PHYSICS

Units 3 & 4 – Written examination

TSSM
Creating VCE Success

2022 Trial Examination

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Answer: A

Explanation:

$m_t = 40$ kg, $m_s = 2.0$ kg, $v_t = 6.0$ m s^{-1}, $v_s = 0$ m s^{-1}, $m_{t+s} = 42$ kg

$$m_t v_t + m_s v_s = m_{t+s} v_{t+s}$$
$$40(6) + 2(0) = 42 v_{t+s}$$
$$v_{t+s} = \frac{240}{42}$$
$$v_{t+s} = 5.7 \text{ m s}^{-1}$$

Question 2

Answer: D

Explanation:

$$\text{V}_{\text{p-p}} = V_{RMS} \times 2\sqrt{2}$$
$$= c$$
$$= 68\,V$$

Question 3

Answer: C

Explanation:

The direction of the magnetic field lines is away from the North pole and towards the South pole.

Question 4

Answer: A

Explanation:

Magnitude of the charge is used to calculate the field strength. Unit is NC^{-1} or Vm^{-1}, but not Vm.

$$\begin{aligned} E &= \frac{kq}{r^2} \\ &= \frac{(8.99 \times 10^9)(4.8 \times 10^{-8})}{3.0^2} \\ &= 47.9467 \\ &= 48 \text{ N C}^{-1} \end{aligned}$$

Question 5

Answer: B

Explanation:

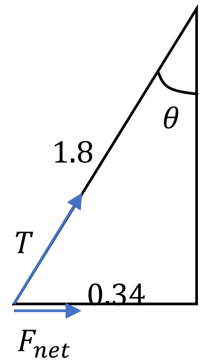
$$p = \frac{h}{\lambda} \qquad v = f\lambda \qquad v = c$$

$$\begin{aligned} p &= \frac{hf}{c} \\ &= \frac{(6.63 \times 10^{-34})(5.16 \times 10^{14})}{3.0 \times 10^8} \\ &= 1.14 \times 10^{-27} \end{aligned}$$

Question 6

Answer: B

Explanation:



$$\sin\theta = \frac{0.34}{1.8}$$

$$\theta = \sin^{-1}\left(\frac{0.34}{1.8}\right)$$

$$= 10.9°$$

$$F_{net} = mg\tan\theta$$

$$= (0.45)(9.8)\tan(10.9)$$

$$= 0.85\text{ N}$$

Question 7

Answer: C

Explanation:

$$T = \sqrt{(F_{net})^2 + (mg)^2}$$

$$= \sqrt{0.85^2 + (0.45 \times 9.8)^2}$$

$$= 4.5\text{ N}$$

OR

$$T = \frac{F_{net}}{\sin\theta}$$

OR

$$T = \frac{mg}{\cos\theta}$$

Question 8

Answer: A

Explanation:

Energy before the ball is dropped

$$\begin{aligned} U_g &= mgh \\ &= (0.624)(9.8)(0.8) \\ &= 4.89 \text{ J} \end{aligned}$$

Energy at the ground

$$\begin{aligned} E_k &= \frac{1}{2}mv^2 \\ &= \frac{1}{2}(0.624)(3.2)^2 \\ &= 3.19 \text{ J} \end{aligned}$$

Loss of energy to surroundings

$$\begin{aligned} E &= U_g - E_k \\ &= 4.89 - 3.19 \\ &= 1.7 \text{ J} \end{aligned}$$

Question 9

Answer: C

Explanation:

According to classical physics, a Muon's half-life is too short for it to be able to reach the Earth's surface before decaying. Observations show that there are **more** Muons that reach the surface of the Earth than predicted by classical physics.

Question 10

Answer: C

Explanation:

At maximum compression, SPE is at a maximum. At natural length, SPE is zero. Maximum velocity occurs at position B.

