2024 VCAA Physics Solutions

Section A Multiple choice

2024 Question 1, 1 mark

Jo is moving at a constant speed, therefore the net force acting on her is zero. There are two forces acting on Jo, the force due to gravity (which is down) and the force exerted on Jo by the lift floor. These two forces are equal and opposite.

$\therefore F_{\text{on Jo by floor}} = mg$
$= 75 \times 9.81$
$= 736 \text{ N}$

$\therefore$ **C (ANS)**

2024 Question 2, 1 mark

For all satellites orbiting the Earth, the ratio of $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$, this ratio does not involve *m*, (the mass of the satellite), therefore the orbital radius will remain constant at *R*.

$\therefore$ **B (ANS)**

2024 Question 3, 1 mark

There are two forces acting on the ball, the force due to gravity and the tension applied by the string.

$\therefore$ **A (ANS)**

2024 Question 4, 1 mark

The energy stored in the spring, given by the area under the graph, is converted into the KE of the ball as it leaves the tube.

$\therefore \frac{1}{2} F \times \Delta x = \frac{1}{2} mv^2$

$\therefore \frac{1}{2} \times 40 \times 10.0 \times 10^{-2} = \frac{1}{2} \times 50.0 \times 10^{-3} \times v^2$

$\therefore v^2 = \frac{\frac{1}{2} \times 40 \times 10.0 \times 10^{-2}}{\frac{1}{2} \times 50.0 \times 10^{-3}}$

$\therefore v^2 = 80$

$\therefore v = 8.94 \text{ m s}^{-1}$

$\therefore$ **C (ANS)**

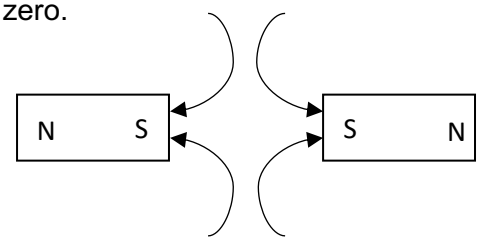
2024 Question 5, 1 mark

The total energy of the rock will remain constant.

$\therefore$ **A (ANS)**

2024 Question 6, 1 mark

If we draw the field lines, is shows that the field at the point X will be very close to zero.



$\therefore$ **A (ANS)**

2024 Question 7, 1 mark

The force on the side PQ is given by

$F = nBiL$

Therefore since there aren't changes in any of the variables, $F_A = F_B$.

The direction of the force is downwards in both diagrams.

In Diagram A the torque is at a maximum value as it is perpendicular to the plane of the loop.

$\therefore$ **D (ANS)**

2024 Question 8, 1 mark

The force on the wire is given by

$F = nBiL$

$\therefore F = 2.0 \times 10^{-3} \times 5.0 \times 4.0 \times 10^{-2}$

$\therefore F = 4.0 \times 10^{-4} \text{ N}$

$\therefore$ **C (ANS)**

2024 Question 9, 1 mark

The new force is larger, therefore the distance between the two charges must be smaller.

The force is given by $F = \frac{kQ_1Q_2}{d^2}$

$\therefore d_{\text{new}} = \sqrt{\frac{1}{6}}\, d_{\text{original}}$

$\therefore d_{\text{new}} = 0.408\, d_{\text{original}}$

$\therefore$ **B (ANS)**

2024 Question 10, 1 mark

On the reasonable assumption that the resistance of the coil remains constant, the current will vary directly as the EMF. Therefore this graph can be modelled as the EMF across the coil.

The induced EMF is given by the gradient of the flux vs time graph. Therefore the flux vs time graph must have a constant gradient, followed by a constant gradient of greater value, followed by a constant gradient of the original value.

∴ **C (ANS)**

2024 Question 11, 1 mark

The energy lost in the transmission lines is given by i^2r, where i is the transmission current and r the transmission line resistance. The power is given by $P = VI$. To transmit a fixed power, if the voltage is increased, the current decreases. This minimises the energy lost in the transmission lines.

