Electric filed strength and electric flux density

All bodies are made up of atoms, which consist of a nucleus containing protons (+ve) and neutrons (neutral) and surrounding the nucleus are orbiting electrons (-ve).

When a body is uncharged it is electrically neutral, it has the same negative charge as positive charge.

If a conductor had a deficit of electrons it would exhibit a net positive charge and if it was to have a surplus of electrons it would exhibit a net negative charge (remember the previous study of the atom reference +ve/-ve ions). An imbalance in charge can be produced by friction (removing or depositing electrons using materials such as silk and fur, respectively) or induction (by attracting or repelling electrons using a second body which is, respectively, positively or negatively charged).

Coulomb's Law states that if charged bodies exist at two points, the force of attraction (if the charges are of opposite polarity) or repulsion (if the charges have the same polarity) will be proportional to the product of the magnitude of the charges divided by the square of their distance apart. Thus:

+

–

+

+

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Q1 and Q2 are the charges present at the two points (in Coulombs), d is the distance separating the two points (in metres), F is the force (in Newtons), and k is a mathematical constant depending upon the medium in which the charges exist.

In a vacuum or ‘ free space’,

Îµ0 is the permittivity of free space (8. 854 x 10-12 F/m – Farad per meter).

The force exerted on a charged particle is a manifestation of the existence of an electric field. The electric field defines the direction and magnitude of a force on a charged object. The field itself is invisible to the human eye but can be drawn by constructing lines which indicate the motion of a free positive charge within the field; the number of field lines in a particular region being used to indicate the relative strength of the field at the point in question.

The figure above shows the electric fields between charges of the same and opposite polarity.

The figure below shows the field which exists between two charged parallel plates.

B

A

As illustrated above, plates A and B are doped and charged to different potentials. If an electron that has a negative charge is placed between the plates, a force will act on the electron tending to push it away from the negative plate B and towards the positive plate A. Similarly, a positive charge would be acted on by a force tending to move it toward the negative plate.

The region between the plates in which an electric charge experiences a force, is called an electrostatic field. The direction of the field is defined by the force acting on a positive charge placed in the field, i. e. the direction of the force is from the positive plate to the negative plate.

Such a field may be represented in magnitude and direction by lines of electric force drawn between the charged surfaces. The closeness of the lines is an indication of the field strength. Whenever a p. d. is established between two points, an electric field will always exist.

The figure above shows two parallel conducting plates separated from each other by air, and are connected to opposite terminals of a battery of voltage V volts. There is therefore an electric field in the space between the plates. If the plates are close together, the electric lines of force will be straight and parallel and equally spaced, except near the edge where fringing will occur (see previous figure). Over the area in which there is negligible fringing,

E is the electric field strength (V/m), V is the applied potential difference across the parallel plates (V) and d is the distance (m).

**Note: Electric Field Strength is also called Potential/Voltage Gradient.

A unit electric flux is defined as emanating from a positive charge of 1 coulomb. Thus electric flux Ïˆ is measured in coulombs, and for a charge of Q coulombs, the electric flux Ïˆ is equal to Q coulombs. Electric flux density D is the amount of flux passing through a defined area A that is perpendicular to the direction of the flux:

Ïˆ is the electric flux measured in coulombs, Q is the electric charge also measured in coulombs, and A is the area in m2 over which the flux is distributed.

Problem 1:

Two parallel rectangular plates measuring 20cm by 40cm carry an electric charge of 0. 2 μC. (a) Calculate the electric ¬, ux density.

(b) If the plates are spaced 5mm apart and the voltage between them is 0. 25 kV determine the electric field strength.

Solution 1:

PERMITTIVITY

At any point in an electric field, the electric field strength E maintains the electric flux and produces a particular value of electric flux density D at that point. For a field established in vacuum (or for practical purposes in air), the ratio D/E is a constant Îµ0, i. e.

Îµ0 is called the permittivity of free space or the free space constant.

The value of Îµ0 is 8. 854 x 10-12 F/m – Farad per meter.