Question 11

Answer: D

Explanation:

$$\begin{aligned} v &= \frac{2\pi r}{T} \\ &= \frac{2\pi(1.89 \times 10^7)}{153 \times 60 \times 60} \\ &= 215.6 \text{ m s}^{-1} \end{aligned}$$

Question 12

Answer: B

Explanation:

$$\begin{aligned} 4\pi^2 r^3 &= GMT^2 \\ 4\pi^2(1.89 \times 10^7)^3 &= (6.67 \times 10^{-11})M(153 \times 60 \times 60)^2 \\ M &= \frac{4\pi^2(1.89 \times 10^7)^3}{(6.67 \times 10^{-11})(153 \times 60 \times 60)^2} \\ &= 1.32 \times 10^{22} \text{ kg} \end{aligned}$$

Question 13

Answer: A

Explanation:

$$\begin{aligned} r &= \frac{mv}{qB} \\ B &= \frac{mv}{qr} \\ &= \frac{(9.1 \times 10^{-31})(3.0 \times 10^5)}{(1.6 \times 10^{-19})(2.0)} \\ &= 8.5 \times 10^{-7} \text{ T} \end{aligned}$$

Question 14

Answer: D

Explanation:

Increasing the resistance will decrease the current passing through the wire, which reduces the force applied on the coil and therefore the overall rotational speed of the coil.

Question 15

Answer: B

Explanation:

As the phone moves downwards, the sound waves beneath it would be closer together, and the sound waves above it would be further apart (doppler effect). The higher frequency sound waves beneath it would at a higher pitch.

Question 16

Answer: A

Explanation:

Polarisation affects waves that are oriented in a specific direction. Longitudinal waves do not orient in any specific direction.

Question 17

Answer: A

Explanation:

The windows act as slits. Distance between bands $\Delta x = \frac{\lambda L}{d}$
As the windows get further apart (increased d), the number of bands projected will increase as the distance between bands Δx decreases.

Question 18

Answer: B

Explanation:

$$E_{k\,\text{max}} = energy\ absorbed\ per\ electron - \phi$$
$$\phi = energy\ absorbed\ per\ electron - E_{k\,max}$$
$$= 3.2 - 0.8$$
$$= 2.4\ \text{eV}$$

Question 19

Answer: D

Explanation:

Uncertainty is $\pm$ half of the lowest increment.

$$\frac{0.1}{2} = 0.05\ \text{kg}$$

$$T = mg$$

Uncertainty in tension:

$$\pm\, 0.05 \times 9.8 = \pm\, 0.49\ \text{N}$$

Question 20

Answer: A

Explanation:

Taking multiple measurements reduces the impact of random error as these values will be far from the rest of the data. Averaging this can reduce the impact of this error.

SECTION B

Question 1 (13 marks)

a.

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

$$= \frac{25 \times 10^3}{0.35}$$ 1 mark

$$= 7.1 \times 10^4 \text{ V m}^{-1}$$ 1 mark

b.

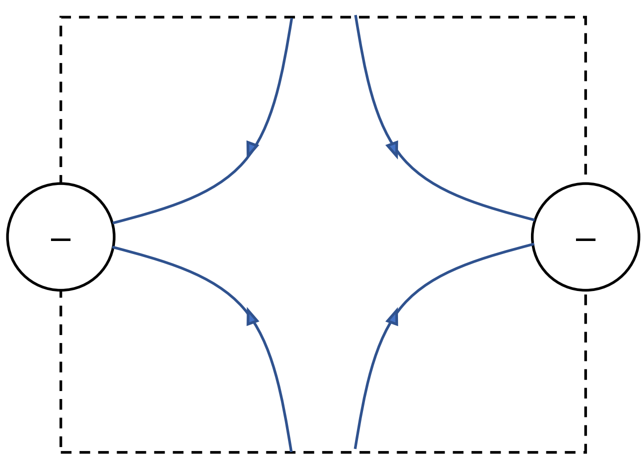
$$\frac{1}{2}mv^2 = qV$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$= \sqrt{\frac{2(1.6 \times 10^{-19})(25 \times 10^3)}{(9.1 \times 10^{-31})}}$$ 1 mark

$$= 9.4 \times 10^7 \text{ m s}^{-1}$$ 1 mark

c.



direction of lines – 1 mark
at least four lines (curved appropriately) – 1 mark

d.

$$F = qvB$$
$$= (1.6 \times 10^{-19})(9.4 \times 10^{7})(150 \times 10^{-6})$$ 1 mark
$$= 2.3 \times 10^{-15} \text{ N}$$ 1 mark

Using the right-hand slap rule – magnetic field is into the page, particle is negatively charged, therefore the force is DOWN. 1 mark

e.

$$r = \frac{mv}{qB}$$
$$= \frac{(9.1 \times 10^{-31})(9.4 \times 10^{7})}{(1.6 \times 10^{-19})(150 \times 10^{-6})}$$ 1 mark
$$= 3.6 \text{ m}$$ 1 mark

f. The photoelectric effect results in the emission of electrons when electromagnetic radiation (photons) is incident on the surface of a material. 1 mark
An electron shining a phosphor screen in a CRT is inverse of the photoelectric effect. 1 mark

Question 2 (6 marks)

a.

