Trial Examination 2017

VCE Physics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

1	A	B	C	**D**	11	A	B	**C**	D
2	A	B	C	**D**	12	A	B	C	**D**
3	A	**B**	C	D	13	**A**	B	C	D
4	A	B	C	**D**	14	A	**B**	C	D
5	A	**B**	C	D	15	A	**B**	C	D
6	A	B	**C**	D	16	A	B	**C**	D
7	A	B	C	**D**	17	A	B	C	**D**
8	A	B	**C**	D	18	A	**B**	C	D
9	A	B	C	**D**	19	A	B	C	**D**
10	**A**	B	C	D	20	**A**	B	C	D

Question 1 D

The electron travels to the right and is equivalent to a positive current travelling to the left. The magnetic field is upwards.

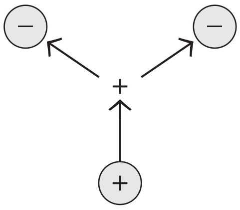
By the right-hand palm rule:

thumb = current to the left

fingers = magnetic field upwards

palm of hand = force into the page

Question 2 D



The arrows show the directions of the individual forces acting on the test charge. The negative charges exert an attractive force toward them, while the positive charge exerts a repulsive force away from it. The graphical sum of the individual forces will be upwards.

Question 3 B

$$E_1 = \frac{kQ}{d^2}$$

and new $E_2 = \frac{k8Q}{(2d)^2}$

$$= \frac{8kQ}{4d^2}$$

$$\Rightarrow E = \frac{2kQ}{d^2}$$

$$= 2E_1$$

Question 4 D

change in momentum $= p_{\text{final}} - p_{\text{initial}}$

$= \longleftarrow - \longrightarrow$

$= \longleftarrow$

Question 5 B

The kinetic energy varies from zero at position X to its maximum value at the midpoint to zero at position Y. The elastic potential energy varies as the square of the extension from X (zero extension) to Y (maximum extension).

Question 6 C

measured time = proper time × γ

where $\gamma = \dfrac{1}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$

$= \dfrac{1}{\sqrt{1-(0.6)^2}}$

$= 1.25$

measured time = 20.00 × 1.25

= 25.00 seconds

Question 7 D

$E_{\text{kinetic}} = mc^2 - m_0c^2$

$= (m - m_0)c^2$

$= (\gamma - 1)(m_0c^2)$

$\gamma = \dfrac{1}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$

$= \dfrac{1}{\sqrt{1-(0.99)^2}}$

$= 7.09$

$E_{\text{kinetic}} = (7.09 - 1) \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2$

$= 4.99 \times 10^{-13}$ J

$\dfrac{4.99 \times 10^{-13}}{1.6 \times 10^{-13}} = 3.12$ MeV

Question 8 C

$P_{\text{primary}} = P_{\text{secondary}}$

$= 60$ W

$V_{\text{primary}} \times I_{\text{primary}} = 60$

$\Rightarrow I_{\text{primary}} = \dfrac{60}{240}$

$= 0.25$ A RMS

$I_{\text{primary}}\text{peak} = I_{\text{primary}}\text{RMS} \times \sqrt{2}$

$= 0.25 \times \sqrt{2}$

$= 0.35$ A peak

Question 9 D

The external flux through the coil is to the left.

As the magnet is pulled to the right, the external flux decreases in magnitude.

Thus the change in flux is to the right.

The coil opposes the change in flux by providing its own (induced) flux to the left to compensate for the external flux reduction.

Using the right hand grip rule, the curl of the fingers are in the direction of the induced flux inside the coil with the thumb taking position on the front and upwards.

In following the current around the coil, it is from X to Y on the straight section of the wire.

Question 10 A

The longest wavelength occurs for the first harmonic.

Since $\lambda_n = \frac{4L}{n}$ where $n = 1, 3, 5$ and $n = 1$ for the first harmonic, $\lambda_n = \frac{4 \times 1.50}{1} = 6.00$ m.

Question 11 C

The resultant wave is the sum of the individual waves at any time.

The resultant wave must commence at zero amplitude at $t = 0$.

