19. Capacitance

19.1 Capacitors and capacitance

Paper 4

Question Paper

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

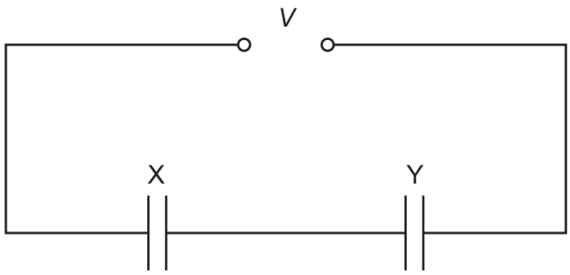


Fig. 6.1

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]

2 **(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*.

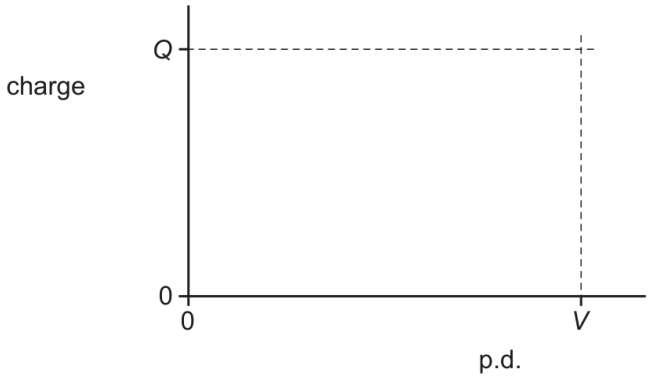


Fig. 7.1

[2]

(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.

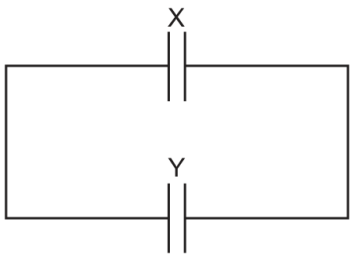


Fig. 7.2

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]

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

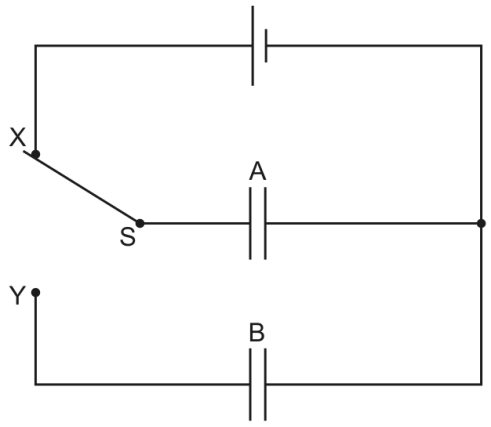


Fig. 5.1

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]

(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]

4 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.

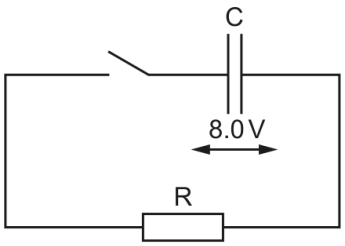


Fig. 6.1

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.

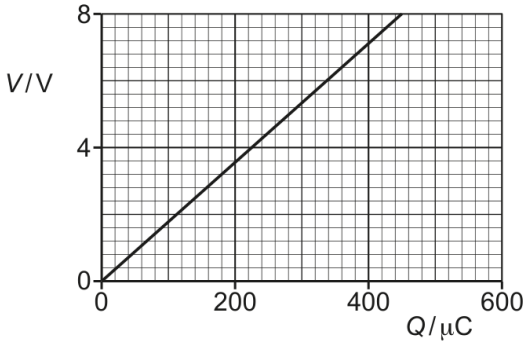


Fig. 6.2

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

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

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.

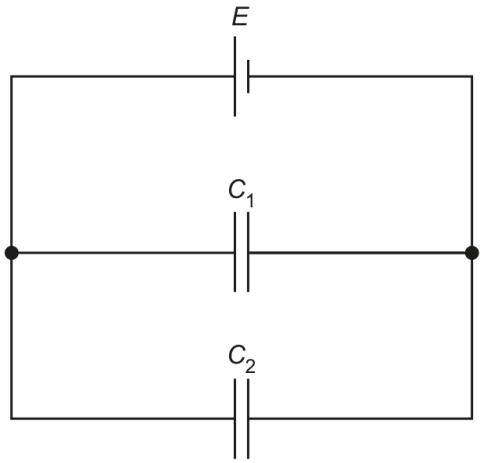


Fig. 5.1

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.

