PHYSICS

Units 3 & 4 – Written examination

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(TSSM's *2012 trial exam updated for the current study design*)

SOLUTIONS

SECTION A – Multiple Choice questions (1 mark each)

Question 1

Answer: D

Explanation:
Two negative charges will repel one another hence D depicts field lines of repulsion.

Question 2

Answer: C

Explanation:
The gravitational field will be inwards towards the proton whereas the electric field will radiate out hence the direction is opposite. The electric field strength will be a lot stronger.

Question 3

Answer: A

Explanation:
Electricity and magnetism depend charge whereas gravity depends on mass.

Question 4

Answer: C

Explanation:
Using the Right Hand Rule, the force would be perpendicular to the field.

Question 5

Answer: C

Explanation:
Using Right Hand rule, the direction of force coming from the back of the hand as it is an electron moving hence the field would be going into the page.

Question 6

Answer: A

Explanation:
Variables measured to see possible effects of a *manipulation*s are *dependent variables*.

Question 7

Answer: D

Explanation:
A hypothesis should not restate the question but offer a prediction to the likely outcome of the experiment.

Question 8

Answer: B

Explanation:
$N = mg\cos\theta$
Therefore increasing the angle decreases the normal reaction force.

Question 9

Answer: D

Explanation:
The velocity will be changing constantly due to the direction, the instantaneous velocity will be on a tangent to the circle and the acceleration is towards the centre. Therefore none of the above.

Question 10

Answer: C

Explanation:
Inertia is a tendency of an object to stay in motion or at rest.

Question 11

Answer: B

Explanation:
Less dense to more dense, light slows hence it will bend towards the normal.

Question 12

Answer: B

Explanation:
Wavelength becomes shorter hence the frequency increases.

Question 13

Answer: B

Explanation:
The uncertainty principle says that we cannot measure the position and the momentum of a particle with absolute precision.

Question 14

Answer: D

Explanation:
Einstein's first postulate is not any different to that of classical relativity but he intended that it should apply to electromagnetic radiation, including light. The second postulate was in complete contradiction to classical physics which held that the velocity of anything depended on the frame of reference in which it was measured.

Question 15

Answer: A

Explanation:
A standing wave results from a reflected wave superimposing with an incident wave in a pipe. The wave is reflected due to a change in pressure as it reaches the opening.

Question 16

Answer: B

Explanation:
$f_n = \frac{nv}{2L} = \frac{1\times 340}{2\times 1.2} = 142 \text{ Hz}$

Question 17

Answer: C

Explanation:
Equation changes to 4L instead of 2L due to there being no phase change of the reflected wave, hence the fundamental frequency is now 71 Hz

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Question 18

Answer: C

Explanation:

$$V_{peak} = \sqrt{2} \times V_{RMS}$$
$$V_{peak} = \sqrt{2} \times 250$$
$$V_{peak} = 354\,V$$

Question 19

Answer: B

Explanation:
V_{prim} = 250 V

$$V_{\sec} = \frac{P}{I} = \frac{400}{40} = 10\,V$$
$$N_{prim} : N_{\sec} = V_{prim} : V_{\sec}$$
$$N_{prim} : N_{\sec} = 250 : 10$$
$$N_{prim} : N_{\sec} = 25 : 1$$

Question 20

Answer: A

Explanation:

$$N_{prim} : N_{\sec} = I_{\sec} : I_{prim}$$
$$25 : 1 = 40 : I_{prim}$$
$$I_{prim} = 1.6\,A$$

SECTION B: Short Answer

Question 1 (7 marks)

a. *Answer*: 3.6 N kg^{-1}

Explanation: Use Newton's Law of Universal Gravitation:

$$g = \frac{GM}{R^2}$$
$$g = \frac{6.67\times10^{-11}\times6.37\times10^{23}}{\left(3.43\times10^{6}\right)^2}$$
$$g = 3.6\,N\,kg^{-1}$$

2 marks

b. *Answer*: 8.21 × 10^5 m

Explanation: Use rearranged satellite equation:

