Capacitors - 1

Exercise A

1.

A 20 μF capacitor has a p.d. across it of 6.0 V. What charge and energy does it store? How would these values change if the p.d. was doubled to 12.0 V?

2.

Show that the unit of capacitance, the farad, F, is equivalent to (coulomb)^2/joule, C^2J^{-1}.

3.

A charge of 1.8×10^{-5} C is stored on a capacitor of capacitance 4.0×10^{-6} F. Calculate the p.d. across the capacitor.

4.

A 200 mF capacitor is charged to a p.d. of 40 V.

(a) Calculate the charge stored on the capacitor.

(b) The capacitor is discharged in 100 μs through a thick wire. Calculate

 (i) the average current and

 (ii) the average power dissipated in the wire during the discharge.

5.

A capacitor of capacitance 0.00100 μF has a 12.0 V battery connected across it as shown in Figure 3(a).

(a) Calculate the charge on the capacitor.

(b) A break develops in the circuit at A. The two ends of the wire at the break are near to one another, so they behave as a capacitor of capacitance 20 pF. The circuit effectively becomes the circuit in Figure 3(b). When this broken circuit is switched on, with both capacitors initially uncharged, what will be:

 (i) the total circuit capacitance?

 (ii) the charge on each capacitor?

 (iii) the p.d. across each capacitor?

Figure 3(a) and Figure 3(b) are on the next page.

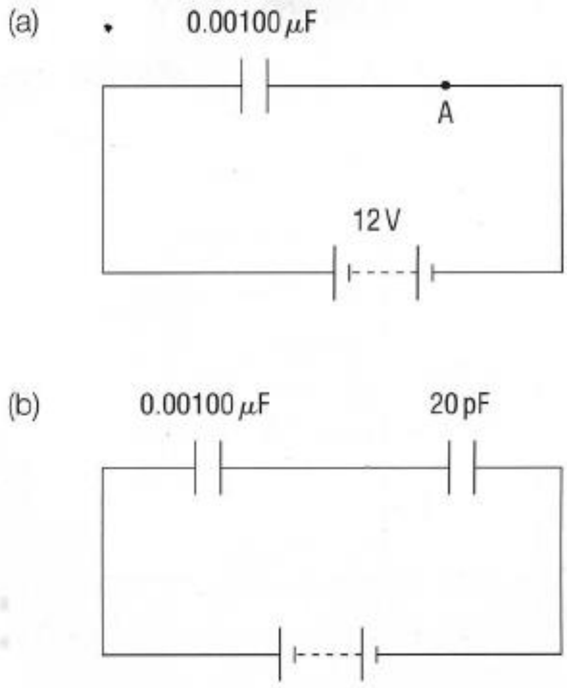

Figure 3 **(a)** A single capacitor in a circuit; **(b)** the modified circuit after a fault develops

6.

Figure 4 shows three capacitors connected to a d.c. supply.

(a) Calculate **(i)** the total capacitance of the system, **(ii)** the charge on and **(iii)** the p.d. across each capacitor.

(b) One of the 3.0 μF capacitors is replaced by one of an unknown value. The total capacitance of the system is 4.0 μF. Calculate the value of the unknown capacitor.

(c) For the capacitor system of part **(b)**, calculate **(i)** the charge on and **(ii)** the p.d. across each capacitor.

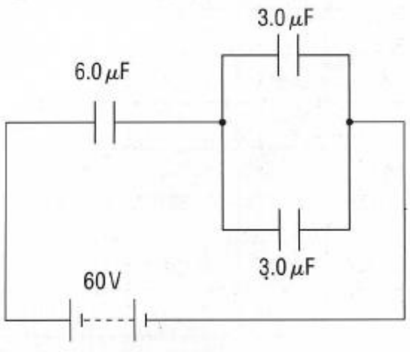

Figure 4

7.

A 1000 μF capacitor is charged from a 15.0 V d.c. supply through a two-way switch. The switch is thrown to connect it to an uncharged 500 μF capacitor as shown in Figure 5.

(a) Calculate **(i)** the initial and **(ii)** the final charge on the 1000 μF capacitor.

(b) Calculate the change in p.d. across the 500 μF capacitor after the switch is thrown.

(c) Calculate **(i)** the initial energy stored in the 1000 μF capacitor and **(ii)** the final energy stored in both capacitors.

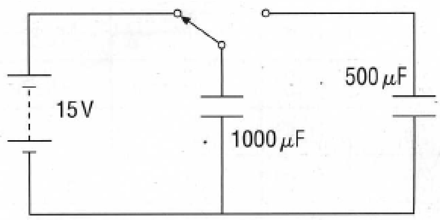

Figure 5

8.

