Neap

Trial Examination 2020

VCE Physics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1 C

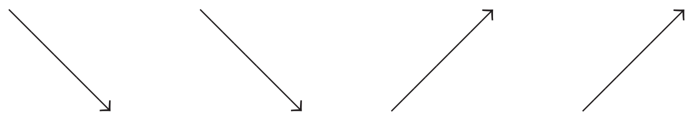
The inverse square law applies to both gravitational and point charge electric point charge fields. Only the electric point charge fields can attract or repel as there are two types of electric charge. Electrical repulsion exists between like charges and electrical attraction exists between unlike charges. However, gravitational fields only create attractive forces.

Question 2 D

$$V_{\text{peak-to-peak}} = V_{\text{RMS}} \times 2\sqrt{2}$$
$$= 6.0 \times 2\sqrt{2}$$
$$= 17 \text{ V}$$

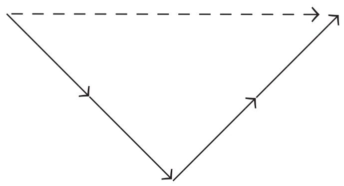
$$I_{\text{peak}} = I_{\text{RMS}} \times \sqrt{2}$$
$$= \frac{6.0 \times \sqrt{2}}{24}$$
$$= 0.35 \text{ A}$$

Question 3 B



field due to top left Q | field due to bottom right Q | field due to bottom left Q | field due to top right Q

The vector sum of these individual fields is shown by the dashed vector arrow below.



Question 4 A

$$F = \frac{kq_1q_2}{d^2}$$
$$= \frac{9.0 \times 10^9 \times (1.0 \times 10^{-6})^2}{(1.0 \times 10^{-2})^2}$$
$$= 9.0 \times 10^1 \text{ N}$$

Question 5 C

The magnetic flux is initially a maximum and then varies positive and negative in a smooth and continuous manner.

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Question 6 D

The split-ring commutator would reverse the voltage polarity every half-cycle, so the original sinusoidal voltage would become direct and either all positive or all negative depending on the rotation direction.

Question 7 D

The whirling 100 g mass experiences a centripetal force provided by the tension in the string.

$$\text{force}_{\text{centripetal}} = \text{tension} = \frac{0.1v^2}{r} = 0.1 \times \text{centripetal acceleration}$$

The stationary 200 g mass experiences the same tension.

tension = 0.2 g = 0.1a

$$\begin{aligned} a &= 2g \\ &= 2 \times 9.8 \\ &= 19.6 \text{ m s}^{-2} \end{aligned}$$

Question 8 C

The net force acting on Jane is given by normal reaction – weight = $m \times a$ (take up as positive). Her mass is 55 kg. If the scales show a mass of 53 kg, then the elevator must be accelerating downwards.

Scales display a mass reading equal to $\frac{\text{normal reaction}}{g}$. Thus, normal reaction = 53 × 9.8 = 519.4 N.

Question 9 B

Both rockets represent inertial frames of reference. As the rockets pass each other, both Maurice and Robin will measure the other's rocket to be shorter than L (length contraction).

Question 10 B

$$\begin{aligned} \text{work done by gravity} &= \text{weight} \times \text{displacement} \\ &= 1 \times 9.8 \times 10 \\ &= 98 \text{ J} \end{aligned}$$

The energy of the ball at ground level is the ball's kinetic energy.

$$\begin{aligned} \frac{1}{2} \times \text{mass} \times \text{speed}^2 &= \frac{1}{2} \times 1 \times 13^2 \\ &= 84.5 \text{ J} \end{aligned}$$

Thus, the work done = change in total energy + loss of energy as heat or sound.

loss of energy as heat or sound = 98 – 84.5 = 13.5 J

Question 11 **C**

$$\text{wave speed} = \frac{\text{distance travelled}}{\text{time taken}}$$
$$= \frac{3.0}{1.5}$$
$$= 2.0 \text{ m s}^{-1}$$

From the diagram, the 3.0 m distance spans three wavelengths, so the wavelength is 1.0 m.

$$\text{wave frequency} = \frac{\text{wave speed}}{\text{wave length}}$$
$$= \frac{2.0}{1.0}$$
$$= 2.0 \text{ Hz}$$

Question 12 **C**

The spread of the diffraction pattern is inversely proportional to the slit width. Increasing the slit width would cause the bright and dark bands to be closer together.

