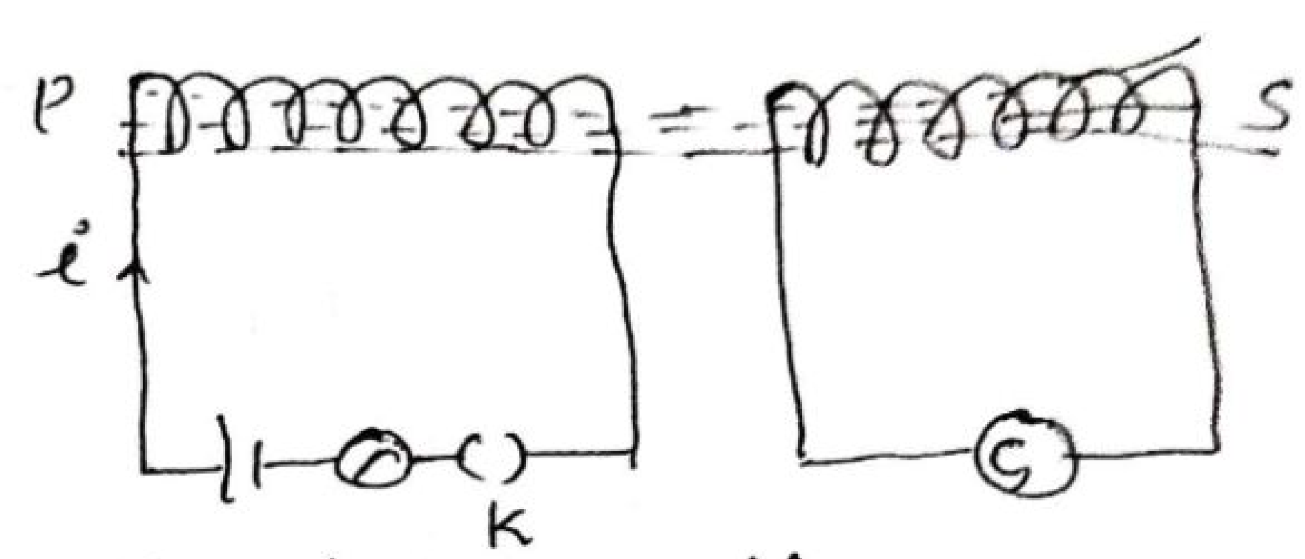
Q Define ~~mu~~ mutual inductance. Find an expression for mutual inductance between two solenoids wound over each other. Describe a method with theory for measuring mutual inductance.)

Ans **Mutual Inductance or Co-efficient of Mutual Induction :→**

Let two coils P (Primary) and S (Secondary) in which current i in P produces a magnetic flux ϕ_B in each turn of S. N_S be the total number of turns in S, then the number of flux linkages through S is $N_S \phi_B$. For two given coils situated in fixed relative position, the flux linkage through the Secondary is proportional to current i in the primary, then



$$N_S \phi_B \propto i \quad \text{or,} \quad N_S \phi_B = Mi$$

Here M is a constant called mutual inductance of the coils.

