PHYSICS
TRIAL TEST TEAM

PHYSICS TRIAL TEST TEAM

UNITS 3 & 4 - PHYSICS

Trial written examination

2017

ANSWERS & SOLUTIONS BOOK

Figure numbers:	In this book the diagrams are shown as **Figure A**, **Figure B**, … to avoid any confusion with those in the Question and Answer Book where they are numbered **Figure 1**, **Figure 2**, …
Mark allocations:	As a guide, suggested mark allocations for each answer are shown within **square** brackets **[ ]**. Statements within **round** brackets **( )** indicate • if they start with the word '***OR***', that this is an alternative acceptable way of expressing a correct response, • otherwise, this is information which further clarifies the answer but which would not be required to gain the indicated mark.
Consequential calculations:	When calculations are using answers from previous questions, the unrounded-off answers have been used, as students tend to retain their unrounded answers in their calculators.
Additional information:	With some answers, to enhance student understanding, further information is shown as **Notes** within **curly** brackets **{ }**.

SECTION A - Multiple-choice questions

1 B A gravitational field would accelerate the electron vertically downwards and a magnetic field would deflect the path of a moving electron and hence the electron would not move in a straight line.

2 A Using the inverse square law and noting that the distance has increased by a factor of 3. So the field will decrease by a factor of $^1/_9$.

3 D

4 D

5 B A: A split-ring commutator in a DC generator would maintain the direction but not the size of the current.
C: This is the role of slip rings (not a split-ring) in an AC generator.
D: A split-ring commutator could not generate this result.

6 A B, C & D: These state the opposite to what would occur.

7 C A, B & D: All these changes would increase not decrease the energy lost in the transmission wires.

8 D Applying Newton's second law to the parcel, and taking the downwards direction as positive,

$$\begin{aligned}
a &= \frac{F_{\text{net}}}{m} \\
&= \frac{F_{\text{on parcel by Earth}} - F_{\text{on parcel by lift}}}{m} \\
2.0 &= \frac{(20 \times 9.8) - F_{\text{on parcel by lift}}}{20} \\
40 &= 196 - F_{\text{on parcel by lif}}\text{t} \\
F_{\text{on parcel by lift}} &= 196 - 40 \\
&= 156 \text{ N, i.e. } 156 \text{ N upwards} \\
\text{But } F_{\text{on lift by parcel}} &= -F_{\text{on parcel by lift}}, \text{ using Newton's third law} \\
&= 156 \text{ N downwards}
\end{aligned}$$

{**Note**: The reason for using $a = \frac{F_{\text{net}}}{m}$ rather than the more familiar $F_{\text{net}} = ma$ for Newton's second law is to emphasise that it is the net force and mass that give rise to the acceleration, and not the mass and acceleration that give rise to the net force. While both forms link the quantities correctly **mathematically**, the former also conveys the **causality**.}

9 C Using the relationship:

$$\begin{aligned}
a &= \frac{F_{\text{net}}}{m} \\
\frac{v^2}{r} &= \frac{F_{\text{net}}}{m}
\end{aligned}$$

$$\frac{v^2}{150} = \frac{2400}{1200}$$
$$v^2 = \frac{2400 \times 150}{1200}$$
$$v = \sqrt{\frac{2400 \times 150}{1200}}$$
$$= 17.32 \text{ m s}^{-1}$$

{Refer to **Note** in Solution 8 above.}

10 B You need to make a reasonable estimate of the vertical distance that the barbell is lifted, say 0.6 m.

Two possible approaches:

(1) Work done on barbell = $F\,s$
= upward force on barbell by Janine (to balance the downward gravitational force on barbell by Earth) × vertical distance barbell moved
= $mg \times s$
≈ (30 × 9.8) × 0.6
= 176.4 J

(2) Work done on barbell = increase in gravitational potential energy of barbell
= $mg\,\Delta h$
≈ 30 × 9.8 × 0.6
= 176.4 J

11 D A and B: The bending of waves as they move from one medium to a different medium is known as refraction. It is caused by the change in speed as they cross the interface.
C: Dispersion occurs when the different wavelengths are separated.

12 C The frequency of the wave is dependent on the source, and the speed of the wave is dependent on the medium. The wavelength is the result of the frequency and the speed of the wave.
{**Note**: A common misunderstanding is that with frequency, velocity and speed, each two of these decides the third. This is not the case. The speed of a wave is dependent on the medium, and the frequency of a wave is dependent on the source. Selecting the answer D, using the commonly used relation $v = f\lambda$ could mean you are using a **mathematically** correct relationship as a **causal** relationship. The relationship here that represents both the **mathematical** and **causal** relationship is

$$\lambda = \frac{v}{f}$$

The wavelength depends on the frequency and the speed of the wave.}

13 D

14 B Electrons propagate like a wave and transfer energy like a particle.

Q	Mark	Solution
15	D	The photon's wavelength can be determined using the relationship: $$\begin{aligned} E_\gamma &= hf \\ &= \frac{hc}{\lambda} \\ 2.5 &= \frac{4.14\times10^{-15} \times 3.0\times10^{8}}{\lambda} \\ \lambda &= \frac{4.14\times10^{-15} \times 3.0\times10^{8}}{2.5} \\ &= 4.968\times10^{-7} \text{ m} \\ &= 4.968\times10^{-7} \times 10^{9} \text{ nm} \\ &= 500 \text{ nm (to 2 sig figs)} \end{aligned}$$
16	C	Heisenberg's uncertainty principle asserts that information about both the exact location of an object and the exact value of its momentum at the same time is not attainable. The principle asserts that the uncertainty in location Δx multiplied by the uncertainty in momentum Δp is has a minimum value of $h/4\pi$.
17	A	The distances are set by the group, making distance the independent variable and the resulting times are measured, making time the dependent variable.
18	C	The average of the five readings is 336.4 mm, and considering the range of the measurements, 0.5 or 0.6 mm would be a reasonable estimate of the uncertainty in this measurement.
19	A	C: Since W changes as t changes, W is clearly not independent of t. B & D: For W to be proportional or directly proportional to t, the graphed line would have to be both **straight** and **intersect the origin**.
20	B	A: With an uncertainty of 0.2 N, in the first decimal place, the value of the force would conventionally contain only one uncertain figure in the result and this would be in the first decimal place, i.e. the '7'. So this would be written (1.7 ± 0.2) N. C: Normally we retain only one significant figure in the uncertainty. So this would be written (6.7 ± 0.5) N, with the second uncertain figure in the uncertainty, the '9', rounding off the first from '4' to '5'. D: The uncertainty of 0.003 N indicates uncertainty in the third decimal place and normally the value would then be given to the third decimal place, but here it is given to only the first decimal place, i.e. the '6'.

