19. Capacitance

19.1 Capacitors and capacitance

Paper 4

Marking Scheme

Q1.

(a)	equal charge on both capacitors	**B1**
	$V_X + V_Y = V$	**M1**
	$(Q / C_X) + (Q / C_Y) = (Q / C_T)$ leading to $(1 / C_X) + (1 / C_Y) = (1 / C_T)$ **or** $(V_X / Q) + (V_Y / Q) = (V / Q)$ leading to $(1 / C_X) + (1 / C_Y) = (1 / C_T)$	**A1**

Q2.

(a)	charge / potential (difference)	**M1**
	charge is charge on one plate, and potential is p.d. between the plates	**A1**
(b)(i)	straight line starting at the origin	**B1**
	line with positive gradient ending at (V, Q)	**B1**
(c)(i)	final p.d. shown as $V / 4$ for both capacitors	**B1**
	final charges add together to give Q	**B1**
	charge on Y = 3 × charge on X (and both charges shown as a multiple of Q) Fully correct answer:	**B1**

	X	Y
final p.d.	$V / 4$	$V / 4$
final charge	$Q / 4$	$3Q / 4$

Q3.

(a)(i)	$Q_A = CV$	**A1**
(b)(i)	some of the charge transfers to (the plates of) capacitor B	**B1**
	transfer is because the p.d.s across the capacitors are not equal **or** transfer stops when the p.d.s across the capacitors become equal	**B1**
(b)(ii)	$V_A = V_B$	**M1**
	charge on A + charge on B = CV	**M1**
	$CV_B + 3CV_B = CV$ leading to $V_B = V / 4$	**A1**
	or	
	$C_T = 4C$	**(M1)**
	$Q_T = CV$	**(M1)**
	$V_B = CV / 4C = V / 4$	**(A1)**

Q4.

(a)(ii)	$C = Q / V$ **or** $E = ½CV^2$	**C1**
	$C = (450 \times 10^{-6}) / 8.0$ **or** $(2 \times 1.8 \times 10^{-3}) / 8.0^2$ $= 5.6 \times 10^{-5}$ F	**A1**

Q5.

(a)	charge / potential (difference)	**M1**
	charge is charge on one plate, and potential is p.d. across the plates	**A1**
(b)	p.d. across both capacitors = E	**B1**
	$Q_T = Q_1 + Q_2$	**B1**
	$C_TE = C_1E + C_2E$ hence $C_T = C_1 + C_2$	**B1**
(c)(i)	$[(1 / 22) + (1 / 47)]^{-1} = 15\ \mu F$	**A1**

Q6.

(a)(i)	$Q = CV$	**C1**
	$Q_0 = 24 \times 470 \times 10^{-6}$ $= 0.011$ C	**A1**

Q7.

(c)(i)	$C = Q / V$	**C1**
	$= [(0.90 \times 10^{-3}) / 7.5] = 1.2 \times 10^{-4}$ C $= 120\ \mu F$	**A1**

Q8.

(a)	charge / potential	**M1**
	charge is on one plate, potential is p.d. between the plates	**A1**
(b)(i)	$I = Q / t$	**M1**
	charge = CV and time = $1 / f$ leading to $I = fCV$	**A1**
(b)(ii)	$4.8 \times 10^{-6} = 150 \times 60 \times C$	**C1**
	$C = 530$ pF	**A1**
(c)	(total) capacitance is halved	**B1**
	charge (for each cycle/discharge) is halved **or** since f and V are constant, current is proportional to capacitance	**B1**
	current = 2.4 μA	**B1**

Q9.

(a)	potential difference applied between the plates	**M1**
	causes charge separation (between the plates) **or** causes energy to be stored (between the plates)	**A1**
(b)(i)	$I = Q / t$	**M1**
	clear substitution of $Q = CV$ and $f = 1 / t$, leading to $I = fCV$	**A1**
(b)(ii)	$2.5 \times 10^{-6} = 50 \times C \times 180$	**C1**
	$C = 280$ pF	**A1**
(c)	(total) capacitance increases	**B1**
	greater charge (for each cycle/discharge) so greater (average) current **or** V and f are constant so (average) current increases **or** I is (directly) proportional to C so (average) current increases	**B1**

Q10.