When a dielectric (i. e. insulating medium separating charged surfaces), such as mica, paper, plastic or ceramic is introduced into the region of an electric field, the ratio of D/E is modified.

Îµr is called the relative permittivity of the insulating material and indicates its insulating power compared with that of vacuum.

Îµr has no units and typical properties of some common insulating dielectric materials are shown below.

The product of Îµ0 Îµr is called the absolute permittivity, Îµ, i. e.

As discussed earlier, the dielectric is an insulating medium separating charged surfaces and has the property of very high resistivity. They are therefore used to separate conductors at different potentials, such as capacitor plates or electric power lines.

The dielectric strength of an insulating dielectric is the maximum electric field strength that can safely be applied to it before breakdown (conduction) occurs.

The amount of charge produced for a given applied voltage on the two parallel plates shown earlier will depend not only on the physical dimensions but also on the insulating dielectric material that appears between the plates. Such materials need to have a very high value of resistivity (i. e. they must not conduct charge) coupled with an ability to withstand high voltages without breaking down.

A more practical arrangement of parallel plates with an insulating dielectric material is shown.

In this arrangement the ratio of charge, Q, to the potential difference, V, is given by the following relationship.

A = area of one on the plates, in m2

D = thickness of the dielectric in m

Îµ = absolute permittivity of the dielectric material

*Later learning, i. e. the parallel plate capacitor/capacitance and physical dimensions.

……… single pair of plates

……… arrangement of ‘ n’ plates

Problem 1:

The ¬, ux density between two plates separated by mica of relative permittivity 5 is 2µC/m2. Find the voltage gradient between the plates.

Solution 1:

Problem 2:

Two parallel plates having a p. d. of 200V between them are spaced 0. 8mm apart.

What is the electric ¬⁾eld strength?

Find also the electric ¬, ux density when the dielectric between the plates is (a) air, and (b) polythene of relative permittivity 2. 3

Solution 2:

SELF ASSESSMENT (1-2)

NOTE: Where appropriate take Îµ0 as 8. 85 x 10-12 F/m

A capacitor uses a dielectric 0. 04mm thick and operates at 30V. What is the electric field strength across the dielectric at this voltage? [Answer: 750kV/m]

A two-plate capacitor has a charge of 25C. If the effective area of each plate is 5cm2 determine the electric ¬, ux density of the electric field. [Answer: 50 kC/m2]

A charge of 1. 5μC is carried on two parallel rectangular plates each measuring 60mm by 80mm. (a) Calculate the electric ¬, ux density. (b) If the plates are spaced 10mm apart and the voltage between them is 0. 5kV determine the electric ¬)eld strength.

[Answer: (a) 312. 5μC/m2, (b) 50kV/m]

Two parallel plates are separated by a dielectric and charged with 10μC. Given that the area of each plate is 50cm2, calculate the electric ¬, ux density in the dielectric separating the plates. [Answer: 2mC/m2]

The electric ¬, ux density between two plates separated by polystyrene of relative permittivity 2. 5 is 5μC/m2. Find the voltage gradient between the plates.

[Answer: 226kV/m]

Two parallel plates having a p. d. of 250V between them are spaced 1mm apart.

(a) Determine the electric ¬)eld strength.

(b) Find also the electric ¬, ux density when the dielectric between the plates is

(i) air and (ii) mica of relative permittivity 5.

[Answer: (a) 250kV/m (bi) 2. 213μC/m2 (bii) 11. 063μC/m2]

CAPACITORS & CAPACITANCE

A capacitor is a device for storing electric charge. In effect, it is a reservoir into which charge can be deposited and then later extracted. In its simplest form a capacitor consists of two parallel metal plates which are separated by an insulating material known as a dielectric.

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Because of the dielectric, current cannot flow from one plate to the other. When the capacitor is connected to a dc source, electrons accumulate on the plate connected to the negative supply terminal. The negative charge repels electrons from the atoms of the other plate. These electrons flow away to the positive terminal of the dc source; this leaves the plate positively charged.