$$\therefore M = \frac{N_S \phi_B}{i} \quad \text{--------- (I)}$$

The e.m.f induced in S is given by

$$E = -\frac{d(N_S \phi_B)}{dt}, \quad \text{But } N_S \phi_B = Mi$$

$$= \frac{-d}{dt}(Mi) = -M\frac{di}{dt}$$

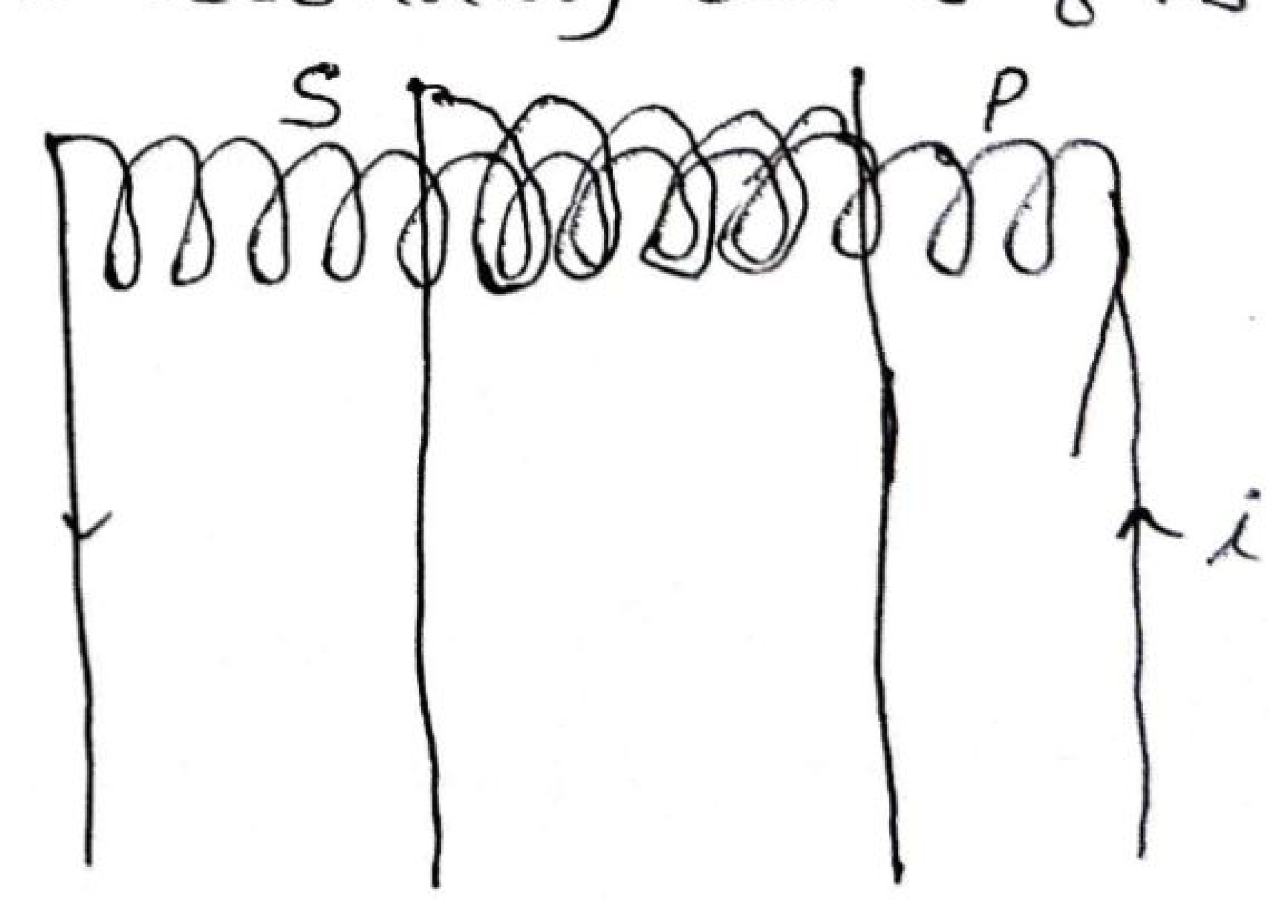
$$\therefore M = -E/di/dt \quad \text{--------- (II)}$$

The mutual inductance of two coils or circuits is numerically equal to the magnetic flux linkage through one coil or circuit when unit current flows through the other.

The mutual inductance of two coils or circuits is numerically equal to the e.m.f in one coil or circuit when the rate of change of current in the other is unity. Its unit is Henry (H).

Mutual Inductance between two Coaxial Solenoids :→

Let a long air cored solenoid as primary coil area of cross-section A and having n_1 turns per meter length of the Solenoid. A Short Second Solenoid as Secondary coil S of N_S turns wound closely over the central portion of the primary P. Let a current i ampere flowing in the primary, then the magnetic field inside the primary is



$$B = \cancel{\mu_0 n_p i} \; \mu_0 N_p i$$

Magnetic flux through each turn of the primary $\phi_B = BA = \cancel{\mu_0 n_p i A} \; \mu_0 N_p i A$

Since the Secondary is wound closely over central portion of primary, the same flux is also linked with turns of the Secondary.

