Selected Questions – Set 7 - Answers

1.

Question			Expected Answers	Marks	Additional Guidance
	a	(i)	uniformly spaced, vertical parallel lines must begin and end on the plates with a minimum of three lines arrow in the correct direction down	B1 B1	ignore any edge effects
		(ii)	E = V / d E = $60 / 5 \times 10^{-3}$ = 12000 (V m^{-1})	A1	
	b	(i)	Use of energy qV and kinetic energy = ½ mv^2 v = $[(2qV)/m]^{1/2}$ v = $[(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ v = 1.97×10^5 (m s^{-1})	M1 M1 A0	
		(ii)	a = F / m a = Eq / m a = $(12000 \times 3.2 \times 10^{-19}) / 6.6 \times 10^{-27})$ = 5.82×10^{11} (m s^{-2})	C1 A1	Both required for the mark
		(iii)	1 t = $\underline{(16 \times 10^{-3}) / 2 \times 10^5}$ = 8×10^{-8} (s) 2 s = ½ a x t^2 = ½ $[5.82 \times 10^{11} \times (8 \times 10^{-8})^2]$ = 1.86×10^{-3} (m)	M1 A0 C1 A1	Answer will depend on number of sf used by candidate. Using u = 2×10^5 scores 0/2 Allow slight variation in answers that follow from the candidates working

2.

Question	Answers	Additional Comments/Guidance	Mark
(a)	force between two (point) charges is proportional to product of charges ✓ inversely proportional to square of distance between the charges ✓	Mention of force is essential, otherwise no marks. Condone "proportional to charges". Do not allow "square of radius" when radius is undefined. Award full credit for equation with all terms defined.	2
(b)	V is inversely proportional to r [**or** $V \propto (-)1/r$] ✓ (V has negative values) because charge is negative [**or** because force is attractive on + charge placed near it **or** because electric potential is + for + charge and – for – charge] ✓ potential is defined to be zero at infinity ✓	Allow $V \times r$ = constant for 1st mark	max 2
(c)(i)	$Q(= 4\pi\varepsilon_0 rV) = 4\pi\varepsilon_0 \times 0.125 \times 2000$ (for example, using any pair of values from graph) ✓ = 28 (27.8) (± 1) (nC) ✓	**or** gradient = $Q/4\pi\varepsilon_0$ = 2000/8 ✓ (gives Q = 28 (27.8) ±1 (nC) ✓	2
(c)(ii)	at r = 0.20m V = –1250V and at r = 0.50m V = –500V so pd ΔV = –500 – (–1250) = 750 (V) ✓ work done ΔW (= $Q\Delta V$) = $60 \times 10^{-9} \times 750$ = $4.5(0) \times 10^{-5}$ (J) (45 μJ) ✓ (final answer could be between 3.9 and 5.1×10^{-5})	Allow tolerance of ± 50V on graph readings. [Alternative for 1st mark: $\Delta V = \frac{27.8 \times 10^{-9}}{4\pi\varepsilon_0} \times \left(\frac{1}{0.2} - \frac{1}{0.5}\right)$ (**or** similar substitution using 60 nC instead of 27.8 nC: use of 60 nC gives ΔV = 1620V)]	2
(c)(iii)	$E\left(= \frac{Q}{4\pi\varepsilon_0 r^2}\right) = \frac{27.8 \times 10^{-9}}{4\pi\varepsilon_0 \times 0.40^2}$ ✓ = 1600 (1560) (V m^{-1}) ✓ [or deduce $E = \frac{V}{r}$ by combining $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ with $V = \frac{Q}{4\pi\varepsilon_0 r}$ ✓ from graph $E = \frac{625 \pm 50}{0.40}$ = 1600 (1560 ± 130) (V m^{-1}) ✓]	Use of Q = 30 nC gives 1690 (V m^{-1}). Allow ecf from Q value in (c)(i). If Q = 60 nC is used here, no marks to be awarded.	2

3.

a	i	required pd ($= 2.5 \times 10^6 \times 12 \times 10^{-3}$) = $3.0(0) \times 10^4$ (V) ✓	1	

a	ii	charge required Q (= CV) = $3.7 \times 10^{-12} \times 3.00 \times 10^4$ ✓ ($= 1.11 \times 10^{-7}$ C) time taken $t\left(=\frac{Q}{I}\right)=\frac{1.11\times10^{-7}}{3.2\times10^{-8}}$ = 3.5 (3.47) (s) ✓	2	Allow ECF from incorrect V from (a)(i).
b	i	time increases ✓ (larger C means) more charge required (to reach breakdown pd) **or** $t=\frac{CV}{I}$ **or** time ∝ capacitance ✓	2	**Mark sequentially** i.e. no explanation mark if effect is wrong.

b	ii	spark is brighter (**or** lasts for a longer time) ✓ more energy (**or** charge) is stored **or** current is larger **or** spark has more energy ✓	2	**Mark sequentially.**

4.
(a)