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$
$$= \sqrt{\frac{4\pi^2(6.4 \times 10^6 + 750 \times 10^3)^3}{(6.67 \times 10^{-11})(6.0 \times 10^{24})}}$$ 1 mark
$$= 6.0 \times 10^3 \text{ s}$$ 1 mark

b.

$$v = \sqrt{\frac{GM}{r}}$$
$$= \sqrt{\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{6.4 \times 10^6 + 750 \times 10^3}}$$ 1 mark
$$= 7.5 \times 10^3 \text{ m s}^{-1}$$ 1 mark

c. The centripetal force due to gravity would pull the satellite radially inwards. 1 mark
This would cause the satellite to return to the Earth's surface (or decrease radius of the orbit). 1 mark

Question 3 (6 marks)

a.

$$F = nIlB$$
$$= (50)(1.5)(0.2)(2.5 \times 10^{-2})$$ 1 mark
$$= 0.375 \text{ N}$$ 1 mark

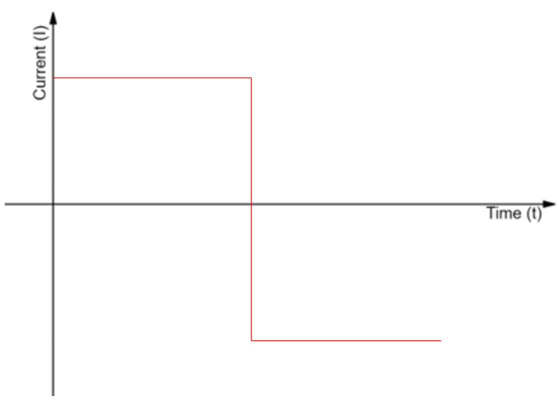
Using the right-hand slap rule, the current is moving from B to A, the magnetic field is from left to right, therefore the force is acting **UPWARDS** on side AB. 1 mark

b. The orientation where the coil is in the horizontal position as shown is when the force on side BC would be zero. 1 mark
This is due to the current moving parallel to the magnetic field. 1 mark

c. Any of:
- Increase the voltage/current through the wire
- Decrease the resistance of the wire
- Increase the number of turns
- Increase the length of the side AB/CD
- Use permanent magnets with stronger magnetic fields 1 mark

Question 4 (6 marks)

a.
Current is proportional to rate of change of flux



Reflected in the y-axis also accepted (depends on how the ammeter is set up) – 1 mark
Curve may also be accepted instead of straight lines. – 1 mark

b.

$$|\varepsilon| = |-N\frac{\Delta\Phi_B}{\Delta t}|$$

$$\frac{\Delta\Phi_B}{\Delta t} = \text{average gradient}$$
$$= \frac{3.5 - 0.5}{2}$$
$$= 1.5 \text{ Wb s}^{-1}$$ 1 mark

$$|\varepsilon| = 4(1.5)$$
$$= 6 \text{ V}$$ 1 mark

c. Magnetic flux is at a maximum when it is perpendicular to a given area.
As the coil is tilted, the perpendicular area decrease. 1 mark
This reduces the magnetic flux through the coil. 1 mark

Question 5 (7 marks)

a.

$$I = \frac{P}{V}$$
$$= \frac{1000}{2.3 \times 10^3}$$ 1 mark
$$= 0.43 \text{ A}$$ 1 mark

b.

$$V_p = V_{RMS} \times \sqrt{2}$$
$$= 2.3 \times 10^3 \times \sqrt{2}$$ 1 mark
$$= 3.3 \times 10^3 \text{ V}$$ 1 mark

c.

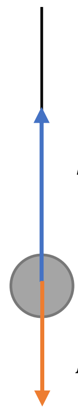
$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$
$$= \frac{2.3 \times 10^3}{230}$$ 1 mark
$$= 10:1$$ 1 mark

1 mark

d. AC power allows the use of a transformer to step up the voltage

Question 6 (15 marks)

a.



