CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 19: Capacitance

Past Papers 2021 – 2025

QUESTION PAPER 14 Questions

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Question 1

(a) A capacitor consists of two parallel metal plates, separated by air, at a variable distance x apart, as shown in Fig. 6.1. The capacitance C is inversely proportional to x.

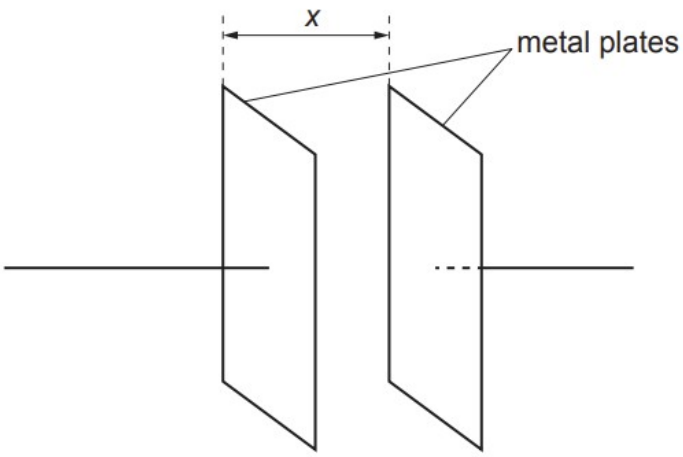


Fig. 6.1

The capacitor is charged by a supply so that there is a potential difference (p.d.) V between the plates.

State expressions, in terms of C and V, for the charge Q on one of the plates and for the energy E stored in the capacitor.

Q = ... E = ... [1]

(b) The charged capacitor in **(a)** is now disconnected from the supply. The plates of the capacitor are initially separated by distance L. They are then moved closer together by a distance D, as shown in Fig. 6.2.

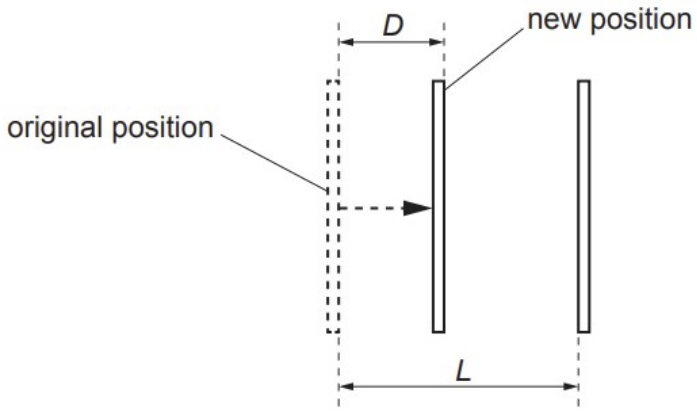


Fig. 6.2

State expressions, in terms of C, V, L and D, for:

(i) the new capacitance C_N

C_N = ... [1]

(ii) the new charge Q_N on one of the plates

Q_N = ... [1]

(iii) the new p.d. V_N between the plates.

V_N = ... [1]

(c) Explain whether reducing the separation of the plates in **(b)** results in an increase or decrease in the energy stored in the capacitor.

.....

.....

..... [1]

[Total: 5]

Question 2

(a) State what is meant by the *capacitance* of a parallel plate capacitor.

.....

.....

..... [2]

(b) A capacitor of capacitance *C* is connected into the circuit shown in Fig. 7.1.

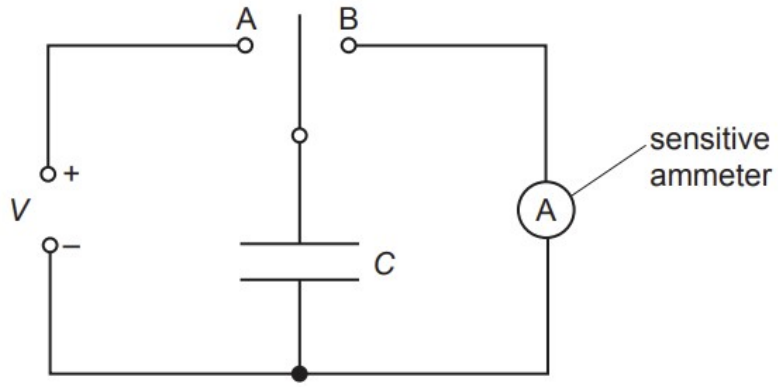


Fig. 7.1

When the two-way switch is in position A, the capacitor is charged so that the potential difference across it is *V*.
The switch moves to position B and the capacitor fully discharges through the sensitive ammeter.

The switch moves repeatedly between A and B so that the capacitor charges and then discharges with frequency *f*.

