6 **(a)** Two parallel plate capacitors C_1 and C_2 are connected to a supply that has a potential difference (p.d.) V_S. The capacitors may be connected in series or in parallel.

The supply provides charge Q_S and the plates of the two capacitors acquire charges Q_1 and Q_2 respectively. The p.d.s across the plates of the capacitors are V_1 and V_2 respectively.

Complete Table 6.1 to indicate how Q_S, Q_1 and Q_2 relate to each other, and how V_S, V_1 and V_2 relate to each other, for series and parallel connections of the capacitors to the supply.

Table 6.1

	relationship between charges	relationship between p.d.s
series		
parallel		

[4]

(b) An isolated capacitor of capacitance 470 μF stores 19 mJ of energy.

(i) Calculate the p.d. across the capacitor.

p.d. = ... V [2]

(ii) Calculate the charge on the capacitor.

charge = ... C [2]

(iii) The capacitor is now connected in parallel with a capacitor of capacitance 180 μF that is initially uncharged.

Determine the total energy, in mJ, now stored in the two capacitors.

energy = ... mJ [3]

7 Fig. 7.1 shows a circuit containing a capacitor of capacitance C and a resistor of resistance R.

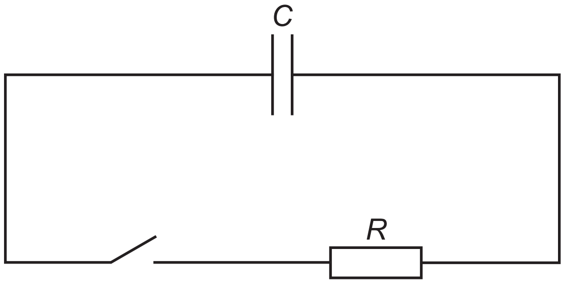

Fig. 7.1

Initially, the switch is open and the potential difference (p.d.) across the capacitor is 12 V.

The switch is closed at time $t = 0$ and the capacitor discharges through the resistor.

Fig. 7.2 shows the variation of the charge Q on the capacitor with the p.d. V_C across the capacitor as the capacitor discharges. Fig. 7.3 shows the variation of the current I in the resistor with the p.d. V_R across the resistor as the capacitor discharges.

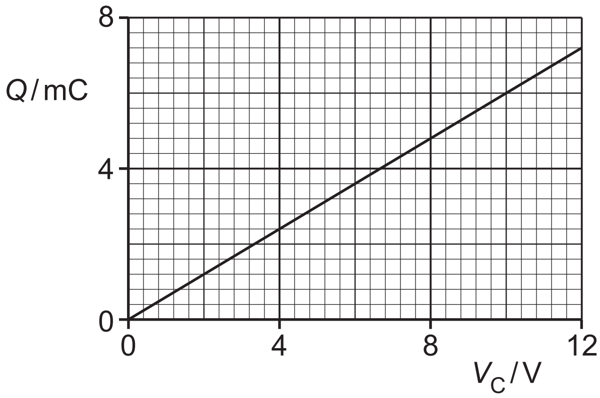

Fig. 7.2

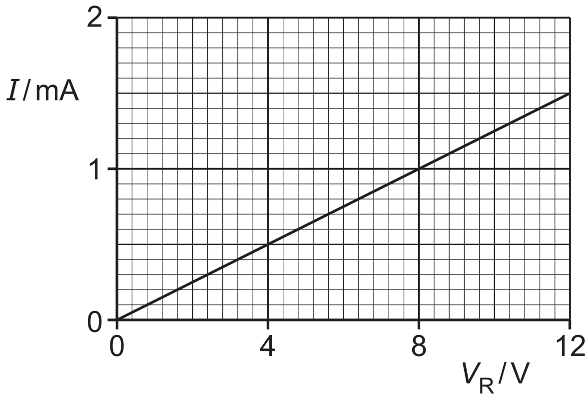

Fig. 7.3

(a) State the relationship between V_C and V_R.

.... [1]

(b) Determine:

(i) the capacitance C, in μF

C = ... μF [2]

(ii) the resistance R, in kΩ

R = ... kΩ [2]

(iii) the time constant τ of the circuit.

τ = ... s [2]

(c) Use Fig. 7.2, Fig. 7.3 and your answer in **(a)** to explain why the variation of Q with t is exponential in nature.

