Neap:

Trial Examination 2018

VCE Physics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1 **C**

The electric field strength is constant throughout the region between the plates.

$$E = \frac{\Delta V}{d}$$
$$= \frac{6 - (-12)}{0.005}$$
$$= 3600 \text{ N C}^{-1}$$

Question 2 **A**

gain in kinetic energy = electrical work done by the field

$$= q\Delta V$$
$$= 1.6 \times 10^{-19} \times 9$$

(since potential varies linearly with distance and the plates have a potential difference of 18 V)

$$= 1.44 \times 10^{-18} \text{ J}$$

Question 3 **B**

centripetal force = magnetic field force

$$\frac{mv^2}{r} = Bvq$$
$$r = \frac{mv}{Bq}$$
$$= \frac{1.37 \times 10^{-22}}{5.0 \times 1.6 \times 10^{-19}}$$
$$= 0.00017 \text{ m}$$
$$= 0.17 \text{ mm}$$

Using the right-hand palm rule with positive current travelling left and the magnetic field into the page, the force coming out of the palm of the hand will be downwards.

Question 4 **D**

In an ideal transformer, the input power and the output power are equal and so their ratio is 1 : 1.

The transformer relationships are as follows:

$$\frac{N_1}{N_2} = \frac{20}{1} = \frac{V_1}{V_2} = \frac{I_1}{I_2}$$

The ratio for the primary current and the secondary current is 1 : 20.

Question 5 **B**

The coil produces a sinusoidal voltage output.

Given that a split-ring commutator is used, this output will have its polarity reversed every half-cycle.

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Question 6 **B**

The 2.0 kg mass has only the tension of the horizontal force acting on it.

Thus $T = 2.0 \times a$.

The falling mass has its downward weight competing with the upward tension, which is the same tension experienced by the 2.0 kg mass.

Thus, for the 1.0 kg mass, $(1.0 \times 9.8) - T = 1.0 \times a$.

Hence $T = 2a$ and $9.8 - T = a$.

Thus, by eliminating a, the equations reduce to:

$$\begin{aligned} T &= 2 \times (9.8 - T) \\ &= 19.6 - 2T \\ &= 6.53 \text{ N} \end{aligned}$$

Question 7 **C**

$$\begin{aligned} \text{mass energy} &= \gamma \times \text{rest mass energy} \\ &= 2.5 \times 0.512 \\ &= 1.281 \text{ MeV} \end{aligned}$$

Question 8 **C**

$$\begin{aligned} \text{work done by spring} &= \text{increase in kinetic energy} \\ &= \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \\ &= \frac{1}{2} \times 0.5 \times 2^2 \\ &= 1.0 \text{ J} \end{aligned}$$

Question 9 **D**

The answer is determined by the graph that has the correct gradient.

$$\begin{aligned} \text{work done by spring} &= \frac{1}{2}k(\Delta x)^2 \\ &= 1.0 \end{aligned}$$

$$\frac{1}{2} \times k \times 0.02^2 = 1.0$$

$$\begin{aligned} k &= \frac{1.0 \times 2}{0.02^2} \\ &= 5000 \text{ N m}^{-1} \\ &= \text{gradient of force–compression graph} \end{aligned}$$

Question 10 **A**

$$\text{harmonic frequencies} = \frac{nv}{2L} = \frac{n \times 25}{2 \times 5.0} = 2.5n$$

Thus the lowest frequencies are 2.5 Hz, 5.0 Hz and 7.5 Hz.

Question 11 **D**

Polarisation occurs for waves such that only those waves that oscillate transversally in a single plane of vibration are passed through a medium.

Question 12 **D**

The refractive index of a material varies slightly with frequency (to three decimal places for refractive index). Although small, the variation is enough to be visible, as in the rainbow effect.

Question 13 **A**

High-resolution imaging is clear and sharp. Blurring is caused by diffraction effects when the wavelengths of the radiation are comparable to the size of any cavities or features of the subjects being photographed. To reduce diffraction, the $\lambda : d$ ratio should be less than 1.

Thus, electron micrographs are sharper in imaging because the de Broglie wavelengths of electrons are smaller than the features of the insect and the optical wavelengths.