Question 13 **B**

The momenta of the electron and photon are given by $p = \frac{h}{\lambda}$ and so for the same wavelength, the electron and photon have the same momentum.

The total energy of an electron is given by $\lambda m_0 c^2$, where λ is the Lorentz factor. At speeds less than 0.1c, an electron's total energy is similar to its kinetic energy, $\frac{1}{2}mv^2$. The total energy of a photon is $E = hf = pc$. Thus, pc does not equate to the same value as $\frac{1}{2}mv^2$ nor $\lambda m_0 c^2$.

Question 14 **C**

$$\text{momentum of photon} = \frac{h}{\text{wavelength}}$$
$$= \frac{h \times \text{frequency}}{\text{speed of light}}$$
$$= \frac{6.63 \times 10^{-34} \times 6.00 \times 10^{14}}{3.00 \times 10^{8}}$$
$$= 1.33 \times 10^{-27}$$

Question 15 **D**

The waves from both speakers interfere destructively at Marie's ears. The path difference of the waves is 5.0 – 3.0 = 2.0 m. Destructive interference occurs when the path difference = $\frac{1}{2}\lambda,\ 1\frac{1}{2}\lambda,\ 2\frac{1}{2}\lambda\ldots$

As $\frac{1}{2}\lambda,\ 1\frac{1}{2}\lambda,\ 2\frac{1}{2}\lambda = 2.0$, the possible $\lambda = 4.0$ m, 1.3 m, 0.8 m…

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Question 16 C

Resonance occurs when two identical waves pass through each other in opposite directions. In order to transfer the maximum energy to the medium, the wave frequency must match the oscillation frequency of the medium.

Question 17 D

As the electrons are observed to strike the screen, they display particle behaviour. The electrons are particular about where they strike the screen; they strike at particular positions, forming bands, as if they were behaving as waves. Thus, they display both particle and wave behaviour.

Question 18 B

The error in a result is represented as the difference between the measured result and the true/expected result.

$$\begin{aligned} \text{error} &= 1.5 - 1.0 \\ &= 0.5 \text{ s} \end{aligned}$$

Question 19 A

The measurements are all close to the true/expected value as they lie at most at a difference of the uncertainty. They are thus accurate. As the measurements are all relatively close to each other, they are precise.

There is no official definition of a true or certain result.

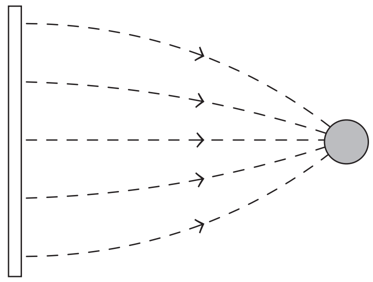
Question 20 C

If the type of ball has been changed in each trial, the air resistance experienced by each ball would have been different due to density, surface texture and diameter. Although the method may still have been reliable and uncertainty would be the same, there would have been more variables affecting the fall time than just the drop height.

SECTION B

Question 1 (4 marks)

a.



2 marks

1 mark for field lines at right angles to the plate curving inwards toward the point charge.
1 mark for the direction of field lines from the positive plate to the negative point charge.
Note: The field lines must not cross. Correct responses with 2–4 lines are awarded 1 mark only. Responses with 1 field line are awarded 0 marks.

b. The electric field between the plate and the point charge is variable. As the charge is attracted and moves towards the plate, the field strength increases. 1 mark

Since force = electric field strength × point charge, the acceleration of the point charge increases. 1 mark

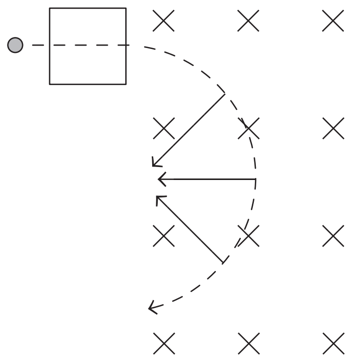
Question 2 (6 marks)

a. Using the right-hand palm rule:

- the charge moves to the right (thumb) – assumes positive charge
- the field is into the page
- the magnetic force at the initial entry point must be up (out of palm of hand).

