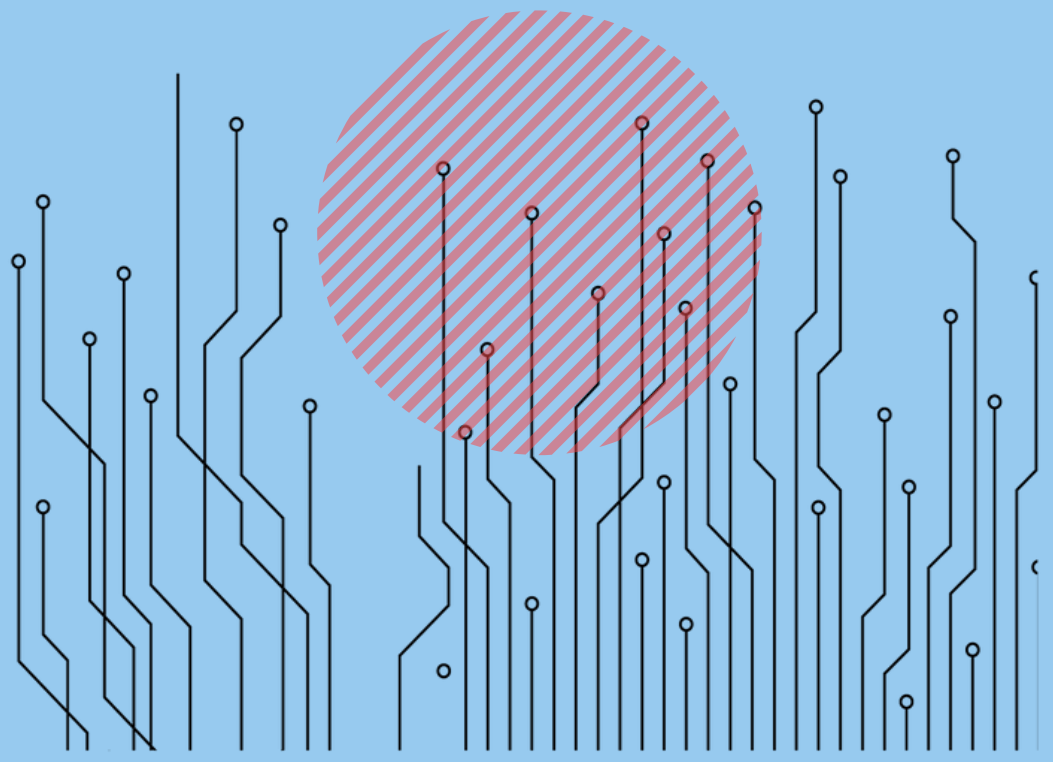
Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021



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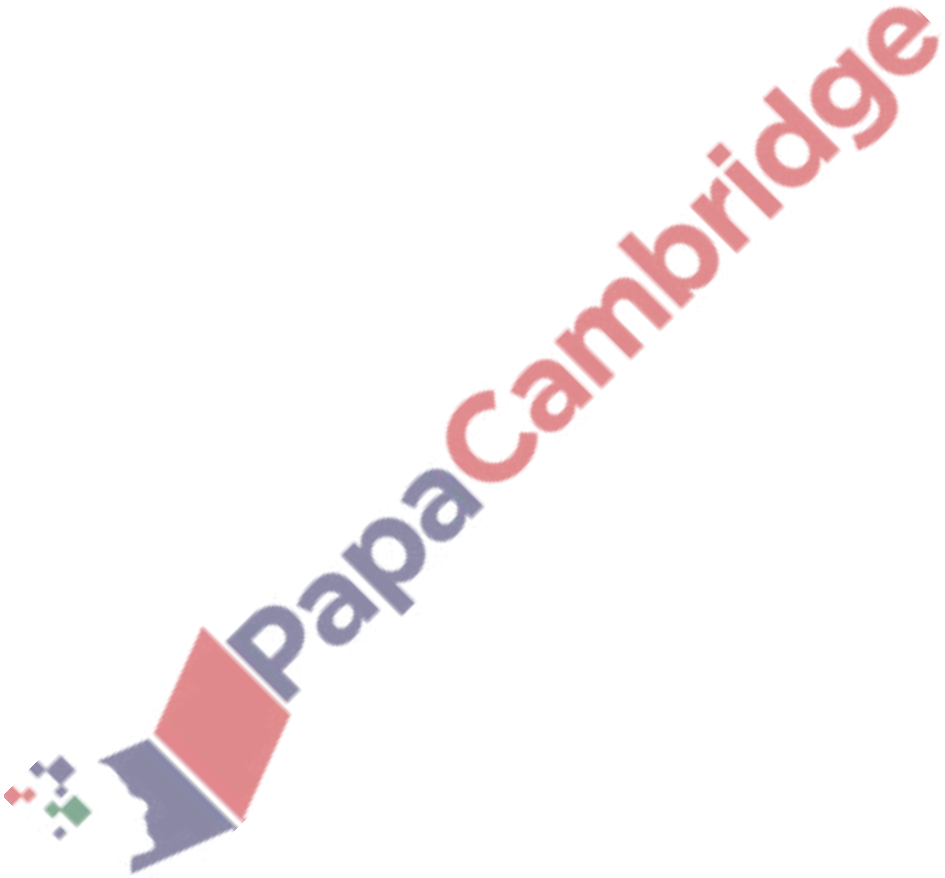
Chapter 9

