PHYSICS

Units 3&4 – Written examination

TSSM
Creating VCE Success

2018 Trial Examination

SOLUTIONS

SECTION A

Question 1

Answer: **C**

Explanation: Use the RH grip rule for the current through the solenoid. This will yield field lines from left to right through the solenoid and so the field at P is directed East.

Question 2

Answer: **D**

Explanation: Use $F = qE$.

$F = 3.2 \times 10^{-19} \times 1.2 \times 10^{4}$
$F = 3.84 \times 10^{-15}$ N

Question 3

Answer: **A**

Explanation: Use $E = \frac{V}{d}$.

$$d = \frac{V}{E}$$
$$d = \frac{150}{1.2 \times 10^{4}}$$
$$d = 0.0125 \text{ m}$$
$$d = 1.25 \text{ cm}$$

Question 4

Answer: **C**

Explanation: Use $\frac{V_1}{V_2} = \frac{n_1}{n_2}$.

$$n_2 = n_1 \times \frac{V_2}{V_1}$$
$$n_2 = 30 \times \frac{225}{15}$$
$n_2 = 450$ turns

Question 5

Answer: **B**

Explanation: Use $P = VI$, then $I_{peak} = I_{RMS} \times \sqrt{2}$

$$I_{RMS\ (SEC)} = \frac{P}{V}$$
$$I_{RMS\ (SEC)} = \frac{450}{225}$$

$I_{RMS\ (SEC)} = 2$ A

$I_{peak} = I_{RMS} \times \sqrt{2}$

$I_{peak} = 2 \times \sqrt{2}$

$I_{peak} = 2.8$ A

Question 6

Answer: **B**

Explanation: Due to Faraday's Law $\varepsilon = -n\frac{\Delta\phi}{\Delta t}$, the *emf* is effectively the negative gradient function of a flux vs. time graph. For example, a constant positive gradient on flux vs. time will lead to a constant negative section on the *emf* graph. Furthermore, constant flux will lead to zero *emf*.

Question 7

Answer: **B**

Explanation: An inertial reference frame is one that is moving at a constant velocity. A, C & D are all accelerating in some way, whilst B is moving at a constant velocity (albeit very fast).

Question 8

Answer: **A**

Explanation: Use $E = mc^2$

$E = mc^2$
$E = 5.6 \times 10^{-27} \times (3 \times 10^8)^2$
$E = 5.0 \times 10^{-10}$ J

Question 9

Answer: **A**

Explanation: Diffraction (spreading) of a wave depends on the wavelength of the source, so there will be variation in intensity with the two different frequencies.

Question 10

Answer: **B**

Explanation: Diffraction (spreading) of a wave is proportional to the wavelength of the source, so the 150 Hz signal (which has a longer wavelength), will spread significantly and thus the intensity at X and Y will be very similar. For the 3000 Hz, there will be less diffraction, so the intensity at X will be greater than at Y.

Question 11

Answer: **A**

Explanation: The Doppler Effect will yield a constant, higher frequency when the source is approaching at a constant velocity. The intensity will also gradually increase as the source is moving closer to the observer. As the source moves away, the frequency will be lower and the intensity decreases due to the effect of distance.

Question 12

Answer: **A**

Explanation: The Uncertainty Principle can be expressed in words as per option A or also in an equation, which indicates the inverse relationship between Δx and Δp_x:

$$\Delta p_x \Delta x \geq \frac{h}{4\pi}$$

Question 13

Answer: **C**

Explanation: Accuracy refers to how close the average value of the measurements is to the true value (here 9.8 N kg^{-1}). Precision refers to the consistency of the results.
In this case, Student A has collected more accurate results as they are closest to the true value. Student B's results are less accurate, but more precise as their range is narrower.

Question 14

Answer: **C**

Explanation: The launch angle is being manipulated by the students, so it is the independent variable.

Question 15

Answer: **D**

Explanation: The range is being investigated as the result of the changes to the angle, so it is the dependent variable.

