Q14. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.

Answer: Considering *l* = Original length, Changed length is *l'*=*l*+5% of *l* = 1.05*l*

Since volume remains same therefore initial volume = final volume

A*l* = A' *l'*

$\therefore \frac{A}{A'} = \frac{l'}{l} = 1.05$, Since $\because R = \rho \frac{l}{A}$

$\frac{R'}{R} = \frac{l'}{l} \times \frac{A}{A'} = \left(\frac{l'}{l}\right)^2 = (1.05)^2 = 1.1025$

Percentage increase in resistance is

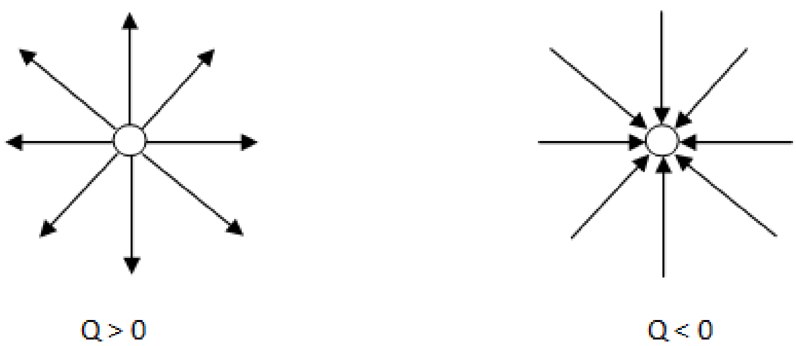
$\frac{R' - R}{R} \times 100 = \left(\frac{R'}{R} - 1\right) \times 100 = (1.1025 - 1) \times 100 = 10.25\%$

Q15. The electric field E due to a point charge at any point near it is defined as $E = \lim_{q \to 0} \frac{F}{q}$, where q is the test charge and F is the force acting on it. What is the physical significance of $\lim_{q \to 0}$ in this expression? Draw the electric field lines of a point charge Q when (I) Q > 0 and (II) Q < 0.

Answer: The $\lim_{q \to 0}$ indicates that the test charge(point charge) q is very small hence presence of this point charge does not disturb the distribution of source charge and its electric field.

The electric fields of the point charge Q are shown in the figure.

Positive Charge lines of force coming out **Negative Charge lines of force coming in**



Or,

Define electric flux. Write its S.I. units. A spherical rubber balloon carries a charge that is uniformly distributed over its surface. As the balloon is blown up and increases in size, how does the total electric flux coming out of the surface change? Give reason.

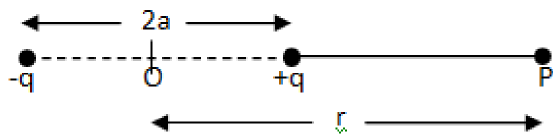
Answer: The electric flux through a given surface area is the total number of electric lines of force passing normally through that area. It is given by $\phi_E = \vec{E}.\overrightarrow{\Delta S}$

SI unit of electric flux is $Nm^2 C^{-1}$.

As the balloon is blown up, the total charge on the balloon surface remains unchanged, so the total electric flux coming out of its surface remains unchanged.

Q16. Deduce an expression for the electric potential due to an electric dipole at any point on its axis. Mention one contrasting feature of electric potential of a dipole at a point as compared to that due to a single charge.

Answer: Let P be an axial point at distance r from the center of the dipole.



Electric potential at point P will be , For +q charge potential is positive as work is done to bring unit positive charge is against the repulsive force also potential for –q charge is negative as work done in favour of attractive force.

$$V = V_1 + V_2 = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r+a} + \frac{1}{4\pi\varepsilon_0}\frac{q}{r-a}$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{1}{r-a} - \frac{1}{r+a}\right] = \frac{q}{4\pi\varepsilon_0}.\frac{2a}{r^2-a^2}$$

$$= \frac{1}{4\pi\varepsilon_0}.\frac{p}{r^2-a^2} \qquad [\because p = \text{dipole moment} = (q)\,2a\,]$$

For a far away point, r >> a

$$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$$

At large distances, dipole potential fall off as $1/r^2$, whereas the potential due to a single charge falls off as 1/r.

