calculations are correct. Mark: 4/4

Chapter 2

Answers to question 1

ANSWER A

- a** acceleration = gradient of the graph
 $= \frac{8.8 - 0}{0.90 - 0}$
 $= 9.8 \text{ m s}^{-2} \checkmark \times$

- e** The student recognises that the acceleration is equal to the gradient, and correctly identifies suitable points on the graph. However, the lower line of the equation should read $(0 - 0.9)$. A compensation mark is given. Mark: 1/2

- b** The brick is slowing down $\checkmark$.

- e** This statement is not convincing but it is just enough to earn the mark. Mark: 1/1

- c** distance = area under the graph
 $= (\frac{1}{2} \times 8.8 \times 0.90) + \times (\frac{1}{2} \times 1.40 \times 0.14) \checkmark$
 $= 4.1 \text{ m}$

- e** The student recognises that the area under the graph is equal to the distance travelled but unfortunately does not realise that for the last 0.14 s the brick is moving downwards, so the velocity is negative. Nevertheless, it is easy to spot the error so only 1 mark is lost. Mark: 1/2

- d** The brick will be moving downwards not upwards $\times$.

- e** This is wrong. The brick had started to move downwards in the earlier example. Neither does it answer the question. Mark: 0/1

ANSWER B

- a** acceleration = gradient of the graph
 $= \frac{8.8 - 0}{0 - 0.90}$
 $= -9.8 \text{ m s}^{-2} \checkmark\checkmark$

- e** This is correct. Mark: 2/2

b The velocity and acceleration are in opposite directions. This shows deceleration ✓.

e This is much more convincing than answer A. Mark: 1/1

c distance = area under the graph
 $= \left(\frac{1}{2} \times 8.8 \times 0.90\right) - \left(\frac{1}{2} \times 1.40 \times 0.14\right)$ ✓
 $= 3.9 \text{ m}$ ✓

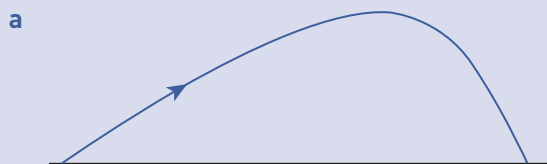
e This is all correct. The student has sensibly rounded the answer to 2 significant figures. Mark: 2/2

d The brick will be travelling much faster. In the earlier example it is almost stationary when it reaches the builder on the scaffold ✓.

e This is a good answer. Mark: 1/1

Answers to question 2

ANSWER A



e The lack of symmetry makes this drawing incorrect. Mark: 0/1

b i Vertical component of velocity = $25 \times \sin 60$
 $= 22 \text{ m s}^{-1}$ ✓
ii Horizontal component of velocity = $25 \times \cos 60$
 $= 13 \text{ m s}^{-1}$ ✓

e Although the calculations are done correctly, it is concerning that the answers are rounded to 2 significant figures without first giving them to 3 significant figures. If these values are to be used in further calculations, this is likely to lead to inaccuracies in subsequent answers. Mark: 2/2

c $0 = 21.6t + 0.5 \times 3.7 \times t^2$ ✗
 Which gives: $21.6 = -1.85t$
 $t = 11.7$ ✓✗

e The student has used the correct equation but has failed to recognise that the velocity is in the opposite direction to the acceleration due to gravity. Consequently, a minus sign must be included. The correct magnitude of the flight time is calculated, but it is not explained why the answer is not precisely the 12 s referred to in the question. Mark: 1/3

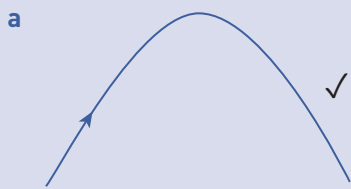
d $s = ut + \frac{1}{2}at^2$ ✗✗
 $= [22 \times 12] + \left[\frac{1}{2} \times 3.7 \times 12^2\right]$
 $= 530 \text{ m}$

e The expression is incorrect as there is no acceleration in the horizontal direction. The component of velocity in the horizontal direction should be used whereas in this case the component of velocity in the vertical direction and the acceleration in the vertical direction have been used. Mark: 0/2

e The gravity on Mars is less than on Earth. ✓

e The basic idea is correct but 'gravitational field strength' would be preferable to 'gravity' and there is no explanation as to why this increases the distance the object travels on Mars. Mark: 1/2

ANSWER B



e This is a good sketch of the ball flight, with the initial movement approximately 60° to the surface of the planet and the flight path shows a good parabolic shape. Mark: 1/1

- b i** Vertical component of velocity = $25 \times \sin 60 = 21.7 \text{ m s}^{-1} \approx 22 \text{ m s}^{-1} \checkmark$
ii Horizontal component of velocity = $25 \times \cos 60 = 12.5 \text{ m s}^{-1} \approx 13 \text{ m s}^{-1} \checkmark$

e The calculation of the components of the original velocity are fully correct. It is good that the components are given to 3 significant figures, so that the calculations in the ensuing parts can be done using all 3 significant figures. Mark: 2/2

- c** Using $s = ut + \frac{1}{2}at^2$
 $0 = 21.6t + 0.5 \times (-3.7) \times t^2 \checkmark$
 which gives: $21.6 = 1.85t$
 $t = 11.7 \checkmark$ or to 2 significant figures $12 \text{ s} \checkmark$

e An excellent response. Mark: 3/3

- d** distance = speed $\times$ time
 $= 12.5 \times 11.7 = 146 \text{ m}$
 $= 150 \text{ m} \checkmark \checkmark$

e The student has realised that for the horizontal displacement the horizontal component of the velocity is required multiplied by the time from part c. Mark: 2/2

- e** The main reason is that g is much smaller so that the time of flight will be greater, and therefore the distance travelled will be greater.

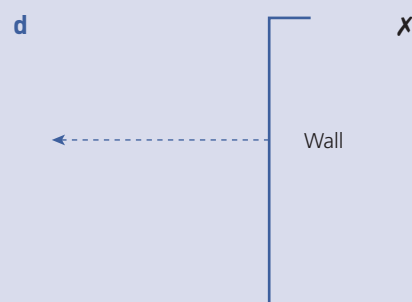
e This is a good answer that fully develops the argument. Mark: 2/2

- b** Initial momentum = $46 \times 25 = 1150 \text{ kg m s}^{-1} \times$
 Final momentum = $46 \times -23 = -1058 \text{ kg m s}^{-1}$
 Change in momentum = $-1058 - 1150 = -2208 \text{ kg m s}^{-1} \checkmark \checkmark$

e The student has used grams rather than kilograms so there is a thousand times (10^3) error in the answer but the method of calculation is correct. Mark: 2/3

- c** acceleration of ball = $\frac{25}{4 \times 10^{-2}} = 625 \text{ m s}^{-2} \times$
 $F = ma = 46 \times 625 = 28750 \text{ N} \times$

e The student has taken only the deceleration of the ball as it strikes the wall but has not considered the acceleration of the ball as it leaves the wall. Mark: 0/2



e The direction of the ball parallel to the ground does not take into account the vertical acceleration downwards. Mark: 0/1

ANSWER B

- a** Mass is the amount of substance; weight is a force due to gravity and is equal to mass $\times$ acceleration of free fall $\times \checkmark$.

e At this level it should be understood that mass is the property of an object that resists change in motion. The description of weight is awarded a mark. Mark: 1/2

- b** Initial momentum = $46 \times 10^{-3} \times 25 = 1.15 \text{ kg m s}^{-1} \checkmark$
 Final momentum = $46 \times 10^{-3} \times -23 = -1.06 \text{ kg m s}^{-1}$
 Change in momentum = $-1.06 - 1.15 = -2.2 \text{ kg m s}^{-1} \checkmark \checkmark$

Chapter 3

Answers to question 1

ANSWER A

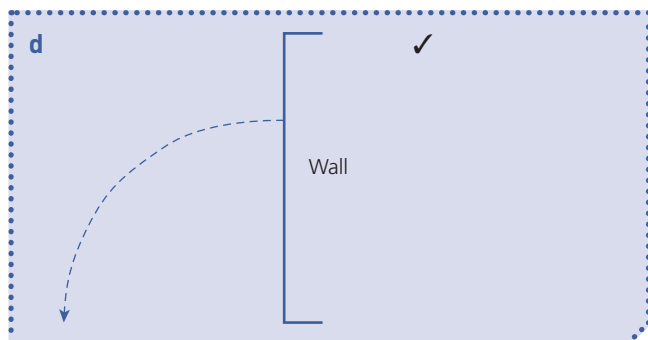
- a** Mass is the weight in kilograms, whereas weight is in newtons $\times$.

e The student has given the units of mass and weight but has not explained the difference between the two quantities. Mark: 0/2

- e** The method of calculation is correct and the student has rounded the answer to 2 significant figures, which is appropriate in this case. Mark: 3/3

c Force = rate of change of momentum = $\frac{\Delta p}{\Delta t}$ ✓
 $= \frac{2.2}{4.0 \times 10^{-2}}$
 $= 55 \text{ N}$ ✓

- e** The student has used the rate of change of momentum to calculate the force, which is correct. Mark: 2/2



- e** The ball will follow a curved path due to the acceleration of free fall acting in a vertical direction. Mark: 1/1

Answers to question 2

ANSWER A

- a** Kinetic energy is conserved ✗.

- e** This is not sufficient – it is not clear what particular kinetic energy the student is referring to. Mark: 0/1

b momentum before the collision = $1.2 \times 6.0 = 7.2 \text{ kg ms}^{-1}$ ✓
 momentum after the collision = $7.2 = (4.8 \times v) + (1.2 \times 3.6)$ ✗
 $v = 0.6 \text{ ms}^{-1}$ ✗

- e** The student earns 1 mark for the correct calculation of the initial momentum. However, the momentum is a vector and direction must be included. The two momenta after collision are in opposite directions so one of them must be negative. Mark: 1/2

c K.E. before = $\frac{1}{2}mv^2 = \frac{1}{2} \times 1.2 \times 6.0 = 3.6 \text{ J}$ ✗
 K.E. after = $\frac{1}{2} \times 4.8 \times 2.4^2 + \frac{1}{2} \times 1.2 \times 3.6^2 = 13.824 + 7.776 = 21.6 \text{ J}$ ✓
 K.E. before the collision = K.E. after the collision? ✗

- e** The student writes down the correct formula for kinetic energy but forgets to square the velocity when calculating the K.E. before the collision. The remainder of the calculation is fine. As this is a 'show that' question and the student has not shown that the total K.E. before the collision is equal to the total K.E. after the collision, then the final mark cannot be awarded. Mark: 1/3

d i acceleration of glider = $\frac{2.4}{30 \times 10^{-3}} = 80 \text{ ms}^{-2}$
 $F = ma = 4.8 \times 80 = 384$ ✗

- e** The answer is a valid way of calculating the force but this is a case where the student is expected to provide the unit since the answer cue does not provide one. Mark: 1/2

- ii** Force is smaller than the other ✗ because the glider is smaller and it is in the opposite direction ✓. Equal to the force on the other glider.

- e** There is recognition that the forces are opposite in direction but not that they are of the same magnitude. Indeed, there is a contradiction in the answer – the student first says that the force is smaller and then that it is equal to the force on the other glider. Mark: 1/2

ANSWER B

- a** The total kinetic energy before a collision is equal to the total kinetic energy after a collision ✓.

- e** The reference to the total kinetic energy before and after collision is sufficient detail for the mark to be awarded. Mark: 1/1

b momentum before the collision = $1.2 \times 6.0 = 7.2 \text{ kg ms}^{-1}$ ✓
 momentum after the collision = $7.2 = (4.8 \times v) + (1.2 \times -3.6)$ ✓
 $v = 2.4 \text{ ms}^{-1}$

e All correct. Mark: 2/2

c In elastic collisions, kinetic energy is conserved. ✓
 K.E. before = $\frac{1}{2} \times 1.2 \times 6.0^2 = 21.6 \text{ J}$ ✓
 K.E. after = $\frac{1}{2} \times 4.8 \times 2.4^2 + \frac{1}{2} \times 1.2 \times 3.6^2 = 13.824 + 7.776 = 21.6 \text{ J}$ ✓

e All correct. Mark: 3/3

d i force = rate of change of momentum
 $= 4.8 \times \frac{[2.4 - 0]}{30 \times 10^{-3}}$ ✓
 $= 384 \text{ N}$ ✓

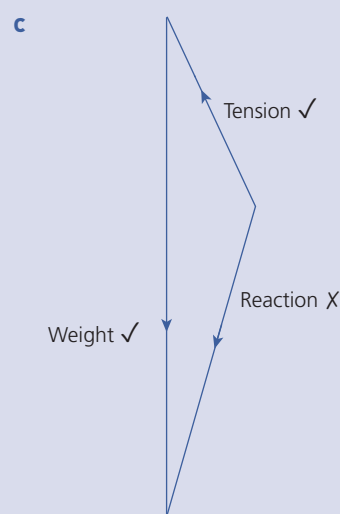
e This is all correct. Mark: 2/2

ii Force is the same magnitude ✓.

e A correct statement about the magnitude of the force, but the student misses the point that the forces are in opposite directions from each other. Mark: 1/2

b the anticlockwise moment = $24 \times 1.8 = 43.2 \text{ Nm}$ ✓
 the clockwise moment = $(6.8 \times 9.81 \times \sin 25)x = 28.2x$ ✗
 Therefore, $28.2x = 43.2$
 and $x = 1.5 \text{ m}$ ✗

e The student has not clarified the point about which the moments are being taken. Also, they have failed to correctly split the weight into the correct component. It should be $\cos 25$ not $\sin 25$. Mark: 1/3



e This is quite a good effort, apart from the arrow for the reaction force being in the incorrect direction. The door is in equilibrium, so the arrows should all go round the triangle in the same direction: anticlockwise in this example. Mark: 2/3

Chapter 4

Answers to question 1

ANSWER A

a An object is in equilibrium is when it is moving at constant speed ✗✗.

e Although this is true if the object is travelling in a straight line, the student does not state this. Also, this does not describe the *conditions* required for equilibrium – it just gives one example of an object in equilibrium. Mark: 0/2

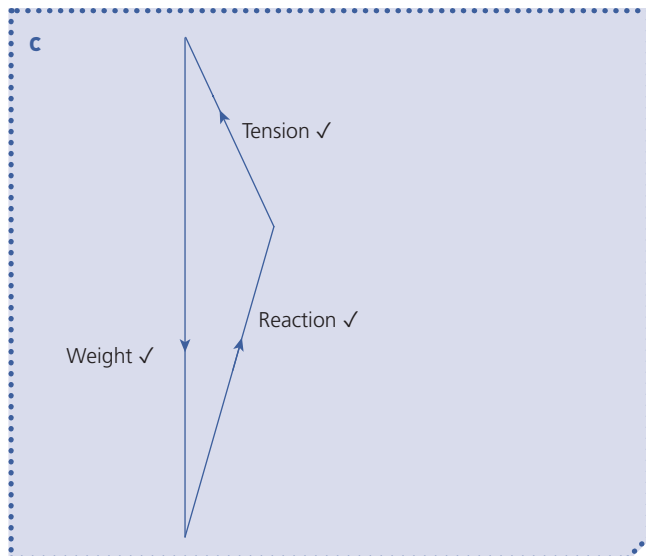
ANSWER B

a An object is in equilibrium when both the resultant force acting on the object is zero and the resultant moment acting on it is zero ✓✓.

e This is correct. Mark: 2/2

b Taking moments about the hinge:
 the anticlockwise moment = $24 \times 1.8 = 43.2 \text{ Nm}$ ✓
 the clockwise moment = $(6.8 \times 9.81 \times \cos 25)x = 60.4x$ ✓
 Therefore, $60.4x = 43.2$
 and $x = 0.71 \text{ m}$ ✓

e This is an excellent response which scores all 3 marks. Mark: 3/3



e This is another exemplary answer. Mark: 3/3

Answers to question 2

ANSWER A

a moment of a force = force $\times$ distance from the pivot **xx**

e The student has some idea of the concept of moment but the explanation is poor. There is no reference to the distance being the perpendicular distance of the force from the stated point. Mark: 0/2

b i $50 \times 48 \text{ x} = 12F$
 $F = 200 \text{ N x}$
ii pressure = $\frac{\text{force}}{\text{area}} = \frac{200}{4 \times 10^{-3}} \checkmark$
 $= 50\,000 \text{ Pa } \checkmark$

e The student has not clarified which point the moments are being taken about. As a result, the distance between the load force and the pivot is wrong. The rest of the calculation is correct. The earlier error is carried forward so both marks for part ii are scored. Mark: 2/4

c load = pressure $\times$ area = $50\,000 \times 1.6 \times 10^{-2} = 800 \text{ N } \checkmark$

e The error is carried forward again, so the mark is scored. Mark: 1/1

d Make the handle of the lever longer $\checkmark$.
 Increase the cross-sectional area of the cylinder **x**.

e The first suggestion is correct. However, in the second idea, the student does not specify which cylinder's cross-sectional area should be increased. Increasing the area of the master cylinder would have the opposite effect from that required. Mark: 1/2

ANSWER B

a The moment of a force is the magnitude of the force $\times$ the perpendicular distance of the force from the point $\checkmark\checkmark$.

e This is correct. Mark: 2/2

b i Taking moments about A:
 $50 \times 60 = 12F \checkmark$
 $F = 250 \text{ N } \checkmark$
ii pressure = $\frac{\text{force}}{\text{area}} = \frac{250}{4 \times 10^{-3}} \checkmark$
 $= 62\,500 \text{ Pa } \checkmark$

e All correct. Mark: 4/4

c load = pressure $\times$ area = $62\,500 \times 1.6 \times 10^{-2} = 1000 \text{ N } \checkmark$

e Correct. Mark: 1/1

d Increase the length of the lever $\checkmark$.
 Increase the cross-sectional area of the slave cylinder $\checkmark$.

e Both correct. Mark: 2/2

Chapter 5

Answers to question 1

ANSWER A

a Work is done when a force moves its point of application **xx**.

e The student's idea of the concept is poor. There is no reference to the movement being in the direction of the line of action of the force. Mark: 0/2

b i $\text{power} = Fv = 5000 \times 50 = 250\,000\text{ W}$ $\times$ ✓
ii $\text{input power} = \frac{\text{power output}}{\text{efficiency}}$ ✓
 $= \frac{250\,000}{0.18}$
 $= 1\,390\,000\text{ W}$ ✓

e In the first, part the student has failed to convert the units of speed from km h^{-1} to ms^{-1} . This runs through the calculation of the input power but the error is penalised once only. Mark: 3/4

iii The output power dissipated in doing work against gravity $= mg \sin 20 \times v$ ✓
 $= 1200 \times 9.81 \times \sin 20 \times 50$
 $= 201\,000\text{ W}$
 The fraction of the output power used against gravity $= \frac{201\,000}{250\,000} = 0.81$ ✓

e The error is carried forward again. It is worth noting that output power and the power used against gravity are incorrect by the same factor, so the two errors cancel out to give the same answer as if the correct figures were used. Mark: 2/2.