After a very small time interval from $t = 0$, both waves X and Y have a negative displacement as they move in their respective directions. The sum of the amplitudes is the resultant amplitude.

Thus the resultant amplitude must have a negative displacement a short time interval after the start.

Question 12 D

The spread of the pattern is $\Delta x = \frac{\lambda L}{w}$, thus the spread will be closer if wavelength and slit-screen distance are increased or the slit separation is decreased or, combinations of these.

$\lambda_{\text{red}} > \lambda_{\text{blue}} > \lambda_{\text{violet}}$

Question 13 A

All diodes are constructed from p–n junctions that are electrically stimulated.

Question 14 B

The likeliness of diffraction is determined by the ratio $\frac{\text{wavelength}}{\text{hair thickness}}$ or $\frac{\text{speed of light}}{\text{frequency} \times \text{hair thickness}}$.

Thus the ratio $= \frac{3 \times 10^{8}}{6.50 \times 10^{14} \times 1.5 \times 10^{-5}} = 0.031$.

Diffraction will occur when the ratio is a minimum of 0.1. Hence diffraction is not visible (will not occur).

Question 15 B

$n_i \sin(i) = n_r \sin(r)$

$$n_{glass} \sin(20) = 1.33 \times \sin(25)$$

$$n_{glass} = \frac{1.33 \times 0.4266}{0.3420}$$

$$= 1.64$$

Question 16 C

The electrons are individually passing through and striking a particular point on the screen as particles do.

The final pattern, however, is typical of constructive and destructive interference, resulting in bright and dark bands as though the electrons were of a wave nature.

During its passage through the double slit, an electron interferes with itself as a wave would.

Question 17 D

25.7 eV occurs from an electron transition of $n = 5$ to $n = 2$.

17.0 eV occurs from $n = 3$ to $n = 2$.

8.70 eV occurs from $n = 5$ to $n = 3$.

7.35 eV does not occur.

Question 18 B

In the wave model, light intensity consists of the power (energy per second) dependent on the square of the amplitude of the light waves.

The wave model predicts that increasing light intensity would affect the maximum kinetic energy (**A** is incorrect), allow all colours to cause photoelectron emission (**C** is incorrect) and reduce the time delay between irradiation and electron emission (**D** is incorrect).

B correctly predicts that increasing light intensity should linearly increase the number of electrons emitted per second.

Question 19 D

$$\lambda_{\text{de Broglie}} = \frac{h}{mv}$$

$$= \frac{h}{\sqrt{2mqV}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.66 \times 10^{-27} \times 1.6 \times 10^{-19} \times 100}}$$

$$= 2.88 \times 10^{-12} \text{ m}$$

Question 20 A

speed = frequency × wavelength

= 49.3 × 0.3521

= 17.4 m s^{-1} to the least number of significant figures (that is, three significant figures)

SECTION B

Question 1 (11 marks)

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

$= \frac{2000}{0.10}$ 1 mark

$= 2.00 \times 10^4 \text{ V m}^{-1}$ 1 mark

b. $W = Vq$

$= 2000 \times 1.6 \times 10^{-19}$ 1 mark

$= 3.2 \times 10^{-16} \text{ J}$ 1 mark

c. $F = Eq$

$= 2.00 \times 10^4 \times 1.6 \times 10^{-19}$ 1 mark

$= 3.2 \times 10^{-15} \text{ N}$ 1 mark

Note: Consequential on answer to ***Question 1a****.*

d. $\text{acceleration} = \frac{F_{net}}{m}$

$= \frac{3.2 \times 10^{-15}}{9.11 \times 10^{-31}}$

$= 3.5 \times 10^{15} \text{ m s}^{-2}$ 1 mark

$u = 0$, $s = 0.10$ m

$s = ut + \frac{1}{2}at^2$

$0.10 = 0 + \frac{1}{2} \times 3.5 \times 10^{15} \times t^2$ 1 mark

$t = \sqrt{\frac{2 \times 0.10}{3.5 \times 10^{15}}}$

$t = 7.6 \times 10^{-9} \text{ s}$ 1 mark

Note: Consequential on answer to ***Question 1c****.*

e. magnetic force = centripetal force

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

$r = \frac{mv}{Bq}$

$= \frac{9.11 \times 10^{-31} \times 1.90 \times 10^7}{0.10 \times 1.6 \times 10^{-19}}$ 1 mark

