Applied Physics
EE I (morning), C.S. I, M.Cad I

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Q: Mention some important uses of capacitors.

Ans: Uses of Capacitors:
Capacitors are very useful circuit elements in any of the electric and electronic circuits. Some of their uses are-

① To produce electric fields of desired patterns, e.g. for Millikan's experiment.

② In radio circuits for tuning.
③ In power supplies for smoothing the rectified current.
④ For producing rotating magnetic fields in induction motors.
⑤ In the tank circuit of oscillators.
⑥ They store not only charge, but also energy in the electric field between their plates.

Effect of dielectric when the battery is kept disconnected from the capacitor.
Let Q_0, C_0, V_0, E_0 and U_0 be the charge, capacitance, potential difference, electric field and energy stored respectively before the dielectric slab is inserted. Then

$$Q_0 = C_0V_0, \quad E_0 = \frac{V_0}{d}, \quad U_0 = \frac{1}{2}C_0V_0^2$$

(i) Charge: The charge on the capacitor plates remains Q_0 because the battery has been disconnected before the insertion of the dielectric slab.

(ii) Electric field: When the dielectric slab is inserted between the plates, the induced surface charge on the dielectric reduces the field to a new value given by -

$$E = \frac{E_0}{k}$$

(iii) Potential difference: The reduction in the electric electric field results in the decrease in potential difference

$$V = Ed = \frac{E_0 d}{k} = \frac{V_0}{k}$$

(iv) Capacitance: As a result of the decrease in potential difference, the capacitance increases k times.

$$C = \frac{Q_0}{V} = \frac{Q_0}{V_0/k} = k\frac{Q_0}{V_0} = kC_0$$

(v) Energy stored: The energy stored decreases by a factor of k.

$$U = \frac{1}{2}CV^2 = \frac{1}{2}(kC_0)\left(\frac{V_0}{k}\right)^2 = \frac{1}{k}\cdot\frac{1}{2}C_0V_0^2$$

$$U = \frac{U_0}{k}$$

Effect of dielectric when battery remains connected across the capacitor.

Let Q_0, C_0, V_0, E_0 and U_0 be the charge, capacitance, potential difference, electric field and energy stored respectively, before the introduction of the dielectric slab. Then

$$Q_0 = C_0V_0, \quad E_0 = \frac{V_0}{d}, \quad U_0 = \frac{1}{2}C_0V_0^2$$

(i) Potential difference: As the battery remains connected across the capacitor, so the potential difference remains constant at V_0 even after the introduction of dielectric slab.

(ii) Electric field: As the potential difference remains unchanged, so the electric field E_0 between the capacitor plates remains unchanged.

$$E = \frac{V}{d} = \frac{V_0}{d} = E_0$$

(iii) Capacitance: The capacitance increases from C_0 to C.

$$C = KC_0.$$

(iv) Charge: The charge on the capacitor plates increases from Q_0 to Q.

$$Q = CV = KC_0 \cdot V_0 = KQ_0$$

(v) Energy stored: The energy stored in the capacitor increases K times. $U = \frac{1}{2}CV^2 = \frac{1}{2}(KC_0)\cdot V_0^2 = K\frac{1}{2}C_0V_0^2 = KU_0$

Current Electricity

Q. What is current electricity?

Ans. The physics of charges at rest is called electrostatics or static electricity. We shall now study the motion or dynamics of charges. As the term current implies some sort of motion, so the motion of electric charges constitutes an electric current.

The study of electric charges in motion is called current electricity.

Q. Electric Current:

The flow of electric charges through a conductor constitutes an electric current. Quantitatively, electric current in a conductor across an area held perpendicular to the direction of flow of charge is defined as the amount of charge flowing across that area per unit time.

If a charge ΔQ passes through an area in time t to $t+\Delta t$, then the current I at time t is given by

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

If the current is steady ie the rate of flow of charge does not change with time, then,

$$\boxed{I = \frac{Q}{t}}$$

$$\text{Electric current} = \frac{\text{Electric charge}}{\text{time}}$$

Where Q is the charge that flows across the given area in time t.

SI unit of current is ampere. If one coulomb of charge crosses an area in one second, then the current through that area is one ampere (A).

