Mark schemes

1 A **[1]**

2 B **[1]**

3 B **[1]**

4 D **[1]**

5 B **[1]**

6 A **[1]**

7 D **[2]**

8 C **[1]**

9 C **[1]**

10 D **[1]**

11 D **[1]**

12 A **[1]**

13 A **[1]**

14 C **[1]**

15 D **[1]**

16 D **[1]**

17 B **[1]**

18 B **[1]**

19 (a) $d = \frac{8.9\times10^{-12}\times2.3\times250\times10^{-4}}{370\times10^{-12}}$ ✓

1.4×10^{-3} m (1.4 (1.38) mm)✓

Data substitution – condone incorrect powers of 10 for C and A ✓

2

(b) New capacitance = 161 pF✓

New V = 0.13 nC / 161pF = 81 V✓

2

(c) Energy stored = ½ × 161 × 10^{-12} × 81^2 ✓

0.53 μJ✓

2

(d) Energy increases because:

In the polar dielectric molecules align in the field with positive charged end toward the negative plate (or WTTE).✓

Work is done on the capacitor separating the positively charged surface of the dielectric from the negatively charged plate (or vice versa).✓

2

[8]

20 (a) (i) energy stored by capacitor (= ½ CV^2)

= ½ × 70 × 1.2^2 ✓ (= 50.4) = 50 (J) ✓

to **2 sf** only ✓

3

(ii) energy stored by cell (= $I\ V\ t$) = 55 × 10^{-3} × 1.2 × 10 × 3600 ✓

(= 2380 J)

$$\frac{\text{energy stored by cell}}{\text{energy stored by capacitor}} = \frac{2380}{50} = 48$$ (ie about 50) ✓

2

(b) capacitor would be impossibly large (to fit in phone) ✓

capacitor would need recharging very frequently
[**or** capacitor could only power the phone for a short time] ✓

capacitor voltage [**or** current supplied or charge] would fall continuously while in use ✓

max 2

[7]

21 (a) ratio of charge to potential

C1

4.2 μC per volt etc

A1

2

(b) (i) method: time for voltage to half/tangent at origin/use of decay equation/1/e value B1

appropriate reading from graph ($T_{½}$ = 440 or 450 μs) B1

substitution into correct equation B1

R correct for method (151/152/155 Ω) B1

4

(ii) **B** smaller than **A** **M0**

B discharges faster/**A** discharges slower B1

reference to decay equation/calculation for **B** B1

2

(c) $E = ½\ CV^2$ or $½\ QV$ seen C1

both 4.0 (V) and 0.9 (V)/16.8 (μC) and 3.8 (μC) seen C1

31.9 (μJ) A1

3

[11]

22 (a) (i) tangent drawn at $t = 0$

M1

coordinates correct and manipulated correctly
0.015 to 0.020 (A) 15 mA – 20 mA
or $V = 4000$ V as in (ii) then $I = 18$ mA

A1

2

(ii) $V = 220 \times$ their (i) condoning powers of 10

C1

about 4000 V (3300 – 4400 V)

A1

or use of $V = Q/C$; $V = 100$ mC/25 μF

C1

4000 V

A1

2

(iii) more charge leads to increased potential difference across the capacitor

M1

pd = $V_R + V_C$
or if V_C increases then V_R decreases

M1

(if V_R falls) so I falls

A1

3

(b) (i) use of energy = ½ Q^2/C or use of $C = Q/V$ and ½ QV

C1

0.083(7) or 0.084 C condone 0.083 C

A1

2

(ii) power = 14 kW

B1

1

(c) time constant = 5.5 s

M1

sensible attempt to find the charge after 8.3 s – by calculation or reading from graph

M1

about 78 mC and needs to be 85 mC/has not reached 85 mC so designer's suspicion is not valid

A1

3

[13]

23 (a) $E \propto V^2$ (or $E = {}^1/_2 CV^2$) **(1)**

pd after 25 s = 6 V **(1)**

2

(b) (i) use of $Q = Q_0\,e^{-t/RC}$ or $V = V_0\,e^{-t/RC}$ **(1)**

(e.g. $6 = 12e^{-25/RC}$) gives $e^{\frac{25}{RC}} = \frac{12}{6}$ and $\frac{25}{RC}$ = 1n 2 **(1)**

(RC = 36(.1) s)

[alternatives for (i):