(a)	$Q = CV$ **and** $E = \frac{1}{2}CV^2$	**B1**
(b)(i)	$C_N = CL / (L - D)$	**B1**
(b)(ii)	(charge is unchanged by moving the plates so) $Q_N = CV$	**B1**
(b)(iii)	$V_N = Q_N / C_N$ $= (CV) / [CL / (L - D)]$ $= V(L - D) / L$	**B1**

Q11.

(b)	$C = Q / V$	**C1**
	$V = Q / (4\pi\varepsilon_0 r)$ and so $C = Q / [Q / (4\pi\varepsilon_0 r)] = 4\pi\varepsilon_0 r$	**A1**
(c)	$Q = 4\pi\varepsilon_0 rV = 4\pi \times 8.85 \times 10^{-12} \times 0.13 \times 4500$ $(= 6.5 \times 10^{-8}\ \text{C})$	**C1**
	$(Q - q) / 13 = q / 5.2$	**C1**
	$5.2Q - 5.2q = 13q$, so $q = (5.2 / 18.2)Q$ $q = (5.2 / 18.2) \times 6.5 \times 10^{-8}$ $= 1.9 \times 10^{-8}\ \text{C}$	**A1**
	or	
	$V_T = Q_T / C_T$ $= 6.5 \times 10^{-8} / [4\pi \times 8.85 \times 10^{-12} \times (0.13 + 0.052)]$ $(= 3210\ \text{V})$	**(C1)**
	$q = 4\pi \times 8.85 \times 10^{-12} \times 0.052 \times 3210$ $= 1.9 \times 10^{-8}\ \text{C}$	**(A1)**

Q12.

(a)(i)	charge per unit potential (difference)	**M1**
	charge on one plate <u>and</u> potential difference across the plates	**A1**
(a)(ii)	any three points from: • smoothing • timing/(time) delay • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
(b)	(capacitors in series have combined capacitance =) 8 μF	**C1**
	capacitance = 8 + 24 = 32 μF	**A1**

Q13.

(a)(i)	charge per unit potential (difference)	**M1**
	charge on one plate and potential difference between the plates	**A1**
(a)(ii)	any three points from: • smoothing • timing/(time) delaying • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
(b)(i)	parallel combination of two in series and a single capacitor	**B1**
(b)(ii)	one capacitor in series with two in parallel	**B1**

Q14.

(a)	Any valid two points e.g.: • to store (electrical) energy • smoothing/reduce ripple (on direct voltages/currents) • to block d.c. • timing/time delay (circuits) • in oscillator (circuits) • in tuning (circuits) • to prevent arcing/sparks	**B2**
(b)	clear indication of equal charge on each capacitor	**B1**
	$E = V_1 + V_2 + V_3$ **and** $V = Q / C$	**M1**
	completion of algebra leading to $1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3$	**A1**
(c)(i)	three capacitors connected in parallel	**B1**
(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	**B1**

Q15.

(a)	(capacitance =) charge / potential	**M1**
	charge is (numerically equal to) charge on one plate	**A1**
	potential is potential difference between plates	**A1**
(b)(i)	4.5×10^{-6} C	**A1**
(b)(ii)	9.0×10^{-8} C	**A1**
(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	**C1**
	$= 7.5 \times 10^{-10}$ F	**A1**
(c)	total capacitance is halved	**B1**
	current is halved	**B1**

Q16.

(a)	capacitance = charge / potential	**M1**
	charge is (numerically equal to) charge on one plate	**A1**
	potential is potential difference between plates	**A1**
(b)(i)	two in series, in parallel with the other (correct symbols)	**A1**
(b)(ii)	two in parallel connected to one in series (correct symbols)	**A1**
(c)(i)	capacitance = 1.2 μF	**A1**
(c)(ii)	**1.** $Q = CV$	**C1**
	$= 1.2 \times 8.0$ $= 9.6\ \mu C$	**A1**
	2. $E = \frac{1}{2}QV$ **and** $V = Q/C$ **or** $E = \frac{1}{2}CV^2$ **and** $V = Q/C$ **or** $E = \frac{1}{2}Q^2/C$	**C1**
	$E = \frac{1}{2}(9.6 \times 10^{-6})^2 / (3.0 \times 10^{-6})$ $= 1.5 \times 10^{-5}$ J	**A1**