ANSWER B

a Work is done when a force moves its point of application in the direction of the line of action of the force ✓✓.

e Correct. Mark: 2/2

b i $\text{power} = Fv = 5000 \times 50/3.6 = 69\,400\text{ W} = 69.4\text{ kW}$ ✓✓
ii $\text{input power} = \text{power output}/\text{efficiency}$ ✓
 $= 69.4/0.18$
 $= 386\text{ kW}$ ✓

e All correct. Note that the student has made it easier by working in kilowatts as opposed to watts. Mark: 4/4

iii The power used in doing work against gravity $= mg \sin 20 \times v$ ✓
 $= 1200 \times 9.81 \times \sin 20 \times 50/3.6 \times 10^{-3}$
 $= 55.9\text{ kW}$
 The fraction of the output power used against gravity $= 55.9/69.4 = 0.81$ ✓

e Note the use of the multiplier of 10^{-3} to convert to kilowatts. Mark: 2/2

Answers to question 2

ANSWER A

a i Energy is the ability to do work. ✓

e This is a perfectly acceptable definition of energy. Mark: 1/1

ii Energy cannot be created or destroyed $\times$.

e The student has some idea of the conservation of energy but does not explain that it can be transferred from one form to another. Mark: 0/1

b i $\text{change in speed} = 6.4 - 9 = -2.6\text{ ms}^{-1}$ $\times$
 $\text{change in kinetic energy} = \text{initial kinetic energy} - \text{final kinetic energy}$
 $= \frac{1}{2} \times 82 \times 2.6^2$ ✓
 $= 277\text{ J}$ $\times$
ii 277 J ✓
iii It is converted into thermal energy ✓.

e The student gets part i incorrect because of the squared nature of the speed: $[v_2^2 - v_1^2]$ is not the same as $[v_2 - v_1]^2$. A consolation mark is given for the correct use of the formula $E_k = \frac{1}{2}mv^2$. Mark: 1/3

In part ii, the student recognises that the work done against friction is equal to the kinetic energy lost. Mark: 1/1

Part iii is a rather isolated statement. Where is the thermal energy? Mark: 1/1

ANSWER B

a i Energy is the capacity to do work. ✓

e This is correct. Mark: 1/1

- ii Energy cannot be created nor destroyed. It can only be transferred from one form to another. ✓

error has already been penalised, the error is carried forward and the mark is awarded even though the answer is incorrect.
Mark: 2/2

- e The student gives a complete description of conservation of energy. Mark: 1/1

- ii vertical velocity = $175 \cos 24^\circ \times = 160 \text{ m s}^{-1} \times$

- b i Change in kinetic energy = $\frac{1}{2} m (v_2^2 - v_1^2)$ ✓
 $= \frac{1}{2} \times 82 \times (6.4^2 - 9.0^2)$ ✓
 $= 1640 \text{ J}$ ✓
 ii 1640 J ✓
 iii The energy is converted into thermal energy of the surroundings ✓.

- e The use of $\cos 24$ is wrong so no marks are awarded. Mark: 0/2

iii $v^2 = u^2 + 2as$
 $0 = 175^2 + 2 \times 9.81 \times s \times$
 $s = \frac{175^2}{2 \times 9.81} = 1.6 \times 10^3 \text{ m} \times$

- e This answer is laid out well and it is clear how the student approached the problems.
Mark: 5/5

- e A mark is not allocated for writing the correct formula here as it is given on the formula page. The acceleration is in the opposite direction to the initial velocity so it should be a negative value rather than positive. Mark: 0/2

Chapter 6

Answers to question 1

ANSWER A

a i $k = \frac{F}{x}$ ✓
 $k = \frac{10}{4.0} = 2.5 \text{ N cm}^{-1}$ ✓

- e The student has written the correct expression and has calculated the spring constant. The units of N cm^{-1} are acceptable at this stage as no unit was specified in the question. Mark: 2/2

ii $E = \frac{1}{2} kx^2$ ✓ $= \frac{1}{2} \times 2.5 \times 7.0^2 = 61 \text{ J} \times$

- e The correct formula is given for elastic potential energy. The use of 2.5 N cm^{-1} is not correct here as it does not give the answer in joules. This is an example of a power of ten error. Mark: 1/2

b i $\frac{1}{2} mv^2 = 61 \text{ J}$ ✓
 $v^2 = \frac{2 \times 61}{4.0 \times 10^{-3}} = 3.05 \times 10^4$
 so $v = \sqrt{3.05 \times 10^4} = 175 \text{ m s}^{-1}$ ✓

- e The correct formula is given for kinetic energy. The student has used the value obtained in part a ii for the energy. As that

ANSWER B

a i $k = \frac{10}{4.0 \times 10^{-2}} = 250 \text{ N m}^{-1}$ ✓✓

- e Correct equation, substitution and answer.
Mark: 2/2

ii $E = \frac{1}{2} kx^2 = \frac{1}{2} \times 250 \times (7.0 \times 10^{-2})^2 = 0.61 \text{ J}$ ✓✓

- e The correct formula for the elastic potential energy is given and substitution of the value from part a i to give the correct answer.

b i $\frac{1}{2} mv^2 = 0.61 \text{ J}$ ✓
 $v = \sqrt{\frac{2 \times 0.61}{4.0 \times 10^{-3}}} = 17.5 \text{ m s}^{-1}$ ✓

- e Correct formula for kinetic energy and correct substitution of the value from part a ii to give the correct answer. Mark: 2/2

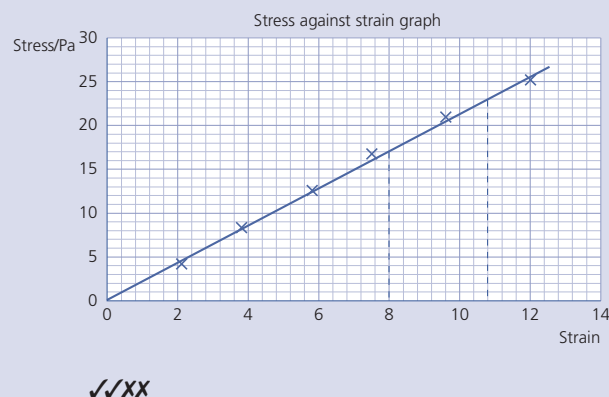
ii $v = 17.5 \sin 24^\circ = 7.12 \text{ m s}^{-1}$ ✓

e The student has used the sine of the angle to find the vertical component of the velocity. Mark: 2/2

iii $s = \frac{v^2 - u^2}{2a}$
 $\frac{0^2 - 7.12^2}{2 \times -9.81}$
 $s = 2.6 \text{ m}$ ✓✓

e This student has taken the upwards direction to be positive and downwards as negative. This is perfectly legitimate. A negative value of the acceleration has been used because the acceleration of free fall is in the opposite direction to the initial vertical velocity. Mark: 2/2

ii



e The axes have been labelled with the correct quantity and unit, but there is a power of ten error on both axes. The error is carried forward when considering the points, which are plotted accurately. The best-fit line does not have an even distribution of points either side of the line. Mark: 2/4

Answers to question 2

ANSWER A

- a i tensile stress = $\frac{\text{force}}{\text{area}}$ ✓
 ii tensile strain = $\frac{\text{extension}}{\text{length}}$ X

e The correct definition for stress has been given, but it is not clear which length the student is referring to in the definition of strain. It should be 'extension' over 'original length'. Mark: 1/2

b i

Mass added/kg	Extension of wire/mm	Stress/Pa X	Strain ✓
0	0.0	0	0.0
0.050	0.5	4.19×10^6	2.1×10^{-4}
0.100	0.9	8.38×10^6	3.8×10^{-4}
0.150	1.4	12.6×10^6	5.8×10^{-4}
0.200	1.8	16.8×10^6	7.5×10^{-4}
0.250	2.3	21.0×10^6	9.6×10^{-4}
0.300	2.8	25.2×10^6	12×10^{-4}

e The values for stress are incorrect because the student has used the diameter in the calculation of area rather than the radius. The values of strain are correct. Mark: 1/2

iii gradient = $\frac{21.0 \times 10^6 - 8.38 \times 10^6}{9.6 \times 10^{-4} - 3.8 \times 10^{-4}}$
 $= 2.2 \times 10^{10}$ XX

e The student has not drawn a triangle on the graph to show how the values were obtained. The values appear to have been taken from the table rather than from the graph line. Mark: 0/2

iv The Young modulus = $\frac{\text{stress}}{\text{strain}}$, which is the same as the gradient = $2.2 \times 10^{10} \text{ N m}^{-2}$ ✓

e The value of the gradient has been used correctly, and the units of N m^{-2} are acceptable. Mark: 1/1

c i The limit of proportionality is the maximum extension the wire can be extended to and still return to its original length X.

e The student has described the elastic limit rather than the limit of proportionality. Mark: 0/1

ii Each time a weight is added to the wire, take it off again and check it returns to its original length X.

e The student has explained how to check the elastic limit is not exceeded. Mark: 0/2

ANSWER B

- a i tensile stress = $\frac{\text{force}}{\text{cross-sectional area}}$ ✓
 ii tensile strain = $\frac{\text{change in length}}{\text{original length}}$ ✓

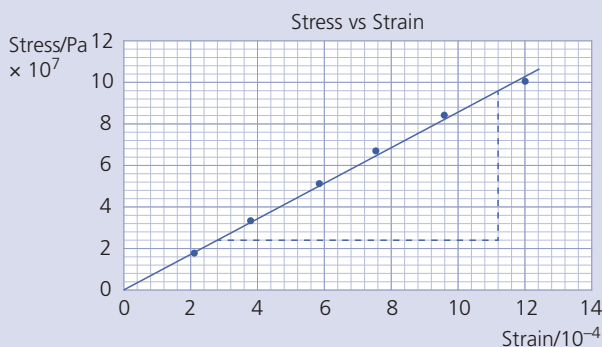
e Correct definitions for stress and strain. Mark: 2/2

b i

Mass added/kg	Extension of wire/mm	Stress/Pa $\times 10^7$ ✓	Strain/ 10^{-4} ✓
0	0.0	0	0.0
0.050	0.5	1.68	2.1
0.100	0.9	3.35	3.8
0.150	1.4	5.02	5.8
0.200	1.8	6.70	7.5
0.250	2.3	8.37	9.6
0.300	2.8	10.0	12

e Correct values calculated and recorded with the correct number of significant figures. Mark: 2/2

ii



e Quantities with correct units on axes, sensible scales chosen, points plotted accurately and the line of best fit drawn. Mark: 4/4

iii gradient = $\frac{9.6 \times 10^7 - 2.4 \times 10^7}{11.2 \times 10^{-4} - 2.8 \times 10^{-4}} = 8.6 \times 10^{10}$ ✓✓

e Clear triangle drawn on the graph. Values taken from the drawn line to calculate the gradient. Mark: 2/2

iv The Young modulus = 8.6×10^{10} Pa ✓

e Value of gradient used with correct unit. Mark: 1/1

c i The limit of proportionality is the point up to which the force is proportional to the extension ✓.

e Correct description of the limit of proportionality. Mark: 1/1

ii The experimenter should plot a force-extension graph as they take each reading. If the graph remains a straight line passing through the origin then it is still within the limit of proportionality ✓✓.

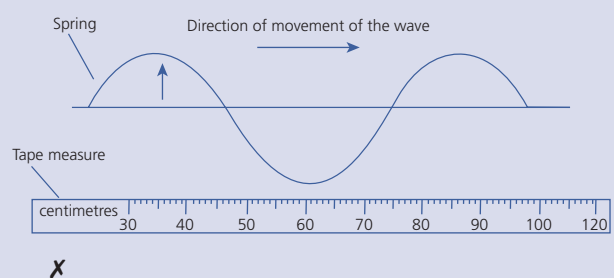
e This is an appropriate method to determine if the extension is within the limit of proportionality. Mark: 2/2

Chapter 7

Answers to question 1

ANSWER A

a i



e Carelessness has cost the student this mark. Care and precision are needed when indicating distances. Mark: 0/1

ii 25 cm ✗

e The half wavelength is measured Mark: 0/1

iii $\frac{3.2}{25} = 0.13$ Hz ✗✓✓

e Although this is not set out very clearly, the student, with the error carried forward,

determines the speed of the wave. However, the units of the speed are ms^{-1} , whereas the units of the wavelength are cm; they have not been converted to make them compatible. Mark: 2/3

b i The car is moving away from the observer.

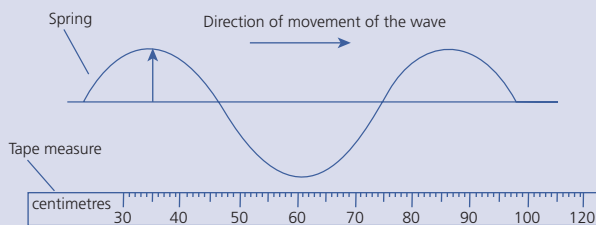
e This is a perfectly good explanation. Mark: 1/1.

$$\begin{aligned}\text{ii } f_o &= \frac{f_s v}{v - v_s} \\ 600 &= \frac{640 \times 330}{330 - v_s} \\ 330 - v_s &= \frac{640 \times 330}{600} = 352 \\ \text{and } -v_s &= 352 - 330 = 22 \text{ ms}^{-1} \checkmark\checkmark\checkmark\end{aligned}$$

e In many ways, this is a good calculation, but the negative sign is used incorrectly on the denominator. This is despite the student recognising that the car is moving away from the observer. Mark: 2/3

ANSWER B

a i



e This is correct. Mark: 1/1

ii 50 cm ✓

e Correct. Mark: 1/1

$$\text{iii } f = \frac{v}{\lambda} = \frac{3.2}{0.50} = 6.4 \text{ Hz } \checkmark\checkmark\checkmark$$

e Correct. Mark: 3/3

b i The car is moving away from the observer ✓ as the pitch of the note heard is less than the note emitted by the stationary car.

e This is a good explanation. Although a reason is not asked for, the reasoning is good. Mark: 1/1

$$\begin{aligned}\text{ii } f_o &= \frac{f_s v}{v + v_s} \\ 600 &= \frac{640 \times 330}{330 + v_s} \\ 330 + v_s &= \frac{640 \times 330}{600} = 352 \\ \text{and } v_s &= 352 - 330 = 22 \text{ ms}^{-1} \checkmark\checkmark\checkmark\end{aligned}$$

e This is a good, clear calculation of the speed of the car. Mark: 3/3

Answers to question 2

ANSWER A

a The particles in a transverse wave move at an angle of 90° to the direction of travel of the disturbance, whereas in a longitudinal wave the particles move in a direction parallel to the direction of travel ✓X.

e The student talks about the movement of the particles but with no hint of the idea of vibration or oscillation. Mark: 1/2

b i The vibrations of unpolarised light are in all directions. In plane-polarised light, the oscillations are in a single direction ✓X.

e There is some understanding but the student does not limit the direction of the vibrations to being perpendicular to the direction of travel. Mark: 1/2

ii The light that is reflected from the road is polarised and so the polarising spectacles will not let it through ✓X.

e The student recognises that the reflected light is polarised but fails to mention either that it is only partially polarised or the relevance of the direction of the axis of transmission to the plane of polarisation. Mark: 1/2

- c 50% of the light falling on the first polarising filter is transmitted, $I_1 = 0.5I_0$ ✓

The intensity of the light transmitted by the second polarising filter is given by:

$$I_T = I_1 \cos^2 \theta$$

$$\text{so: } I_T = 0.5I_0 \cos^2 60$$

$$= 0.125I_0 \text{ ✓}$$

- e This is good as far as it goes, but the student only gives the fraction of the original intensity of the transmitted light. The percentage change in intensity is not explored. Mark: 2/3.