Since the force is downwards, the charge must be **negative**. 1 mark

b.



2 marks

1 mark for vectors of equal length.
1 mark for vector arrows pointing towards the centre of the circle.

c. force = qvB

$= 1.6 \times 10^{-19} \times 8.00 \times 10^{6} \times 7.00$ 1 mark

$= 9.0 \times 10^{-12}$ N 2 marks

1 mark for correct substitution into the equation.
1 mark for correct answer.
1 mark for answer given to two significant figures.

Question 3 (5 marks)

a. Using the right-hand palm rule, the force on the side EF is upwards and the force on the side GH is downwards. 1 mark

These two forces provide the same torque or rotation effect that is clockwise from the front view shown in Figure 3. 1 mark

The two forces are equal ($F = nIlB$ is the same for both) and opposite, so they sum to zero. 1 mark

b. force $= N \times B \times \frac{V_{\text{battery}}}{R} \times l \times \sin(\theta)$

$= 50 \times 0.020 \times \frac{6.0}{24} \times 0.050 \times \sin(90)$ 1 mark

$= 0.0125$ N 1 mark

Question 4 (4 marks)

Method 1 (counting squares):

energy required = mass of rocket × area of gravitational field strength versus distance graph [from current position to final position]

area of gravitational field strength versus distance graph = number of grid squares × area of one square [from 7.30×10^6 m to 1.00×10^7 m]

$A_{graph} = 148 \times (1 \times 0.1 \times 10^6)$ 1 mark

$= 1.48 \times 10^7 \text{ N m kg}^{-1}$ 1 mark

1 mark for correct number of squares.
1 mark for area calculation.
Note: Whole squares include complete squares and those made up by the sum of partial squares.

energy required $= 1.48 \times 10^7 \times 10\,000$

$= 1.48 \times 10^{11}$ J 1 mark

The energy required is greater than the energy available, so the energy available is not enough to allow the rocket to move to the new position. 1 mark

Note: If the total energy calculation is not carried out, then the final mark (regarding lack of energy) is not awarded.

Method 2 (trapezium method):

$\left[\frac{7.5 + 4}{2}\right] \times 2.7 \times 10^6 = 1.55 \times 10^7$ 2 marks

1 mark for correct estimation of the sides.
1 mark for multiplying by the multipliers.

Note: This value is slightly higher than the value calculated using the counting squares method. This is expected because the trapezium has a slightly greater area than the actual graph.

energy required $= 1.55 \times 10^7 \times 10\,000$

$= 1.55 \times 10^{11}$ J 1 mark

The energy required is greater than the energy available, so the energy available is not enough to allow the rocket to move to the new position. 1 mark

Note: If the total energy calculation is not carried out then the final mark (regarding lack of energy) is not awarded.

Question 5 (3 marks)

Use the equation to determine the period, T.

$\frac{r^3}{T^2} = \frac{GM_{\text{Moon}}}{4\pi^2}$ where r = radius of the Moon + altitude.

$r = (1.74 \times 10^6) + (1.23 \times 10^5)$

$= 1.86 \times 10^6$ m 1 mark

The equation for the period is $T = 2\pi\sqrt{\frac{r^3}{GM_{\text{Moon}}}}$.

$T = 2\pi\sqrt{\frac{(1.86 \times 10^6)^3}{(6.67 \times 10^{-11}) \times (7.35 \times 10^{22})}}$ 1 mark

$= 7216$ s

$= 7.2 \times 10^3$ s 1 mark

Note: Award 1 mark only for an answer that does not add the altitude to the radius of the Moon but is otherwise correct.

Question 6 (8 marks)

a. effective resistance = 10 + total wire resistance

= 10 + (2 × 1.6)

= 13.2 Ω 1 mark

$V_{\text{battery}} = R_{\text{effective}} \times I_{\text{circuit}}$, $V_{\text{battery}} = 12$ V, $V_{\text{voltmeter}} = V_{10}$

$I_{\text{circuit}} = \frac{12}{13.2}$

$= 0.91$ A 1 mark

$V_{10} = R_{10} \times I_{\text{circuit}}$

$= 0.91 \times 10$ 1 mark

$= 9.1$ V

b. $P_{\text{loss}} = \text{current}^2 \times \text{wire resistance}$

$= 0.91^2 \times 3.2$ 1 mark

$= 2.6$ W 1 mark

OR

$P_{\text{loss}} = \frac{V_{\text{loss}}^2}{R_{\text{line}}}$

$= \frac{(12 - 9.1)^2}{3.2}$ 1 mark

$= \frac{8.41}{3.2}$

$= 2.6$ W 1 mark

c. As the power supply is AC, using transformers to step voltage up and down would be successful.

