Neap

Trial Examination 2023

VCE Physics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

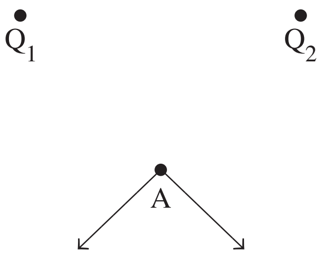
Question	Answer	Question	Answer
1	C	11	D
2	D	12	D
3	B	13	D
4	C	14	C
5	A	15	C
6	A	16	A
7	B	17	B
8	A	18	D
9	A	19	A
10	C	20	A

Question 1 C

The electric field strength due to one point charge is determined by $\frac{kQ}{d^2}$. Since Q_1 and Q_2 are identical, their fields have equal values at the same position.

Thus, the electric field strength at Q_1 and Q_2 is $\frac{9.0 \times 10^9 \times 1.0 \times 10^{-6}}{1.0^2} = 9.0 \times 10^3 \text{ N C}^{-1}$.

The directions of the two fields at point A are shown in the diagram below.



Thus, the magnitude of the electric field at point A is given by the vector sum of the vertical components:

$2 \times (9.0 \times 10^3) \times \cos(30) = 1.56 \times 10^4 \text{ N C}^{-1}$

Question 2 D

The force of Q_1 on the test charge is attractive and to the left. The distance between them is $\frac{d}{4}$.

The value of Q_1 is given by:

$$F_{1 \text{ on test}} = \frac{kQ_1 \times Q_{\text{test}}}{d^2} = \frac{kQ \times Q}{\left(\frac{d}{4}\right)^2} = \frac{16kQ^2}{d^2}$$

The force of Q_2 on the test charge is attractive and to the right. The distance between them is $d - \frac{d}{4} = \frac{3d}{4}$.

The value of Q_2 is given by:

$$F_{2 \text{ on test}} = \frac{kQ_2 \times Q_{\text{test}}}{d^2} = \frac{k4Q \times Q}{\left(\frac{3d}{4}\right)^2} = \frac{64kQ^2}{9d^2} = \frac{7.11kQ^2}{d^2}$$

As $F_{1 \text{ on test}}$ is greater than $F_{2 \text{ on test}}$, the resulting force on the test charge is in the same direction as $F_{1 \text{ on test}}$; that is, to the left.

Question 3 B

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

Its value is given by:

$$E = \frac{\text{potential difference}}{\text{plate distance}}$$
$$= \frac{12}{0.2}$$
$$= 60 \text{ N C}^{-1}$$

The potential varies linearly along the length of the field.

At point X, the potential is one quarter of the total:

$$\frac{12-0}{4} = 3.0 \text{ V}$$

At point Y, the potential is one half of the total:

$$\frac{12-0}{2} = 6.0 \text{ V}$$

Question 4 C

C is correct. Infrared radiation is used in heat provision and image formation in night-vision cameras.

A is incorrect. Gamma rays are not used for telecommunications as they are harmful.

B is incorrect. Fiber-optic communications use infrared radiation, not radio waves.

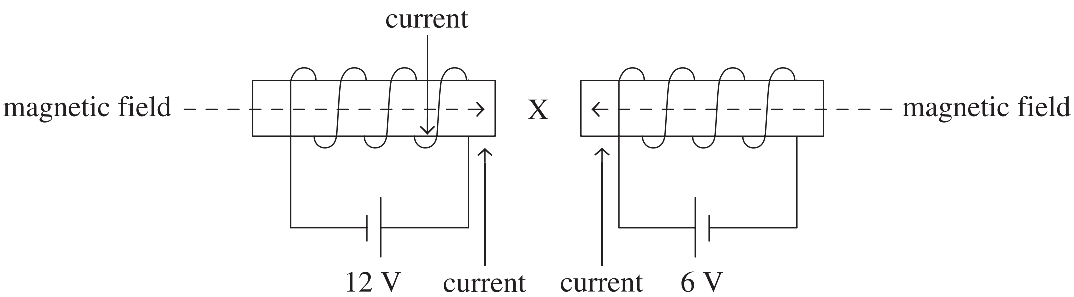
D is incorrect. Ultraviolet radiation is not used in medical imaging as the wavelengths are too large.

Question 5 A

The right-hand grip rule can be used to determine the direction of magnetic field around a coil.

For the left coil, the current on the front of the coil is downwards; when the right thumb points downwards, the right-hand fingers curl to the right. Therefore, the left coil's magnetic field is to the right at point X.

For the right coil, the current on the front of the coil is upwards; when the right thumb points upwards, the right-hand fingers curl to the left. Therefore, the right coil's magnetic field is to the left at point X.