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If the capacitor is disconnected from the supply, the charges remain. The capacitor stores the electric charge indefinitely.

The symbols for a fixed capacitor and a variable capacitor used in electrical circuit diagrams are shown below.

Typical applications include reservoir and smoothing capacitors for use in power supplies, coupling a. c. signals between the stages of amplifiers, and decoupling supply rails (i. e. effectively grounding the supply rails as far as a. c. signals are concerned).

The following figures illustrate what happens to a capacitor when it is charging and discharging.

If the switch is left open (position A), no charge will appear on the plates and in this condition there will be no electric field in the space between the plates nor will there be any charge stored in the capacitor.

When the switch is moved to position B, electrons will be attracted from the positive plate to the positive terminal of the battery. At the same time, a similar number of electrons will move from the negative terminal of the battery to the negative plate. This sudden movement of electrons will manifest itself in a momentary surge of current (conventional current will flow from the positive terminal of the battery towards the positive terminal of the capacitor).

Eventually, enough electrons will have moved to make the e. m. f. between the plates the same as that of the battery. In this state, the capacitor is said to be fully charged and an electric field will be present in the space between the two plates.

If, at some later time the switch is moved back to position A, the positive plate will be left with a deficiency of electrons whilst the negative plate will be left with a surplus of electrons. Furthermore, since there is no path for current to flow between the two plates the capacitor will remain charged and a potential difference will be maintained between the plates.

Now assume that the switch is moved to position C. The excess electrons on the negative plate will flow through the resistor to the positive plate until a neutral state once again exists (i. e. until there is no excess charge on either plate). In this state the capacitor is said to be fully discharged and the electric field between the plates will rapidly collapse. The movement of electrons during the discharging of the capacitor will again result in a momentary surge of current (current will flow from the positive terminal of the capacitor and into the resistor).

The figure below shows the direction of current flow during charging (i. e. the switch in position B) and discharging (i. e. the switch in position C). It should be noted that current flows momentarily in both circuits even though you may think that the circuit is broken by the gap between the capacitor plates!

The charge Q (in coulombs) stored in a capacitor is given by:

I is the current in amperes and t is the time in seconds.

Charge Q on a capacitor is proportional to the applied voltage V, i. e. Q V.

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$$\mathbf{Q = CV}$$

The constant of proportionality C is the capacitance.

The unit of capacitance C is the farad F (or more usually μF = 10-6F or pF = 10-12F), and is defined as the capacitance when a p. d. of one volt appears across the plates when charged with one coulomb.

Capacitance is the ability of a circuit or object (i. e. in this case a capacitor) to store electric charge.

Problem 1:

(a) Determine the p. d. across a 4 μF capacitor when charged with 5 mC

(b) Find the charge on a 50 pF capacitor when the voltage applied to it is 2 kV.

Solution 1:

Problem 2:

A direct current of 4A flows into a previously uncharged 20 μF capacitor for 3 ms. Determine the p. d. between the plates.

Solution 2:

Problem 3:

A 5μF capacitor is charged so that the p. d. between its plates is 800V. Calculate how long the capacitor can provide an average discharge current of 2 mA.

Solution 3:

SELF ASSESSMENT (3)

Find the charge on a 10 μF capacitor when the applied voltage is 250 V. (Answer: 2. 5 mC)

Determine the voltage across a 1000Ï¼F capacitor to charge it with 2 μC. (Answer: 2 kV)

The charge on the plates of a capacitor is 6 mC when the potential between them is 2. 4 kV. Determine the capacitance of the capacitor. (Answer: 2. 5 μF)

For how long must a charging current of 2 A be fed to a 5 μF capacitor to raise the p. d. between its plates by 500V. (Answer: 1. 25 ms)

A direct current of 10 A flows into a previously uncharged 5 μF capacitor for 1 ms. Determine the p. d. between the plates. (Answer: 2 kV)