Capacitance



196. 9702_m21_qp_42 Q: 6

(a) State a similarity between the gravitational field lines around a point mass and the electric field lines around a point charge.

.....

..... [1]

(b) The variation with radius r of the electric field strength E due to an isolated charged sphere in a vacuum is shown in Fig. 6.1.

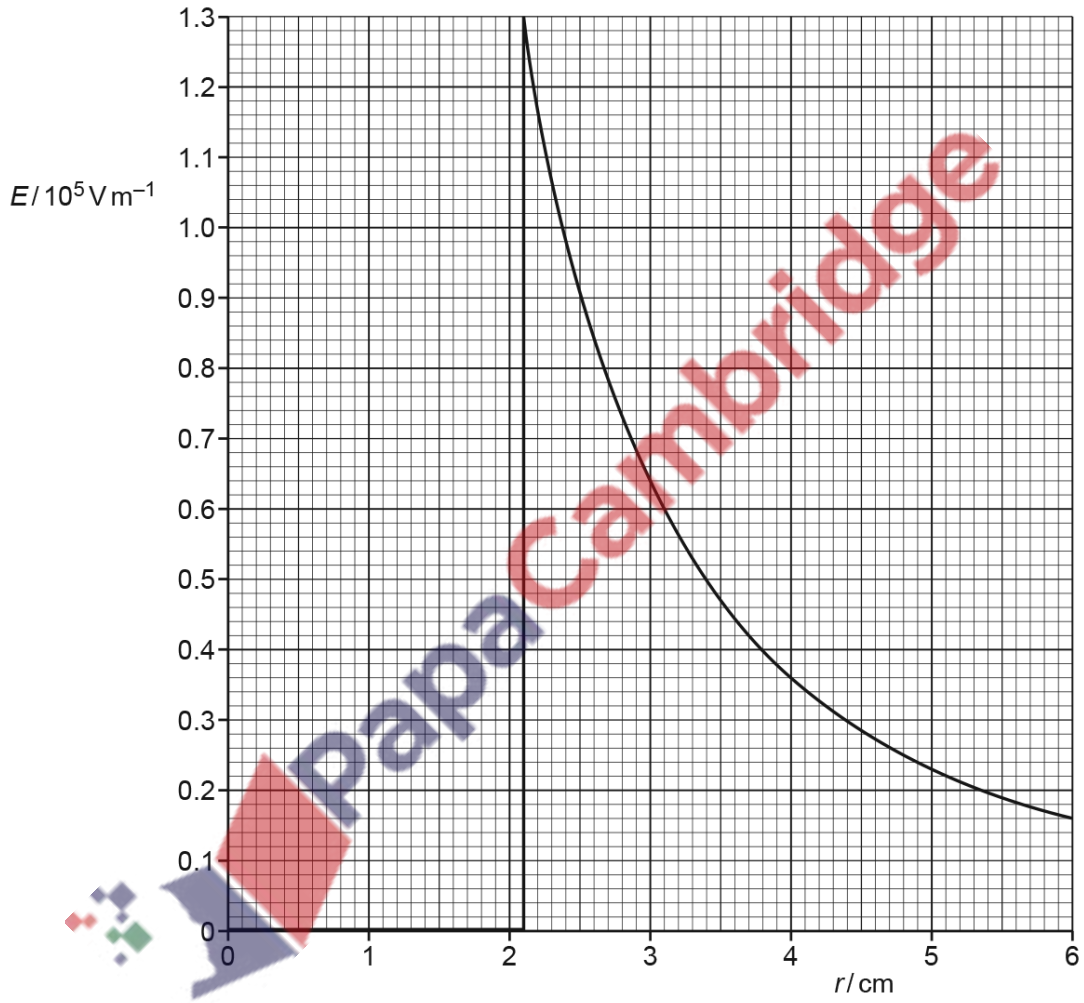


Fig. 6.1

Use data from Fig. 6.1 to:

(i) state the radius of the sphere

radius = ... cm [1]

(ii) calculate the charge on the sphere.

charge = ... C [2]

(c) Using the formula for the electric potential due to an isolated point charge, determine the capacitance of the sphere in **(b)**.

capacitance = ... F [3]

[Total: 7]

197. 9702_s21_qp_41 Q: 7

(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.

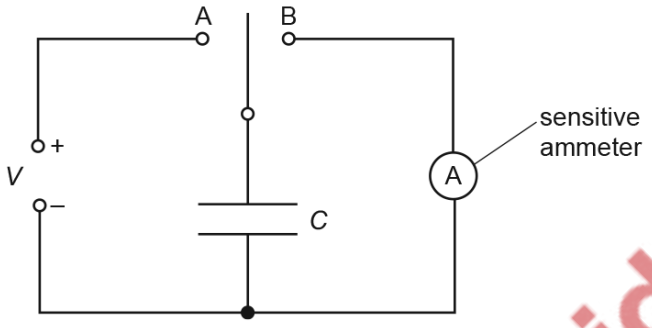


Fig. 7.1

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]

198. 9702_s21_qp_42 Q: 6

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

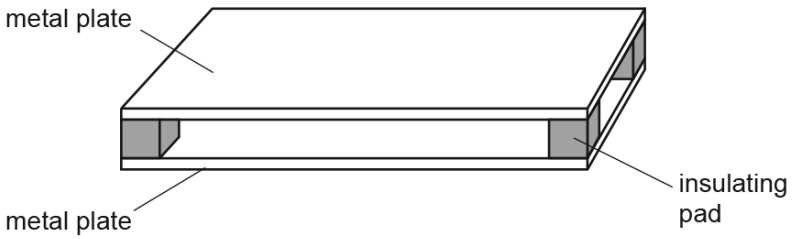


Fig. 6.1

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.

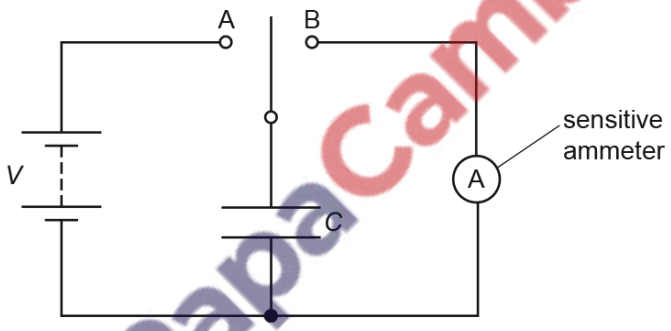


Fig. 6.2

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]

199. 9702_s21_qp_43 Q: 7

(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.

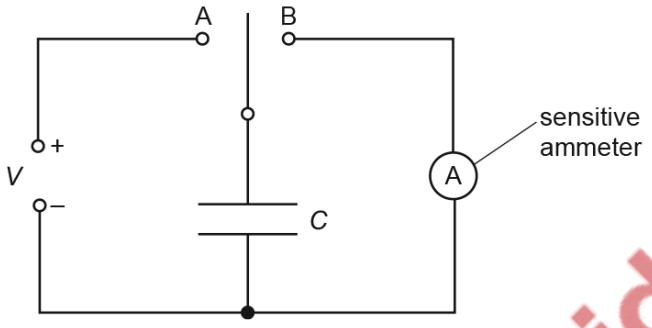


Fig. 7.1

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]

200. 9702_w21_qp_42 Q: 6

(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]

201. 9702_m20_qp_42 Q: 6

Two positively charged identical metal spheres A and B have their centres separated by a distance of 24 cm, as shown in Fig. 6.1.

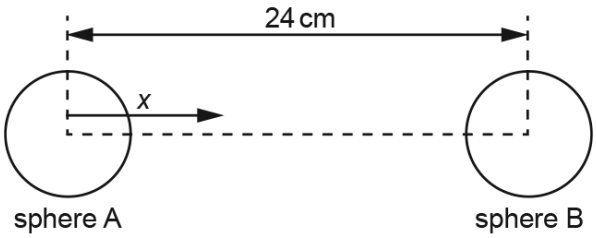


Fig. 6.1 (not to scale)

The variation with distance x from the centre of A of the electric field strength E due to the two spheres, along the line joining their centres, is represented in Fig. 6.2.