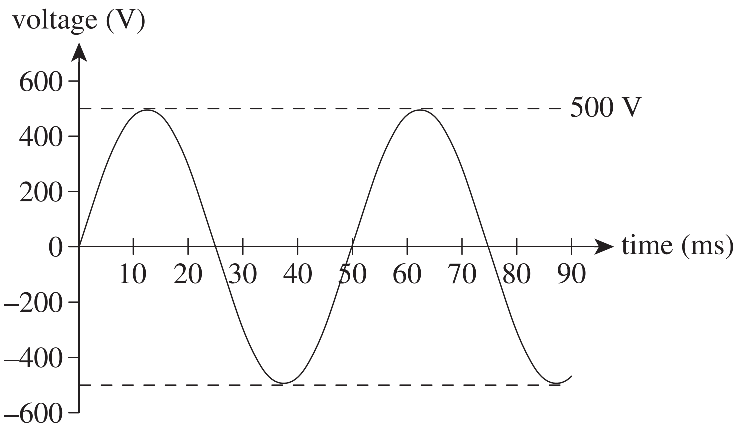


The size of the field is dependent on the current in the coil. As the left coil uses a 12 V battery, it has approximately twice the amount of current passing through it than the right coil. Therefore, the left coil's magnetic field is approximately twice the magnitude of the right coil.

Thus, the magnetic field pointing to the right is greater than the magnetic field pointing to the left, and so the resulting magnetic field at point X is to the right.

Question 6 A

The RMS voltage can be found by multiplying $\frac{1}{\sqrt{2}}$ by the peak voltage. Reading from the graph, the peak voltage is 500 V.



Therefore, calculating the RMS voltage gives:

$$\frac{1}{\sqrt{2}} \times 500 = 354\ \text{V}$$

Calculating the frequency gives:

$$\frac{1}{\text{period}} = \frac{1}{50 \times 10^{-3}\,\text{sec}}$$
$$= 20\ \text{Hz}$$

Question 7 B

The forces between the Moon and Earth are equal and opposite as the forces are internal between them, according to Newton's third law. Thus, $F_{\text{E on M}} = F_{\text{M on E.}}$

The gravitational field strength of a body is given by $\frac{GM_{\text{body}}}{d^2}$. The distance between Earth and the Moon is the same for each body. However, as Earth has a greater mass, it will also have a greater gravitational field strength at the position of the Moon than the Moon at the position of the Earth.

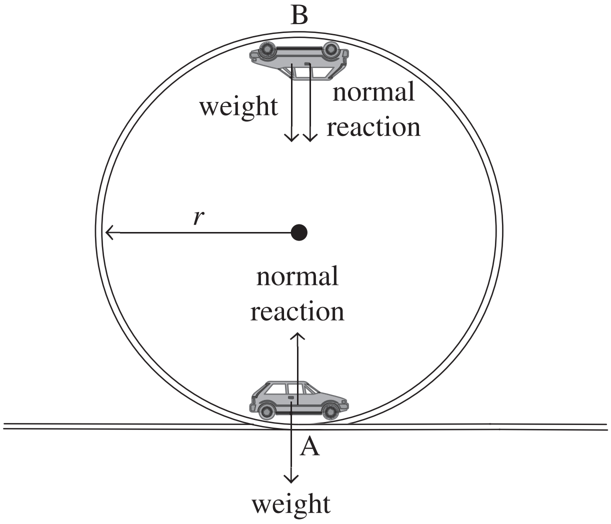
Thus, $g_{\text{E}} > g_{\text{M.}}$

Question 8 A

Heisenberg's uncertainty principle states that the more precisely the position of some particle is measured, the less precisely its momentum can be measured and vice versa. The two quantities occur in the same plane.

Question 9 A

The resulting force is the centripetal force, which is the combination of the individual forces acting at each position as shown in the diagram below.



The positive direction is taken towards the centre of the circle.

At position A:

$$F_{\text{centripetal at A}} = \text{normal reaction} - \text{weight}$$

$$\text{normal reaction at A} = F_{\text{centripetal at A}} + mg$$

At position B:

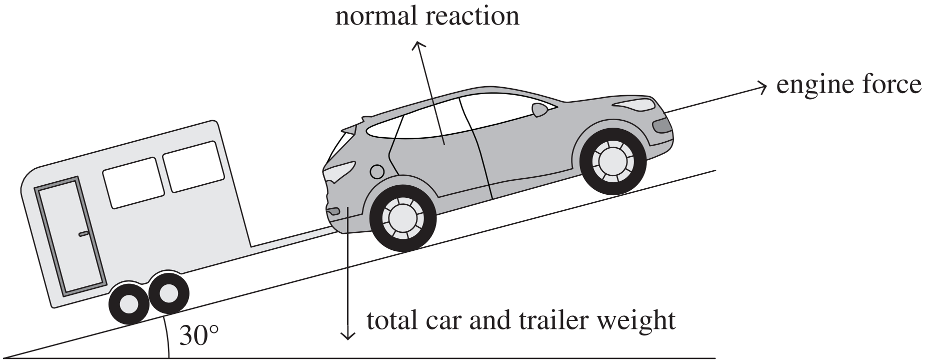
$$F_{\text{centripetal at B}} = \text{normal reaction} + \text{weight}$$

$$\text{normal reaction at B} = F_{\text{centripetal at B}} - mg$$

Thus, the ratio is $\dfrac{F_{\text{centripetal at A}} + mg}{F_{\text{centripetal at B}} - mg}$.

Question 10 C

The engine force is required to tow both the car and the trailer up the incline. Thus, they can be combined as one unit. The forces acting on the unit are shown in the diagram below.



