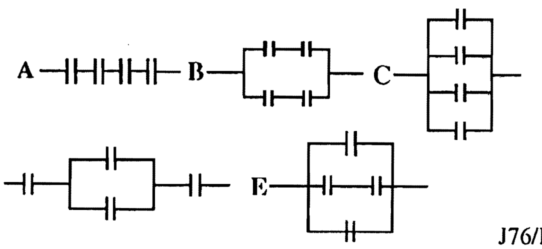
TOPIC 20 Capacitance

1 Four capacitors each of capacitance 2 μF are connected in such a way that their total capacitance is also 2 μF. Which one of the following systems gives this value?



J76/II/2

2 A 2 μF capacitor is charged to a potential of 200 V and then isolated. When it is connected in parallel with a second capacitor which is initially uncharged, the common potential becomes 40 V. The capacitance of the second capacitor is

A 2 μF
B 4 μF
C 6 μF
D 8 μF
E 16 μF

J77/II/22

3 A photographic flash unit consists of a xenon-filled tube energised by the discharge of a capacitor previously charged by a 1000 V source. The average power delivered to the flash tube is 2000 W and the flash lasts 0.040 s. The capacitance of the capacitor can be estimated as

A 40×10^{-6} F
B 80×10^{-6} F
C 160×10^{-6} F
D 80×10^{-3} F
E 160×10^{-3} F

J78/II/24

4 A capacitor of capacitance 160 μF is charged to a potential difference of 200 V and then connected across a discharge tube, which conducts until the potential difference across it has fallen to 100 V. The energy dissipated in the tube is

A 6.4 J
B 4.8 J
C 3.2 J
D 2.4 J
E 0.8 J

N78/II/21

5 A parallel-plate capacitor is charged in air. It is then electrically isolated and lowered into a liquid dielectric. As a result,

A both the capacitance and the potential difference across the plates decrease.
B the capacitance decreases and the potential difference across the plates increases.
C the capacitance increases and the potential difference across the plates decreases.
D both the capacitance and the charges on the plates decrease.
E both the capacitance and the charges on the plates increase.

J82/II/22; N78/II/23

6 A capacitor made from two thin, flat metal sheets separated by a small thickness of insulating material has a capacitance C. Each metal sheet is then cut into four smaller identical sheets, which are used to make another capacitor as shown below (Fig. 1). The same thickness of insulator is used between the interleaved sheets.

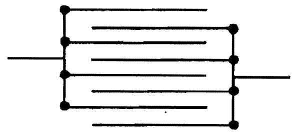


Fig. 1

Neglecting end-effects, the capacitance of the reconstructed capacitor is approximately

A C **B** $7C/4$ **C** $7C$ **D** $8C$ **E** $28C$

J80/II/22

7 The electric field between the plates of an isolated air-spaced parallel-plate capacitor is E. What is the field between the plates after immersing the capacitor in a liquid of relative permittivity 2?

A $E/2$
B $E/\sqrt{2}$
C $\sqrt{2E}$
D $2E$
E $4E$

J81/II/18

8 A 10 μF capacitor and a 20 μF capacitor, both initially uncharged, are connected in series with a 3 kV supply (Fig. 2).

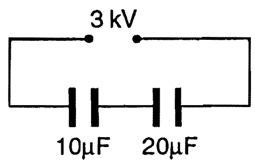


Fig. 2

The charge on the 10 μF capacitor finally becomes

A 4.5 mC
B 10 mC
C 15 mC
D 20 mC
E 30 mC

J81/II/24

9 A 3 μF capacitor and a 6 μF capacitor, both initially uncharged, are connected in series with a 10 V battery. What charges reside on the capacitors?

	3 μF capacitor	6 μF capacitor
A	30 μC	60 μC
B	15 μC	30 μC
C	20 μC	20 μC
D	30 μC	15 μC
E	60 μC	30 μC

N81/II/22

10 Two capacitors, of capacitance C and $2C$, are charged to potential differences V and $2V$ respectively. If the two positive plates are connected together and the two negative plates are connected together, then this system of capacitors

A gains charge but loses energy.
B gains energy but loses charge.
C loses both energy and charge.
D loses charge but energy remains constant.
E loses energy but charge remains constant. N83/II/22

11 A 20 μF capacitor is charged by a constant current of 10 mA. If the capacitor is initially uncharged, how long does it take for the potential difference across the capacitor to reach 300 V?