....

....

....

....

.... [3]

5 **(a)** A capacitor of capacitance C_1 is connected in series with a second capacitor of capacitance C_2.

Show that the combined capacitance C of the two capacitors is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}.$$

[2]

(b) Three identical capacitors, each of capacitance C, are connected in a network as shown in Fig. 5.1.

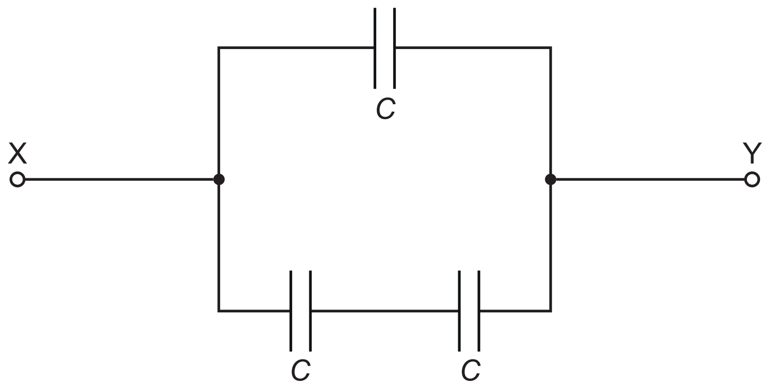

Fig. 5.1

The variation of the charge Q with the potential difference (p.d.) V between the terminals X and Y is shown in Fig. 5.2.

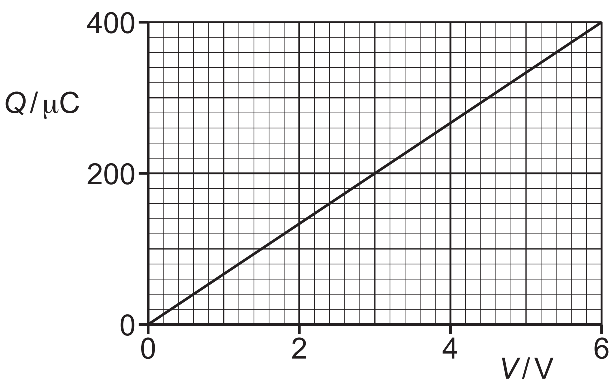

Fig. 5.2

Show that C is equal to $44\,\mu F$.

[3]

(c) The capacitor network in Fig. 5.1 is charged and then connected to a resistor of resistance $54\,k\Omega$. The capacitor network discharges through the resistor.

(i) Determine the time constant τ of the circuit. Give a unit with your answer.

τ = ... unit .... [2]

(ii) Determine the time taken for the discharge current to reduce to 15% of the initial discharge current.

time = ... s [2]

7 **(a)** Define the capacitance of a parallel-plate capacitor.

....

....

.... [2]

(b) An initially uncharged capacitor X, of capacitance C, is gradually charged so that the final potential difference (p.d.) between its plates is V and the final charge is Q.

(i) On Fig. 7.1, sketch the variation of charge with p.d. for capacitor X as the p.d. increases from 0 to V.

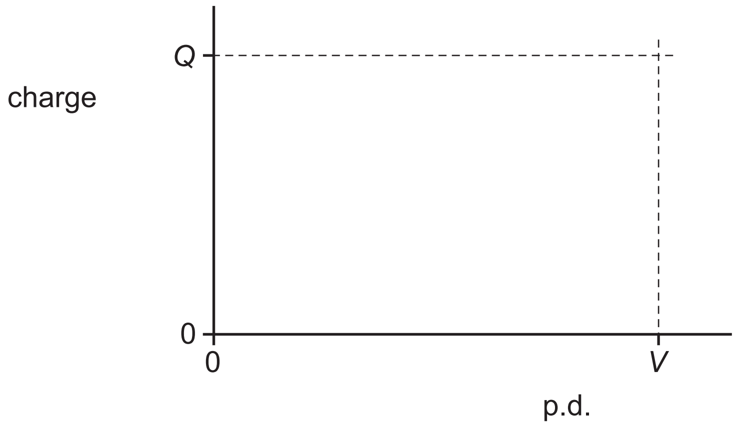

Fig. 7.1

[2]

(ii) Determine an expression, in terms of Q and V, for the work W done on capacitor X during the charging process. Explain your reasoning.