Question 16

Answer: **D**

Explanation: The most effective way to reduce random error is due perform repeated trials.

Question 17

Answer: **D**

Explanation: The characteristics describe a laser source. A, B & C are all incoherent sources and have higher divergence. Intensity varies for all. Lasers are also the only one to be restricted to a single wavelength.

Question 18

Answer: **B**

Explanation: A gravitational field is radial and decreases in magnitude as the distance increases. Thus it is non-uniform. However, it maintains a constant shape so is static in nature.

Question 19

Answer: **C**

Explanation: Use $E_K = (\gamma - 1)m_o c^2$ to determine the kinetic energy.

$E_K = (\gamma - 1)m_o c^2$
$E_K = (1.8 - 1) \times 1.67 \times 10^{-27} \times (3 \times 10^8)^2$
$E_K = 1.2 \times 10^{-10}$ J

Question 20

Answer: **B**

Explanation: Use the link between impulse and change in momentum. Given the force is not constant, use area under the graph to find the impulse.

$Impulse = change\ in\ momentum$
$F\Delta t = m\Delta v$
$0.5 \times 20 \times 0.4 = 0.35 \times \Delta v$
$\Delta v = 11.4$ m s^{-1}

SECTION B

Question 1

Answer: $\mathbf{0.15\ m}$

Explanation: Use $F = \frac{kq_1q_2}{r^2}$.

$r = \sqrt{\frac{kq_1q_2}{F}}$

$r = \sqrt{\frac{8.99\times10^9\times3\times10^{-6}\times2\times10^{-6}}{2.4}}$ (1 mark)

$r = 0.15\ \text{m}$ (1 mark)

Question 2a

Explanation: Use $r = \frac{mv}{Bq}$.

$v = \frac{rBq}{m}$ (1 mark)

$v = \frac{0.027\times2.2\times1.6\times10^{-19}}{1.67\times10^{-27}}$ (1 mark)

$v = 5.7\times10^6\ \text{m s}^{-1}$

Question 2b

Answer: $\mathbf{1.7\times10^5\ V}$

Explanation: Use $E_K = Vq$ where $E_K = \frac{1}{2}mv^2$

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

$V = \frac{mv^2}{2q}$

$V = \frac{1.67\times10^{-27}\times(5.7\times10^6)^2}{2\times1.6\times10^{-19}}$ (1 mark)

$V = 1.7\times10^5\ \text{V}$ (1 mark)

Question 2c

Answer: $\mathbf{7.0 \times 10^{-14}}$ **m**

Explanation: Use $\lambda = \frac{h}{mv}$ to determine the de Broglie wavelength.

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

$\lambda = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times5.7\times10^{6}}$ (1 mark)

$\lambda = 7.0 \times 10^{-14}$ m (1 mark)

Question 2d

Explanation: Use the diffraction relationship: Diffraction $\alpha \frac{\lambda}{w}$

Diffraction $\alpha \frac{\lambda}{w}$

$\frac{\lambda}{w} = \frac{7.0\times10^{-14}}{1.7\times10^{-6}}$

$= 4.1 \times 10^{-8}$ (1 mark)

As the ratio is very close to zero, very little diffraction would be observed. (1 mark)

Question 3a

Explanation: Use $g = \frac{GM}{r^2}$.

$g = \frac{GM}{r^2}$

$r = \sqrt{\frac{GM}{g}}$

$r = \sqrt{\frac{6.67\times10^{-11}\times5.98\times10^{24}}{8.21}}$

$r = 6.97 \times 10^{6}$ m (1 mark)

$Altitude = r - r_{Earth}$

$= 6.97 \times 10^{6} - 6.37 \times 10^{6}$

$= 0.6 \times 10^{6}$ m

$= 600$ km (1 mark)

Question 3b

Answer: **96 mins**

Explanation: Use the satellite equation: $\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$.