A 6.0×10^{-4} s
B 0.60 s
C 15 s
D 1.5×10^{4} s
E 6.0×10^{5} s

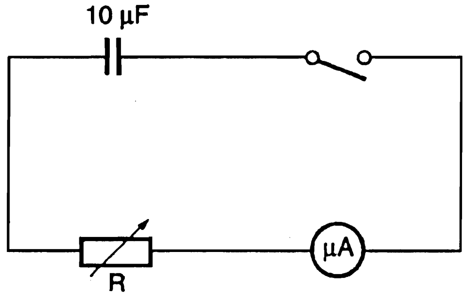
N86/I/17

12 An isolated parallel-plate capacitor of plate area A, plate separation d and capacitance C $(=\epsilon A/d)$ is found to lose charge slowly by conduction through the dielectric, which has resistivity ρ. What is the resistance of the dielectric?

A $\frac{\rho\epsilon}{C}$
B $\rho C\epsilon$
C $\frac{C\epsilon}{\rho}$
D $\frac{\rho C}{\epsilon}$
E $\frac{\rho}{C\epsilon}$

J87/I/15

13 The circuit shown was used to discharge the 10 μF capacitor through the variable resistor R.



For a period of 40 s, the current was kept constant at 20 μA by continuous adjustment of R.

By how much did the potential difference across the capacitor fall during this time?

A 1.3×10^{-2} V
C 20 V
B 14 V
D 80 V

N87/I/18; N97/I/17

14 A photographic flash unit consists of a xenon-filled tube energised by the discharge of a capacitor previously charged by a 1000 V source. The average power delivered to the flash tube is 1000 W and the flash lasts 0.040 s. The capacitance of the capacitor can be estimated as

A 40×10^{-6} F
B 80×10^{-6} F
C 160×10^{-6} F
D 80×10^{-3} F
E 160×10^{-3} F

J88/I/16

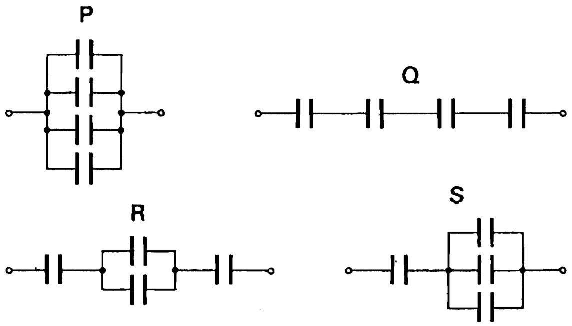
15 A 2μF capacitor charged initially by a 30V source is disconnected from the source and then connected to an uncharged 1 μF capacitor.

What is the final potential difference across the capacitors?

A 10V B 15V C 20V D 25V E 30V

N91/I/18

16 Four identical capacitors are connected as shown in the diagrams.



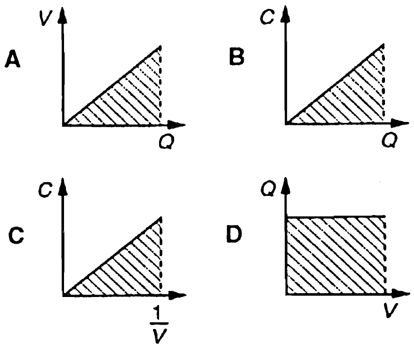
Which of the following lists the arrangements in order of increasing capacitance?

A PQRS **B** PRSQ **C** PSRQ **D** QRSP **E** QSRP

N92/I/16

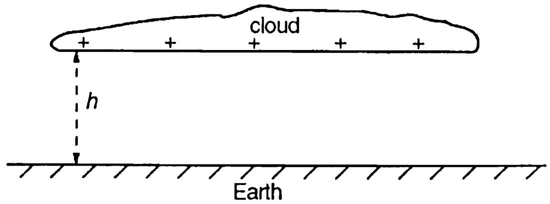
17 The energy stored in a capacitor of capacitance C, carrying charge Q with potential difference V between its plates, may be obtained by calculating the area under an appropriate graph.