Using Newton's second law along the incline and positive in the direction of the engine force:

$\sum$forces = mass × acceleration

Since the unit is not accelerating:

$$\text{engine force} - \text{weight} \times \sin(30) = 0$$

$$\begin{aligned}\text{engine force} &= \text{weight} \times \sin(30)\\ &= (1250 + 750) \times 9.8 \times 0.5\\ &= 9800\ \text{N}\end{aligned}$$

Question 11 D

In accordance with the conservation of energy, the spring's potential energy is converted to the ball's gravitational potential energy. Therefore, the maximum height can be found using:

$$mgh = \frac{1}{2}kx^2$$

$x = 0.10$ m

$$\begin{aligned}k &= \text{gradient of graph}\\ &= \frac{50}{0.10}\\ &= 500\ \text{N m}^{-1}\end{aligned}$$

$m = 0.10$ kg

Therefore:

$$\begin{aligned}h &= \frac{\frac{1}{2} \times 500 \times 0.10^2}{0.1 \times 9.8}\\ &= 2.55\ \text{m}\end{aligned}$$

 VCE_Phys34_SS_2023

Question 12 D

D is correct, and **A** and **C** are incorrect. Since the speed is greater than 0.1*c*, length contraction occurs; thus, option **A** is incorrect.

The horizontal length of the frame contracts by a multiplication factor of $\frac{1}{\gamma}$.

$$\begin{aligned}\frac{1}{\gamma} &= \sqrt{1-\frac{v^2}{c^2}} \\ &= \sqrt{1-0.95^2} \\ &= 0.31\end{aligned}$$

The contracted length of the frame is less than half of the original length. Thus, option **D**, not option **C**, shows an appropriate amount of contraction.

B is incorrect. This option shows contraction in the vertical dimension, which does not occur when travelling horizontally.

Question 13 D

The frequency of wave Y is three times the frequency of wave X. Therefore:

$$\begin{aligned}\text{frequency of wave X} &= \frac{\text{speed}}{\text{wavelength}} \\ &= \frac{12}{3.0} \\ &= 4.0 \text{ Hz} \\ \text{frequency of wave Y} &= 3 \times 4.0 \\ &= 12 \text{ Hz}\end{aligned}$$

Question 14 C

The sound waves travel at the speed of sound in air.

If the ambulance was stationary, both Justin and Margaret would hear the siren at 800 Hz.

As the ambulance moves towards Margaret, the waves are compressed, so she hears the siren at a frequency greater than 800 Hz.

As the ambulance moves away from Justin, the waves are stretched, so he hears the siren at a frequency less than 800 Hz.

Question 15 C

C is correct and **A** and **B** is incorrect. The refractive index of a material is slightly higher for violet light than for red light, so red light will refract through a smaller angle than violet light. Thus, red light cannot completely internally reflect, so it must pass into medium 2.

D is incorrect. As the ray of violet light travels along the boundary, medium 2 must have a lesser refractive index than medium 1. Therefore, no ray of light refracts near the normal to the boundary in medium 2.

Question 16 A

The wavelength represents the length of the string. In this case, it is 2.0 m.

$$\lambda_n = \frac{2L}{n}$$
$$= \frac{4}{n}$$

As n represents the number of envelopes, substituting various values of n gives the standing waves that would be accommodated by the string. Therefore:

$n = 1$, $\lambda = 4.0$ m

$n = 2$, $\lambda = 2.0$ m

$n = 3$, $\lambda = 1.33$ m

$n = 4$, $\lambda = 1.0$ m

$n = 5$, $\lambda = 0.8$ m

$n = 6$, $\lambda = 0.67$ m

$n = 7$, $\lambda = 0.57$ m

$n = 8$, $\lambda = 0.5$ m

and so on.

Only option **A** lists three correct possibilities.

Question 17 B

Longitudinal waves cannot be polarised as they oscillate parallel to their flow of energy, but are able to diffract, interfere and reflect. An example of this is sound waves; sound consists of longitudinal waves and it is known that sound can diffract (bend around corners), refract (change angle in passing from one material to another) and interfere (give rise to loud and dead sound regions in open hall areas).

Question 18 D

In experiment X, the electrons only struck the screen at two positions, indicating that they had passed through either of the two slits. Thus, experiment X shows that the electrons behaved as particles only.

In experiment Y, the electrons struck the screen at multiple specific positions, as they have a wave nature and constructively interfere with themselves. However, the fact that the electrons struck at particular positions indicates that they have collided as a particle. Thus, experiment Y shows that the electrons behaved as both particles and waves.

Question 19 A

The maximum kinetic energy is determined by photon energy – work function.

Given that photon energy = hf and work function = hf_c, where $f_c = 4.0 \times 10^{14}$ Hz:

$$\begin{aligned} E_{\text{k max}} &= hf - hf_c = h(f - f_c) \\ &= 6.63 \times 10^{-34} \times (6.0 \times 10^{14} - 4.0 \times 10^{14}) \\ &= 1.326 \times 10^{-19} \text{ J} \\ &= \frac{1.326 \times 10^{-19}}{1.6 \times 10^{-19}} \\ &= 0.83 \text{ eV} \end{aligned}$$

Question 20 A

Precision is the agreement of a set of results among themselves regardless of their accuracy to the true value. A set of data that has high precision has low deviation between individual data points. Thus, option **A** gives the most precise set of values.

