Level 3 Physics: Demonstrate understanding of electrical systems – DC Capacitors - Answers

In 2013, **AS 91526** replaced **AS 90523.**

The Mess that is NCEA Assessment Schedules….

In AS 90523 there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff).

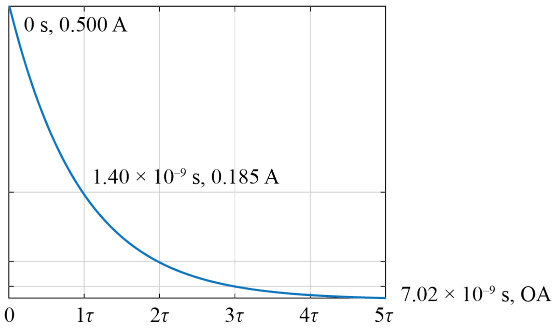
From 2003 to 2008, the NCEA shaded columns that were not relevant to that question.

In 91526, from **2013 onwards**, each part of a question contributes to the overall Grade Score Marking of the question and there are no longer separate criteria. There is no shading anymore. There is no spoon. At least their equation editor has stopped displaying random characters over the units.

In **2018**, the Assessment Schedule states that the Marking convention is "a = 1, m = 2, e = 3 and for E at least one e is required and for M at least one m is required"

In **2019**, the Assessment Schedule states that the Marking convention is "a = 1, m = 2, e = 3 and for E at least one e is required"

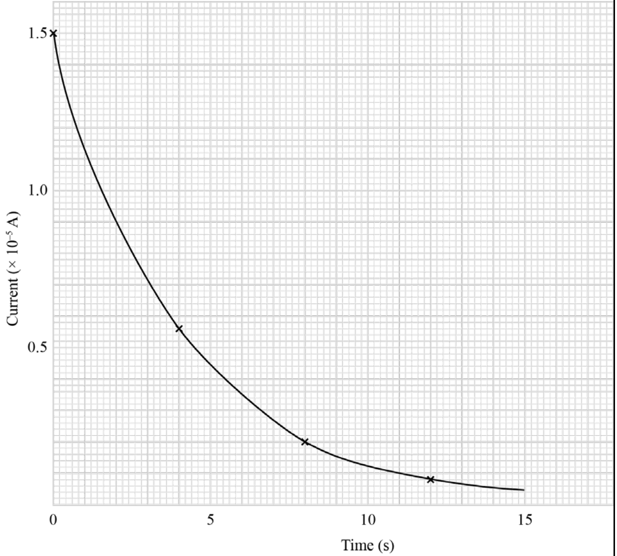
Question	Evidence	Achievement	Merit	Excellence
2019(3) (a)	$C = \frac{8.85\times10^{-12}\ \text{F}\times0.687\ \text{m}^2}{0.0519\ \text{m}} = 1.17\times10^{-10}\ \text{F}$	• C = 1.17 x 10^{-10} F **SHOW QUESTION**		

(b)	$I_{max} = \frac{V_{source}}{R} = 0.500 \text{ A at } t = 0.$ reduces exponentially to zero at $t = 5\,RC = 7.02 \times 10^{-9}$ s $I_\tau = 0.37 \times I$max = 0.185 A at $t = RC = 1.40 \times 10^{-9}$ s $I_{2\tau} = 0.37 \times 0.185$ A = 0.0685 A at 2.808×10^{-9} s 	• Exponential decay shape • $\tau = 1.40 \times 10^{-9}$ s • $I1 = 0.185$ A	• Correct **shape** with values shown $I_T = 0.5$ A & $I_\tau = 0.185$ A OR $I_\tau = 0.185$ A & $I_{2\tau} = 0.0685$ A	
(c)	$C_{new} = 2.303011 \times 10^{-10}$ F $C = \frac{Q}{V}$ $C_{new} \times V_{cap\ new} = Q = C_{original} \times V_{cap\ original}$ $V_{cap\ new} = \frac{C_{original} \times V_{cap\ original}}{C_{new}}$ $= \frac{1.17 \times 10^{-10} \times 6.00 \text{ V}}{2.303 \times 10^{-10} \text{ F}} = 3.05 \text{ V}$	• C ↑, therefore V ↓. • $Q = 7.03 \times 10^{-10}$ C	• Vcap new = 3.05 V **SHOW QUESTION**	

