

Name of the Student: _____

Max. Marks : 17 Marks

Time : 17 Minutes

Mark Schemes

Q1.

(a) ($Q = Q_0 e^{-t/RC}$ gives) $1.0 = 4.0e^{-300/RC}$ ✓

from which $\frac{300}{RC} = \ln 4$ ✓ and time constant $RC = 220$ (216) (ms) ✓

[Alternative answer:time constant is time for charge to decrease to Q_0/e [or $0.37 Q_0$] ✓

$$4.0/e = 1.47$$
 ✓

reading from graph gives time constant = 216 ± 10 (ms) ✓

In alternative scheme, $4.0/e = 1.47$ subsumes 1st mark. Also, accept $T_{1/2} = 0.693 RC$ (or $= \ln 2 RC$) for 1st mark.

3

(b) current is larger (for given V)(because resistance is lower)

[or correct application of $I = V/R$]

current is rate of flow of charge

[or correct application of $I = \Delta Q / \Delta t$]

larger rate of flow of charge (implies greater rate of discharge)

[or causes larger rate of transfer of electrons from one plate back to the other] ✓

[Alternative answer:time constant (or RC) is decreased (when R is decreased) ✓explanation using $Q = Q_0 e^{-t/RC}$ or time constant explained ✓]

Use either first or alternative scheme; do not mix and match.

Time constant = RC is insufficient for time constant explained.

max 2

[5]

Q2.

(a) (i) initial discharge current $\left(= \frac{V}{R} = \frac{6.0}{1.0 \times 10^5} \right) = 6.0 \times 10^{-5}$ (A) (1)

1

(ii) time constant is time for V to fall to $(1/e)$ [or 0.368] of initial value (1)

pd falls to $(6.0/e) = 2.21$ V when $t =$ time constant (1)reading from graph gives time constant = $22 (\pm 1)$ (1)

unit: s **(1)** (Ω F not acceptable)

[**alternatively** accept solutions based on use of $V = V_0 e^{-t/RC}$

$$\text{eg } 1.5 = 6.0 e^{-30/RC} \text{ (1) gives } RC = \frac{30}{\ln(6.0/1.5)} \text{ (1) } = 22 \text{ (1) s (1)}$$

4

(iii) capacitance of capacitor $C = \left(\frac{\text{time constant}}{R} = \frac{22}{1.0 \times 10^5} \right)$
 $= 2.2 \times 10^{-4} \text{ (F)} = 220 \text{ (}\mu\text{F)} \text{ (1)}$

1

(iv) energy $\propto V^2$ (or energy $= \frac{1}{2} CV^2$) **(1)**

$$\therefore \frac{E_2}{E_1} = 0.10 \text{ gives } = \frac{V_2}{V_1} (0.10)^{1/2} \text{ (1) } (= 0.316)$$

$$\therefore V_2 = 0.316 \times 6.0 = 1.90 \text{ (V) (1)}$$

reading from graph gives $V_2 = 1.90 \text{ V}$ when $t = 25 \text{ s}$ **(1)**

[**alternatively** accept reverse argument:

ie when $t = 25 \text{ s}$, $V_2 = 1.9 \text{ V}$ from graph **(1)**

$$\text{final energy stored} = \frac{1}{2} \times 2.2 \times 10^{-4} \times 1.9^2$$

$$= 3.97 \times 10^{-4} \text{ (J) and initial energy stored} = 3.96 \times 10^{-3} \text{ (J) (1)}$$

which is 10 $\times$ greater, so 90% of initial energy has been lost **(1)**

[**alternatively**, using exponential decay equation:

$$\text{use of } V = V_0 e^{-t/RC} \text{ with } t = 25 \text{ s and } RC = 22 \text{ s gives } V = 1.93 \text{ V (1)}$$

$$\text{energy } \propto V^2 \text{ (or energy} = \frac{1}{2} CV^2 \text{) gives } \frac{E_2}{E_1} = \left(\frac{1.93}{6.0} \right)^2 = 0.103 \text{ (1)}$$

$$\therefore \text{fraction of stored energy that is lost} = \frac{E_2 - E_1}{E_1} = 1 - \frac{E_2}{E_1} = 0.90 \text{ (1)}$$

3

(b) (i) initial energy stored is 4 $\times$ greater **(1)**

because energy $\propto V^2$ (and V is doubled) **(1)**

2

(ii) time to lose 90% of energy is unchanged because time constant is unchanged (or depends only on R and C) **(1)**

1

[12]