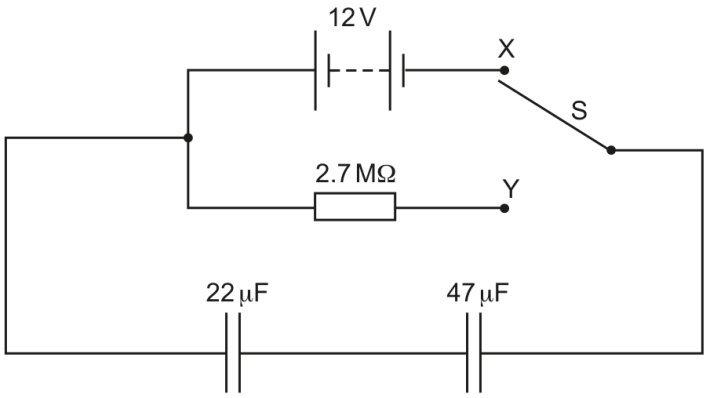


Fig. 5.2

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

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

[1]

6 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.

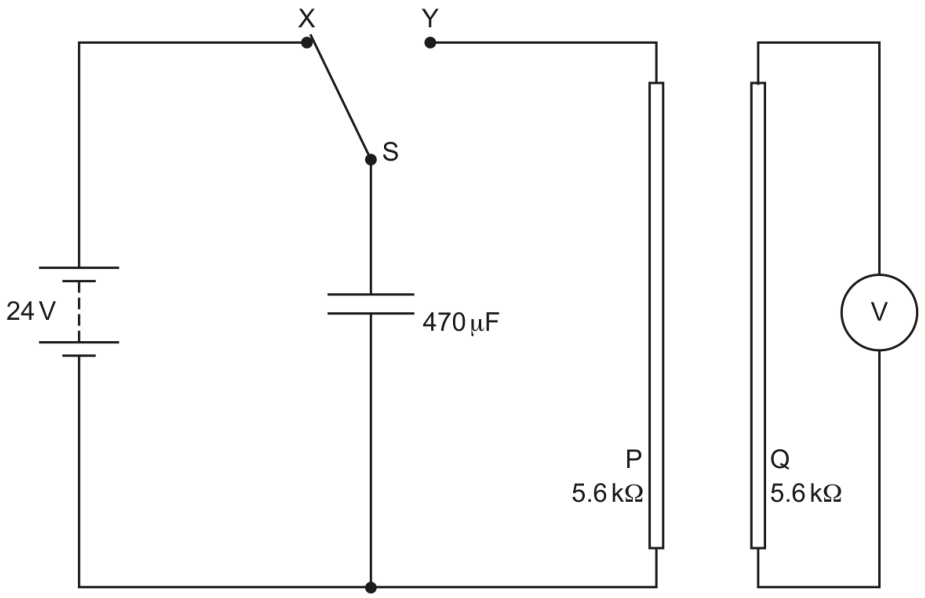


Fig. 5.1

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]

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

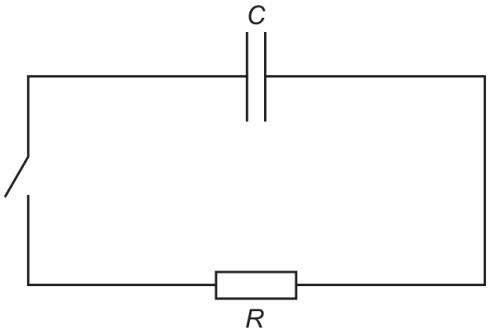


Fig. 6.1

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.

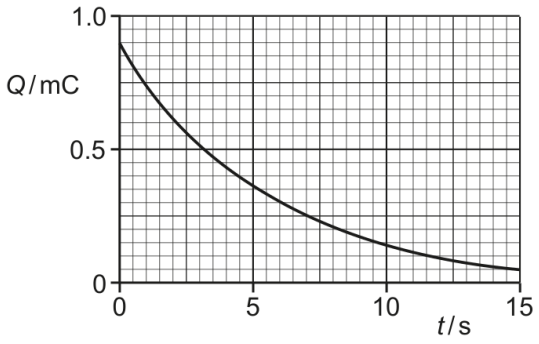


Fig. 6.2

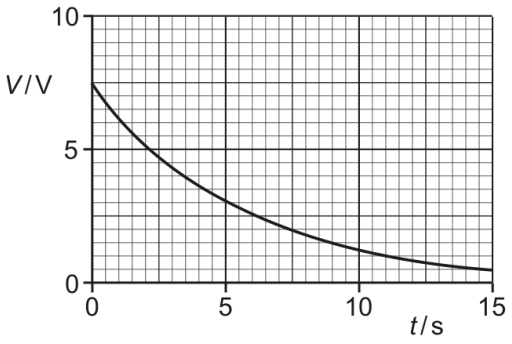


Fig. 6.3

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

(i) capacitance C, in μF

C = ... μF [2]

8 **(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.