(d)	When the plates are pushed together, *Q* is initially constant, but *C* is increased, therefore *V*1 (cap) will decrease, according to *C*= Q/V. Since the capacitor voltage is now less than the source voltage, a difference in voltage exists across the resistor and the current will flow from the source to the capacitor. So there will be a momentary current reading on the ammeter, and a momentary voltage reading on V_2 (across the resistor). $I = \frac{V_2}{R} = \frac{V_s - V_1}{R} = \frac{6.00\text{ V} - 3.05\text{ V}}{12\,\Omega} = 0.246\text{ A}$	• V_1 (cap) ↓ • V_2 (r) ↑ • *I* ↑ • V_2 = 2.95 V • pd between V_s and V_c therefore current flows.	• $V_{source} = V_1 + V_2$, V_1 ↓ & V_2 ↑ • $V_{source} = V_1 + V_2$, V_1 & V_2 change • Kirchoff's Law Σ *V* = 0, so V_1 ↓ and V_2 ↑ • *I* = 0.246 A • pd between V_s and V_c therefore V_1 ↓ V_2 ↑ & *I* ↑	• $V_{source} = V_1$ (cap) + V_2 (r), V_1↓ and V_2 ↑ AND I = 0.246 A • pd between V_s and V_c therefore V_1 ↓ V_2 ↑ & *I* ↑ AND *I* = 0.246 A
2018(1) (c)	Voltage after 1 time constant = 0.63 x V_{max} = 0.63 x 6.02 V = 3.79 V From graph: (time, 3.79 V) Time constant = 1.0 x 10^{-5}s Time constant = *R* x *C* 1.0 x 10^{-5} s = 3.09 Ω x *C* *C* = 3.24 x 10^{-6} F (or 3.3 x10^{-6} if used *R* = 3.00 Ω) (or 3.1 x 10^{-6} if used *R* = 3.175Ω)	• Voltage after one time constant= 3.79 V • Time constant = 0.9-1.0 x 10^{-5} s • Correct working for τ = *RC*, but with incorrect *T.* (Accept working with V_{max} = 6.00 V.)	C = 0.28 – 0.33 x 10^{-5} (Accept with mistaken *t* =1.0 s if everything else is correct but not τ = 5/5 = 1.0 s)	

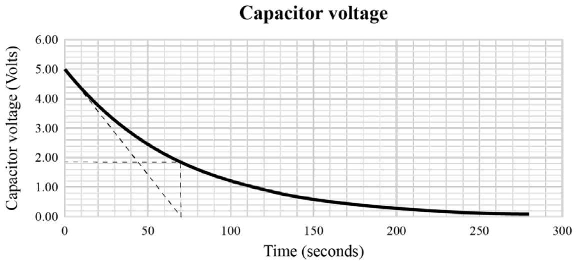
(d)	The capacitor will charge more quickly because the circuit has less resistance and $T = RC$, so current is higher, delivering charge to the plates more quickly.(No energy would have been converted to light, but) more energy would be converted to heat passing through the (internal) resistance of the battery and coil since current is now higher. So the same amount of energy will be converted in the charging process (it just happens faster). The fully charged capacitor will store the same amount of energy as before. Energy stored is $E = ½ CV^2$ or $E = ½QV$ and none of these values have changed.	• Capacitor will charge more quickly • Same amount of energy will be converted during charging. • Same amount of energy will be stored when capacitor is fully charged. • Less energy to light but more heat energy.	• Capacitor will charge more quickly BECAUSE: $\tau = RC$ and R is lower OR Current is higher, so Q is delivered more quickly. • Energy converted during charging will be the same (less light but more heat) BECAUSE The reduced resistance will increase current, which will increase the lost voltage across the battery. OR The capacitor always receives half of the energy supplied by the battery. • Energy stored will be equal because: $E = ½ CV^2$ or $E = ½QV$ or E does not depend on R of circuit. OR Plates will still hold the same Q and be at the same V.	Any two bullet points from Merit.
2018(3) (a)	$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$ $= 8.85 \times 10^{-12}\ \text{F m}^{-1} \times \frac{8.90 \times 1.20\ \text{m}^2}{1.00 \times 10^{-4}\ \text{m}}$ $= 9.4518 \times 10^{-7}\ \text{F} = 9.45 \times 10^{-7}\ \text{F}$	• Correct working and answer. (SHOW question)		

