Experiment No. 15(A)

Object : *To determine the self-inductance of a given coil at different frequencies by Anderson's bridge.*

Apparatus Required : Post-office box, inductive coil, dial type decimal resistance box, condenser (capacity $\approx 0{\cdot}2\ \mu F$ to $0{\cdot}5\ \mu F$), a stretched resistance wire on a wooden strip with sliding contact, galvanometer, audio frequency oscillator, head phone, accumulator, two two-way keys, connection wires.

Description of Apparatus : Post-office box : Fig. 55 shows the post-office box. There are three terminals A, B and C in its upper part. Between the terminals A and B, there is a resistance P and between the terminals B and C, there is a resistance Q. In both of these arms, there are three standard resistances of 10 Ω, 100 Ω and 1000 Ω connected in series.

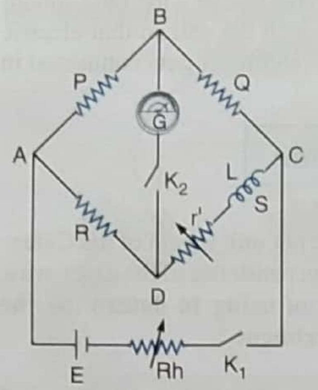

Fig. 53. Wheatstone bridge

There is an ordinary resistance box R between the terminals A and D. The unknown resistance S is connected between the terminals C and D.

Theory : Fig. 53 shows the electric circuit for the determination of ohmic resistance S of the coil with the help of post office box. The ratio arms AB and BC have resistances P and Q respectively and the known arm AD has the resistance R. In the balanced condition of bridge when there is no current in the galvanometer (*i.e.*, $V_B = V_D$),

$$\frac{P}{Q} = \frac{R}{S} \quad \text{or} \quad S = R\frac{Q}{P} \qquad \text{...(i)}$$

Fig. 54 shows the electric circuit of wheatstone's bridge with the a.c. source to determine the self inductance of the coil. In the ratio arm AB, a condenser C of known capacity and a low resistance *r* in series are joined across the resistance P in parallel. In the diagonal BD, a head phone is connected, instead of galvanometer, and in the diagonal AC, the audio frequency a.c. source (oscillator) is connected instead of d.c. source (cell). In the balanced condition of bridge when there is minimum sound in the head phone (or there is no current in the head phone), the distribution of current is shown in the circuit. According to Kirchhoff's laws,

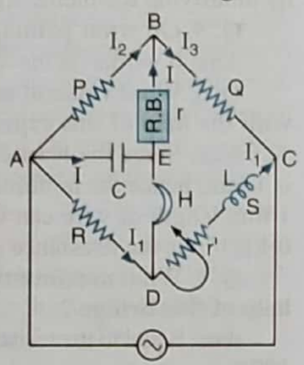

Fig. 54. Anderson's bridge

At the point B, $\qquad I + I_2 - I_3 = 0 \qquad$ ...(ii)

In the circuit AEBA, $\qquad \left(r + \frac{1}{j\omega C}\right) I = PI_2 \qquad$ ...(iii)

In the circuit ADEA, $\qquad I \times \frac{1}{j\omega C} = RI_1 \qquad$ ...(iv)

In the circuit BCDB, $\qquad (S + j\omega L)\, I_1 = rI + QI_3 \qquad$ ...(v)

Substituting $I_2 = I_3 - I$ in eqn. (iii),

$$\left(P + r + \frac{1}{j\omega C}\right) I = PI_3 \qquad \text{...(vi)}$$

Substituting the value of I_1 from eqn. (iv) in eqn. (v),

$$(S + j\omega L)\frac{I}{j\omega CR} = rI + QI_3$$

or

$$\left(\frac{S + j\omega L - j\omega CRr}{j\omega CR}\right) I = QI_3 \qquad \text{...(vii)}$$

Dividing eqn. (vi) by eqn. (vii),

$$\frac{j\omega CR\left(P + r + \frac{1}{j\omega C}\right)}{(S + j\omega L - j\omega CRr)} = \frac{P}{Q}$$

or $\quad PS + j\omega LP - j\omega CRrP = j\omega CRQ\,(P + r) + QR \quad$ ...(viii)

Equating the real and imaginary quantities on the two sides in the above eqn. (viii), we get

$$PS = QR \text{ or } P/Q = R/S$$

and $\quad \omega LP - \omega CRrP = \omega CRQ\,(P + r)$

or $\quad L = CRr + CRQ\left(1 + \frac{r}{P}\right)$

or $\quad L = C\left[Rr + RQ + \frac{RQr}{P}\right]$

$\quad = C\,[(R + S)\,r + RQ]$ (since $S = RQ/P$)

Thus the value of L can be calculated which is independent of frequency of a.c. source.