W = ... [2]

(c) Another capacitor Y is initially uncharged. The fully charged capacitor X in **(b)** is now connected to capacitor Y, as shown in Fig. 7.2.

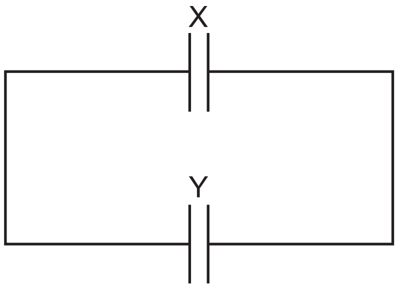

Fig. 7.2

The capacitance of capacitor Y is 3*C*.

(i) Complete Table 7.1 to show expressions, in terms of *Q* and *V*, for the final p.d.s across, and the final charges on, the two capacitors.
Use the space below for any working that you need.

Table 7.1

	X	Y
final p.d.		
final charge		

[3]

(ii) State whether the total energy stored in the two capacitors is less than, the same as, or greater than the energy initially stored in capacitor X.

.... [1]

6 **(a)** Two capacitors X and Y are connected in series to a power supply of voltage V, as shown in Fig. 6.1.

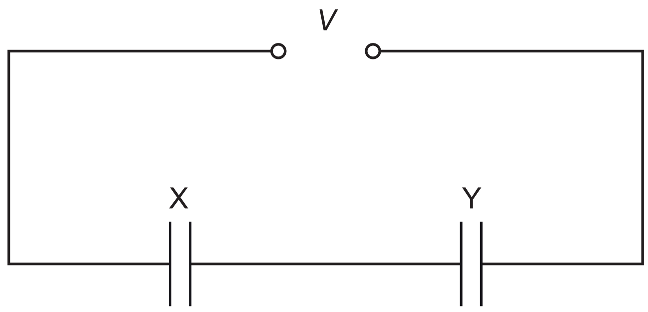

Fig. 6.1

The capacitance of X is C_X and the capacitance of Y is C_Y.

Derive an expression, in terms of C_X and C_Y, for the combined capacitance C_T of the capacitors in this circuit.
Explain your reasoning.

[3]

(b) Two capacitors P and Q are connected in parallel to a power supply of voltage V.
The capacitance of P is 200 μF. The capacitance C_Q of Q can be varied between 0 and 400 μF.
When C_Q = 0, the total energy stored in the capacitors is 2.5 mJ.

(i) Show that the supply voltage V is 5.0 V.

[2]

(ii) Calculate the total energy, in mJ, stored in the capacitors when C_Q has its maximum value.

total energy = ... mJ [3]

(iii) On Fig. 6.2, sketch the variation of the total energy E stored in the capacitors with C_Q, as C_Q varies from 0 to 400 μF.

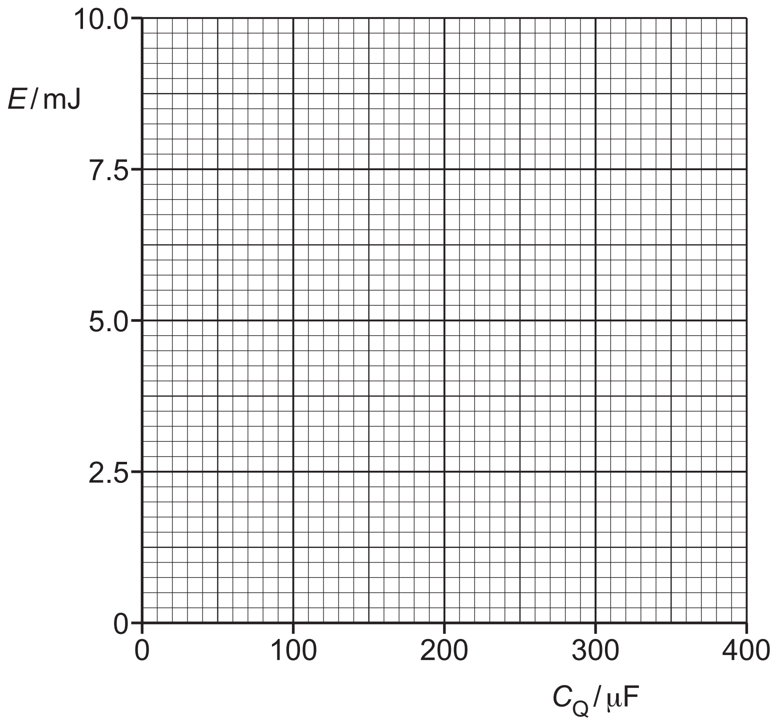

Fig. 6.2

[2]