∴ Total magnetic flux through the secondary

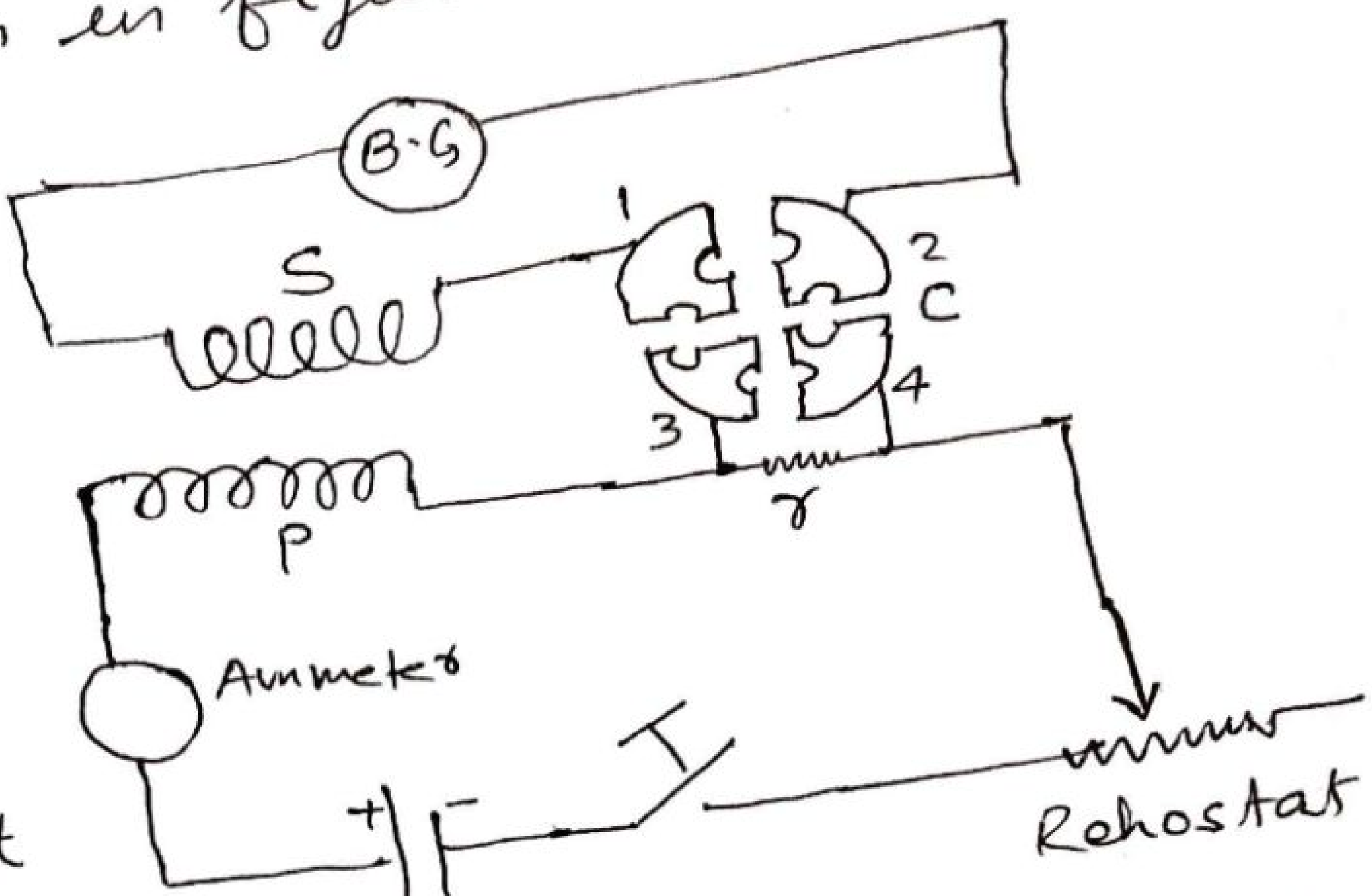
$N_S \phi_B = \mu_0 N_S i A$

By definition of the mutual inductance of the two coils is given by $M = \frac{N_S \phi_B}{i} = \mu_0 N_P N_S A$

Measurement of ~~the~~ Mutual Inductance :→

The circuit diagram for measurement of mutual-inductance is shown in figure.

Primary P and Secondary S are two coils whose mutual-inductance M is to be determined. Ballistic galvanometer (B·G) is C, is a four-segment commutator and 'r' is a very small resistance of the order of $1/100\ \Omega$



Workings:→ First of all, the Segment ① and ② are connected togather so that the Ballistic galvanometer and the secondary coil S from the closed circuit. The resistance r is kept short-circuited by connecting ③ and ④. The rehostat is adjusted so that a suitable current pass through the primary on depressing the Key K. As Key K is depressed the current in the primary P takes some time to grow and t flux through the Secondary S changes during this time.

Hence an induced e.m.f is set up in the Seco and a momentary current flow and the galvanometer gives a t

Let 'i' be the current at any instant in primary, the e.m.f induced in the Secondary is given by

$$E = -M\, di/dt$$

The instantaneous current 'i' in the Secondary is

$$i = \frac{E}{R} = \frac{-M}{R}\frac{dI}{dt} \qquad R = \text{Total resistance of Second circuit}$$

Therefore, the charge dq passing through the G meter in a short time interval dt is given by

$$q = \int_0^{i_0} \frac{M}{R}\, di = \frac{M}{R}\, i_0$$

Let 'A' be the first observed throw of the coil of t

$$q = \frac{T}{2\pi} \cdot \frac{c}{NBA} \theta_1 \left(1 + \frac{\lambda}{2}\right)$$

where the symbols have their usual meanings

Hence, $\frac{M}{R} i_0 = \frac{T}{2\pi} \frac{c}{NBA} \theta_1 \left(1 + \frac{\lambda}{2}\right)$ ...... (1)

To eliminate i_0 and $\frac{c}{NBA}$, the contac between 1 and 2 and that between 3 and 4 are broken. The contact between 1 and 3 and that between 2 and 4 are made. The resistance r is now included in the primary circuit. The same steady current i_c is now pass in the primary circuit. As the value of 'r' is very small the steady current i_0 in the primary circuit remain unch The potential difference across r is $i_0 r$ and it sends a steady current $\frac{i_0 r}{R}$ through the galvanometer.

Let ϕ be the steady deflection correspon to this current then. ...... (1

$$\frac{i_0 r}{R} = \frac{c}{NBA} \phi \quad ...$$

~~Divi~~ Dividing eqn (1) by eqn (2), we get

$$\therefore M = \frac{rT}{2\pi} \cdot \frac{\theta}{\phi} \left(1 + \frac{\lambda}{2}\right)$$