SECTION B

1a 2 **Statement 1**
(An electric / A magnetic) field is used to accelerate the negatively charged particle to the right in Section A in Figure 1. The direction of this field is (to the right / to the left / into the page / out of the page / up the page / down the page). [1 mark if both the correct options are circled]

Statement 2
In order to move the negatively charged particle in the direction shown in the shaded region in Section C, the direction of the magnetic field must be (to the right / to the left / into the page / out of the page / up the page / down the page). [1 mark]

1b 2 1.2×10^4 m s^{-1} The speed can be obtained using the relationship:

$$a = \frac{F_{\text{net}}}{m}$$

$$\frac{v^2}{r} = \frac{qvB}{m}$$

$$\frac{v^2}{\frac{0.020}{2}} = \frac{3.2\times10^{-19} \times v \times 0.10}{2.7\times10^{-26}}$$

$$v = \frac{3.2\times10^{-19} \times 0.10 \times \frac{0.020}{2}}{2.7\times10^{-26}} \quad [1\,\text{mark}]$$

$$= 1.185\times10^4$$

$$= 1.2\times10^4 \text{ m s}^{-1} \text{ (to 2 sig figs)} \quad [1\,\text{mark}]$$

{Refer to the **Note** in Solution 8 in Section A.}

1c 2 5.9 V The potential difference can be found from the relationship:

$$W = qV$$

$$\Delta E_{\text{k}} = qV$$

$$E_{\text{k final}} - E_{\text{k initial}} = qV$$

$$\tfrac{1}{2} mv_{\text{final}}^2 - \tfrac{1}{2} mv_{\text{initial}}^2 = qV$$

$$\tfrac{1}{2}\times 2.7\times10^{-26} \times \left(1.185\times10^4\right)^2 - 0 = 3.2\times10^{-19}\, V \quad [1\,\text{mark}]$$

$$V = \frac{\tfrac{1}{2}\times 2.7\times10^{-26} \times \left(1.185\times10^4\right)^2}{3.2\times10^{-19}}$$

$$V = 5.924\text{V}$$

$$= 5.9 \text{ V (to 2 sig figs)} \quad [1\,\text{mark}]$$

Consequential answer: $4.219 \times 10^{-8} \times (\text{Ans1b})^2$

1d 2 590 N C^{-1} The electric field can be determined using the relation:

$$E = \frac{V}{d}$$

$$= \frac{5.924}{0.010}$$

$$= 592.4 \quad [1\,\text{mark}]$$

$$= 590 \text{ N C}^{-1} \text{ (to 2 sig figs)} \quad [1\,\text{mark}]$$

Consequential answer: 100 × Ans1c

Q **Mark** **Answer** **Solution**

1e 1 static changing uniform non-uniform
[1 mark for circling both responses]

2a 3 6.4×10^{-20} N Directed from J to K

The force can be found using Coulomb's law:

$$F = \frac{kQq}{r^2}$$

$$= \frac{8.99\times10^{9} \times 4.0\times10^{-14} \times 1.6\times10^{-19}}{(3.0\times10^{-2})^2} \quad [1\,\text{mark}]$$

$$= 6.392\times10^{-20}$$

$$= 6.4\times10^{-20}\ \text{N (to 2 sig figs)} \quad [1\,\text{mark}]$$

Direction is from J to K [1 mark]

2b 2 9.5×10^{17} kg The mass of K could be found from the Law of Gravitation:

$$F = \frac{GMm}{r^2}$$

$$6.392\times10^{-20} = \frac{6.67\times10^{-11} \times M \times 9.1\times10^{-31}}{(3.0\times10^{-2})^2} \quad [1\,\text{mark}]$$

$$M = \frac{6.392\times10^{-20}\times(3.0\times10^{-2})^2}{6.67\times10^{-11}\times 9.1\times10^{-31}}$$

$$= 9.477\times10^{17}$$

$$= 9.5\times10^{17}\ \text{kg (to 2 sig figs)} \quad [1\,\text{mark}]$$

Consequential answer: $1.482 \times 10^{37} \times$ (Ans2a)

{**Note**: Have another look at that answer. Here, for the gravitational force to match the electrical force, the mass of K would have to be about10^{18} kg, i.e. 10^{15} tonne!}

3a 3 7.9×10^9 J (acceptable range 7.4×10^9 to 8.6×10^9 J)

The 'area' under the gravitational field strength graph between the two locations, surface of the Earth and the orbital position, 'represents' the change in gravitational potential energy of the satellite per unit mass as it moves between these two locations. So multiplying this 'area' representation by the mass of SENTINEL 2B gives the change in gravitation potential energy of the satellite.

$\Delta GPE_{\text{Earth surface to orbit}}$

= ('area under graph' in Figure A between 6.37×10^6 m and 7.20×10^6 m from the Earth's centre) × mass of SENTINEL 2B

Modelling this 'area under the graph' in Figure A as a trapezium under the broken line,

'Area' = ½(9.8 + 7.0) × (7.20 – 6.37) × 10^6 [1 mark]

= 8.4 × 0.83 × 10^6

= 6.972×10^6 J kg^{-1}

$\Delta GPE_{\text{Earth surface to orbit}}$

= 'area under graph' × mass of SENTINEL 2B

= 6.972×10^6 × 1140 [1 mark]

= 7.948×10^9

= 7.9×10^9 J (to 2 sig figs) [1 mark]