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$$
$$R = \sqrt[3]{\left(\frac{6.67\times10^{-11}\times6.37\times10^{23}\times8450^2}{4\pi^2}\right)}$$
$$Altitude = R - R_{mars}$$
$$Alt = 4.25\times10^6 - 3.43\times10^6$$
$$Alt = 8.21\times10^5\,m$$

3 marks

c. *Answer*: 7.0 × 10^9 J

Explanation:

$$v = \sqrt{\frac{GM}{R}}$$
$$and: KE = \frac{1}{2}mv^2$$
$$KE = \frac{GMm}{2R}$$
$$KE = \frac{6.67\times10^{-11}\times6.37\times10^{23}\times1400}{2\times4.25\times10^6}$$
$$KE = 7.0\times10^9\,J$$

2 marks

Question 2 (7 marks)

a. *Answer*: 4.0×10^{-15} J

$W = qV = 1.6{\times}10^{-19}{\times}25{\times}10^{3}$
$W = 4.0 \times 10^{-15}$ J

2 marks

b. $E_k = 4.0{\times}10^{-15} + 1.3\,{\times}10^{-16} = 4.13{\times}10^{-15}$ J

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

$4.13{\times}10^{-15} = \frac{1}{2}\,{\times}1.67{\times}10^{-26}{\times}v^2$

$v = 7.0\,{\times}10^{5}$ m s^{-1}

3 marks

c. W = Fd

$4.0{\times}10^{-15} = F{\times}1.2$

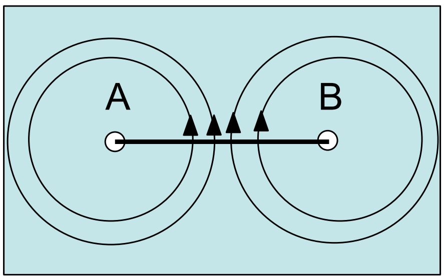
$F = 2.66{\times}10^{-15}N$

2 marks

Question 3 (7 marks)

a. *Answer*: **See picture below**

Plan View



Explanation: Field lines must be continuous. Use RH grip rule to determine direction.

2 marks

b. *Answer*: **5.4×10^{-3} N, directed UP**

Explanation: Using the RH slap rule with magnetic field directed out of the page due to the current in the loop (as per side view), force on 0.2 A carrying wire:

$F = BIL$

$F = 0.3 \times 0.2 \times 0.09$

$F = 5.4 \times 10^{-3} N$

3 marks

c. *Answer*: **0 N, direction: none**

Explanation: Current is parallel to direction of magnetic field, so RH slap rule dictates no force on the wire.

2 marks

Question 4 (6 marks)

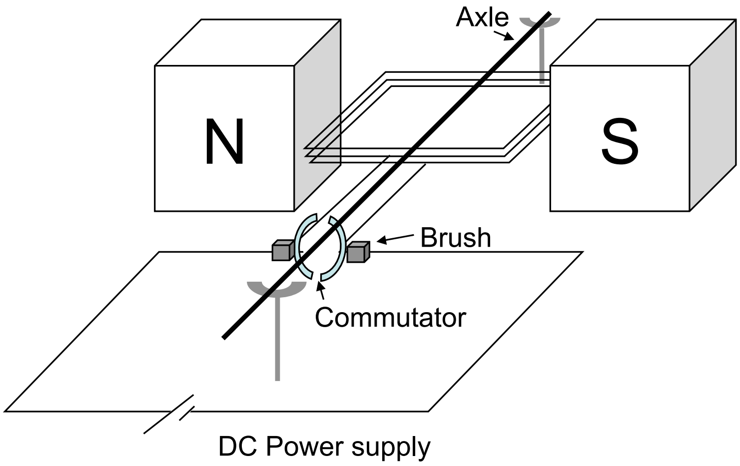
a. *Answer*: **5.2 A, directed from A to B (into the page).**

Explanation: Use RH slap rule for direction: field left to right, force down.

$$F = nBIL$$
$$I = \frac{F}{nBL}$$
$$I = \frac{1.3}{25 \times 0.25 \times 0.04}$$
$$I = 5.2 \text{ A}$$

3 marks

b. *Answer*: **See picture below**



Explanation: The loop will experience no torque in the vertical position (i.e. Forces concurrent and no rotation achieved). Thus, the commutator must be oriented so it reverses the current at this vertical position.