(i) Show that the average current *I* in the ammeter is given by the expression

$$I = fCV.$$

[2]

(ii) For a potential difference V of 150 V and a frequency f of 60 Hz, the average current in the ammeter is 4.8 μA.

Calculate the capacitance, in pF, of the capacitor.

capacitance = ... pF [2]

(c) A second capacitor, having the same capacitance as the capacitor in **(b)**, is connected into the circuit of Fig. 7.1. The two capacitors are connected in series.

State and explain the new reading on the ammeter.

new reading = ... μA

.....

.....

..... [3]

[Total: 9]

Question 3

(a) Two flat metal plates are held a small distance apart by means of insulating pads, as shown in Fig. 6.1.

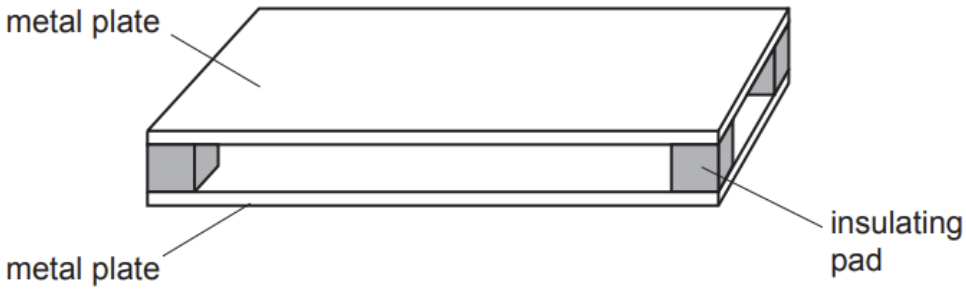


Fig. 6.1

Explain how the plates could act as a capacitor.

.....

.....

..... [2]

(b) The arrangement in Fig. 6.1 has capacitance *C*.
The arrangement is connected into the circuit of Fig. 6.2.

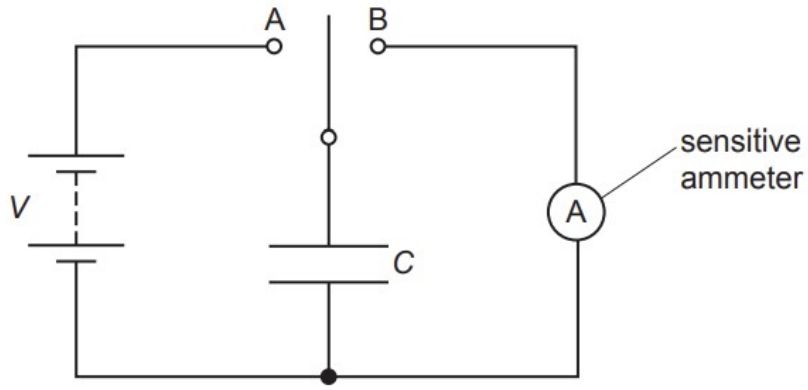


Fig. 6.2

When the two-way switch is moved to position A, the capacitor is charged so that the potential difference across it is *V*. When the switch moves to position B, the capacitor fully discharges through the sensitive ammeter.

The switch moves repeatedly between A and B so that the capacitor charges and then discharges with frequency *f*.

(i) Show that the average current I in the ammeter is given by

$$I = CVf.$$

[2]

(ii) For a potential difference V of 180 V and a frequency f of switching of 50 Hz, the average current I in the ammeter is 2.5 μA.

Calculate the capacitance, in pF, of the parallel plates.

capacitance = ... pF [2]

(c) A second capacitor is connected into the circuit of Fig. 6.2.
The two capacitors are connected in parallel.

State and explain the change, if any, in the average current in the ammeter.

.....

.....

..... [2]

[Total: 8]

Question 4

(a) Define *electric potential*.

.....

.....

..... [2]

(b) An isolated conducting sphere in a vacuum has radius r and is initially uncharged. It is then charged by friction so that it carries a final charge Q. This charge can be considered to be acting at the centre of the sphere.

By considering the electric potential at its surface, show that the capacitance C of the sphere is given by

$$C = 4\pi\varepsilon_0 r$$

where ε_0 is the permittivity of free space.

[2]

(c) The dome of an electrostatic generator is a spherical conductor of radius 13 cm. It is initially charged so that the electric potential at the surface is 4.5 kV.

A smaller isolated sphere of radius 5.2 cm, initially uncharged, is brought near to the dome. Sparking causes a current between the two spheres until they reach the same potential. Assume that any charge on a sphere may be considered to act as a point charge at its centre.

Calculate the charge that is transferred between the two spheres.

charge = ... C [3]

[Total: 7]

Question 5

(a) Define the capacitance of a parallel plate capacitor.

.....