Which graph shows the correct relationship between a pair of the quantities C, Q and V, and in addition shows a shaded area which corresponds to the energy stored in the capacitor?



N92/I/17; J96/I/17

18 A thundercloud and the Earth's surface may be regarded as a pair of charged parallel plates separated by a distance h as shown in the diagram. The capacitance of the system is C.

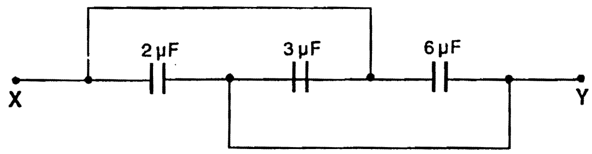


When a lightning flash of mean current I and time duration t occurs, the electric field strength between cloud and Earth is reduced by

A $\frac{It}{Ch}$ B $\frac{It}{C}$ C $\frac{It}{h}$ D CIt E $\frac{CIt}{h}$

J93/I/17

19 Three capacitors are arranged as shown.

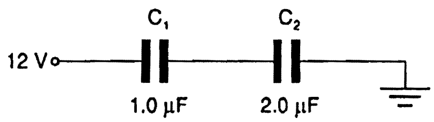


What is the effective capacitance between **X** and **Y**?

A 1 µF B 2 µF C 3µF D 11 µF

N93/I/15; N98/I/18

20 Two capacitors are connected in series as shown in the diagram.



What is the charge carried by each of these capacitors?

	charge on C_1/µC	*charge on* C_2/µC
A	4.0	4.0
B	4.0	8.0
C	8.0	4.0
D	8.0	8.0

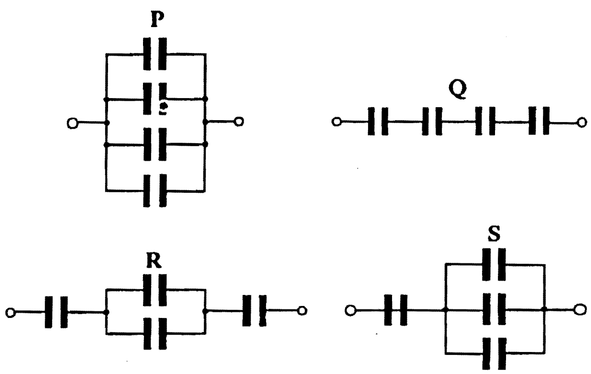
J94/I/16

21 A capacitor which has a capacitance of 1 farad will

A be fully charged in 1 second by a current of 1 ampere.
B store 1 coulomb of charge at a potential difference of 1 volt.
C gain 1 joule of energy when 1 coulomb of charge is stored on it.
D discharge in 1 second when connected across a resistor of resistance 1 ohm.

N94/I/18

22 Four identical capacitors are connected as shown.

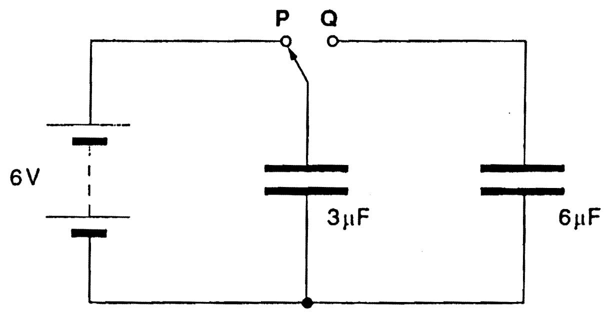


Which of the following lists the arrangements in order of **decreasing** capacitance?

A PQRS B PSRQ C QRSP D QSRP

N95/I/18; J99/I/18

23 In the circuit shown, a capacitor of capacitance 3 µF is charged from a battery of e.m.f. 6V with the switch connected to terminal **P**.