To reduce the power loss in the wiring and achieve a higher voltage to the resistor, a step-up transformer should be placed immediately after the power supply so that the long distance lines attach to the transformer output. 1 mark

This will step up the transmission voltage, which reduces the long distance line current and the power loss in the line. 1 mark

At the end of the long distance line, the equivalent step-down transformer should be inserted such that its output connects to the 10 Ω resistor and supplies it with a voltage closer to 12 V_{RMS}. 1 mark

Question 7 (12 marks)

a. maximum flux = area of coil perpendicular to field

$= B \times A$

$= 0.20 \times 0.10 \times 0.04$ 1 mark

$= 8.0 \times 10^{-4}$ Wb 1 mark

b. The coil commences at ZERO flux position and so needs $\frac{1}{4}$ of the period.

time $= \frac{1}{4} \times \frac{1}{2.5}$

$= 0.10$ s 1 mark

c. average voltage $= N \times \frac{\Delta\phi}{\Delta t}$

$= 25 \times \frac{8.0 \times 10^{-4}}{0.10}$ 1 mark

$= 0.2 \times 10$

$= 2.0$ V 1 mark

*Note: Consequential on answers to **Question 7a** and **Question 7b.***

d. The new output has a lower peak value and commences from 0 V. Since the period is the same, the rotation rate is maintained.

In order for the output to commence at ZERO value, the coil's starting position must be one of maximum flux. 1 mark

This is because the voltage at any instant is proportional to the rate of change of flux, which has maximum value when the flux is maximum. 1 mark

Any one of:

- As the voltage amplitude is proportional to the number of turns, 1 mark
  a reduction in the number of turns would reduce the peak value. 1 mark
- The transformer steps up the peak voltage output by the ratio
  $\frac{\text{number of secondary turns}}{\text{number of primary turns}}$ 1 mark
  thus reducing the number of turns on the transformer secondary coil would reduce the peak voltage. 1 mark

e. The DC motor uses a split-ring commutator connection between the DC battery and the coil. However, the transformer is not necessary.

The transformer requires a variable current in its primary in order to transfer energy to its secondary. 1 mark

The DC battery only provides a constant current to the primary, which will not result in a current in the secondary. Thus, the coil will experience zero current and zero magnetic force, so the coil will not rotate. 1 mark

Thus, the new assembly will not operate as a motor. 1 mark

Question 8 (5 marks)

a. Horizontally, the speed is constant.

$$\text{speed}_{\text{horizontal}} = \text{initial speed} \times \cos(25)$$

$$\text{flight time} = \frac{\text{distance}_{\text{horizontal}}}{\text{speed}_{\text{horizontal}}}$$

$$= \frac{87.0}{30\cos(25)}$$ 1 mark

$$= \frac{87.0}{27.189}$$ 1 mark

$$= 3.2 \text{ s}$$

b. Vertically (take upwards as positive):

u_v = initial speed = 30sin(25) = 12.68 m s^{-1} 1 mark

a_v = acceleration = –9.8 m s^{-2}

t_{air} = 3.2 s

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

$$s = (12.68 \times 3.2) + \left(\frac{1}{2} \times -9.8 \times 3.2^2\right)$$ 1 mark

$$= 40.57 + (-50.18)$$

$$= 9.6 \text{ m}$$ 1 mark

Question 9 (5 marks)

a. total momentum before collision = total momentum after collision

Take the direction to the right as positive.

$$P_{\text{car before}} + P_{\text{truck before}} = P_{\text{car after}} + P_{\text{truck after}}$$

$$(1000 \times 20) + (3000 \times -5) = (1000 \times -10) + (3000v)$$ 1 mark

$$20 + (-15) = -10 + 3v \quad \text{[divide both sides by 1000]}$$

$$3v = 15$$

$$v = 5 \text{ m s}^{-1}$$ 1 mark

b. Elastic/inelastic collisions are determined by comparing the total kinetic energy of the vehicles before and after the collision.