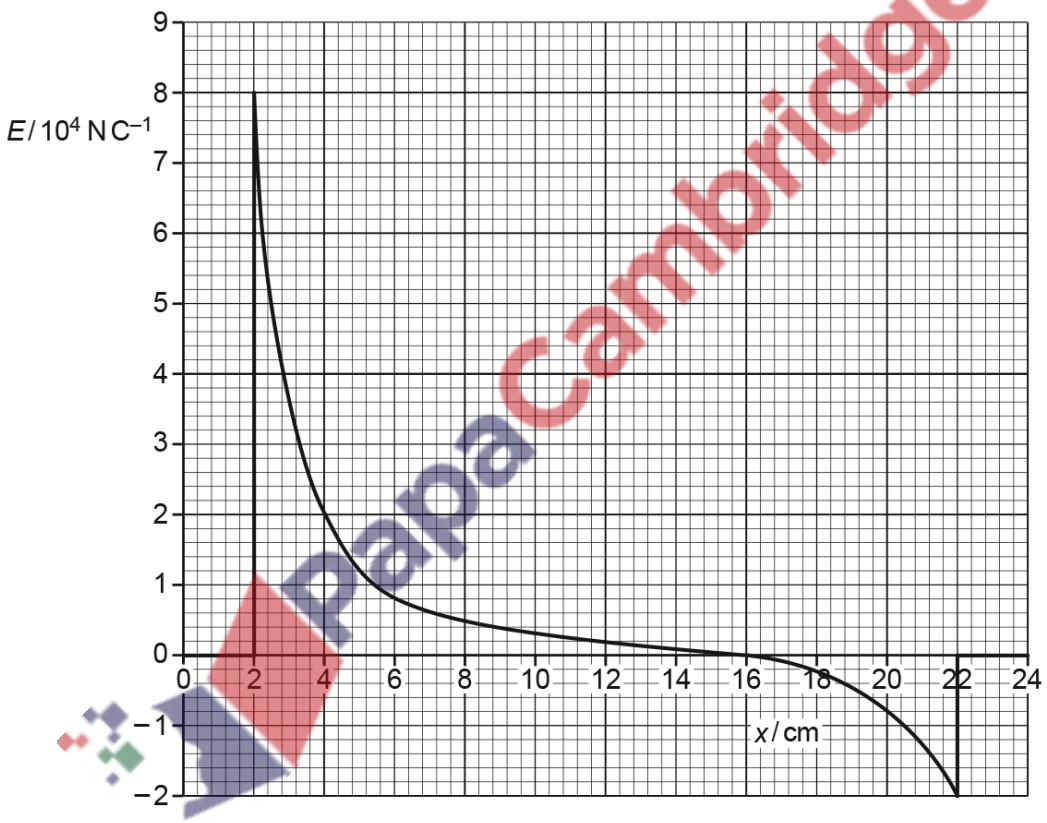


Fig. 6.2

(a) State the radius of the two spheres.

radius = ... cm [1]

(b) The charge on sphere A is 3.6×10^{-9} C. Determine the charge Q_B on sphere B.

Assume that spheres A and B can be treated as point charges at their centres.

Explain your working.

Q_B = ... C [3]

(c) **(i)** Sphere B is removed.

Use information from **(b)** to determine the electric potential on the surface of sphere A.

electric potential = ... V [2]

(ii) Calculate the capacitance of sphere A.

capacitance = ... F [2]

[Total: 8]

(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.

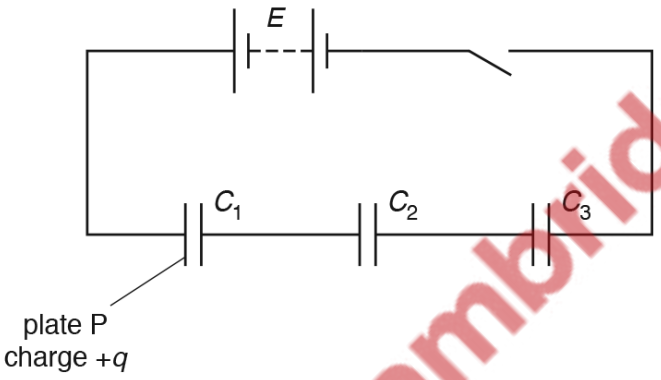


Fig. 6.1

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]

[Total: 7]

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

1. .....