.....

..... [2]

(b) Two capacitors, of capacitances C_1 and C_2, are connected in parallel to a power supply of electromotive force (e.m.f.) E, as shown in Fig. 5.1.

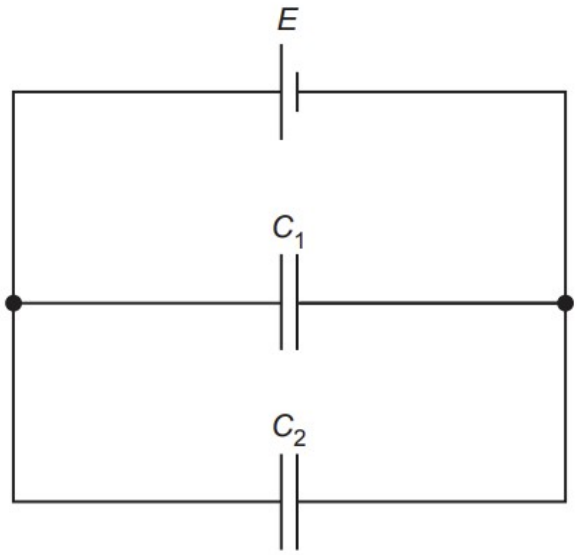


Fig. 5.1

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

$$C_T = C_1 + C_2.$$

Explain your reasoning. You may draw on Fig. 5.1 if you wish.

[3]

(c) Two capacitors of capacitances 22 μF and 47 μF, and a resistor of resistance 2.7 MΩ, are connected into the circuit of Fig. 5.2.

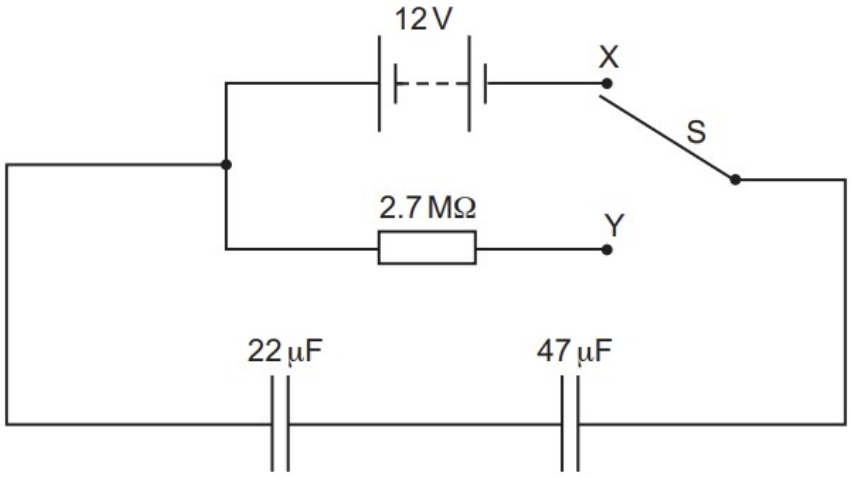


Fig. 5.2

The battery has an e.m.f. of 12 V.

(i) Show that the combined capacitance of the two capacitors is 15 μF.

[1]

(ii) The two-way switch S is initially at position X, so that the capacitors are fully charged.

Use the information in **(c)(i)** to calculate the total energy stored in the two capacitors.

total energy = ... J [2]

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

Determine the time taken for the potential difference (p.d.) across the 22 μF capacitor to become 6.0 V.

time = ... s [3]

[Total: 11]

Question 6

The variation with potential difference V of the charge Q on one of the plates of a capacitor is shown in Fig. 5.1.