Q **Mark** **Answer** **Solution**

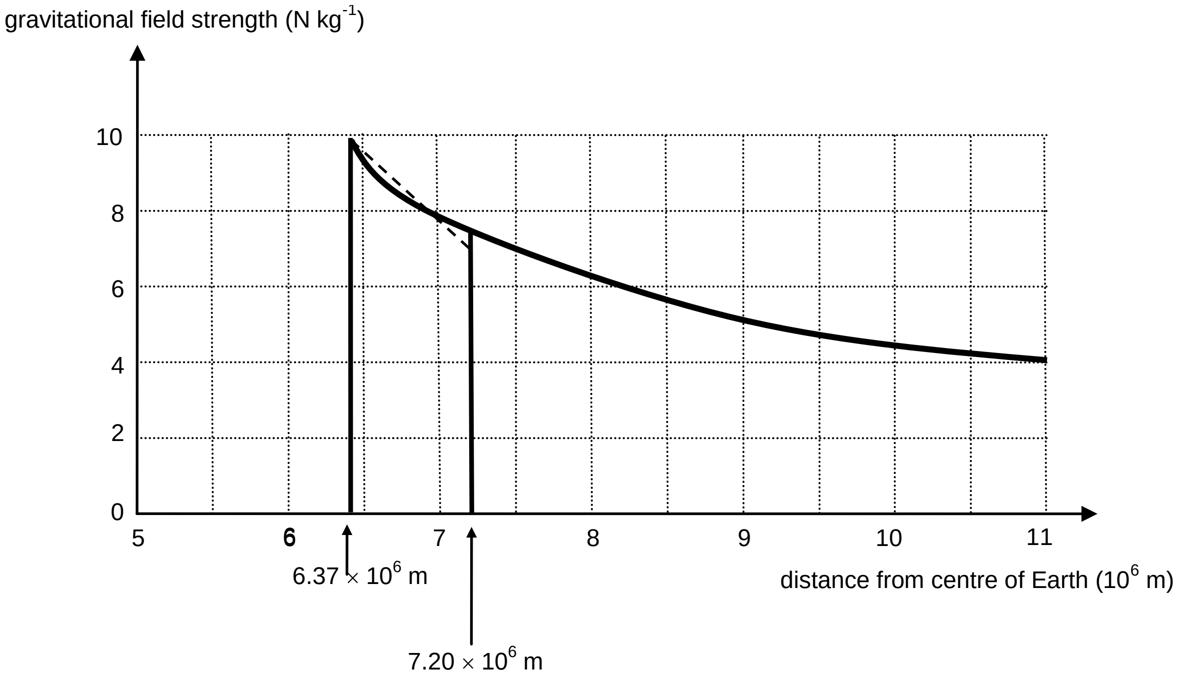

Figure A

3b 2 8.8×10^3 N

The force keeping it in orbit is the gravitational force the Earth exerts on SENTINEL 2B,

$$F = \frac{GMm}{r^2}$$

$$F = \frac{6.67\times10^{-11} \times 5.98\times10^{24} \times 1140}{(7.20\times10^6)^2} \qquad [1\,\text{mark}]$$

$$F = 8.771\times10^3$$

$$= 8.8\times10^3 \text{ N (to 2 sig figs)} \qquad [1\,\text{mark}]$$

4a 2 9.6×10^{-4} Wb

The magnetic flux can be obtained using the relation

$\Phi_B = B_\perp A$

$= 0.16 \times (0.10 \times 0.06)$ [1 mark]

$= 9.6 \times 10^{-4}$ Wb [1 mark]

{**Note:** Not 1.92×10^{-2} Wb, from multiplying the flux through the coil by the number of coils, 20. This is a common mistake. The ‘multiplying by 20’ only becomes relevant when obtaining the total EMF generated in the whole coil, where the ‘rate of change of magnetic flux’ or EMF in **each** loop has to be multiplied by the number of loops as all these EMFs are generated in series.}

4b 1 9.6×10^{-4} Wb

After being rotated through 90^o the plane of the coil is horizontal and so parallel to the magnetic field. Hence there is now zero flux through the coil. Thus the magnitude of the change is 9.6×10^{-4} Wb.

Consequential answer: Ans4a

Q	Mark	Answer	Solution

4c 2 8.7×10^{-2} V

The average EMF generated in the coil can be calculated from the relation

$$\begin{aligned}\varepsilon &= -N\frac{\Delta \Phi_B}{\Delta t}\\ &= -20\times\frac{9.6\times10^{-4}}{0.22} \quad [1\,\text{mark}]\\ &= -8.727\times10^{-2}\\ &= -8.7\times10^{-2}\,\text{V (to 2 sig figs)} \quad [1\,\text{mark}]\end{aligned}$$

Hence the magnitude of average EMF is 8.7×10^{-2} V.
Consequential answer: $90.9 \times$ Ans4b

4d 3 From E to F

From E to F [1 mark]

Two approaches for the explanation:

(1) From first principles:
To find the direction of conventional current in EF, consider a sample positive charge in that wire. As the coil is rotated anticlockwise from the position shown in Figure 7, that positive charge is moving down, equivalent to downward current and the magnetic field is to the left.
[1 mark]
So (using a rule such as the right hand push/slap rule) the force on that positive change is in the direction from E to F.
[1 mark]

(2) Using Lenz's law:
Using Lenz's law, the direction of the induced current is such that its magnetic field opposes the change in magnetic flux that generated it.
The **change in flux** was from 9.6×10^{-4} Wb in through the right hand side of the coil in Figure 7 to zero when the coil was horizontal. [1 mark for this or an equivalent statement]
The flux (or magnetic field) caused by the induced current will be in a direction that opposes that change and is therefore in through the right side of the coil (Figure 7). Using a rule such as the right hand grip rule tells us that the current must have been in the direction from E to F. [1 mark]
{**Note**: Some students who obtained the opposite answer, i.e. from F to E, may have used the incorrect idea that the induced flux opposes the **original flux** rather than the **change in flux** that caused it. This is a common mistake.}

5a 2 679 V

The peak-to-peak voltage could be found firstly using the relation

$$V_{RMS} = \frac{1}{\sqrt{2}}V_p$$

$$V_p = \sqrt{2}\,V_{RMS}$$

Then
$$\begin{aligned}V_{p\text{-}p} &= 2V_p\\ &= 2\times\sqrt{2}\times240 \quad [1\,\text{mark}]\\ &= 678.8\\ &= 679\text{ V (to 3 sig figs)} \quad [1\,\text{mark}]\end{aligned}$$

Q	Mark	Answer	Solution

5b 2 30 V

Two approaches:

(1) The output voltage V_o can be determined from the relation

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{V_o}{240} = \frac{20}{160} \qquad [1\,\text{mark}]$$

$$V_o = \frac{20 \times 240}{160}$$

$$= 30 \text{ V (to 2 sig figs)} \qquad [1\,\text{mark}]$$

(2) Without using the standard relationship above:
As the number of turns in the transformer secondary coil is $^1/_8$ of that in the primary, the voltage generated will be dropped to $^1/_8$ of the primary voltage, and so to 30 V.