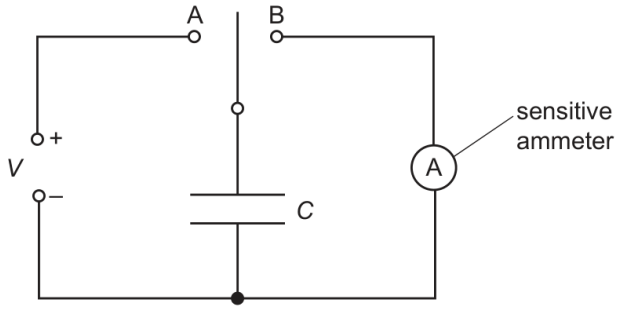


Fig. 7.1

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]

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

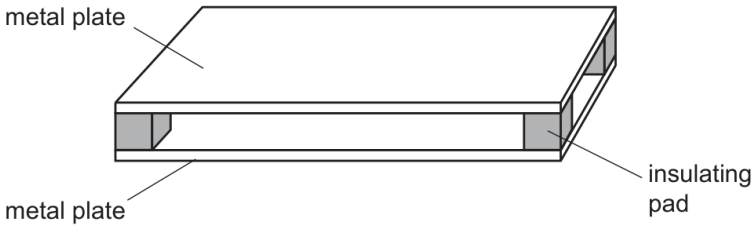


Fig. 6.1

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.

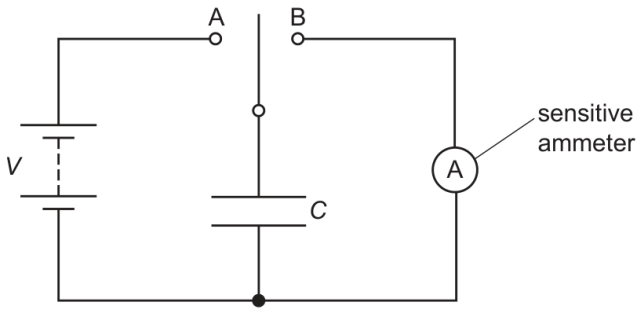


Fig. 6.2

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]

10 **(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.

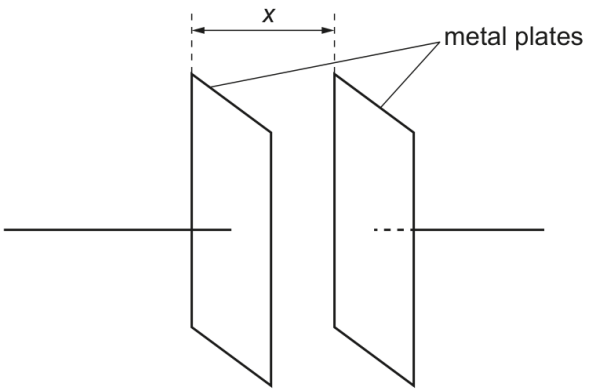


Fig. 6.1

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.

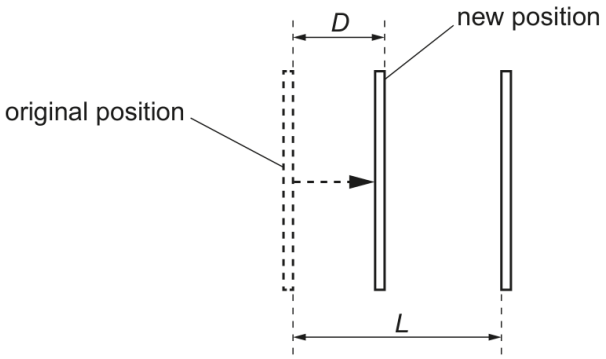


Fig. 6.2

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]

11 (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]

12 (a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

.....

..... [2]

(ii) State **three** functions of capacitors in electrical circuits.

1. .....

2. .....

3. .....

[3]

(b) A student has available four capacitors, each of capacitance 24 μF.

The capacitors are connected as shown in Fig. 6.1.

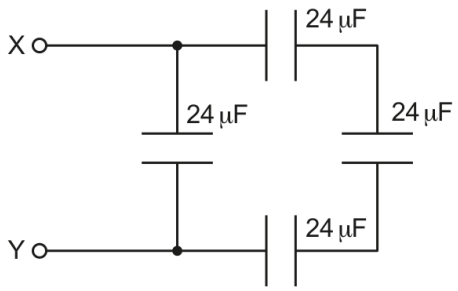


Fig. 6.1

Calculate the combined capacitance between the terminals X and Y.

capacitance = ... μF [2]

13 (a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

.....