Question 14 **B**

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^{8}}{3.0 \times 10^{15}} = 1.0 \times 10^{-7} = 100 \text{ nm}$$

This is found in the ultraviolet region.

Question 15 **D**

Synchrotron light is produced from the change in direction of travel of electrons by use of magnetic fields.

Question 16 **A**

By Heisenberg's uncertainty principle, any attempt to reduce the uncertainty in a position along a plane increases the uncertainty in the momentum along that plane.

Question 17 **B**

$$\text{spread of bands} = \frac{\lambda \times (\text{slit – screen distance})}{\text{slit separation}}$$

Question 18 A

$p = \frac{h}{\lambda}$ applies to both the photon and the electron. Thus the photon and electron have the same momentum.

$$\text{photon energy} = \frac{hc}{\lambda}$$
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$$
$$= \frac{1.99 \times 10^{-25}}{\lambda}$$

$$\text{electron energy} = \frac{h^2}{2m\lambda^2}$$
$$= \frac{(6.63 \times 10^{-34})^2}{2 \times 9.11 \times 10^{-31} \times \lambda^2}$$
$$= \frac{2.41 \times 10^{-37}}{\lambda^2}$$

$$\frac{\text{photon energy}}{\text{electron energy}} = 8.24 \times 10^{11} \times \lambda$$
$$= 8.24 \times 10^{11} \times 2.0 \times 10^{-10}$$
$$= 165$$

Thus the photon energy is greater than the electron energy.

Question 19 B

The error is the difference between the measurement and the accepted value.

$$\text{error} = |1.33 - 1.35|$$
$$= 0.02$$

The uncertainty is the range of variation of the measurement as determined by the experimenter.

uncertainty = ± 0.15

Question 20 D

Precision refers to how small the deviation between the results is.

Accuracy refers to how close the results or their average is to the accepted value of a quantity.

Set X is precise but not accurate.

Set Y has an average that is accurate or more accurate than set X.

SECTION B

Question 1 (5 marks)

a. $F_{net} = F(Q_1 \text{ on } Q_3) + F(Q_2 \text{ on } Q_3)$

$F(Q_2 \text{ on } Q_3) = F_{net} - F(Q_1 \text{ on } Q_3)$

$F(Q_2 \text{ on } Q_3) = \longleftarrow - \longrightarrow$ 1 mark

$= \longleftarrow$

$= -1.0 - 2.0$

$= -3.0$ N

$= 3.0$ N 1 mark

direction: D (to the left) 1 mark

b. If the force of Q_1 on Q_3 is to the right and the net force is to the left, then the force of Q_2 on Q_3 is to the left.

Given that Q_3 is positive and Q_2 is to the left of Q_3, then Q_2 must be negative. 1 mark

$$F(Q_2 \text{ on } Q_3) = \frac{kQ_2Q_3}{d^2}$$

$$3.0 = \frac{9.0 \times 10^9 \times 1.49 \times 10^{-5} \times Q_2}{(1.0)^2}$$

$$Q_2 = \frac{3.0}{9.0 \times 10^9 \times 1.49 \times 10^{-5}}$$

$$= 2.24 \times 10^{-5} \text{ C}$$ 1 mark

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

Question 2 (5 marks)

a. force = $N \times B \times I \times l$

$$I = \frac{V}{R}$$

$$= \frac{6.0}{5.0}$$

$= 1.2$ A 1 mark

force = $20 \times 0.50 \times 1.2 \times 0.10$

$= 1.2$ N 1 mark

By the right-hand palm rule:
thumb = current out of page
fingers = B field to the right
palm of hand = force upwards
Direction: U 1 mark

b. The coil ends are connected to the same battery terminals and so the current direction relative to the coil does not change. From the starting position shown, the force on the side DC is up and the force on the side AB is down, resulting in an anti-clockwise rotation viewed from the battery side. Once the plane of the coil reaches its vertical position, as it turns over and the current direction does not change, the forces on the sides AB and DC therefore remain in the same directions, causing the coil to return in a clockwise direction. 1 mark

The coil then oscillates and slows down until it remains at rest in the vertical position. 1 mark

Question 3 (12 marks)

a. magnetic flux = magnetic field × cross-sectional area being threaded

$$= 0.10 \times \frac{\pi \times (0.060)^2}{4}$$ 1 mark

$$= 2.83 \times 10^{-4} \text{ Wb}$$ 1 mark

b. Given $a = 9.8 \text{ m s}^{-1}$, $u = 0$, $s = 0.30$ m:

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

$$0.30 = 0 + 4.9t^2$$

$$t = \sqrt{\frac{0.30}{4.9}}$$

$$= 0.25 \text{ s}$$ 1 mark

c. EMF = magnitude of $\frac{\Delta \Phi}{\Delta t}$

$$= \frac{(2.83 \times 10^{-4}) - 0}{0.25}$$ 1 mark

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

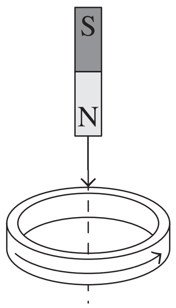
*Note: Consequential on answers to **Question 3a.** and **Question 3b.***

d. As the external magnetic flux increases in the downward direction through the ring, the ring opposes this increase in flux 1 mark

by producing its own flux upwards. 1 mark

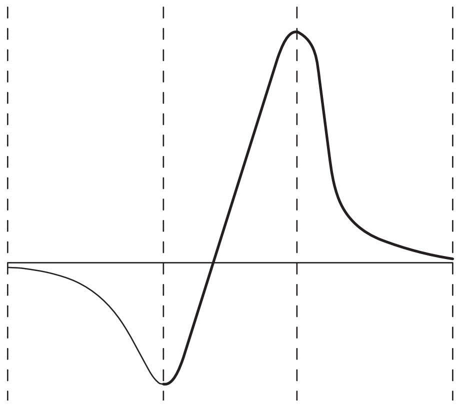
This induced flux in the ring must have the associated current to produce it. By the right-hand grip rule, as the induced flux is upwards (fingers pointing upwards), the thumb points **tangentially to the right on the ring when viewed from the front**. 1 mark

Thus, when the diagram is viewed from the front, the current travels around the ring, as shown below.



1 mark

e.



2 marks

Note: The height of the peak must be greater than the depth of the trough as the magnet accelerates through the ring. The peak must also be positive due to the inversion of the induced flux as the magnet passes through it.
The EMF drops to zero more quickly than when the EMF changes from zero to maximum upon approach, since the magnet accelerates away from the ring. Thus the graph returns to zero EMF as an asymptote.

Question 4 (5 marks)

a. $V_{\text{trans}} = V_{\text{primary}} \times 25$

$= 20 \times 25$

$= 500 \text{ kV}$ 1 mark

$I_{\text{line peak}} = \dfrac{P_{\text{supply}}}{V_{\text{trans}}} \times \sqrt{2}$

$= \dfrac{500 \times 10^6}{500 \times 10^3} \times \sqrt{2}$ 1 mark

$= 1000 \times \sqrt{2}$

$= 1.4 \times 10^3 \text{ A}$ 1 mark

b. $7.81 \times 10^6 = 1000^2 \times R_{\text{line}}$ 1 mark

$R_{\text{line}} = 7.8 \ \Omega$ 1 mark

Note: Consequential on working in ***Question 4a.***

Question 5 (4 marks)

a. Horizontally, the ball travels at a constant speed.

$v_{\text{horizontal}} = \dfrac{d_{\text{horizontal}}}{t}$

$t = \dfrac{6.00}{10.68 \times \cos(40)}$ 1 mark

$= 0.733 \text{ s}$ 1 mark

Note: Subtract 1 mark if not correct to three significant figures.

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b. For the ball to enter the plane of the ring, it must be at a vertical height of 2.40 m at a time of 0.733 seconds.

Vertically, $a = -9.8 \text{ m s}^{-2}$, $u = 10.68\sin(40)$, $t = 0.733$ sec.