∴ **B (ANS)**

2024 Question 12, 1 mark

The flux through the coil is decreasing, therefore the induced EMF will create a current that has a field to oppose this decrease in flux. The induced field need to be upwards (trying to 'add to' the diminishing field).

To create a field upwards, the current in the coli needs to anticlockwise as viewed from above.

∴ **C (ANS)**

2024 Question 13, 1 mark

The split ring commutator will produce a DC output that varies as a function of time.

∴ **A (ANS)**

2024 Question 14, 1 mark

As the person is travelling relative to the window, they will measure a contracted length in the direction of relative motion.

∴ **D (ANS)**

2024 Question 15, 1 mark

With a Lorentz factor of 200, the initial speed of the electrons can be calculated.

Use $\gamma = \dfrac{1}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ to get

$$v = \sqrt{1-\left(\frac{1}{200}\right)^2}\ c$$

$\therefore\ v = 0.999987\ c.$

E_k is given by $(\gamma - 1)mc^2$.

Therefore there will be a small increase in the speed of the electron and a large increase in the kinetic energy.

∴ **B (ANS)**

This is a poorly worded question. For many students it would be difficult to visualise that an increase in the order of 10^{-18} J, is a large increase in energy.

2024 Question 16, 1 mark

This is a challenging question, as it not appropriate to assume that the diagram is drawn to scale (as stated in the instructions for Section A).

Having said that, in my opinion the only way to do this question is to ignore the instructions and assume that you can put a scale to the energy levels and work from there.

I will model my answer on the following guestimates.

$E_5 - E_4 = 1$
$E_4 - E_3 = 1.3$
$E_3 - E_2 = 2.4$
$E_1 - E_1 = 5.3$

Therefore $E_5 - E_1 = 10$
$E_4 - E_1 = 9$
$E_3 - E_1 = 7.7$
$E_5 - E_2 = 4.7$
$E_5 - E_3 = 2.3$

Using $E = hf$, this would give the relative frequencies.

To decide between B and D, I drew it out to scale. D was the better answer.

∴ **D (ANS)**

2024 Question 17, 1 mark

As this is a standing wave, the nodes will remain as nodes, and the antinodes, will cycle from a maximum, through zero, to another maximum (in the opposite direction) and back to the original position. In 0.010 s, the wave will have moved half a cycle.

∴ **B (ANS)**

2024 Question 18, 1 mark

Use $\Delta x = \frac{\lambda L}{d}$
Therefore, if L is doubled, Δx will double.
If d is halved, Δx will double.
The net effect will be, Δx increases by a factor of 4.
∴ **D (ANS)**

2024 Question 19, 1 mark

From $v = \sqrt{\frac{GM}{r}}$, we get
$v^2 = \frac{GM}{r}$ therefore a plot of v^2 vs $\frac{1}{r}$, will give a straight line with a gradient GM
∴ **D (ANS)**

2024 Question 20, 1 mark

Precision is defined as 'the closeness of the data to itself'.
∴ **B (ANS)**

Section B

2024 Question 1a, 1 mark

Use $F_{net} = ma$
$\therefore F_{net} = 9.2 \times 10^4 - (1.2 \times 10^4 + 1.4 \times 10^4)$
$\therefore F_{net} = 6.6 \times 10^4$ N.
$\therefore 6.6 \times 10^4 = (5.0 \times 10^5 + 6.0 \times 10^5) \times a$
$\therefore a = 0.06$ m s^{-2}.
∴ **6.0×10^{-2} m s^{-2} (ANS)**