2017(1) (a)	The time constant is the time taken for the value of the current or voltage to change by 63%. OR It is also the time it would have taken had the rate of change stayed the same as at the start.	Correct explanation.		
	Only half the energy supplied by the cell is stored in the capacitor. The rest of the energy is changed to heat due to resistance. $E_p = \frac{1}{2}CV^2 \Rightarrow \frac{1}{2} \times 5.00 \times 10^{-6} \times 12.0^2 = 3.60 \times 10^{-4}$ J OR $E = \frac{7.2 \times 10^{-4}}{2}$	Correct energy for either capacitor. OR Correct reasoning why less energy is stored in the capacitor.	Both energy correct AND explanation for difference.	

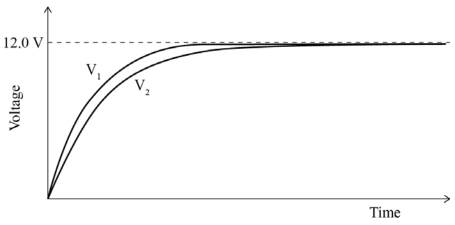
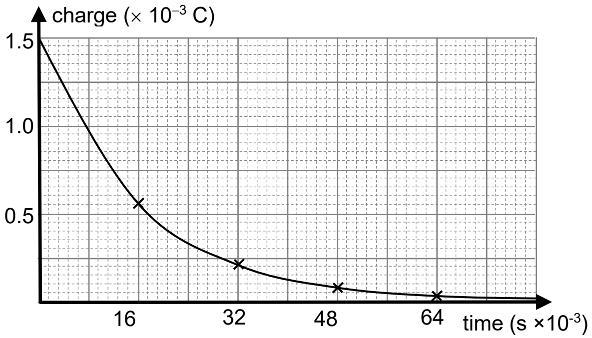
(c)	$\tau = RC \Rightarrow 8.00\times10^5 \times 5.00\times10^{-6} \Rightarrow 4.00$ s $I_{max} = \frac{V}{R} = \frac{12.0}{8.00\times10^5} = 1.5\times10^{-5}$ A After one time constant, $I = I_{max} \times 0.37 = 0.56 \times 10^{-5}$ A  Graph is a decay curve. The graph is a decay curve because as the capacitor begins to get charged, the current is a maximum at the start when the rate of flow of charge is a maximum. As more charges accumulate on the capacitor plates, the voltage across the capacitor increases, opposing the source voltage. It becomes harder for charges to accumulate on the plates, so the current decreases.	τ = 4.00 s I = 0.56 A Graph correct shape starting at 1.5 A V_C increases Potential difference between cap and battery decreases V_C opposes source voltage Repulsion of charges I decreases	Correct time constant and correct shape of graph. Indication that the rate of flow of charge is a maximum at the start of the charging process and that current falls to zero once the capacitor is fully charged.	Full explanation with links and reasoning and correct graph including correct time constant and two non-zero values on each axes. If graph touches zero, not extended to 15 s or curves up.

(d)	The second capacitor is added parallel. This increases the capacitance $\tau = RC$, so the time constant increases. This causes the capacitor to charge up more slowly. OR Time taken to charge up increases.	Capacitance increases when another capacitor is added in parallel. OR Time constant increases, so charging time increases.	Correct explanation linking ideas.	
2016(1) (a)	$Q = CV = 2.20 \times 10^{-6} \times 5 = 1.10 \times 10^{-5}$ C	Correct answer.		
(b)	The maximum voltage is approximately 5.0 V. The time constant is the time taken to reach 0.63 × 5.0 V (3.15 V). This is approximately 1.1 s OR Estimates time constant correctly using $5 \times \tau = 5s$ This is approximately 1.1 s $\tau = RC$ $R = \frac{\tau}{C} = \frac{1.1}{2.2 \times 10^{-6}} = 5.00 \times 10^{5}\ \Omega$ Allow variation due to reading off graph.	Correct time constant. Correct working for R with incorrect time constant, uses 37% of V so $V = 1.85$ and R = 2.27×10^{5}.	Correct answer. $R = 4.5 – 5.0 \times 10^{5}$	