1 mark

1 mark

b.

i.

$$F_{net} = T - F_g$$

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

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

$$= \frac{(0.07)(8)^2}{0.7} + (0.07)(9.8)$$ 1 mark

$$= 7.1 \text{ N}$$ 1 mark

ii.

$$F_{net} = T + F_g$$

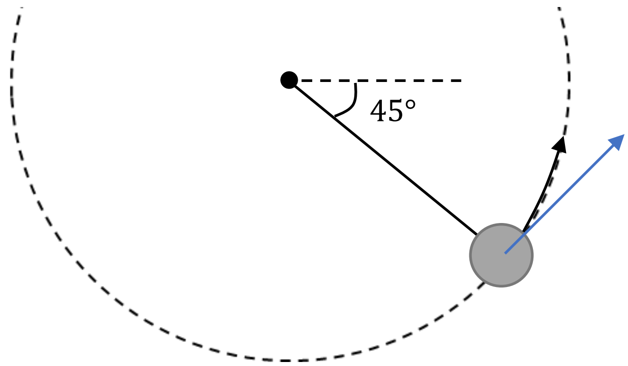
$$\frac{mv^2}{r} = T + mg$$

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

$$= \frac{(0.07)(8)^2}{0.7} - (0.07)(9.8)$$ 1 mark

$$= 5.7 \text{ N}$$ 1 mark

c.



1 mark

d.

i.

$$u_{vertical} = u\sin(\theta)$$
$$= 4\sin(45)$$
$$= 2.8 \text{ m s}^{-1}$$

1 mark

Resolving motion in the vertical direction to the peak (up is positive)
Starting position to top of arc

$t_1 = ?$, $s_1 = ?$, $u_1 = 2.8 \text{ m s}^{-1}$, $v_1 = 0 \text{ m s}^{-1}$, $a = -9.8 \text{ m s}^{-2}$

$$t_1 = \frac{v_1 - u_1}{a}$$
$$= \frac{0 - (2.8)}{-9.8}$$
$$= 0.29 \text{ s}$$

1 mark

ii.

$$s_1 = \frac{v_1^2 - u_1^2}{2a}$$
$$= \frac{0^2 - 2.8^2}{2(-9.8)}$$
$$= 0.4 \text{ m}$$

1 mark

Top of arc to floor

$$v_2 = ?, \qquad t_2 = ?, \qquad u_2 = 0\ m\ s^{-1}, \qquad a = 9.8\ m\ s^{-2}$$

$$s_2 = -0.4 + (-1) = -1.4 \text{ m}$$ 1 mark

$$v_2 = \pm\sqrt{u_2^2 + 2as_2}$$
$$= \pm\sqrt{0^2 + 2(-9.8)(-1.4)}$$
$$= -5.2 \text{ m s}^{-1}$$

$$t_2 = \frac{2s_2}{u_2 + v_2}$$
$$= \frac{2(-1.4)}{0 + (-5.2)}$$
$$= 0.53 \text{ s}$$ 1 mark

Total time of the arc

$$t_{total} = t_1 + t_2$$
$$= 0.29 + 0.53$$
$$= 0.82 \text{ s}$$ 1 mark

iii.

Horizontal distance

$$u_{horizontal} = u\cos(\theta)$$
$$= 4\cos(45)$$
$$= 2.8 \text{ m}^2$$ 1 mark

$$s = ?, \qquad u = 2.8 \text{ m s}^{-1}, \qquad t = 0.82 \text{ s}, \qquad a = 0 \text{ m s}^{-2}$$

$$s = ut + \frac{1}{2}at^2$$
$$= (2.8)(0.82) + \frac{1}{2}(0)(0.82)^2$$
$$= 2.3 \text{ m}$$ 1 mark

Question 7 (5 marks)

a.

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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

$$= \sqrt{\left(1 - \frac{1}{3^2}\right) (c^2)}$$ 1 mark

$$= \sqrt{0.88c^2}$$

$$= 0.94c$$ 1 mark

b.

