Neap:

Trial Examination 2019

VCE Physics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1 **B**

12.0 V RMS is equivalent to a peak voltage of $12 \times \sqrt{2} = 17.0$ V and a peak-to-peak voltage of $17.0 \times 2 = 34.0$ V.

Potential varies linearly with distance and the plates have a potential difference of 18 V.

Question 2 **D**

$$\begin{aligned}\text{electric force} &= \frac{kq_1q_2}{d^2}\\ &= \frac{8.99 \times 10^9 \times 10 \times 10^{-6} \times 100 \times 10^{-6}}{0.01^2}\\ &= 9.0 \times 10^4 \text{ N}\end{aligned}$$

Question 3 **B**

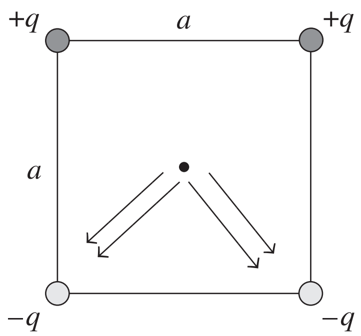
The electric field strength equation is $E = \frac{kq}{d^2}$ for each charge, where d = the distance from each charge to the centre.

$$d^2 = \left(\frac{a}{2}\right)^2 + \left(\frac{a}{2}\right)^2 = \frac{a^2}{2}$$

Substituting for d^2 gives $E = \frac{2kq}{a^2}$.

Question 4 **C**

The individual electric fields due to each of the four charges are shown below. The resulting force will be in the direction of the resulting electric field. By summation of the electric field vectors, this is downwards.



Question 5 **B**

The net acceleration is centripetal and of value $g.\tan(\theta)$. Thus $a = 9.8 \times \tan(20°) = 3.6 \text{ m s}^{-2}$.

Question 6 **C**

Using the law of conservation of momentum (to the right is positive):

total momentum prior to coupling = total momentum couple

$$[50 \times 4.0] + [30 \times 2.0] = [50 + 30] \times v$$

$$v = \frac{260}{80}$$

$$= 3.25 \text{ m s}^{-1}$$

$$= 3.3 \text{ m s}^{-1}$$

Question 7 **A**

The elastic or inelastic nature is determined by comparing the total kinetic energy of the system before and after the collision. The total kinetic energy after the collision is calculated using the value calculated in **Question 6**.

$$\text{total kinetic energy before the collision} = \left[\frac{1}{2} \times 50 \times 4.0^2\right] + \left[\frac{1}{2} \times 30 \times 2.0^2\right]$$

$$= 400 + 60$$

$$= 460 \text{ J}$$

$$\text{total kinetic energy after the collision} = \frac{1}{2} \times (50 + 30) \times 3.25^2$$

$$= 422.5 \text{ J}$$

The collision is inelastic because the total kinetic energy has reduced. This is due to the coupling and is independent of the conservation of momentum.

Question 8 **C**

The impulse acting on the car is mathematically equal to the change in momentum of the car.

$$\text{change in momentum} = |1000(0 - 10)|$$

$$= 10\,000 \text{ kg m s}^{-1}$$

Question 9 **D**

The feeling of weightlessness when in orbit is due to there being no contact with any surfaces or objects. This is equivalent to free-falling or accelerating towards Earth.

Question 10 **A**

The notes played by the string are a result of standing waves being produced. The frequencies of the notes are all whole-number multiples of the first harmonic; that is, where whole numbers have the sequence 1, 2, 3, 4 and so on.

Question 11 D

Light intensity and light colour are chosen by the experimenter and so cannot be dependent variables. Photoelectron speed cannot be an independent variable as it is affected by light colour. The only possible option remaining is **D**. Altering the light intensity (independent variable) only alters the number of photoelectrons (dependent variable).

Question 12 C

The expression of the result and its uncertainty (12.2 ± 0.1) is a measure of the best readable result and the confidence limits (12.2 cm and 12.4 cm) that the true result lies between.

Question 13 B

The hypothesis is refuted because the refractive indices are precise and above the hypothesised maximum value of 1.33.

Question 14 A

Increasing diffraction occurs with increasing wavelength. From left to right, gamma has the least, followed by X-ray, infrared and microwave.