SECTION B

Question 1 (7 marks)

a. clockwise — 1 mark

Using the right-hand rule on the side closest to the south pole, the current (right thumb) points into the page, the magnetic field (right fingers) points to the left, and the force causing the rotation (right palm) points upwards.

b. $F = nIlB$

$= 10 \times 0.050 \times 0.030 \times 0.10$ — 1 mark

$= 1.5 \times 10^{-3}$ N — 1 mark

c. The split ring is important as it allows the direction of the current to alternate relative to the coil. — 1 mark

This occurs every half cycle. — 1 mark

Alternating the direction of the current allows the forces on the side perpendicular to the magnetic field to alternate, which maintains a continuous direction of rotation. — 1 mark

d. 0 A — 1 mark

When the coil is at right angles, the split ring commutator causes the circuit to be open and no current passes in that instant.

Question 2 (6 marks)

a. Given that the period of 2.0 hours = 7200 seconds:

$$\frac{r^3}{T^2} = \frac{GM_{\text{Mars}}}{4\pi^2}$$

$$\frac{r^3}{7200^2} = \frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{4 \times \pi^2}$$ — 1 mark

$$\frac{r^3}{7200^2} = 1.0796 \times 10^{12}$$ — 1 mark

$$r = \sqrt[3]{7200^2 \times 1.0796 \times 10^{12}}$$

$$= 3.8251 \times 10^6 \text{ m}$$ — 1 mark

altitude = orbit radius − Mars radius

$= 3.8251 \times 10^6 - 3.3896 \times 10^6$

$= 4.36 \times 10^5$ m

$= 436$ km — 1 mark

b. **Method 1:**

$$v = \sqrt{\frac{GM_{\text{Mars}}}{r_{\text{orbit}}}}$$ 1 mark

$$= \sqrt{\frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{3.83 \times 10^{6}}}$$

$$= 3.4 \times 10^{3}\ \text{m s}^{-1}$$ 1 mark

Method 2:

$$v = \frac{2\pi r_{\text{orbit}}}{T}$$ 1 mark

$$= \frac{2 \times 3.1416 \times 3.83 \times 10^{6}}{7200}$$

$$= 3.4 \times 10^{3}\ \text{m s}^{-1}$$ 1 mark

Note: Consequential on answer to ***Question 2a.***

Question 3 (8 marks)

a.

$$qV = \frac{1}{2}mv^{2}$$

$$3.2 \times 10^{-19} \times V = \frac{1}{2} \times 1.06 \times 10^{-25} \times \left(2.4 \times 10^{5}\right)^{2}$$ 1 mark

$$V = \frac{1.06 \times 10^{-25} \times (2.4 \times 10^{5})^{2}}{2 \times 3.2 \times 10^{19}}$$ 1 mark

$$= 9540$$

$$= 9.5 \times 10^{3}\ \text{V}$$ 1 mark

b. The displacement is the diameter of the circular path. Therefore, letting $d = 2r$ gives:

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

$$d = \frac{2mv}{Bq}\ \textit{(substituting d and rearranging)}$$

$$d = \frac{2 \times 1.06 \times 10^{-25} \times 2.4 \times 10^{5}}{1.60 \times 3.2 \times 10^{-19}}$$ 1 mark

$$= 0.099\ \text{m}$$ 1 mark

c. Both the ion and the Moon undergo circular motion, requiring a centripetal force. 1 mark

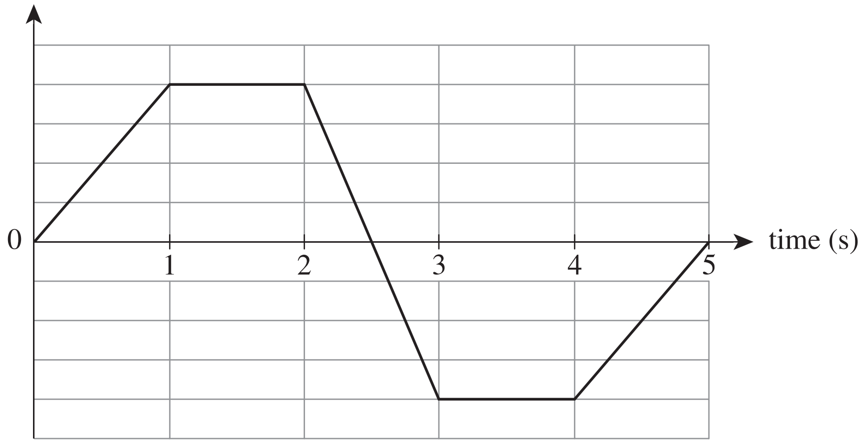
The ion experiences a magnetic force that is perpendicular to the magnetic field. 1 mark

The Moon experiences a gravitational force that is parallel to the gravitational field. 1 mark

Note: Accept responses that state that both the ion and the Moon travel at right angles to the fields causing their motion.