Thus it needs to be shown that vertically, $s = 2.40$ m. Use $s_v = u\sin(40)t + \frac{1}{2}at^2$.

$$s = (10.72 \times \sin(40) \times 0.733) - \left(\frac{1}{2} \times 9.8 \times 0.733^2\right)$$ 1 mark

$$= 5.0345 - 2.6327$$

$$= 2.40 \text{ m as required}$$ 1 mark

Question 6 (4 marks)

a. As the net motion of the rider is one of horizontal circular motion, she must have a net force that is horizontal and towards the centre of her turning circle. 1 mark

This centripetal force is provided by the horizontal component of the road reaction on the motorcycle. This horizontal component also represents the inward road-tyre's friction. 1 mark

b. vertically: $R\cos(\theta) - mg = 0$ (**eq. 1**)

horizontally: $R\sin(\theta) = \frac{mv^2}{r}$ (**eq. 2**)

Divide (**eq. 1**) by (**eq. 2**).

$$\tan(\theta) = \frac{v^2}{rg}$$ 1 mark

$$v = \sqrt{rg\tan(\theta)}$$

$$= \sqrt{40 \times 9.8 \times \tan(35)}$$

$$= 16.56 \text{ m s}^{-1}$$ 1 mark

Question 7 (5 marks)

a. At the top of the loop, the normal reaction and the weight are both downwards, as is the net force or centripetal force.

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

Thus $mg + mg = 2mg = \frac{mv^2}{r}$.

$$v = \sqrt{2gr}$$ 1 mark

$$= \sqrt{2 \times 9.8 \times 6.0}$$

$$= 10.84 \text{ m s}^{-1}$$ 1 mark

b. Using total mechanical energy conservation with the ground as the zero for height:

$$mgh_{top} + \frac{1}{2}mv^2_{top} = \frac{1}{2}mv^2_{bottom} \text{ (divide out } m\text{)}$$ 1 mark

$$(9.8 \times 12) + \left(\frac{1}{2} \times 8.5^2\right) = \left(\frac{1}{2} \times v^2\right)$$

$$v = 17.53 \text{ m s}^{-1}$$ 1 mark

Question 8 (6 marks)

a. As the distance between the markers is stationary for SU13, then the moving clock is that of MX5. Thus it will measure a smaller time than that measured for the same event by SU13, which will have measured the dilated time.

Thus $t(\text{according to MX5}) = 3.704 \times 10^{-6} \times \sqrt{(1 - 0.9^2)}$ 1 mark

$= 1.615 \times 10^{-6}$ s 1 mark

b. Both spacecraft represent inertial frames of reference 1 mark
and so from their perspective their result is correct in their frame. 1 mark

SU13 measured the time interval of MX5 moving from a marker to a different marker; that is, at two different positions. MX5 measured a time interval as the markers passed the same point in front of it. 1 mark

Thus the time measured by MX5 is regarded as the proper time of the event, with the time measured by SU13 as the dilated time. 1 mark

Question 9 (8 marks)

a. magnitude of $F_{\text{ISS acting on Earth}}$ = magnitude of $F_{\text{Earth acting on ISS}}$

$F = m_{\text{ISS}} \times g_{\text{Earth}}$

$= 4.19 \times 10^5 \times 8.67$ 1 mark

$= 3.63 \times 10^6$ N 1 mark

b. $T = 2\pi\sqrt{\dfrac{r_{\text{orbit}}}{g}}$

$= 2\pi\sqrt{\dfrac{6.38 \times 10^6 + 4.05 \times 10^5}{8.67}}$ 2 marks

1 mark for r_{orbit}.
1 mark for working.

$= 5558$ s 1 mark

c. The orbital speed of a satellite varies inversely as the square root of the orbital radius for the same central body; that is, $v \alpha \dfrac{1}{\sqrt{r}}$.

Thus:

Harry's claim cannot be true, since for the satellite to travel faster it must be closer to Earth. 1 mark

Mel's claim is also not true, since the orbital speed of a satellite is independent of its mass. 1 mark

Dana's claim is true. 1 mark

Note: The first sentence must be stated in order to validate all three comments about the claims. Subtract 1 mark if the first sentence is not mentioned but all three claims are correct.