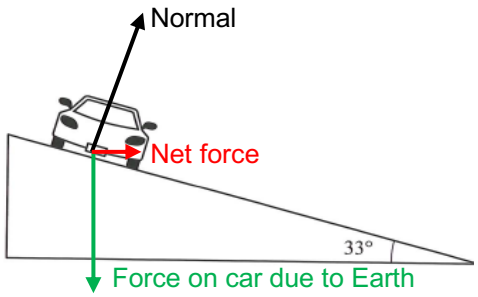
2024 Question 1b, 2 marks

The tension in rope 2 is providing the force to accelerated Boat 3.
Use $F_{net} = ma$
$\therefore T_{rope\ 2} - \text{Friction} = 6.0 \times 10^5 \times 6.0 \times 10^{-2}$
$\therefore T_{rope\ 2} = 6.0 \times 10^5 \times 6.0 \times 10^{-2} + 1.4 \times 10^4$
∴ **$T_{rope\ 2} = 5.0 \times 10^4$ N (ANS)**

2024 Question 2a, 3 marks

Resolving the forces acting on the car which are the Normal force and the force of gravity, we get $\tan\theta = \frac{v^2}{Rg}$.
$\therefore v = \sqrt{Rg \tan\theta}$
$\therefore v = \sqrt{1.2 \times 10^3 \times 9.81 \times \tan 33^0}$
$\therefore v = 87.43$
∴ **$v = 87$ m s^{-1} (ANS)**

2024 Question 2b, 1 mark



The two forces acting on the car are the vertical force on the car due to the Earth, and the normal force. When these two forces are combined the resultant is radially inwards. The normal force, because it is at an angle, has a component in the horizontal. This horizontal component is the unbalanced force that provides the centripetal acceleration.

2024 Question 3a, 3 marks

In the vertical direction, use
$h = ut - \frac{1}{2}gt^2$. (Use $g = -9.81$)
$\therefore h = 48 \times \sin 35^0 \times 6.2 + \frac{1}{2} \times -9.81 \times 6.2^2$.
$\therefore h = -17.85$
This means that the ball lands 17.85 m below it launch position (Which is the height of the cliff).
∴ **$h = 18$ m (ANS)**

2024 Question 3b, 2 marks

In the horizontal, the distance travelled is given by $s = vt$.
$\therefore s = 48 \times \cos 35^0 \times 6.2$
$\therefore s = 243.78$
∴ **$s = 240$ m (ANS)**

2024 Question 3c, 2 marks

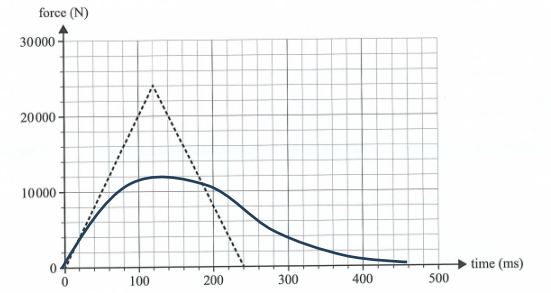
In real life, air resistance will take energy out of the system. Therefore the ball will not travel as high or as far.

2024 Question 4a, 2 marks

The impulse is the given by the area under the F vs t graph.
$\therefore I = \frac{1}{2} \times 240 \times 10^{-3} \times 24\ 000$
$\therefore I = 2\ 880$
∴ **$I = 2.88 \times 10^3$ N s (ANS)**

2024 Question 4b, 2 marks

There will be the same change in momentum, therefore the same impulse.



The graph needs to extend out to 480 ms but have the same area as the original.

2024 Question 5a, 2 marks

The change in momentum is given by

$\Delta p = p_{final} - p_{initial}$.

$\therefore \Delta p = 0.63 \times 10 - - 0.63 \times 12$

$\Delta p = 13.86$

$\Delta p = 14$ kg m s^{-1} (ANS)

The direction is **UP (ANS)**

2024 Question 5b, 2 marks

The collision is inelastic, because the final speed is less than the initial speed, therefore the final E_k is less than the initial E_k. Therefore Kinetic Energy is not conserved.

2024 Question 6, 3 marks

The gravitational force of attraction is given by $F = \frac{GMm}{r^2}$ and for Kwan's suggestion to work, this needs to be the same as the centripetal force given by

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

$$\therefore \frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$\therefore \frac{GM}{r} = v^2$$

$$\therefore GM = v^2 r$$

To check the viability, find the radius 'r'.