$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$

$T = \sqrt{\frac{4\pi^2 \times (6.97\times10^6)^3}{6.67\times10^{-11}\times5.98\times10^{24}}}$ (1 mark)

$T = 5789$ s

$= 96$ mins (1 mark)

Question 3c

Answer: $\mathbf{7.6 \times 10^3}$ **m s**$^{-1}$

Explanation: Use the equation: $v = \sqrt{\frac{GM}{R}}$.

$v = \sqrt{\frac{GM}{R}}$

$v = \sqrt{\frac{6.67\times10^{-11}\times5.98\times10^{24}}{6.97\times10^6}}$ (1 mark)

$v = 7.6 \times 10^3$ m s^{-1} (1 mark)

Question 4

Answer: $\mathbf{4.1 \times 10^3}$ **m s**$^{-1}$

Explanation: Use the idea that the area underneath the graph is the change in potential energy per kg.

At 8.0×10^6 m, $g = 6.2$ N kg^{-1} (from graph) and $v_i = 1.50 \times 10^3$ m s^{-1}
At 7.0×10^6 m, $g = 8.1$ N kg^{-1} (from graph) and v_f (to be determined)

$KE_i = \frac{1}{2}mv^2 = \frac{1}{2} \times 260(1.50 \times 10^3)^2$

$KE_i = 2.93 \times 10^8$ J (1 mark)

$\Delta GPE = Area \times m$ (assume a trapezium)

$\Delta GPE = \frac{6.2 + 8.1}{2} \times 1 \times 10^6 \times 260$

$\Delta GPE = 1.86 \times 10^9$ J (1 mark)

$\Delta GPE = \Delta KE$
$KE_f = KE_i + \Delta GPE$
$\frac{1}{2}mv^2 = 2.93 \times 10^8 + 1.86 \times 10^9$ (1 mark)
$v_f = 4.1 \times 10^3 \text{ m s}^{-1}$ (1 mark)

Question 5a

Answer: **222 N**

Explanation: Use the equation: $v = \frac{2\pi r}{T}$, then $F = \frac{mv^2}{r}$

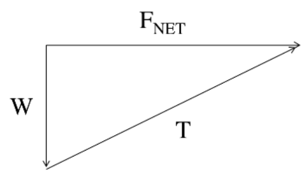
$v = \frac{2\pi r}{T}$
$v = \frac{2\pi \times 0.6}{0.4}$
$v = 9.4 \text{ m s}^{-1}$ (1 mark)

$F = \frac{mv^2}{r}$
$F = \frac{1.5 \times 9.4^2}{0.6}$
$F = 222 \text{ N}$ (1 mark)

Question 5b

Answer: **223 N**

Explanation: Use balanced forces, $F_{NET} = W + T$



$T = \sqrt{W^2 + F_{NET}{}^2}$
$T = \sqrt{(1.5 \times 9.8)^2 + (222)^2}$ (1 mark)
$T = 223 \text{ N}$ (1 mark)

Question 6a

Answer: **500 Hz**

Explanation: Standing wave shown is the third harmonic, f_3.

$f_3 = \frac{3v}{2L}$

$f_3 = \frac{3\times1.5\times10^2}{2\times0.45}$ (1 mark)

$f_3 = 500$ Hz (1 mark)

Question 6b

Explanation: Standing wave are formed due to the process of resonance. Waves reflect of the ends of the string and interact via superposition. (1 mark) Where constructive interference occurs, antinodes are created (points of maximum amplitude). (1 mark) Where destructive interference occurs, nodes are created (points of zero amplitude). (1 mark).
Here, there are three antinodes and two nodes, so it is the third harmonic.