ANSWER B

- a The particles in a transverse wave vibrate perpendicular to the direction of travel of the disturbance. In a longitudinal wave, the particles vibrate in a direction parallel to the direction of travel ✓✓.

- e Correct. Mark: 2/2

- b i The oscillations of unpolarised light are in all directions perpendicular to the direction of travel of the wave. In plane-polarised light, the oscillations are in a single direction (perpendicular) to the direction of travel of the light ✓✓.

- e This answer shows a clear understanding of polarisation and is expressed well. Mark: 2/2

- ii The reflected light is partly polarised. Half the unpolarised part of the glare will pass through the polarising spectacles ✓ whatever the orientation of the transmission axis of the spectacles. Varying amounts of the polarised light will also pass through depending on the relationship between the transmission axis of the spectacles and the plane of polarisation of the polarised light ✓.

- e This is an excellent response, fully exploring the reasons for both the cutting out of the glare and to why some light is transmitted. Mark: 2/2

- c The intensity of the light after passing through the first polarising filter is $= 0.5I_0$ ✓

The intensity of the light transmitted by the second polarising filter is given by:

$$I_T = I_1 \cos^2 \theta$$

$$\text{so: } I_T = 0.5I_0 \cos^2 60$$

$$= 0.125I_0 \text{ ✓}$$

$$\text{The fractional change in the intensity} = \frac{I_0 - I_T}{I_0}$$

$$= \frac{I_0 - 0.125I_0}{I_0} = 0.875$$

The percentage change is 87.5% ✓.

- e This is a good explanation followed through to the end. Mark: 3/3

Chapter 8

Answers to question 1

ANSWER A

- a In a stationary wave, energy is stored in the vibrating particles ✗.
In a stationary wave, all the points are in phase whereas in a progressive wave all the points have different phases ✗.

- e This answer has errors in both parts. In the first part, the statement regarding the energy stored in a stationary wave is correct, but there is no comparison with the progressive wave. In the second part, the student fails to limit the particles to those between two nodes, and in the comparison it is only those particles in a single wavelength that have different phases. Mark: 0/2

- b i $\lambda = 4L = 4 \times 0.60 = 2.4 \text{ m}$ ✓✓

- e The calculation is correct. Mark: 2/2

- ii $v = f\lambda$
 $= 128 \times 2.4$
 $= 307 \text{ m s}^{-1}$ ✓✓

- e This calculation is correct but the final answer could be given to 2 significant figures. Mark: 2/2

iii $\lambda_4 = 4 \times 2.4 = 48\text{ m}$ ✗

- e The student clearly does not remember the sequence for calculating the wavelengths of different harmonics. Mark: 0/1

ANSWER B

- a In a stationary wave, the amplitudes of different points vary from a maximum to zero whereas in a progressive wave all the points along the wave have the same amplitude ✓.
In a stationary wave, energy is stored in the vibrating particles and in a progressive wave energy is transferred from one place to another ✓.

- e Two good statements, each clearly describing the difference between the two types of wave, achieve both marks. Mark: 2/2

b i $\lambda = 4L = 4 \times 0.60 = 2.4\text{ m}$ ✓✓

- e This is correct. Mark: 1/1

ii $v = f\lambda$
 $= 128 \times 2.4$
 $= 310\text{ Hz}$ ✓✓

- e This is correct. Mark: 2/2

iii $\lambda_4 = \frac{4 \times 0.60}{7}$ ✓
 $= 0.34\text{ m}$

- e The calculation is correct. Mark: 1/1

Answers to question 2

ANSWER A

- a i Two sources are coherent if they have no phase difference ✗✗.

- e This answer demonstrates a common error. Students often ignore the fact that light from two sources can be coherent if there is a phase difference, provided the phase difference is constant. The necessity for the two sources to have the same frequency is not mentioned. Mark: 0/2

- ii They are not coherent ✓.

- e The statement is correct and so gains a mark. However, the question asks the student to *explain* and there is no explanation given as to why the sources are not coherent. Mark: 1/2

b i $n\lambda = \frac{ax}{D}$ where $n = 9$ ✗
 $x = \frac{13 \times 10^{-3}}{9} = 1.44 \times 10^{-3}$
 $\lambda = \frac{1.2 \times 10^{-3} \times 1.44 \times 10^{-3}}{3}$
 $\lambda = 5.8 \times 10^{-7}\text{ m}$ ✓

- e The student has counted the nine minima but there are only eight fringes. The rest of the calculation is completed correctly, for 1 mark. Mark: 1/2

- ii Blue light has a longer wavelength than red light ✗ so the fringes would be further apart ✓.

- e The student should be aware that the blue end of the spectrum has the shortest wavelengths of visible light. The correct conclusion has been drawn from the original error, so the second mark is scored. Mark: 1/2

ANSWER B

- a i Two sources are coherent if they have a constant phase difference ✓. For this, they must have the same frequency ✓.

- e Correct. Mark: 2/2

- ii Light is not emitted as a single wave train but as short wave trains. The phases of the different wave trains are random ✓, so the wave trains from the two sources are not coherent ✓.

- e This is an excellent answer, showing true understanding of coherence. Mark: 2/2

b i $n\lambda = \frac{ax}{D}$ where $n = 8$
 $x = \frac{13 \times 10^{-3}}{8} = 1.63 \times 10^{-3}$
 $\lambda = \frac{1.2 \times 10^{-3} \times 1.63 \times 10^{-3}}{3}$ ✓
 $\lambda = 6.5 \times 10^{-7}\text{ m}$ ✓

e Correct. Mark: 2/2

- ii Blue light has a shorter wavelength than red light ✓ so the fringes would be closer together ✓.

e This is a good explanation. The student has noted that a reason is needed. Mark: 2/2

Chapter 9

Answers to question 1

ANSWER A

- a** The number density of charge carriers is the number of charge carriers per cubic metre **x**.

e When describing a quantity, it is important that it is given in terms of other quantities. The correct description is the number of charge carriers per unit volume. Mark: 0/1

b i $Q = It, Q = 0.30 \times 60 = 18 \text{ C}$
 $\therefore \text{number of electrons} = \frac{18}{1.6 \times 10^{-19}}$
 $= 1.13 \times 10^{20} \checkmark \checkmark$

e The student has calculated the quantity of charge flowing past a point in 1 minute correctly, then divided by the charge on one electron to find the total number of electrons. Mark: 2/2

ii $I = nAvq$
 $v = \frac{I}{nAq}$
 $v = \frac{0.30}{1.13 \times 10^{20} \times \pi \times (0.24 \times 10^{-3})^2 \times 1.6 \times 10^{-19}}$
 $= 9.17 \times 10^4 \text{ m s}^{-1} \text{ x}$

e The student has rearranged the formula correctly and substituted the correct value to calculate the area, but has used the total number of electrons from part bi rather than the number density. Mark: 1/3

c $\text{power} = I^2 R = 0.30^2 \times 0.45 = 4.1 \times 10^{-2} \text{ W} \checkmark \checkmark$

e The correct formula is stated and the correct values substituted. Mark: 2/2

ANSWER B

- a** The number density is the number of charge carriers per unit volume ✓.

e The definition is correct. Mark: 1/1

b i $\text{number of electrons} = \frac{0.30 \times 60}{1.6 \times 10^{-19}}$
 $= 1.13 \times 10^{20} \checkmark \checkmark$

e The student has divided the total charge by the charge on each electron. Mark: 2/2

ii $v = \frac{I}{nAq}$
 $v = \frac{0.30}{5.9 \times 10^{28} \times \pi \times (0.24 \times 10^{-3})^2 \times 1.6 \times 10^{-19}}$
 $= 1.8 \times 10^{-4} \text{ m s}^{-1} \checkmark \checkmark \checkmark$

e The formula has been rearranged correctly and the correct values substituted. Mark: 3/3

c $\text{power} = I^2 R = 0.30^2 \times 0.45 = 0.041 \text{ W} \checkmark \checkmark$

e The correct formula is stated and the correct values substituted. Mark: 2/2

Answers to question 2

ANSWER A

- a** Ohm's law states that current is proportional to potential difference **x**.

e This statement only covers part of Ohm's law. The law applies to a metallic conductor at constant temperature. Mark: 1/2

b i $I = \frac{V}{R} = \frac{1.56}{4.0} = 0.39 \text{ A} \checkmark \checkmark$

e Correct expression, correct substitution and answer. Mark: 2/2

ii $P = I^2 R = 0.39^2 \times 4.0 = 0.61 \text{ W} \checkmark \checkmark$

e Correct expression, correct substitution and answer. Mark: 2/2

c i $R = \rho \frac{L}{A}$

The length stays the same and the resistivity stays the same so $R \propto \frac{1}{A}$. The diameter halves so the area halves so the resistance doubles to 8.0Ω ✓X.

e The student has correctly stated that the resistance is inversely proportional to the area, but the area will be a quarter of the original if the diameter is halved. Mark: 1/2

ii The resistance is doubled and $P \propto R$ so the power is doubled XX.

e If the resistance doubles, the current is halved, and since $P = I^2 R$, the change in current has a greater effect than the change in resistance. Mark: 0/2

ANSWER B

a Ohm's law states that for a metallic conductor at constant temperature, the current flowing through the conductor is directly proportional to the potential difference across its ends ✓✓.

e This is a detailed description of Ohm's law. Mark: 2/2

b i $I = \frac{1.56}{4.0} = 0.39\text{ A}$ ✓✓

e Correct substitution and correct answer. Mark: 2/2

ii $P = 0.39^2 \times 4.0 = 0.608\text{ W}$ ✓✓

e Correct substitution and correct answer. Mark: 2/2

c i $R \propto \frac{1}{A}$ and $A \propto d^2$ so $R \propto \frac{1}{d^2}$

This means if the diameter is halved, the resistance will be four times greater, i.e. 16.0Ω ✓✓

e The student has stated that resistance is inversely proportional to the area and has worked out that it is inversely proportional to the square of the diameter, so the resistance will be four times greater. Mark: 2/2

ii $P = \frac{V^2}{R}$ so as the p.d. remains constant and the resistance is four times greater, the power will be a quarter of its original value, i.e. 0.152 W .

e The student has realised that the power is inversely proportional to the resistance and so it will be a quarter of the value in part bii. Mark: 2/2

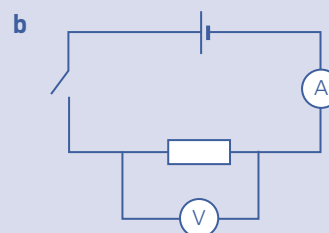
Chapter 10

Answers to question 1

ANSWER A

a The electromotive force is the energy transferred in driving charge around a circuit ✓X.

e The definition is missing '...per unit charge'. Mark: 1/2



✓X

e The student has used the correct circuit symbols, but the voltmeter is in parallel with the resistor not the cell. While this makes no difference when the switch is closed, it will give a reading of zero volts when the switch is open. Mark: 1/2

c The voltmeter reading falls because the energy is being transferred around the circuit XX.

e The student has not made any reference to the internal resistance. When current flows, there will be a potential difference across the internal resistance of the cell which is not measured by the voltmeter. Mark: 0/2

d i $R = \frac{V}{I} = \frac{1.54}{0.40} = 3.85\Omega$ ✓X

- e** The formula for resistance is correct, but the student has used the e.m.f. rather than the p.d. across the resistor. Mark: 1/2

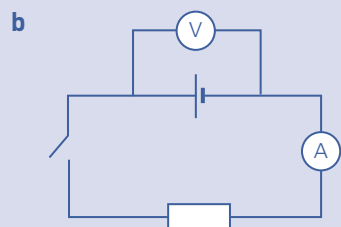
$$\text{ii } R = \frac{V}{I} = \frac{1.28}{0.40} = 3.20 \, \Omega \text{ xx}$$

- e** The student has used the terminal potential difference rather than the p.d. across the internal resistance. Mark: 0/2

ANSWER B

- a** The e.m.f. is the energy transferred per unit charge in driving charge around a circuit ✓✓.

- e** This is a complete definition. Mark: 2/2



- e** The correct circuit symbols in the correct positions. Mark: 2/2

- c** The reading falls because of lost volts across the internal resistance ✓✓.

- e** The student has identified the internal resistance as the cause of the change in the voltmeter reading. Mark: 2/2

$$\text{d i } R = \frac{V}{I} = \frac{1.28}{0.40} = 3.2 \, \Omega \text{ ✓✓}$$

- e** The formula is correct, the substitution has been made correctly and the correct answer is given. Mark: 2/2

$$\begin{aligned} \text{ii } E - V &= Ir \\ 1.54 - 1.28 &= 0.40r \\ \text{Therefore, } r &= \frac{0.26}{0.40} = 0.65 \, \Omega \text{ ✓✓} \end{aligned}$$

- e** The student has subtracted the terminal p.d. from the e.m.f. to find the p.d. across the internal resistance and has divided this value by the current to give the value of the internal resistance.

Answers to question 2

ANSWER A

- a** Kirchoff's second law states that the sum of the voltages is equal to the total voltage xx.

- e** The word voltage is ambiguous here. It is not clear whether this refers to electromotive force or potential difference. Mark: 0/2

- b** By Kirchoff's second law, the supply voltage $V = V_1 + V_2$, and the current I in a series circuit is constant. Dividing both sides by I gives:

$$\frac{V}{I} = \frac{V_1}{I} + \frac{V_2}{I} \text{ ✓}$$

$$\frac{V}{I} = R \therefore R = R_1 + R_2 \text{ ✓}$$

- e** The sum of the potential differences is shown, and the student has divided through by the current to give the correct expression for resistors in series. Mark: 2/2

- c i** As the temperature rises, the resistance of the thermistor decreases ✓.

- e** This is a correct statement. Mark: 1/1

- ii** As the temperature rises, the potential difference goes down xx.

- e** The student has stated what happens to the potential difference across the thermistor rather than the resistor. Mark: 0/2

- iii** $I = \frac{V}{R}$ so as both the potential difference and the resistance decrease, the current stays the same so the reading on the ammeter does not change xx.

- e** The total resistance of the circuit will decrease, so the current will increase. Mark: 0/2

ANSWER B

- a In any closed loop in an electric circuit, the algebraic sum of the electromotive forces is equal to the algebraic sum of the potential differences ✓✓.

e This is a correct statement of Kirchhoff's second law. Mark: 2/2

b $V = V_1 + V_2$ so $\frac{V}{I} = \frac{V_1}{I} + \frac{V_2}{I}$ ✓
so $R = R_1 + R_2$ ✓

e The formulae are all correct and lead to the correct expression for resistors in series, but it would have been useful to have more explanation in terms of Kirchhoff's second law. Mark: 2/2

- c i The resistance of the thermistor decreases as the temperature increases ✓.

e The statement is correct. Mark: 1/1

- ii The resistor and the thermistor in series make a potential divider. As the resistance of the thermistor decreases, its share of the p.d. decreases. As the supply p.d. remains constant, the resistor's share of the p.d. increases ✓✓.

e The student has used the principle of the potential divider to explain why the p.d. across the resistor increases. Mark: 2/2

- iii The resistance of the thermistor decreases and the resistance of the resistor remains the same. As $R = R_1 + R_2$ then the total resistance of the circuit decreases. The supply voltage remains constant so the current increases and the ammeter reading rises ✓✓.

e The decrease in total resistance is linked to the increase in current and the reading on the ammeter rising. Mark: 2/2

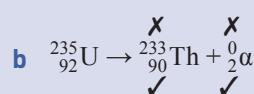
Chapter 11

Answers to question 1

ANSWER A

- a The nucleus is very small compared with the size of the atom, and most of the mass of the atom is in the nucleus ✓XX.

e The statement about the size and mass of the nucleus is correct, but the student has not supported it with any reference to the results. Mark: 1/3

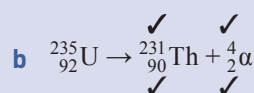


e The values for the proton numbers are correct, but those for the nucleon numbers are not. Mark: 2/4

ANSWER B

- a The large number of alpha particles passing through with little deviation indicates that the nuclei are far apart from each other. The deflections greater than 90° show that the mass of each nucleus is large compared to the mass of the alpha particle, and the very small number of deflections more than 90° show that the mass is concentrated in a very small volume. Therefore, the nucleus is very small compared to the size of the atom and contains most of the mass of the atom ✓✓✓.

e The results of the alpha particle scattering are linked to the conclusions about mass and size. Mark: 3/3



e The nucleon numbers and proton numbers are correct for the products of U-235 decay. Mark: 4/4

Answers to question 2

ANSWER A

a i $228 - 91 = 137$ neutrons ✗

e The answer is for the proactinium nucleus, not the thorium nucleus that the question required. Mark: 0/1

ii 137 atomic mass units ✗

e The student has used the number of neutrons rather than the number of nucleons to calculate the number of atomic mass units. Mark: 0/2

b i The quark composition of a proton is UP, UP, DOWN ✓.

e The quark composition is correct. Mark: 1/1

ii In β^+ decay, a proton in the nucleus changes into a neutron ✗✗.

e The statement is true but the question asks for the change in the quark composition not the change in nucleons. Mark: 0/2

iii The other lepton is a neutrino ✓.

e The answer is correct. Mark: 1/1

c i A meson consists of two quarks or antiquarks ✗, while a baryon has three quarks or antiquarks ✓.

e The description of baryons is correct, but a meson consists of a quark and an antiquark. Mark: 1/2

ii The charge on an up quark is $+2/3$ and on an antistrange quark it is $+1/3$, so the charge of the meson is $2/3 + 1/3 = +1$ ✓✓.

e The calculation is correct and as the question refers to relative charge, the answer of $+1$ is acceptable. If the question had asked for charge, the correct answer would be $+1e$. Mark: 2/2

ANSWER B

a i 228 nucleons, 90 protons
 $228 - 90 = 138$ neutrons ✓

e The proton number has been subtracted from the nucleon number to give the number of neutrons. Mark: 1/1

ii There are 228 nucleons so the mass is 228 atomic mass units ✓✓.

e The number of nucleons has been converted to atomic mass units. Mark: 2/2

b i uud or up up down ✓

e The quark composition is correct. Mark: 1/1

ii One of the up quarks changes to a down quark, so the quark composition is udd, which is a neutron ✓✓.

e This is a correct description of the change of quark. Mark: 2/2

iii The other lepton is a neutrino ✗.

e The spelling here is important. The correct answer is neutrino, the word 'neutrino' is too similar to neutron so this answer is not acceptable. Mark: 0/1

c i A meson consists of a quark and an antiquark ✓ whereas a baryon consists of three quarks ✗.

e The description of a meson is correct, but a baryon can also be three antiquarks as well as three quarks. Mark: 1/2

ii up is $+2/3e$, antistrange is $+1/3e$ ✓
The charge on the meson is $+2/3e + 1/3e = +1e$ ✓

e The charges for the up quark and the antistrange quark are correct, and they are added to give the charge of the meson. Mark: 2/2

Exam-style question answers and commentary

Chapter 12

Answers to question 1

ANSWER A

- a** A radian is a measure of angle subtended when the arc length is equal to the diameter of the circle **x**.