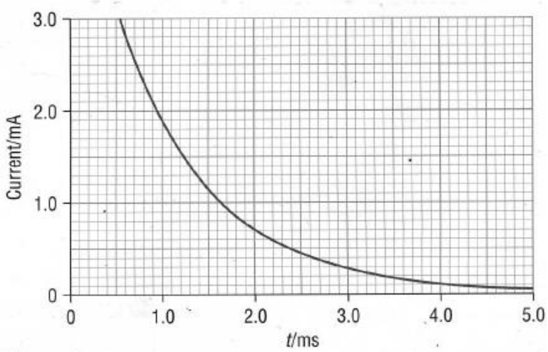

Figure 4

A capacitor discharges through a resistor. Figure 4 shows the variation in current in the resistor against time for part of the discharge. The graph is an exponential decay curve. For this to be true the ratio of the values of the current will be the same at equal intervals of time.

(a) Estimate the values of the current $I_{0.5}$, $I_{1.0}$ and $I_{1.5}$ at t = 0.5, 1.0 and 1.5 ms.

(b) Calculate the values of $I_{0.5}/I_{1.0}$ and $I_{1.0}/I_{1.5}$. These should be approximately equal.

(c) Repeat **(a)** and **(b)** to find the ratios at t = 1.5 to 2.0 ms, etc. up to 3.0 ms.

9.

A 22.2 μF capacitor is connected to a 9.00 V battery and fully charged. The battery is then removed and the capacitor is discharged through a 90.1 kΩ resistor, starting at time $t = 0$.

Calculate

(a) the time constant for the discharge circuit,

(b) **(i)** the charge on the capacitor when $t = 0$

(ii) the current when $t = 0$

(c) **(i)** the charge on the capacitor when $t = 1.50$ s

(ii) the current when $t = 1.50$ s

(d) **(i)** the charge on the capacitor at a time equal to the time constant.

10.

A 200 μF capacitor is charged to 26 V and then discharged through a 40 kΩ resistor.

(a) Calculate the initial current in the resistor.

(b) **(i)** After 5.5 s the p.d. has fallen to 13 V. Find the p.d. after another 5.5 s.

(ii) Calculate the current in the resistor at 11 s.

(c) Calculate **(i)** the p.d. and **(ii)** the current in the resistor after 8.0 s.

(d) Show that the values in (c) are related to the values in (b) by a factor close to 0.69, which is ln 2.

(e) How long does it take for the p.d. to fall to 1.0 V?

Exercise B

1.

A 2200 μF capacitor is charged to a pd of 9.0 V then discharged through a 100 kΩ resistor using a circuit as shown in Figure 1.

a Calculate:

i the initial charge stored by the capacitor,

ii the time constant of the circuit.

b Calculate the pd after a time:

i equal to the time constant,

ii 300 s.

2.

A 50 μF capacitor is charged by connecting it to a 6.0 V battery then discharged through a 100 kΩ resistor.

Calculate:

a **i** the charge stored in the capacitor immediately after it has been charged,

ii the time constant of the circuit.

b **i** Estimate how long the capacitor would take to discharge to about 2 V.

ii Estimate the resistance of the resistor that you would use in place of the 100 kΩ resistor if the discharge is to be 99% completed within about 5 s.

3.

A 68 μF capacitor is charged to a pd of 9.0 V then discharged through a 20 kΩ resistor.

a Calculate:

i the charge stored by the capacitor at a pd of 9.0 V,

ii the initial discharge current.

b Calculate the pd and the discharge current 5.0 s after the discharge started.

4.

A 2.2 μF capacitor is charged to a pd of 6.0 V and then discharged through a 100 kΩ resistor. Calculate:

a the charge and energy stored in this capacitor at 6.0 V,

b the pd across the capacitor 0.5 s after the discharge started,

c the energy stored at this time.

5.

An uncharged 4.7 μF capacitor is charged to a pd of 12.0 V through a 200 Ω resistor and then discharged through a 220 kΩ resistor. Calculate:

a **i** initial charging current,

ii the energy stored in the capacitor at 12.0 V,

b the time taken for the pd to fall from 12.0 V to 3.0 V,

c the energy lost by the capacitor in this time.

(Question 6 is on the next page)

6.

A parallel-plate capacitor consists of two insulated metal plates separated by an air gap. A battery in series with a switch is connected to the plates. The capacitor is charged by closing the switch to charge the capacitor to a constant pd. A sheet of dielectric is then inserted between the plates.

a When the sheet of dielectric is inserted, state the change that takes place to:

i the capacitance C of the capacitor,

ii the charge Q stored by the capacitor.

b State and explain the change that takes place to the energy stored by the capacitor.

7.

An air-filled parallel-plate capacitor has a capacitance of 1.4 pF.

a The space between the plates is completely filled with a sheet of dielectric that has a relative permittivity of 7.0. Calculate the capacitance of the capacitor with the dielectric present.

b Calculate the energy stored by the capacitor in **(a)** when the pd across it is 15.0 V.