Question 7a

Answer: **0.125 m**

Explanation: Use the magnetic force equation: $F = nBIL$

$F = nBIL$

$L = \frac{F}{nBI}$

$L = \frac{0.45}{10\times0.6\times0.6}$ (1 mark)

$L = 0.125$ m (1 mark)

Question 7b

Answer: **Negative** (1 mark)

Explanation: Use the right-hand slap rule, whereby force on AB is down (required for ACW rotation), field is right to left, current is out of the page. Follow connecting wires to show X will be a negative terminal.

Question 8a

Explanation: Use the transformation of elastic potential energy to kinetic energy.

$EPE = KE$

$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ (1 mark)

$v = \sqrt{\frac{kx^2}{m}}$

$v = \sqrt{\frac{50\times0.2^2}{0.15}}$ (1 mark)

$v = 3.65$

$v \sim 3.7 \text{ m s}^{-1}$

Question 8b

Answer: $\mathbf{0.56}$ **m**

Explanation: This solution follows the following process:

1. Identify forces at the top of the loop.
2. Determine the speed of the cart required for N = 0 at the top of the loop.
3. Determine KE of cart in terms of radius at the top of the loop.
4. Equate KE at base with GPE+KE at top, all in terms of *h*.
5. Solve for *h*.

$Part\ 1.\ F_{NET} = N + mg$

$Part\ 2.\ \frac{mv^2}{r} = 0 + mg$ (*N* = 0 for minimum speed)

$v^2 = rg$ (1 mark)

$Part\ 3.\ \frac{1}{2}mv^2 = \frac{1}{2}mrg$

$KE_{top} = \frac{1}{2}mrg$ (1 mark)

$Part\ 4.\ KE_{base} = PE_{top} + KE_{top}$

$\frac{1}{2}mv^2 = mgh + \frac{1}{2}mrg$

$\frac{1}{2}m \times 3.7^2 = mg \times h + \frac{1}{2}m \times \frac{h}{2}g$ (1mark)

$Part\ 5.\ \frac{1}{2}m \times 3.7^2 = \frac{5mgh}{4}$

$h = \frac{2\times3.7^2}{5\times9.8}$

$h = 0.56 \text{ m}$ (1mark)

Question 9a

Answer: **0.05 m**

Explanation: Use the flux equation $\phi = BA$

$\phi = BA$
$2.4 \times 10^{-3} = 0.3 \times \pi \times r^2$
$r = \sqrt{\frac{2.4\times10^{-3}}{0.3\times\pi}}$ (1 mark)
$r = 0.05$ m (1 mark)

Question 9b

Answer: **1.25 Hz**

Explanation: Use Faraday's equation $emf = -n\frac{\Delta\phi}{\Delta t}$, then $f = \frac{1}{T}$

$emf = -n\frac{\Delta\phi}{\Delta t}$
$0.3 = -25 \times \frac{2.4\times10^{-3}}{\Delta t}$ (1 mark)
$\Delta t = 0.2$ s (1 mark)
So, $T = 4 \times \Delta t = 0.8$ s
$f = \frac{1}{0.8}$
$f = 1.25$ Hz (1 mark)

Question 10a

Answer: **$20:1$**

Explanation: Use the step-up voltage and voltage drop across the transmission lines.

$I_{gen} = \frac{P}{V}$
$I_{gen} = \frac{50\times10^6}{15\times10^3}$
$I_{gen} = 3.3 \times 10^3$ A

$I_{lines} = \frac{3.3\times10^3}{5}$
$I_{lines} = 6.7 \times 10^2$ A (1 mark)

$V_{sec\ (after\ gen)} = 15 \times 10^3 \times 5 = 75$ kV
$V_{loss} = IR$

$V_{loss} = 6.7 \times 10^2 \times 4$
$V_{loss} = 2.7 \times 10^3$ V (1 mark)

$V_{prim\ (after\ lines)} = 75 \times 10^3 - 2.7 \times 10^3$
$V_{prim\ (after\ lines)} = 72.3 \times 10^3$ V

$Ratio = \frac{V_{prim\ (after\ lines)}}{3617}$
$Ratio = 20$

So, step-down transformer is 20:1 (1 mark)