..... [2]

(ii) State **three** functions of capacitors in electrical circuits.

1. .....

2. .....

3. .....

[3]

(b) A student has available **three** capacitors, each of capacitance 12 μF.

Draw diagrams, one in each case, to show how the student connects the capacitors to give a combined capacitance between the terminals of:

(i) 18 μF



[1]

(ii) 8 μF.



[1]

14 (a) State **two** different functions of capacitors in electrical circuits.

1. .....

.....

2. .....

.....

[2]

(b) Three uncharged capacitors of capacitances C_1, C_2 and C_3 are connected in series with a battery of electromotive force (e.m.f.) E and a switch, as shown in Fig. 6.1.

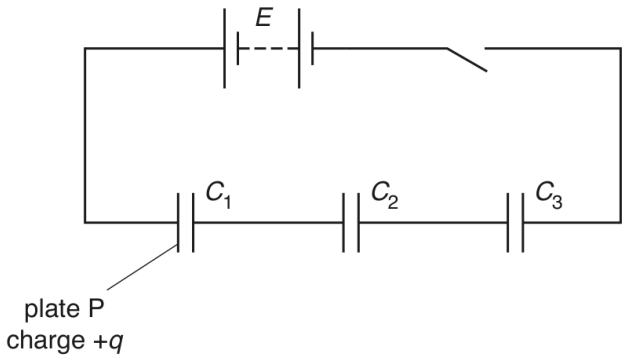


Fig. 6.1

When the switch is closed, there is a charge $+q$ on plate P of the capacitor of capacitance C_1.

Show that the combined capacitance C of the three capacitors is given by the expression

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

[3]

(c) A student has available four capacitors, each of capacitance 20 μF.

Draw circuit diagrams, one in each case, to show how the student may connect some or all of the capacitors to produce a combined capacitance of:

(i) 60 μF

[1]

(ii) 15 μF.

[1]

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

.....

.....

.....

.....[3]

(b) A parallel plate capacitor C is connected into the circuit shown in Fig. 7.1.

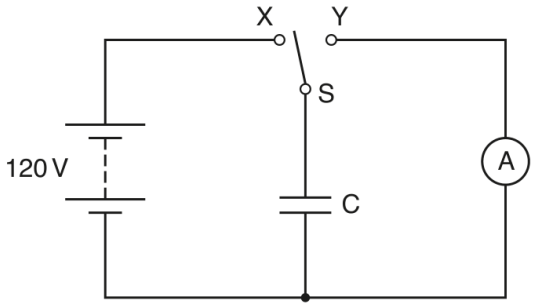


Fig. 7.1

When switch S is at position X, the battery of electromotive force 120 V and negligible internal resistance is connected to capacitor C.
When switch S is at position Y, the capacitor C is discharged through the sensitive ammeter.

The switch vibrates so that it is first in position X, then moves to position Y and then back to position X fifty times each second.

The current recorded on the ammeter is 4.5 μA.

Determine

(i) the charge, in coulomb, passing through the ammeter in 1.0 s,

charge = ... C [1]

(ii) the charge on one plate of the capacitor, each time that it is charged,

charge = ... C [1]

(iii) the capacitance of capacitor C.

capacitance = ... F [2]

(c) A second capacitor, having a capacitance equal to that of capacitor C, is now placed in series with C.

Suggest and explain the effect on the current recorded on the ammeter.

.....

.....

.....[2]

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

.....

.....

.....

.....[3]

(b) Three parallel plate capacitors each have a capacitance of 6.0 μF.

Draw circuit diagrams, one in each case, to show how the capacitors may be connected together to give a combined capacitance of

(i) 9.0 μF,

[1]

(ii) 4.0 μF.

[1]

(c) Two capacitors of capacitances 3.0 μF and 2.0 μF are connected in series with a battery of electromotive force (e.m.f.) 8.0 V, as shown in Fig. 6.1.

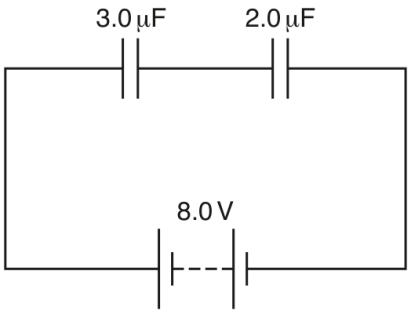


Fig. 6.1

(i) Calculate the combined capacitance of the capacitors.

capacitance = ... μF [1]

(ii) Use your answer in **(i)** to determine, for the capacitor of capacitance 3.0 μF,

1. the charge on one plate of the capacitor,

charge = ... μC

2. the energy stored in the capacitor.

energy = ... J

[4]