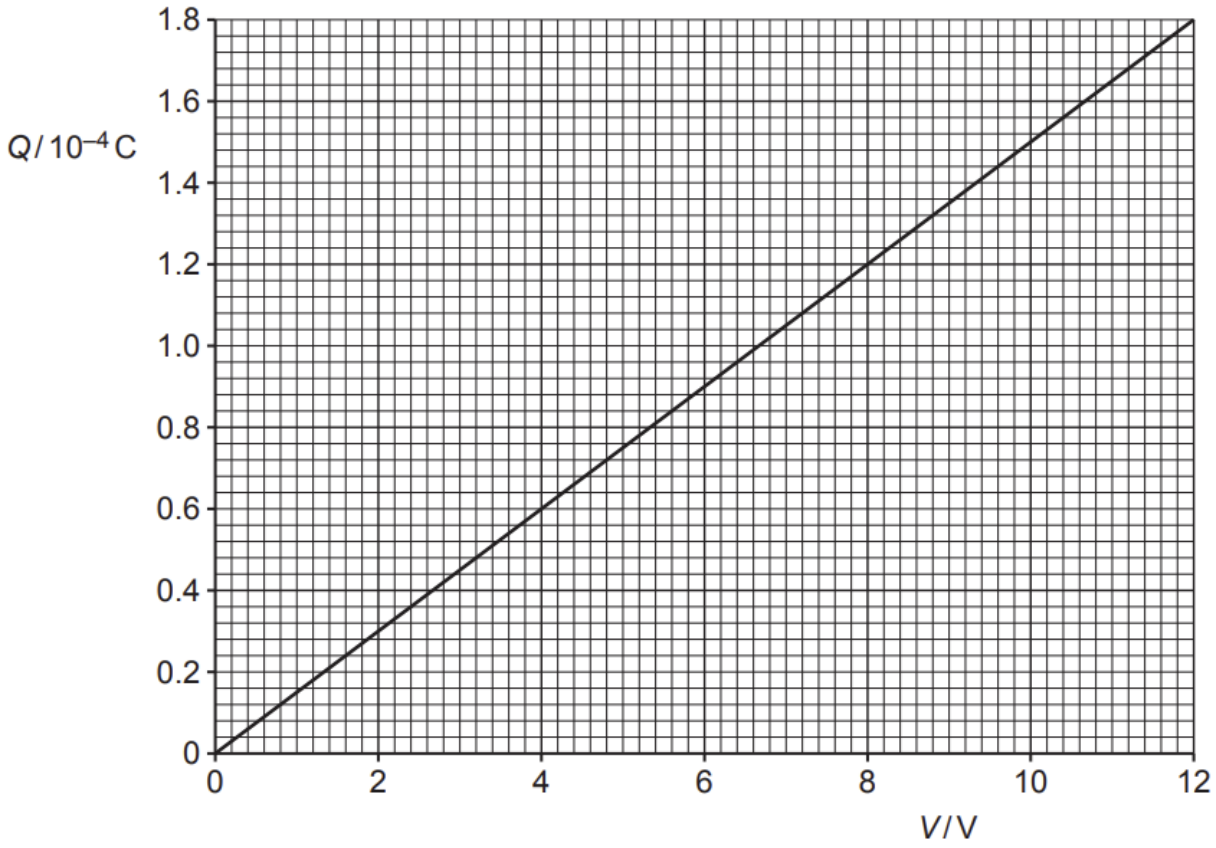


Fig. 5.1

The capacitor is connected to an 8.0 V power supply and two resistors R and S as shown in Fig. 5.2.

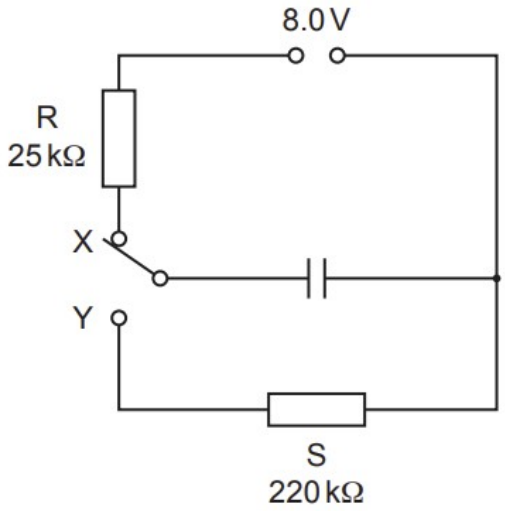


Fig. 5.2

The resistance of R is 25 kΩ and the resistance of S is 220 kΩ.

The switch can be in either position X or position Y.

(a) The switch is in position X so that the capacitor is fully charged.

Calculate the energy *E* stored in the capacitor.

E = ... J [2]

(b) The switch is now moved to position Y.

(i) Show that the time constant of the discharge circuit is 3.3 s.

[2]

(ii) The fully charged capacitor in **(a)** stores energy E.

Determine the time t taken for the stored energy to decrease from E to $E/9$.

t = ... s [4]

(c) A second identical capacitor is connected in parallel with the first capacitor.

State and explain the change, if any, to the time constant of the discharge circuit.

.....

.....

..... [2]

[Total: 10]

Question 7

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.