Question 10b

Answer: $\mathbf{3.6}$%

Explanation: Use power loss $P_{loss} = I^2R$

$P_{loss} = I^2R$
$P_{loss} = (6.7 \times 10^2)^2 \times 4$
$P_{loss} = 1.78 \times 10^6$ W (1 mark)
$P_{loss} = \frac{1.78\times10^6}{50\times10^6} \times 100\%$
$P_{loss} = 3.6\%$ (1 mark)

Question 11

Answer: $\mathbf{22.2}$ **m s^{-1} at 85.3°**

Explanation: Use kinematics equations.

Maximum height is 25 m:
$s = 25$
$v = 0$
$u\ (vertical\ component\ of velocity) = ?$
$a = -9.8$

$v^2 = u^2 + 2as$
$0 = u^2 + 2 \times (-9.8) \times 25$
$u = 22.1$ m s^{-1} (1 mark)

Time to reach a height of 20 m (note that there will be two solutions, with the larger being the one sought as it represents the time taken to reach 20 m after the ball has reached its maximum height:
$s = 20$
$t = ?$
$u = 22.1$

$a = -9.8$

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

$20 = 22.1 \times t + \frac{1}{2} \times (-9.8) \times t^2$

$t = 1.25$ s, t = 3.27 s

Horizontal range of 6 m:

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

$v = \frac{6}{3.27}$

$v = 1.83$ m s^{-1}

Overall velocity:

$v = \sqrt{1.83^2 + 22.1^2}$

$v = 22.2$ m s^{-1} (1 mark)

Launch angle:

$\theta = \tan^{-1}\left(\frac{22.1}{1.83}\right)$ (1 mark)

$\theta = 85.3^o$ (1 mark)

Question 12a

Answer: $\mathbf{0.998c}$

Explanation: Use Lorentz factor equation (rearranged): $v = c\sqrt{1 - \frac{1}{\gamma^2}}$

$v = c\sqrt{1 - \frac{1}{16^2}}$ (1 mark)

$v = 0.998c$ (1 mark)

Question 12b

Answer: **96 μs**

Explanation: Particles at moving relative to the physicist, so 6 μs is the proper time and the physicist measures dilated time.

$t = \gamma t_o$
$t = 16 \times 6$ (1 mark)
$t = 96$ μs (1 mark)

Question 12c

Answer: **1.6 m**

Explanation: The particles are moving relative to the device, so 26 m (proper length) will appear contracted.

$l = \frac{l_o}{\gamma}$
$l = \frac{26}{16}$ (1 mark)
$l = 1.6$ m (1 mark)

Question 13

Answer: ***Isolated*** & ***Elastic***

Explanation: To determine whether the collision is isolated, compare the momentum of the system before and after the collision. To determine whether the collision is elastic, compare the kinetic energy of the system before and after the collision.

$\sum p_i = 6.0 \times 3.0 + 2.0 \times 2.0 = 22$ N s

$\sum p_f = 2.8 \times 3.0 + 6.8 \times 2.0 = 22$ N s (1 mark)

So, as momentum is conserved, the collision can be considered isolated. (1 mark)

$\sum KE_i = \frac{1}{2} \times 3.0 \times 6.0^2 + \frac{1}{2} 2.0 \times 2.0^2 = 58$ J

$\sum KE_f = \frac{1}{2} \times 3.0 \times 2.8^2 + \frac{1}{2} 2.0 \times 6.8^2 = 58$ J (1 mark)

So, as kinetic energy is conserved, the collision can be considered elastic. (1 mark)

Question 14a

Answer: $\mathbf{2.9}$ **m**

Explanation: The elastic potential energy at the lowest point is equal to the gravitational potential energy at the initial release point.