Question 15 D

A standing wave is set up in the rope and *d* represents half a wavelength. The standing wave shows 3.5 envelopes or 1.75 wavelengths. Thus:

$$1.75\lambda = 1.80 \text{ m}$$

$$\lambda = 1.029 \text{ m}$$

$$\frac{1}{2}\lambda = d$$

$$d = 0.51 \text{ m}$$

Question 16 D

As the car moves away from Frida, the speed of sound remains the same but the wavelength of the sound reaching her is longer. This is the Doppler effect.

Question 17 C

Experiment 2 has a lower current plateau, indicating a light of lesser intensity.

It also indicates a stopping potential intercept of greater value. This suggests greater electron energy and thus a greater frequency (lower wavelength) of light was used.

Question 18 B

The spread of the rings are affected by the wavelengths of the X-rays and the electrons. The patterns have the same spread, indicating that the X-rays and the electrons have the same wavelength. The wavelength is linked because both have the same momentum.

Question 19 B

The energies of the electrons are manifested as standing wave states with their de Broglie wavelengths.

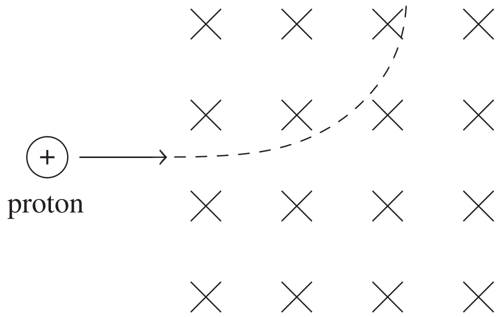
Question 20 D

As the width of the slit is increased, the uncertainty in the position of the photon in the *y*-direction is increased. According to Heisenberg's uncertainty principle, the uncertainty in the momentum of the photon in the *y*-direction is decreased.

SECTION B

Question 1 (8 marks)

a. Using the right-hand palm rule, the proton travels to the right (thumb) and the magnetic field is into the page (fingers). The force acting on the proton comes out of the palm of the hand and upwards. This causes the proton to turn in the direction of the force. As the hand turns, so too does the direction of the force so that it is at a right angle to the palm of the hand. Thus the force is centripetal and the path of the proton is circular.



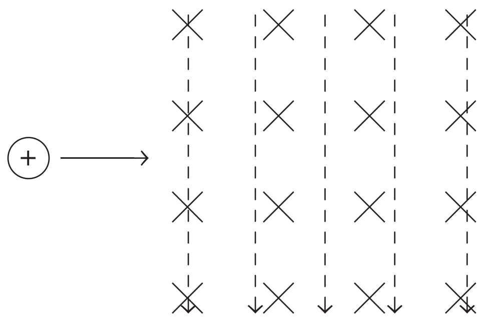
1 mark

b. $F = Bvq$

$= 0.10 \times 1.0 \times 10^{6} \times 1.6 \times 10^{-19}$ 1 mark

$= 1.6 \times 10^{-14}$ N 1 mark

c. The force due to the magnetic field is upwards, as determined in **Question 1a**. For the proton to pass through without any change to its velocity, the electric force must be of equal value as the magnetic force and downwards. Thus the electric field must be downwards.



1 mark

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

d. As the proton passes through unimpeded, the electric force must have the same value as the magnetic force.

$F = 1.6 \times 10^{-14}$ N 2 marks

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

e. $E = \dfrac{F}{q}$

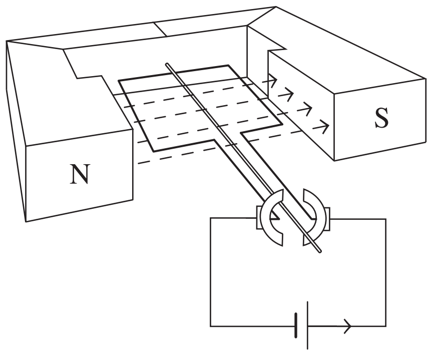
$= \dfrac{1.6 \times 10^{-14}}{1.6 \times 10^{-19}}$ 1 mark

$= 1.0 \times 10^{5}$ N C^{-1} 1 mark

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

Question 2 (8 marks)

a.