total kinetic energy before the collision $= \left(\frac{1}{2} \times 1000 \times 20^2\right) + \left(\frac{1}{2} \times 3000 \times 5^2\right)$

$= 200\ 000 + 37\ 500$

$= 237\ 500$ J — 1 mark

total kinetic energy after the collision $= \left(\frac{1}{2} \times 1000 \times 10^2\right) + \left(\frac{1}{2} \times 3000 \times 5^2\right)$

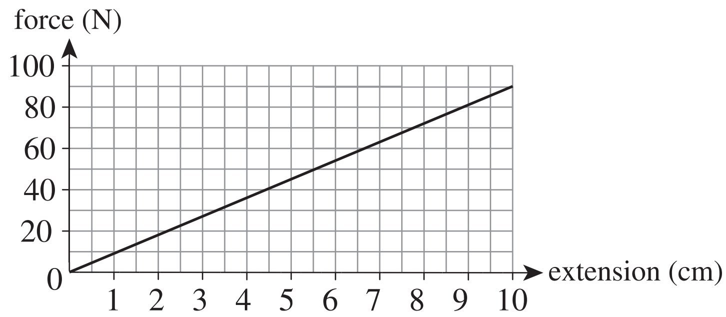
$= 50\ 000 + 37\ 500$

$= 87\ 500$ J — 1 mark

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

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

Question 10 (5 marks)



3 marks

1 mark for linear sketch showing correct gradient of 900 N m^{-1}.
1 mark for vertical scale.
1 mark for horizontal scale.

The graph will have a constant gradient and pass through the origin.

The gradient is the stiffness constant and is calculated by total mechanical energy conservation.

total mechanical energy before release of the pellet = total mechanical energy after release of the pellet

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

$$\frac{1}{2}k(0.10)^2 = 0.0255 \times 9.8 \times 18.1$$ — 1 mark

$$0.005k = 4.5232$$

$$k = \frac{4.5232}{0.005}$$

$$= 904.64$$

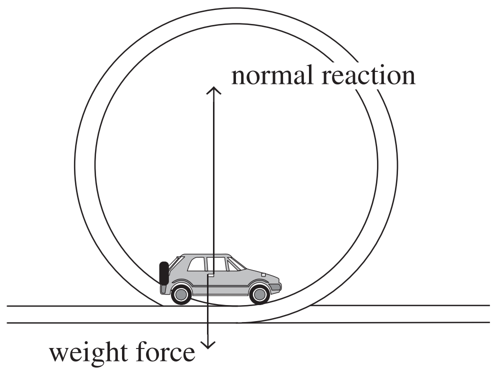
$= \text{approximately } 900 \text{ N m}^{-1}$ — 1 mark

OR

gradient $= \frac{90}{10} = 9 \text{ N cm}^{-1}$ — 1 mark

Question 11 (5 marks)

a.



2 marks

1 mark for labelled force vectors.

1 mark for relative length of force vectors.

Note: Both forces must be drawn to receive marks. Normal reaction force is greater than the weight force since the net force is centripetal (upwards towards centre of circle).

b. sum of forces = net force [take upwards as positive]

$$\text{normal reaction} - \text{weight} = m\frac{v^2}{r}$$

$$\text{normal reaction} = \text{weight} + m\frac{v^2}{r}$$ 1 mark

$$= \left(800 \times 9.8 + \left(800 \times \frac{12^2}{5}\right)\right)$$ 1 mark

$$= 7840 + 23\ 040$$

$$= 30\ 880\ \text{N}$$ 1 mark

Question 12 (6 marks)

a. Lorentz factor, $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

$$= \frac{1}{\sqrt{1 - 0.51^2}}$$ 1 mark

$$= 1.16$$ 1 mark

b. Gianna measures a contracted length as spacecraft B moves past her. Her spacecraft (spacecraft A) has the value of the proper length.