From the particle's frame of reference:

$$L = \frac{L_0}{\gamma}$$

$$= \frac{3.8 \times 10^5}{3}$$ 1 mark

$$= 1.3 \times 10^5 \text{ m}$$ 1 mark

$$v = \frac{d}{t} = \frac{L}{t_0}$$

$$t_0 = \frac{L}{v}$$

$$= \frac{1.3 \times 10^5}{0.94 \times (3.0 \times 10^8)}$$

$$= 4.5 \times 10^{-4} \text{ s}$$ 1 mark

OR

It can be calculated using the dilated time in the scientist's frame of reference:

$$t = \frac{L_0}{v}$$

$$= \frac{3.8 \times 10^5}{0.94 \times (3.0 \times 10^8)}$$ 1 mark

$$= 1.3 \times 10^{-3} \text{ s}$$ 1 mark

$$t = t_0 \gamma$$

$$t_0 = \frac{t}{\gamma}$$

$$= \frac{1.3 \times 10^{-3}}{3}$$

$$= 4.5 \times 10^{-4} \text{ s}$$ 1 mark

Question 8 (5 marks)

a.

$$W = Fs \text{ (area under the graph)}$$

$$= \frac{1}{2}(12)(0.06)$$ 1 mark

$$= 0.36 \text{ J}$$ 1 mark

b.

In stage one, E_k is zero as it is stationary, U_g is at a maximum as it is at the highest point, and U_s is at a maximum as the spring is compressed. 1 mark

In stage two, E_k is at a maximum as the U_g and U_s are converted to E_k. U_g decreases. 1 mark

In stage three, E_k is zero as it is stationary at the bottom, U_g is at a minimum as it is at the lowest point, and U_s is at a maximum as it is fully extended. 1 mark

Question 9 (8 marks)

a.
Classical physics:

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

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\frac{2(1.98 \times 10^{-10})}{3.24 \times 10^{-27}}}$$ 1 mark

$$= 3.50 \times 10^8 \text{ m s}^{-1}$$ 1 mark

$$v = \frac{3.50 \times 10^8}{3.0 \times 10^8}$$

$$= 1.17c$$ 1 mark

b.

Relativistic physics:

$$E_k = (\gamma - 1)mc^2$$

$$\gamma = \frac{E_k}{mc^2} + 1$$

$$= \frac{1.98 \times 10^{-10}}{(3.24 \times 10^{-27})(3.0 \times 10^8)^2} + 1$$ 1 mark

$$= 1.68$$ 1 mark

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$v = c\sqrt{1 - \frac{1}{\gamma^2}}$$

$$= c\sqrt{1 - \frac{1}{1.68^2}}$$

$$= 0.803\ c$$ 1 mark

c. The relativistic calculation is more accurate as the particle is travelling near the speed of light, exhibiting relativistic effects. 1 mark

The classical calculations fall off as you approach the speed of light, as can be seen, it was calculated that the particle was travelling faster than light. 1 mark

Question 10 (10 marks)

a. From the graph: peak-to-peak or trough-to-trough is 20 cm $= 0.2$ m 1 mark

b.

$$v = f\lambda$$

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

$$= \frac{0.4}{0.2} \quad \text{1 mark}$$

$$= 2 \text{ Hz} \quad \text{1 mark}$$

c. Point A is an node as destructive interference is occurring (crest meeting a trough).
1 mark

d.

$$\text{path difference} = |P_1B - P_2B|$$

From diagram:

$$P_1B = 3\lambda, \qquad P_2B = 1.5\lambda$$

$$\text{path difference} = |3\lambda - 1.5\lambda| \quad \text{1 mark}$$

$$= 1.5\lambda$$

$$= 1.5(0.2)$$

$$= 0.3 \text{ m} \quad \text{1 mark}$$

e.

$$\text{path difference} = |3.1 - 2.2|$$

$$= 0.9 \text{ m}$$

$$\frac{\text{path difference}}{\lambda} = \frac{0.9}{0.2}$$

$$= 4.5 \quad \text{1 mark}$$

As this is offset by $\frac{1}{2}$, it satisfies:

$$\text{path difference} = \left(\text{n} - \frac{1}{2}\right)\lambda$$

Therefore, the interference at the point on the edge of the pool is destructive. 1 mark

f. The reflection off the surface of the water that causes glare is generally in a horizontal direction. Polarised glasses if oriented properly (vertically aligned) can block some if not most of that reflection from reaching the users eyes as light is a transverse wave 2 marks

Question 11 (5 marks)

a.

$$\Delta x = \frac{\lambda L}{d}$$

$$= \frac{(638 \times 10^{-9})(1.6)}{3.8 \times 10^{-4}}$$ 1 mark

$$= 2.69 \times 10^{-3} \text{ m}$$ 1 mark

b.