Answers	Additional comments/Guidelines	Mark
$V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$ with substitution attempted with V_0 being larger than V ✓1 Time to charge to 4.0 V = $t_2 = -R_1C\ln\left(1-\frac{4}{6}\right)$ **OR** Time to charge to 2.0 V = $t_1 = -R_1C\ln\left(1-\frac{2}{6}\right)$ ✓2 $t = t_2 - t_1 = -R_1C\ln\left(\frac{1}{3}\right) - \left\{-R_1C\ln\left(\frac{2}{3}\right)\right\}$ $\left(= -R_1C\left(\ln\frac{1}{3} - \ln\frac{2}{3}\right) = -R_1C\ln\left(\frac{\frac{1}{3}}{\frac{2}{3}}\right)\right) = -R_1C\ln\left(\frac{1}{2}\right) = 0.69R_1C$ **OR** $= R_1C(1.10 - 0.41) = 0.69R_1C$ ✓3	NB The answer can be obtained incorrectly by finding the time to charge to 2V using a 4V supply. This approach may only gain the first mark for an attempted use of the equation. Award 0 for a solution using the discharge equation. Condone R for R_1 ✓2 If given in an equation then then time must be the subject or be in a form that is used to obtain mp3 can be awarded for $t_2 = 1.10 \times R_1C$ **OR** $t_1 = 0.41 \times R_1C$ ✓3 Must see 0.69 R_1C for 3 marks. Only award MP3 for $0.69R_1C$ if the solution involves a time difference.	3

(b)

Answers	Additional comments/Guidelines	Mark
Attempt to find usable data from **Figure 9** ✓$_1$ Determine scaling factor **OR** Determine R_1 ✓$_2$ Calculate Q the charge stored at 4 V or the charging time constant **from a valid method** ✓$_3$ Determine C to a value that rounds to 1×10^{-4} (F) to 2 or more sf (expect to see 1.0×10^{-4} F) ✓$_4$ **Method 1 (from area)** ✓$_{1a}$ Attempt at finding area under I–t graph by counting boxes ✓$_{2a}$ 1 cm^2 box corresponds to charge 0.5×10^{-5} C ✓$_{3a}$ Number of 1 cm^2 boxes = 80 (78 to 82) $Q = (80 \times 0.5 \times 10^{-5}) = (3.9 \text{ to } 4.1) \times 10^{-4}$ (C) ✓$_{4a}$ $C = \frac{\text{their } Q}{4}$ = a value that rounds to 1×10^{-4} (F) (≥ 2 sf required) Award **MAX 1** for estimating the average current by sight and using $C = \frac{IT}{V}$.	**Method 2 (from individual data points)** Possible methods are shown but only final answers requested are needed to gain marks. ✓$_{1b}$ Use of a current and voltage across the resistor, e.g. $I = 2.0 \times 10^{-5}$ A and voltage across resistor = 2 V (when capacitor has 4 V) **OR** $I = 6.0 \times 10^{-5}$ A and voltage across resistor = 6 V (when capacitor has 0 V) ✓$_{2b}$ $R_1 = \frac{V}{I} = \frac{2.0}{2.0 \times 10^{-5}}$ **OR** $\left(\frac{V}{I} = \frac{6}{6 \times 10^{-5}}\right) = 1.0 \times 10^{5}$ (Ω) ✓$_{3b}$ Charging time constant = R_1C Eg using $I = I_0 e^{\frac{-t}{R_1 C}}$ then $R_1C = \frac{t}{\ln\left(\frac{I_0}{I}\right)}$ Substituting $I = 2 \times 10^{-5}$ A and $I_0 = 6 \times 10^{-5}$ A and $t = 11$ s. OR Graphical method must include evidence from Figure 9 charging time constant $(R_1C) = 10.(0)$ (s) ✓$_{4b}$ $C = \frac{\text{time constant}}{R_1} = \frac{10.0}{1.0 \times 10^{5}}$ = a value that rounds to 1×10^{-4} (F) (≥ 2 sf required)	4

(c)

Answers	Additional comments/Guidelines	Mark
Reading of relevant discharge data from **Figure 10** provided there is an attempt to use data ✓$_1$ A valid substitution of their data into a relevant equation to find R_1 or R_{Total} ✓$_2$ $R_2 = R_{Total} - \text{their } R_1 = 2.0 \times 10^5\ \Omega$ ✓$_3$ allow **one** ecf from either their R_{Total} **or** their R_1 When R_1 is derived in an earlier question accept this value of R_1 and allow ecf for R_{total} When R_1 is derived in this question, allow one ecf from either their R_{total} or their R_1	✓$_1$ From **Figure 10** this can be the time taken for the voltage to fall to half its value. ✓$_2$ Finding R_{Total} from **Figure 10** 4.0 V to 2.0 V in (32 − 11) s using $t_{\frac{1}{2}} = 0.69RC$ allow $= 0.7RC$ $R_{Total} = 3.0 \times 10^5\ \Omega$ Finding R_1 from **Figure 9** 6.0 A to 3.0 A in 6.8 s using $t_{\frac{1}{2}} = 0.69RC$ allow $= 0.7RC$ $R_1 = 1.0 \times 10^5\ \Omega$ **OR** Using $I = I_o e^{\frac{-t}{R_1 C}}$ for example, with $I = 2 \times 10^{-5}$ A and $I_o = 6 \times 10^{-5}$ A and $t = 11$ s Note R_1 may be taken from **05.2** and not use the graph information.	3

5.