The switch is now connected to Q. This charges the 6 µF capacitor from the 3 µF one.

What is the new potential difference across the combination?

A 1V B 2V C 4V D 6V

N96/I/17

24 A capacitor is charged to a voltage V and then discharged through a small d.c. motor. As the capacitor discharges, the motor raises a mass through a height h. The experiment is repeated for several values of V.

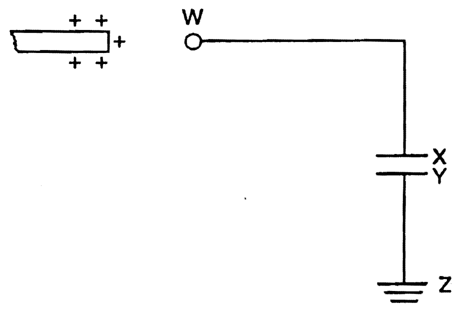
A constant fraction of the capacitor energy is converted to gain of gravitational potential energy.

Which graph would be expected to give a straight line?

A h against V^2 C h against $\sqrt{V}$
B h against V D h against $1/\sqrt{V}$

J97/I/18

25 An uncharged capacitor is connected between earth Z and a terminal W. A positively charged rod is brought close to W.

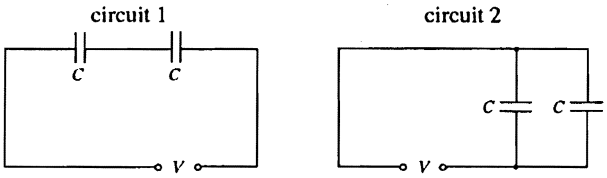


Which of the following describes the movement of charge?

A Electrons move from W to X and from Y to Z.
B Electrons move from W to X but not from Y to Z.
C Electrons move from X to W and from Z to Y.
D Electrons move from X to W but not from Z to Y.

J98/I/13

26 The diagrams show two ways of connecting two identical capacitors of capacitance C in circuits each with a supply of p.d. V.



What is the value of

$$\frac{\text{total electrical energy stored in the capacitors in circuit 1}}{\text{total electrical energy stored in the capacitors in circuit 2}}?$$

A $\frac{1}{4}$ C $\frac{2}{1}$

B $\frac{1}{2}$ D $\frac{4}{1}$ J98/I/17

27 A capacitor of capacitance C_1 is charged to a potential difference of 100 V and then disconnected. When a second uncharged capacitor of capacitance C_2 is connected in parallel across it, the new p.d. is 60 V.

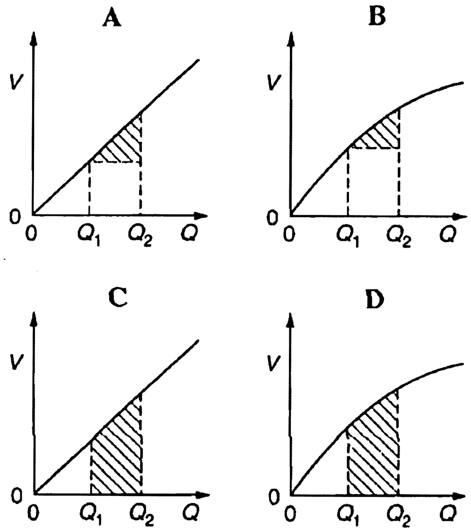
What is the value of the ratio $\frac{C_1}{C_2}$?

A $\frac{3}{5}$ C $\frac{3}{2}$

B $\frac{2}{3}$ D $\frac{5}{3}$ N99/I/17

28 Four students are asked to draw graphs to show how the p.d. V across a capacitor depends on its charge Q. They are also asked to shade the area that represents the increase in energy stored in the capacitor when the charge is increased from Q_1 to Q_2.