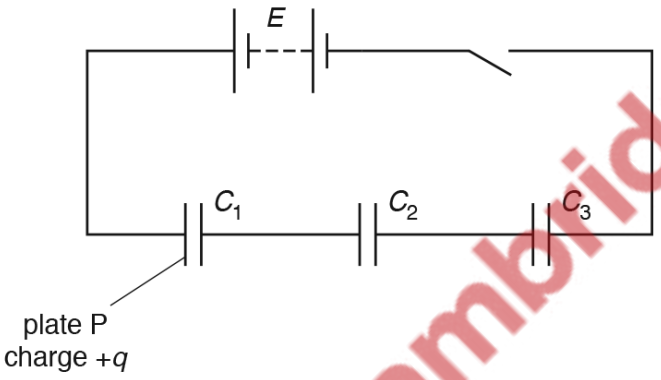
.....

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.



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(i) 60 μF

[1]

(ii) 15 μF.

[1]

[Total: 7]

204. 9702_s18_qp_41 Q: 7

(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.

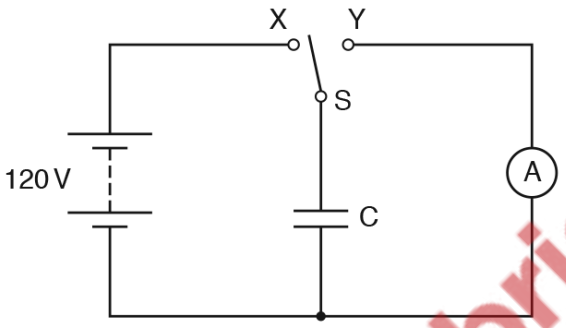


Fig. 7.1

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]

[Total: 9]

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

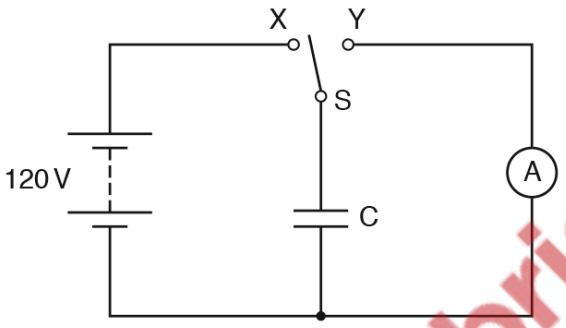
.....

.....

.....

.....[3]

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



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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.

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(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]

[Total: 9]

206. 9702_w17_qp_41 Q: 6

Two capacitors P and Q, each of capacitance *C*, are connected in series with a battery of e.m.f. 9.0 V, as shown in Fig. 6.1.

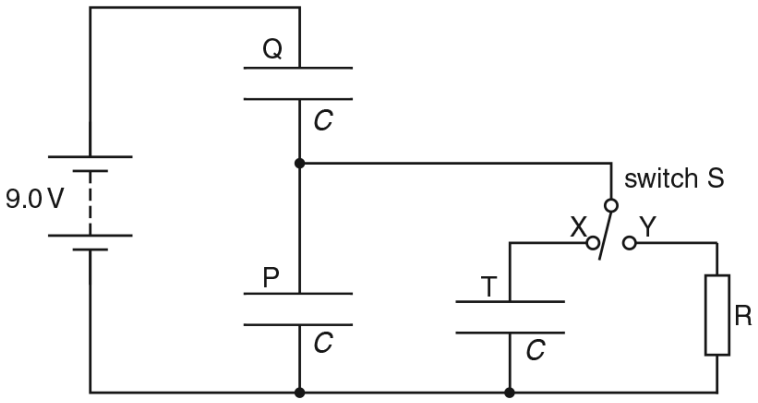


Fig. 6.1

A switch S is used to connect either a third capacitor T, also of capacitance *C*, or a resistor R, in parallel with capacitor P.

(a) Switch S is in position X.

Calculate

(i) the combined capacitance, in terms of *C*, of the three capacitors,

capacitance = ... [2]

(ii) the potential difference across capacitor Q. Explain your working.

potential difference = ... V [2]

(b) Switch S is now moved to position Y.
State what happens to the potential difference across capacitor P and across capacitor Q.

capacitor P: .....

.....

.....