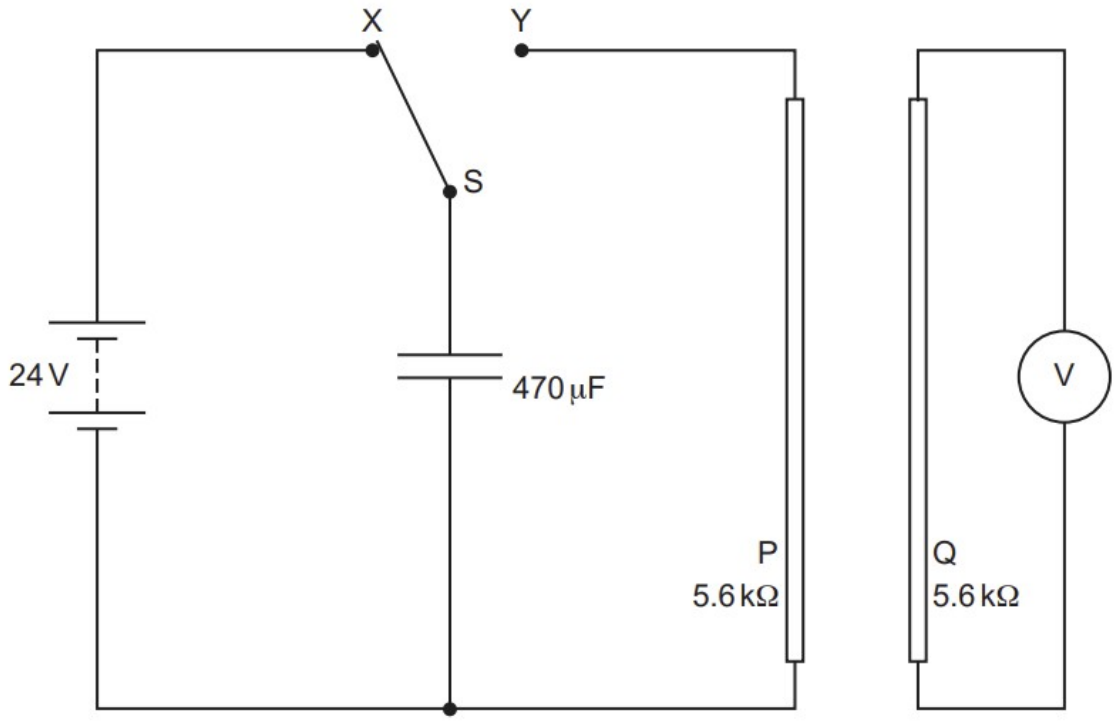


Fig. 5.1

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]

[Total: 11]

Question 8

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

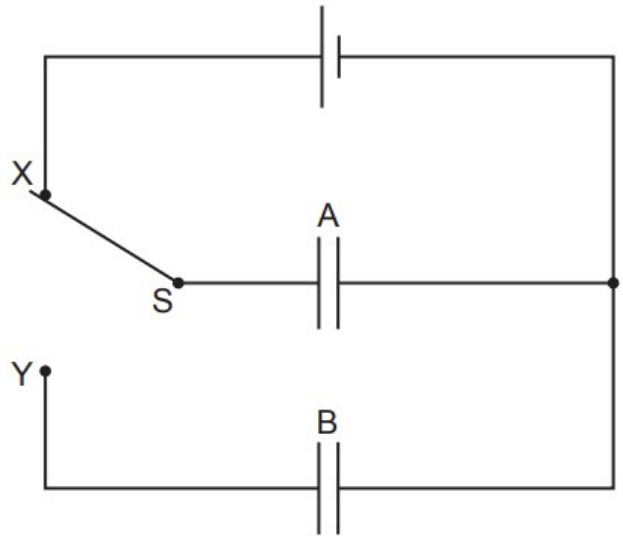


Fig. 5.1

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]

[Total: 9]

Question 9

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.

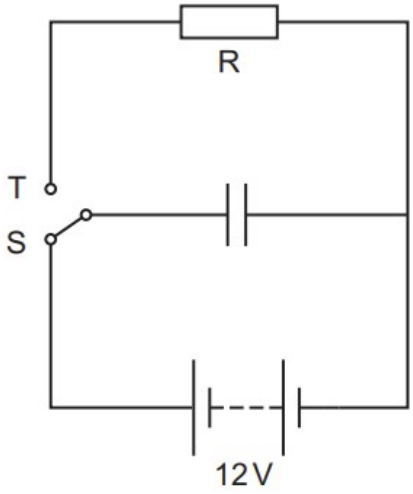


Fig. 5.1

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.