1 mark

c. A commutator is designed to change the direction of the current in the coil so that the force on side AB (and the opposite side of the loop) reverses every 180°. This ensures continuous rotation.

2 marks

Question 5 (5 marks)

a. *Answer*: **A**

Explanation: When the switch is connected, the solenoid will generate a strong magnetic field from right to left (i.e. A North pole at the left end). This will repel the hanging permanent magnet and continue to do so until the switch is disconnected.

2 marks

b. Temporary current flows from B to A, back to zero once the magnet is stationary. Bringing the north pole towards the solenoid will increase the flux, which is opposed by an induced field in the solenoid (to the left), in accordance with Lenz's Law. Application of the RH grip rule shows that induced current would flow from B to A, but only during the time that the magnet is moving (i.e. While flux is changing).

3 marks

Question 6 (12 marks)

a. *Answer*: **80 V**

Explanation: Use the transformer ratios.

Voltage on the secondary side of the generator transformer is 2500 V (step up)
Voltage on the primary side of the factory transformer is 2420 V (step down).
The difference is the voltage drop in the cables, 80 V.

2 marks

b. *Answer*: **12000 turns**

Explanation: Turns ratio of 1:10 in the step up transformer, so $1200 \times 10 = 12000$.

1 mark

c. *Answer*: $\mathbf{1 \times 10^5}$ **W**

Explanation: Use the answer to Question 6a, $V_{drop} = 80$ V and the resistance of 2 Ω, so $I_{cables} = 40$ A

$$V = IR$$

$$I = \frac{V}{R}$$

$$I = \frac{80}{2}$$

$$I = 40\,A$$

Then, $I_{gen} = 40 \times 10 = 400$ A due to the transformer.
Thus, $P_{gen} = VI = 250 \times 400 = 100{,}000$ W

2 marks

d. *Answer*: **1131 A**

Explanation:

$$I_{p-p} = 2\sqrt{2} \times I_{RMS}$$
$$I_{p-p} = 2\sqrt{2} \times 400$$
$$I_{p-p} = 1131A$$

2 marks

e. *Answer*: **97 %**

Explanation:

$$\%efficiency = \frac{P_{factory}}{P_{generator}}$$
$$\%efficiency = \frac{242 \times 400}{10000}$$
$$\%efficiency = 97\%$$

2 marks

f. The turns ratio of the two transformers would need to be increased, so that the current in the lines was further reduced. Thus Power Loss ($P = I^2R$) would be reduced and the overall efficiency of the system would be increased. Practically, there would be safety constraints that would limit the voltage in the lines, so the transformers could not step up the generator voltage too high.

3 marks

Question 7 (8 marks)

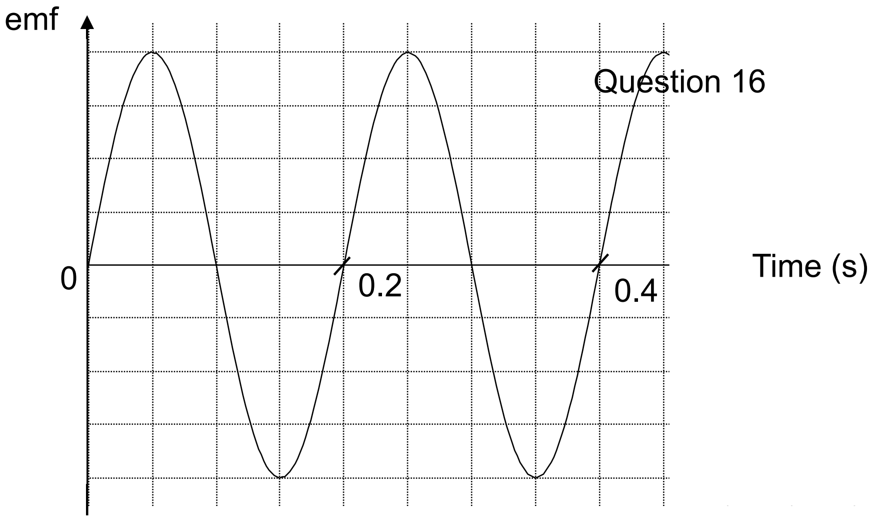
a. *Answer*: **1.0×10^{-3} Wb**

Explanation: Note that flux is not dependent on the number of loops in a coil.