2 marks

Note: 1 mark for completing the circuit with correct current direction.
1 mark for battery with positive and negative as shown.

b. $F = NBIL$

$= 5 \times 0.20 \times 0.60 \times 0.030$ — 1 mark

$= 0.018$ N — 1 mark

c. The forces on the sides nearest the magnetic poles are equal and opposite in direction. — 1 mark

Because of this, the net force acting on the coil is zero. — 1 mark

The rotation of the coil occurs because the forces do not act along the same line of transmission, so there is a resulting torque or rotation effect. Thus Minh is correct. — 1 mark

Jose is incorrect for the reasons stated above. — 1 mark

Question 3 (6 marks)

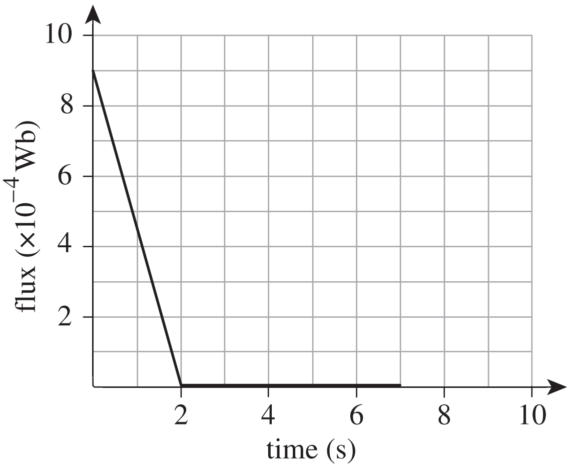
a. $\Phi = B \times A$

$= 0.30 \times (0.050 \times 0.060)$ — 1 mark

$= 9.0 \times 10^{-4}$ Wb — 1 mark

b. At 3.0 cm s^{-1}, it takes the coil 2 s to travel through region A from maximum flux to zero flux.

At 3.0 cm s^{-1}, it takes the coil 5 s to travel through region B maintaining zero flux.



2 marks

1 mark for correct 0–2 s profile.

1 mark for correct 2–7 s profile.

c. induced voltage $= Nx\left|\dfrac{\Delta\Phi}{\Delta t}\right|$

= number of turns × magnitude of the gradient of the flux–time graph

$= 10 \times \dfrac{|9\times10^{-4}|}{2}$ 1 mark

$= 4.5\times10^{-3}$ V 1 mark

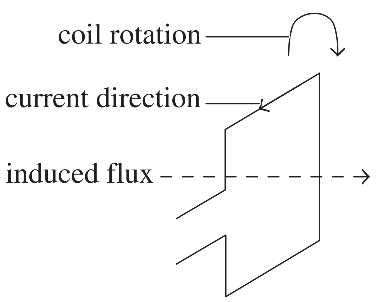
Question 4 (3 marks)

The coil turns clockwise from zero flux to maximum flux. There is an increase in external flux to the left, following the external magnetic field lines' flow. 1 mark

According to Lenz's law, the coil opposes the increase in external flux by providing its own change in flux in the opposite direction (to the right). 1 mark

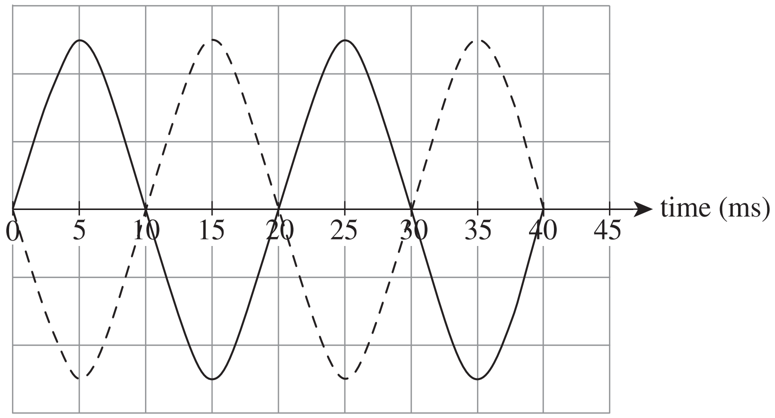
Using the right-hand grip rule (the fingers represent the field and flux to the right, the thumb represents the direction of the current in the coil), the current on the top side of the coil is as shown below.

By following the connection to the slip rings from this position, the current travels X → Y through the ammeter. 1 mark



Question 5 (5 marks)

a.



3 marks

1 mark for either positive (solid line) or negative (dashed line) sinusoidal profile.