$V = 12\,e^{-25/36}$ gives V = 6.0 V **(1)** (5.99 V)

or time for pd to halve is 0.69RC

$\therefore RC = \frac{25}{0.69}$ **(1)** = 36(.2) s]

(ii) $R = \frac{36.1}{680 \times 10^{-6}}$ **(1)** = 5.3(0) × 10^4 Ω **(1)**

4

[6]

24 (a) (i) straight line through origin **(1)**

(ii) $\frac{1}{\text{capacitance}}$ **(1)**

(iii) energy (stored by capacitor) **(1)** (or work done (in charging capacitor))

3

(b) (i) $RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3}$ **(1)** (= 38.1 s)

$V(= V_0\ e^{-t/RC}) = 12\ e^{-26/38.1}$ **(1)**

$= 6.1$ V **(1)** (6.06 V)

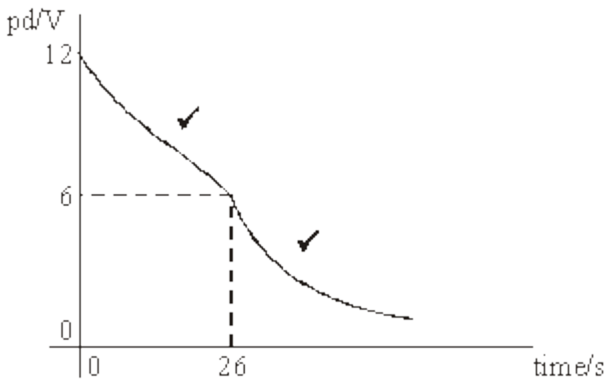
[or equivalent using $Q = Q_0 e^{-t/RC}$ and $Q = CV$]

(ii) $(RC)' = 2.8 \times 10^{3} \times 6.8 \times 10^{-3}$ **(1)** (= 19.0 s)

$V (= 6.06\ e^{-14/19}) = 2.9(0)$ V **(1)**

(use of $V = 6.1$ V gives $V = 2.9(2)$ V)

(iii)



7

[10]

25 (a) $Q (= CV = 330 \times 9.0) = 2970$ (μC) **(1)**

$E (= ½QV) = ½ \times 2.97 \times 10^{-3} \times 9.0 = 1.34 \times 10^{-2}$J **(1)**

[or $E (= ½CV^2) = ½ \times 300 \times 10^{-6} \times 9.0^2$ **(1)** $= 1.34 \times 10^{-2}$J **(1)**]

2

(b) time constant (= RC) = $470 \times 10^3 \times 330 \times 10^{-6} = 155$ s **(1)**

1

(c) $Q\left(= Q_0 e^{-t/RC}\right) = 2970 \times e^{-60/155}$

$= 2020$ (μC)

(allow C.E. for time constant from (b))

$V = \left(\frac{Q}{C}\right) = \frac{2020}{330} = 6.11\ V$ **(1)**

(allow C.E. for Q)

[or $V = V_0 e^{-t/RC}$ **(1)** $= 9.0\ e^{-60/155}$ **(1)** $= 6.11$ V **(1)**]

3

[6]

26 (a) $Q = CV$ **(1)**
(= $4.7 \times 10^{-6} \times 6.0$) = 28×10^{-6} C or 28 μC **(1)**

2

(b) $E = ½CV^2$ **(1)**
$= ½ \times 4.7 \times 10^{-6} \times 2.0^2$ **(1)**
$= 9.4 \times 10^{-6}$ J **(1)**
[or $E = ½QV$ **(1)**
$= ½ \times 9.4 \times 10^{-6} \times 2.0$ **(1)**
$= 9.4 \times 10^{-6}$ J **(1)**]

3

(c) time constant is time taken for V to fall to $\frac{V_0}{e}$ **(1)**

$\therefore V$ must fall to 2.2 V **(1)**
time constant = 32 ms **(1)**
[or draw tangent at $t = 0$ **(1)**
intercept of tangent on t axis is time constant **(1)**
accept value 30 - 35 ms **(1)**]
[or $V = V_0$ exp($-t / RC$) or $Q = Q_0$ exp($-t / RC$) **(1)**

correct substitution **(1)**
time constant = 32 ms **(1)**]