Q17. A parallel plate capacitor, each with plate area A and separation d, is charged to a potential difference V. the battery used to charge it is then disconnected. A dielectric slab of thickness d and dielectric constant K is now placed between the plates. What change, if any, will take place in

(I) charge on the plates
(II) electric field intensity between the plates
(III) capacitance of the capacitor
Justify your answer in each case.

Answer:

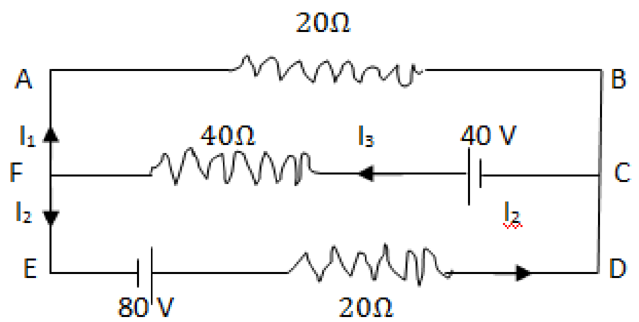
(I) Introduction of dielectric slab will have no effect on charge on plates of capacitor, hence the charge q on the capacitor plates remains same.
(II) Because of dielectric slab electric field intensity between the capacitor plates decreases as surface charges induced on the dielectric. Actual field and induced field directions are different hence net electric field decreases.

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

(III) Q=CV , since V i.e. potential difference decreases ,net charge remains constant hence Capacitance C will increase

$$C = K \, . \, C_0$$

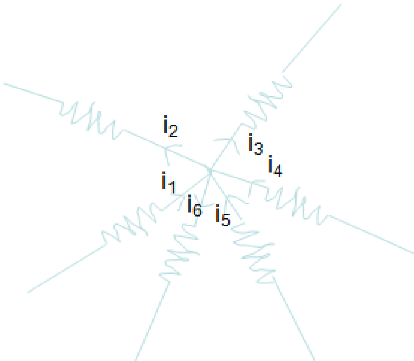
Q18. State Kirchhoff's rules of current distribution in an electrical network. Using these rules determine the value of the current I_1 in the electric circuit given as



Answer: **Kirchhoff's law** : In a complicated networks to find current flowing through different branches we apply Kirchhoff's law.

First law: The algebraic sum of currents meeting at a point is zero. i.e.Σi = 0

Explanation: Let us follow a convention current flowing towards the point is taken as positive and flowing away from the point is taken as negative.



$$\sum i = i_1 - i_2 - i_3 + i_4 + i_5 - i_6 = 0$$

Kirchhoff's first law is also known as point theorem or junction theorem.

Second law : "In a closed mesh of electrical conductors the algebraic sum of product of resistance and the respective current in the different branches is equal to the total e.m.f applied in the closed mesh"

Kirchhoff's second law is also known as loop theorem.

Solution of Numerical: By Kirchhoff's rule, $I_1 + I_2 = I_3$.

Applying loop rule to both the lower and upper loops, we get

$40\ I_3 + 20\ I_1 = 40$ (In loop ABCF)

$40\ I_3 + 20\ I_2 = 80 + 40$ (In loop CDEF)

Adding the two equations, we get

$80\ I_3 + 20\ (I_1 + I_2) = 160$

Or, $80\ I_3 + 20\ I_3 = 160$

or, $I_3 = \frac{160}{100} = 1.6\ A$

Again, $40 \times 1.6 + 20\ I_1 = 40$

or, $20\ I_1 = 40 - 64 = -24$

or, $I_1 = -\frac{24}{20} = -1.2\ A$

Q19. Write the mathematical relation for the resistivity of a material in terms of relaxation time, number density and mass and charge of charge carriers in it. Explain, using this relation, why the resistivity of a metal increases and that of a semi-conductor decreases with rise in temperature.