Question 4 (6 marks)

a. magnetic flux (Wb)

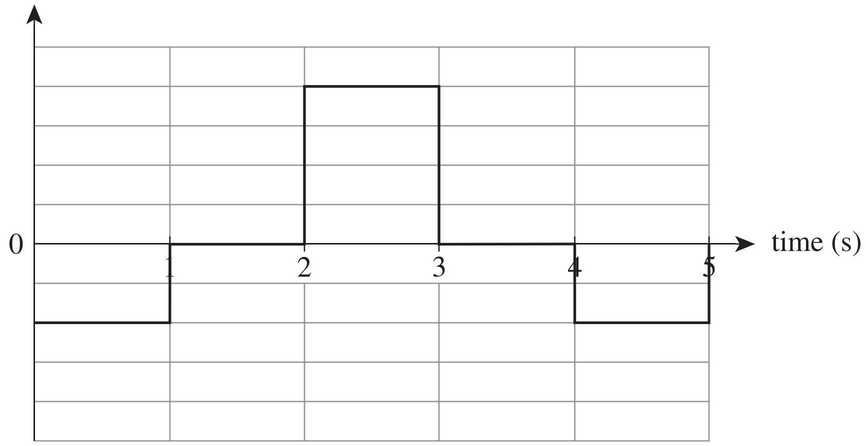


3 marks

Award 1 mark for 1–2 correct features.
Award 2 marks for 3–4 correct features.
Award 3 marks for all correct features.

b. The EMF is the negative gradient function of the flux graph.

EMF (V)



3 marks

Award 1 mark for 1–2 correct features.
Award 2 marks for 3–4 correct features.
Award 3 marks for all correct features.
Note: Accept the positive gradient function of the flux graph. Consequential on answer to ***Question 4a.***

Question 5 (5 marks)

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

$= 400^2 \times 4.0$ 1 mark

$= 6.4 \times 10^5$ W 1 mark

b. $$\frac{\text{substation peak current}}{\text{transmission line peak current}} = \frac{\text{substation RMS current}}{\text{transmission line RMS current}}$$

Since the number of turns is unknown, the primary and secondary coil voltages of T_2 have to be used. Therefore:

$$\frac{\text{substation RMS current}}{\text{transmission line RMS current}} = \frac{\text{voltage in primary coil of } T_2}{\text{voltage in secondary coil of } T_2}$$ 1 mark

voltage in secondary coil of T_2 = 50 kV

voltage in primary coil of T_2 = transmission voltage − transmission line voltage loss

$= 500 \times 10^3 - 400 \times 4.0$

$= 498 \times 10^3$ V 1 mark

$$\frac{\text{voltage in primary coil of } T_2}{\text{voltage in secondary coil of } T_2} = \frac{498 \times 10^3}{50 \times 10^3}$$

$= 9.96$ 1 mark

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

Question 6 (4 marks)

a. $$\text{average EMF} = \text{N} \times \left| \frac{\Phi_{\text{final}} - \Phi_{\text{initial}}}{\Delta t} \right|$$

Given that $A = \pi r^2$:

$\Phi_{\text{initial}} = BA$

$= 0.10 \times \pi \times 0.025^2$

$= 0.00019635$ Wb 1 mark

$\Phi_{\text{final}} = 0$

Therefore:

$$\text{average EMF} = 10 \times \left| \frac{0 - 0.00019635}{0.50} \right|$$ 1 mark

$= 0.003927$

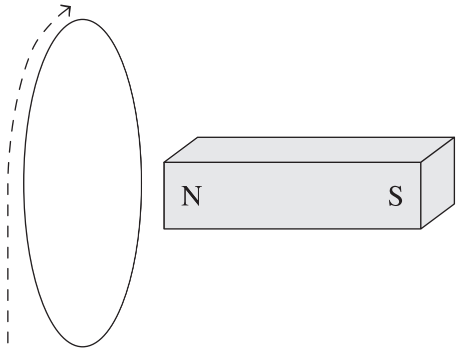
$= 3.9 \times 10^{-3}$ V 1 mark

Note: If the diameter is used or the radius is not converted to metres, award 1 mark maximum.

b. As the coil is pulled away from the magnet, it experiences a decreasing external flux to the left.

It opposes this loss of external flux by providing its own (induced) flux to the left.

Using the right-hand grip rule, the direction of the fingers represents the direction of the induced magnetic field and flux. Thus, the direction of the thumb represents the direction of the induced current, which is shown in the diagram below.



1 mark

Question 7 (8 marks)

a. Letting the total mechanical energy of the lower position equal the total mechanical energy of the higher position, and the collision plane be zero for height, gives:

$$\frac{1}{2}mv^2 = mgh_{\text{top}}$$

$$\frac{1}{2} \times 0.050 \times v^2 = 0.050 \times 9.8 \times 1.00$$ 1 mark

$$v = \sqrt{2 \times 9.8 \times 1.00}$$

$$= \sqrt{19.6}$$

$$= 4.43 \text{ m s}^{-1}$$ 1 mark

b. Taking to the right to be positive and using momentum conservation gives:

$$\Sigma mv \text{ after collision} = \Sigma mv \text{ before collision}$$

$$mv_{50} + mv_{100} = mv_{50}$$

$$(0.050 \times 1.0) + (0.100 \times v) = 0.050 \times 4.43$$ 1 mark

$$0.050 + 0.100v = 0.2215$$

$$v = \frac{0.2215 - 0.050}{0.100}$$ 1 mark

$$= 1.7 \text{ m s}^{-1}$$ 1 mark

c. Calculating the total kinetic energy of the system before and after the collision gives:

$$E_{\text{k before}} = \frac{1}{2}mv^2$$
$$= \frac{1}{2} \times 0.050 \times 4.43^2$$
$$= 0.49 \text{ J}$$ 1 mark

$$E_{\text{k after}} = \frac{1}{2}mv^2{}_{50} + \frac{1}{2}mv^2{}_{100}$$
$$= \left(\frac{1}{2} \times 0.050 \times 1.0^2\right) + \left(\frac{1}{2} \times 0.100 \times 1.7^2\right)$$
$$= 0.17 \text{ J}$$ 1 mark