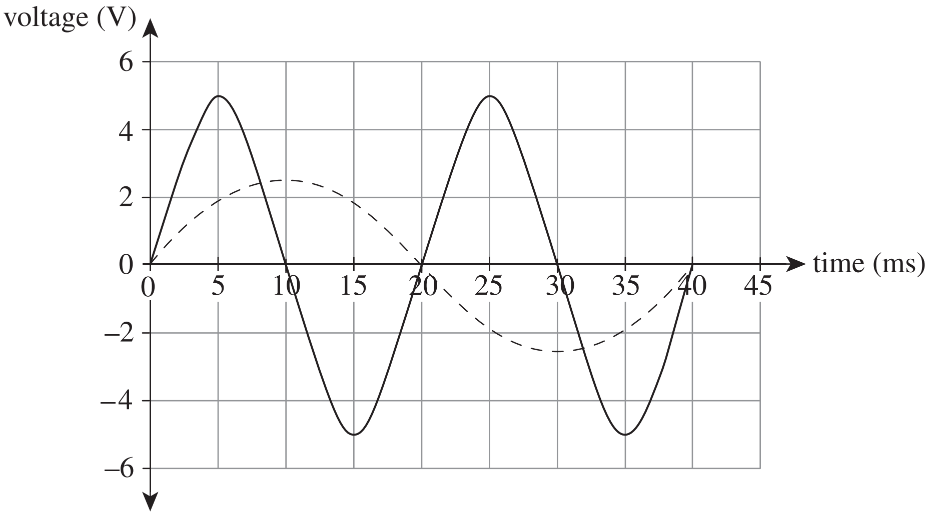
1 mark for the period of one cycle = 20 ms.

1 mark for the magnetic flux at 0 for t = 0.

Note: With a frequency of 50 Hz, the period of one cycle is $\frac{1}{50}$ *= 0.02 s = 20 ms.*

The magnetic flux is proportional to the size of the current at any instant.

b.



2 marks

1 mark for a profile with a doubled period.

1 mark for a profile with a halved maximum voltage (amplitude).

Question 6 (11 marks)

a. $V_{\text{battery}} - V_{\text{resistor}} = V_{\text{line}}$

$12.0 - 7.5 = 4.5\ \text{V}$ 1 mark

$I_{\text{line}} = 1.5\ \text{A}$

$R = \dfrac{12.0 - 7.5}{1.5}$

$= 3.0\ \Omega$ 1 mark

One of the wires must therefore represent half the total resistance.

$\dfrac{3.0}{2} = 1.5\Omega$ 1 mark

b. transformer equation:

$\dfrac{V_2}{V_1} = \dfrac{N_2}{N_1}$

$V_{\text{XY}} = 12 \times \dfrac{10}{1}$ 1 mark

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

c. $P_{\text{loss}} = I^2 \times R_{\text{line}}$

$\dfrac{I_{\text{XY}}}{I_1} = \dfrac{N_1}{N_2}$

$I_{\text{XY}} = 1.5 \times \dfrac{1}{10}$ 1 mark

$= 0.15\ \text{A}$ 1 mark

$P_{\text{loss}} = (0.15)^2 \times 3.0$

$= 0.068\ \text{W}$ 1 mark

d. The voltmeter reading is determined as follows:

$V_{\text{end of line}} = V_{\text{XY}} - V_{\text{loss}}$

$= 120 - [I_{\text{XY}} \times R_{\text{line}}]$

$= 120 - [0.15 \times 3.0]$ 1 mark

$= 119.55\ \text{V}$ 1 mark

Note: Consequential on answer to ***Question 6b.***

$V_{\text{resistor}} = \dfrac{N_2}{N_1} \times V_{\text{WZ}}$

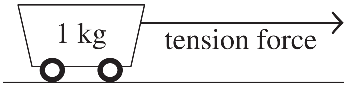
$= \dfrac{1}{10} \times 119.55$

$= 11.96\ \text{V}$

The voltmeter reading is 11.96 V, which is greater than 7.5 V. 1 mark

Question 7 (5 marks)

a. Horizontally, the only force acting on the 1 kg cart is the tension to the right as shown below.

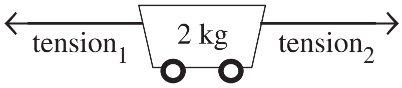


tension force of the string = $\text{mass}_{1\text{ kg}} \times$ acceleration — 1 mark

$= 1 \times 4.9$

$= 4.9$ N — 1 mark

b.