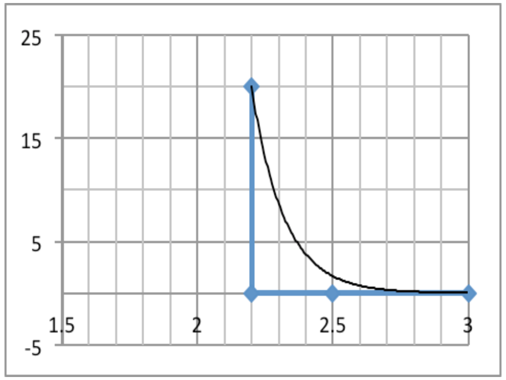
(c)	$V = \frac{Q}{C}$ When the switch is first closed, the capacitor is uncharged, so the capacitor voltage starts at zero. Electrons flow on to the capacitor fast initially (current is maximum) and so voltage rises rapidly. ($V = \frac{Q}{C}$ and *C* is constant) As more and more charges accumulate on the plates, it will be harder for electrons to accumulate on the plates due to repulsive forces. Electrons will then start flowing on to the capacitor more slowly (current decreases) and so voltage rises more slowly (less difference in potential between supply and capacitor). When the capacitor is fully charged, the current is zero, the resistor voltage is zero so the capacitor voltage equals the battery voltage	Correct explanation for the initial rate of change in voltage (*I* max therefore $\frac{Q}{V}$ increases) Correct explanation for the rise in voltage. *Q* = *CV*, *Q* increases therefore *V* increases. Correct explanation for the final rate of change in voltage.	Correct explanation for the initial voltage. AND Correct explanation for the rise in voltage. OR Correct explanation for the rise in voltage. AND Correct explanation for the final voltage.	All three concepts: Initial, rise and final voltages.
(d)	The final voltage will be half the original voltage (OR *V* = 2.5 V) because the battery voltage is shared between two capacitors. $\tau = RC$ and the total capacitance has decreased, so the time constant will decrease.	New C = 1.1×10^{-6} F. Final voltage halved (2.5 V). Time constant decreases with reason.	Full explanation for both.	
2015 (2) (a)	Calculate voltage across cell 9.00 – 6.40 = 2.60 V Uses this to show that $\frac{2.60}{0.208}$ = 12.5 Ω OR $r = R_T - R_C$	V_r = 2.60 V $r = R_T - R_C$	*r* = 12.5 Ω **(Must clearly indicate how 2.6 is derived)** **(SHOW THAT Q)**	

(b)	$C = \frac{\varepsilon_0 \varepsilon_R A}{d}$ $A = \frac{Cd}{\varepsilon_0 \varepsilon_R}$ $A = \frac{2.75 \times 10^{-9} \times 2.26 \times 10^{-4}}{8.85 \times 10^{-12} \times 1}$ $A = 7.02 \times 10^{-2}\ \text{m}^2$	A = 7.02×10^{-2} m^2		
(c)	 63% change interpolated on graph as 65 – 75 by either method. $\tau = RC$ so $R = \frac{\tau}{C} = \frac{68}{15} = 4.50\ \Omega$ $I = \frac{V}{R} = \frac{5.00}{4.50} = 1.11\ \text{A}$	Correct method used to estimate time constant. Shows some understanding of a decrease in *V* leading to extrapolating Time constant. Correct method used leading to incorrect *I* (used 33/37 or 63/67%)	Correct method used to estimate time constant. AND Time constant used to calculate *R*. **(SHOW THAT Q)**	Correct method used to estimate time constant. AND Time constant used to calculate *R*. AND Initial current calculated from τ and *R*.