{**Note**: Which of these two methods emphasises the basic physics of what is happening and is also simpler to use?}

5c 2 0.41 A

Two approaches:

(1) Using the current/turns ratio formula,

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

$$\frac{I_p}{3.3} = \frac{20}{160} \qquad [1\,\text{mark}]$$

$$I_p = \frac{20 \times 3.3}{160}$$

$$= 0.4125$$

$$= 0.41 \text{ A (to 2 sig figs)} \qquad [1\,\text{mark}]$$

(2) Without using the standard formula above:
For an ideal transformer as is the case here, the power developed in the primary is equal to the power in the secondary. So if the voltage decreases to $^1/_8$ of the primary voltage, the secondary current must be 8 times as large. With a secondary current of 3.3 A, the primary will be $^1/_8$ of that, i.e. $^1/_8$ of 3.3 A, i.e. 0.4125 A.

{**Note**: See the **Note** in Solution 5b.}

5d 2 30 V

30 V [1 mark]
The RMS value of an AC voltage is the DC voltage which would give the same power (and so brightness) to a light globe as the AC voltage [1 mark], i.e. 30 V.
Consequential answer (for the first mark): Ans5b

Q	Mark	Answer	Solution

6a 1 $I_{\text{lines}} = \dfrac{V_1 - V_2}{R_{\text{lines}}}$

Output voltage from power station

= voltage across transmission lines
+ input voltage across township transformer

$$V_1 = V_{\text{lines}} + V_2$$
$$V_{\text{lines}} = V_1 - V_2$$
$$I_{\text{lines}} = \frac{V_{\text{lines}}}{R_{\text{lines}}}$$
$$= \frac{V_1 - V_2}{R_{\text{lines}}}$$

6b 2 2.1×10^6 W

The rate at which heat energy is being generated

$$P_{\text{lines}} = I_{\text{lines}}^2 \ R_{\text{lines}}$$
$$= \left(\frac{V_1 - V_2}{R_{\text{lines}}}\right)^2 \ R_{\text{lines}}$$
$$= \left(\frac{40\,000 - 39\,500}{0.12}\right)^2 \times 0.12 \quad [1\,\text{mark}]$$
$$= 2.083 \times 10^6$$
$$= 2.1 \times 10^6 \text{ W (to 2 sig figs)} \quad [1\,\text{mark}]$$

7 2 5.0 m s^{-1}

As the collision can be regarded as isolated, the total momentum is conserved.

$$p_{\text{total initial}} = p_{\text{total final}}$$
$$800 \times 25 = 800v + 1000 \times 16 \quad [1\,\text{mark}]$$
$$20\,000 = 800v + 16\,000$$
$$v = \frac{20\,000 - 16\,000}{800}$$
$$= 5.0 \text{ m s}^{-1} \text{ (to 2 sig figs)} \quad [1\,\text{mark}]$$

8a 2 7.4 m s^{-2}

Possible approaches:

(1) Applying Newton's second law to the whole system of the two blocks:

$$a = \frac{F_{\text{net}}}{m},$$

They have the same size acceleration, the total mass being moved is $m_1 + m_2$, and the only force causing this forward acceleration is the downward gravitational force on m_2, i.e. $m_2 g$.

$$\text{So } a = \frac{F_{\text{net}}}{m}$$
$$= \frac{m_2 g}{m_1 + m_2}$$

$= \dfrac{0.75 \times 9.8}{0.25 + 0.75}$ [1 mark]

$= 7.35$

$= 7.4\ \text{m s}^{-2}$ (to 2 sig figs) [1 mark]

(2) Applying Newton's second law to each block separately.
For block A the only force moving it forward is the tension in the string *T*.

Thus $a = \dfrac{F_{\text{net}}}{m_1}$

$a = \dfrac{T}{m_1}$

$T = m_1 a$ …………..(1)

For block B, the net force comprises tension *T* upwards and the gravitational force $m_2 g$ on B downwards.

Thus $a = \dfrac{F_{\text{net}}}{m_2}$

$a = \dfrac{m_2 g - T}{m_2}$ ……...(2)

Substituting (1) in (2), eliminating *T*,

$a = \dfrac{m_2 g - m_1 a}{m_2}$ [1 mark for this or equivalent statement]

$m_2 a = m_2 g - m_1 a$

$a(m_1 + m_2) = m_2 g$

$a = \dfrac{m_2 g}{m_1 + m_2}$

$= \dfrac{0.75 \times 9.8}{0.25 + 0.75}$

$= 7.35$

$= 7.4\ \text{m s}^{-2}$ (to 2 sig figs) [1 mark]

{**Note**: See Note in Solution 8 in Section A.}

(3) Essentially method (2) with a mathematical shortcut:
Equation (2) above, modified:

$m_2 g - T = m_2 a$ …………..(3)

$T = m_1 a$ …………..(1)

In order to eliminate *T*,
sum of left sides of Equations (3) and (1)
= sum of right sides of Equations (3) and (1)

$m_2 g = m_1 a + m_2 a$

$a(m_1 + m_2) = m_2 g$

$a = \dfrac{m_2 g}{m_1 + m_2}$ [1 mark]

$= \dfrac{0.75 \times 9.8}{0.25 + 0.75}$

$= 7.35$

$= 7.4\ \text{m s}^{-2}$ (to 2 sig figs) [1 mark]

Q **Mark** **Answer** **Solution**

8b 2 The student is incorrect [1 mark]. According to Newton's third law, the action-reaction force pairs have to have the following form: $F_{\text{on A by B}} = -F_{\text{on B by A}}$. (They are forces on *different* objects whereas the student's example quotes forces on the *same* object.) Correct examples in this context would be

(1) the force on block B by the string **and** the force on the string by block B, or

(2) the gravitational force on block B by the Earth **and** the gravitational force on the Earth by block B.