$\therefore 6.67 \times 10^{-11} \times 4.5 \times 10^5 = 0.436^2 \times$

$\therefore r = 1.58 \times 10^{-4}$ m

Kwan's suggestion will not work.

2024 Question 7a, 1 mark

The magnetic force on the electron is given by $F = Bqv$, and since the electron moves in a circular path this is the same as $F = \frac{mv^2}{r}$

$$\therefore Bqv = \frac{mv^2}{r}$$

$$\therefore Bq = \frac{mv}{r}$$

$$\therefore v = \frac{Bqr}{m}$$

$$\therefore v = \frac{5.00 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.50 \times 10^{-2}}{9.11 \times 10^{-31}}$$

$\therefore v = 1.317 \times 10^7$ m s^{-1}

$\therefore v = 1.32 \times 10^7$ m s^{-1}

2024 Question 7b, 1 mark

The work done by the electric field is given by qV, this is the E_k.

$\therefore 1.6 \times 10^{-19} \times V = \frac{1}{2} \times 9.11 \times 10^{-31} \times (1.32 \times 10^7)^2$

$\therefore V = 496$ V (ANS)

2024 Question 7c, 3 marks

The proton has the same magnitude of charge as the electron, but the opposite sign. Therefore the force on the proton will initially be in the opposite direction. This will result in the proton moving in a circular path, but initially bending upwards.

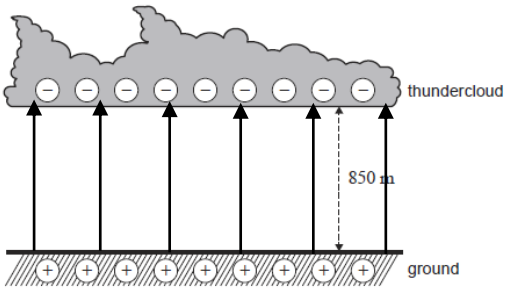
Using $Bqv = \frac{mv^2}{r}$, on rearrangement we get $r = \frac{mv}{Bq}$.

As v, B and q, are the same magnitude, and m_{proton} is approximately 2000 times $m_{electron}$, then $R_{new} = 27$ m.

The circular nature of this motion will be quite difficult to observe.

Even though the question states that no calculations are required, there is no harm (other then lost time) in doing some calculations to confirm your thinking.

2024 Question 8a, 2 marks



2024 Question 8b, 2 marks

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

$$E = \frac{1.20 \times 10^9}{850}$$

$\therefore$ **$E = 1.41 \times 10^6$ V m^{-1} (ANS)**

2024 Question 8c, 2 marks

The energy transferred is given by power multiplied by time.

$\therefore E = VIt$

$\therefore E = 1.20 \times 10^9 \times 30.0 \times 10^3 \times 60.0 \times 10^{-6}$

$\therefore$ **$E = 2.16 \times 10^9$ J (ANS)**

2024 Question 9a, 2 marks

When the coil of wire is in the vertical plane, the current through the split ring commutator is zero. Therefore the force on side FG = 0.

When the coil is in the horizontal plane, the current in FG is parallel to the magnetic field, therefore the force on side FG will be zero.

2024 Question 9b, 2 marks

When the coil of wire is in the vertical plane, the current through the split ring commutator is zero. Therefore the force on all sides is zero.
When the coil is vertical, the force on FE and HG is vertically outwards. The torque is zero, therefore the coil will not start to rotate from this position.

2024 Question 9c, 1 mark

The torque is given by $\tau = BiL \times r$, where r is the radius of action. If i, L and r need to remain the same, then the strength of the magnetic field needs to be increased to increase torque.

2024 Question 10a, 2 marks

The purpose of the slip rings is to maintain a constant point of contact with the rotating loop so that the output alternates.

It will produce an AC voltage because the current in the coil is constantly reversing as the coil rotates.