$= 1.1 \times 10^{-3} \text{ m}$ 1 mark

Question 2 (13 marks)

a. $g = \frac{GM_{\text{Earth}}}{r^2}$

$r = r_{\text{Earth}} + \text{altitude}$

$= 6.37 \times 10^6 + 370 \times 10^3$

$= 6.74 \times 10^6$ m — 1 mark

$g = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.74 \times 10^6)^2}$ — 1 mark

$= 8.78$ N kg^{-1} — 1 mark

b. $v = \sqrt{\frac{GM_{\text{Earth}}}{r}}$

$r = r_{\text{Earth}} + \text{altitude}$

$= 6.37 \times 10^6 + 370 \times 10^3$

$= 6.74 \times 10^6$ m — 1 mark

$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{6.75 \times 10^6}}$ — 1 mark

$= 7.69 \times 10^3$ m s^{-1} — 1 mark

c. As the astronaut floats inside the space station, she is not in contact with any of the inner surfaces and so experiences zero normal reaction. — 1 mark

The state of non-contact with any surfaces implies that the only force acting on the astronaut is her weight, and so she is accelerating under gravity. — 1 mark

Hence she feels apparently weightless, where it is as if no forces are acting on her. — 1 mark

d. change in gravitational potential energy = area beneath graph between distances

area = area of trapezium

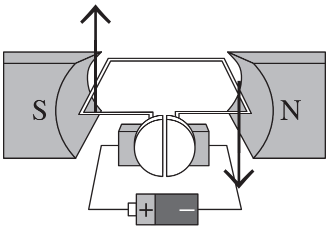
$= \frac{1}{2} \times (7.551 + 7.533) \times 10^4 \times (6.748 - 6.740) \times 10^6$ — 3 marks

$= 6.034 \times 10^8$ J — 1 mark

1 mark for the vertical dimensions of trapezium.
1 mark for the horizontal dimensions of trapezium.
1 mark for including the multiplier values.
Note: Subtract 1 mark if 4 significant figures are not shown.

Question 3 (8 marks)

a.



1 mark

Note: 1 mark for showing both arrows.

b. In order for the coil to start to rotate, a minimum force of 0.050 N is required.

$F = NBIl$

$0.050 = 1 \times 0.20 \times I \times 0.080$ — 1 mark

$I = 3.1$ A — 1 mark

c. The coil is in a position of an open circuit whereby no current can pass through the coil. — 1 mark

Without the current, no electrical force exists in the coil, and so no rotation can occur. — 1 mark

d. The current passes into the coil and creates forces on the sides which rotate the coil in a clockwise direction. — 1 mark

Once the coil goes past the vertical plane position, the forces on the sides remain in the same direction and the coil discontinues rotating in the clockwise direction. — 1 mark

The coil then oscillates about its mean position in the vertical plane until it comes to rest in this position. — 1 mark

Question 4 (12 marks)

a. change in magnetic flux $= |\Phi_{\text{final}} - \Phi_{\text{initial}}|$ where $\Phi = BA$

$= 0.25 \times |(0.060 \times 0.050) - (-0.060 \times 0.050)|$ — 1 mark

$= 1.5 \times 10^{-3}$ Wb — 1 mark

b. period $= \dfrac{1}{\text{frequency}}$

$= \dfrac{1}{4}$

$= 0.25$ seconds

time of a half rotation $= \dfrac{1}{2} \times 0.25$

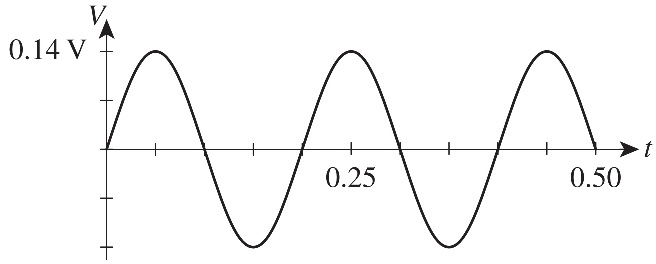
$= 0.125$ seconds — 1 mark

average EMF $= N\dfrac{|\Delta\Phi|}{\Delta t}$

$= 10 \times \left|\dfrac{1.5 \times 10^{-3}}{0.125}\right|$ — 1 mark

$= 0.12$ V — 1 mark

c.