6 Fig. 6.1 shows a capacitor of capacitance *C* connected in series with a resistor of resistance *R*.

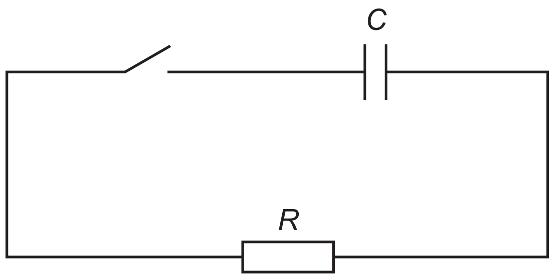

Fig. 6.1

Initially the switch is open and there is a p.d. of 12 V across the capacitor.

At time $t = 0$, the switch is closed so that there is a current I in the resistor.

Fig. 6.2 shows the variation of I with t.

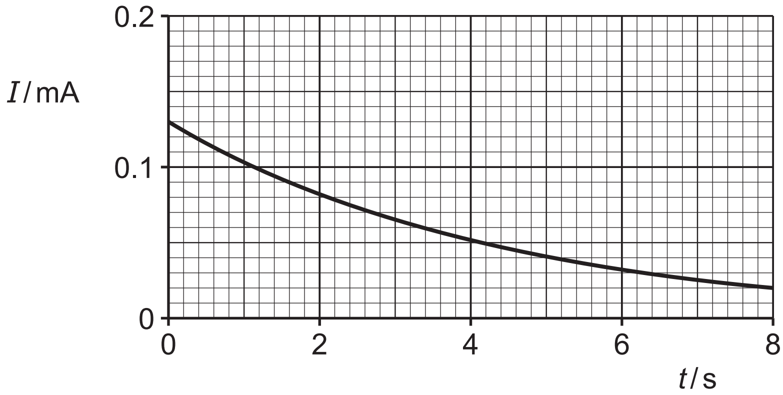

Fig. 6.2

(a) Explain the shape of the line in Fig. 6.2.

....

....

....

....

.... [3]

(b) Use Fig. 6.2 to determine:

(i) resistance R

R = ... Ω [2]

(ii) the time constant τ of the circuit in Fig. 6.1.

τ = ... s [3]

(c) Use your answers in **(b)** to determine capacitance C.

C = ... F [2]

4 **(a)** Three capacitors are connected as shown in Fig. 4.1.

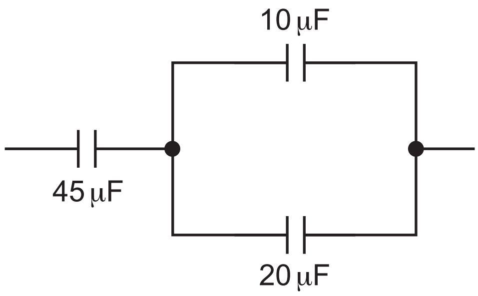

Fig. 4.1

Determine the total capacitance, in μF, of the network of three capacitors.

capacitance = ... μF [2]

(b) A capacitor of capacitance 45 μF is connected to a variable power supply initially set at 8.0 V. The output of the power supply increases so that the potential difference (p.d.) across the capacitor increases to 9.6 V.

Calculate the increase in energy ΔE stored in the capacitor.

ΔE = ... J [2]

(c) A sinusoidal a.c. power supply is connected to the input of a bridge rectifier. The output of the rectifier is connected to a load resistor.

(i) Complete the circuit in Fig. 4.2 by adding a capacitor to smooth the p.d. across the load resistor.

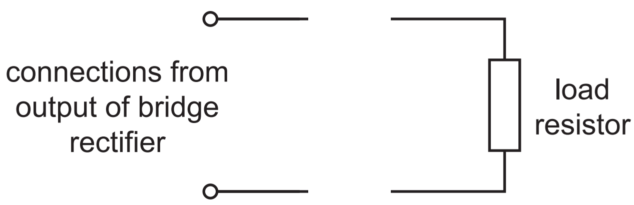

Fig. 4.2

[1]

(ii) The variation with time t of the p.d. V of the smoothed output is shown in Fig. 4.3.