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

$$\boxed{1A = 1Cs^{-1}}$$

1 milliampere = 1 mA = 10^{-3} A
1 microampere = 1 μA = 10^{-6} A

Q. Is electric current a scalar or vector quantity?

Ans: Electric current is a scalar quantity.
Although electric current has both magnitude and direction, yet it is a scalar quantity. This is because the laws of ordinary algebra are used to add electric currents and the laws of vector addition are not applicable to the addition of electric currents. For example in given fig. two different currents of 3A and 4A ~~and~~ flowing in two mutually perpendicular wires AO & BO

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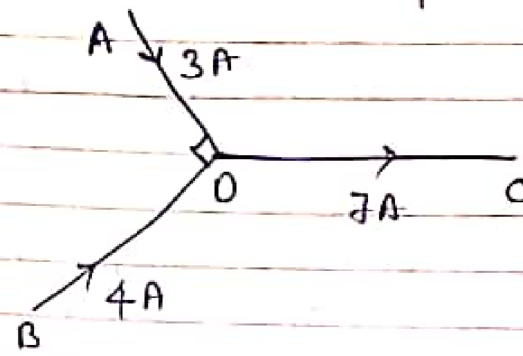
meet at the junction O and then flow along wire OC. The current in wire OC is 7A which is the scalar addition of 3A and 4A and not 5A are required by vector addition.



Q: In a hydrogen atom, an electron moves in an orbit of radius 5.0×10^{-11} m with a speed of 2.2×10^{6} ms^{-1}. Find the equivalent current. (Electronic charge $= 1.6 \times 10^{-19}$ coulomb)

Soln: Here, $r = 5.0 \times 10^{-11}$ m

$v = 2.2 \times 10^{6}$ ms^{-1}, $e = 1.6 \times 10^{-19}$ C

Period of revolution of electron,

$$T = \frac{2\pi r}{v} = \frac{2\pi \times 5.0 \times 10^{-11}}{2.2 \times 10^{6}} \text{ s}$$

frequency, $$\nu = \frac{1}{T} = \frac{2.2 \times 10^{6}}{2\pi \times 5.0 \times 10^{-11}}$$

$$= \frac{2.2 \times 10^{17}}{2 \times 22 \times 5}$$

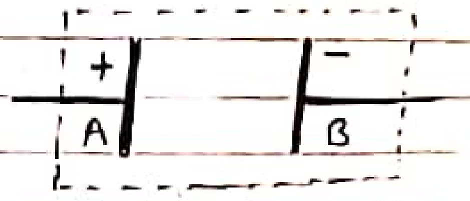
$$= 7 \times 10^{15} \; s^{-1}$$

current, $I = e\upsilon$

$$= 1.6 \times 10^{-19} \times 7 \times 10^{15}$$

$$\boxed{I = 1.12 \times 10^{-3} A}$$

Electromotive force: EMF



The electromotive force of a source may be defined as the work done by the source in taking a unit positive charge from lower to the higher potential.

The emf of a source may be defined as the energy supplied by the source in taking a unit positive charge once round the complete circuit.

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$$\text{emf} = \frac{\text{work done}}{\text{charge}}$$

$$\mathcal{E} = \frac{W}{q}$$

SI unit of emf is volt; If an electrochemical cell supplies an energy of 1 joule for the flow of 1 coulomb of charge through the whole circuit (including the cell), then its emf is said to be one volt.

Q. Give important points of differences between electromotive force and potential difference.

Ans: Electromotive force:

① ~~It is the work done by a source in taking a unit charge once round the complete circuit.~~

~~②~~

Electromotive force	Potential difference
① It is the work done by a source in taking a unit charge once round the complete circuit.	① It is the amount of work done in taking a unit charge from one point of a circuit to another.
② It is equal to the maximum potential difference b/w the two terminals of a source when it is in an open circuit.	② Potential difference may exist between any two points of a closed circuit
③ It exists even when the circuit is not closed.	③ It exists only when the circuit is closed.
④ It has non-electrostatic origin.	④ It originates from the electrostatic field set up by the charges accumulated on the two terminals of the source.
⑤ It is a cause. When emf is applied in a circuit, potential difference is caused.	⑤ It is an effect.

6. It is equal to the sum of potential differences across all the components of a circuit including the P.d. required to send current through the cell itself.	5. Every circuit component has its own potential difference across its ends.
7. It is larger than the P.d. across any circuit element	7. It is always less than the emf.
8. It is independent of the external resistance in the circuit.	8. It is always less than the emf.