Formula Used : With the d.c. source, in the condition of balanced bridge

$$S = \frac{RQ}{P}$$

where S = ohmic resistance of inductive coil, P and Q = resistances in the ratio arms of post-office box, and R = resistance in the known arm.

With a.c. source, in the balanced condition of bridge

$$L = C\ [(R + S)\,r + RQ]$$

where L = self-inductance of coil, C = capacity of condenser, and *r* = low resistance connected with the condenser.

Procedure : The experiment is performed in the following two steps :

(1) For the balance with d. c. source : (i) First complete the electric circuit of Post-office box as shown in Fig. 55 and note the capacity of condenser.

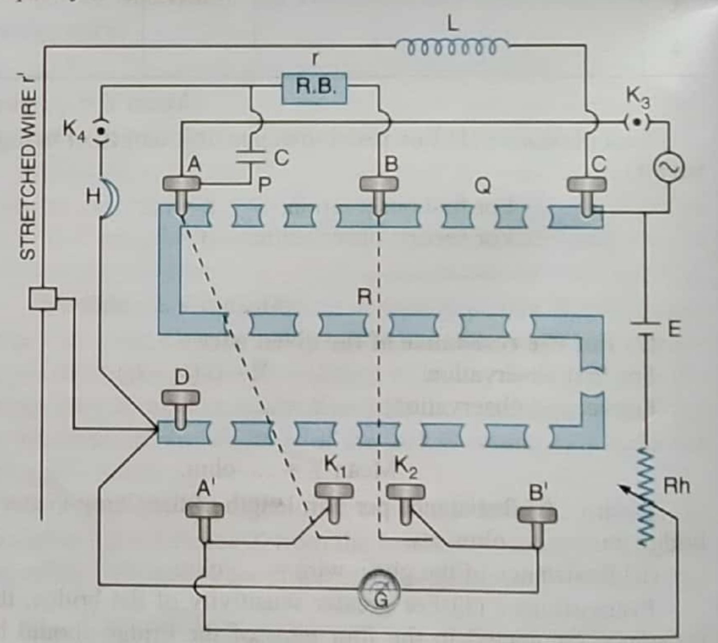

Fig. 55. Post-office box

(ii) Take out the plugs from the key K_3 and key K_4.

(iii) Keeping P = 10 ohm and Q = 10 ohm, the value of resistance R is so adjusted that there is no deflection in the galvanometer G on pressing first the cell key K_1 and then the galvanometer key K_2. If this adjustment is not possible with the resistance R, the position of sliding contact on the stretched wire is so adjusted to get no deflection in the galvanometer. Note the value of resistance R.

(iv) The experiment is repeated by keeping P = 100 ohm and Q = 10 ohm, and again with P = 1000 ohm and Q = 10 ohm.

(2) For the balance with a. c. source : (i) Insert the plugs in the keys K_3 and K_4. A hummering sound is heared in the head phone.

(ii) Without disturbing the balance obtained with the d.c. source, the resistance r connected with the condenser C is so adjusted that no sound is heared in the head phone. Note the value of r.

(iii) Repeat the experiment with P = 100 ohm and Q = 10 ohm, and again with P = 1000 ohm and Q = 10 ohm.

(iv) The experiment can then be repeated at different frequencies of a.c. source.

Observations :

Capacity of condenser C = ... μF = ... $\times 10^{-6}$ F

S. No.	P (in ohm)	Q (in ohm)	R (in ohm)	r (in ohm)
1.	10	10		
2.	100	10		
3.	1000	10		

Calculations : From the above observations, the value of S is calculated using the formula $S = \frac{RQ}{P}$ and than the value of L is calculated using the formula $L = C[(R + S)r + RQ]$ for each observation.

For first observation, S = ...ohm, L =.....henry
For second observation, S = ...ohm, L =.....henry
For third observation, S = ...ohm, L =.....henry
∴ Mean value of L = ...henry

Result : Self-inductance of the given coil L = ...henry.

Precautions : (1) The capacity of condenser should be low, otherwise it will be difficult to obtain balance with the a.c. source [because from $L = C[(R + S)r + RQ]$, it is clear that $L > CRQ$].

(2) The impedance in the four arms of the post-office box should be nearly equal.

(3) While obtaining the a.c. balance, the balance obtained with the d.c. source (*i.e.*, the value of R) should not be disturbed.