$GPE = EPE$

$mgh = \frac{1}{2}kx^2$ (1 mark)
$15 \times 9.8 \times 17 = \frac{1}{2} \times 25 \times (17 - l)^2$ (1 mark)
$l = 2.86$ m (1 mark)

Question 14b

Answer: $\mathbf{11.3}$ **m**

Explanation: When the mass comes to rest, the forces acting on it must be balanced. That is, the weight force acting on the mass must be equal to the spring force.

$mg = kx$
$15 \times 9.8 = 25 \times x$
$x = 5.88$ m (1 mark)

So, the height above ground will be equal to:

$x = 20 - 5.88 - 2.86 = 11.26$ m (1 mark)

Question 15

Answer: $\boldsymbol{n = 1.41}$

Explanation: Use Snell's Law for refraction: $n_1 \sin i = n_2 \sin r$.

$n_1 \sin i = n_2 \sin r$
$n_1 \sin 40 = 1.00 \sin 65$ (1 mark)
$n_1 = 1.41$ (1 mark)

Question 16

Answer: $\mathbf{81^o}$

Explanation: Use Snell's Law for refraction: $n_1 \sin i = n_2 \sin r$, where r = 90 at the critical angle.

$n_1 \sin i = n_2 \sin r$
$1.47 \sin i_c = 1.45 \sin 90$ (1 mark)
$i_c = 81^o$ (1 mark)

Question 17a

Answer: $\mathbf{0.63}$ **m**

Explanation: Use Pythagoras to determine path difference and then equate this to 2λ, given Z is the second antinode from the centre of the pattern. Note that the fringe spacing formulae $\Delta x = \frac{\lambda L}{d}$ is not valid here as the angles are too large for $\sin\theta \sim \tan\theta$.

$ZA = \sqrt{5.5^2 + 15^2} = 15.97$ m

$ZB = \sqrt{8.5^2 + 15^2} = 17.24$ m (1 mark) – *combined*

$PD = 2\lambda = ZB - ZA$
$2\lambda = 17.24 - 15.97$ (1 mark)
$\lambda = 0.63$ m

Question 17b

Answer: ***Away*** (1 mark)

Explanation: If the frequency of the signal is decreased, the wavelength of the signal increases. This serves to increase the spacing of the nodes and antinodes, so the student would need to move away from the centre to return to the second loud point (antinode) (1 mark)

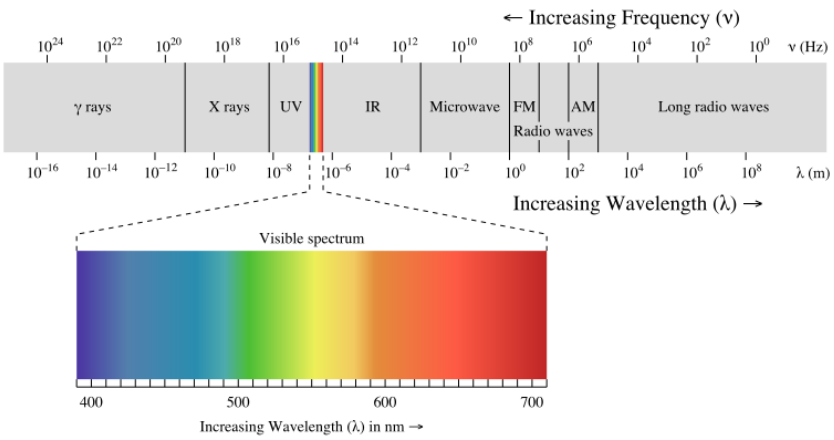
Question 17c

Explanation: A quiet point is formed when the path difference between the sources is equal to a half-integer multiple of the wavelength of the signal (i.e. $0.5\lambda, 1.5\lambda, 2.5\lambda \ldots$). (1 mark) When this occurs the sources will be completely out of phase and thus destructive interference occurs. (1 mark) This means that there will be a quiet point as the amplitude of the result is zero. (1 mark)

Question 18a

Answer: ***Ultraviolet*** (1 mark)

Explanation: As per definition of the electromagnetic spectrum.