3

(d) time constant = RC **(1)**

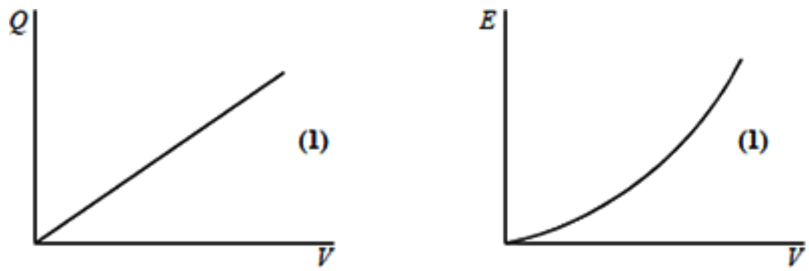
$R = \dfrac{32 \times 10^{-3}}{4.7 \times 10^{-3}}$ = 6800 Ω **(1)**

(allow C.E. for value of time constant from (c))

2

[10]

27 (a)



capacitance [or charge per volt or Q/V] **(1)**

(3)

(b) (i) $Q = CV$ (= 0.68 × 6.0) = 4.1 C **(1)**

(ii) $E\left(=\frac{1}{2}QV = \frac{1}{2} \times 4.1 \times 6.0\right)$ = 12 J **(1)**

(2)

[5]

28 (a) (i) remains constant since connected to constant p.d. **(1)**

(ii) decreases because $C \propto \frac{1}{d}$ **(1)**

(iii) decreases because $Q = CV$ and C has decreased **(1)**

(iv) decreases because $E = \frac{1}{2}CV^2$ and C has decreased **(1)**

4

(b) (i) $C\left(=\frac{\varepsilon_0 A}{d}\right)=\frac{8.85\times10^{-12}\times8.0\times10^{6}}{0.75\times10^{3}}$ **(1)** (= 9.44×10^{-8} F)

E (= $\frac{1}{2}$ CV^2) = $\frac{1}{2}\times9.44\times10^{-8}\times(200\times10^{3})^{2}$ **(1)**

= 1890J **(1)**

(ii) $I\left(=\frac{Q}{t}\right)=\frac{9.44\times10^{-8}\times200\times10^{3}}{120\times10^{-6}}$ use of $Q = CV$ **(1)** use of $I = \frac{Q}{t}$ **(1)**

= 157 A **(1)**

6

[10]

29

(a) $1/C = 1/500 + 1/1000$ or $C=\frac{500\times1000}{500+1000}$

C1

330 (333) μF

A1

2

(b) (i) Q = VC *or* Q = *0.25 × 9*

C1

2.3 or 2.25 C (c.a.o. unit essential)

A1

(ii) *energy = ½ CV^2* or $0.5 \times 0.25 \times 9^2$ or ½ *QV* used

C1

10(.1) J (allow e.c.f. for *Q*)

A1

(iii) $V = V_o e^{-t/RC}$

C1

7

$0.1 = 9\ e^{-t/(8.5 \times 0.25)}$

C1

9.6 (9.56) s

A1

(c) (i) $Q = mc\Delta\theta$ or mass = volume × density

C1

correct substitution $10.1 = (2.2 \times 10^{-7} \times 8900 \times 400 \times \Delta\theta)$

C1

12 (12.3) K or °C ecf for energy from (b) (ii)

A1

5

(ii) some energy raises temperature of the thermometer

B1

energy/heat lost to (raise temperature of) surroundings

B1

[14]

30 (a) 1 coulomb of charge is stored for a p.d. of 1 V between the plates
(or equivalent statement) Condone I coulomb per volt

B1

1

(b) (i) Correct substitution in $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$ (ignore powers of 10)

C1

Plate area = 4.65×10^{-3} m^2 or $C = \frac{\varepsilon_0 \varepsilon_r \pi r^2}{d}$ with correct data

A1

Radius = (their area /3.14)1/2; 0.038(4 or 5) m if correct

B1

3

(ii) E = ½ CV^2 or correct numerical substitution or
E = ½ QV & Q = VC

C1

4.1(4) × 10^{-10} J

A1

2

(c) Time constant = *RC* or Time to halve = *0.69 RC*
or $V = V_0 e^{-t/RC}$

C1

Time to fall to 1/e (0. 19 ms) or time to halve (0. 13 ms)
or V_0 = 6 V and correct coordinates of point on line
(0.6 ms max)

C1

8.1 - 8.6 MΩ

A1

3

[9]