$$\phi = BA$$
$$\phi = 0.4 \times (0.05)^2$$
$$\phi = 1.00 \times 10^{-3}\,Wb$$

2 marks

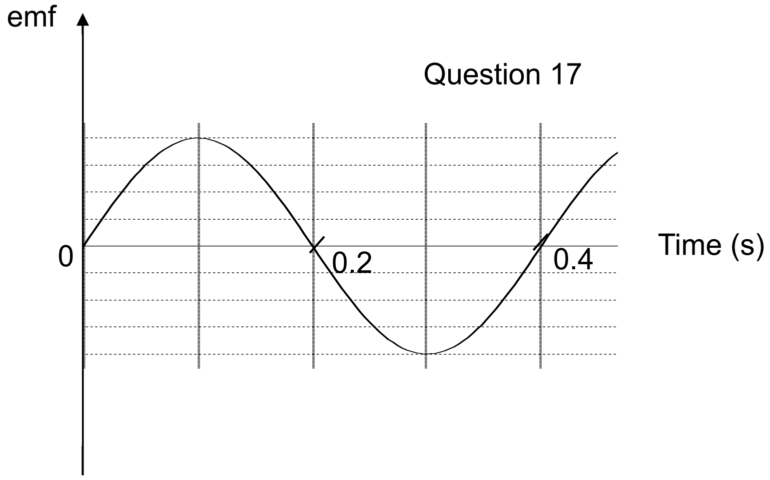
b. *Answer*: See diagram below.



Explanation: emf is induced in accordance with Faraday's law ($\xi = -n\dfrac{\Delta\phi}{\Delta t}$) and is proportional to the change in flux over time. Furthermore, Lenz explains that the field will oppose any change in flux so the voltage is negative. Thus, the emf curve is essentially a negative gradient function of the flux curve.

2 marks

c. *Answer*: See diagram below. Note: The vertical scale is halved.



Explanation: Similar to Question 7b, but now period is doubled as the rotation is slower. This reduces emf by a factor of 2 due to Faraday's law. The effect of doubling field strength and halving number of loops cancel each other out. So, overall voltage is reduced by a factor of 2 and period is doubled.

2 marks

d. A commutator would reverse the direction of the current through the load every 180°, so the overall voltage would be "fully rectified" (see sample picture below). In contrast, slip rings are connected to the same side of the coil at all times, so they would simply take the voltage as it is generated and the load would experience AC.

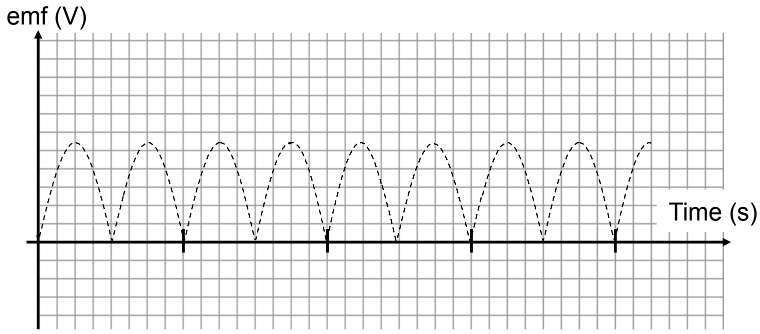


Figure: Voltage output across load with commutator used.