Answer: Resistivity, $\rho = \frac{m}{ne^2\ \tau}$

(I) **In Metallic conduction:** As the temperature increases, the thermal speed of electrons increases. Free electrons collide more frequently with the positive metal ions. The relaxation time τ decreases. Consequently, the resistivity ρ of the metal increases.

(II) **In Semiconductors:** The relaxation time τ does not change with temperature. But the number density (n) of free electrons increases exponentially with temperature. As a result, the resistivity of semiconductor decreases exponentially with the increase in temperature.

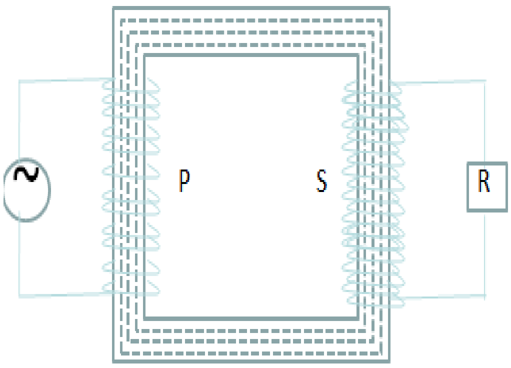
Q20. Explain with the help of a labeled diagram the underlying principle and working of a step up transformer. Why cannot such a device be used to step-up d.c. voltage?

Answer: Transformer is a device for converting high voltage at low current to high current at low voltage or vice versa. The A.C transformer is based on the principle of electromagnetic induction and are basically mutual inductance.

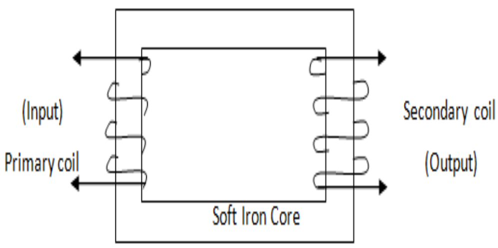
A transformer which increases the A.C. voltage is called a **step up transformer**. A transformer which decreases the a.c. voltage is called **step down transformer.**

Principle: A transformer is based on the principle of mutual induction. (i.e. whenever the amount of magnetic flux linked with a coil changes, an emf is induced in the neighboring coil).

Construction:



It consists of two coils known as Primary (P) and Secondary(S) having different no. of turns and are would on two opposite arms of a thick laminated iron core. The alternating emf to be transformed is connected across the primary coil. The varying current flowing through the primary coil produce varying magnetic lines of force. The magnetic ion core provides an easy path for the flow of lines of force hence the lines of force flowing through the core cuts the secondary coil and induces an emf across the secondary. An induced current flows through the secondary coil and thus a potential drop is obtained across the resistance which is known as output voltage.



Working: When an alternating voltage is applied to the primary coil, the resulting current produces an alternating magnetic flux which links the secondary coil and induces an emf in it. The value of emf depends on the number of turns in the secondary coil.

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We consider an ideal transformer. Let ϕ be the flux in each turn in the core at time t due to current in primary coil when voltage V_p is applied. Then induced emf E_s in the secondary coil is

$$E_s = -N_s \frac{d\phi}{dt}$$

The alternating flux ϕ also induced back emf in the primary coil.

$$\therefore\ E_p = -N_p \frac{d\phi}{dt}$$

But $E_p = V_p$, Since primary coil has zero resistance and $E_s = V_s$, if the current taken in secondary coil is small where V_s is the voltage across secondary coil.

$$\therefore\ V_s = -N_s \frac{d\phi}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{and}\ V_p = -N_p \frac{d\phi}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Dividing (1) by (2), we get

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

If the transformer is assumed to be 100% efficient, then power input is equal to power output.

$$\therefore\ I_pV_p = I_sV_s$$

$$\text{or,}\quad \frac{I_p}{I_s} = \frac{V_s}{V_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

From (3) and (4), we have

$$\frac{I_p}{I_s} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

(II) Why cannot such a device be used to step-up d.c. voltage?

For electromagnetic induction one of the primary condition is magnetic lines of force (flux) should change, if direct current passed then magnetic lines will not change hence mutual induction will not happen, transformer will not work. Thus, the transformer cannot be used to step-up D.C. voltage.