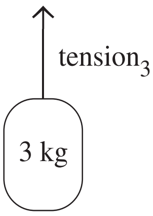
$\text{tension}_2 - \text{tension}_1 = \text{mass}_2 \times \text{acceleration}$ — 1 mark

$\text{tension}_2 - 4.9 = 2 \times 4.9$ — 1 mark

$\text{tension}_2 = 14.7$ N — 1 mark

OR

$\text{tension}_2 = \text{tension}_3$



$\text{weight} - \text{tension}_3 = \text{mass}_3 \times \text{acceleration}$ — 1 mark

$(3 \times 9.8) - \text{tension}_3 = 3 \times 4.9$ — 1 mark

$\text{tension}_3 = (3 \times 9.8) - (3 \times 4.9)$

$= 14.7$ N — 1 mark

Question 8 (4 marks)

a. horizontal speed × time in air = horizontal distance travelled

$$\text{time in air} = \frac{\text{horizontal distance travelled}}{\text{horizontal speed}}$$

$$= \frac{2.8}{7.0 \times \cos(60)}$$ — 1 mark

$$= \frac{2.8}{7.0 \times 0.5}$$

$= 0.80$ s — 1 mark

b. $a = -9.8 \text{ m s}^{-2}$

$u = 7.0 \times \sin(60) = 6.06 \text{ m s}^{-1}$

$t = 0.80 \text{ s}$

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

Let $s = h$.

Vertically, given the above:

$h = (6.06 \times 0.80) + \frac{1}{2}(-9.8)(0.80)^2$ 1 mark

$= 4.85 - 3.14$

$= 1.71 \text{ m}$ 1 mark

Question 9 (5 marks)

a. At the top of the loop-the-loop, the two forces acting downwards are the normal reaction and the weight of the car. Because the toy car undertakes circular motion, the following equation is used.

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

At the minimum speed, the normal reaction becomes zero. Thus:

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

$v_{min} = \sqrt{rg}$

$= \sqrt{0.15 \times 9.8}$ 1 mark

$= 1.21 \text{ m s}^{-1}$ 1 mark

b. Using the law of conservation energy:
total mechanical energy at the release height = total mechanical energy at the top of the loop.

$mgh_{release} = mgh_{top\ of\ loop} + \frac{1}{2}mv^2$ (the mass of the car can be divided out)

$9.8 \times h_{release} = (9.8 \times 0.30) + \left(\frac{1}{2} \times 1.21^2\right)$ 1 mark

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

$h_{release} = \frac{2.94 + 0.73}{9.8}$ 1 mark

$= 0.37 \text{ m}$ 1 mark

Note: Accept either 0.37 m or 0.38 m based on rounded or unrounded data used in the calculation.

Question 10 (5 marks)

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

$$\frac{1}{2} \times k \times (0.49)^2 = 1 \times 9.8 \times 0.49$$ 1 mark

$$k = \frac{2 \times 9.8}{0.49}$$

$$= 40 \text{ N m}^{-1}$$ 1 mark

b. The net force acting on the mass is given by the difference of the weight and the upward tension in the spring.

$$\text{net force} = mg - k(\Delta x)$$

$$\text{net acceleration} = \frac{mg - k(\Delta x)}{m}$$

$$= g - \frac{k(\Delta x)}{m}$$ 1 mark

The greatest acceleration occurs when the mass has been released but the spring has not yet fully extended. 1 mark

The value of the greatest acceleration of the mass is 9.8 m s^{-2}. 1 mark

Question 11 (5 marks)

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

$$= \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(2.66 \times 10^7)^2}$$ 1 mark

$$= 0.564 \text{ N kg}^{-1}$$ 1 mark

b. $$\frac{r^3}{T^2} = \frac{GM_{\text{Earth}}}{4\pi}$$

$$T = 2\pi\sqrt{\frac{r^3}{GM_{\text{Earth}}}}$$

$$= 2\pi\sqrt{\left(\frac{(2.66 \times 10^7)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}\right)}$$ 1 mark

$$= 43\ 161 \text{ s}$$ 1 mark

$$= \frac{43\ 161}{3\ 600}$$

$$= 11.98$$

$$= 12.0 \text{ h}$$

1 mark

Note: Deduct 1 mark if answer is not given to three significant figures.