Since $E_{\text{k before}} > E_{\text{k after}}$, the collision is inelastic. 1 mark

Note: The difference in the kinetic energy has been transferred to heat and sound.
Consequential on answer to ***Question 7b.***

Question 8 (3 marks)

When the van takes the turn, the resulting force experienced by the van will be centripetal force. The centripetal force is provided by the friction force.

For the van to remain on the road without slipping, the centripetal force required must not exceed the maximum friction force available.

The velocity of the van as it takes the turn is:

$$v = 100 \text{ km h}^{-1}$$
$$= \frac{100}{3.6}$$
$$= 27.78 \text{ m s}^{-1}$$ 1 mark

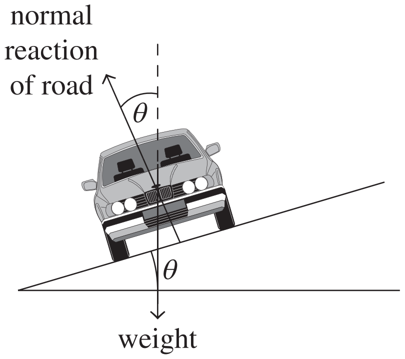
Therefore, finding the centripetal force gives:

$$F_c = \frac{mv^2}{r}$$
$$= \frac{1000 \times 27.78^2}{80}$$
$$= 9645 \text{ N}$$ 1 mark

Since the maximum friction available (7200 N) is less than the centripetal force needed, the van will slip off the road. 1 mark

Question 9 (4 marks)

The forces acting on the car are shown in the diagram below.



1 mark

1 mark for drawing both forces correctly.

The banking of the road enables the normal reaction to act at right angles to the road.

The horizontal component of the normal reaction enables the centripetal force to exist according to F_c = normal reaction × sin(θ). 1 mark

Vertically, the weight force is balanced by normal reaction × cos(θ) = mg.

Combining the two equations and eliminating the normal reaction gives:

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

Thus, the greater the banking angle, θ, the greater the speed the car can travel on the curve. Banked turns enable vehicles to travel at greater speeds than road-tyre friction for turns with the same radius. 1 mark

Question 10 (3 marks)

$$\begin{aligned}\text{mass of four hydrogen atoms} &= 4 \times 1.674 \times 10^{-27} \\ &= 6.696 \times 10^{-27} \text{ kg}\end{aligned}$$

mass of helium atom = 6.646×10^{-27} kg

$$\begin{aligned}\text{mass difference} &= 6.696 \times 10^{-27} - 6.646 \times 10^{-27} \\ &= 5 \times 10^{-29} \text{ kg}\end{aligned}$$ 1 mark

$$E = mc^2$$

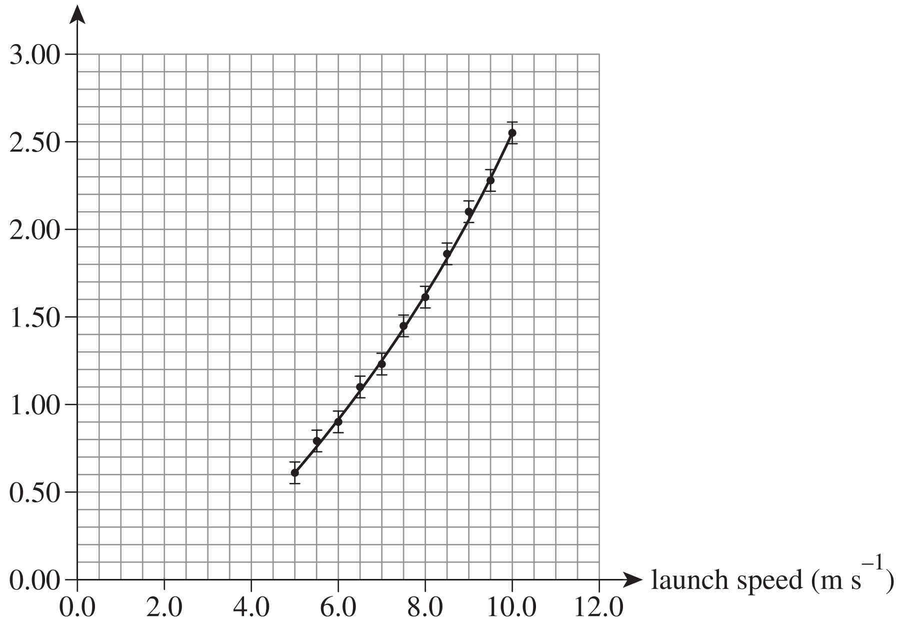
$$= 5 \times 10^{-29} \times (3 \times 10^8)^2$$ 1 mark

$$= 4.5 \times 10^{-12} \text{ J}$$

$$= 5 \times 10^{-12} \text{ J}$$ 1 mark

Question 11 (12 marks)

a. maximum height (m)