2024 Question 10b, 2 marks

The peak to peak voltage is **8 V (ANS)**
The frequency is the number of cycles per second, $f = \frac{1}{T}$ Where T, the period is the time to complete one cycle.

$\therefore f = \frac{1}{0.2}$

$\therefore$ **$f = 5$ Hz (ANS)**

2024 Question 10c, 3 marks

The magnitude of the induced EMF has double, whilst the period has remained constant.

Use EMF = $n\frac{\Delta(BA)}{\Delta t}$, where Δt needs to remain constant (otherwise the period would change).
Therefore Taylor needs to double the strength of the magnetic field, double the number of turns in the coil (or use two coils), or double the area of the coil.

2024 Question 11a, 1 mark

Use $\frac{n_1}{n_2} = \frac{V_1}{V_2}$

$\therefore \frac{460}{n_2} = \frac{230}{36}$

$\therefore n_2 = 72$

$\therefore$ **72 Turns (ANS)**

2024 Question 11b, 2 marks

The transformer is ideal, therefore the power in = power out.

$\therefore (VI)_{in} = (VI)_{out}$

$\therefore 230 \times I_{in} = 36 \times 0.8$

$\therefore I_{in} = 0.125$

$\therefore$ **$I_{in} = 0.13$ A (ANS)**

2024 Question 11c, 2 marks

The transformer relies on an AC input, so that the changing current in the primary coil produces a changing magnetic field in the soft iron core of the secondary coil, of the transformer. This changing field creates a changing flux in the secondary coil which induces the EMF across the secondary. If the input to the primary is a constant DC input, then there isn't a change in the flux to induce an EMF across the secondary coil.

2024 Question 12a, 1 mark

The maximum power is the sum of the individual panels.

$\therefore 50 \times 600 = 3.0 \times 10^4$

$\therefore$ **30 kW (ANS)**

2024 Question 12b, 2 marks

The maximum output voltage is the sum of the voltages in a string, as they are connected in series.

$\therefore 10 \times 20$ **= 200 V (ANS)**

The current through each of the panels in a string is the same, because they are connected in series.

Each panel has a maximum output of 600 W and 20 V, therefore the current is **30 A (ANS)**

2024 Question 12c, 2 marks

As the strings are connected in parallel, the maximum output voltage will be the maximum voltage across each string.

$\therefore$ **200 V (ANS)**

As they are connected in parallel the maximum output current will be the sum of the maximum current in each string.

$\therefore 30 \times 5 =$ **150 A (ANS)**

2024 Question 12d, 1 mark

The function of the inverter is to change DC output to an AC output.

2024 Question 13a, 1 mark

Use $v = \frac{d}{t}$, to get $t = \frac{d}{v}$

$$\therefore t = \frac{9700 - 6500}{0.985 \times 3.00 \times 10^8}$$

$\therefore t = 1.0829 \times 10^5$

$\therefore t = 10.8$ μs

2024 Question 13b, 1 mark

No, If the muons have a mean lifetime of 2.20 μs, they would need to live through almost 5 lifetimes to make it to the top of the mountain.

2024 Question 13c, 2 marks

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

$$\therefore \gamma = \frac{1}{\sqrt{1 - (0.985)^2}}$$

$\therefore \gamma = 5.795$

$\therefore$ **γ = 5.80 (ANS)**

2024 Question 13d, 1 mark

The mean lifetime of the muon (which is what the examiner meant to ask, and is different to the mean half-life) will be the dilated proper time. The physicists are measuring the dilated time because they need to use two clocks, one where the muon is created and one where the muon ceases to exist.

$\therefore t = 5.795 \times 2.20 \times 10^{-6}$

$\therefore t = 1.249 \times 10^{-5}$

$\therefore$ **t = 12.5 μs (ANS)**

2024 Question 13e, 3 marks

If muons are stationary to an inertial frame of reference their mean lifetime is a 'proper time', $t_0 = 2.20$ μs.