[1 mark for a satisfactory explanation]

{**Note**: Misconceptions of Newton's third law are very common. The '**action-reaction**' term is unfortunate as it suggests that one of the forces acts and **then** this causes the other to react. They are **simultaneous** forces describing an interaction of either attraction or repulsion between two objects. A preferable term would be '**partner forces**'.}

9 3 See Figure B. [½ mark for the two zero values for the kinetic energy at both ends of the graphed line. For **each** of the 5 sections of the graph, ½ mark for having **both** the correct general shape **and** size relative to other sections of the graph. Then round down to a whole number of marks.]

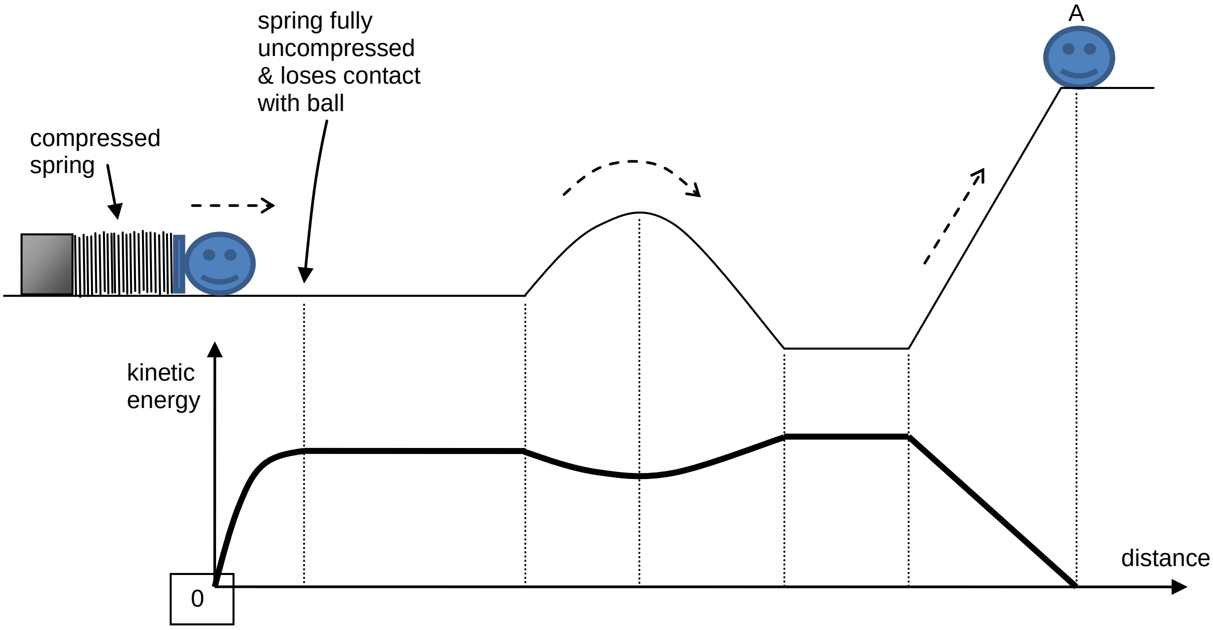

Figure B

10a 2 8.0 μs The time measured in the frame in which the accelerator is at rest will be dilated by the Lorentz factor γ due to the motion of the muons.

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1-\frac{(0.95c)^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1-0.95^2}}$$

$$= 3.202 \qquad [1\,\text{mark}]$$

Q **Mark** **Answer** **Solution**

$$\begin{aligned} t &= t_0\gamma \\ &= 2.5 \times 3.202 \\ &= 8.005 \\ &= 8.0\ \mu\text{s (to 2 sig figs)} \qquad \text{[1 mark]} \end{aligned}$$

10b 2 9.4 m

From the frame of reference in which the muons are at rest, the distance from target to detector will be contracted [1 mark] due to the motion of the equipment relative to the muons. It will be contracted by the Lorentz factor γ.

$$\begin{aligned} L &= \frac{L_0}{\gamma} \\ &= \frac{30}{3.202} \\ &= 9.369 \\ &= 9.4\ \text{m (to 2 sig figs)} \qquad \text{[1 mark]} \end{aligned}$$

10c 2 7.3×10^{-12} J

The kinetic energy of the muons is given by the expression

$$\begin{aligned} E_k &= (\gamma - 1)m_0c^2 \\ &= (3.202 - 1) \times 3.7 \times 10^{-29} \times (3.0 \times 10^8)^2 \qquad \text{[1 mark]} \\ &= 7.332 \times 10^{-12} \\ &= 7.3 \times 10^{-12}\ \text{J (to 2 sig figs)} \qquad \text{[1 mark]} \end{aligned}$$

11a 2 See Figure C.

[1 mark for correct direction and labelling of both forces and 1 mark for clearly showing the upward force on the bolt to be greater than the downward gravitational force]

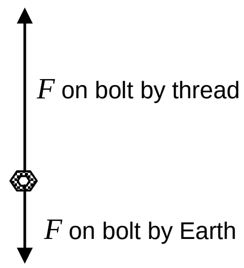

Figure C

11b 3 0.34 m

To find the **horizontal** distance d, we know the horizontal initial velocity u and horizontal acceleration, zero. We need another quantity. Time taken t is the same for both the vertical and horizontal components of the projectile path. So we need to find the time first by considering **vertical components** of the flight.

$u = 0$ m s^{-1}, $a = 9.8$ m s^{-2}, $s = 1.0$ m, $t = ?$

$$\begin{aligned} s &= ut + \tfrac{1}{2}at^2 \\ 1.0 &= 0 + \tfrac{1}{2} \times 9.8t^2 \qquad \text{[1 mark]} \\ &= 4.9t^2 \\ t^2 &= \frac{1.0}{4.9} \\ t &= 0.4517\ \text{s} \qquad \text{[1 mark]} \\ &= 0.45\ \text{m (to 2 sig figs)} \end{aligned}$$

Now considering the horizontal components of the parabolic flight,
t = 0.4517 s, u = 0.75 m s^{-1}, a = 0 m s^{-2}, s = d

$$\begin{aligned} s &= ut + \tfrac{1}{2}at^2 \\ d &= 0.75 \times 0.4517 + 0 \\ &= 0.3387 \\ &= 0.34 \text{ m (to 2 sig figs)} \qquad [1\,\text{mark}] \end{aligned}$$

12a 2 See Figure D. [1 mark for bending the light towards the normal at the first interface and away from the normal at the second interface for both rays. 1 mark for showing the blue light refracting more than the red light.]

