

1. (a) (i) $C_p = 2 + 4 = 6 \mu\text{F}$ A1
- (ii) $1/C = 1/2 + 1/4$ C1
 $C_s = 4/3 = 1.33 \mu\text{F}$ A1
- (b) (i) 6.0 V A1
- (ii) $Q = C_p V$ C1
 $= 6 \times 6 = 36 \mu\text{C}$ A1
- (c) $E = \frac{1}{2} C_s V^2$ C1
 $= 24 \times 10^{-6}$ A1
- (d) (i) The capacitors discharge through the voltmeter. B1
- (ii) $V = V_0 e^{-t/CR}$
 $1/4 = e^{-t/(6 \times 12)}$ C1
 $\ln 4 = t / 72$ C1
 $t = 72 \ln 4 \approx 100 \text{ s}$ A1
- [12]**
2. (a) $Q_0 = CV = 1.2 \times 10^{-11} \times 5.0 \times 10^3; = 6.0 \times 10^{-8}; \text{C (3)}$ 3
- (b) (i) $RC = 1.2 \times 10^{15} \times 1.2 \times 10^{-11} \text{ or } = 1.44 \times 10^4 \text{ (s) (1)}$ 1
- (ii) $I = V/R = 5000/1.2 \times 10^{15} \text{ or } = 4.16 \times 10^{-12} \text{ (A) (1)}$ 1
- (iii) $t = Q_0/I; = 6 \times 10^{-8} / 4.16 \times 10^{-12} = 1.44 \times 10^4 \text{ (s)}$ 2
- (iv) $Q = Q_0 e^{-1}; Q = 0.37 Q_0 \text{ so } Q \text{ lost} = 0.63 Q_0$ 2
- (c) (i) capacitors in parallel come to same voltage (1)
so Q stored \propto C of capacitor (1)
capacitors in ratio 10^3 so only $10^{-3} Q_0$ left on football (1) 3
- (ii) $V = Q/C = 6.0 \times 10^{-8} / 1.2 \times 10^{-8} \text{ or } 6.0 \times 10^{-11} / 1.2 \times 10^{-11} \text{ or only } 10^{-3}$
Q left so $10^{-3} V$ left; = 5.0 (V) 2

3. (a) (i) $Q = VC$; $W = \frac{1}{2} VC.V (= \frac{1}{2} CV^2)$ (2)
 (ii) parabolic shape passing through origin (1)
 plotted accurately as $W = 1.1 V^2$ (1) 4
- (b) (i) $T = RC$; $= 6.8 \times 10^3 \times 2.2 = 1.5 \times 10^4 \text{ s} = 4.16 \text{ h}$ 2
 (ii) $\Delta W = \frac{1}{2} C(V_1^2 - V_2^2) = 1.1(25 - 16)$; $= 9.9 \text{ (J)}$ 2
- (iii) $4 = 5 \exp(-t/1.5 \times 10^4)$; giving $t = 1.5 \times 10^4 \times \ln 1.25 = 3.3 \times 10^3 \text{ (s)}$ 2
- (iv) $P = \Delta W/\Delta t = 9.9/3.3 \times 10^3 = 3.0 \text{ mW}$ *ecf b(ii) and (iii)* 1
allow $P = V_{av}^2/R = 4.5^2/6.8 \times 10^3 = 2.98 \text{ mW}$

[11]

4. (a) (i)

capacitor	capacitance / μF	charge / μC	p.d. / V	energy / μJ
X	5	30	$= Q/C$ $= 6 \text{ (V) (1)}$	$= \frac{1}{2} CV^2(1)$ $= \frac{1}{2} \times 5 \times 6^2$ $= 90 \text{ (1)}$
Y	25	$= CV$ $= 25 \times 6$ $= 150 \text{ (}\mu\text{C) (1)}$	$= 6 \text{ (V) (1)}$	$= 450 \text{ (1)}$
Z	10	$30 + 150 =$ $180 \text{ (}\mu\text{C) (1)}$	$= Q/C$ $= 180/10$ $= 18 \text{ (V) (1)}$	$= 1620 \text{ (1)}$

Each box correctly calculated scores (1) + (1) for $\frac{1}{2} CV^2$ 9

- (ii) 1 $18 \text{ V} + 6 \text{ V} = 24 \text{ (V) (1)}$
 2 $180 \text{ (}\mu\text{C) (1)}$
 3 $180 / 24 = 7.5 \text{ (1)}$
 4 $90 + 450 + 1620 = 2160 \text{ (}\mu\text{J) (1)}$ 4
- (b) (i) Kirchoff's second law OR conservation of energy (1) 1
 (ii) Kirchoff's first law OR conservation of charge (1) 1
- (c) (i) time constant = CR (1)
 $= 7.5 \times 10^{-6} \times 200\,000 = 1.5 \text{ (s) (1)}$ 2
- (ii) $Q = Q_0 e^{-\frac{4CR}{CR}}$ (1)

$$Q/Q_0 = e^{-4} = 0.0183 \text{ (1)}$$

2

[19]

5. (i) $C_p = C + C = 6 \mu\text{F}$; $1/C_s = 1/2C + 1/C$; $= 3/2C$ giving $C_s = 2C/3 = (2 \mu\text{F})$

3

(ii) 2 sets of (3 in series) in parallel/ 3 sets of (2 in parallel) in series

2

[5]