A 16 μF capacitor is charged at a constant current of 4 μA for 2 minutes. Determine the final p. d. across the capacitor and the corresponding charge in coulombs. (Answer: 30V, 480 μC)

A steady current of 10 A flows into a previously uncharged capacitor for 1. 5 ms when the p. d. between the plates is 2 kV. Find the capacitance of the capacitor. (Answer: 7. 5μF)

CAPACITANCE AND PHYSICAL DIMENSIONS (Conventional Parallel Plate Capacitor)

The capacitance of a capacitor depends upon the physical dimensions of the capacitor (i. e. the size of the plates and the separation between them) and the dielectric material between the plates. The capacitance of a conventional parallel plate capacitor is given by:

Where, C = Capacitance, unit of measure farads (F)

Îµ0 = Permittivity of free space or the free space constant (8. 85 x 10-12 F/m)

Îµr = Relative permittivity of the dielectric medium between the plates

(Îµr has no units as it is a ratio of density material/vacuum)

A = Area of one of the plates (m2)

d = Thickness of the dielectric or separation between the plates (m)

In order to increase the capacitance of a capacitor, many practical components employ multiple plates as shown.

Ten plates are shown, forming nine capacitors with a capacitance nine times that of one pair of plates.

Such an arrangement has n plates then capacitance C âˆ (n -1). Thus capacitance is then given by:

Problem 1:

A ceramic capacitor has an effective plate area of 4cm2 and separated by 0. 1 mm of ceramic of relative permittivity 100. Calculate the capacitance of the capacitor in picofarads (ÏF).

If the capacitor in part (a) is given a charge of 1. 2µC what will be the p. d. between the plates?

Solution 1:

Problem 2:

A waxed paper capacitor has two parallel plates, each of effective area 800 cm2. If the capacitance of the capacitor is 4425 pF determine the effective thickness of the paper if its relative permittivity is 2. 5.

Solution 2:

Problem 3:

A parallel plate capacitor has nineteen interleaved plates each 75 mm by 75 mm and separated by mica sheets 0. 2 mm thick. Assuming that the relative permittivity of the mica is 5, calculate the capacitance of the capacitor.

Solution 3:

n = 19, thus (n – 1) = 18

A = 75 x 75 = 5625mm2

Îµr = 5, Îµ0 = 8. 85 x 10-12 F/m

d = 0. 2mm = 0. 2 x 10-3m

SELF ASSESSMENT (4)

** Where appropriate take Îµ0 as 8. 85 x 10-12 F/m.

A capacitor consists of two parallel plates each of area 0. 01 m2, spaced 0. 1 mm in air. Calculate the capacitance in picofarads (pF). [Answer: 885 pF]

A waxed paper capacitor has two parallel plates, each of effective area 0. 2m2. If the capacitance is 4000 pF determine the effective thickness of the paper if its relative permittivity is 2. [Answer: 0. 885 mm]

Calculate the capacitance of a parallel plate capacitor having 5 plates, each 30 mm by 20 mm and separated by a dielectric 0. 75 mm thick having a relative permittivity of 2. 3. [Answer: 65. 14 pF]

How many plates does a parallel plate capacitor have if its capacitance is 5nF, each plate is 40mm by 40mm and each dielectric is 0. 102mm thick with a relative permittivity of 6? [Answer: 7]

A parallel plate capacitor is made from 25 plates, each 70mm by 120mm interleaved with mica of relative permittivity 5. If the capacitance of the capacitor is 3000pF determine the thickness of the mica sheet. [Answer: 2. 97mm]

The capacitance of a parallel plate capacitor is 1000pF. It has 19 plates, each 50mm by 30mm separated by a dielectric of thickness 0. 40mm. Determine the relative permittivity of the dielectric. [Answer: 1. 67]

CAPACITORS CONNECTED IN PARALLEL AND SERIES

CAPACITORS CONNECTED IN PARALLEL

The figure above shows three capacitors, C1, C2 and C3 connected in parallel with a supply voltage V applied across the arrangement. (Note: just like resistors in parallel, the supply voltage V is the same across each parallel capacitor)