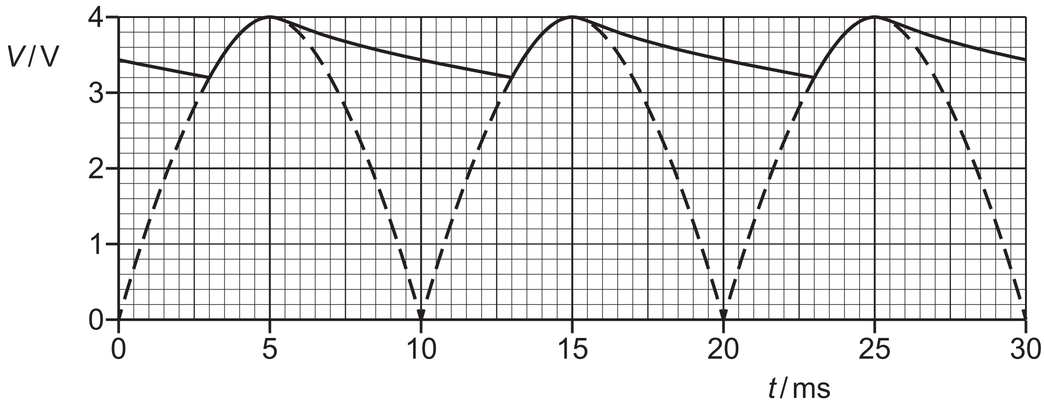

Fig. 4.3

Determine the time constant, in ms, of the smoothing circuit.

time constant = ... ms [3]

(d) A sinusoidal a.c. power supply has a maximum power of 16 W.

State the value of the mean power when the output of the power supply is:

(i) full-wave rectified

mean power = ... W [1]

(ii) half-wave rectified.

mean power = ... W [1]

6 A capacitor C is charged so that the potential difference (p.d.) V across its terminals is 8.0 V. The capacitor is connected into the circuit of Fig. 6.1.

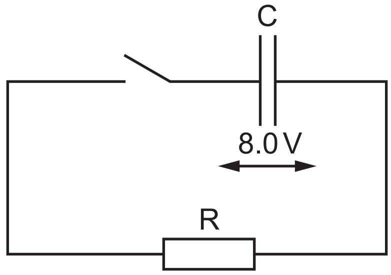

Fig. 6.1

The switch is initially open. The switch is closed at time $t = 0$.

(a) Fig. 6.2 shows the variation of V with the charge Q on the plates of capacitor C as the capacitor discharges.

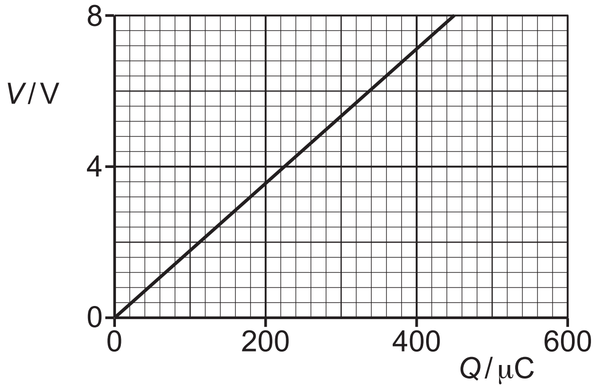

Fig. 6.2

(i) Show that the energy stored in capacitor C at time $t = 0$ is 1.8 mJ.

[2]

(ii) Determine the capacitance of capacitor C. Give a unit with your answer.

capacitance = ... unit .... [2]

(b) Fig. 6.3 shows the variation with t of $-\ln\left(\dfrac{V}{8.0\,\text{V}}\right)$.