From the frame of reference of the muon, the Earth is in relative motion, so the distance travelled by the Earth is contracted. Therefore the Earth travels (552 m) to the muon (at a speed of 0.985c) in the time (1.87 μs) before it has decayed.

Which results in more muons arriving than would be predicted from classical mechanics.

2024 Question 14a, 2 marks

Use $E = \Delta mc^2$

$\therefore E = 2 \times 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2$

$\therefore E = 1.6398 \times 10^{-13}$

$\therefore$ ***E* = 1.64 × 10^{-13} J (ANS)**

2024 Question 14b, 1 mark

Momentum is conserved in all collisions. The initial momentum was close enough to zero, therefore the final momentum needs to be zero. Since each gamma ray has momentum, they both need to travel in opposite directions to result in zero net momentum.

2024 Question 15a, 2 marks

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

$\therefore p = \frac{6.63 \times 10^{-34}}{2.00 \times 10^{-10}}$

$\therefore$ ***p* = 3.32 × 10^{-24} kg m s^{-1} (ANS)**

2024 Question 15b, 2 marks

Max is correct.
The wavelength of the electron close to, but, smaller than the interatomic spacing, this will lead to a pattern being formed.

2024 Question 15c, 2 marks

The shape of the diffraction patterns depends on the ratio of $\frac{\lambda}{w}$, where λ is the wavelength and w is the gap spacing. As the gap spacing was identical, if they both have the same patterns then the electrons must have a wavelength similar to that of the X-rays.

2024 Question 15d, 2 marks

The diffraction is given by the ratio of $\frac{\lambda}{w}$, where λ is the wavelength and w is the diffraction grid spacing.

To get two identical patterns the wavelength of the X-rays needs to be the same as that of the electrons.

The energy of the X-rays is, $E = \frac{hc}{\lambda}$,

$\therefore E = \frac{4.14 \times 10^{-15} \times 3.00 \times 10^{8}}{5.01 \times 10^{-11}}$