V = V1 = V2 = V3

When the charging current I reaches point A it divides, some flowing into C1, some flowing into C2 and some into C3. Hence the total charge QT (i. e. QT= I x t) is divided between the three capacitors. The capacitors each store a charge and these are shown as Q1, Q2 and Q3 respectively. Hence,

But, QT= CV (where C is the total equivalent circuit capacitance)

And, $Q1= C1V$

$Q2= C2V$

$Q3= C3V$

Therefore, $CV = C1V + C2V + C3V$ (where C is the total equivalent circuit capacitance)

Dividing throughout by the common V giving,

$C = C1 + C2 + C3 \ldots\ldots. + Cn$

The equivalent capacitance of a group of parallel connected capacitors is the sum of the capacitances of the individual capacitors.

CAPACITORS CONNECTED IN SERIES

The figure above shows three capacitors, C1, C2 and C3 connected in series across a supply voltage V. Let the p. d. across the individual capacitors be V1, V2 and V3 respectively as shown.

Let the charge on the plate ‘ a’ of the capacitor C1 be +Q coulombs. This induces and equal but opposite charge of -Q coulombs on plate ‘ b’. The conductor between plates ‘ b’ and ‘ c’ is electrically isolated from the rest of the circuit so that an equal but opposite charge of +Q coulombs must appear on plate ‘ c’, which, in turn, induces an equal and opposite charge of -Q coulombs on plate ‘ d’, and so on.

Hence when capacitors are connected in series the charge on each is the same.

$QT = Q1 = Q2 = Q3$

In a series circuit: $V = V1 + V2 + V3$ (Similar to resistors in series)

Since, then (where C is the total equivalent circuit capacitance)

Dividing throughout by the common Q giving,

(Where C is the total equivalent circuit capacitance)

For series connected capacitors, the reciprocal of the equivalent capacitance is equal to the sum of the reciprocals of the individual capacitance.

For special case of two capacitors in series,

Hence,

i. e.

Problem 1:

Calculate the equivalent capacitance of two capacitors of 6Î¼F and 4Î¼F connected in

(a) Parallel

(b) Series.

Solution 1:

Problem 2:

What capacitance must be connected in series with a 30Î¼F capacitor for the equivalent capacitance to be 12Î¼F?

Solution 2:

Problem 3:

Capacitances of 1Î¼F, 3Î¼F, 5Î¼F and 6Î¼F are connected in parallel to a direct voltage supply of 100V. Determine (a) the equivalent circuit capacitance, (b) the total charge and (c) the charge on each capacitor.

Solution 3:

Problem 4:

Capacitances of 3Î¼F, 6Î¼F and 12Î¼F are connected in series across a 350V supply. Calculate (a) the equivalent circuit capacitance, (b) the charge on each capacitor, and (c) the p. d. across each capacitor.

Solution 4:

Problem 5:

For the arrangement shown, find (a) the equivalent capacitance of the circuit, (b) the voltage across QR and (c) The charge on each capacitor.

Solution 5:

SELF ASSESSMENT (5)

Capacitors of 2µF and 6µF are connected (a) in parallel and (b) in series. Determine the equivalent capacitance in each case. [Answers: (a) 8Î¼F (b) 1. 5Î¼F]

Find the capacitance to be connected in series with a 10µF capacitor for the equivalent capacitance to be 6µF. [Answer: 15Î¼F]

What value of capacitance would be obtained if capacitors of 0. 15μF and 0. 10μF are connected in (a) series and (b) parallel? [Answers: (a) 0. 06Î¼F (b) 0. 25Î¼F]

Two 6μF capacitors are connected in series with one having a capacitance of 12μF. Find the total equivalent circuit capacitance. What capacitance must be added in series to obtain a capacitance of 1. 2μF? [Answers: (a) 2. 4Î¼F (b) 2. 4Î¼F]