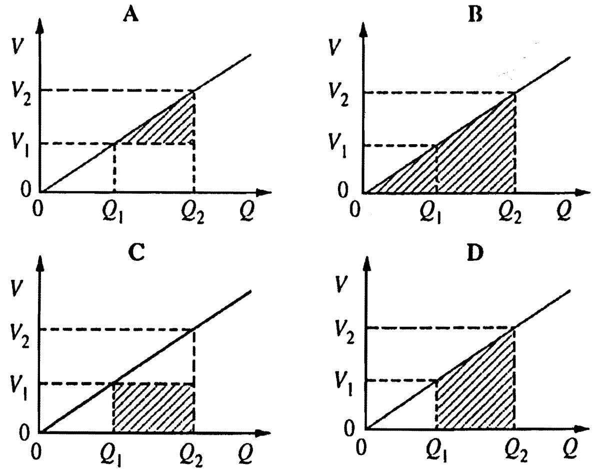
Which graph is correct?



J2000/I/18

29 When the potential difference V between the plates of a capacitor is increased from V_1 to V_2 the charge Q on the plates increases from Q_1 to Q_2.

On the graphs, which shaded area represents the increase in the energy stored in the capacitor?



N2000/I/17

30 An uncharged 0.1 μF capacitor is charged to a p.d. of 500 V by a battery. Calculate

(*a*) the energy stored in the capacitor,

(*b*) the charge circulated by the battery,

(*c*) the energy provided by the battery,

(*d*) the total heat dissipated in the resistance of the connecting wires and of the battery. N76/I/7

31 The capacitance of a certain variable capacitor may be varied between limits of 1×10^{-10} F and 5×10^{-10} F by turning a knob attached to the movable plates. The capacitor is set to 5×10^{-10} F, and is charged by connecting it to a battery of e.m.f. 200 V.

(*a*) What is the charge on the plates?

The battery is then disconnected and the capacitance changed to 1×10^{-10} F.

(*b*) Assuming that no charge is lost from the plates, what is now the potential difference between them?

(*c*) How much mechanical work is done against electrical forces in changing the capacitance? J79/I/9

32

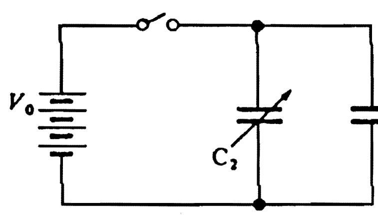


Fig. 3

In Fig. 3, C_1 is a fixed capacitor of capacitance C_0, and C_2 is a variable capacitor. The e.m.f. of the battery is V_0.

(*a*) Initially, the switch is closed and C_2 is adjusted so that its capacitance is also C_0. Find, in terms of C_0 and V_0, the total energy stored in the two capacitors.

(*b*) The switch is then opened and C_2 is adjusted so that its capacitance becomes $C_0/4$.

(i) What is the resulting potential difference across the capacitors?

(ii) How much work is done against electrical forces in reducing the capacitance of C_2?

J83/I/9

33 A rolled paper capacitor is made from strips of metal foil of dimensions 2 cm × 40 cm separated by paper of relative permittivity 2 and thickness 0.002 cm. Estimate its capacitance. N86/III/5

34 Given a number of capacitors each with a capacitance of 2 μF and a maximum safe working potential difference of 10 V, how would you construct capacitors of

(*a*) 1 μF capacitance, suitable for use up to 20 V,

(*b*) 2 μF capacitance, suitable for use up to 20 V?

J87/III/3

35 (*a*) Define *capacitance.* [1]

(*b*) A capacitor of capacitance 10 μF is fully charged from a 20 V d.c. supply.

(i) Calculate the charge stored by the capacitor. [2]

(ii) Calculate the energy delivered by the 20 V supply. [1]

(iii) Calculate the energy stored by the capacitor. [2]

(iv) Account for the difference between the answers for (ii) and (iii). [1]

J92/II/4 (part)

36 An initially uncharged conducting sphere of capacitance 4.5×10^{-12}F is suspended by an insulating thread between two metal plates as shown in Fig. 4.