5 marks

1 mark for plotting the correct data points.
1 mark for using an appropriate scale for the maximum height.
1 mark for using an appropriate scale for the launch speed.
1 mark for including uncertainty bars for at least 3 data points.
1 mark for drawing an appropriate line of best fit.

b. The graph of the data shows a non-linear profile, particularly as (0, 0) is expected to be part of the data. 1 mark

Therefore, the student's hypothesis is rejected. 1 mark

Note: Consequential on answer to ***Question 11a.***

c. Given that the profile of the graph in Figure 10 is fairly linear, it can be concluded that maximum height varies according to launch speed^2. 1 mark

If external forces such as air resistance existed in a significant manner, or if any of the data was invalid, then the profile of the graph would not have been linear. Thus, any external forces or inconsistencies are insignificant. 1 mark

d. From the equation, it can be determined that launch speed^2 is multiplied by a constant that is equal to the gradient of the graph. Thus:

$$\text{gradient} = \frac{\sin^2(\theta)}{2g}$$

Calculating the gradient gives:

$$\frac{2.60 - 1.05}{100 - 40} = 0.02583$$ 1 mark

As $\theta = 45°$, $\sin(45°) = 0.7071$.

Therefore:

$$\text{gradient} = \frac{\sin^2(\theta)}{2g}$$

$$0.02583 = \frac{0.7071^2}{2g}$$

$$g = \frac{0.7071^2}{2 \times 0.02583}$$ 1 mark

$$= 9.68 \text{ m s}^{-2}$$ 1 mark

Note: Accept gradients in the range of ±0.04.

Question 12 (5 marks)

a. In the muons' frame of reference, they travel:

$$\text{distance} = \text{speed} \times \text{time}$$

$$= 0.9999 \times 3 \times 10^8 \times 2.2 \times 10^6$$ 1 mark

$$= 660 \text{ m}$$ 1 mark

b. From the frame of reference of a stationary observer on the ground, the muons' mean lifetime is dilated according to:

$$t = \frac{2.2 \times 10^{-6}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= 2.2 \times 10^{-6} \times 70.7$$

$$= 1.56 \times 10^{-4} \text{ s}$$ 1 mark

Thus, the distance the muons will travel in the observer's frame of reference is:

$$\text{distance} = \text{speed} \times \text{time}$$

$$= 0.9999 \times 3 \times 10^8 \times 1.56 \times 10^{-4}$$

$$= 4.674 \times 10^4 \text{ m}$$

$$= 46.7 \text{ km}$$ 1 mark

Hence, if muons are created at 10 km above the ground, they will be observed striking the ground. 1 mark

Question 13 (9 marks)

a. All colours of light will have a central band of constructive interference for a zero path difference; therefore, they will all have a coloured band centrally. 1 mark

As all colours converge on the centre, the coloured bands combine to form a band of white light. 1 mark

b. The coloured bands exist because of the constructive interference of their light from the two slits at the positions shown in Figure 12, whereby each position has a path difference equal to a whole number of wavelengths. 1 mark

The spread of the bands from each other at these positions is dependent on the wavelength of the light for constant slit spacing and screen-to-slit distance, according to:

$$\text{distance between consecutive bands} = \frac{\text{wavelength} \times \text{screen-to-slit distance}}{\text{slit separation}}$$ 1 mark

Violet light has the smallest wavelength and red has the largest wavelength. The consecutive violet bands have the smallest separation and the consecutive red bands have the largest separation from the central white band. 1 mark

Since these bands do not occur at the same position, they cannot overlap to form white light. 1 mark

c. The distance between the centres of the green band and the white band is given by:

$$\text{distance between consecutive bands} = \frac{\text{wavelength} \times \text{screen-to-slit distance}}{\text{slit separation}}$$

$$2.2 \times 10^{-2} = \frac{\text{wavelength} \times \text{screen-to-slit distance}}{\text{slit separation}}$$

$$\text{wavelength} = \frac{2.2 \times 10^{-2} \times 0.10 \times 10^{-3}}{4.00}$$

$$= 5.5 \times 10^{-7} \text{ m}$$ 1 mark

$$\text{frequency} = \frac{\text{speed of light}}{\text{wavelength}}$$

$$= \frac{3.0 \times 10^{8}}{5.5 \times 10^{-7}}$$ 1 mark

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

Question 14 (3 marks)

In this scenario, the incident medium is the water and the refractive medium is the air. Therefore:

$\theta_1 = 90 - 62$

$= 28°$

$\theta_2 = 90 - 49$

$= 41°$ 1 mark

$n_2 = 1.00$

Using Snell's law gives:

$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

$n_1 \times \sin(28°) = 1.00 \times \sin(41°)$

$n_1 = \frac{1.00 \times 0.656}{0.469}$ 1 mark

$= 1.40$ 1 mark

Note: If the incorrect angles are used, award 1 mark maximum.