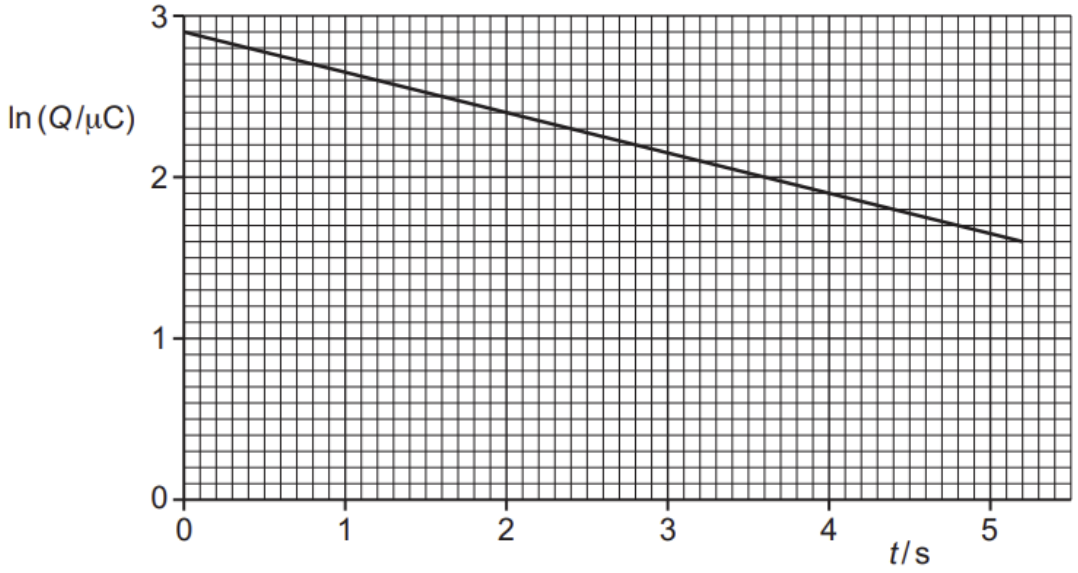


Fig. 5.2

(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]

[Total: 10]

Question 10

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.

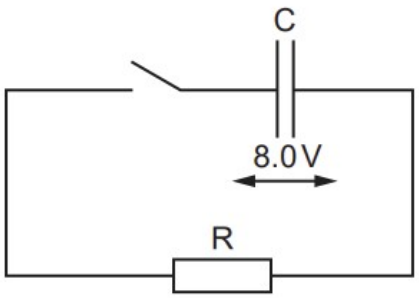


Fig. 6.1

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.

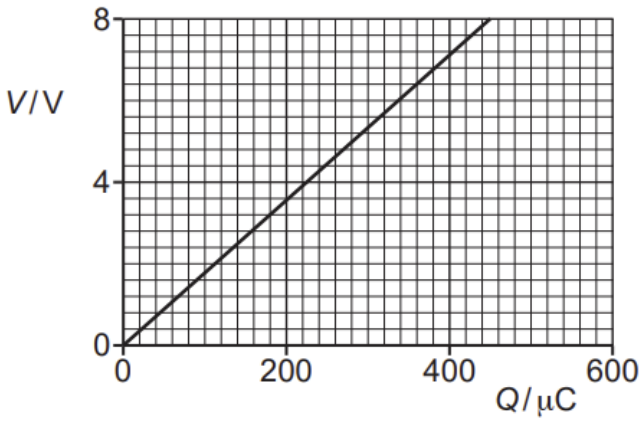


Fig. 6.2

(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 $-\ln\left(\frac{V}{8.0\,\text{V}}\right)$.

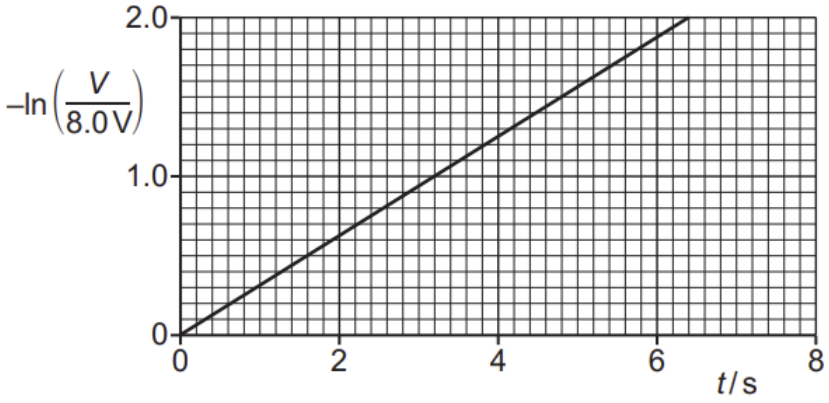


Fig. 6.3

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

[Total: 9]

Question 11

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

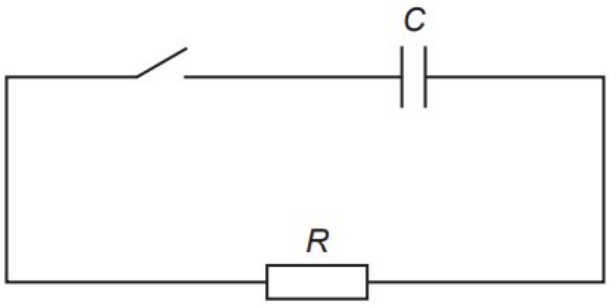


Fig. 6.1

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.