Question 10 (4 marks)

Momentum conservation needs to be used to determine the forward speed of the car.

total momentum of system after collision = total momentum of system before collision

$$(5000 \times 5.0) + (800 \times 2.0) = (5000 \times 4.5) + (800 \times v)$$ 1 mark

$$25\,000 + 1600 = 22\,500 + 800v$$

$$v = \frac{4100}{800}$$

$$= 5.125 \text{ m s}^{-1}$$ 1 mark

Total system kinetic energies now need to be determined.

$$\text{total kinetic energy before collection} = \frac{1}{2} \times 5000 \times 5.0^2 + \frac{1}{2} \times 800 \times 2.0^2$$

$$= 62\,500 + 1600$$

$$= 64\,100 \text{ J}$$

$$\text{total kinetic energy after collision} = \frac{1}{2} \times 5000 \times 4.5^2 + \frac{1}{2} \times 800 \times 5.125^2$$

$$= 50\,625 + 10\,506.25$$

$$= 61\,131.25 \text{ J}$$ 1 mark

Note: 1 mark for the calculation of kinetic energy before collision and kinetic energy after collision. Consequential on calculation of car speed.

Since the total kinetic energy after the collision is less than that before the collision, the collision is inelastic. 1 mark

Note: The difference in kinetic energy has been transferred to heat, sound and some crumpling of the vehicles' contact points.

Question 11 (4 marks)

a. $$\frac{\sin(i)}{\sin(r)} = \frac{v_i}{v_r}$$

$$\frac{\sin(60)}{\sin(34.5)} = \frac{3.00 \times 10^8}{v_{\text{glass}}}$$

$$v_{\text{glass}} = 3.00 \times 10^8 \times \frac{0.5664}{0.866}$$ 1 mark

$$= 1.96 \times 10^8 \text{ m s}^{-1}$$ 1 mark

b. The largest angle of refraction occurs when the angle of incidence is 90°.

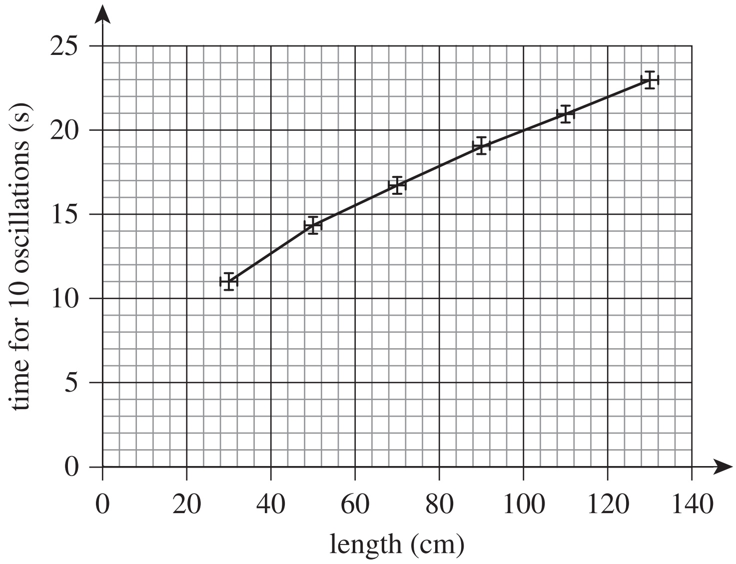
$$\therefore \frac{\sin(r)}{\sin(90)} = \frac{\sin(34.5)}{\sin(60)}$$ 1 mark

$$r = \sin^{-1}\left(\frac{0.5664}{0.866}\right)$$

$$= 40.85°$$ 1 mark

Question 12 (13 marks)

a.



6 marks

1 mark for correct plotting of coordinates.
1 mark for smooth curve.
1 mark for correct scales (both must be correct).
1 mark for correct labels with their units.
1 mark for correct vertical uncertainty bars.
1 mark for correct horizontal uncertainty bars.

b.

Classification	Variable
controlled	mass of bob/angle of release
dependent	time for (1 or 10) oscillation(s)
independent	string length

3 marks

1 mark for each correct row.

c. Their hypothesis is incorrect, as they indicate the relationship to be linear, 1 mark
and the graph of the data shows the relationship to be curved or non-linear. 1 mark

d. The graph is valid as the multiplication factor of 10 does not alter the profile (shape/curve) of the graph – the graph does not need to be replotted with the times divided by 10. 1 mark

The graph is valid as the multiplication factor of 100 does not alter the profile (shape/curve) of the graph – the graph does not need to be replotted with the distances divided by 100. 1 mark

Question 13 (9 marks)

a. Phoebe walks through a region which contains a standing wave as a result of the reflected wave interfering with the oncoming wave. Thus she hears a series of highs and lows in sound that are equal distances between their positions and alternating in high/low intensity. 1 mark