$$\Delta x = \frac{\lambda L}{d}$$

$$L_2 = \frac{d\Delta x}{\lambda}$$

$$= \frac{(3.8 \times 10^{-4})(2.69 \times 10^{-3})}{458 \times 10^{-9}}$$

$$= 2.23 \text{ m}$$ 1 mark

Distance to move the screen back:

$$L = L_2 - L_1$$

$$= 2.23 - 1.6$$

$$= 0.63 \text{ m}$$ 1 mark

c. Any of: 1 mark

- Decrease the distance between the two slits.
- Use a laser with a higher wavelength (less than the red laser) **and** increase the screen distance **or** decrease the distance between the two slits accordingly.
- Use a laser with a higher wavelength (more than the red laser) **and** decrease the screen distance **or** increase the distance between the two slits accordingly.

Using a laser with a lower wavelength is not appropriate, as more adjustments are required.

Question 12 (7 marks)

a.

$$v = f\lambda$$

$$f_0 = \frac{v}{\lambda}$$

$$= \frac{3.0 \times 10^8}{790 \times 10^{-9}}$$

$$= 3.8 \times 10^{14} \text{ Hz}$$ 1 mark

$$E_{k\ \max} = hf - \phi$$

$E_{k\ max} = 0$ at f_0

$$\phi = hf_0$$

$$= (6.63 \times 10^{-34})(3.8 \times 10^{14})$$ 1 mark

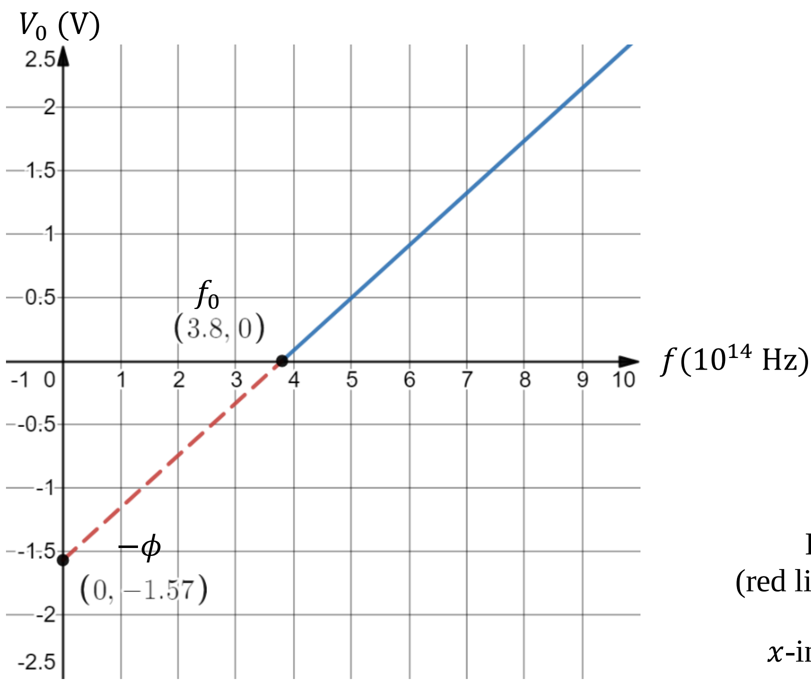
$$= 2.5 \times 10^{-19} \text{ J}$$

$$= \frac{2.5 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= 1.57 \text{ eV}$$ 1 mark

b. Changing the wavelength is effectively changing the frequency. 1 mark
This supports the particle-like nature of light as the photoelectric effect is only observed when a threshold frequency is reached, which suggests that photon carries their own quanta of energy sufficient to release electrons from a material. 1 mark

c.



Line with correct gradient
(red line not required) – 1 mark

x-intercept labelled – 1 mark

Question 13 (3 marks)

a.

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

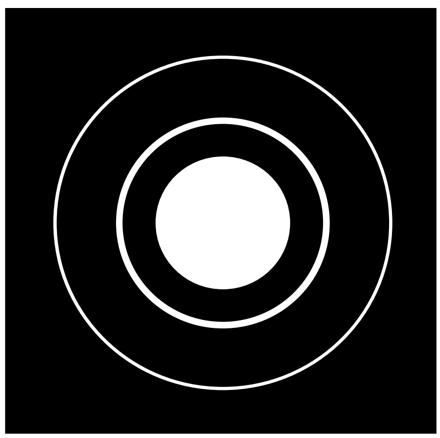
$$= \frac{h}{mv}$$

$$= \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31})(2.36 \times 10^{4})}$$ 1 mark

$$= 3.09 \times 10^{-8} \text{ m}$$

$$= 30.9 \text{ nm}$$ 1 mark

b. Increasing the speed would decrease the wavelength. This would decrease the radii of the diffraction pattern.