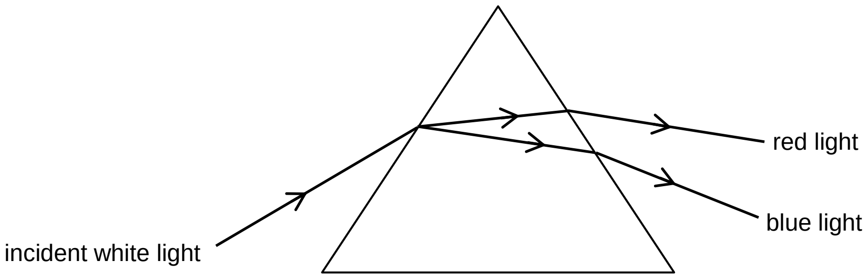

Figure D

12b 2 **Two approaches**:

(1) Using the speed of light.
As light moves from air into the prism, refraction occurs because the light slows down and bends towards the normal, and as it leaves the prism, it speeds up and bends away from the normal. [1 mark] Blue light slows down to a greater extent than the red light and so changes direction by a greater amount. [1 mark]

(2) Using refractive index.
The glass has a larger refractive index for blue light than for red light [1 mark]. So blue light refracts more than red light and therefore spreads out more [1 mark].

13a 2 See Figure E. [1 mark for 3 evenly spaced antinodes, 1 mark for nodes at both ends.]

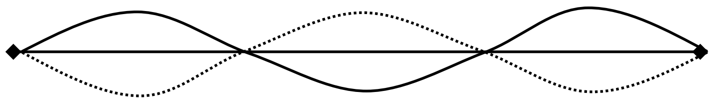

Figure E

Q	Mark	Answer	Solution

13b 2 980 Hz

Figure E shows the wavelength is $^{2}/_{3}$ the length of the string:

$$\lambda = \tfrac{2}{3} \times 0.61$$

$$\lambda = \frac{v}{f}$$

$$\tfrac{2}{3} \times 0.61 = \frac{400}{f}$$

$$f = \frac{400}{\tfrac{2}{3} \times 0.61} \qquad [1\,\text{mark}]$$

$$= 983.6$$

$$= 980\ \text{Hz (to 2 sig figs)} \qquad [1\,\text{mark}]$$

{**Note**: See the Note in Solution 12 in **Section A**.}

14a 2 The spectral pattern undergoes a shift according to the Doppler effect [1 mark]. The shift is to a lower frequency (red shift) when the movement is away from the observer and to a higher frequency (blue shift) when the movement is towards the observer [1 mark]. The spectral pattern shift will show the relative movement of the star to the observer.

14b 2 See Figure F. The spectral line would undergo a red shift, that is a shift toward a lower frequency. [1 mark for each new line shown to the right of the previous lines. Magnitude of shift not required.]

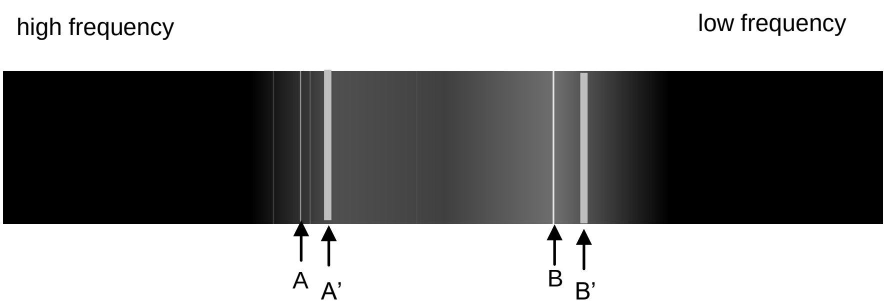

Figure F

15a 2 The light passes through the slits and undergoes diffraction and interference. The second nodal line is a region of destructive interference (or cancellation) [1 mark] producing a dark region. This occurs when the difference between the distance from one slit to that position on the screen and the distance from the second slit to that position on the screen, is an odd multiple of half a wavelength. The second nodal line occurs when this path difference is 3/2 λ [1 mark].

15b 1 Since the bright and dark regions can be explained by the interference of waves passing through the two slits and interference is a wave property, this supports the wave nature of light.

15c 1 Fringe X — See Solution 15d.

15d 3 Longer wavelengths diffract more than shorter wavelengths [1 mark]. Red light has a longer wavelength than blue light and diffracts more producing a pattern that is more spread. This produces a red fringe on the outer side of each maximum [1 mark]. Therefore the red fringe is more pronounced further away from the central maximum [1 mark].

Q **Mark** **Answer** **Solution**

15e 1 Use a larger wavelength, a larger distance between the slits and the screen and a smaller slit separation. [1 mark if all three ways are stated]

16a 2 1.0×10^{-27} kg m s^{-1} (or N s)

The momentum p of a photon can be determined from its wavelength λ by the relation:

$$\lambda = \frac{h}{p}$$

$$650 \times 10^{-9} = \frac{6.63 \times 10^{-34}}{p} \qquad [1\,\text{mark}]$$

$$p = \frac{6.63 \times 10^{-34}}{650 \times 10^{-9}}$$

$$= 1.02 \times 10^{-27}$$

$$= 1.0 \times 10^{-27} \text{ kg m s}^{-1} \text{ (to 2 sig figs)} \qquad [1\,\text{mark}]$$

{Note: The relation used here is given in the form of $\lambda = \frac{h}{p}$ rather than the more common $p = \frac{h}{\lambda}$, even though both are **mathematically** equivalent.

The former emphasises that the wavelength results from the momentum of the photon rather than the momentum resulting from the wavelength, thereby additionally indicating **causality**.}

16b 1 1.0×10^{-27} kg m s^{-1} (or N s)

Since the electron has the same wavelength as the photon it will have the same momentum.

Consequential answer: Ans16a

16c 1

Less spread out The same More spread out

Electrons with increased speed will have increased momentum. Since $\lambda = h/p$, they will have decreased wavelength, giving rise to a diffraction pattern that is less spread out.

16d 2 See Table A.