- e** A radian is the angle subtended when the arc length is equal to the radius not the diameter. Mark: 0/1

b i $T = \frac{1}{f} = \frac{1}{0.36} = 2.8 \text{ s}$ ✓

- e** The calculation is correct. Mark: 1/1

ii $\omega = 2\pi f = 2\pi \times 2.8 = 17.6 \text{ rad s}^{-1}$ **x**

- e** Instead of using the frequency of the rotation, the student has used the time period. Mark: 0/2

iii $F = m\omega^2 r$ ✓
 $= 1 \times 17.6^2 \times 12$
 $= 3700 \text{ N kg}^{-1}$ **x**

- e** The error is carried forward from the previous section without penalty. However, the student should realise that the force per kilogram is nearly 400 times that of gravity. Mark: 1/2.

ANSWER B

- a** One radian is the angle subtended at the centre of a circle when the arc length is equal to the radius of the circle ✓.

- e** This is a correct definition. Mark: 1/1

b i $T = \frac{1}{f} = \frac{1}{0.36} = 2.8 \text{ s}$ ✓

- e** This is a clear and correct calculation with the correct unit. Mark: 1/1

ii $\omega = 2\pi f = 2\pi \times 0.36 = 2.26 \text{ rad s}^{-1}$ ✓✓

- e** This is a clear correct calculation. Mark: 2/2

iii $F = m\omega^2 r = 1 \times 2.26^2 \times 12$
 Force per kilogram = 61 N kg^{-1} ✓✓

- e** This excellent answer shows a full understanding of the situation. Mark: 2/2

Answers to question 2

ANSWER A

- a** A centripetal acceleration is an acceleration towards the centre of a circle **x✓**.

- e** The student omits the constant magnitude of the acceleration. Mark: 1/2

b $a = \frac{v^2}{r} = \frac{7^2}{1.9} = 25.8 \times 2$ gives $a = 52 \text{ m s}^{-2}$ **x**

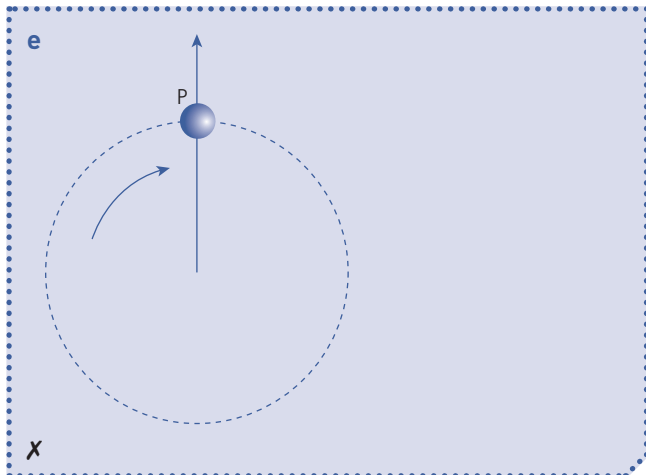
- e** The diameter has been used not the radius and then the answer obtained is multiplied by 2 without explanation. Mark: 0/2

c $F = ma = 0.040 \times 52 = 2.1 \text{ N}$ ✓✓

- e** This calculation is done correctly. Mark: 2/2

- d i** The centripetal acceleration decreases. **x**
ii The tension in the string remains unchanged. **x**

- e** The student has not grasped the fact that the centripetal acceleration is independent of the mass and depends only on the speed of the ball and the radius of the circle it is describing. Mark: 0/2



- e** The student has taken the idea that the ball does not wish to rotate in the circle to the extreme, and seems to have invented a force away from the centre of the circle pushing the ball outwards away from the circular path. Mark: 0/1

ANSWER B

- a** A centripetal acceleration is a constant magnitude acceleration towards the centre of a circle ✓✓.

- e** The definition is correct. Mark: 2/2

b $a = \frac{v^2}{r} = \frac{7^2}{(0.5 \times 1.9)}$
 $a = 51.6 \approx 52 \text{ m s}^{-2}$ ✓✓

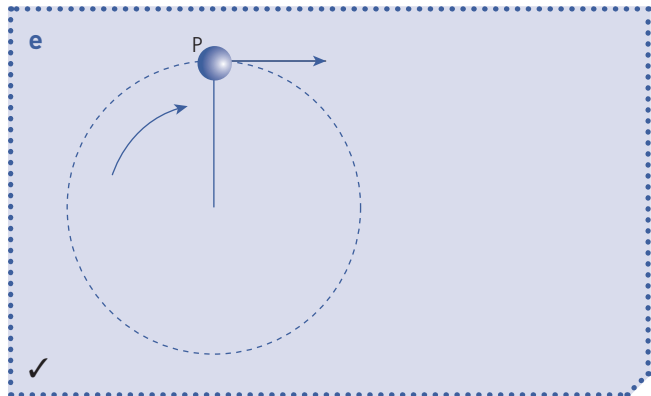
- e** Correct. Mark: 2/2

c $F = ma = 0.040 \times 51.6 = 2.06 \approx 2.1 \text{ N}$ ✓✓

- e** This is a clear and correct calculation. Mark: 2/2

- d i** The centripetal acceleration remains the same. ✓
ii The tension in the string increases. ✓

- e** Both correct. Mark: 2/2



- e** The student shows an understanding that when the centripetal force is removed then the ball continues in a straight tangential line. Mark: 1/1

Chapter 13

Answers to question 1

ANSWER A

- a** The gravitational potential at a point is the gravitational energy per unit mass of an object ✓X.

- e** Although not strictly incorrect, this does not define gravitational potential at a point. It is defined in terms of the work done per unit mass in bringing a test mass from infinity to the point. Mark: 1/2

b i $\Phi = \frac{GM}{r} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.4 \times 10^6}$ X
 $= 6.3 \times 10^7 \text{ J kg}^{-1}$ ✓

- e** This is a good effort, but there is no recognition that the potential at a point in a gravitational field is negative – the test mass has zero energy at infinity and it has less energy when close to a gravitational object. Mark: 1/2

ii Work done = $\Phi \times m$
 $= 6.25 \times 10^7 \times 800$
 $= 5.0 \times 10^{10} \text{ J}$ ✓✓

- e** Although the student has, again, not included the negativity of the potential, the calculation is completed successfully. Mark: 2/2

iii $\frac{1}{2}mv^2 = \text{work done}$
 $0.5 \times 800v^2 = 5.0 \times 10^{10} \checkmark$
 Therefore, $v = \sqrt{\frac{5.0 \times 10^{10}}{0.5 \times 800}} \checkmark$
 $v = 1.3 \times 10^8 \text{ m s}^{-1} \times$

e The calculation is done well until the student fails to take the square root of the right-hand side of the equation. Mark: 2/3.

ANSWER B

a The gravitational potential at a point is the work done per unit mass in bringing a test mass from infinity to that point.

e This is a correct definition. Mark: 2/2

b i $\Phi = -\frac{GM}{r} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.4 \times 10^6} \checkmark$
 $= -6.3 \times 10^7 \text{ J kg}^{-1} \checkmark$

e This is a clear and correct calculation with the correct unit. Mark: 2/2

ii Work done $= -\Phi \times m$
 $= +6.25 \times 10^7 \times 800$
 $= 5.0 \times 10^{10} \text{ J} \checkmark \checkmark$

e This is a clear correct calculation. Mark: 2/2

iii $\frac{1}{2}mv^2 = \text{work done}$
 $0.5 \times 800v^2 = 5.0 \times 10^{10} \checkmark$
 Therefore: $v = \sqrt{\frac{5.0 \times 10^{10}}{0.5 \times 800}} \checkmark$
 $v = 1.1 \times 10^4 \text{ m s}^{-1} \checkmark$

e A clear and fully correct answer. Mark: 3/3

Answers to question 2

ANSWER A

a i A gravitational field is an area around a large object, such as a planet, where there are forces on masses $\times \checkmark$.

e The student shows some understanding of the action of a force on a mass. But gravitational fields are not only around large objects (or masses) but around all masses. Mark: 1/2

ii For an object of mass m to orbit a planet with a circular path, the centripetal force $= m\omega^2 r$. The centripetal force is equal to the gravitational force on the object $= \frac{GMm}{r^2}$. Therefore, $m\omega^2 r = \frac{GMm}{r^2}$, the m 's cancel and cross-multiplying gives:

$$\omega^2 = \frac{GM}{r^3}$$

If we add in the radius of the Earth this becomes $\omega^2 = \frac{GM}{(R+r)^3}$

e There is some knowledge shown here, but no explanation has been provided to support the sudden addition of the radius of the Earth into the equation in the last line. Mark: 1/2

b i frequency $= \text{six per day} = \frac{6}{24 \times 60} = 4.2 \times 10^{-3}$
 per second $\times$
 $\omega = 2\pi f = 2\pi \times 4.2 \times 10^{-3}$
 $= 26.4 \times 10^{-3} \text{ rad s}^{-1} \checkmark$

e The simple arithmetic error of converting to minutes (not seconds) results in a mark being deducted from this otherwise good answer. Mark: 1/2

ii $\omega^2 = \frac{GM}{(R+r)^3}$
 Therefore, $(R+r)^3 = \frac{GM}{\omega^2}$
 $= \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(26.4 \times 10^{-3})^2} \checkmark$
 $= 5.7 \times 10^{17}$
 $(R+r) = 8.3 \times 10^5 \text{ m} \checkmark$
 $r = 6.4 \times 10^6 - 8.3 \times 10^5 = 5.6 \times 10^6 \text{ m} \times$

e The error from the previous section is carried forward and the first half of the calculation is done well. However, this gives an orbital radius of less than the Earth's diameter. Consequently, the calculation to subtract the Earth's radius from the orbital radius is incorrect. Mark: 2/3

ANSWER B

- a i A gravitational field is a region in space in which masses experience a force ✓✓.

e This correct definition gains both marks.
Mark: 2/2

- ii For an object of mass m to orbit a planet with a circular path, the centripetal force $= m\omega^2x$, where x is the orbital radius. In this case, $x = (R + r)$, so the centripetal force $= m\omega^2(R + r)$ ✓.
The centripetal force is equal to the gravitational force on the object $= \frac{GMm}{(R + r)^2}$.
Therefore, $m\omega^2(R + r) = \frac{GMm}{(R + r)^2}$, the m 's cancel and cross-multiplying gives: ✓
$$\omega^2 = \frac{GM}{(R + r)^3}$$

e A good clear derivation. Mark: 2/2

- b i frequency = six per day $= \frac{6}{24 \times 60 \times 60}$ = per second
 $\omega = 2\pi f = 2\pi \times 6.94 \times 10^{-5}$
 $= 4.36 \times 10^{-4} \text{ rad s}^{-1}$ ✓✓

e A clear and correct calculation. Mark: 2/2

- b ii $\omega^2 = \frac{GM}{(R + r)^3}$
Therefore, $(R + r)^3 = \frac{GM}{\omega^2}$
 $= \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(4.36 \times 10^{-4})^2}$ ✓
 $= 2.09 \times 10^{21}$
 $(R + r) = 1.28 \times 10^7 \text{ m}$ ✓
 $R = 0.5 \times 12700 \text{ km} = 6.35 \times 10^6 \text{ m}$
Therefore, $r = 12.8 \times 10^6 - 6.35 \times 10^6 = 6.5 \times 10^6 \text{ m}$ ✓

e This is a clear and concise calculation.
Mark: 3/3

Chapter 14**Answers to question 1****ANSWER A**

- a The specific heat capacity is the energy required to change the temperature of 1 kilogram of a substance by 1 degree kelvin ✓X.

e Specific heat capacity is a quantity. It is therefore defined in terms of other quantities so the use of 1 kilogram instead of unit mass and 1 kelvin instead of unit temperature means the second mark cannot be awarded.
Mark: 1/2

- b i Change in temperature of iron $= 130 - 19 = 111^\circ\text{C}$

$$\text{SHC} = \frac{\text{energy}}{\text{mass} \times \text{temperature change}} \quad \checkmark$$

$$\text{SHC} = \frac{\text{energy}}{0.15 \times 111}$$

$$\text{SHC} = \frac{\text{energy}}{16.65}$$

$$\text{Change in temperature of water} = 19 - 10 = 9^\circ\text{C}$$

$$4200 = \frac{\text{energy}}{200 \times 9} \quad \times$$

$$\text{energy} = 7.56 \times 10^6 \text{ J}$$

$$\text{SHC} = \frac{7.56 \times 10^6}{16.65}$$

$$\text{SHC} = 4.54 \times 10^5 \text{ J kg}^{-1} \quad \checkmark \times$$

e The formula for specific heat capacity is correct and the student has used the correct values of temperature change in the calculations. There is a power of ten error in the mass of the water – it should be 0.200 kg, and the final unit is not correct. Mark: 2/4

- ii All of the iron is at 130°C at the beginning X.

e This statement is true, but it is not sufficient to be awarded a mark as the stem of the question states that the iron block has been heated to 130°C . Mark: 0/1

ANSWER B

- a The specific heat capacity is the energy required to change the temperature of unit mass of a substance by unit temperature ✓✓.

e This is a correct description of specific heat capacity. Mark: 2/2

- b i The energy lost by the iron is equal to the energy gained by the water.
- $$\frac{\text{SHC}_{\text{iron}} \times \text{mass}_{\text{iron}} \times \text{temp change}_{\text{iron}}}{\times \text{mass}_{\text{water}} \times \text{temp change}_{\text{water}}} = \text{SHC}_{\text{water}} \checkmark$$
- $$\text{SHC}_{\text{iron}} \times 0.15 \times 111 = 4200 \times 0.200 \times 9 \checkmark$$
- $$\text{SHC}_{\text{iron}} = \frac{7560}{16.65}$$
- $$\text{SHC}_{\text{iron}} = 454 \text{ J kg}^{-1} \text{ K}^{-1} \checkmark \checkmark$$

e The initial equation and the substitution are both correct, leading to a correct answer and unit. Mark: 4/4

- ii That all of the energy lost by the iron is gained by the water and none of the energy is lost to the surroundings ✓.

e This is a valid assumption as any thermal energy lost to the surroundings would not be taken into account in the calculation. Mark: 1/1

Answers to question 2

ANSWER A

- a The specific latent heat of fusion of a material is the energy required to change the state of one kilogram of a material ~~XX~~.

e The definition of specific latent heat of fusion of a material must include the change of state being between solid and liquid, and any specific latent heat must occur at a single temperature. Mark: 0/2

- b i 18°C ✓

e This is correct. Mark: 1/1

- ii The energy transferred from the water to the ice = $mc\Delta\theta = 400 \times 4.2 \times 18 = 30\,240$ ~~XX~~✓
The energy received by the ice = $mL = 330 \times m$
Therefore, $m = \frac{30\,240}{330} = 91.6 \text{ g}$ ✓

e The student has not recognised that the ice, once melted, needs more energy to heat up from -5 to 0°C. Mark: 2/4

ANSWER B

- a The specific latent heat of fusion is the energy required to convert unit mass of the material from solid to liquid without change in the temperature ✓✓.

e This is a correct description of specific heat capacity. Mark: 2/2

- b i 18°C ✓

e This is correct. Mark: 1/1

- ii The energy lost by the water is equal to the energy gained by the ice.
- $$m_{\text{water}} \times c_{\text{water}} \times \Delta\theta_{\text{water}} = m_{\text{ice}} \times L_{\text{fusion}} + m_{\text{ice}} \times c_{\text{ice}} \times \Delta\theta_{\text{ice}} \checkmark$$
- $$0.40 \times 4200 \times 18 = (m_{\text{ice}} \times 3.3 \times 10^5) + m_{\text{ice}} \times 2100 \times 5 \checkmark$$
- $$30\,240 = (3.3 \times 10^5 + 10\,500)m_{\text{ice}}$$
- $$\text{Therefore, } m_{\text{ice}} = \frac{3.024 \times 10^4}{3.405 \times 10^5} = 0.089 \text{ kg} \checkmark \checkmark$$

e This is an excellent answer. The energy released by the cooling water has been used to warm the ice from -5°C to 0°C and then melt the ice. Mark: 4/4