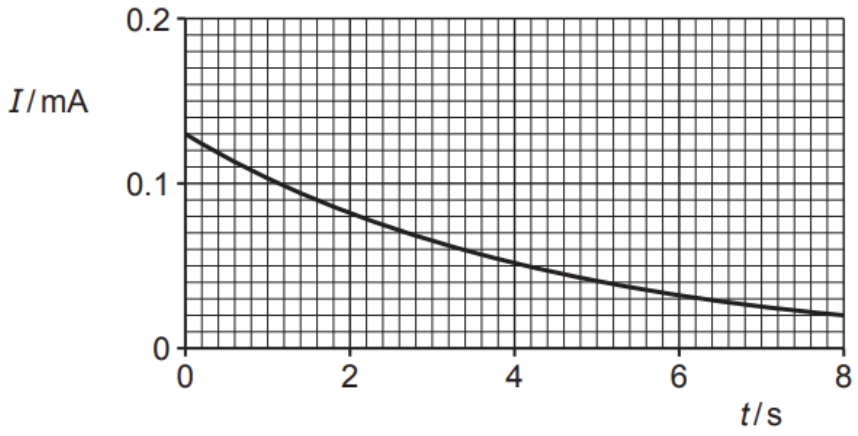


Fig. 6.2

(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]

[Total: 10]

Question 12

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

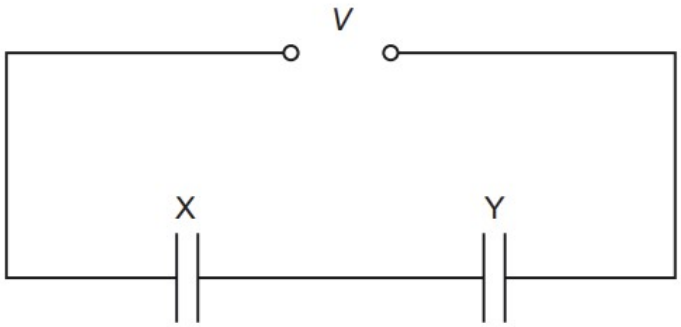


Fig. 6.1

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.

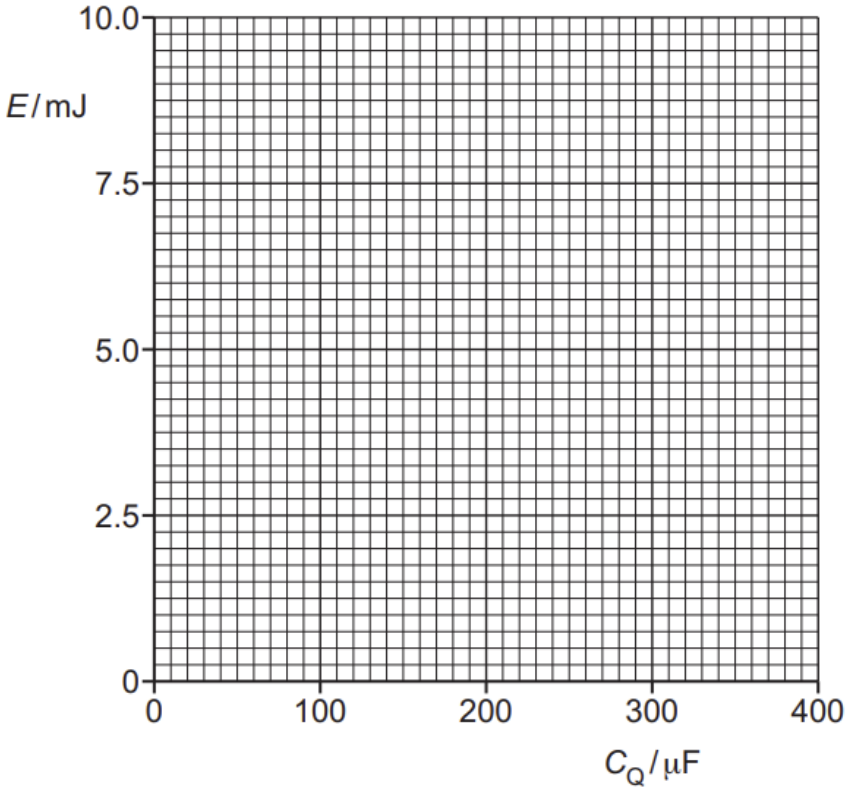


Fig. 6.2

[2]

[Total: 10]

Question 13

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

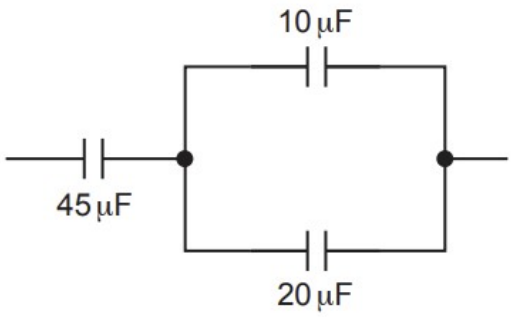


Fig. 4.1

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.