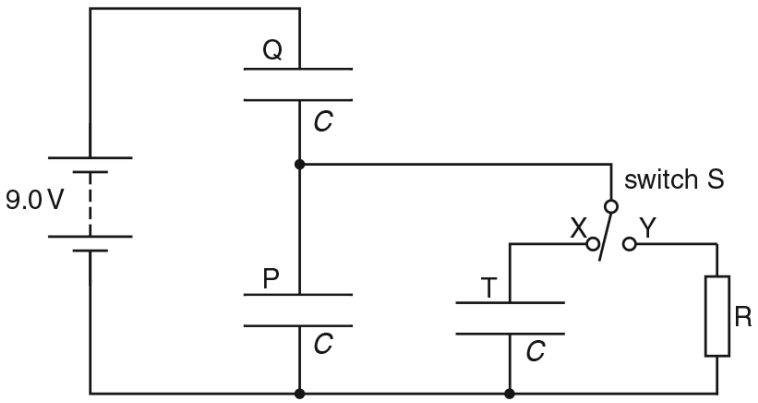
capacitor Q: .....

.....

.....
[4]

[Total: 8]

Two capacitors P and Q, each of capacitance *C*, are connected in series with a battery of e.m.f. 9.0 V, as shown in Fig. 6.1.



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Calculate

(i) the combined capacitance, in terms of *C*, of the three capacitors,

capacitance = ... [2]

(ii) the potential difference across capacitor Q. Explain your working.

potential difference = ... V [2]

(b) Switch S is now moved to position Y.
State what happens to the potential difference across capacitor P and across capacitor Q.

capacitor P: .....

.....

.....

capacitor Q: .....

.....

.....
[4]

[Total: 8]

---

208. 9702_w16_qp_42 Q: 7

(a) **(i)** Define *capacitance*.

.....

.....[1]

(ii) Use the expression for the electric potential due to a point charge to show that an isolated metal sphere of diameter 25 cm has a capacitance of 1.4×10^{-11} F.

[2]

(b) Three capacitors of capacitances 2.0 μF, 3.0 μF and 4.0 μF are connected as shown in Fig. 7.1 to a battery of e.m.f. 9.0 V.

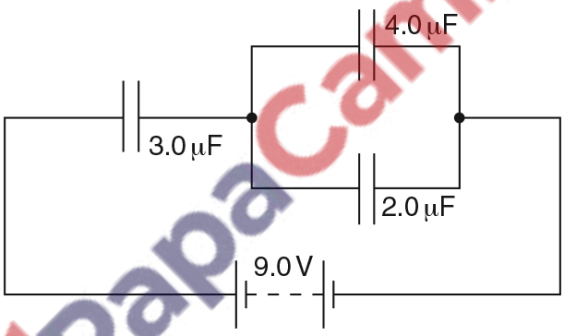

Fig. 7.1

Determine

(i) the combined capacitance of the three capacitors,

capacitance = ... μF [1]

(ii) the potential difference across the capacitor of capacitance 3.0 μF,

potential difference = ... V [2]

(iii) the positive charge stored on the capacitor of capacitance 2.0 μF.

charge = ... μC [2]

[Total: 8]

(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.

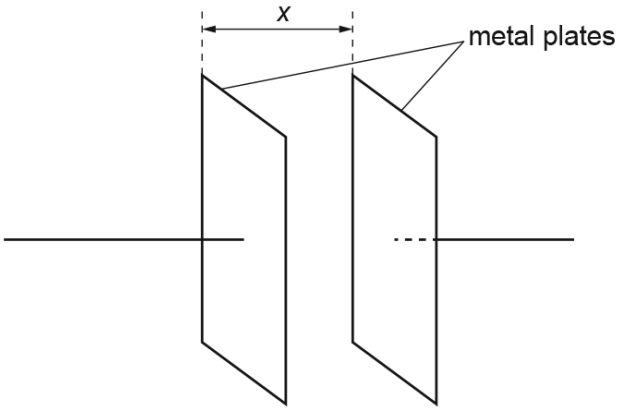

Fig. 6.1

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.

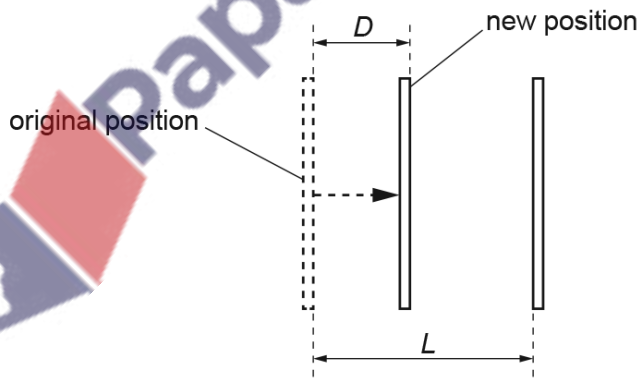

Fig. 6.2

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]

(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.