Chapter 15

Answers to question 1

ANSWER A

- a An ideal gas has no forces between its molecules, the volume of the container is much greater than the volume of the gas molecules and the molecules all move with random motion ~~XX~~.

e The student has written the assumptions of the kinetic theory of gases not a description of an ideal gas. Mark: 0/2

b $pV = nRT$ so $n = \frac{pV}{RT}$
 $n = \frac{2.0 \times 10^6 \times 0.20}{8.31 \times 273}$ ✓
 $n = 176 \text{ moles}$ ✓

e The correct expression is given with the correct substitution, leading to the correct answer. Mark: 2/2

c i $n = \frac{5.0 \times 10^3 \times 120 \times 10^{-2}}{8.31 \times 300}$
 $n = 2.41 \text{ moles}$ ✗

e There is an error in the conversion of 120 cm^3 to m^3 . Mark: 0/1

ii number of bulbs = $\frac{176}{2.41} = 73 \text{ bulbs}$ ✓

e The power of ten error in part ci is carried forward so the student earns full credit even though the answer is numerically incorrect. Mark: 1/1

ANSWER B

a An ideal gas is one that obeys the equation $pV \propto T$ at all pressures, volumes and temperatures ✓✓.

e This is the correct description of an ideal gas. Mark: 2/2

b $n = \frac{pV}{RT}$
 $n = \frac{2.0 \times 10^6 \times 0.20}{8.31 \times 273}$ ✓
 $n = 176 \text{ moles}$ ✓

e The correct expression is given with the correct substitution, leading to the correct answer. Mark: 2/2

c i $n = \frac{5.0 \times 10^3 \times 120 \times 10^{-6}}{8.31 \times 300}$
 $n = 2.41 \times 10^{-4} \text{ moles}$ ✓

e The correct expression is given with the correct substitution, leading to the correct answer. Mark: 1/1

ii number of bulbs = $\frac{176}{2.41 \times 10^{-4}}$
 $= 7.3 \times 10^5 \text{ bulbs}$ ✓

e The student has used the answers from parts b and ci to find the number of bulbs. Mark: 1/1

Answers to question 2

ANSWER A

a The root-mean-square speed is the square root of the mean speed squared ✗✗.

e The correct answer should make reference to the mean of the square of the speeds of the molecules. The mean speed squared is not correct as it is the mean of the speed of all the molecules that is then squared. Mark: 0/2

b i $pV = nRT$ so $n = \frac{pV}{RT}$ ✓
 $n = \frac{1.02 \times 10^5 \times 0.140}{8.31 \times 20}$
 $n = 86 \text{ moles}$ ✗

e The student has written the correct expression, but in the substitution they have used temperature in Celsius – it should be absolute temperature ($273 + 20 = 293 \text{ K}$). Mark: 1/2

ii $\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 20$
 $= 4.14 \times 10^{-22} \text{ J}$ ✓✓

e A mark is awarded for the correct expression. Although temperature in Celsius has been used, this error has already been penalised in part bi, so the error is carried forward and, as the physics is correct, full marks are

awarded even though the answer gives the wrong value. Mark: 2/2

$$\text{iii } \langle c^2 \rangle = \frac{2 \times 4.14 \times 10^{-22}}{6.6 \times 10^{-27}} \checkmark \\ = 1.25 \times 10^5 \text{ ms}^{-1} \times$$

e The correct equation is given for the calculation of the mean of the square speeds, but the student has not taken the square root. Mark: 1/2

$$\text{c i } V = \frac{nRT}{p} = \frac{86 \times 8.31 \times 77}{1.02 \times 10^5} = 0.54 \text{ m}^3 \checkmark \checkmark$$

e This is another example of an error carried forward. The temperature is in Celsius, but that error has already been penalised in part bi. Mark: 2/2

$$\text{ii } \begin{aligned} &\text{The average kinetic energy of one molecule} \\ &= \frac{3}{2} kT \text{ so kinetic energy of all the molecules} \\ &= \frac{3}{2} NkT \text{ where } N \text{ is the total number of} \\ &\text{molecules} = nN_A, \text{ where } n = \text{number of} \\ &\text{moles and } N_A \text{ is the Avogadro constant. So} \\ &\text{total kinetic energy} = \frac{3}{2} nN_A kT \checkmark. \\ &\text{Total KE} = \frac{3}{2} \times 86 \times 6.02 \times 10^{23} \times 1.38 \times 10^{-23} \times 77 \\ &\text{Total KE} = 8.25 \times 10^4 \text{ J} \checkmark \end{aligned}$$

e The substituted expression is correct, although the temperature is in Celsius this is another example of error carried forward from part bi. Mark: 2/2

ANSWER B

a This is the square root of the average of the squares of the velocities of the molecules in a gas $\checkmark \checkmark$.

e This is a correct description of the root-mean-square speed. Mark: 2/2

$$\text{b i } n = \frac{pV}{RT} \checkmark \\ n = \frac{1.02 \times 10^5 \times 0.140}{8.31 \times 293} \\ n = 5.86 \text{ moles} \checkmark$$

e The correct formula is given. The student has converted the value of the temperature in Celsius to absolute temperature and all the other values are substituted, leading to the correct answer. Mark: 2/2

$$\text{ii } E_k = \frac{3}{2} kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 293 \checkmark \\ E_k = 6.07 \times 10^{-21} \text{ J} \checkmark$$

e Correct formula and substitution, leading to the correct answer. Mark: 2/2

$$\text{iii } \langle c^2 \rangle = \frac{2E_k}{m} \\ = \frac{(2 \times 6.07 \times 10^{-21})}{(6.6 \times 10^{-27})} \checkmark \\ = 1.84 \times 10^6 \\ \text{Therefore } \sqrt{\langle c^2 \rangle} = 1.36 \times 10^3 \text{ ms}^{-1} \checkmark$$

e This is a good answer laid out clearly. The student has calculated the mean square speed of the molecules and has then taken the square root of this value to give the average speed of the helium molecules. Mark: 2/2

$$\text{c i } \frac{V_1}{T_1} = \frac{V_2}{T_2} \checkmark \\ V_2 = \frac{0.140 \times 350}{293} \\ V_2 = 0.167 \text{ m}^3 \checkmark$$

e Correct formula and substitution, leading to the correct answer. Mark: 2/2

$$\text{ii } \text{Total } E_k = \frac{3}{2} pV \checkmark \\ \text{Total } E_k = \frac{3}{2} \times 1.02 \times 10^5 \times 0.167 \\ \text{Total } E_k = 2.56 \times 10^4 \text{ J} \checkmark$$

e This is a more straightforward method than that used by the student for Answer A. Mark: 2/2

Chapter 16

Answers to question 1

ANSWER A

- a The sum of the random kinetic and potential energies of a gas **XX**.

- e The student has not referred to the energies of the molecules. Mark: 0/2

- b i $W = p\Delta V \checkmark = 1.02 \times 10^5 \times 2.6 \times 10^{-2}$
 $= 2.65 \times 10^3 \text{ J } \text{X}$

- e The formula is correct, but the final volume has been used in the calculation, not the change in volume. Mark: 1/2

- ii $\Delta U = q + W$
 $\Delta U = 1.5 + 2.65 = 4.15 \text{ kJ } \text{XX}$

- e As the gas expands, work is done by the gas, so the work done should be subtracted from the thermal energy supplied not added to it. Mark: 0/2

- iii As the volume increases, the temperature increases **✓X**.

- e The statement is true, but there is no explanation to support it. Mark: 1/2

- c i Work is done by the gas **X**.

- e The volume of the gas decreases so work is done on the gas. Mark: 0/2

- ii The internal energy decreases **XX**.

- e While this statement is true, there is no explanation for this change, which is what the question has asked for. Mark: 0/2

ANSWER B

- a The sum of a random distribution of the kinetic and potential energies of the molecules of a system **✓✓**.

- e This is a correct definition. Mark: 2/2

- b i $W = p\Delta V = 1.02 \times 10^5 \times 0.6 \times 10^{-2} = 612 \text{ J } \checkmark\checkmark$

- e The student has found the product of the pressure and the change in volume to give the correct answer. Mark: 2/2

- ii $\Delta U = q - W \checkmark$
 $\Delta U = 1.5 \times 10^3 - 612$
 $\Delta U = 888 \text{ J } \checkmark$

- e The student has realised that work is done by the gas as it expands, so the work done is subtracted from the heat supplied to give the change in internal energy. Mark: 2/2

- iii The internal energy of the gas increases hence the average kinetic energy of the molecules of the gas increases so the temperature of the gas increases **✓✓**.

- e The change in internal energy has been linked to the change in kinetic energy of the molecules and the temperature change. Mark: 2/2

- c i Since $\frac{pV}{T}$ is a constant and the gas has returned to its original pressure and temperature, the volume must have decreased. Work done $= p\Delta V$. As the gas cools, its volume decreases, so ΔV is negative, which means that work is done on the gas **✓✓**.

- e This is a detailed description of what happens to the volume as the gas cools at constant pressure. Mark: 2/2

- ii The temperature of the gas has decreased, so the average kinetic energy of the molecules has decreased, which means that the sum of the kinetic energies of the molecules is lower and the internal energy of the gas has decreased **✓✓**.

- e The internal energy has been linked to the kinetic energy of the molecules and the change in internal energy. Mark: 2/2

Chapter 17

Answers to question 1

ANSWER A

a i $\omega = \frac{2\pi}{T}$ ✓
 $\omega = 3.14 \text{ rad s}^{-1}$ ✓

e The correct formula is used and the correct answer given with the correct unit. Mark: 2/2

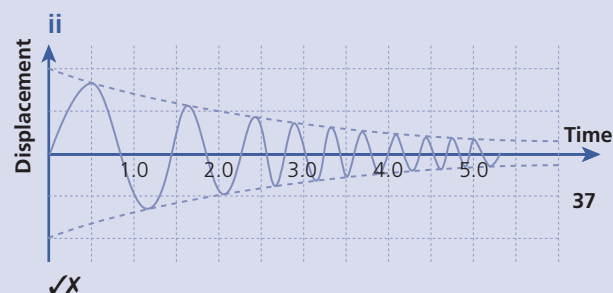
ii $F = m\omega^2 x_0$
 $F = 0.75 \times 3.14^2 \times 12$
 $F = 89 \text{ N}$ ✓X

e The working is reasonably clear and gets the nearly correct answer, although it is not quite clear where the π^2 (3.14^2) comes from (it is ω^2). Unfortunately, in the equation, the amplitude is not converted into metres. Mark: 1/2

b i maximum speed = $\omega r = \pi \times 12 = 38 \text{ cm s}^{-1}$ ✓
 $E_k = \frac{1}{2}mv^2 = 0.5 \times 0.75 \times 38^2 = 542 \text{ J}$ ✓X
 ii $mgh = ?$ X

e This is a repeated error, only this time not converting cm s^{-1} into m s^{-1} . This is not penalised a second time, although the student should have realised that the answer obtained is far too large. Part bii is not answered because the student does not understand that the kinetic energy and the potential energy add to give the total energy, which remains constant. Mark: 2/4

c i Its amplitude is decreasing X.



e There is some understanding of light damping but the graph is poor. Although the envelope is correct, the question asks for a graph of this particular motion, which indicates some values are needed — in this case the period. The student does not show the period as 2s but reduces the period as the amplitude decreases. Mark: 1/3

ANSWER B

a i $\omega = 2\pi f$ and $f = \frac{1}{T}$
 $f = \frac{1}{2.0} = 0.5 \text{ Hz}$
 $\omega = 2\pi \times 0.5 = 3.14 \text{ rad s}^{-1}$

e Two calculation steps have been taken in this method which lead to the correct answer. Mark: 2/2

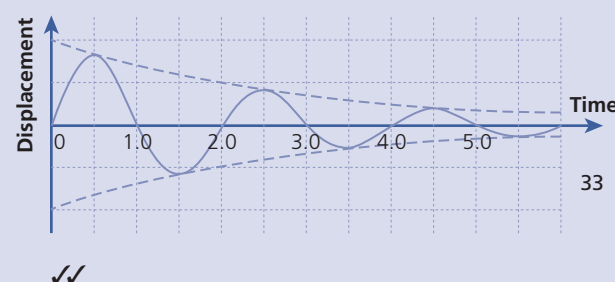
ii $F = ma$ $a = -\omega^2 x_0$ $F = -0.75 \times 3.14^2 \times 0.12$
 $F = -0.89 \text{ N}$

e There is clear working here to arrive at the correct answer, with the understanding that the maximum restoring force is at maximum displacement. The inclusion of the minus sign, while not an absolute requirement, shows an appreciation that the force is a restoring force. Mark: 2/2

b i maximum speed = $\omega r = \pi \times 0.12 = 0.38 \text{ m s}^{-1}$ ✓
 $E_k = \frac{1}{2}mv^2 = 0.5 \times 0.75 \times 0.38^2 = 0.054 \text{ J}$ ✓✓
 ii 0.054 J ✓

e Once more there is clear working leading to the correct answer, and then a clear understanding that the kinetic energy is converted to potential energy. Mark: 4/4

c It is having to do work against something like friction, so it gradually loses energy and the amplitude decreases slowly ✓.



e The answer shows a clear understanding of damping and the diagram confirms an understanding of light damping. The period is correct (and constant). Mark: 3/3

Answers to question 2

ANSWER A

- a i The straight line shows that the acceleration is directly proportional to the displacement ✓**x**.

e The student has explained that acceleration is proportional to displacement, but they have not referred to the direction of the acceleration being opposite to the displacement. Mark: 1/2

- ii The amplitude is 1.2 m ✓

e The amplitude is the maximum displacement, and the value has been correctly read from the graph. Mark: 1/1

iii $a = -\omega^2 x_0$ ✓ $-0.30 = -\omega^2 \times 1.20$
 $\omega = \frac{0.30}{1.20}$ **x**
 $\omega = 0.25 \text{ rad s}^{-1}$

e The formula for acceleration is correct, but the value given is ω^2 . The student has not taken the square root to find the correct answer. Mark: 1/2

iv $\omega = 2\pi f \Rightarrow f = \frac{0.25}{2\pi} \Rightarrow f = 0.040 \text{ Hz}$
 $T = \frac{1}{f} = \frac{1}{0.04}$ ✓
 $T = 25 \text{ s}$ ✓

e The student has used the value of angular frequency calculated in part a iii. As this has already been penalised, the error is carried forward here and all the marks are awarded. Mark: 2/2

v $v = \omega \sqrt{(x_0^2 - x^2)}$
 $= 0.5 \times \sqrt{(1.22^2 - 0.60^2)} = 0.52 \text{ m s}^{-1}$ ✓

e The correct formula for velocity is written, and the carried-forward value from part a iii for angular frequency is used, so all the marks are awarded. Mark: 2/2

- b An earthquake near the building would cause the building to shake vigorously **xx**.

e The statement is true, but there is no explanation linking an increase in amplitude to the frequency. Mark: 0/2

ANSWER B

- a i When acceleration is positive, the displacement is negative. This shows that the acceleration acts in the opposite direction to the displacement. The straight line shows that the acceleration is directly proportional to the displacement, i.e. $a \propto -x$, which is the condition for simple harmonic motion ✓✓.

e A detailed explanation of how the graph shape links to the conditions for simple harmonic motion. Mark: 2/2

- ii The amplitude is the maximum displacement, which is 1.2 m ✓

e The amplitude is the maximum displacement, and the value has been correctly read from the graph. Mark: 1/1

iii $a = -\omega^2 x_0$ ✓ $\Rightarrow -0.30 = -\omega^2 \times 1.20$
 $\omega = \sqrt{\frac{0.30}{1.20}}$
 $\omega = 0.50 \text{ rad s}^{-1}$ ✓

e The correct formula has been given with the values substituted leading to the correct answer. Mark: 2/2

iv $\omega = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{0.50} \Rightarrow T = 12.6 \text{ s}$ ✓✓

e The correct formula has been given with the values substituted leading to the correct answer. Mark: 2/2

v $v = \omega \sqrt{(x_0^2 - x^2)}$
 $= 0.5 \times \sqrt{(1.22^2 - 0.60^2)} = 0.52 \text{ m s}^{-1}$ ✓

e The correct formula has been given with the values substituted leading to the correct answer. Mark: 2/2

- b** The frequency of 0.08 Hz is the same as the natural frequency of vibration of the building. This would act as a driver frequency causing the building to resonate and oscillate with increasingly large amplitude ✓✓.