2 marks

1 mark for writing the peak voltage on the scale.

1 mark for writing the period on the scale.

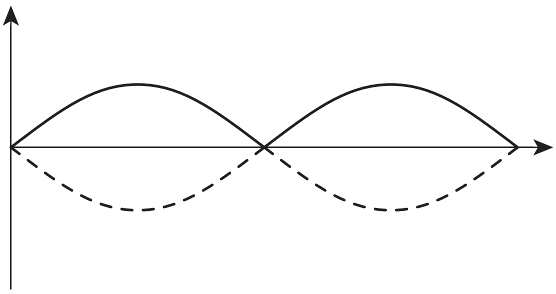
$$\text{peak voltage} = \text{RMS voltage} \times \sqrt{2}$$
$$= 0.10 \times 1.414$$
$$= 0.14 \text{ V}$$

1 mark

$$\text{period} = \frac{1}{\text{frequency}}$$
$$= \frac{1}{4}$$
$$= 0.25 \text{ seconds}$$

1 mark

d.



accept two possibilities —— - - -

amplitude varies with frequency
new amplitude = half original amplitude — 1 mark

period varies inversely as frequency
new period = twice original period — 1 mark

The output is DC; that is, either all positive or all negative. — 1 mark

Note: Will accept two possible graphs as shown above.

Question 5 (12 marks)

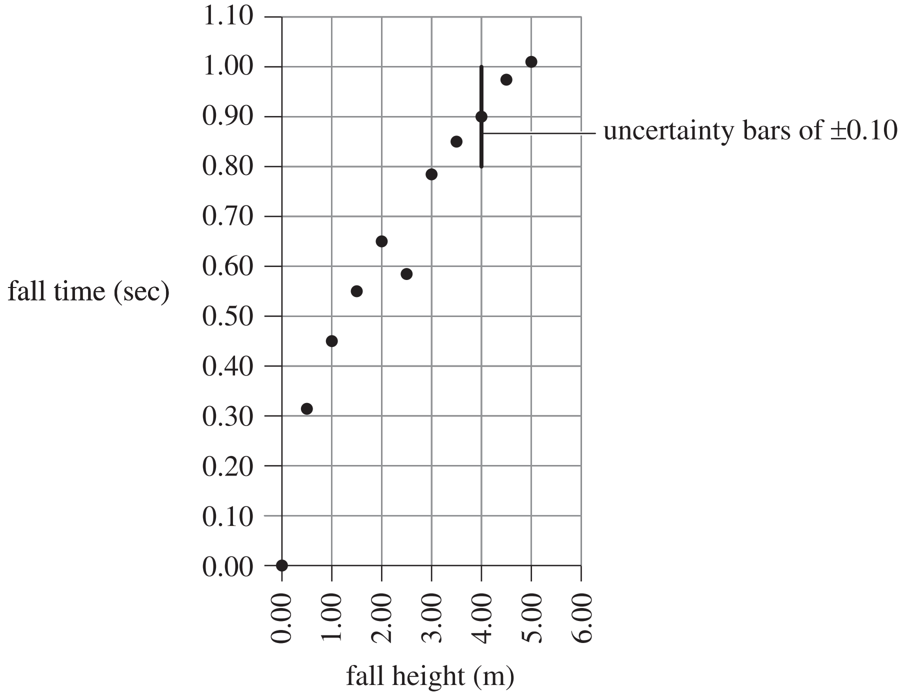
a. The independent variable is the one altered by the experimenters. — 1 mark

The dependent variable is the one that changes with the change in the independent variable. — 1 mark

independent variable = fall height
dependent variable = fall time — 1 mark

1 mark for both the independent variable and dependent variable.

b. See the graph below for the uncertainty bars.