For the arrangement shown below, find (a) the equivalent circuit capacitance and (b) the voltage across a 4. 5Î¼F capacitor. [Answers: (a) 1. 2Î¼F (b) 100V]

Three 12μF capacitors are connected in series across a 750V supply. Calculate (a) the equivalent capacitance, (b) the charge on each capacitor and (c) the p. d. across each capacitor. [Answers: (a) 4μF (b) 3mC (c) 250V]

If two capacitors having capacitances of 3μF and 5μF respectively are connected in series across a 240V supply, determine (a) the p. d. across each capacitor and (b) the charge on each capacitor. [Answers: (a) 150V, 90V (b) 0. 45 mC on each]

Capacitances of 4μF, 8μF and 16μF are connected in parallel across a 200V supply. Determine (a) the equivalent capacitance, (b) the total charge and (c) the charge on each capacitor. [Answers: (a) 28 μF (b) 5. 6mC (c) 0. 8mC, 1. 6mC, 3. 2mC]

DIELECTRIC STRENGTH

The maximum safe working voltage is the maximum voltage that can be applied to the terminals of a capacitor without causing damage to the capacitor.

The manufacturer specifies this voltage. The limit is necessary so that the field strength in the dielectric does not exceed a value that would cause the dielectric to breakdown and loose its insulating properties. The figure quoted by the manufacturer for a capacitor is also known as the dielectric strength and will be in volts per metre.

E is the dielectric strength (V/m), V is the applied potential difference across the parallel plates (V) and d is the distance (m).

**Note: Equation identical to Electric Field Strength (Potential/Voltage Gradient).

Problem1:

A capacitor is to be constructed so that its capacitance is 0. 2μF and to take a p. d. of 1. 25kV across its terminals. The dielectric is to be mica and has a dielectric strength of 50MV/m. Find (a) the thickness of the mica needed, and (b) the area of a plate assuming a two-plate construction. (Assume Îμr for mica to be 6).

Solution 1:

ENERGY STORED IN CAPACITORS

The energy, W, stored by a capacitor is given by,

Where,

W is the energy (in Joules),

C is the capacitance (in Farads), and

V is the potential difference (in Volts).

Problem 1:

(a) Determine the energy stored in a 3µF capacitor when charged to 400V.

(b) Find also the average power developed if this energy is dissipated in a time of 10µs.

Solution 1:

Problem 2:

A 12µF capacitor is required to store 4J of energy. Find the p. d. to which the capacitor must be charged.

Solution 2:

Problem 3:

A capacitor is charged with 10mC. If the energy stored is 1. 2J, determine (a) the voltage and (b) the capacitance.

Solution 3:

SELF ASSESSMENT (6)

** Where appropriate take Îµ0 as 8. 85 x 10-12 F/m.

When a capacitor is connected across a 200V supply the charge is 4µC. Find (a) the capacitance and (b) the energy stored. [Answer: (a) 0. 02µF (b) 0. 4mJ]

Find the energy stored in a 10μF capacitor when charged to 2kV. [Answer: 20 J]

A 3300pF capacitor is required to store 0. 5mJ of energy. Find the p. d. to which the capacitor must be charged. [Answer: 550 V]

A capacitor is charged with 8mC. If the energy stored is 0. 4J, determine (a) the voltage and (b) the capacitance. [Answer: (a) 100V (b) 80 μF]

A capacitor, consisting of two metal plates each of area 50 cm2 and spaced 0. 2mm apart in air, is connected across a 120V supply. Calculate (a) the energy stored (b) the electric ¬, ux density and (c) the potential gradient (i. e. electric field strength). [Answer: (a) 1. 593μJ (b) 5. 31μC/m2 (c) 600kV/m]

D. C TRANSIENTS

Networks of capacitors and resistors (known as C-R circuits) form the basis of many timing and pulse shaping circuits and are thus often found in practical electronic circuits.