- e** The student has linked the earthquake frequency and the natural frequency of the building to explain that resonance occurs, which would increase the amplitude of oscillation. Mark: 2/2

- e** This is a good definition. Mark: 1/1

b $V = \frac{Q}{4\pi\epsilon_0 r}$
 $65 \times 10^3 = \frac{Q}{4\pi \times 8.85 \times 10^{-12} \times 0.25}$
 $Q = 1.80 \times 10^{-6} \text{ C} \checkmark\checkmark$

- e** This is a good, clear calculation, resulting in the correct answer. Mark: 2/2

Chapter 18

Answers to question 1

ANSWER A

- a** The electrical potential at a point is the work done in bringing charge from infinity to the point. ✗

- e** There is no reference that it is the work done per unit charge. Mark: 0/1

b $V = \frac{Q}{4\pi\epsilon_0 r}$
 $65 \times 10^3 = \frac{Q}{4\pi \times 8.85 \times 10^{-12} \times 0.5}$
 $Q = 3.6 \times 10^{-6} \text{ C} \checkmark\checkmark$

- e** This is a reasonable effort. It is correct apart from the diameter (0.5 m), rather than the radius (0.25 m), of the dome being used. Mark: 1/2

- c** change in voltage = 53 kV
 Therefore, change in energy = $\frac{1}{2}QV = 0.5 \times 3.60 \times 10^{-6} \times 53 \times 10^3 = 9.5 \times 10^{-2} \text{ J} \checkmark\text{xxx}$

- e** The student is taking the energy to vary linearly with the voltage – it varies with voltage squared. The easiest way of calculating the discharge energy is to find both the energy before and the energy after discharge. Then find the difference between them. A compensation mark is given for the use of the formula $\frac{1}{2}QV$. Mark: 1/4

ANSWER B

- a** The electrical potential at a point is the work done per unit charge when a small test charge is brought from infinity to the point ✓.

- c** energy before discharge = $\frac{1}{2}QV = 0.5 \times 1.80 \times 10^{-6} \times 65 \times 10^3 = 5.9 \times 10^{-2} \text{ J} \checkmark\checkmark$
 Charge after the discharge = $4\pi\epsilon_0 Vr = 4\pi \times 8.85 \times 10^{-12} \times 12 \times 10^3 \times 0.25 = 0.336 \times 10^{-6} \text{ C}$
 Energy after discharge = $\frac{1}{2}QV = 0.5 \times 0.336 \times 10^{-6} \times 12 \times 10^3 = 2.0 \times 10^{-3} \text{ J} \checkmark$
 Energy change = $5.8 \times 10^{-2} - 2.0 \times 10^{-3} = 5.6 \times 10^{-2} \text{ J} \checkmark$

- e** The problem is tackled in a logical manner, and the working is easy to follow. Mark: 4/4

Answers to question 2

ANSWER A

a energy (W) = $\frac{1}{4\pi\epsilon_0} \times \frac{Q}{r}$
 Therefore, $r = \frac{1}{4\pi\epsilon_0} \times \frac{Q}{W}$
 $= 8.99 \times 10^9 \times \frac{1.6 \times 10^{-19}}{2.2 \times 10^{-18}}$
 $= 6.5 \times 10^8 \text{ m} \text{ ✗}$

- e** The student has forgotten that to find the energy change both the charge on the proton and the charge on the electron need to be taken into consideration. The answer of more than 10^5 m should have highlighted the error. Mark: 0/2

b $\text{Vm}^{-1} = \text{JC}^{-1}\text{m}^{-1} = \text{NmC}^{-1}\text{m}^{-1} = \text{NC}^{-1} \checkmark$

- e** This is a neat way of showing that the units are equivalent without going all the way to base units. Mark: 1/1

c i $E = \frac{V}{d}$
 $= \frac{2.0}{5.0} \checkmark$
 $= 0.40 \text{ NC}^{-1} \times$

e The formula is correct, but the units need to be given in volts and metres. Mark: 1/2

ii $F = Eq = 0.40 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-20} \text{ N} \checkmark \checkmark$

e The error for E in part ci is carried forward and it is a correct calculation, so full marks are given. Mark: 2/2

iii acceleration $= \frac{F}{m} = \frac{6.4 \times 10^{-20}}{9.11 \times 10^{-31}}$
 $= 7.03 \times 10^{10} \text{ ms}^{-2} \checkmark$

From $v^2 = u^2 + 2as$ we get $v = \sqrt{2as} \checkmark$

So $v = \sqrt{2 \times 7.03 \times 10^{10} \times 5 \times 10^{-2}}$
 $= 8.4 \times 10^4 \text{ ms}^{-1} \times$

e The student has used the correct formulae to calculate the velocity but has used a distance of 5.0 cm, which is the total distance between the plates rather than 2.5 cm, which is the distance travelled in the vertical direction by the electron. Mark: 2/3

iv $v = \sqrt{(v_H^2 + v_V^2)}$
 $= \sqrt{(8.4 \times 10^4)^2 + (2.8 \times 10^7)^2} \checkmark$
 $= 2.8 \times 10^7 \text{ ms}^{-1} \checkmark$

e The earlier error carried forward for E becomes quite significant here. The vertical velocity is very much smaller than the horizontal velocity, so (to the accuracy we are working) the overall velocity is effectively equal to the horizontal velocity. Nevertheless, the student has correctly worked through the calculation. Mark: 2/2

v The curve would be less steep $\times$ and the positron would be attracted to the negative plate $\checkmark$.

e Although the positron is attracted to the negative plate, the steepness of the curve remains the same. Has the student misread positron as proton? Mark: 1/2

ANSWER B

a energy (W) $= \frac{1}{4\pi\epsilon_0} \times \frac{Q_1 Q_2}{r}$

Therefore: $r = \frac{1}{4\pi\epsilon_0} \times \frac{Q_1 Q_2}{W}$

$= 8.99 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{22 \times 10^{-18}} \checkmark$
 $= 1.04 \times 10^{-10} \text{ m} \checkmark$

e This is clear and the student lays the work out well. Mark: 2/2

b Base units of NC^{-1} are: $\text{kg ms}^{-2} \text{A}^{-1} \text{s}^{-1} = \text{kg ms}^{-3} \text{A}^{-1} \checkmark$
 units of V are: $\text{JC}^{-1} = \text{NmA}^{-1} \text{s}^{-1} = \text{kg ms}^{-2} \text{mA}^{-1} \text{s}^{-1} = \text{kg m}^2 \text{s}^{-3} \text{A}^{-1}$
 Therefore, the base units of Vm^{-1} are: $\text{kg m}^2 \text{s}^{-3} \text{A}^{-1} \text{m}^{-1} = \text{kg ms}^{-3} \text{A}^{-1} \checkmark$
 Both versions have the same base units $\checkmark$

e A good demonstration of understanding of homogeneity of units. Mark: 2/2

c i $E = \frac{V}{d}$
 $= \frac{2000}{5.0 \times 10^{-2}} \checkmark$
 $= 40\,000 \text{ Vm}^{-1} \checkmark$

e This is a clear and correct calculation. Mark: 2/2

ii $F = Eq = 40\,000 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-15} \text{ N} \checkmark \checkmark$

e A correct calculation. Mark: 2/2

iii acceleration $= \frac{F}{m}$
 $= \frac{6.4 \times 10^{-15}}{9.11 \times 10^{-31}}$
 $= 7.03 \times 10^{15} \text{ ms}^{-2} \checkmark$
 From $v^2 = u^2 + 2as$ we get $v = \sqrt{2as} \checkmark$
 So $v = \sqrt{2 \times 7.03 \times 10^{15} \times 2.5 \times 10^{-2}}$
 $= 1.9 \times 10^7 \text{ ms}^{-1} \checkmark$

e A correct calculation. Mark: 3/3

$$\begin{aligned}\text{iv } v &= \sqrt{v_H^2 + v_V^2} \\ &= \sqrt{(1.9^2 + 2.8^2)} \times 10^7 \checkmark \\ &= 3.4 \times 10^7 \text{ m s}^{-1} \checkmark\end{aligned}$$

e A correct calculation. Mark: 2/2

v The curve would be the same shape, but the positron would accelerate to the earthed plate, unlike the electron. $\checkmark$

e This is a good clear explanation. Mark: 1/1

e The student's reference to the capacitors having the charge divided equally between them is correct. They have then used their knowledge of capacitance to determine the p.d. across each capacitor, then calculated the energy stored on one capacitor. They have forgotten to add the energy stored on the other capacitor. Mark: 2/3

iv Some of the energy has been wasted as heat $\times$.

e There is no explanation to support this statement. Mark: 0/1

Chapter 19

Answers to question 1

ANSWER A

a The capacitance is the charge divided by the potential difference $\times \checkmark$.

e There is no reference to the charge on one plate or the p.d. between the plates. This is a general description of capacitance rather than the capacitance of a parallel plate capacitor. Mark: 1/2

b i $Q = CV = 2200 \times 10^{-6} \times 12 = 2.64 \times 10^{-2} \text{ F} \checkmark \times$

e The formula, substitution and answer are all correct, but the unit is given as farad, which is the unit of capacitance not the unit of charge. Mark: 1/2

ii $E = \frac{1}{2} CV^2 = \frac{1}{2} \times 2200 \times 10^{-6} \times 12^2 \checkmark$
 $E = 0.16 \text{ J} \checkmark$

e The formula, substitution and answer are all correct. Mark: 2/2

iii The charge is now shared between the two capacitors, so each capacitor has 1.3×10^{-2} coulombs of charge.
 $V = \frac{Q}{C}$ so the p.d. across the capacitor
 $= \frac{1.32 \times 10^{-2}}{2200 \times 10^{-6}} = 6.0 \text{ V} \checkmark$
 $E = \frac{1}{2} CV^2 = \frac{1}{2} \times 2200 \times 10^{-6} \times 6.0^2 = 0.0396 \text{ J} \checkmark \times$

ANSWER B

a The capacitance of a parallel plate capacitor is the charge on the capacitor divided by the potential difference between the plates $\checkmark$.

e The student realises that capacitance is the ratio of charge to potential difference, but it is not clear from this description that for a parallel plate capacitor the charge required is the charge on a single plate. Mark: 1/2

b i $Q = CV = 2200 \times 10^{-6} \times 12 = 2.6 \times 10^{-2} \text{ C} \checkmark \times$

e The formula and substitution are correct but the answer should have been given to 3 significant figures. Mark: 1/2

ii $E = \frac{1}{2} QV = \frac{1}{2} \times 2.6 \times 10^{-2} \times 12 \checkmark$
 $E = 0.16 \text{ J} \checkmark$

e The value calculated in part bi has been used with the correct formula to give the energy stored. Mark: 2/2

iii The capacitors are connected in parallel so the total capacitance is $4400 \mu\text{F}$.

$$\begin{aligned}E &= \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} \times \frac{(2.6 \times 10^{-2})^2}{4400 \times 10^{-6}} \checkmark \checkmark \\ E &= 0.077 \text{ J} \checkmark\end{aligned}$$

e The student realises that the capacitors are now connected in parallel, so the total capacitance is the sum of the individual capacitances. The value for the charge in part i should have been given to 3 significant

figures and consequently some inaccuracy creeps in, but the error was penalised in part i. Mark: 3/3

- iv When the capacitors are connected together, work is done in transferring charge from one capacitor to the other. This energy is dissipated as thermal energy, so there is less energy left stored on the plates ✓.

- e This is a well-reasoned explanation for the difference in energy. Mark: 1/1

Answers to question 2

ANSWER A

a $Q = CV = 2200 \times 10^{-6} \times 12 = 2.6 \times 10^{-2} \text{ C}$ ✓✓

- e The student has written the formula, substituted the values of capacitance and potential difference to arrive at the correct answer. Mark: 2/2

b Time constant = $RC = 2200 \times 10^{-6} \times 2.0 \times 10^3 = 4.4$ ✓✗

- e The student has calculated the value of the time constant correctly but has missed out the unit which is seconds. Mark: 1/2



- e A curve with a decreasing gradient that does not touch the x-axis is the correct shape, but the student should also have included values of charge and time on *both* axes and axis labels. Mark: 1/3

d $Q = Q_0 e^{\frac{-t}{RC}} \Rightarrow Q = 2.6 \times 10^{-2} \times e^{-\frac{4.4}{20}}$
 $Q = 2.1 \times 10^{-2} \text{ C}$ ✗✗

- e There is no credit for writing the formula as this is given on the data sheet. The student has inverted the formula for the time constant so the answer is wrong. Mark: 0/2

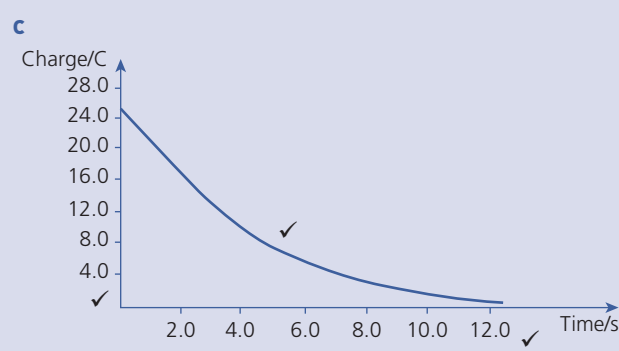
ANSWER B

a $Q = CV = 2200 \times 10^{-6} \times 12 = 2.64 \times 10^{-2} \text{ C}$

- e Correct formula, substitution and answer. Mark: 2/2

b Time constant = $RC = 2200 \times 10^{-6} \times 2.0 \times 10^3 = 4.4 \text{ s}$ ✓✓

- e The time constant is calculated correctly. Mark: 2/2



- e The student has included labels and values of charge and time on the axes and has plotted a curve with a decreasing gradient starting at $26 \times 10^{-3} \text{ C}$. Mark: 3/3

d $Q = Q_0 e^{\frac{-t}{RC}}$ at 20 s $\frac{t}{RC} = \frac{20.0}{4.4} = 4.55$
 $Q = 2.64 \times 10^{-2} \times e^{-4.55}$
 $Q = 2.8 \times 10^{-4} \text{ C}$

- e The value for the time constant calculated in part b has been used to calculate a value for t/RC , which has been substituted into the formula to arrive at the correct answer. Mark: 2/2

Chapter 20

Answers to question 1

ANSWER A

a energy = $eV = 1.6 \times 10^{-19} \times 4.8 = 7.68 \times 10^{-19} \text{ J}$ ✗
 $7.68 \times 10^{-19} = 0.5 \times 9.1 \times 10^{-31} \times v^2$
 $v = \sqrt{\frac{7.68 \times 10^{-19}}{0.5 \times 9.1 \times 10^{-31}}} = 1.3 \times 10^6 \text{ ms}^{-1}$ ✓✓

e This is a good effort, although the student has forgotten to change kilovolts to volts. The work is set out reasonably well, but it would be improved by including the expression for kinetic energy. Nevertheless, it is easy to spot the mistake, so only 1 mark is lost. Mark: 2/3

b i The force is at right angles to the velocity ✓, so the motion is circular.

e The student scores the first mark for recognising that the force is at right angles to the velocity but does not develop the argument. Mark: 1/2

ii $F = Bqv = 4.0 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2.8 \times 10^7 = 1.79 \times 10^{-14} \text{ N}$ ✓✓

e This part is done well and scores both marks. Mark: 2/2

iii $F = \frac{1}{2} \frac{mv^2}{r}$ ✗
 $1.79 \times 10^{-14} = \frac{1}{2} \times \frac{9.1 \times 10^{-31} \times (2.8 \times 10^7)^2}{r}$
 $r = \frac{1}{2} \times \frac{9.1 \times 10^{-31} \times (2.8 \times 10^7)^2}{1.79 \times 10^{-14}}$
 $= 1.99 \times 10^{-2} \text{ m}$ ✗

e The formula is wrong. The student has added in a '1/2', as if it were kinetic energy. This is a serious error, showing a failure to understand the physics, so both marks are lost. Mark: 0/2

c The radius is reduced ✓ because it decreases when the velocity decreases ✗.

e The student recognises that the radius decreases – perhaps the result is remembered from the experiment being carried out during

the course. However, the reasoning simply repeats what has been said already. Mark: 1/2

ANSWER B

a energy of the electrons = $eV = 1.6 \times 10^{-19} \times 4.8 \times 10^3 = 7.68 \times 10^{-16} \text{ J}$
 $E_k = \frac{1}{2}mv^2$
 $7.68 \times 10^{-16} = 0.5 \times 9.1 \times 10^{-31} \times v^2$
 $v = \sqrt{\frac{7.68 \times 10^{-16}}{0.5 \times 9.1 \times 10^{-31}}} = 4.1 \times 10^7 \text{ ms}^{-1}$ ✓✓✓

e This is a clear, well set out and correct calculation. Mark: 3/3

b i The force is at right angles to the velocity of the electrons, so there is no change in the magnitude of the velocity. As the direction of the velocity changes, so does the force direction, always remaining at right angles to the velocity. The magnitude of the velocity remains constant ✓✓.

e This excellent description takes the argument further than answer A, explaining how the direction of the force changes continuously as the velocity direction changes. Mark: 2/2

ii $F = Bev = 4.0 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2.8 \times 10^7 = 1.79 \times 10^{-14} \text{ N}$ ✓✓

e This shows good, clear use of the equation for the force on a charged particle in a magnetic field. The student uses e for the charge, because it is the charge on an electron. Mark: 2/2

iii $F = \frac{mv^2}{r}$
 $1.79 \times 10^{-14} = \frac{9.1 \times 10^{-31} \times (2.8 \times 10^7)^2}{r}$ ✓
 $r = \frac{9.1 \times 10^{-31} \times (2.8 \times 10^7)^2}{(1.79 \times 10^{-14})} = 4.0 \times 10^{-2} \text{ m}$ ✓

e This is a clear use of the equation for circular motion. Mark: 2/2

c The radius is reduced because the velocity falls. The centripetal force is equal to $Bqv = mv^2/r$, thus $r = mv/Bq$. B , q and m are unchanged, so r is proportional to v . ✓✓

e This is a well-reasoned argument. Mark: 2/2

Answers to question 2

ANSWER A

- a An induced e.m.f. is equal to the rate of cutting magnetic flux ✓X.