Question	Answers	Additional Comments/Guidelines	Mark
(a)	(using mass defect = $\Delta m = Z\, m_p + N\, m_n - M_{Co}$) $\Delta m = 27 \times 1.00728 + 32 \times 1.00867 - 58.93320$ (u) ✓ $\Delta m = 0.5408$ (u) ✓ Binding Energy = $0.5408 \times 931.5 = 503.8$ (MeV) ✓ (CE this mark stands alone for the correct energy conversion even if more circular routes are followed.	Look at use of first equation and if electrons are used or mass of proton and neutron confused score = 0. If subtraction is the wrong way round lose 1 mark. Data may come from rest mass eg m_n =939.551 MeV or 1.675×10^{-27} kg or 1.00867 u. So if kg route used $\Delta m = 8.83 \times 10^{-28}$ kg BE = 7.95×10^{-28} J and 497 Mev. Conversion mark (2nd) may come from a wrong value worked through. 0.47(5)	3
(b)	$(2.52 - 1.76) \times 10^{-13} = 7.6 \times 10^{-14}$ J ✓ $7.6 \times 10^{-14} / 1.60 \times 10^{-13} = 0.47$ or 0.48 MeV ✓(0.475 MeV)	Correct answer scores both marks.	2
(c)	6 (specific wavelengths)		1
(d)	(longest wavelength = lowest frequency = smallest energy) $(2.29 \times 10^{-13} - 2.06 \times 10^{-13}) = 2.3 \times 10^{-14}$ (J) ✓ λ (= $h\, c\, /\, E$) = $6.63 \times 10^{-34} \times 3.00 \times 10^{8} / 2.3 \times 10^{-14}$ ✓ $\lambda = 8.6 - 8.7 \times 10^{-12}$ (m) ✓ (8.6478×10^{-12} m)	Allow a CE in the second mark only if the energy corresponds to an energy gap including those to the ground state. The allowed energy gaps for CE are: 2.29, 2.06, 1.76, 0.53, 0.30 all x 10^{-13}J Note substitution rather than calculation gains mark. The final mark must be as shown here and not from a CE above.	3

6.

Question			Expected Answers	Marks	Additional Guidance
	a		ANY ONE from X-rays interact with matter by: the photoelectric effect where an (orbital) electron is ejected from atom / atom is ionised Compton scattering where X-ray scattered by the interaction with (orbital) electron Pair production where X-ray photon interacts with the nucleus / atom and an electron and positron are produced [allow one mark for statement and one for explanation] **Max 2**	**(B2)** **(B2)** **(B2)** **B2**	Allow electrons ejected from metal surface if reference is made to <u>free</u> electrons Allow: X-ray diffraction **B1** X-ray passes through the 'slits' / atomic gap formed by the atoms **B1**

	b		$I = I_0e^{-\mu x}$ $0.1 = e^{-\mu 3}$ $0.5 = e^{-\mu x}$ $\ln 0.5 / \ln 0.1 = x/3$ $x = 0.903$ (mm)	C1 C1 A1	Calculation of μ =0.768 C1 Substitution into second equation C1 Allow 0.9 (1sf) If question misread and 0.9 used for change μ = 0.035 and x = 19.7 (allow 20) give 2/3
	c	(i)	Absorption of X-rays by (silver halide molecules) by a photographic film Uses of fluorescent / scintillator/ phosphor Photon releases electron (that is accelerated onto a fluorescent screen) number of electrons increased /multiplied **MAX B2** QWC: Phosphor / Intensifier/ it converts X-ray photon into increased number of 'visible' photons	**(B1)** **(B1)** **(B1)** **(B1)** **B2** **B1**	

More details about X-ray image intensifiers are given on the next page.

		(ii)	Different soft body tissue produce little difference in contrast/attenuation (Contrast media with) high atomic number / Z used / iodine or barium (used to give greater contrast) liquids injected or swallowed into soft tissue areas / or examples of such **MAX B2**	**(B1)** **(B1)** **(B1)** **B2**	This method produces good contrast for soft tissue /for similar Z values

More details for Question 6c(i):

An X-ray image intensifier is a device used in medical imaging to convert X-rays into a brighter, visible image, allowing doctors to observe internal body structures in real time. X-rays first pass through the patient and strike an input fluorescent screen, where they are converted into visible light. This light then hits a photocathode, which emits electrons via the photoelectric effect. These electrons are accelerated and focused using electric fields toward a smaller output fluorescent screen. When the high-energy electrons strike this screen, they produce a large number of visible light photons, resulting in a much brighter image than the original. This intensified image can then be viewed directly or captured using a camera for display on a monitor, allowing for clearer imaging with lower X-ray doses.