3 marks
1 mark for correct horizontal scale and plot.
1 mark for correct vertical scale and plot.
1 mark for vertical uncertainty bar of ±0.10 sec for t = 0.90.

c. The data point (fall height = 2.50 m, fall time = 0.58 sec) must be a recording error or incorrect fall height recording error as it does not fit the pattern of the rest of the data. 1 mark

The remainder of the data otherwise is modelled by a non-linear relationship between the fall time and fall height. 1 mark

d. The procedure is not correct 1 mark
as even with the inclusion of the uncertainty bars, the relationship is non-linear and so a straight line of best fit does not apply here. 1 mark

e. The hypothesis requires that the power be constant; that is, the ratio of gravitational potential energy (and therefore height) with fall time must be constant. Hence the hypothesis assumes the relationship between fall height and fall time to be linear. 1 mark

Thus the hypothesis does not agree with the evidence/conclusion from the results. 1 mark

Question 6 (8 marks)

a. The bounce height of the ball will vary with air pressure in the ball and for a relationship to be determined between the drop height and the bounce height, the air pressure needs to be a constant; that is, a controlled variable. 1 mark

Thus the deflation of the ball has caused the bounce height to vary with changing ball pressure as well as changing drop height. 1 mark

b. As the bounce height is affected by the drop height as well as the changing ball pressure. 1 mark
this means that the data is invalid. 1 mark

c. The ball needs to be either repaired or replaced such that its internal air pressure remains the same throughout the experiment. 1 mark

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d. $\text{ratio} = \dfrac{\text{bounce height}}{\text{drop height}}$

$= \dfrac{0.10}{0.70}$

$= 0.14$ 1 mark

Note: For 1 mark 2 significant figures must be shown.

$$\frac{E_{\text{ratio}}}{\text{ratio}} = \frac{E_{\text{bounce height}}}{\text{bounce height}} + \frac{E_{\text{drop height}}}{\text{drop height}}$$

$$E_{\text{ratio}} = 0.14 \times \left[\frac{0.02}{0.10} + \frac{0.01}{0.70}\right]$$

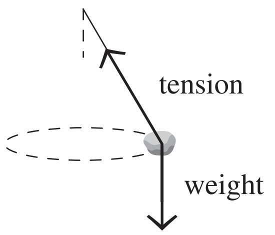
$= 0.03$ 1 mark

ratio = [0.14 ± 0.03] 1 mark

1 mark for correct decimal place consistency.

Question 7 (13 marks)

a.



The net force acting on the stone is the centripetal force that is horizontal.