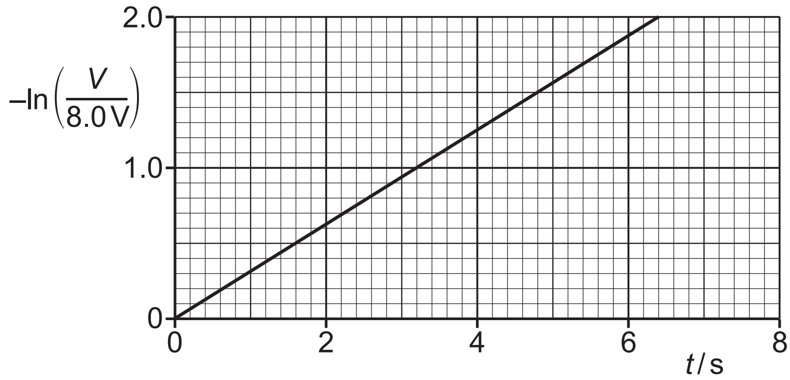

Fig. 6.3

(i) Show that, when t is equal to one time constant, the value of $-\ln\left(\dfrac{V}{8.0\,\text{V}}\right)$ is equal to 1.0.

[2]

(ii) Determine the time constant τ of the circuit in Fig. 6.1.

τ = ... s [1]

(iii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

5 Two capacitors A and B are connected into the circuit shown in Fig. 5.1.

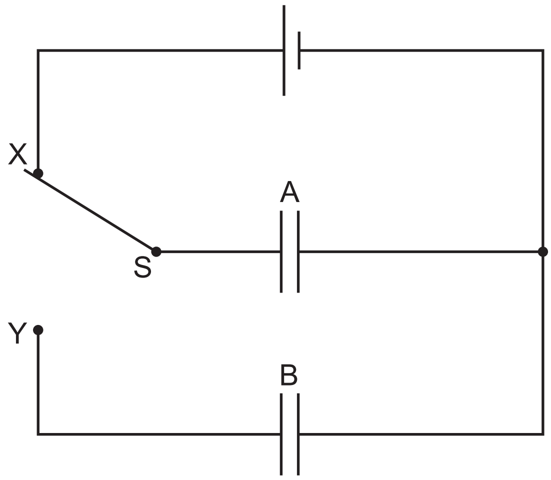

Fig. 5.1

Capacitor A has capacitance C and capacitor B has capacitance $3C$.
The electromotive force (e.m.f.) of the cell is V.
The two-way switch S is initially at position X, and capacitor B is initially uncharged.

(a) State, in terms of V and C, expressions for:

(i) the initial charge Q_A on the plates of capacitor A

Q_A = ... [1]

(ii) the initial energy E_A stored in capacitor A.

E_A = ... [1]

(b) The two-way switch S is now moved to position Y.

(i) State and explain what happens to the charge that was initially on the plates of capacitor A.

....

....

.... [2]

(ii) Show that the final potential difference (p.d.) V_B across capacitor B is given by

$$V_B = \frac{V}{4}.$$

Explain your reasoning.

[3]

(iii) Determine an expression, in terms of V and C, for the decrease ΔE in the total energy that is stored in the capacitors as a result of the change of the position of the switch.

ΔE = ... [2]

5 A capacitor, a battery of electromotive force (e.m.f.) 12 V, a resistor R and a two-way switch are connected in the circuit shown in Fig. 5.1.

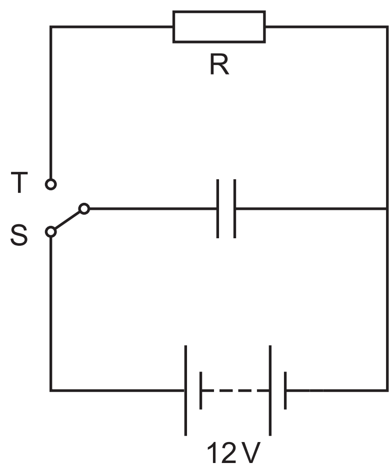

Fig. 5.1

The switch is initially in position S. When the capacitor is fully charged, the switch is moved to position T so that the capacitor discharges. At time t after the switch is moved the charge on the capacitor is Q.

The variation with t of $\ln(Q/\mu C)$ is shown in Fig. 5.2.