(d)	$E = ½CV^2 = ½ \times 400 \times 5.00^2 = 5000$ J This is about 1% of the 6×10^5 J of energy required. $\tau = RC = 4.5 \times 400 = 1800$ s The time to fully discharge, 5 time constants is 9000 s. The capacitor will take a long time (2.5 hours) to discharge and does not rapidly discharge.	$E = ½CV^2 = ½ \times 400 \times 5^2$ $= 5000$ J $\tau = RC = 4.5 \times 400 = 1800$ s Discharge will occur in 4 – 5 time constants.	No it won't charge because: $E = ½CV^2 = ½ \times 400 \times 5^2 = 5000$ J. This is less than the energy required. **OR** $\tau = RC = 4.5 \times 400 = 1800$ s The capacitor will take about 9000 s to discharge (5 time constants is 9000 s). This is too long.	No it won't charge because: $E = 6 \times 10^5$, $Q = 2.6 \times 10^5$, so $C = 4800$ F, this is much larger than 400 F AND $\tau = RC = 4.5 \times 400 = 1800$ s The capacitor will take about 9000 s to discharge (5 time constants is 9000 s or reference to fact that its 63% discharged). This is too long. **OR** $E = ½CV^2 = ½ \times 400 \times 5^2$ $= 5000$ J. This is less than the energy required. AND $\tau = RC = 4.5 \times 400 = 1800$ s The capacitor will take about 9000 s to discharge (5 time constants is 9000 s or reference to fact that its 63% discharged). This is too long.
2014 (3) (a)	The potential of the +ve terminal of the battery is higher than the capacitor plate it is connected to, and the –ve terminal is at a lower potential than the plate it is connected to. Charge flows from high to low, so electrons will move from the negative terminal on to the plate, and from the plate on to the positive terminal. Charge will flow until there is no potential difference between each plate and the terminal it is connected to. This happens when the voltage across the capacitor plates is equal to the voltage of the battery.	Indication that the current will become zero only when the voltages in the circuit are equal and opposite. Voltage of battery is greater than voltage of capacitor therefore voltage of capacitor increases. Parallel components have same voltages. Current / charges flow from battery onto capacitor. It is gaining / storing energy. It is fully charged.	Because the plates are charged, they will have a potential difference, which will increase until it matches the voltage of the battery. Because they are in parallel and voltage across resistor is zero. Kirchhoff's law explanation. $Q = CV$, as the capacitor charges, Q increases, therefore V increases.	

(b)	$E_P = ½QV = 0.5 × 8.6 × 10^{-3} × 12$ $= 0.0516 = 0.052$ J	0.052 J		
(c)		Correct shape.		
2013 (1) (a)	$Q = VC = 12 × 125 × 10^{-6} = 1.5 × 10^{-3}$ C	Correct answer $1.5 × 10^{-3}$ C OR 0.0015 C.		
(b)	Resistance is very small, so current is very large. Resistance is small and the capacitance is also very small / Time constant is very small 5τ is small.	Correct explanation.	Some indication to tell that 5τ is small.	
(c)		Exponential decay (approx) ignore time axis labels + one of the following: • decay starts from the value $1.5 × 10^{-3}$C. • The line shows 63% drop correctly. • Time constant = 0.016s calculated.	Achievement plus at least 2 other plots shown from 0.555, 0.2, 0.08, 0.03. Time axis should have correct values	

(d)	The lamp will be at or above its normal brightness if the voltage across it is at, or above, the voltage of the lamp. When $V = 9.0$ V, $Q = 9.0 \times 125 \times 10^{-6} = 1.125 \times 10^{-3}$ C. Reading from the graph: $\text{when } Q = 1.125 \times 10^{-3}\text{ C} \quad t = 16 \times 10^{-3} \times \frac{3.5}{10} = 0.0056\text{ s}$	Correct charge calculated **1.125×10^{-3} C** OR Correct time scale used for part (c)	TWO of: • Correct charge and • Correct time scale used for part (c) • If the time axis is incorrect, but time is consequently calculated correctly.	Correct Time Accept 0030 – .0064 s OR If the only error is the incorrect time constant used for *x*-axis scale, but time is consequently calculated correctly Accept range 0.00004 – 0.00009 s.
(e)	$\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{tot} = \frac{125 \times 10^{-6}}{2}$ $= 62.5 \times 10^{-6} = 63\ \mu\text{F}$	Correct answer. Working must be shown.		
(f)	The time constant is reduced because the capacitance of the circuit is less ($\tau = RC$). Less charge is stored on the plates of each capacitor ($Q = CV$). Less charge can flow off the plates of the capacitors more quickly.	$\tau = RC$ so lower τ because lower C.		
2012(2) (b)	$\frac{4.5}{e} = 1.655$ Therefore $\tau = 2400$ s $R = \tau/C = 2400/500 = 4.8\ \Omega$	[2]Correct time constant. Must show the working. $\frac{4.5}{e} = 1.655$	[2]Uses $\tau = RC$ and gets correct answer linking graph shape to 4.8 Ω.	
(c)	$500 \times 3 = 1500$ F Exponential decay curve drawn stretched × 3 wider.	[1]Exponential decay curve drawn stretched approx × 3 wider or clear attempts to do this. [2]1500 F.		
(d)	Three 500 F capacitors connected in parallel or drawn	[1]Correct statement or correct diagram.		
2011(1) (a)	$\tau = RC = 1000 \times 0.12 \times 10^{-6} = 120 \times 10^{-6}$ s (or 0.12 ms, 0.12×10^{-3} s, 1.2×10^{-4} s, 0.00012s)	[2]Correct answer.		