- e The student has some concept of Faraday's law. The idea of cutting flux is a useful model, although it could be argued that it excludes a change in flux density. Another fault is that it does not include the idea of flux linkage, which includes the number of turns in a coil. This definition only really caters for a single wire in the field. Nevertheless, the examiner has given the student the benefit of the doubt. Mark: 1/2

- b i $E = BA \sin \theta$
 $E = 34 \times 10^{-6} \times 180 \times 42 \times \sin 30 = 0.13 \text{ V}$ ✓XX

- e This is not explained well. The student has worked out the area swept out by multiplying the speed by the wingspan but has used the incorrect angle. It is the vertical component that induces the e.m.f. across the wings, not the horizontal component. Mark: 1/3

- ii The voltage is too small to drive a meaningful current X.

- e The student has not spotted the fact that the conductor would have to move along with the aeroplane. Mark: 0/1

- iii There would be no voltage as the aeroplane would be flying parallel to the flux. XX

- e It is the vertical component of the field that induces an e.m.f. across the wings. The horizontal component would induce an e.m.f. between the top and the bottom of the aeroplane. Mark: 0/2

ANSWER B

- a The magnitude of an induced e.m.f. is equal to the rate of change of magnetic flux linkage ✓✓.

- e This is a textbook definition that includes all the relevant points. Mark: 2/2

b i $E = -\frac{\Delta \phi}{\Delta t} = \frac{\Delta A}{\Delta t} B \sin \theta$

area swept out per unit time = $Lv = 42 \times 180 = 7560 \text{ m}^2 \text{ s}^{-1}$ ✓

vertical component of the flux induces this e.m.f. = $B \sin 60$ ✓

$E = 7560 \times 34 \times 10^{-6} \times \sin 60 = 0.22 \text{ V}$ ✓

- e This is done well. The student shows each stage of the calculation clearly. Mark: 3/3

- ii The conductor would also travel through the magnetic field and therefore have an equal magnitude, e.m.f. opposing the original e.m.f. induced across it ✓.

- e This is a good answer. Mark: 1/1

- iii There would be no change ✓. It is the vertical component that induces the field across the wing ✓.

- e The student has spotted the important factor and explained it concisely. Mark: 2/2

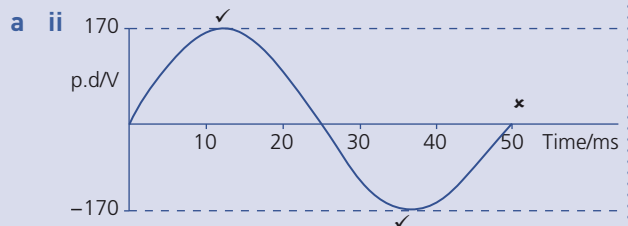
Chapter 21

Answers to question 1

ANSWER A

a i $\omega = \frac{2\pi}{T}, \quad T = \frac{2\pi}{314} = 2.00 \times 10^{-2} \text{ s}$
 $f = \frac{1}{T} = \frac{1}{2.00 \times 10^{-2}} = 50 \text{ Hz}$ ✓✓

- e The value of the time period has been calculated and used to determine the frequency. Mark: 2/2



- e The curve reaches the correct peak value and shows both positive and negative values of potential difference. The time period is

incorrect. The student appears to have confused the frequency with the time period. Mark: 2/3

b i $V = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120 \text{ V} \checkmark\checkmark$

e The formula for V_{rms} has been used to find the correct answer. Mark: 2/2

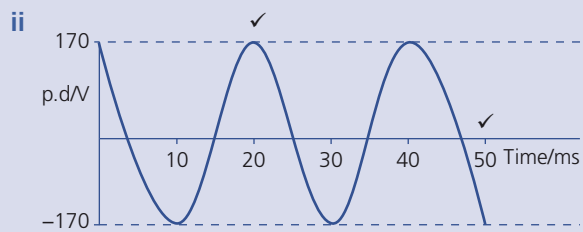
ii $P = \frac{V^2}{R} = \frac{170^2}{18} = 1600 \text{ W} \checkmark\text{X}$

e The student has written the correct formula for finding power, but the peak value of the p.d. has been used rather than the r.m.s. value. Mark: 1/2

ANSWER B

a i $f = \frac{\omega}{2\pi} = \frac{314}{2\pi} = 50 \text{ Hz} \checkmark\checkmark$

e The formula for frequency has been used to calculate the correct answer. Mark: 2/2



e A sine curve with positive and negative peak values for p.d. and the time period is correct for a frequency of 50 Hz. Mark: 3/3

b i $V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120 \text{ V} \checkmark\checkmark$

e The formula for V_{rms} has been used to calculate the correct answer. Mark: 2/2

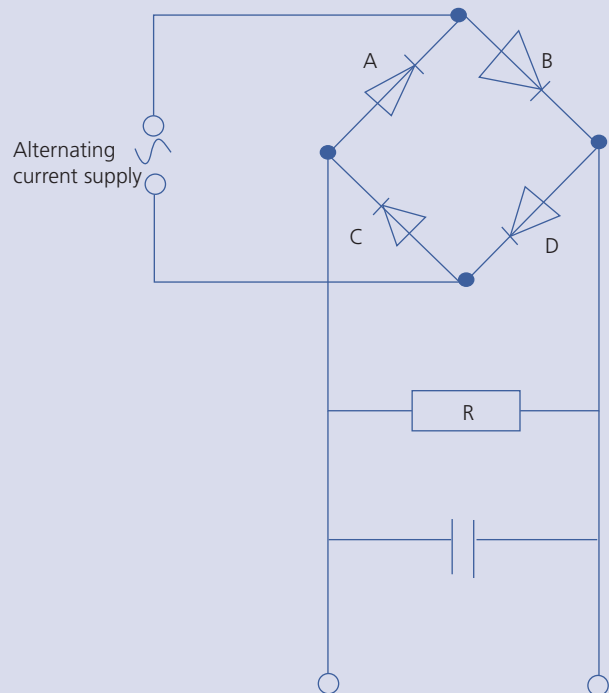
ii $P = \frac{V^2}{R} = \frac{120^2}{18} = 800 \text{ W} \checkmark\checkmark$

e The r.m.s. value of voltage has been substituted into the formula for power to calculate the correct answer. Mark: 2/2

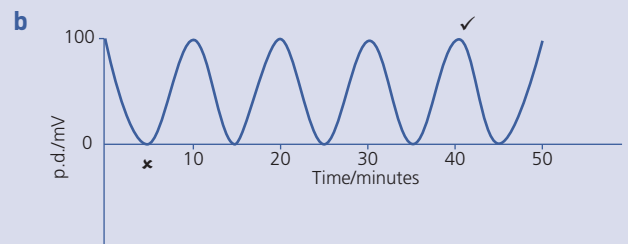
Answers to question 2

ANSWER A

a and c



e The circuit symbols for diodes are correct, but diodes C and D are facing the wrong way. Mark: 1/2



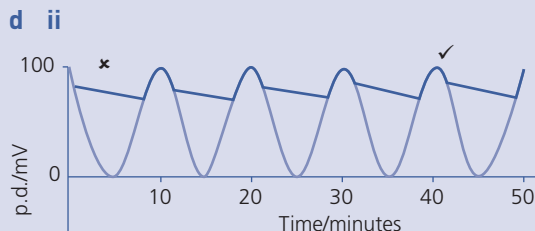
e All the values of p.d. are positive and the time period of the curve is correct. However, the student has drawn a complete sine curve which implies a gradual change in p.d. near the time axis, which is not correct. Mark: 1/2

c See diagram in part a

e The capacitor is positioned correctly to give a smoothed output. Mark: 2/2

d i time constant = $RC = 50 \times 10^{-6} \times 1.2 \times 10^3 = 6.0 \times 10^{-2} \text{ s}$ ✓✓

e The time constant has been calculated correctly. Mark: 2/2



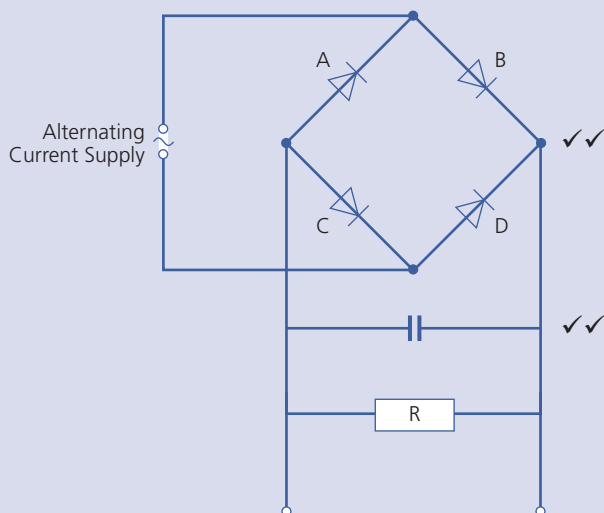
e The error for drawing a sine curve has already been penalised in part b. The curved section of the smoothed output is correct. The straight-line section leaves the curve too far below the peak – it should begin from the peak. Mark: 1/2

iii The time constant would double to 0.12 s so the graph would be flatter **XX**.

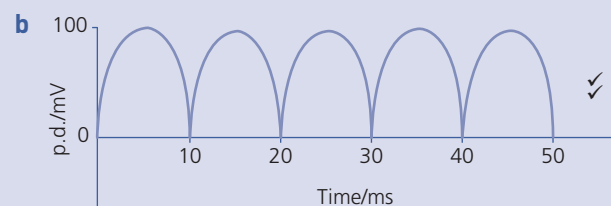
e The statement about the time constant is true, but the description of what would happen to the graph is too vague – it is not clear what part of the graph would be flatter. Mark: 0/2

ANSWER B

a and c



e The circuit symbols for diodes have been used and they are all positioned correctly. Mark: 2/2



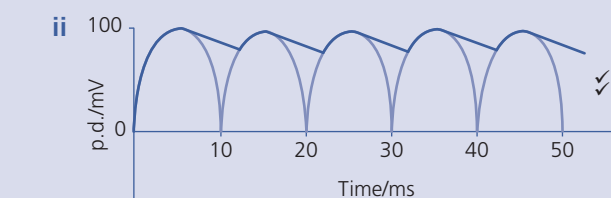
e The curves are accurately drawn and all the values of p.d. are positive with the correct peak value and time period. Mark: 2/2

c See diagram in part a

e The capacitor is in the correct position to give a smoothed output. Mark: 2/2

d i time constant = $RC = 50 \times 10^{-6} \times 1.2 \times 10^3 = 6.0 \times 10^{-2} \text{ s}$ ✓✓

e The correct value of the time constant has been calculated. Mark: 2/2



e The curved elements are drawn accurately. The straight-line sections begin at the peak and drop to a suitable point on the adjacent curve. Mark: 2/2

iii The slope on the straight lines on the graph would be less steep and so the ripple would be smaller ✓✓.

e The student has made two relevant points about the changes to the shape of the graph. Mark: 2/2

Chapter 22

Answers to question 1

ANSWER A

- a** The threshold frequency of a metal is the frequency of electromagnetic radiation incident on the metal that will cause electrons to be emitted from the surface of the metal ✓✗.

- e** Although there is some useful work here, it is imperative there is a recognition that this is the minimum frequency that liberates electrons from the metal surface. Mark: 1/2

b i $E = \frac{hc}{\lambda}$
 $= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9}} \checkmark$
 $= 6.63 \times 10^{-19} \text{ J } \checkmark$

- e** This is a correct calculation. Mark: 2/2

ii $\Phi = hf_{\text{threshold}}$
 $= 6.63 \times 10^{-34} \times 8.8 \times 10^{14} \checkmark$
 $= 5.83 \times 10^{-21} \text{ J } \times$

- e** The correct formula has been used but the student has made an arithmetic error in the powers of 10. Mark: 1/2

iii $E_{k_{\text{max}}} = (6.63 \times 10^{-19}) - (5.83 \times 10^{-21}) \checkmark$
 $= 6.57 \times 10^{-19} \text{ J } \checkmark$

- e** The kinetic energy is calculated from the energies calculated in parts i and ii. The earlier error has already been penalised so the student gains both marks here. Mark: 2/2

iv $\lambda = \frac{h}{p} = \frac{h}{mv}$
 $v = \sqrt{\frac{2E_k}{m}}$
 $= \sqrt{\frac{2 \times 6.57 \times 10^{-19}}{9.11 \times 10^{-31}}}$
 $= 1.20 \times 10^6 \text{ m s}^{-1} \checkmark$

Therefore, $\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.2 \times 10^6}$
 $= 6.1 \times 10^{-10} \text{ m } \checkmark$

- e** Once more the physics is correct and the student scores both marks. Mark: 2/2

- c** Visible light has a higher frequency than ultraviolet light and therefore has a larger photon energy. ✗

- e** The frequency of visible light is lower than ultraviolet so this answer is wrong. Mark: 0/2

ANSWER B

- a** The threshold frequency of a material is the minimum frequency of electromagnetic radiation incident on the metal that will cause an electron to be emitted from the surface of the metal ✓✓.

- e** The definition is correct. Mark: 2/2

b i $E = \frac{hc}{\lambda}$
 $= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9}} \checkmark$
 $= 6.63 \times 10^{-19} \text{ J } \checkmark$

- e** The calculation is correct. Mark: 2/2

ii $\Phi = hf_{\text{threshold}}$
 $= 6.63 \times 10^{-34} \times 8.8 \times 10^{14} \checkmark$
 $= 5.83 \times 10^{-21} \text{ J } \checkmark$

- e** This is worked through well to give the correct answer. Mark: 2/2

$$\text{iii } E_{k_{\max}} = (6.63 - 5.83) \times 10^{-19} \checkmark \\ = 8.0 \times 10^{-20} \text{ J } \checkmark$$

e This is a correct calculation. Mark: 2/2

$$\text{iv } \lambda = \frac{h}{p} = \frac{h}{mv} \\ v = \sqrt{\frac{2E_k}{m}} \\ = \sqrt{\frac{2 \times 6.57 \times 10^{-19}}{9.11 \times 10^{-31}}} \\ = 4.19 \times 10^5 \text{ m s}^{-1} \checkmark \\ \text{Therefore, } \lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.2 \times 10^6} \\ = 1.7 \times 10^{-9} \text{ m } \checkmark$$

e This is worked through well. Mark: 2/2

c Visible light has a longer wavelength than ultraviolet light and therefore has a smaller photon energy. The photon energy of the longest wavelength visible light (red) is less than the work function of zinc $\checkmark\checkmark$.

e A good clear explanation. Mark: 2/2

Answers to question 2

ANSWER A

a A photon is a packet of energy $\checkmark\checkmark$.

e The idea that a photon is a packet of energy is correct, but the electromagnetic nature of it is ignored. Mark: 1/2

$$\text{b } E = 3.40 - 0.54 = 2.86 \text{ eV } \checkmark = 2.86 \times 1.6 \times 10^{-19} \text{ J} \\ = 4.6 \times 10^{-19} \text{ J } \checkmark$$

e It is better to work from the idea that the energies are negative, but this is acceptable and produces the correct result. Mark: 2/2

c i The transitions from levels $n = 6$ to $n = 5$, $n = 5$ to $n = 4$, $n = 4$ to $n = 3$ and $n = 3$ to $n = 2$ give the visible light $\times\times$.

e This is incorrect. The student has not thought about the energy changes needed to produce visible light. Mark: 0/2

$$\text{ii } E = \frac{hc}{\lambda} \\ E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.35 \times 10^{-7}} \\ E = 4.57 \times 10^{-19} \text{ J } \checkmark \\ \text{This does not tally with any of the transitions } \times.$$

e The student has not converted the photon energy into electronvolts, explaining why the figures appear not to tally. Mark: 1/2

ANSWER B

a A photon is a packet of electromagnetic energy $\checkmark\checkmark$.

e The correct definition. Mark: 2/2

$$\text{b } E = -3.40 + 0.54 = 2.86 \text{ eV } \checkmark \\ = 2.86 \times 1.6 \times 10^{-19} \text{ J} \\ = 4.6 \times 10^{-19} \text{ J } \checkmark$$

e A correct calculation. Mark: 2/2

c i The four transitions are from levels $n = 3$, $n = 4$, $n = 5$ and $n = 6$ to $n = 2$, all the other transitions are of too small an energy change to produce visible light $\checkmark\checkmark$.

e This answer shows an appreciation of the situation. Mark: 2/2

$$\text{ii } E = \frac{hc}{\lambda} \\ E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.35 \times 10^{-7}} \\ E = 4.57 \times 10^{-19} \text{ J} = 2.85 \text{ eV } \checkmark \\ \text{This is closest to the transition from } n = 5 \text{ to } n = 2 \checkmark.$$

e Correct Mark: 2/2

Chapter 23

Answers to question 1

ANSWER A

- a Nuclear fission is the process of splitting an atom releasing neutrons ✓✓.