Table A

	Sub-atomic particles, modelled as a …		**Light**, modelled as a ...	
Phenomenon	particle	wave	particle	wave
Young’s double slit experiment using red laser light				✔
Electron diffraction pattern		✔		
Photoelectric effect			✔	
Discrete energy states of a hydrogen atom		✔		

[2 marks for 3 or 4 correct; 1 mark for 1 or 2 correct]

17a 2 Possible sources of uncertainty:

(1) The limit of reading the scale on a meter with a moving pointer (***OR*** interpolating the position of the pointer between two adjacent scale divisions)

(2) The precision of the last digit on a digital meter (***OR*** the size of the minimum change in the last digit. {**Note**: this is known as the least count on the meter.}

(3) The accuracy of the instrument (given by the manufacturer, but often hard to find in an average laboratory)

(4) The consistency of repeated readings.

[1 mark for each of the above points, with a maximum of 2 marks. If more than two are given, marks awarded for only the first 2.]

{**Note**: No mark for a zero error or zero correction. These can be rectified and do not give rise to necessary uncertainties. If there is a zero error on a meter, it can often be dealt with by adjusting the meter to register zero before taking any readings. A zero correction, if there is one, can be dealt with by adjusting all readings by this correction.}

17b 2 Something like: "When I shone a light of frequency 5×10^{14} Hz onto the metal surface, a potential difference of between 0.7 and 0.9 V was required to prevent electrons from reaching the opposite electrode." [1 mark for the range 0.7 to 0.9 V, and 1 mark for relating the frequency 5×10^{14} Hz to the potential difference]

17c 2 Any value fitting the relation $0.8 \leq W \leq 1.4$ eV

Two possible solutions:

(1) A simple and direct method:
Figure 23 is shown redrawn as Figure G with the two possible **extreme** lines, which must pass through all the uncertainty bars. The work function of the metal can be deduced from the intercept on the *V* axis. So it is in the range of 0.8 to 1.4 eV. Any answer in that range is acceptable.

(2) Using the relation $W = hf_0$ by determining the value of Planck's constant *h* (See Solution 17e below) from a gradient of the graph and multiplying it by the threshold frequency f_0 of the metal, given by the intercept on the frequency axis, approximately 3×10^{14} Hz.

[2 marks for an answer in the range $0.8 \leq W \leq 1.4$ eV. 1 mark if the answer is given in joule, i.e. 1.3×10^{-15} to 2.2×10^{-15} J]

Q Mark Answer **Solution**

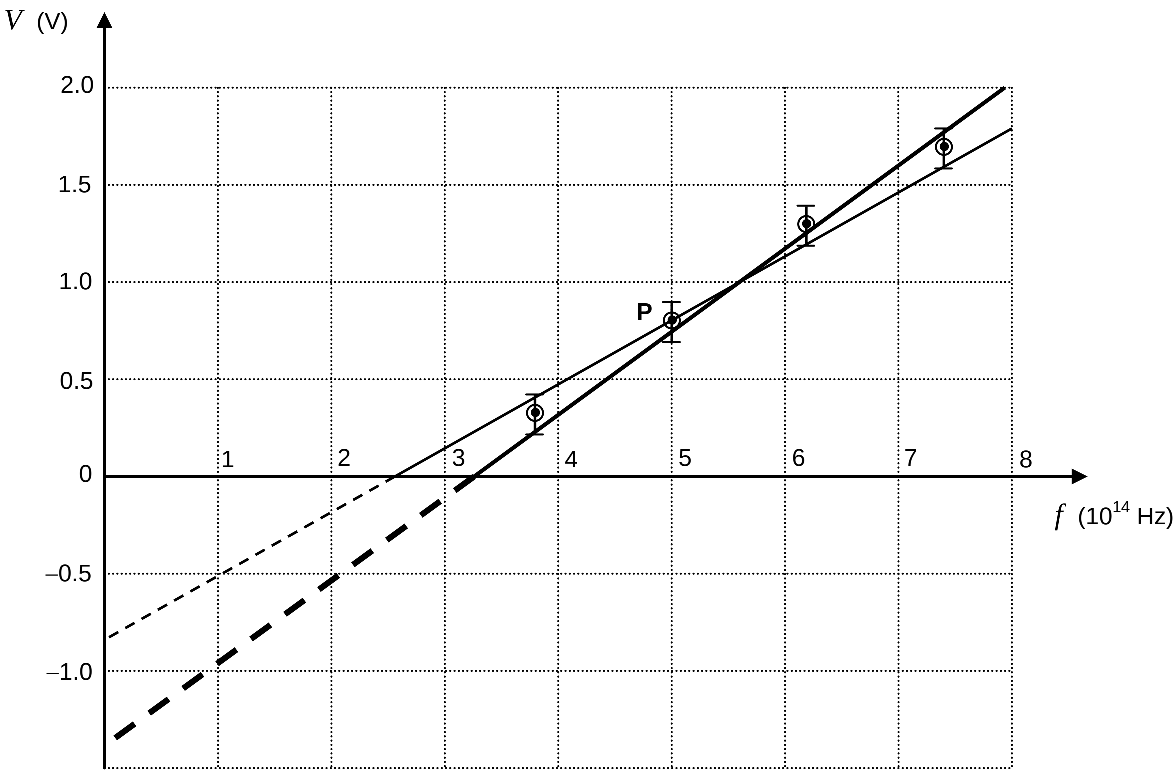

Figure G

17d 1 The heavier of the two graphed lines on Figure G.

Since Planck's constant can be obtained from the gradient of the graph, the line with the steeper slope will give rise to the higher value of *h*.