2 marks

Question 8 (4 marks)

a. 1.58 m s^{-2}

Explanation: Be careful to consider the total moving mass of man and crate when calculating overall acceleration.

$$F_{net} = m_{crate}g - m_{man}g$$
$$F_{net} = 110\times10 - 80\times10$$
$$F_{net} = 300(\text{on both the man and the crate})$$
$$F_{net} = ma$$
$$300 = (80+110)\times a$$
$$a = 1.58\,ms^{-2}$$

2 marks

b. *Answer*: 926 N

Explanation: Tension and weight force on man should give an acceleration of 1.58 m s^{-2} on the man

$$F_{net} = ma$$
$$T - m_{man}g = 80 \times 1.58$$
$$T = 80 \times 1.58 + 800$$
$$T = 926\,N$$

2 marks

Question 9 (5 marks)

a. *Answer:* 8.13 m

Explanation:
Max height is given by shortcut formula plus the 2.5 m starting height of the ramp:

$$h_{\max} = \frac{v^2 \sin^2 \theta}{2g} + 2.5$$
$$h_{\max} = \frac{21^2 \sin^2 30}{2 \times 9.8} + 2.5$$
$$h_{\max} = 8.125m$$

Can also solve using traditional SUVAT equations.

$$v^2 = u^2 + 2as$$
$$s = \frac{v^2 - u^2}{2a}$$
$$s = \frac{0 - (21 \sin 30)^2}{2 \times 8.8}$$
$$s = 5.625m$$
$$Plus\,2.5m\,ramp : s = 8.125m$$

2 marks

b. *Answer:* The rider will not make the jump.

Explanation: Determine the time taken to travel the 30 m horizontal distance to the edge of the building and then assess the height to check whether he has cleared the roof line.

$$time = \frac{x}{v\cos\theta}$$
$$time = \frac{30}{21\cos 30}$$
$$time = 1.65s$$
$$height = 2.5 + ut - \frac{1}{2}at^2$$
$$height = 2.5 + v\sin\theta \times 1.65 - \frac{1}{2}\times 9.8\times 1.65^2$$
$$height = 6.48m$$

Clearly, this is too low for a building which is 7 m high.

3 marks

Question 10 (6 marks)

a. *Answer:*

i. The relativity postulate: the laws of physics apply in every inertial reference frame.

ii. The speed of light postulate: The speed of light in vacuum is the same for any inertial reference frame ($c = 3.00 \times 10^8$ ms^{-1}). This is true no matter how fast a light source is moving relative to an observer.

2 marks

b.

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{0.6c^2}{c^2}}} = 1.25$$

2 marks

c. $t = t_o\gamma = 1.25 \times 4 = 5$ s

2 marks

Question 11 (6 marks)

a.

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

$$325 = 1150\sqrt{1 - \frac{v^2}{c^2}}$$

$v = 0.96c = 2.88{\times}10^8$ m s^{-1}

2 marks

b.

i. $E = mc^2 = 75 \times (3{\times}10^8)^2 = 6.75 \times 10^{18}$ J

2 marks

ii. $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{0.96c^2}{c^2}}} = 3.57$

$E = \gamma mc^2 = 3.57 \times 6.75 \times 10^{18} = 2.41 \times 10^{19}$ J

2 marks

Question 12 (5 marks)

a. *Answer:* Collision 2, with calculation as per below.

Explanation: In Collision 2, Car A experiences a greater change in momentum and thus for the same impact time, it will experience a larger force and more damage.

For Collision 1:

$$F = \frac{m\Delta v}{\Delta t}$$

$$F = \frac{1100 \times 20}{0.2} =$$

$$F = 1.1 \times 10^5\ N$$

For Collision 2:

$$F = \frac{m\Delta v}{\Delta t}$$

$$F = \frac{1100 \times 40}{0.2} =$$

$$F = 2.2 \times 10^5\, N$$

3 marks

b. Figure 6 collision is not isolated as momentum is transferred to the ground via the wall.

2 marks

Question 13 (5 marks)

a. *Answer*: 67.5 N

Explanation:

$$AppWeight = m \times (g - a)$$

$$AppWeight = 9 \times (10 - \frac{v^2}{r})$$

$$AppWeight = 9 \times (10 - \frac{10^2}{40})$$

$$AppWeight = 9 \times (10 - 2.5)$$

$$AppWeight = 67.5\, N$$

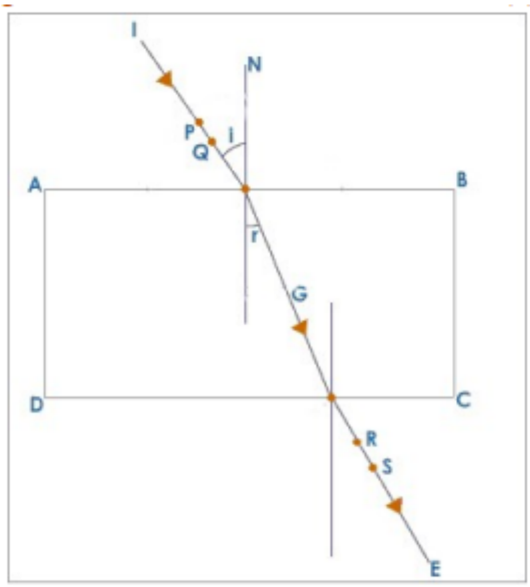
3 marks

b. Lighter, because 67.5 N apparent weight is less than his “rest” weight of 90 N.

2 marks

Question 14 (9 marks)

a. The apparatus was set up as shown in diagram. A glass block was placed on a sheet of paper and its outline ABCD drawn. Two pins, P & Q were placed on one side of the block and two other pins, R & S were placed on the other side of the block so that they were in a straight line with pins P & Q, as seen viewed through the block. The block was then removed and the incident ray, I, the refracted ray, G and the emergent ray, E, as well as the normal N were drawn. The angle of incidence, i and the angle of refraction, r are then measured using a protractor.

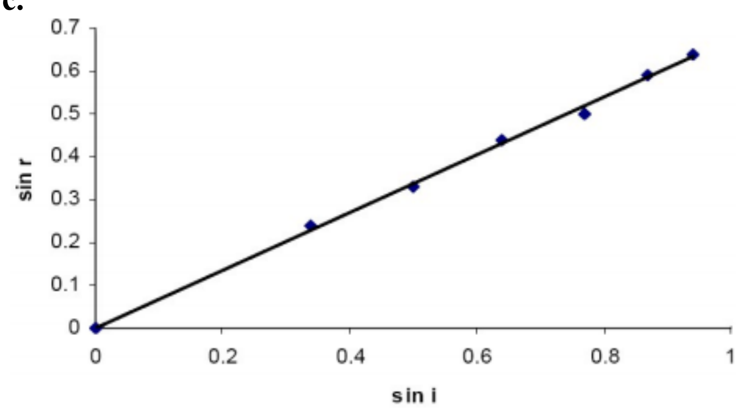


2 marks

b. Dependent = angle of refraction
Independent = angle of incidence

2 marks

c.



The graph of sin i against sin r is a straight line passing through the origin. Therefore sin i is proportional to sin r and Snell's law is thus verified.

3 marks

d. Random or personal reading error – angles may not have been accurately measured by the observer

2 marks

Question 15 (6 marks)

a. *Answer*: **1.02×10^{-6} m**

Explanation: $S_1A - S_2A$ represents the path difference, which would be 2λ if A is the third bright band (including the centre, C).
So,
$PD = 2\lambda = 2 \times 510 = 1020\,nm$

2 marks

b. When the path difference between Slit 1 and Slit 2 is a whole integer multiple of the wavelength (e.g. 2λ), light from each source will arrive at the screen in phase and complete constructive interference will result, leading to a bright band. This concept of constructive interference is purely in the domain of the wave model. The particle model cannot effectively explain the alternating dark and bright bands.

2 marks

c. *Answer*: **C and D**

Explanation: Decreasing the distance between the slits would lead to a wider pattern, but the path difference remains proportional only to the wavelength
($S_1A - S_2A = n\lambda = 2\lambda$)

2 marks

Question 16 (4 marks)

a. *Answer*: **589 nm**

Explanation:

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E}$$

$$\lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2.11}$$

$$\lambda = 5.89 \times 10^{-7}\,m$$

2 marks

b. In this case, the discrete energy levels at 2.11 eV and 1.63 eV do not permit a jump of 2.00 eV, so a photon of this energy will not be emitted.
Electrons can be considered as particles in terms of the way they make transitions between energy levels in an atom. However, they must also be considered to have wavelike properties as they can only exist as standing waves with only discrete wavelengths feasible to form an excited state. Discrete wavelengths correspond to discrete momenta, which implies discrete energy levels around the nucleus.