Question 15 (9 marks)

a. X represents the stopping voltage. Therefore:

$qV_{\text{stopping}} = \frac{hc}{\lambda} - \text{work function}$

When using the eV value for *h*, the charge of the electron is ignored. Therefore:

$V_{\text{stopping}} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{480 \times 10^{-9}} - 2.30$ 1 mark

$= 2.59 - 2.30$ 1 mark

$= 0.29 \text{ V}$ 1 mark

b. i. To determine whether the graph is possible, the energy of a photon of the light needs to be known to find the value of X. Light of frequency 4.0×10^{14} Hz has a photon energy of:

$E_{\text{photon}} = 4.14 \times 10^{-15} \times 4.0 \times 10^{14}$

$= 1.65 \text{ eV}$ 1 mark

No graph can be drawn for the second trial because the photon energy is less than the work function of the photocathode metal. 1 mark

ii. The particle model of light states that light consists of a stream of photons that are distinct packets of energy, 1 mark

which can either be totally absorbed or not absorbed at all by electrons. 1 mark

An electron will only absorb a photon of light if the energy of the photon is greater than the work function for the metal in which the electron resides. 1 mark

The work function is defined as the minimum energy needed to liberate an electron from an atom of the metal. 1 mark

VCE_Phys34_SS_2023

Question 16 (7 marks)

a. The dark bands (where the wavelengths are shown) indicate that these colours have energies that can be absorbed by a hydrogen atom. 1 mark

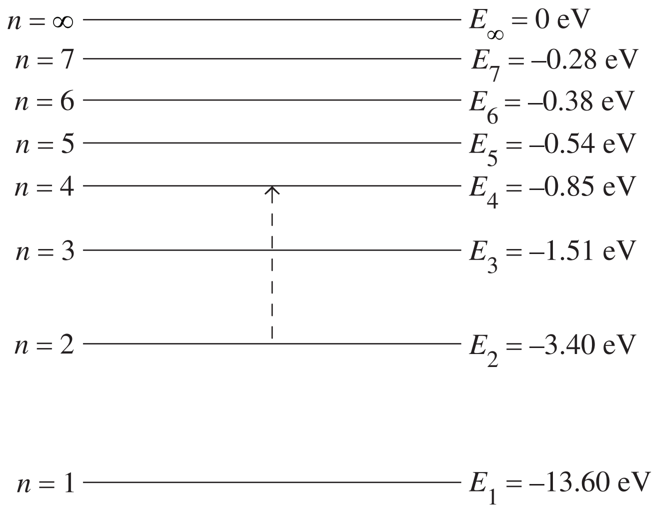
The single electron in the hydrogen atom exists at a certain energy level (an orbit of a particular radius); the electron cannot absorb light of wavelength 550 nm as this will not allow it to transit to any higher energy level. 1 mark

b. The electron of a hydrogen atom has a known mass, momentum and position in an energy level, indicating that it is a particle. 1 mark

In an energy level, the electron's energy is manifested as a standing wave with a de Broglie wavelength so that it can remain in a stable orbit without radiating energy away. 1 mark

The electron thus displays particle and wave characteristics simultaneously in this situation. 1 mark

c.



The arrow must point upwards, as the band on the absorption spectrum indicates that the electron has absorbed energy when transitioning a higher level. 1 mark

The difference between the two energy levels in the transition must equal 2.55 eV; thus, the arrow should be drawn between $n = 2$ and $n = 4$ $(-3.40 - (-0.85) = -2.55)$. 1 mark

Note: Award 1 mark only if the arrow is drawn pointing downwards from n = 4 to n = 2.

Question 17 (5 marks)

a. The patterns occur as a result of the electrons displaying wave behaviour to interfere with each other, which constructively produces bright bands and destructively produces dark bands. 1 mark

The small interatomic distances in the crystal are equal to, or smaller than, the de Broglie wavelength of the electrons; thus, the electrons can diffract as they pass between the atoms.

Wave behaviour is exhibited when $\frac{\text{wavelength}}{\text{interatomic distance}} \geq 0.1$. 1 mark

b. The formula for a de Broglie wavelength is $\lambda = \frac{h}{mv}$. Given that $mv = \sqrt{2 \times m_e \times E_\text{k}}$ and $E_\text{k} = qV$, combining all three equations gives:

$$\lambda = \frac{h}{\sqrt{2 \times m_e \times q \times V}}$$ 1 mark

According to the equation, at a higher voltage the de Broglie wavelength is smaller. 1 mark

Hence, the separation of the bands decreases in accordance with the de Broglie wavelength as the voltage increases. 1 mark

Question 18 (6 marks)

a. An energy of 30 eV indicates that the accelerating voltage of the electron is 30 V.

$$\lambda = \frac{h}{\sqrt{2 \times m_e \times q \times V}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 30}}$$ 1 mark

$$= \frac{6.63 \times 10^{-34}}{2.96 \times 10^{-24}}$$ 1 mark

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

b. To determine if diffraction will occur, the $\frac{\lambda}{d}$ ratio needs to be found.

$$\frac{\lambda}{d} = \frac{2.24 \times 10^{-10}}{0.215 \times 10^{-9}}$$ 1 mark

$$= 1.04$$ 1 mark

Given that the ratio is greater than 0.1, diffraction will occur. 1 mark

Note: If the incorrect ratio is found, but the correct conclusion is drawn, award 1 mark for the statement.