$\text{period} = T$

$= \dfrac{1}{f}$

$= \dfrac{34}{15}$

$= 2.65\ \text{sec}$ 1 mark

$$\text{speed} = \frac{2 \times \pi \times L\sin(30)}{T}$$

$$= \frac{2 \times \pi \times 1.50\sin(30)}{2.65}$$

$= 2.08\ \text{m s}^{-1}$

$$F_{\text{centripetal}} = \frac{mv^2}{r}$$

$$= \frac{0.500 \times (2.08)^2}{1.50\sin(30)}$$ 1 mark

$= 2.89\ \text{N}$ 1 mark

b. horizontally

$F_{\text{centripetal}} = \text{tension} \times \sin(30)$

$= \frac{mv^2}{r}$ 1 mark

$\text{tension} = \frac{2.89}{\sin(30)}$

$= \frac{2.89}{0.5}$

$= 5.77\ \text{N}$ 1 mark

OR

vertically

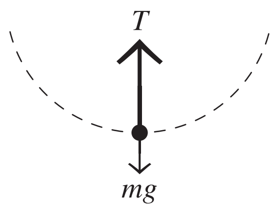
tension × cos(30) – mg = 0 1 mark

$\text{tension} = \frac{mg}{\cos(30)}$

$= \frac{0.500 \times 10}{0.866}$

$= 5.77\ \text{N}$ 1 mark

c. at the bottom



$\text{tension} - mg = \frac{mv^2}{r}$

$3mg - mg = \frac{mv^2}{r}$ 1 mark

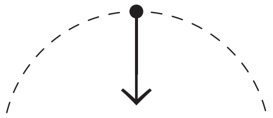
$2mg = \frac{mv^2}{r}$

$v = \sqrt{2rg}$

$= \sqrt{2 \times 1.50 \times 10}$ 1 mark

$= 5.48\ \text{m s}^{-1}$ 1 mark

d. at the top



$mg + \text{tension} = \frac{mv^2}{r}$

$mg = \frac{mv^2}{r}$ 1 mark

$v = \sqrt{rg}$

$= \sqrt{1.50 \times 10}$

$= 3.87 \text{ m s}^{-1}$ 1 mark

e. vertically (up is +)

$a = -10 \text{ m s}^{-2}$

$u_{\text{vertically}} = 10\sin(45)$ 1 mark

$= 7.07 \text{ m s}^{-1}$

$v_{\text{top}} = 0$

$v_{\text{vertically}}^2 = u_{\text{vertically}}^2 + 2a_{\text{vertically}}s_{\text{vertically}}$

$0 = 7.07^2 + 2(-10)(s_{\text{vertically}})$

$s_{\text{vertically}} = \frac{7.07^2}{20}$

$= 2.50 \text{ m}$ 1 mark

height above ground = 2.60 + 2.50

= 5.10 m 1 mark

Question 8 (4 marks)

a. $TME_{\text{top}} = TME_{\text{bottom}}$

$mgd = \frac{1}{2}kd^2$

$mg = \frac{1}{2}kd$ 1 mark

$20 \times 10 = \frac{1}{2} \times 250 \times d$

$d = 1.6 \text{ m}$ 1 mark

b. $TME_{\text{before}} = TME_{\text{after}}$

$\frac{1}{2}k(\Delta x)^2 = \frac{1}{2}mv^2 + mgh$ 1 mark

$\frac{1}{2} \times 250 \times (1.0)^2 = \frac{1}{2} \times 20xv^2 + 20 \times 10 \times 0.5$

$125 = 10v^2 + 100$

$v = \sqrt{2.5}$

$v = 1.58 \text{ m s}^{-1}$ 1 mark

Question 9 (6 marks)

a. total momentum prior to collision = total momentum after collision (right is positive)

$m_X u_X + m_Y u_Y = m_X v_X + m_Y v_Y$

$(4000 \times 1.0) + (6000 \times -0.5) = (4000 \times v_X) + (6000 \times 0.2)$

$4000 - 3000 = 4000v_X + 1200$ 1 mark

$v_X = \frac{-200}{4000}$

$= 0.05 \text{ m s}^{-1}$ left 2 marks

1 mark for correct answer.
1 mark for correct position.

b. A comparison of the system's total kinetic energy before and after the collision is required.

total kinetic energy before $= \left[\frac{1}{2} \times 4000 \times 1.0^2\right] + \left[\frac{1}{2} \times 6000 \times 0.5^2\right]$

$= 2750$ J 1 mark

total kinetic energy after $= \left[\frac{1}{2} \times 4000 \times 0.05^2\right] + \left[\frac{1}{2} \times 6000 \times 0.2^2\right]$

$= 125$ J 1 mark

Since the total kinetic energy of the system has decreased as a result of the collision, the collision is inelastic with the difference in kinetic energy transferred to heat, sound and possibly crumpling. 1 mark

Note: Consequential on answer to ***Question 9a****.*

Question 10 (8 marks)

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

$= \frac{0.40}{20}$

$= 0.02$ m 1 mark

b. Point V shows a crest from each slit meeting there. 1 mark

The waves interfere constructively resulting in an amplitude equal to the sum of the amplitudes of the two waves from the slits meeting at point V. 1 mark

c. $d(S_1W) - d(S_2W) = 2.5\lambda$

$d(S_2W) = 13.0 - 2.5 \times 2.0$ — 1 mark

$= 8.0$ cm — 1 mark

*Note: Consequential on answer to **Question 10a**.*

d. The increase in frequency results in a decrease in the wavelength. — 1 mark

Since the lateral spread of the interference pattern varies with wavelength, — 1 mark

the pattern of maximum and minimum lines will move closer to the central maximum. — 1 mark