Question 12 (4 marks)

a. mass of muon relative to observer $= \dfrac{\text{rest mass of muon}}{\sqrt{\left(1 - \dfrac{v^2}{c^2}\right)}}$

$= \dfrac{207 \times \text{rest mass}_{\text{electron}}}{\sqrt{(1 - 0.99^2)}}$ 1 mark

$= 207 \times 7.09 \times \text{rest mass}_{\text{electron}}$

$= 1467 \times \text{rest mass}_{\text{electron}}$ 1 mark

b. chamber length relative to the muons $= \text{rest length} \times \sqrt{\left(1 - \dfrac{v^2}{c^2}\right)}$

$= 1000 \times \sqrt{(1 - 0.99^2)}$ 1 mark

$= 1000 \times 0.1411$

$= 141.1\ \text{m}$ 1 mark

Question 13 (6 marks)

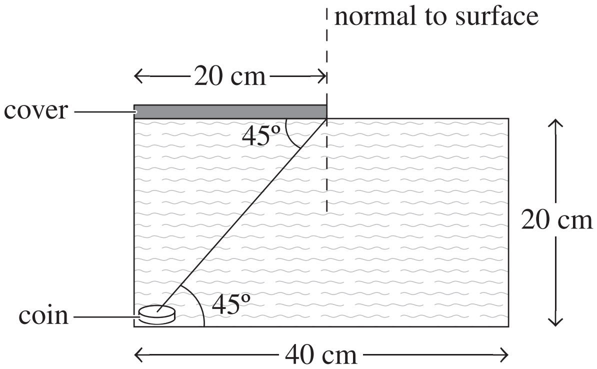
a. $n_{air} \times speed_{air} = n_{oil} \times speed_{oil}$

$1.00 \times 3.0 \times 10^8 = 1.47 \times speed_{oil}$ 1 mark

$= \dfrac{1.00 \times 3.0 \times 10^8}{1.47}$

$= 2.04 \times 10^8 \text{ m s}^{-1}$ 1 mark

b. In order for the student to see the coin, a ray from the coin to the oil's surface must refract into the air and in the direction of the student, as shown below.



As the ray passes from the vegetable oil into air, the ray will bend away from the normal. If the angle of incidence is too large, the light will totally internally reflect into the oil and the coin will not be visible to the student.

The critical angle (largest allowable incident angle for light travelling from the oil to the air) is given by the equation below.