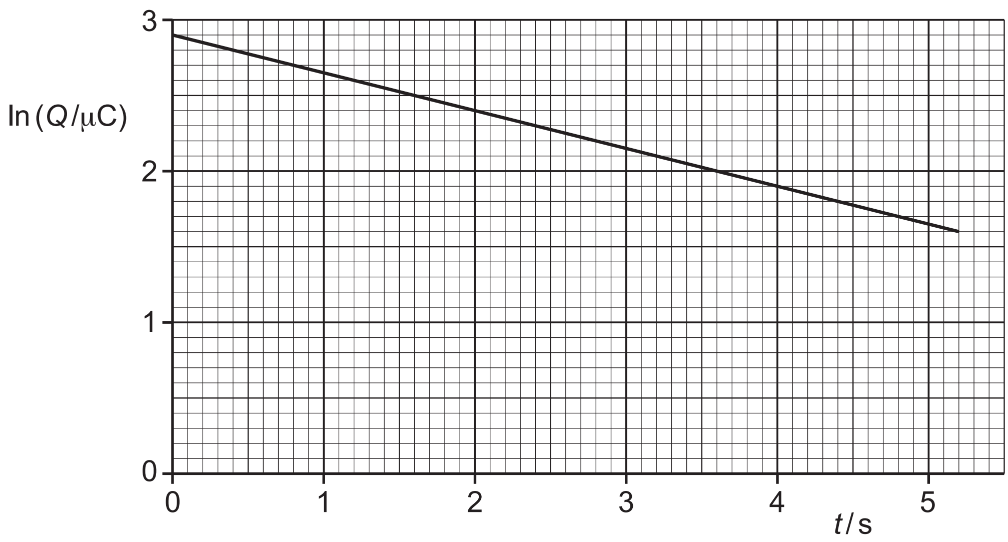

Fig. 5.2

(a) Show that the capacitance of the capacitor is 1.5 μF.

[3]

(b) Determine the resistance of R.

resistance = ... Ω [3]

(c) Calculate the energy stored in the capacitor at time $t = 0$.

energy = ... J [2]

(d) A second identical resistor is now connected in parallel with R.

The switch is initially in position S. When the capacitor is fully charged, the switch is moved to position T so that the capacitor discharges. At time t after the switch is moved the charge on the capacitor is Q.

On Fig. 5.2, sketch a line to show the variation of $\ln(Q/\mu C)$ with t between time $t = 0$ and time $t = 5.0\,s$. [2]

6 A capacitor of capacitance C and a resistor of resistance R are connected as shown in Fig. 6.1.

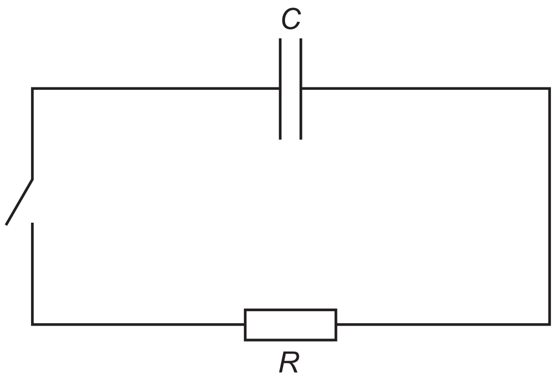

Fig. 6.1

Initially, the capacitor is charged and the switch is open.

The switch is closed at time $t = 0$.

Fig. 6.2 and Fig. 6.3 show, respectively, the variations with t of the charge Q on the capacitor and the potential difference (p.d.) V across the resistor.

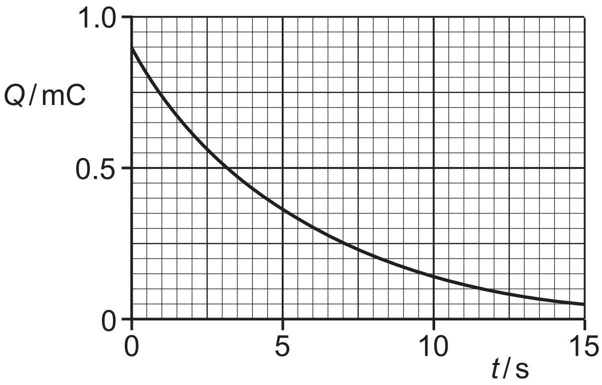

Fig. 6.2

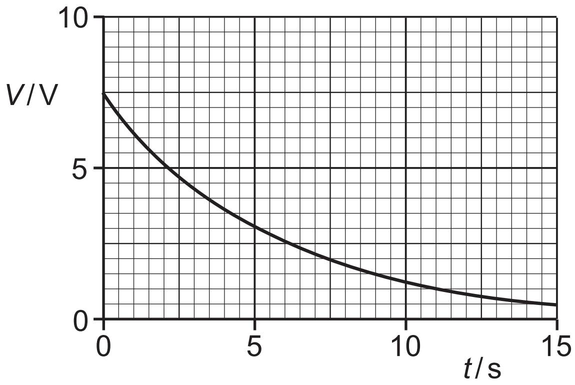

Fig. 6.3

(a) Explain the shape of the line in Fig. 6.3 representing the variation of V with t.