Source: *UC Davis ChemWiki*

Question 18b

Answer: $\mathbf{1.30 \times 10^{15}}$ **Hz**

Explanation: Use Pythagoras to determine path difference and then equate this to 2λ, given Z is the second antinode from the centre of the pattern.

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

$$f = \frac{3\times10^{8}}{231\times10^{-9}}$$

$$f = 1.30 \times 10^{15} \text{ Hz}$$ (1 mark)

Question 18c

Answer: **3.8 eV**

Explanation: Use the standard photoelectric effect equation: $Vq = hf - W$.

$Vq = hf - W$
$1.6 \times 1.6 \times 10^{-19} = 6.63 \times 10^{-34} \times 1.30 \times 10^{15} - W$ (1 mark)
$W = 6.05 \times 10^{-19}$ J
$W = 3.8$ eV (1 mark)

Question 18d

Explanation: The threshold frequency is defined as the minimum frequency (1 mark) of the light source required to liberate an electron from the metal surface. (1 mark)

Question 18e

Explanation:

1. A threshold frequency exists. This supports the particle model as the energy of an individual photon is proportional to its frequency ($E = hf$), so any frequency lower than f_o will not liberate an electron, regardless of the intensity of the source. The wave model would suggest a delay, but eventual liberation as energy accumulated. (2 marks)
2. Photocurrent is proportional to intensity of the source. This is because, under the particle model, higher intensity light simply implies more photons, so more electrons would be liberated and hence more current. In contrast, the wave model would suggest that higher intensity would increase the energy of the wave, meaning a higher stopping voltage. This is not observed. (2 marks)

Question 19a

Answer: **400 nm**

Explanation: As the electron transitions from n = 4 to n = 2, a photon is emitted in line with: $\Delta E = \frac{hc}{\lambda}$.

$\lambda = \frac{hc}{\Delta E}$
$\lambda = \frac{4.14\times10^{-15}\times3\times10^{8}}{6.7-3.6}$ (1 mark)
$\lambda = 4.0 \times 10^{-7}$
$\lambda = 400$ nm (1 mark)

Question 19b

Explanation: An emission spectrum is the set of wavelengths generated by the transition of electrons from higher to lower energy states. (1 mark) An absorption spectrum is the set of wavelengths absorbed by electrons as they move from the ground state to higher energy levels. It appears as a full spectrum with black lines in the place of wavelengths absorbed. (1 mark)

Question 19c

Explanation: According to de Broglie's model of the atom, electrons are modelled as standing waves around the nucleus. Their wavelengths are restricted to discrete values to "fit" as only certain wavelengths will support standing waves. (1 mark) Discrete wavelengths means discrete momenta and thus discrete energy levels, which we see as quantised energy states. (1 mark)

Question 20a

Answer: **226 eV**

Explanation: As electromagnetic radiation, energy of x-rays: $E = \frac{hc}{\lambda}$.

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

$E = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{5.5 \times 10^{-9}}$ (1 mark)

$E = 226$ eV (1 mark)

Question 20b

Answer: **0.05 eV**

Explanation: Given the wavelength of the x-rays must match that of the electrons (for similar diffraction patterns), we use the wavelength to derive the momentum of the electrons and thus their energy.

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

$p = \frac{6.63 \times 10^{-34}}{5.5 \times 10^{-9}}$

$p = 1.21 \times 10^{-15}$ N s (1 mark)

$KE = \frac{p^2}{2m}$

$KE = \frac{(1.21\times10^{-15})^2}{2\times9.1\times10^{-31}}$ (1 mark)

$KE = 8.0 \times 10^{-21}$ J

$KE = 0.05$ eV (1 mark)

Question 21a

Answer: $\pm\mathbf{5.0 \times 10^{13}}$ **Hz**

Explanation: From the information given the magnitude of the error on wavelength is equal to half of the minimum marking, so ± 25 nm (1 mark). This corresponds to a percentage error of: $\frac{25}{400} \times 100\% = 6.25\%$ for the 400 nm measurement. Then, 6.25% of 7.5×10^{14} Hz is 5.0×10^{13} Hz. (1 mark) . For graphing purposes, this is 0.5×10^{14} Hz.