$$\text{contracted length} = \text{proper length} \times \sqrt{1 - \frac{v^2}{c^2}}$$

$$103.22 = \text{proper length} \times \sqrt{1 - 0.51^2}$$ 1 mark

$$103.22 = \text{proper length} \times 0.86$$

$$\text{proper length} = \frac{103.22}{0.86}$$

$$= 120 \text{ m}$$ 1 mark

c. Both spacecraft are equivalently inertial frames of reference. 1 mark

Thus, scientists in both spacecraft will observe the other spacecraft travel past them in an equally dilated time. 1 mark

Question 13 (4 marks)

a. wave speed = frequency × wavelength

rope length = 1.25 × wavelength from Figure 13

$$\text{wavelength} = 0.8 \times 1.20$$

$$= 0.96 \text{ m}$$

$$\text{wave speed} = 1.5 \times 0.96$$ 1 mark

$$= 1.44 \text{ m s}^{-1}$$ 1 mark

b. The patterns in Figures 13 and 14 represent standing wave frequencies that suit the length of the rope.

These frequencies are given by $f_n = \frac{n \times \text{wave speed}}{4 \times \text{rope length}}$, where the wave speed and the length of the rope remain constant and $n = 1, 3, 5 \ldots$ 1 mark

Thus, $n = 1$ for Figure 14 and $n = 5$ for Figure 13.

Thus, $f_5 = 5f_1$. 1 mark

Question 14 (6 marks)

a. The path difference for each of the minima is $\left(\text{whole number} + \frac{1}{2}\right) \times$ wavelength.

That is, $\frac{1}{2}\lambda, 1\frac{1}{2}\lambda, 2\frac{1}{2}\lambda \ldots$

Hence, each successive minimum increases its path difference by 1λ. 1 mark

Thus, path difference to $M_A = 5.02 - 3.62 = 1.40$ m.

Thus, path difference to $M_B = 4.43 - 3.43 = 1.00$ m.

Thus, path difference to $M_C = 3.95 - 3.35 = 0.60$ m.

1 mark

Note: Mark is awarded for M_A, M_B and M_C calculations.

As the increase in the path difference value is 0.40 m each time, then $\lambda = 0.40$ m 1 mark

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b. As long as the distance between the slit-plane and screen is small, the separation of the minima are determined by $\frac{\text{wavelength} \times \text{distance between slit-plane and screen}}{\text{slit separation}}$. 1 mark

Thus, the separation of the minima depends on the wavelength as it is the only variable.

Hence, separation $\propto$ wavelength, or $\frac{1}{\text{frequency}}$.

Thus, a higher frequency will cause the minima separation to decrease. 1 mark

Chen is correct and Melinda is incorrect. 1 mark

Note: To be awarded the final mark, responses must correctly assess both Chen and Melinda's statements.

Question 15 (13 marks)

a. Green light has a photon energy that is able to release electrons from the metal cathode. 1 mark

Thus the release of electrons from the shining of the green light is registered by the ammeter as a flow of current. 1 mark

Increasing the battery voltage to 2.03 V creates an electric field across the photocell that slows down ejected photoelectrons such that they do not reach the collector cathode to register as current in the circuit. 1 mark

b. $qV = hf - W$

$W = hf - qV$

$= (4.14 \times 5.5 \times 10^{14}) - 2.03$ 1 mark

$= 0.25$ eV 1 mark

c. **i.** Photoelectrons will still be ejected because photons of violet light are more energetic than photons of green light, so there is a non-zero ammeter reading. 1 mark

Since there are double the violet photons than the green photons, there are approximately twice as many photoelectrons. Thus, the ammeter reading is approximately double that of the first experiment. 1 mark

ii. The emitted electrons will now have a greater maximum kinetic energy since $hf - W$ is now greater for the violet light than for the green light due to the greater photon energy for the same work function. 1 mark

Thus, a greater stopping voltage than 2.03 V would be required to reduce the current to zero. 1 mark

Hence, at $V = 2.03$ V, some electrons will still traverse the electric field in the vacuum tube, and thus the ammeter reading will be a non-zero but lesser reading. 1 mark

d. In the wave model, the doubling of intensity of light involves a doubling of energy provided to the electrons. 1 mark

The wave model predicts that doubling the intensity would cause an increase in the number of photoelectrons ejected and that they would eject with greater kinetic energy. Overall, the wave model fails to account for the observations. 1 mark