(b)		[1]Sketch shows approx exponential decay shape. OR Demonstrates understanding of exponential decay shape with reference to exponential/constant percentage drop per time constant in written answer.	[1]Sketch shows exponential decay shape with roughly 37% of 20V (7.4 V) after 0.12 ms, or clear deliberate attempt to do this.	
(c)	$Q = CV = 0.12 \times 10^{-6} \times 20 = 2.4 \times 10^{-6}$ C 0.24 ms is 2 time constants, so the charge will drop to 37% of its full value, twice. Ie to $0.37 \times 0.37 = 0.137$ 2.4×10^{-5} C $\times 0.1360 = 3.29 \times 10^{-7}$ C/3.25×10^{-7} C	[2]Correct full charge. OR TWO time constants calculated.	[2]Correct full charge and correct use of time constant. OR Voltage after TWO time constants found correctly.	[2]Correct working and answer.
2010(2) (a)	Capacitance decreases because the relative permittivity has decreased and $C = \frac{\varepsilon_r \varepsilon_0 A}{d}$	[1]Capacitance decreases and reason given.	[1]An in-depth answer which involves discussion of how water affects relative permittivity (and hence as the wood dries, C decreases). This should link the polarity of water molecules/the mobility of electrons within a water molecule.	

(b)	$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$ $\varepsilon_r = \frac{Cd}{\varepsilon_0 A}$ $\varepsilon_r = \frac{4.99 \times 10^{-11} \times 0.0150}{8.85 \times 10^{-12} \times 0.0500 \times 0.650}$ $\varepsilon_r = 26.0$	[2]Correct answer.		
2009(3) (a)	$C = \frac{\varepsilon_0 \varepsilon_r A}{d} = \frac{8.85 \times 10^{-12} \times 0.5}{0.82 \times 10^{-3}} = 5.4 \times 10^{-9}$ F	[2]Correct answer.		
(b)	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{d_1}{\varepsilon_0 \varepsilon_r A} + \frac{d_2}{\varepsilon_0 \varepsilon_r A}$ $= \frac{d_1 + d_2}{\varepsilon_0 \varepsilon_r A} \Rightarrow C_T = \frac{\varepsilon_0 \varepsilon_r A}{d_1 + d_2}$	[2]Correct use of capacitor addition but gets lost in the algebra.	[2]Correct proof.	
(c)	$d_1 + d_2$ is constant because if d_1 increases then d_2 will decrease by the same amount (and vice versa).	[1]Correct idea.		
(d)	The total capacitance and the voltage across the capacitor arrangement have not changed. As $Q_{tot} = V_{tot} C_{tot}$ the total charge has not changed. As there is no change in the charge stored there will be no movement of charge and therefore no current.	[1]One point made correctly.	[1]Correct answer, lacking detailed reasoning.	[1]Correct, complete answer.