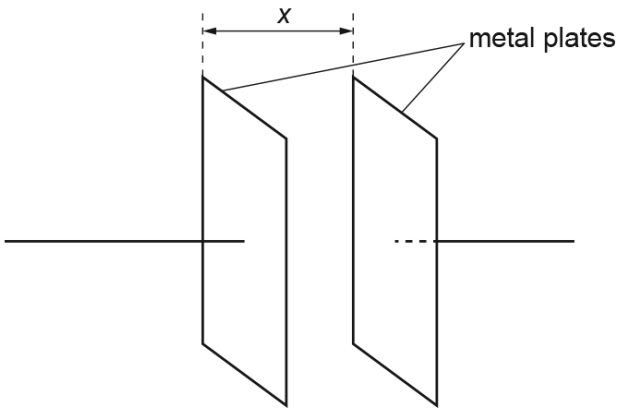

Fig. 6.1

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.

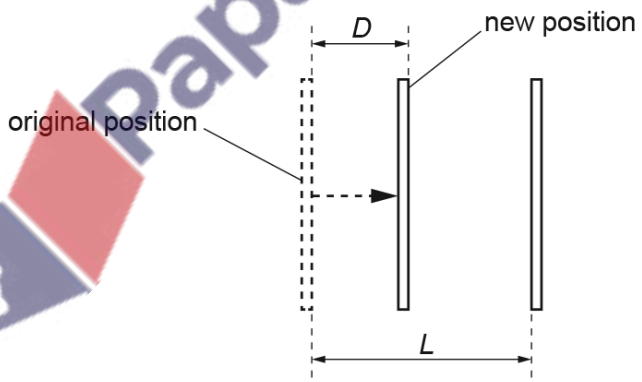

Fig. 6.2

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]

211. 9702_m19_qp_42 Q: 6

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

.....

.....

..... [2]

(b) A student has three capacitors. Two of the capacitors have a capacitance of 4.0 μF and one has a capacitance of 8.0 μF.

Draw labelled circuit diagrams, one in each case, to show how the three capacitors may be connected to give a total capacitance of:

(i) 1.6 μF

[1]

(ii) 10 μF.

[1]

(c) A capacitor C of capacitance 47 μF is connected across the output terminals of a bridge rectifier, as shown in Fig. 6.1.

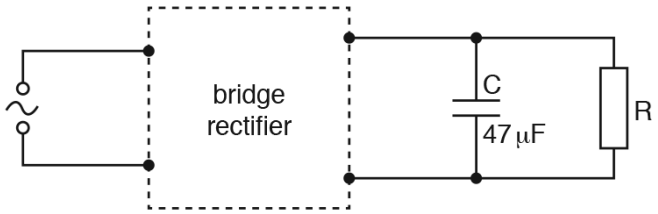

Fig. 6.1

The variation with time *t* of the potential difference *V* across the resistor R is shown in Fig. 6.2.

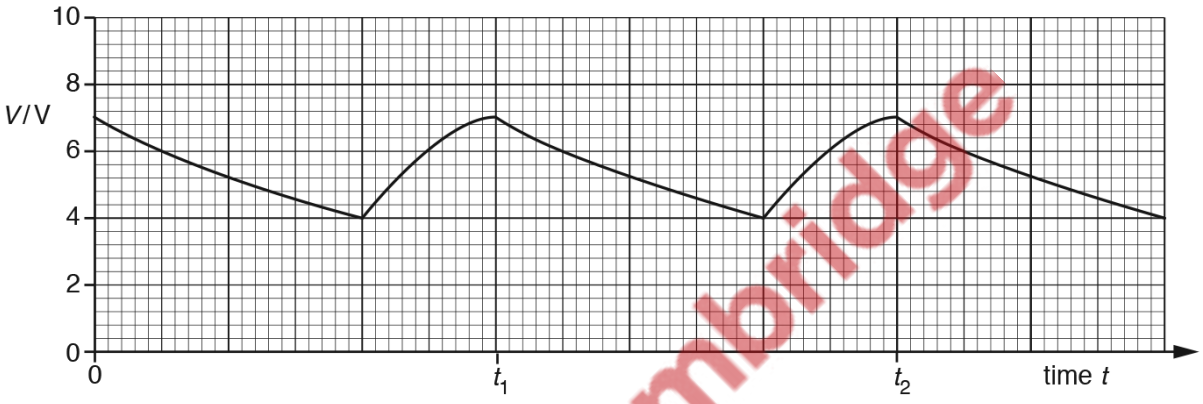

Fig. 6.2

Use data from Fig. 6.2 to determine the energy transfer from the capacitor C to the resistor R between time t_1 and time t_2.

energy = ...J [3]

[Total: 7]

212. 9702_s18_qp_42 Q: 6

(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.