When a d. c. voltage is applied to a capacitor C and resistor R connected in series, there is a short period of time immediately after when the voltage is connected that the current flowing in the circuit and voltages across C and R are changing.

These changing values are called transients.

CHARGING A CAPACITOR

The figure above shows a series connected C-R circuit.

When the switch S is closed, then by Kirchhoff's valotage law: V = Vc + VR

The battery voltage V is constant.

The capacitor voltage Vc is given by,

The voltage drop across R (i. e. VR) is given by,

Hence at all times:

At the instant of closing S (i. e. initial circuit condition), assuming there is no initial charge on the capacitor, Q is zero (i. e. Q0), hence Vc is zero (i. e. VC0). (Note: From equation Vc = Q / C).

Thus from equation V = Vc + VR,

V = 0 + VR (i. e. V = VR = IR)

A short time later at time T1 seconds after closing S, the capacitor is partly charged to, say, Q1 coulombs because current has been flowing. The voltage VC1 is now,

If the current flowing is I1 amperes, then the voltage drop across R has fallen to

VR1 = I1R volts. Thus from equation V = Vc + VR

A short time later still, say at time T2 seconds after closing S, the charge has increased to Q2 coulombs and VC has increased to,

Since V = VC + VR and V is a constant, then VR decreases to I2R. Thus VC is increasing and ‘ I’ and VR are decreasing as time increases.

Ultimately, a few seconds after closing S (i. e. at the final or steady state condition), the capacitor is fully charged to, say Q coulombs, current no longer flows, i. e. I = 0, and hence VR = IR = 0. It follows from equation V = Vc + VR that V = VC.

Curves showing the changes in VC, VR and ‘ I’ with time are shown below.

The curve showing the variation of VC with time is called an exponential growth curve and the graph is called the ‘ capacitor voltage / time’ characteristic.

The curves showing variations of VR and ‘ I’ with time are called exponential decay curves, and the graphs are called ‘ resistor voltage / time’ and ‘ current / time’ characteristics respectively.

The name ‘ exponential’ shows that the shape can be expressed mathematically by an exponential mathematical equation, as shown below.

Growth of capacitor voltage,

Decay of resistor voltage,

Decay of resistor current,

TIME CONSTANT (Ï„ – ‘ TAU’) FOR A C-R CIRCUIT

As shown earlier, if a constant d. c. voltage is applied to a series connected C-R circuit, a exponential transient growth curve of capacitor voltage VC results as shown below.

With reference to the figure below, the constant voltage supply is replaced by a variable voltage supply at time t1 seconds. The voltage is varied so that the current flowing in the circuit is constant.

Since the current flowing is a constant, the curve will follow a tangent, AB, drawn to the curve at point A.

Let the capacitor voltage VC reach its final value of V at time t2 seconds.

The time corresponding to (t2-t1) seconds is called the time constant of the circuit, denoted by the Greek letter ‘ tau’, Ï„. The value of the time constant is CR seconds, i. e. for a series connected C-R circuit,

(seconds)

Where C is capacitance (F), R is the resistance (â„¦) and Ï„ is the time constant (s)

DISCHARGING A CAPACITOR

When a capacitor is charged (i. e. with the switch in position ‘ A’), and the switch is then moved to position ‘ B’, the electrons stored in the capacitor keep the current flowing for a short time.

Initially, at the instant of moving from A to B, the current flow is such that the capacitor voltage VC is balanced by equal and opposite voltage (Kirchhoff’s 2nd law), i. e. VC = VR = IR.

Finally the transients decay exponentially as current is reduced to zero, i. e. VC = VR = 0.

The transient curve representing the voltages and current are shown below.

The equations representing the transient curves during discharge period of a series connected C-R circuit are:

Decay of voltage,

Decay of current,

When a capacitor has been disconnected from the supply it may still be charged and it may retain this charge for some considerable time. Thus precautions must be taken to ensure that the capacitor is automatically discharged after the supply is switched off. This is done by connecting a high value resistor across the capacitor terminals.

Problem 1:

A capacitor is charg