(e)	When the middle plate moves, d_1 decreases and so C_1 increases. $C = \dfrac{\varepsilon_0 \varepsilon_r}{d}$ $Q = VC$. Because the capacitors are connected in series the charge on C_1 stays constant. hence V_1 decreases as C_1 increases.	[1] Idea that the decrease in distance increases the capacitance.	[1] Increase in capacitance linked to decrease in voltage by Q = VC	[1] Complete correct explanation. Constant Q must be specifically stated.
(f)	Q is same before and after the movement. $\Rightarrow V_{after}C_{after} = V_{total}C_{total} = V_{before}C_{before}$ $\Rightarrow \dfrac{V_{after}}{d_{after}} = \dfrac{V_{total}}{d_{total}} = \dfrac{V_{before}}{d_{before}}$ $d_{after} = \dfrac{5.1 \times 0.00164}{12}$ OR $\dfrac{5.1 \times 0.00082}{6}$ $= 6.97 \times 10^{-4}$ $\Delta d = 8.2 \times 10^{-4} - 6.97 \times 10^{-4} = 0.12$ mm	[2] Recognition that constant Q can be applied in this situation and calculation of a charge.	[2] New separation calculated.	[2] Correct answer.
2008(3) (a)	$C = \dfrac{\varepsilon_r A}{d}$ $A = \dfrac{Cd}{\varepsilon_r}$ $= \dfrac{1.65 \times 10^{-8} \times 1.00 \times 10^{-4}}{8.84 \times 10^{-12}}$ $= 0.187$ m^2	[2] Correct answer.		

(b)	Decrease separation. Use a dielectric (plastic/ paper). Roll the metal foil up.	[1] Two methods.		
(c)	$R = \frac{V}{I}$ – use the intercept value $= \frac{19.5}{0.00013}$ $= 150\ 000\ \Omega$	[2] Correct use of intercept and working (allow intercept values 0.00013 – 0.000135).		
(d)	$\frac{1}{e} \times 0.000\ 13 = 0.0478\ \text{A}$ Time constant works out, from graph at 0.0032 ± 0.0003 s $C = \frac{\tau}{R}$ $= \frac{0.032}{150\ 000}$ $= 2.1 \times 10^{-8}$ F (range from time constant values 1.93 → 2.33 x 10^{-8} F)	[2] Correct method to find time constant	[2] Correct time constant within limits.	[2] Correct answer consistent with time constant measured from graph within limits.
2007(1) (a)	$\tau = RC = (215 + 1.20) \times 7.7 \times 10^{-3}$ $= 216.5 \times 7.7 \times 10^{-3} = 1.665$ = **1.7 s** **Note 1.20 Ω resistor needed**	[2] Correct answer [1] Answer rounded to 2sf, plus correct unit.		
(c)	$V_C = 2.50$ V	[1] Correct voltage		

(d)	When the capacitor is fully charged, the voltage across it equals the source voltage. The capacitor voltage opposes the source voltage and so the circuit voltage, and hence circuit current, is zero.	[1]Idea of capacitor voltage equalling the supply voltage **OR** Idea of charge building up (in cap) but must say **why** current reduces as cap charges	[1]Capacitor voltage is **opposing** the source voltage **OR** Zero circuit voltage	
(e)	The capacitor discharges through the bulb. The bulb will glow when the power delivered to it is high enough. *P* = *IV*. As the capacitor discharges, both *I* and *V* decrease, so the power will quickly drop below the required value.	[1]They must explain **both** the **glow** and the bulb **going out**. e.g. Discharging of charge or current until insufficient current / charge to make the bulb go (be seen) **OR** something similar (perhaps involving voltage) and is correct e.g. V_{cap} reduces as charge reduces until the charges have insufficient voltage/energy to make the bulb go (be seen).	[1]Explanation links the initial glowing of the bulb to **sufficient power,** (and the power decrease as smaller *I* or *V*).	
(i)	The bulb is designed to operate off a 2.5 V supply. The maximum voltage the capacitor can supply is 0.85 V, which will not give enough power to make the bulb glow.	[1]Idea of voltage (of capacitor) too low.		
(j)	Switch 1 must be closed so that the capacitor can charge. Switch 2 must be open because if it is closed, the battery will always be supplying current to the outside loop, which means that the voltage drop across the resistances will reduce the fully-charged voltage across the capacitor.	[1]Correct switch 1 answer.	[1]Correct switch 2 answer. A voltage reason is needed to explain why the cap must be fully charged (not a current one).	[1]There must be some idea of the resistor's voltage having an effect on the voltage across the cap.