....

....

....

....

.... [3]

(b) Use Fig. 6.2 to show that the time constant of the circuit in Fig. 6.1 is 5.5 s.

[3]

(c) Use Fig. 6.2, Fig. 6.3 and the information in **(b)** to determine:

(i) capacitance *C*, in μF

C = ... μF [2]

(ii) resistance *R*, in kΩ.

R = ... kΩ [2]

5 A capacitor of capacitance 470 μF is connected to a battery of electromotive force (e.m.f.) 24 V in the circuit of Fig. 5.1.

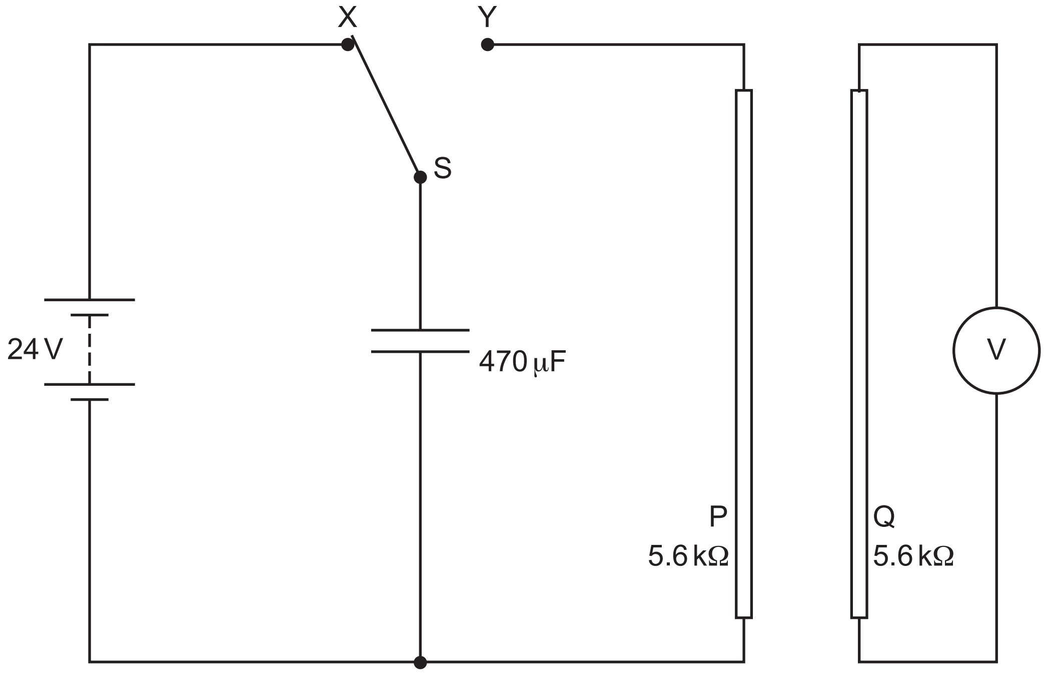

Fig. 5.1

The two-way switch S is initially at position X.

P and Q are identical long straight wires, each with a resistance of 5.6 kΩ. These wires are placed near to, and parallel to, each other. Wire Q is connected to a voltmeter.

At time $t = 0$, switch S is moved to position Y so that the capacitor discharges through wire P.

(a) **(i)** Calculate the charge Q_0 on the capacitor at time $t = 0$.

Q_0 = ... C [2]

(ii) Calculate the current I_0 in wire P at time $t = 0$.

I_0 = ... A [1]

(iii) Calculate the time constant τ of the discharge circuit.

τ = ... s [2]

(iv) On Fig. 5.2, sketch a line to show the variation with t of the current I in wire P as the capacitor discharges.

Fig. 5.2

[2]

(b) (i) Explain why there is an induced e.m.f. across wire Q during the discharge of the capacitor.

....

....

....

.... [3]

(ii) On Fig. 5.3, sketch a line to suggest the variation with t of the voltmeter reading V.

Fig. 5.3

[1]