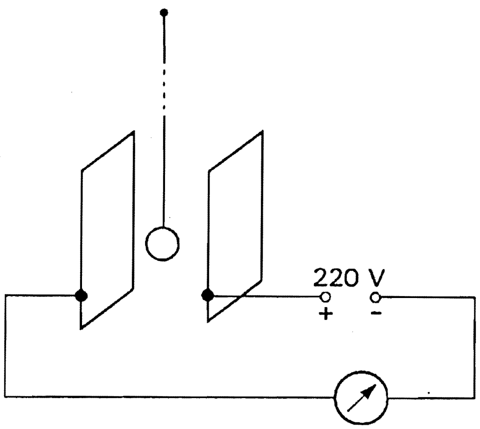


Fig. 4

The plates are connected in series with a d.c. supply of e.m.f. 220 V and a microammeter. The sphere is moved to one side so that it touches the positive plate.

(*a*) Calculate the magnitude of the charge transferred when the sphere touches the plate. [2]

(*b*) The sphere in (*a*) is now released and it is seen to oscillate between the two plates, touching each plate in turn. The frequency of oscillation is 3.5 Hz.

(i) Briefly explain why a current is detected in the circuit. [4]

(ii) Calculate the magnitude of this current. [3]

N92/II/4

37 A capacitor of capacitance C = 220 μF is charged by a battery which has an e.m.f. of 6.0V.

(*a*) Calculate the charge on the capacitor when there is a potential difference of 6.0V across it. [2]

(*b*) How much energy does the capacitor store when the potential difference across it is 6.0 V? [2]

N95/II/3 (part)

38 (*a*) A capacitor is marked as having a capacitance of 100 μF. It is also marked 20 V.

(i) Explain what is meant by 'a capacitance of 100 μF'.

(ii) How much charge is stored by the capacitor when a p.d. of 20 V is applied across it?

(iii) Write down the maximum charge which may safely be stored by the capacitor.

(iv) Calculate the energy stored by the capacitor when charged as in (ii). [5]

(*b*) Suggest why the maximum voltage to be used is marked on a capacitor. [1]

J96/II/3 (part)

39 (*a*) An isolated capacitor of capacitance 200 μF has a potential difference across it of 30 V. Calculate

(i) the charge stored on one plate of the capacitor,

charge = ... C

(ii) the energy stored by the capacitor

energy = ... J [4]

(*b*) An uncharged capacitor of capacitance 100 μF is then connected across the charged 200 μF capacitor in (*a*). For this combination, state which electrical quantity

(i) will have the same total value before and after connection,

(ii) will be the same for each of the capacitors after connection. [2]

(*c*) Calculate the total energy stored by the two capacitors in (*b*) after they have been connected.

energy = ... J [5]

J99/II/4

Long Questions

40 Define *capacitance*. Name the SI units for all the quantities involved. [4]

How would you attempt to show that the capacitance of a large conducting sphere is constant, whatever the p.d. applied? [6]

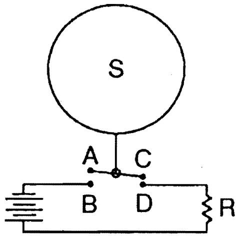


Fig. 5

A large conducting sphere S is connected in the circuit shown in Fig. 5. CD is opened and AB is closed, then AB is opened and CD closed. Discuss what happens.

N77/III/4 (part)

41 Compare the energy stored in a fully charged 2.0 volt 30 ampere hour accumulator with that stored in a Van de Graaff machine of capacitance 10^{-10} F charged to a potential of 2×10^6 V. Which would you consider the more dangerous? Give your reasons.

N78/III/6 (part)

42 What do you understand by the *capacitance* of a conductor? Explain, with reference to your definition, why a nearby earthed metal plate increases the capacitance of such a conductor.

Describe an experiment which shows that the capacitance of a conductor may also be increased by increasing its exposed surface area.

Two capacitors of capacitances C_1 and C_2 are charged to potentials V_1 and V_2 respectively. They are then connected so as to provide a larger capacitance C. Derive an expression for the potential V of this larger capacitor in terms of C_1, C_2, V_1 and V_2. Explain clearly the steps in your argument.

Calculate the energy loss when the capacitors are so connected if $C_1 = C_2 = 2\ \mu F$ and $V_1 = 200$ V and $V_2 = 0$ V. Comment on this loss in relation to the principle of conservation of energy.