17e 2 An answer in the range $(4.3 \pm 0.3) \times 10^{-15}$ eV s

The solution is based on the relation between the maximum kinetic energy $E_{\text{k max}}$ of the ejected photoelectrons, the frequency *f* of the radiation, Planck's constant *h* and the work function *W* of the metal surface,

$$E_{\text{k max}} = hf - W$$

But $E_{\text{k max}}$ = the stopping voltage × the charge on the electron

= *V* from the graph × *e*

$$\text{So } Ve = hf - W$$

$$V = \frac{h}{e} f - \frac{W}{e}$$

Hence our graph of *V* against *f*, Figure G, is a straight line with a gradient of *h*/*e*.

$$\text{Thus } \frac{h}{e} = \frac{\Delta V}{\Delta f}$$

$$\frac{h}{1} = \frac{2.0}{7.9\times10^{14} - 3.3\times10^{14}} \qquad [1\,\text{mark}]$$

$$h = 4.347\times10^{-15}$$

$$= 4.3\times10^{-15}\ \text{eV s} \qquad [1\,\text{mark}]$$

[1 mark maximum if the answer is given in joule seconds, and is in the range $(6.9 \pm 0.4) \times 10^{-34}$ J s]

Q **Mark** **Answer** **Solution**

18a 2 1.9×10^{14} Hz

The **broken line arrow** in Figure H shows the transition.
The frequency of the emitted photon is equal to the decrease in excitation energy of the mercury atom divided by Planck's constant. Thus:

$$f = \frac{\Delta E}{\lambda}$$

$$= \frac{5.74 - 4.95}{4.14 \times 10^{-15}} \qquad [1\,\text{mark}]$$

$$= 1.908 \times 10^{14}$$

$$= 1.9 \times 10^{14}\ \text{Hz (to 2 sig figs)} \qquad [1\,\text{mark}]$$

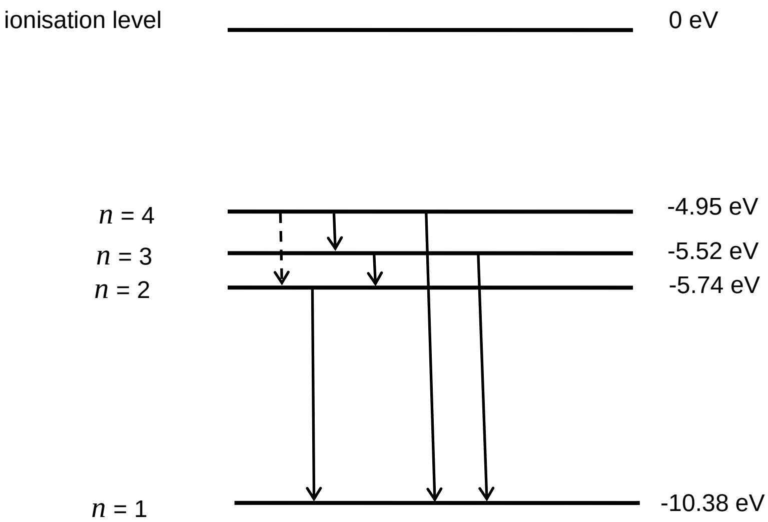

Figure H

18b 1 6

There are 6 possible transitions that can occur between the n = 4, 3, 2 and 1 states shown by the arrows in Figure H (including the broken line), giving rise to 6 different bright lines in the emission spectrum.

18c 2

The spectrum from a mercury lamp consists of a finite number of discrete lines (and is often referred to as a line emission spectrum). It results from transitions between discrete energy levels in the mercury atom. [1 mark]
The spectrum from an incandescent source is different and consists of all the colours across the visible spectrum (and is often referred to as a continuous emission spectrum). It arises from random collisions between charged particles, producing light of a wide and continuous range of frequencies. [1 mark]

18d 3 6.0 eV

[1 mark for 6.0 eV as the only energy]
None of the energy differences between the ground state and any of the excited states equals 6.0 eV. [1 mark] So the mercury atoms exposed to 6.0 eV photons will remain in their ground state. Only 6.0 eV photons from the incoming beam will be observed leaving the sample, that is 6.0 eV photons will not interact with ground state mercury atoms. [1 mark]

Q	Mark	Answer	Solution

19 3 When the size of the slit through which electrons are passing is reduced, the resulting diffraction pattern spreads out. Δx, the uncertainty in the position of the electron in the x-direction is reduced. [1 mark] (Here the x-direction refers to the distance across the slit.)

Using Heisenberg's uncertainty principle, $(\Delta p)(\Delta x) \geq \frac{h}{4\pi}$, it follows that Δp, the uncertainty in the value of the momentum of the electrons in the x direction, increases, meaning there will be a broader range in the momenta of the emerging electrons in the x direction, and so the central maximum of the diffraction patterns will be more spread out. [1 mark for explaining what Δx and Δp mean, and 1 mark for deducing why the pattern will be more spread out, using Heisenberg's uncertainty principle]

20 4 A number of possible improvements, with some more important than others:

(1) They ought to have recorded more than 4 measurements.
(2) The points tested should have been more evenly spread (***OR*** the 3 points on the right are too close together).
(3) The points tested should have been spread across the whole range (rather than less than half the range).
(4) Uncertainties could have been determined and uncertainty bars added to the graphed points.
(5) The graphed line of best fit should not have been extrapolated to the left well beyond the plotted points.
(6) More information may have been gained by expanding the horizontal scale, (from 0.3 to 0.8 m).
(7) More information may have been gained by expanding the vertical scale, (from 0.06 to 0.10 N).

[1 mark for each of the above points, with a maximum of 4 marks. If more than 4 improvements given, marks awarded on only the first 4.]

21 2 Some of the many items could be:

(1) Make the components of your poster large enough to be legible at a reasonable distance (of say about 1.5 m).
(2) Give your investigation a prominently shown title.
(3) Frame your title as a question.
(4) Use fonts, font size and colours that can be easily read.
(5) State your initial hypotheses.
(6) Include a summary or abstract of your investigation and what you found.
(7) Give a brief description of your methodology.
(8) Use visual representations, such as graphs, bar charts, different colours, etc to emphasise important aspects of your research.
(9) Do not include both a table of results and a graph as they both represent the same information.
(10) Make sure your graphics and photographs are clear, easily read, titled and labelled.
(11) Use physics conventions such as tabulating, graphing, units, use of significant figures, etc. correctly.
(12) Highlight data trends or relationships based on evidence from your results.
(13) Include only one sample calculation for a series of repeated calculations you performed.
(14) Indicate whether your hypotheses were supported or not.
(15) Identify appropriate uncertainties in measurements recorded.
(16) State limitations of your experimental design and possible improvements.
(17) Identify any relevant health and safety issues.
(18) Give references and acknowledgements.

[There would be other acceptable suggestions apart from those mentioned above. 2 marks for 4 acceptable suggestions, 1 mark for 2 or 3 acceptable suggestions, 0 marks for 1 or no acceptable suggestions. If more than 4 suggestions given, marks awarded on only the first 4.]