Hence, Samantha's prediction is incorrect. 1 mark

Hence, Harold's prediction is also incorrect. 1 mark

b. The path difference (value of difference in distance travelled by each wave from the speaker to the position) of the sounds in comparison to the wavelength will indicate the nature of the interference and therefore the sound intensity heard at each position. 1 mark

If the path difference is a whole number value of the wavelength of the sound, then the listener will hear a high in intensity as a result of constructive interference (the waves are in phase and the resultant is the sum resulting in a wave of higher amplitude). 1 mark

If the path difference is a (whole number + $\frac{1}{2}$) value of the wavelength of the sound, then the listener will hear a zero or low in intensity as a result of destructive interference (the waves are out of phase and the resultant is a zero amplitude or near zero amplitude wave). 1 mark

c. At X, path difference $= 6.6 - 5.0$

$= 1.6$ m

$= (0, 1, 2, 3\ldots) \times \lambda$

Thus $\lambda = 1.6$ m, 0.8 m, 0.53 m, 0.4 m and so on. 1 mark

At Y, path difference $= 5.1 - 2.3$

$= 2.8$ m

$= \left(\frac{1}{2}, 1\frac{1}{2}, 2\frac{1}{2}, 3\frac{1}{2}\ldots\right) \times \lambda$

Thus $\lambda = 5.6$ m, 1.86 m, 1.12 m, 0.8 m and so on. 1 mark

The wavelength must be the same at both positions and so $\lambda = 0.8$ m is the largest option.

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

$= \frac{340}{0.8}$

$= 425$ Hz (the smallest frequency possible) 1 mark

Question 14 (9 marks)

a. The wave model predicts that light of all colours will cause photoelectron emission regardless of how long the process will take. The results indicate that the emission of photoelectrons will occur only for photons of minimum frequency of 5.5×10^{14} Hz. Thus only colours of light whose frequency is above this will cause photoelectron emission, and so the wave model prediction is incorrect. 1 mark

The wave model predicts that the increase of kinetic energy of electrons is caused by an increase in the brightness of the light irradiating the metal target. The graph indicates that it is the increase in the frequency of the light used rather than its brightness that causes an increase in the kinetic energy. 1 mark

b. Light of frequency of 11×10^{14} Hz corresponds to electron kinetic energy of 2.3 eV from the graph. 1 mark

This equates to a decelerating (stopping) voltage of $V = \frac{E_k}{q}$, where 2.3 eV equates to 2.3 V. 1 mark

c. The frequency of the green light is as follows:

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

$$= \frac{3 \times 10^{8}}{545 \times 10^{-9}}$$

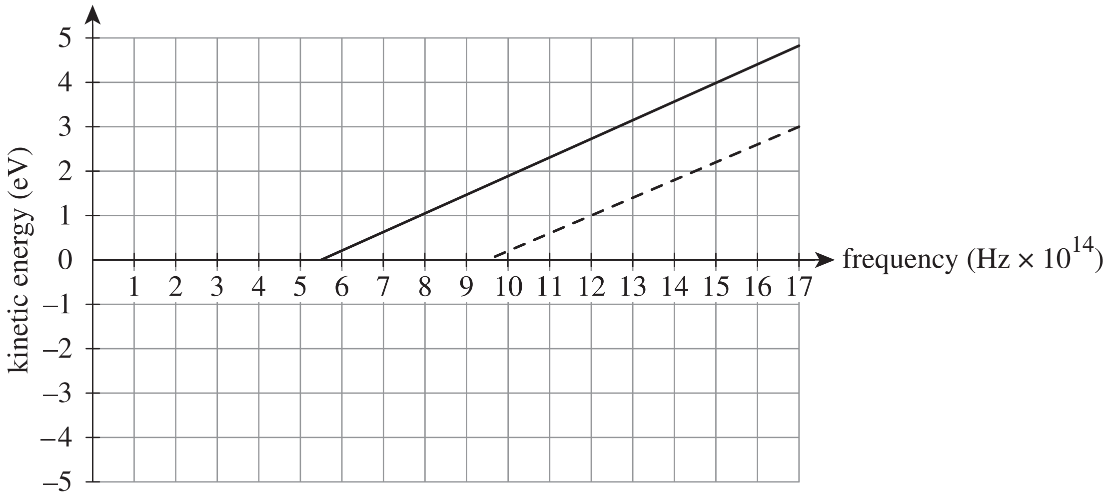
$$= 5.5 \times 10^{14} \text{ Hz}$$ 1 mark

This frequency happens to be the critical frequency (x-intercept).