N80/III/4

43 Define *capacitance* and name its unit. Write down an expression for the potential at the surface of a conducting sphere carrying charge Q. Hence show that the capacitance of an isolated conducting sphere is proportional to its radius.

J82/III/5 (part)

44 The cap of a negatively charged electroscope is irradiated with α-particles in a vacuum. The potential difference between the electroscope and earth is initially 2.5 kV and the capacitance of the electroscope is 1.2×10^{-12} F. Calculate

(i) the initial charge on the electroscope,

*(ii) the time for the leaves to collapse completely if the rate of arrival of the α-particles is $1.1 \times 10^7\ s^{-1}$.

In air, much shorter times of leaf collapse are observed. Explain this.

N82/III/5 (part)

45 What do you understand by *capacitance* and a *farad*?

Describe in terms of electron flow what happens when an isolated positively charged conducting sphere is connected to earth

(a) by a large resistance,

(b) by a parallel-plate capacitor of capacitance equal to that of the sphere.

Calculate the time for the charge on the sphere in *(a)* to fall to half its initial value if its capacitance is 1×10^{-11} F and the resistance is $1 \times 10^9\ \Omega$.

J83/III/5 (part)

46 What do you understand by the *capacitance* of an isolated conductor? Explain why the concept would be inappropriate for an insulator.

Explain why the capacitance of a metal plate is increased if another earthed metal plate is brought near.

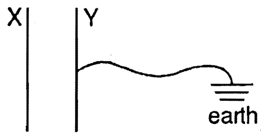


Fig. 6

A parallel plate capacitor is shown in Fig 6. Copy the diagram and show the distribution of charges and the electric field pattern established when a negative charge is given to plate X. Indicate the direction of conventional current flow in the wire connecting plate Y to earth while X is being charged. Show also the direction of the electrostatic force on X.

X is disconnected from the charging system. Explain why the force on X is independent of its distance from Y, neglecting edge effects. Write down expressions for

(a) the capacitance of a parallel plate capacitor of plate area A and separation d,

(b) the energy of a parallel plate capacitor in terms of plate area A, separation d and charge q.

By considering energy changes when the plate X is moved, with q remaining constant, deduce an expression for the force on the plates. Calculate this force for plates of area 100 cm² carrying charge of 1 μC, in vacuum.

N83/III/3

47 Explain what is meant by the *capacitance of*

(a) an isolated conductor,

(b) a parallel-plate capacitor.

Derive an expression for the capacitance of two capacitors of capacitance C_1 and C_2 connected in series.

Explain, in terms of electron flow, how a capacitor can

(c) offer infinite resistance to direct current, but

(d) allow alternating current to pass when an alternating e.m.f. is applied. J84/III/4 (part)

48 Derive a formula for the capacitance of a parallel plate capacitor. Explain why the presence of a dielectric between the plates of a parallel plate capacitor increases the capacitance.

What is meant by *relative permittivity*? Describe a method by which it may be measured.

A parallel plate capacitor has a capacitance of 120 pF when the space between the plates is completely filled with an insulator of relative permittivity 6.0. The capacitor is charged to a potential difference of 100 V. What is

(a) the charge on the plates of the capacitor,

(b) the energy stored in the capacitor?

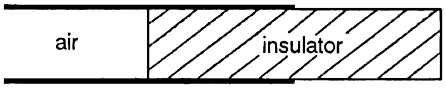


Fig. 7

The capacitor is now isolated and the insulator is withdrawn so that only half of the space between the plates is filled (see Fig. 7). If the air-filled and insulator-filled sections may be considered as two separate capacitors, calculate

(c) the new value of the total capacitance,

(d) the energy now stored.

Comment on the difference between your answers in *(b)* and *(d)*. N85/III/12

49 *(a)* What do you understand by (i) the capacitance C of a capacitor,

(b) Two capacitors of capacitances C_1 and C_2 are charged to potentials V_1 and V_2 respectively. The capacitors are then connected by connecting the positively charged plates and by connecting the negatively charged plates. Derive an expression for the final potential difference V across this combination. Explain your working carefully. [5]

J88/III/12 (part)

50 *(a)* An isolated, positively charged conducting sphere is situated above a large flat metal plate which is earthed (see Fig. 8).