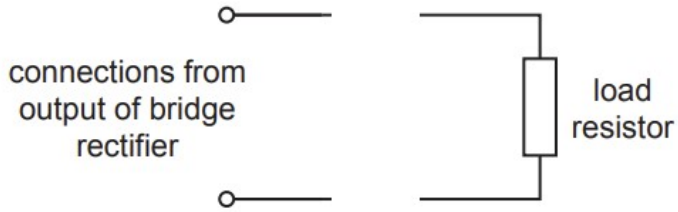


Fig. 4.2

[1]

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

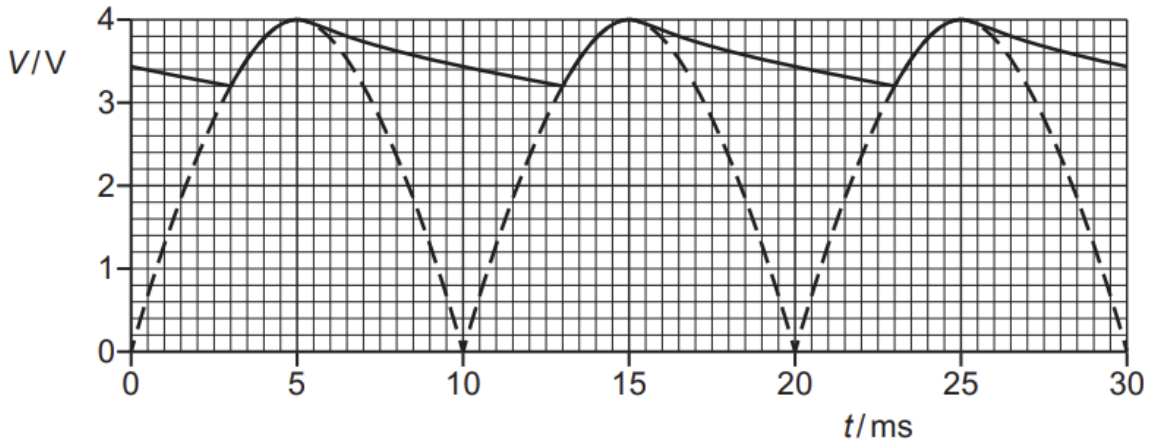


Fig. 4.3

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]

[Total: 10]

Question 14

(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.

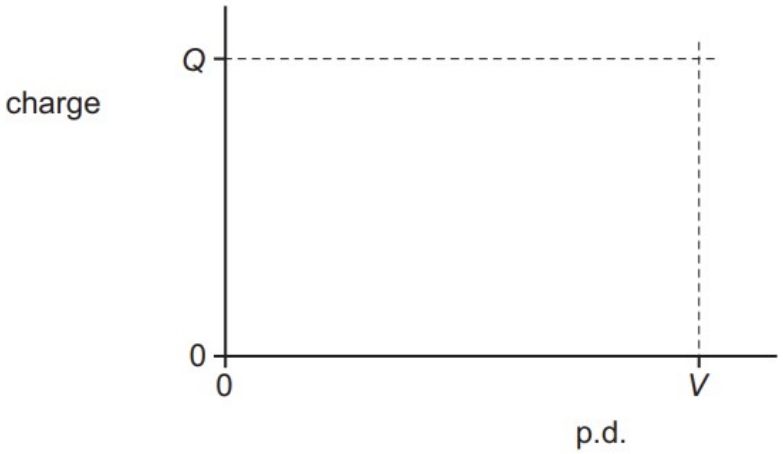


Fig. 7.1

[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.

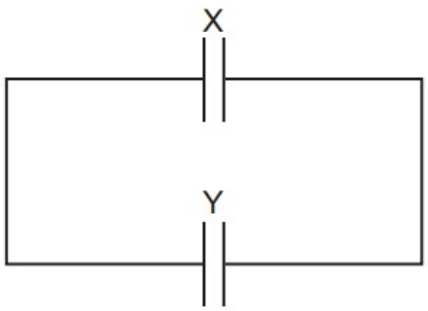


Fig. 7.2

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]

[Total: 10]

End of Question Paper • Waseem Ahmad, A Level Physics Teacher • examspath.com