Q24. (a) Define self inductance. Write its SI units.
(b) Derive an expression for self inductance of a solenoid of length l cross sectional area A having n number of turns.
Answer
Self inductance (or coefficient of self induction) : Self inductance of a coil is numerically equal to the amount of magnetic flux linked with the coil when unit current flows through the coil. Its SI unit is henry (H).

Self inductance of a long solenoid: Considering a long solenoid.

l =length of solenoid,

N = number of turns

r= radius

I= current flowing through solenoid

B= Magnetic field set up in the coil is

$$\phi = \vec{B}\cdot\vec{A} = BA\cos 0 = BA$$

$$\phi = \mu_0 \frac{Ni}{l}\pi a^2 \rightarrow (1)$$

Since the flux is varying the induced emf across the coil at an instant t

$$e = -N\frac{d\phi}{dt} \text{ (from Faradays laws of electromagnetic induction)}$$

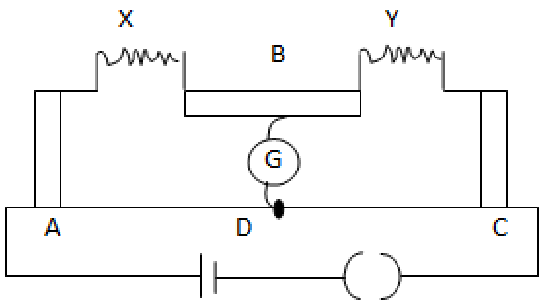
$$\text{Using equation(1)}: \ e = -N\frac{\mu_0 N\pi a^2}{l}\frac{di}{dt}$$

$$\text{Putting } \frac{\mu_0 \pi N^2 a^2}{l} = L = \text{Constant of the coil} = \text{Coefficient of self induction}$$

$$e = -L\frac{di}{dt} \quad \left\{ L = \frac{Henry}{m}\frac{m^2}{m} = Henry \right.$$

$$\therefore \text{Self inductance}, L = \frac{\Phi}{l} = \frac{\mu_0 N^2 A}{l}$$

Q25.



The figure shows experimental set up of a meter bridge. When the two unknown resistances X and Y are inserted, the null point D is obtained 40 cm from the end A. when the resistance of 10 Ω is connected in series with X, the null points shifts by 10 cm. Find the position of the null point when the 10 Ω resistance is instead connected in series with resistance 'Y'. Determine the values of the resistances X and Y.

Answer: In Meter bridge ABCD forms Wheatstone bridge, so the resistance in first(X) and 2nd (Y) arm should be equal to the ratio of 3rd (AD) and 4th Arm(DC).

At the null point at D

$\frac{X}{Y} = \frac{AD}{DC}$

$\frac{X}{Y} = \frac{40}{100-40} \Rightarrow \frac{X}{Y} = \frac{40}{60}$

$\frac{X}{Y} = \frac{2}{3} \Rightarrow X = \frac{2}{3}Y \ \ldots\ldots\ldots\ldots (1)$

When a resistance of 10 Ω is connected in series with X.

$\therefore$ At the new null point

$\frac{X+30}{Y} = \frac{50}{100-50} \Rightarrow \frac{X+30}{Y} = \frac{50}{50} = 1 \ \therefore X + 30 = Y \ldots\ldots\ldots\ldots. (2)$

Putting the value of X, we get

$\frac{2}{3}Y + 30 = Y$

$30 = Y - \frac{2}{3}Y \Rightarrow 30 = \frac{1}{3}Y \Rightarrow Y = 90\ \Omega$

Putting the value of Y in (1), we get

$X = \frac{2}{3} \times 90 = 60\ \Omega$

When the 10 Ω resistance is connected in series with Y then

$\frac{X}{Y+30} = \frac{60}{90+30} = \frac{60}{120} = \frac{60}{100+20}$. Hence null point is shifted 20 cm towards right.

Q26. Derive the expression for force per unit length between two long straight parallel current carrying conductors. Hence define one ampere.

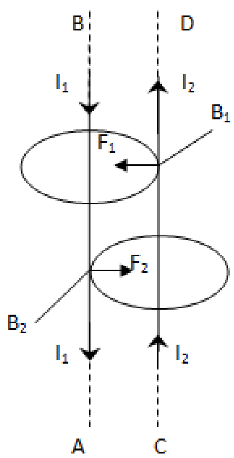
Answer:

Force between two parallel current carrying wires

Given: AB and CD are two infinitely long conductors, placed parallel to each other

r= distance of separation between two wires.

I_1 and I_2 = current flowing through AB and CD respectively (direction of current taken same).



Magnetic field produced by current I_1 at any point on CD is

$B_1 = \frac{\mu_0 I_1}{2\pi r}$

This field acts perpendicular to CD and into the plane of paper. It exerts a force on wire CD carrying current I_2 is

$F = B_1\, I_2\, l$

$F = \frac{\mu_0}{2\pi r} \times I_1 \,.\, I_2\, l$

$F = \frac{\mu_0}{2\pi} \,.\, \frac{I_1 I_2}{r} \,.\, l$

$\therefore$ Force per unit length is

$F = \frac{\mu_0}{2\pi} \,.\, \frac{I_1 I_2}{r}$

$\therefore F = \frac{\mu_0}{4\pi} \,.\, \frac{2 I_1 I_2}{r}$

By Fleming's left hand rule, this force will be attractive.

Definition of ampere :

Let I1 = I2 = 1 A, r = 1 m then

$F = \frac{4\pi \times 10^{-7} \times 2 \times 1 \times 1}{4\pi \times 1}$

$[\because \mu_0 = 4\pi \times 10^{-7}]$

$F = 2 \times 10^{-7}\ Nm^{-1}$

Thus, one ampere can be defined as the amount of current which when flows through each of the two parallel uniform long linear conductors placed in free space at a distance of one metre from each other will attract or repel each other with a force of 2×10^{-7} N per metre of their length.

Magnetic field Pattern: The pattern of the magnetic field indicates the force of attraction between two parallel conductors carrying current in the same direction (Fig. a) and force of repulsion between two parallel conductors carrying current in opposite direction (Fig. b).

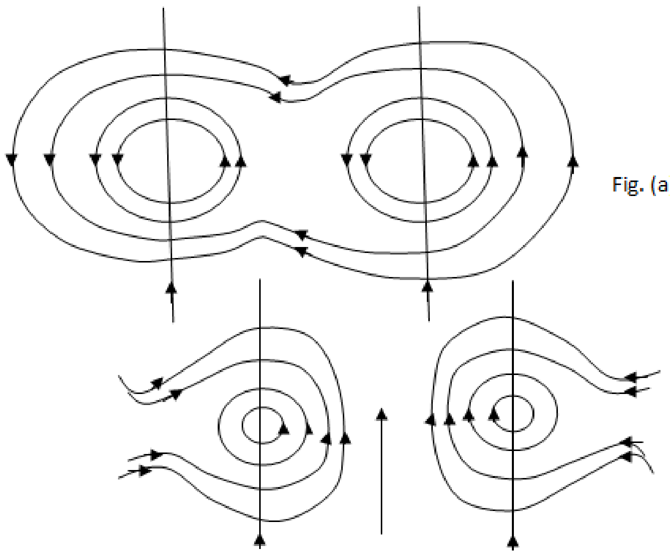


Fig. (a)

Fig. (b)