2006(1) (a)	When the switch is closed, the capacitor will charge and current will flow through the circuit resistance.	[1]Idea of charge flowing on to the capacitor plates **and** around the circuit.		
(b)	When the bounce breaks the circuit and isolates $R_{circuit}$ from the supply, the charged capacitor discharges through the circuit.	[1]Idea that the capacitor acts as the voltage source.		
(c)	$\tau = RC \Rightarrow C = \frac{\tau}{R}$ $C = \frac{0.11}{1450} = 7.5862 \times 10^{-5} = 76\ \mu F$ (2 sf)	[2]Correct working. [1]Answer rounded to 2 sf plus correct units given in 4 answers.		
(d)	$Q = VC = 5.50 \times 7.5862 \times 10^{-5}$ $= 4.17241 \times 10^{-4} = 4.2 \times 10^{-4}$ C	[2]Correct answer.		
(e)	For the capacitor to be able to act as the voltage supply, the capacitor must be charged to maximum voltage when the first break happens. As it takes several time constants before full charge is reached the time before the break must be longer than one time constant.	[1]Some idea that the capacitor needs to be charged when the first break comes.	[1]Link made between the requirement for the capacitor to be fully charged and the short period of time for this to happen.	[1]Clear, accurate and complete.

(f)	Supply voltage will divide in the ratio of the resistances $V_C = 9.00 \times \frac{1450}{(1450 + 22)}$ = 8.86549 = 8.87 V OR $9.00 - 22.0 \times I - V_C = 0$ $9.00 = (22.0 + 1450) \times I$ $I = 6.11413 \times 10^{-3}$ A $\Rightarrow V_C = 9.00 - 22.0 \times 6.11413 \times 10^{-3}$ = 8.86549 = 8.87 V	[1]Correct voltage ratio / correct application of Kirchhoff	[2]Correct I / correct answer from incorrect *I*	[2]Correct answer.
2006(2) (d)	When all transient effects have ceased the current will be zero, and so the only voltages in the circuit will be the source and the capacitor. As voltages must sum to zero they must be equal and opposite to each other.	[1]One correct and relevant statement.	[1]Link made between zero current and voltages being equal.	[1]Equal voltages linked to zero voltage across resistor / no rate of change of current in inductor.
(e)	$Q = CV = 0.47 \times 10^{-6} \times 25 = 1.175 \times 10^{-5}$ C $E = ½QV = 0.5 \times 1.175 \times 10^{-5} \times 25 = 1.46875 \times 10^{-4} = 1.5 \times 10^{-4}$ J		[2]Correct answer.	
(f)	It will be converted to heat by the resistor as the capacitor discharges through the switch.	[1]One correct and relevant statement.	[1]Converted to heat by the resistor.	
(g)	If there were no resistor in the discharge circuit, the transient current through the switch would be high and could damage the contacts.	[1]Answer relates a lower current to the presence of resistance.	[1]Answer relates a high capacitor discharge current through the switch to potential damage.	
2005(1) (e)	$\tau = CR = 5.00 \times 10^{-3} \times 64.3$ = **0.322 s**	Correct answer.		

(f)	As charging progresses, the current in the circuit will decrease and so the internal resistance of the cell will also decrease. This means that the time constant will be decreasing. As the rate at which the current decreases is inversely related to the time constant, this rate will be increasing, hence it will take a shorter time for the capacitor to fully charge. **OR** Increasing V_C means decreasing current in solar cell. This means decreasing current and hence decreasing internal resistance. The reduced internal resistance means a slower drop off in current. (compared to the fixed resistor circuit).	ONE correct and relevant statement: Time is shorter (but if followed by a contradictory statement do not allow) internal resistance will decrease current will decrease time constant will be decreasing.	Time for solar cell is shorter and: Any ONE of the linkages below gives merit Decreasing current and hence decreasing internal resistance **OR** decreasing internal resistance means decreasing time constant (τ = RC) Time for solar cell is shorter and: Increasing V_C means decreasing current in solar cell **OR** Decreasing current and hence decreasing internal resistance **OR** Reduced internal resistance means a slower drop off in current (compared to the fixed resistor circuit).	Time for solar cell is shorter and: Decreasing current and hence decreasing internal resistance to decreasing time constant (τ = RC) and hence shorter charging time. Time for solar cell is shorter and: Increasing V_C means decreasing current in solar cell. This means decreasing current and hence decreasing internal resistance The reduced internal resistance means increased current (or a slower drop off in current).