Question 11 (8 marks)

a. use gradient method

$$\text{gradient} = \frac{V_2 - V_1}{f_2 - f_1}$$

$$= 4.14 \times 10^{-15}$$

$$\frac{V - 0}{1.20 \times 10^{15} - 5.8 \times 10^{14}} = 4.14 \times 10^{-15}$$ — 1 mark

$$V = 4.14 \times 10^{-15} \times 6.2 \times 10^{14}$$

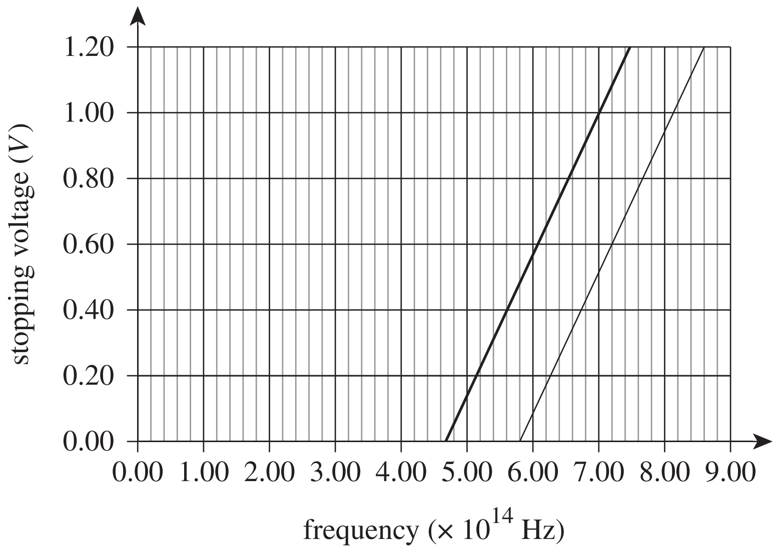
$$V = 2.6 \text{ V}$$ — 1 mark

b. A work function of 1.95 eV would have a threshold frequency of $f = \dfrac{1.95}{4.14 \times 10^{-15}}$

$= 4.7 \times 10^{14}$ Hz — 1 mark

Thus graph should start at this frequency on the horizontal axis — 1 mark

and ascend with the same gradient as the existing data. — 1 mark



c. The same metal is used as the data shown in Figure 19.

Thus the threshold frequency is 5.8×10^{14} Hz.

A wavelength of 450 nm is equivalent to a frequency of $\dfrac{3 \times 10^{8}}{650 \times 10^{-9}} = 4.6 \times 10^{14}$ Hz. — 1 mark

Since this is less than the critical frequency, no electrons will be emitted — 1 mark

and so no graph will exist for this. — 1 mark

Question 12 (4 marks)

The X-rays have a wavelength of $\dfrac{3 \times 10^{8}}{4.12 \times 10^{18}} = 7.28 \times 10^{-11}$ m . 1 mark

The electrons have a de Broglie wavelength given by $\dfrac{6.63 \times 10^{-34}}{1.82 \times 10^{-23}} = 3.64 \times 10^{-11}$ m . 1 mark

The electrons have a smaller (approximately half) wavelength than the X-rays. They will produce a pattern of similar circular concentric rings 1 mark

but the pattern of rings will be have smaller radii (approximately half of those in Figure 21). 1 mark

Question 13 (4 marks)

As the electron passes through the slit, it has a probability of diffracting and therefore having a vertical velocity and momentum. 1 mark

Its uncertainty in position in the *y* plane becomes approximately half the slit width. 1 mark

If the slit width is reduced to define the particle's position, the electron has a greater probability of diffracting further up the *y* plane. Thus the uncertainty in its momentum increases. 1 mark

The product of the position and momentum uncertainties is of a minimum value given by the Heisenberg uncertainty principle. 1 mark

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