Question 21b

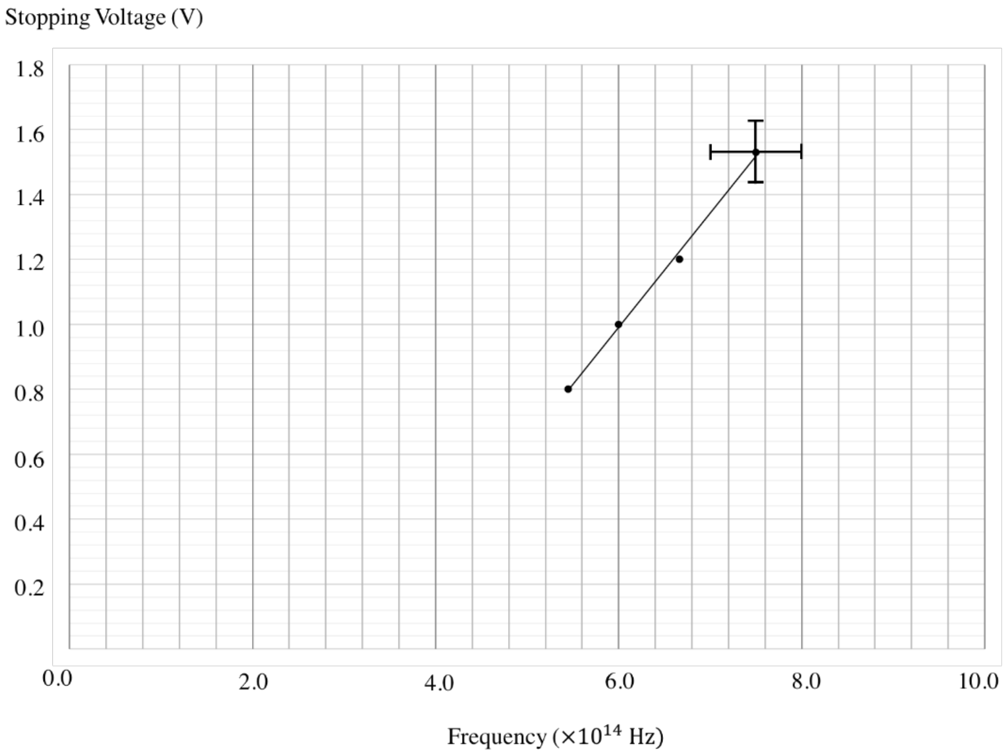
Answer: $\mathbf{1.53 \pm 0.1}$ **V**

Explanation: The average is determined by normal methods. (1 mark) The error is estimated by taking half of the range of the trials: $Error = \frac{1.64-1.44}{2} = 0.1$ (1 mark)

Question 21c

Answer: See graph below.

Explanation: Award marks for accuracy of plot (1 mark), line of best fit (1 mark), error bars (1 mark).



Question 21d

Answer: $\mathbf{3.5 \times 10^{-15}}$ **eV s**

Explanation: Planck's constant is determined by the gradient of the graph. Award full marks (2 marks) for 3.1 to 3.9. Award 1 mark for 2.9 to 4.1.

Question 22

Explanation: Sending particles (electrons or photons) through a double-slit apparatus one at a time results in single particles appearing on the screen, as expected. However, an interference pattern emerges when these particles are allowed to build up one by one (as per diagram). This demonstrates the wave-particle duality, which states that all matter (and photons) exhibits both wave and particle properties: the particle is measured as a single pulse at a single position (1 mark), while the wave describes the probability of the particle at a specific place on the screen. (1 mark).