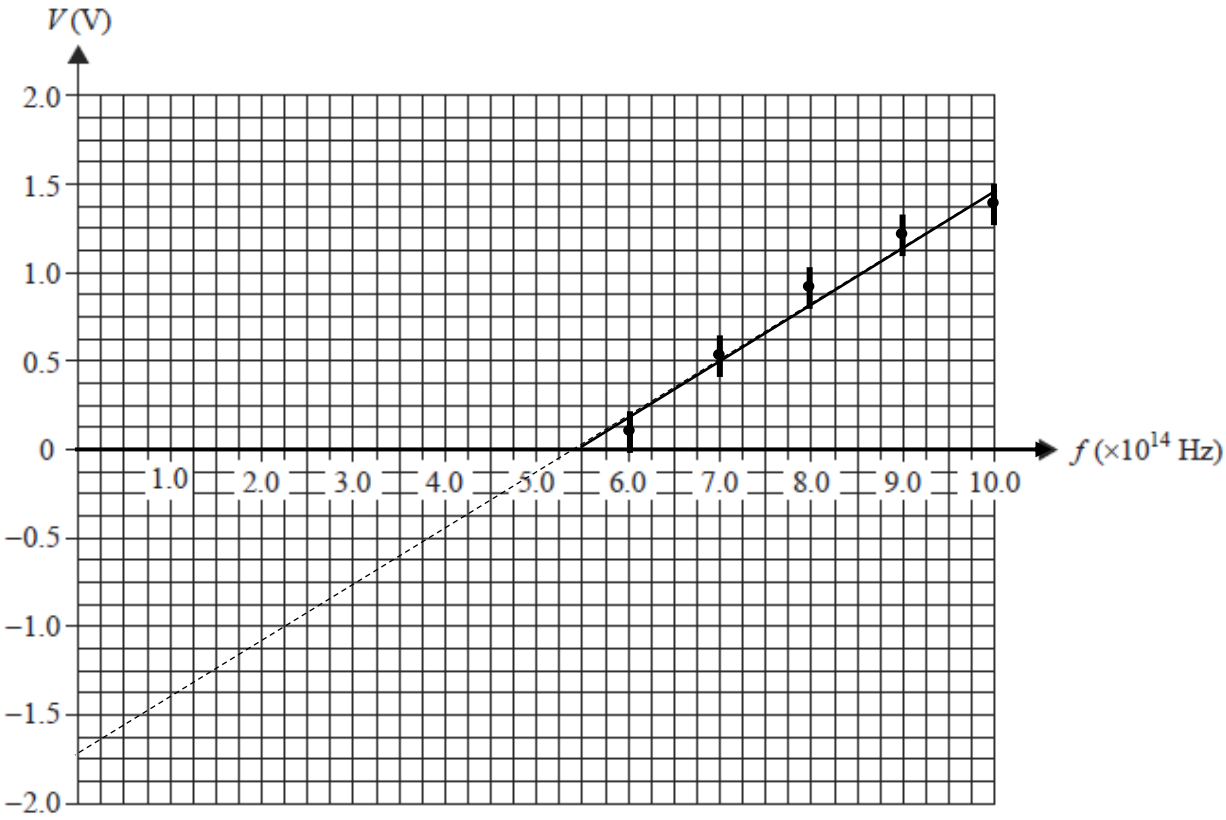
$\therefore E = 24{,}790$

$\therefore$ ***E* = 2.48 × 10^{4} eV (ANS)**

2024 Question 16a, 3 marks

Controlled
metal surface in the photocell
Dependent
Voltage required to stop the current
Independent
Frequency of light source

2024 Question 16b, 3 marks



2024 Question 16c i, 2 marks

Planck's constant is the gradient of the line. Make sure that you use two points on your line.
Use $(10.0 \times 10^{14}, 1.48)$ and $(5.5 \times 10^{14}, 0)$

$$\text{Gradient} = \frac{1.48 - 0.0}{10.0 \times 10^{14} - 5.5 \times 10^{14}}$$

$\therefore$ h = 3.3 × 10^{-15} eV s (ANS)

2024 Question 16c ii, 1 mark

The threshold frequency is the horizontal intercept.

$\therefore$ 5.5 × 10^{14} Hz (ANS)

2024 Question 16c iii, 1 mark

The work function is the vertical intercept.

1.75 eV (ANS)

2024 Question 16d, 2 marks

The voltage measurement is a measure of the energy required to prevent the most energetic photoelectron that was released from the metal surface reaching the collector. The collector is at a negative potential to the emitter and so the emitted photoelectrons need to work against the electric field to reach the collector. Increasing the voltage increases the electric field, making it more difficult for the electrons to reach the collector. Therefore the voltage is a measure of the maximum KE of the emitted photoelectrons.

2024 Question 16e, 1 mark

Using a different metal, will mean that the work function of the metal changes. The gradient of the graph will remain the same, (Planck's constant) but both intercepts will change on the graph. The new graph will be parallel to the original.

2024 Question 16f, 2 marks

Replacing the green filter with a blue filter, leads to the incident photons having more energy. Therefore the ejected photoelectrons can be emitted with more energy, as hence the voltage required to

stop the most energetic photoelectron will increase. This will move the point P to the left.

Left (ANS)

2024 Question 16g, 2 marks

Since the power of both light sources is identical, and since the blue photons have more energy, then when the blue light is used less photons per second will be produced. This means that less photoelectrons will be released each second. Therefore the photocurrent will be smaller.

Lower (ANS)

2024 Question 16h, 3 marks

The cut off frequency can be explained using the particle model but not the wave model.
Einstein's explanation of the photo electric effect said that the electron needed a certain amount of energy to escape the metal. Therefore the incident photon needed to give the electron at least this amount of energy. The photon model says that the energy of the photon is $E = hf$, so there is a minimum frequency needed to release a photoelectron. This is the cut-off frequency, below which no electrons will be emitted from the metal.