$i_c = \sin^{-1}\left(\dfrac{n_{air}}{n_{oil}}\right)$

$= \sin^{-1}\left(\dfrac{1.00}{1.47}\right)$ 1 mark

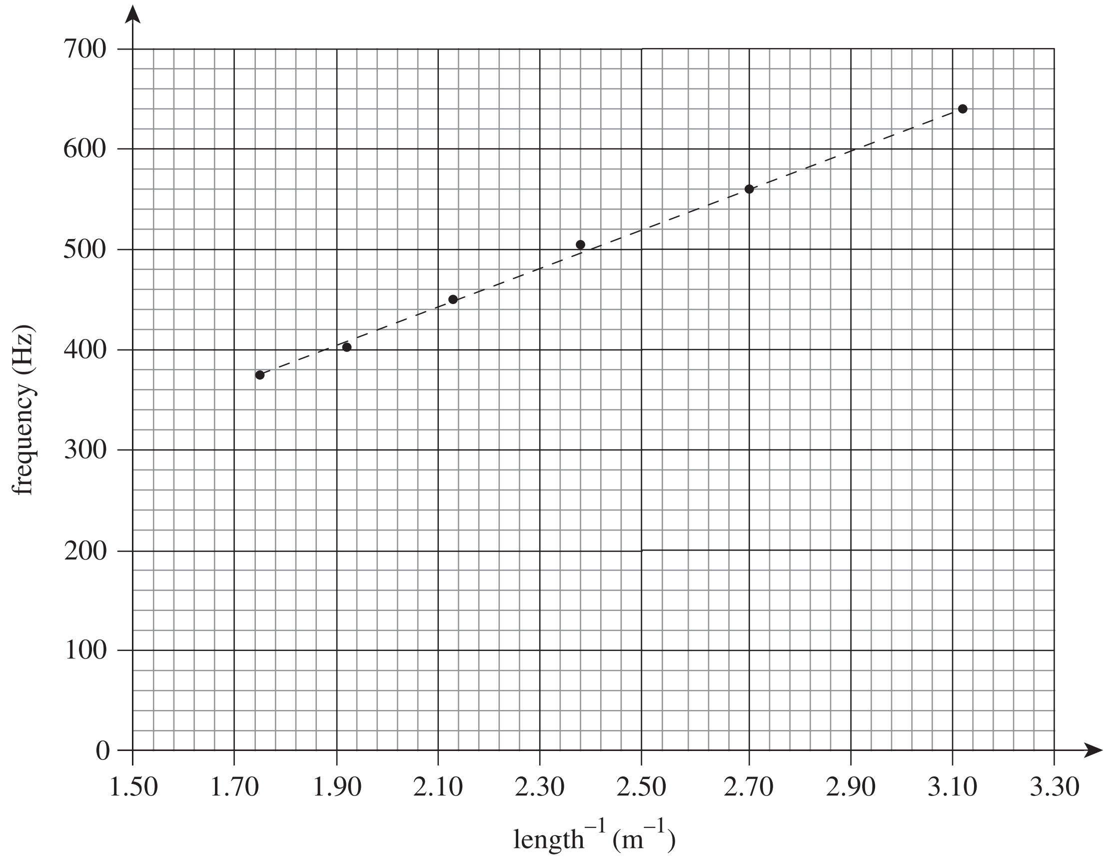
$= 42.9°$ 1 mark

The smallest incident angle that the ray from the coin to the oil surface can make is 45°. 1 mark

Because of this, all angles of incidence (above 45°) will cause the rays of light to totally internally reflect back into the tank, so the coin will not be visible to the student. 1 mark

Question 14 (7 marks)

a.



4 marks

1 mark for correct vertical scale.
1 mark for correct horizontal scale.
1 mark for correct line of best fit.
1 mark for correctly plotted data points.

b. The wave in the guitar string is manifested as a standing wave where the frequency is given by the following:

frequency = $\frac{nv}{2L}$, where $n = 1$, v = wave speed (m s^{-1}) and L = string length (m)

The value of the constant gradient represents $\frac{v}{2}$ and a calculation must be shown.

$\frac{v}{2}$ = gradient, or $v = 2 \times$ gradient (students should use coordinates that lie on the line of best fit).

$v = 2 \times \left(\frac{655 - 370}{3.13 - 1.75}\right)$ 1 mark

$= 2 \times 206.52$ 1 mark

$= 413$ m s^{-1} 1 mark

Note: Award only 1 mark for a response that uses the equation to produce a correct estimate of the speed without reference to the graph.
Allow a range of results from approximately [400–425] m s^{-1}.

Question 15 (10 marks)

a. The work function is $W = hf_{\text{critical}}$, and f_{critical} = the horizontal intercept from the graph (4.4×10^{14} Hz).

$$W = \frac{6.6 \times 10^{34} \times 4.4 \times 10^{14}}{1.6 \times 10^{19}}$$ 1 mark

$= 1.82$ eV 1 mark

OR

$W = 4.14 \times 10^{-15} \times 4.4 \times 10^{14}$ 1 mark

$= 1.82$ eV 1 mark

b. In order for electrons to absorb a photon of a particular frequency, the photon energy and therefore frequency must be above a minimum value. In this case, the frequency must be above the critical value of 4.4×10^{14} Hz. 1 mark

Light of frequency 3.0×10^{14} Hz will not be absorbed, so no electrons will be emitted. 1 mark

c. The largest wavelength corresponds to the smallest allowable frequency that causes electron emission.

smallest frequency = 4.4×10^{14} Hz

$$\text{largest wavelength} = \frac{\text{speed of light}}{\text{smallest frequency}} \times 10^{9}$$

$$= \frac{3.0 \times 10^{8}}{4.4 \times 10^{14}} \times 10^{9}$$ 1 mark

$= 682$ nm 1 mark

d. The increase in intensity will enable more photons of the same energy to strike the metal. More electrons will be emitted as a result, but their maximum energy will not increase compared to dimmer light. 1 mark