2 marks

Question 17 (6 marks)

a. The diffraction pattern is evidence of wavelike behaviour of electrons. Furthermore, both electrons and x-rays will diffract in similar ways, as long as the de Broglie wavelength of the electron is comparable to that of the x-rays. For the electrons: $\lambda = \frac{h}{p} = \frac{h}{mv}$. So if similar diffraction patterns are observed, we can conclude that the momentum of these electrons and x-rays are essentially the same.

1 mark

b. *Answer*: **2.49 nm**

Explanation:

$$E = \frac{hc}{\lambda}$$
$$\lambda = \frac{hc}{E}$$
$$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{8 \times 10^{-17}}$$
$$\lambda = 2.49 \times 10^{-9}\, m$$

2 marks

c. *Answer*: **2.93×10^{5} m s^{-1}**

Explanation:

$$\lambda = \frac{h}{mv}$$
$$v = \frac{h}{m\lambda}$$
$$v = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2.49 \times 10^{-9}}$$
$$v = 2.93 \times 10^{5}\, m\, s^{-1}$$

2 marks

d. *Answer*: **B**

Explanation: Increasing the accelerating voltage would increase the speed and thus decrease the de Broglie wavelength of the electrons. Diffraction is proportional to $\frac{\lambda}{w}$, so this would decrease and the pattern would become compressed (reduced radius).

1 mark

Question 18 (8 marks)

a. *Answer*: **359 nm**

Explanation:

$$Vq = hf - W$$

$$Vq + W = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{Vq + W}$$

$$\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.9\times1.6\times10^{-19}+2.5\times10^{-19}}$$

$$\lambda = 3.59\times10^{-7}\,m$$

2 marks

b. *Answer*: **3.77 × 10^{14}** Hz

Explanation:

$$W = hf_0$$

$$f_0 = \frac{W}{h}$$

$$f_0 = \frac{2.5\times10^{-19}}{6.63\times10^{-34}}$$

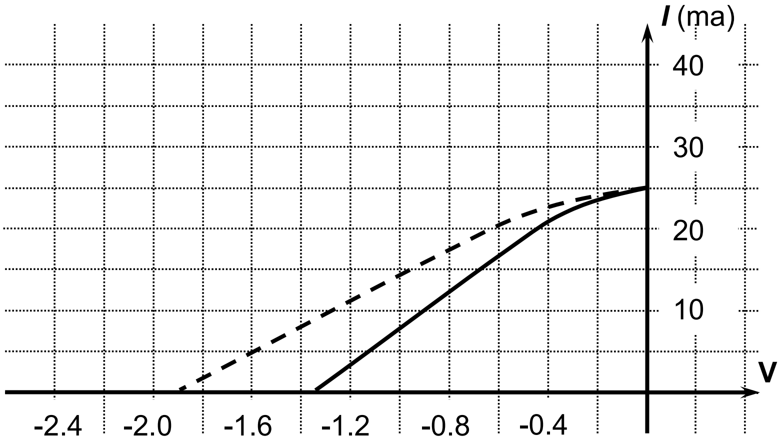
$$f_0 = 3.77\times10^{14}\,Hz$$

2 marks

c. The existence of a threshold frequency as a minimum frequency required to liberate an electron in the photoelectric effect is important because it violates a prediction of the wave model and can be explained effectively using the photon (particle) model for light. The wave model predicts that, even at low frequencies, sufficient energy will accumulate (over time) to eventually liberate an electron (wave energy can add to one electron). In contrast, the photon model correctly predicts that low frequency, low energy photons (less than the work function) will not liberate any electrons as they operate in a one-to-one relationship.

2 marks

d. *Answer*: **See picture below (answer is solid line)**



Explanation: Increasing the work function of the metal will lead to less energetic electrons being ejected (more photon energy is absorbed by the metal). This will mean that the stopping voltage will be less.
However, assuming the intensity of the source is maintained and the frequency of the source is still above the threshold, the number of photons will remain constant. So, when no retarding voltage is applied, *I* will be the same for both metals.

2 marks