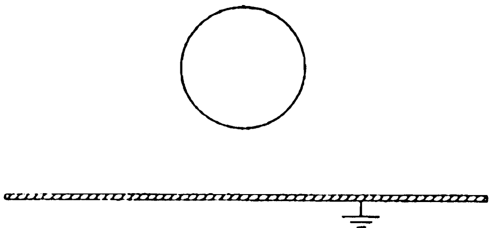


Fig. 8

(i) Copy the diagram of Fig. 8 and show the pattern of electric field lines in the region surrounding the sphere. [3]

(ii) Describe, in terms of electron flow, what happens when the sphere is connected to the plate by means of a parallel plate capacitor of capacitance approximately equal to that of the sphere. [4]

N88/III/11 (part)

51 *(a)* An uncharged capacitor is connected in series with a battery of e.m.f. E and a switch. When the switch is closed, a charge Q flows through the battery. Write down expressions in terms of E and Q for

(i) the energy supplied by the battery,

(ii) the energy stored in the capacitor.

Comment on your answers with reference to the law of conservation of energy. [5]

J89/III/11 (part)

52 *(a)* Draw a simple circuit diagram in which a capacitor is used. Explain the function of the capacitor in the circuit you have drawn. [4]

(b) A capacitor of capacitance 64 μF, which is initially uncharged, is connected to a supply which gives a constant current of 0.16 mA. Calculate

(i) the time taken for the potential difference across the capacitor to become 30 V,

(ii) the energy stored by the capacitor when the potential difference across it is 30 V. [5]

(c) Two capacitors of capacitances 22 μF and 47 μF are connected in series with a constant 24 V supply. The capacitors are initially uncharged. Calculate

(i) the total circuit capacitance,

(ii) the charge delivered by the supply,

(iii) the charge on each capacitor,

(iv) the potential difference across the capacitor of capacitance 47 μF. [7]

(d) (ii) Explain why it is that some items of electronic equipment have the warning message "DANGER: EVEN WHEN SWITCHED OFF, IT MAY BE DANGEROUS TO REMOVE THE BACK OF THIS EQUIPMENT". [4]

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53 *(a)* (i) Sketch a graph to show the variation with potential of the charge on an isolated conductor.

(ii) By reference to your graph in (i),

1. define what is meant by *capacitance*,

2. derive an expression for the energy E stored in a capacitor of capacitance C charged to a potential V. [6]

(b) Four capacitors, each of capacitance 50 μF, are connected as shown in Fig. 9 to a high-voltage supply, a resistor and a switch S.

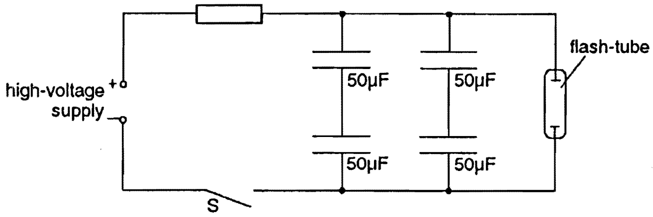

Fig. 9

A flash-tube is connected across the combination of capacitors. When S is closed, the capacitors charge up gradually and, when the potential difference across the flash-tube reaches 540 V, the capacitors discharge rapidly through the flash-tube. A flash of light is emitted as the capacitors discharge 63% of their energy.

(i) 1. Determine the total capacitance of the arrangement of capacitors.

2. Suggest one advantage of this arrangement compared with a single capacitor of the same total capacitance. [3]

(ii) The potential difference across the flash-tube creates an electric field in the tube. State two differences between the force due to the electric field on the nucleus and the force due to the electric field on an electron of an atom of xenon gas in the tube. [2]

(iii) Suggest why there is a current in the tube when the potential difference across it is sufficiently large. [2]

(iv) Calculate

1. the energy dissipated in one flash of light,

2. the potential difference across each capacitor immediately after the flash of light has occurred. [4]

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