While the number of electrons did double, their maximum kinetic energy remained the same. This is contrary to the results of the experiment. 1 mark

Question 16 (5 marks)

a. $\lambda = \dfrac{h}{\sqrt{2mqV}}$

$= \dfrac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 2.0}}$ 2 marks

$= 8.68 \times 10^{-10}$ m

b. Given that the de Broglie wavelength is greater than both separations of the carbon atoms in the powdered graphite, $\dfrac{\lambda}{d} > 1$, 1 mark

diffraction through the gaps between the atoms will occur (diffraction is observable). 1 mark

The electrons will therefore display wave behaviour. 1 mark

Question 17 (6 marks)

a. In the $n = 3$ state the total energy of the state is 12.1 eV. In order to lose 2.0 eV, there must be a total energy state at 10.1 eV. 1 mark

As there is no such state, it is not possible for the electron to lose 2.0 eV. 1 mark

b. Although there is no state that exists at 14.1 eV, a 2.0 eV photon is still able to be absorbed. 1 mark

The electron would not rise to a higher state but would be emitted as a photoelectron. 1 mark

c. The electrons that exist in the energy states are particles that have a mass and velocity. Their energy is manifested as standing waves that are stable and fit the circumference of the orbits of the state. 1 mark

The electrons have a de Broglie wavelength that enable these standing waves to exist. 1 mark

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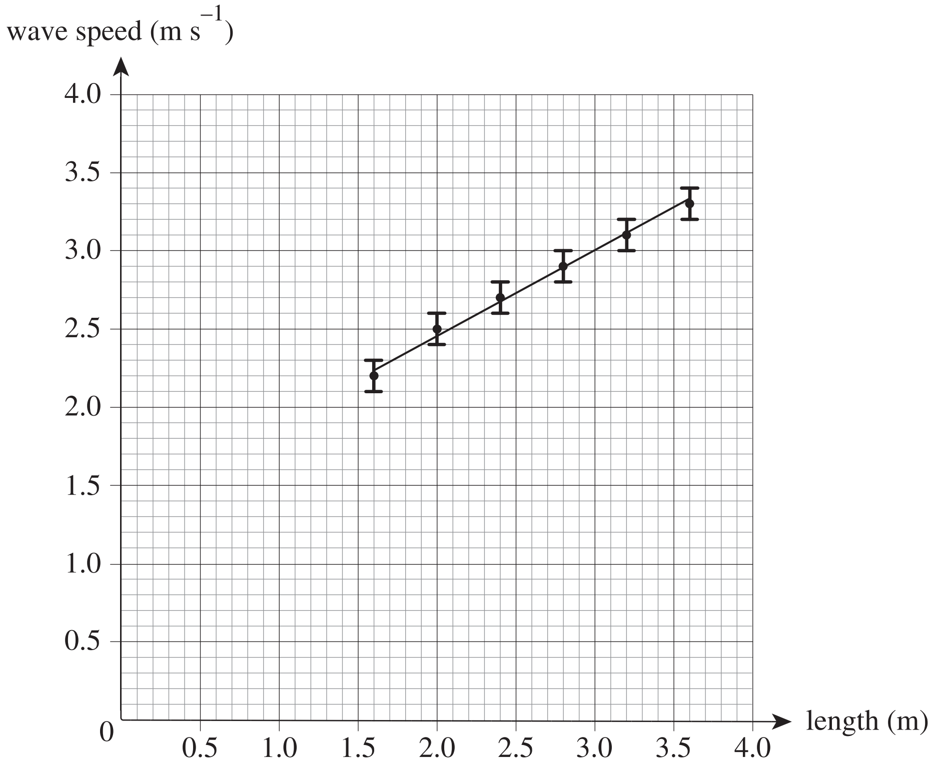
Question 18 (8 marks)

a.



5 marks

1 mark for correctly plotted points.
1 mark for vertical scale.
1 mark for horizontal scale.
1 mark for uncertainty bars.
1 mark for line of best fit.

b. The students' hypothesis is rejected since the wave speed is not a constant over the lengths of the spring. 1 mark

The relationship shows that wave speed increases with increasing spring length. 1 mark

The increase is linear to within the uncertainties. 1 mark

Note: To be awarded the final mark, responses must refer to the increase being within the uncertainties.