Since the frequency of red light is less than that of green light in the electromagnetic spectrum, 1 mark

red light lies in the domain of the graph below the critical frequency where it is not absorbed by electrons. since a photon of this colour would not have enough energy to release an electron from the atom. 1 mark

d. The dashed line below shows the final sketch.



2 marks

1 mark for the same gradient as the original since it represents Planck's constant.

1 mark for the graph including the coordinate ($f = 12 \times 10^{14}$ Hz, $E_k = 1$ eV).

Note: Deduct 1 mark if the graph extends below $E_k = 0$ eV).

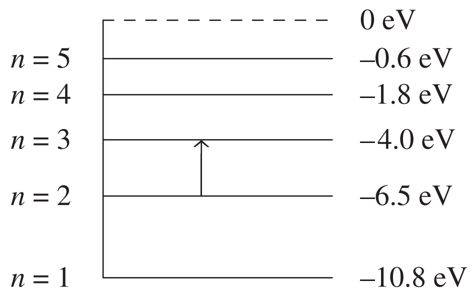
Question 15 (5 marks)

a. $E = hf$

$= 4.14 \times 10^{-15} \times 6.04 \times 10^{14}$

$= 2.5$ eV 1 mark

This corresponds to the transition (shown below) between $n = 2$ and $n = 3$.



1 mark

b. All energy levels are such that an electron's energy manifests itself in the form of a standing wave. 1 mark

In order for this standing wave to exist around the nucleus, the circumference of the standing wave must be a whole number of wavelengths ($2\pi r = 2\lambda$). 1 mark

Hence, this circumference equates to a standing wave energy of –6.5 eV. 1 mark

Question 16 (9 marks)

a. 1% of the speed of light $= 0.01 \times 3 \times 10^8$

$= 3 \times 10^6 \text{ m s}^{-1}$

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

$$= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3 \times 10^6}$$ 1 mark

$= 2.43 \times 10^{-10}$ m 1 mark

$$= \frac{2.43 \times 10^{-10}}{1 \times 10^{-9}}$$

$= 0.243$ nm 1 mark

b. electrical work done $= qV$ **OR** $V = \frac{h^2}{\sqrt{2mq\lambda^2}}$

$= \text{change in kinetic energy}$

$= \Delta E_k$

Note: The use of the second equation involving the answer from ***part a.*** *would be given full marks if the answer to* ***part a.*** *is correct. As there is an alternative method involving the first equation (electrical work), no marks are given if the correct working is provided using the second equation but the answer to* ***part a.*** *was incorrect. The method to be used preferentially is that involving the first equation.*

$$V = \frac{\Delta E_k}{q}$$

$$= \frac{\frac{1}{2} \times 9.11 \times 10^{-31} \times (3 \times 10^6)^2}{1.6 \times 10^{-19}}$$ 1 mark

$= 25.62$ V 1 mark

c. The bright/dark circular bands are positions of constructive and destructive interference of the electrons with each other. 1 mark

This indicates that the electrons displayed wave-like behaviour. 1 mark

d. The reason for which the electrons displayed wave-like behaviour is that their de Broglie wavelength to interatomic distance ratio is greater than 0.1 $\left(\frac{\text{de Broglie wavelength}}{\text{interatomic distance}} > 0.1\right)$. 1 mark

This indicates that diffraction of the electrons through the spacing occurs such that they constructively and destructively interfere with each other. 1 mark

Question 17 (3 marks)

As the electrons pass one at a time through the plane of the two slits and then strike the detector screen at a certain point, they are recorded one at a time in sequence and so show their particle nature. 1 mark

Over time, the recording shows that the electrons strike preferentially at particular positions, indicating that they are constructively interfering with themselves in order to arrive at these points. Thus the multiple recordings in regularly spaced positions indicate their wave nature. 1 mark

Collectively, the data displays the dual wave-particle nature of the electrons as they behave both as particles and are wave-like. 1 mark