For this reason, Sal's statement is incorrect. 1 mark

A higher work function refers to light requiring a greater energy and therefore frequency to be used to release electrons from the metal. The frequencies between 1×10^{14} and 4×10^{14} Hz, which currently are below the minimum frequency required, will have energies that remain too low for the higher work function. 1 mark

For this reason, Jenna's statement is incorrect. 1 mark

Question 16 (7 marks)

a. $\lambda = \dfrac{h}{mv}$ and $E_k = \dfrac{1}{2}mv^2$

$$mv = \sqrt{2mE_k}$$

$$\therefore \lambda = \frac{h}{\sqrt{2mE_k}}$$

$$\lambda_{\text{de Broglie}} = \frac{h}{\sqrt{2mqV}}$$

$$= \frac{6.63 \times 10^{-34} \times 10^{9}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 10\ 000}}$$ 1 mark

$$= 0.0123 \text{ nm}$$ 1 mark

b. $p = \dfrac{h}{\lambda_{\text{de Broglie}}}$

$$= \frac{6.63 \times 10^{-34}}{1.23 \times 10^{-11}}$$ 1 mark

$$= 5.40 \times 10^{-23} \text{ kg m s}^{-1}$$ 1 mark

Note: Consequential on answer to ***Question 16a.***

c. Electrons display wave behaviour if the $\dfrac{\lambda_{\text{de Broglie}}}{\text{gap width}}$ ratio is greater than 0.1 and display particle behaviour if the ratio is less than 0.1. 1 mark

$$\frac{1.23 \times 10^{-11}}{0.295 \times 10^{-9}} = 0.042$$ 1 mark

As 0.042 is less than 0.1, the electrons display particle behaviour and pass right through the leaf of gold metal. 1 mark

Question 17 (4 marks)

The colours that are absorbed represent the photon energies that will cause electrons in their orbits to transition to a higher orbit. 1 mark

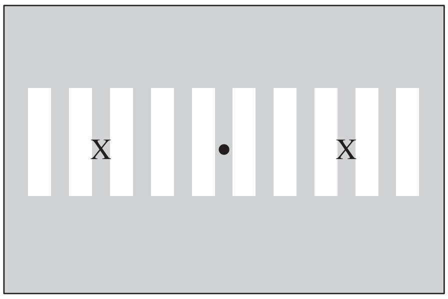
Electrons will only absorb photons of light that represent this exact energy difference. 1 mark

Electrons exist in specific orbits around the nucleus that correspond to their energies being manifested as standing waves. 1 mark

These standing waves can only fit in specific orbits that have a circumference representing a whole number of de Broglie wavelengths possessed by the electrons. This implies that only specific photon energies will be absorbed to cause electron transition to higher orbits. 1 mark

Question 18 (4 marks)

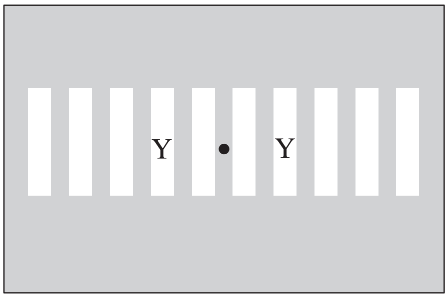
a. Given $\lambda = 635$ nm, the path difference is $1905 = 3\lambda$. This represents constructive interference (the third grey bands left and right of the dot).



1 mark

Note: X can be marked on either side of the dot as shown.

b. Given $\lambda = 635$ nm, the path difference is $952.5 = 1.5\lambda$. This represents destructive interference (the second white bands left and right of the dot).



1 mark

Note: Y can be marked on either side of the dot as shown.

c. The spread of the bands in the pattern varies directly with the wavelength; thus, a reduction in wavelength will cause the pattern to contract. The dark and light bars would become closer to the dot in the middle of Figure 21. 1 mark

A change in intensity would not affect the spread of the bands, but would increase the brightness of the bright bands. 1 mark

Question 19 (3 marks)

A single electron is observed to pass through one of the slits and it strikes a particular position on the screen. This is particle behaviour. 1 mark

As time passes, more single electrons pass through a slit and strike a position on the screen. A pattern builds up over time. The pattern shows bands of electron strikes separated by bands where no electrons strike.

The pattern of electron strikes indicates that the electrons were particular about where they struck the screen. 1 mark

The bands of electron strikes fit within the wave model. The electrons display wave-like behaviour because they diffract to desired positions. 1 mark