- e The phrase 'splitting an atom' is too vague – the student should refer to division of a nucleus into two smaller nuclei. The reference to the production of neutrons earns a mark. Mark: 1/2

b i $\text{Total mass} = 95.934284 + 137.911011 + 1.008665 \times$
 $= 234.853960 \text{ u}$

- e There are two neutrons in the product, but only one is included in the calculation. Mark: 0/1

ii $\text{mass defect} = 235.043923 + 1.00865 - 234.853960 = 1.198628 \text{ u} \checkmark\checkmark$

- e The value of the mass from part bi has been carried forward to this calculation so the answer receives full marks. Mark: 2/2

iii $\text{Binding energy} = c^2\Delta m \checkmark = (3.00 \times 10^8)^2 \times 1.198628 \times 1.67 \times 10^{-27} \times$
 $1.198628 \times 1.67 \times 10^{-27} \times = 1.259 \times 10^{-10} \text{ J} \times$

- e 1 mark is awarded for writing the correct expression, but the mass of a proton has been used in the calculation rather than the atomic mass unit. Mark: 1/2

- c Nuclear fusion is the combination of two nuclei to produce a larger nucleus ✓✓.

- e This statement is true, but further detail is needed, such as the total binding energy increases, to be awarded the second mark. Mark: 1/2

ANSWER B

- a Nuclear fission is when a large nucleus divides into two smaller nuclei and releases some more neutrons ✓✓.

- e The student has referred to a nucleus and has added extra detail by stating that neutrons are released. Mark: 2/2

b i $\text{Total mass} = 95.934284 + 137.911011 + 2 \times 1.008665$
 $= 235.862625 \text{ u} \checkmark$

- e The values supplied in the table have been used to determine the total mass of the products. Mark: 1/1

ii $\text{mass defect} = \text{mass of particles before fission} - \text{mass of particles after fission}$
 $= 235.043923 + 1.008665 - 235.862625 \checkmark$
 $= 0.189963 \text{ u} \checkmark$

- e The student has structured the answer so that it is easy to follow the working. Mark: 2/2

iii $\text{binding energy} = c^2\Delta m \checkmark$
 $\Delta m = 0.189963 \times 1.66 \times 10^{-27} = 3.153 \times 10^{-28} \text{ kg}$
 $\text{binding energy} = (3.00 \times 10^8)^2 \times 3.153 \times 10^{-28} = 2.838 \times 10^{-11} \text{ J} \checkmark$

- e 1 mark is awarded for writing the correct formula and the second mark is given for the correct answer. Mark: 2/2

- c Very high temperatures cause two light nuclei to combine to form a single heavier nucleus ✓✓.

- e The statement about combining nuclei is correct and the final mark is awarded for the reference to very high temperatures. Mark: 2/2

Answers to question 2

ANSWER A

- a i The half-life is the time ✓ taken for half of the substance to decay ✓.

- e** The student has recognised that half-life is a time, but it is not clear what the fraction is half of or what substance is being referred to. Mark: 1/2

$$\text{ii } \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{70.2} = 9.87 \times 10^{-3} \checkmark \times$$

- e** The value has been calculated, but the units of s^{-1} are missing. Mark: 1/2

- b i** There is a reading because there is background radiation present all the time $\checkmark \times$.

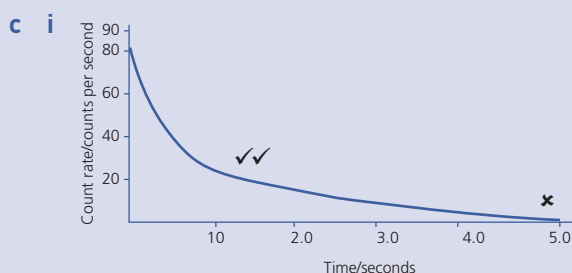
- e** The student knows there is background radiation but has not linked this to the count rate. Mark: 1/2

- ii** The count rate is decreasing because the number of β particles being released per second is decreasing $\times \times$.

- e** There is no explanation of why the number is decreasing. Mark: 0/2

$$\begin{aligned} \text{iii } x &= x_0 e^{-\lambda t} \Rightarrow \ln\left(\frac{x}{x_0}\right) = -\lambda t \\ \ln\left(\frac{51.2}{81.2}\right) &= -9.87 \times 10^{-3} \times t \times \\ t &= 46.7 \text{ s } \checkmark \end{aligned}$$

- e** The method of calculation is correct, but the student has not subtracted the background count rate from the actual count rate. Mark: 1/2



- e** This is not an exponential curve, but it does show the count rate decreasing with a decreasing gradient. However, the curve touches the x-axis at about 5 minutes, which is not correct. Mark: 2/3

- ii** The count rate will have decreased to zero $\times \times$.

- e** This is not correct as there will still be a background count rate. Mark: 0/2

ANSWER B

- a i** The half-life is the time taken for the number of undecayed nuclei in a sample of a radioactive isotope to be reduced to half its original number $\checkmark \checkmark$.

- e** This is the correct definition of the half-life. Mark: 2/2

$$\text{ii } \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{70.2} = 9.87 \times 10^{-3} \text{ s}^{-1} \checkmark \checkmark$$

- e** The decay constant has been calculated and the correct unit given. Mark: 2/2

- b i** There is radiation from human and natural sources that is present all the time, known as background radiation. The detector is detecting the background count rate due to this radiation $\checkmark \checkmark$.

- e** An explanation has been given for the background count rate. Mark: 2/2

- ii** The count rate is a measure of the activity of the source. As the source decays, there are fewer nuclei left to decay so the activity and hence the count rate decrease $\checkmark \checkmark$.

- e** The student has linked the change in count rate to the decrease in activity, which is due to the decreasing number of radioactive nuclei in the original sample. Mark: 2/2

Chapter 24

Answers to question 1

ANSWER A

- a** A rapidly varying voltage is applied across a special crystal ✓, which causes the crystal to vibrate with the same frequency as the applied voltage. The crystal hits air molecules causing an ultrasound wave (or sound wave depending on the frequency) to be formed ✓. This ultrasound wave is sent into the patient.

iii $x = x_0 e^{-\lambda t}$

where x = the count rate at time t .

The background count rate is $\frac{36}{60} = 0.6$ counts per second.

At $t = 0.0$ s, the true count rate is $81.2 - 0.6 = 80.6$ counts per second.

At the third reading, the true count rate is $51.2 - 0.6 = 50.6$ counts per second.

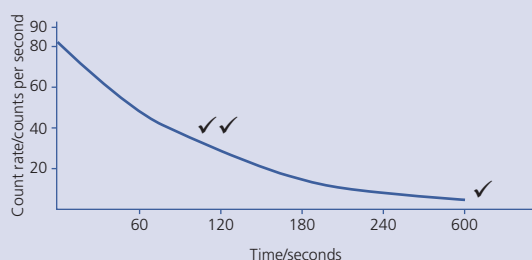
$$\ln\left(\frac{x}{x_0}\right) = -\lambda t \Rightarrow \ln\left(\frac{50.6}{80.6}\right) = -9.87 \times 10^{-3} \times t \checkmark$$

$$t = \frac{0.4655}{9.87 \times 10^{-3}}$$

$$t = 47.2 \text{ s } \checkmark$$

- e** The background count rate has been subtracted from the actual count rate and the corrected count rate has been used to calculate the time. Mark: 2/2

c i



- e** This is an exponential decay curve with a decreasing gradient that does not touch the time axis. Mark: 3/3

- ii The count rate is almost down to background count rate after 5 minutes. After 24 hours the count rate from the protactinium will be so low it will not be distinguishable from the background count rate, so it will average 36 counts per minute ✓✓.

- e** The student recognises that the count rate from the source will be very low so only the background count rate will register. Mark: 2/2

- e** This is a reasonable description of the production of the ultrasound. However, there is no mention of the name of the effect (the piezoelectric effect) nor of the fact that the wave is pulsed. Furthermore, there is no attempt to describe how reflected pulses are detected. Mark: 2/4

- b i** acoustic impedance $[Z] = \rho c$ and thus $c = Z/\rho$ ✗
 $\rho = 1.70 \times 10^6 \times 1080$
 $= 1.8 \times 10^9 \text{ m s}^{-1}$ ✗

- e** The equation is remembered correctly, but the student fails to rearrange the equation correctly and gets an answer faster than the speed of electromagnetic radiation in vacuo. This should tell the student that there is an error. Mark: 0/2

ii $\frac{I}{I_0} = \frac{Z_1^2 - Z_2^2}{Z_1^2 + Z_2^2}$ ✗
 $= \frac{(1.70 \times 10^6)^2 - (1.58 \times 10^6)^2}{(1.70 \times 10^6)^2 + (1.58 \times 10^6)^2}$
 $= 0.073$ ✗

- e** The student has remembered the equation incorrectly: $(x^2 - y^2)$ is not equal to $(x - y)^2$ and $(x^2 + y^2)$ is not equal to $(x + y)^2$. Mark: 0/2

ANSWER B

- a** Sound and ultrasound are both produced by a vibrating source. A rapidly varying voltage applied across a quartz crystal causes it to vibrate ✓. A short pulse of the varying voltage is applied to the crystal, and the vibrating crystal interacts with the air producing a short pulse of ultrasound which is directed into the patient ✓. The ultrasound is then reflected from the interfaces between different types of tissue and the return waves are picked up by the crystal. At the crystal, the reverse process occurs: the crystal acts as a detector ✓, the returning wave causes the crystal to vibrate which, in turn, produces an e.m.f. across the crystal ✓.
- The process of a varying voltage applied across a crystal and the reverse process, a voltage being induced when the crystal vibrates, is known as the piezoelectric effect.

- e** This is an excellent and clear account of the production and detection of ultrasound as used in scanning. Mark: 4/4

- b i** acoustic impedance $[Z] = \rho c$ and thus $c = \frac{Z}{\rho}$ ✓

$$\rho = \frac{1.70 \times 10^6}{1080}$$

$$= 1570 \text{ m s}^{-1} \text{ ✓}$$

- e** The calculation is correct. Mark: 2/2

ii
$$\frac{I}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

$$= \frac{(1.70 \times 10^6 - 1.58 \times 10^6)^2}{(1.70 \times 10^6 + 1.58 \times 10^6)^2}$$

$$= 1.34 \times 10^{-3}$$

- e** The calculation is correct. Mark: 2/2

Answers to question 2**ANSWER A**

- a i** When a particle and its antiparticle meet, they destroy each other and their mass is converted to energy ✓.

- e** This is a reasonable explanation, but there is no mention that the energy formed is in the form of a photon (or of being electromagnetic in nature). Mark: 1/2

ii $E = mc^2$
 $E = 2 \times 1.68 \times 10^{-27} \times (3 \times 10^8)^2 \text{ ✓}$
 $= 3.02 \times 10^{-10} \text{ J ✓}$
 Using $E = \frac{hc}{\lambda}$:
 $\lambda = \frac{hc}{E}$
 $\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3.02 \times 10^{-10}} \text{ ✗}$
 $= 6.6 \times 10^{-16} \text{ m ✓}$

- e** This is quite a good effort, although it is not always clear what the student is calculating. Also, there is no recognition that there are two photons produced, so the total energy is shared between them. Mark: 3/4

- b** A tracer is a chemical, such as glucose, in which molecules of radioactive isotopes have been attached ✓✗.

- e** The student has some understanding of the meaning of a tracer. However, the replacement of the usual atoms with atoms of similar chemical properties, but which are radioactive, are not explored. Mark: 1/2

- c** The patient is surrounded by a ring of detectors which detect the emitted photons. The position of the annihilation is pinpointed by both the detectors, which are triggered, and the time of arrival of the photons ✓✗✗.

- e** There is some idea of the process but the description is vague and does not include the fact that there are two photons triggering two different detectors. Nor is it clear what role the time of arrival of the two photons plays. Mark: 1/3

ANSWER B

- a i** When a particle and its antiparticle meet, they destroy each other ✓ and their mass becomes energy in the form of photons ✓.

- e** The correct definition is given. Mark: 2/2

- ii mass of a neutron = mass of an antineutron = $1.68 \times 10^{-27} \text{ kg}$

Using $E = mc^2$ to find the mass-energy of a neutron gives:

$$E = 1.68 \times 10^{-27} \times (3 \times 10^8)^2 \checkmark$$

$$= 1.51 \times 10^{-10} \text{ J} \checkmark$$

Two photons are formed, each with this

energy, so using $E = \frac{hc}{\lambda}$:

$$\lambda = \frac{hc}{E}$$

$$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.51 \times 10^{-10}} \checkmark$$

$$= 1.3 \times 10^{-15} \text{ m} \checkmark$$

e A correct calculation: Mark: 4/4

- b** A tracer is a natural substance, such as glucose, in which one or more atoms have been replaced $\checkmark$ by radioactive isotopes of those atoms $\checkmark$.

e This is a good answer. Mark: 2/2

- c** The patient is surrounded by a ring of γ -ray detectors $\checkmark$. When a positron meets an electron and they annihilate, two photons are produced which move at 180° to each other. The photons are detected by sensors on either side of the patient, giving a line of response along which the event occurred $\checkmark$. The precise position of the event is computed by the time lag between the two detectors receiving the photons $\checkmark$.

e This is correct. Mark: 3/3

Chapter 25

Answers to question 1

ANSWER A

- a** i A standard candle is a star of known luminosity $\checkmark$.

e It is not always a star. For distant galaxies, it is a supernova explosion. Mark: 1/2

- ii A Cepheid variable $\checkmark$ can be used to estimate the distance of a star from us $\checkmark$.

e A Cepheid variable is a standard candle and it is used to determine the distance to another star. Mark: 2/2

- b** i The surface area and the surface temperature determine the luminosity $\checkmark$.

e The student has only named the variables but has not said anything about their effects on the luminosity. Mark: 1/2

ii $F = \frac{L}{4\pi d^2}$

Therefore: $d^2 = \frac{L}{4\pi F}$

$$= \frac{6.4 \times 10^{28}}{4 \times \pi \times 4.3 \times 10^{-3}} \checkmark$$

$$= 1.18 \times 10^{30} \text{ m}$$

e What is given is correct, but the student has forgotten to find the square root and has left the answer as d^2 . Mark: 1/2

ANSWER B

- a** i A standard candle is an astronomical object of known luminosity $\checkmark$.

e This is a good description. Mark: 2/2

- ii Supernovas (class 1A) $\checkmark$ are used to calculate the distances to distant galaxies $\checkmark$ in which the supernovas occurred.

e This is correct. Mark: 2/2

- b** i The two variables that determine the luminosity of a star are the surface area of the star and its surface temperature $\checkmark$. The larger the surface area, the greater the luminosity, and the larger the surface temperature, the larger the luminosity $\checkmark$.

e Both parts of the question are answered well. Mark: 2/2

ii $F = \frac{L}{4\pi d^2}$
 Therefore: $d^2 = \frac{L}{4\pi F}$

$$= \frac{6.4 \times 10^{28}}{4 \times \pi \times 4.3 \times 10^{-3}} \checkmark$$

$$= 1.18 \times 10^{30} \text{ m}$$

$$d = \sqrt{1.18 \times 10^{30}} = 1.1 \times 10^{15} \text{ m} \checkmark$$

e A correct calculation. Mark: 2/2

Answers to question 2

ANSWER A

a An emission line spectrum has coloured lines on a dark background, whereas an absorption line spectrum has dark lines on a coloured background. $\checkmark$

e This description of the two types of spectrum is good, but a brief description of their formation is needed to explain the difference. Mark: 1/2

b $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

$$\Delta\lambda = \frac{100}{3.0 \times 10^8} \times 121.6 \checkmark$$

$$= 0.0004 \text{ nm} \times$$

e The formula is correct but on substituting into the equation the speed of approach is left in km s^{-1} , rather than converted to m s^{-1} . Mark: 1/2

c i $d = \frac{v}{H_0} = \frac{1.8 \times 10^7}{2.4 \times 10^{-18}} \checkmark$

$$= 7.5 \times 10^{24} \text{ m} \checkmark$$

e The calculation is correct. Mark: 2/2

ii $T = \frac{1}{H_0} = \frac{1}{2.4 \times 10^{-18}} \checkmark$

$$T = 4.17 \times 10^{17} \times$$

 All galaxies are moving away from each other $\times$.

e What is given of the calculation is correct, but it is not converted into years and there is no unit. The assumption is irrelevant and not strictly true. Some local galaxies are moving towards the Milky Way, probably due to gravitational attraction. Mark: 1/3

ANSWER B

a An emission line spectrum shows bright lines on a dark background while an absorption line spectrum is similar to a continuous spectrum with dark lines superimposed on it $\checkmark$. The emission line spectra are formed when electrons drop from a higher energy level to a lower energy level. The absorption line spectra are formed as light travels through a gas and photons of energy equal to the difference in energy between two energy levels excite electrons from the lower to the higher level and are thus absorbed $\checkmark$.

e This is a full and complete description and explanation. Mark: 2/2

b $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

$$\Delta\lambda = \frac{1.0 \times 10^5}{3.0 \times 10^8} \times 121.6 \checkmark$$

$$= 0.04 \text{ nm} \checkmark$$

e The calculation is correct. Mark: 2/2

c i $d = \frac{v}{H_0} = \frac{1.8 \times 10^7}{2.4 \times 10^{-18}} \checkmark$

$$= 7.5 \times 10^{24} \text{ m} \checkmark$$

e A correct calculation Mark: 2/2

ii $T = \frac{1}{H_0} = \frac{1}{2.4 \times 10^{-18}} \checkmark$

$$T = 4.17 \times 10^{17} \text{ s} = \frac{4.17 \times 10^{17}}{365 \times 24 \times 3600} =$$

$$1.3 \times 10^{10} \text{ years} \checkmark$$

This assumes speed of recession of the different galaxies have been constant throughout the history of the Universe $\checkmark$.

e The calculation is correct and the standard assumption when using Hubble's Law is given. Mark: 3/3