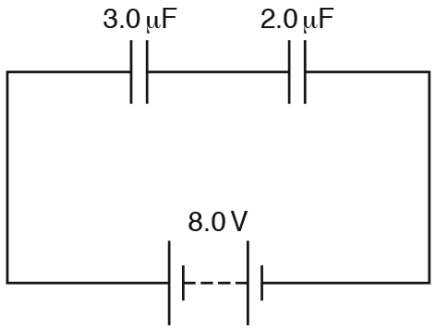

Fig. 6.1

(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]

[Total: 10]

213. 9702_s17_qp_42 Q: 7

A capacitor consists of two parallel metal plates, separated by an insulator, as shown in Fig. 7.1.

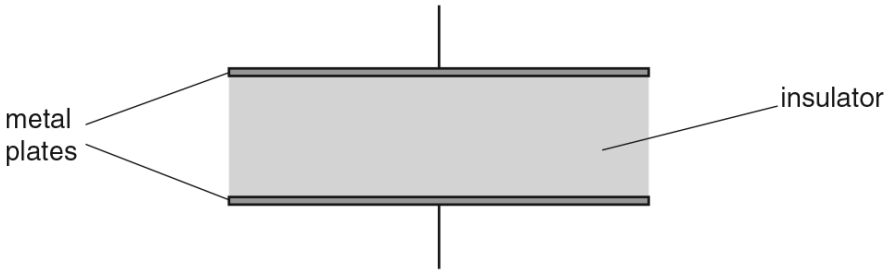

Fig. 7.1

(a) Suggest why, when the capacitor is connected across the terminals of a battery, the capacitor stores energy, not charge.

.....

.....

.....[2]

(b) Define the *capacitance* of the capacitor.

.....

.....

.....[2]

(c) The capacitor is charged so that the potential difference between its plates is V_0.
The capacitor is then connected across a resistor for a short time. It is then disconnected.
The energy stored in the capacitor is reduced to $\frac{1}{16}$ of its initial value.

Determine, in terms of V_0, the potential difference across the capacitor.

potential difference = ...[2]

[Total: 6]

214. 9702_m16_qp_42 Q: 7

(a) Define *capacitance*.

.....

.....[1]

(b) Three capacitors of capacitances C_1, C_2 and C_3 are initially uncharged. They are then connected in series to a battery, as shown in Fig. 7.1.

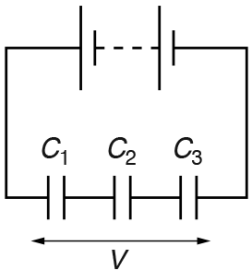

Fig. 7.1

The battery applies a potential difference V across the three capacitors.

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

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

[2]

(c) A battery of e.m.f. 12V and negligible internal resistance is connected to a network of two capacitors and a resistor, as shown in Fig. 7.2.

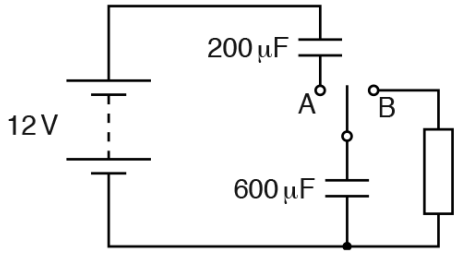

Fig. 7.2

The capacitors have capacitances of 200 μF and 600 μF. The switch has two positions, A and B.

(i) The switch is moved to position A.

Calculate

1. the combined capacitance of the two capacitors,

combined capacitance = ... μF [1]

2. the charge on the 600 μF capacitor,

charge = ... C [1]

3. the potential difference across the 600 μF capacitor.

potential difference = ... V [1]

(ii) The switch is now moved from position A to position B.

Calculate the potential difference across the 600 μF capacitor when it has discharged 50% of its initial energy.

potential difference = ... V [3]

[Total: 9]