1 mark

Drawing as inverted colours acceptable

Question 14 (6 marks)

a. From diagram – count the different levels an electron can jump between.
Mathematically – $3! = 6$ 1 mark

b.

$$\Delta \text{E} = |-11.8 - (-2.6)|$$
$$= 9.2 \text{ eV}$$ 1 mark

$$E = hf$$

$$f = \frac{E}{h}$$
$$= \frac{9.2}{4.14 \times 10^{-15}}$$
$$= 2.2 \times 10^{15} \text{ Hz}$$ 1 mark

$$\lambda = \frac{c}{f}$$
$$= \frac{3.0 \times 10^{8}}{2.2 \times 10^{15}}$$
$$= 1.35 \times 10^{-7} \text{ m}$$ 1 mark

c. Electrons have a de Broglie wavelength and therefore, they can only exist in stable orbits (the energy levels) when standing waves can form, when orbit is an integer factor multiple of the de Broglie wavelength. 1 mark
This means only those energy levels that provide de Broglie wavelengths of standing waves are permitted.. 1 mark

Question 15 (8 marks)

a. Any two of: 2 marks
- Shape of the aerofoil
- Air speed/velocity
- Size of the wind tunnel
- Temperature of the room
- Etc.

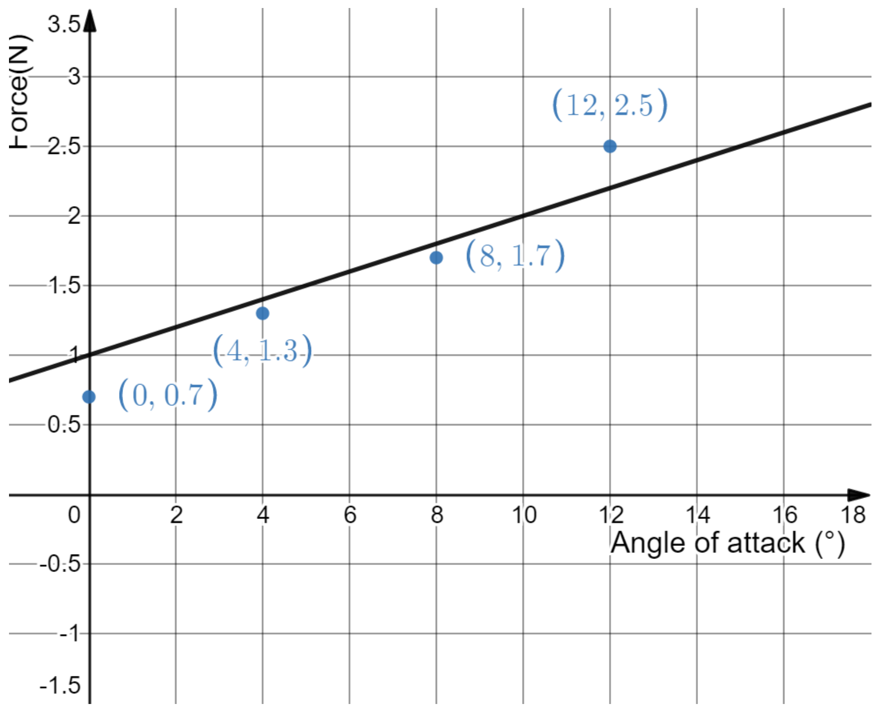
b.

i. Uncertainty $= \pm\frac{1}{2}(\text{smallest increment}) = \pm\frac{1}{2}(0.1)$
$= \pm 0.05$ N

Note: Must include $\pm$
1 mark

ii. This would be represented as error bars in the y direction as the force measured is the dependent variable. 1 mark

c.



Correctly plotted points – 1 mark

Line of best fit (between the points) – 1 mark

d. It is not a good fit for the data 1 mark

Any of: 1 mark

- There are not enough measurements taken (within the data or outside)
- There were not multiple measurements taken to determine outliers
- The line is outside of the uncertainty bars if they were to be plotted
- The relationship between force and AOA may not be linear.