ACTIVITY

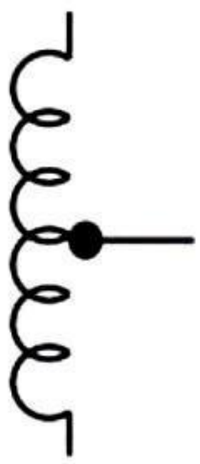
AIM

To measure the resistance and impedance of an inductor with or without an iron core.

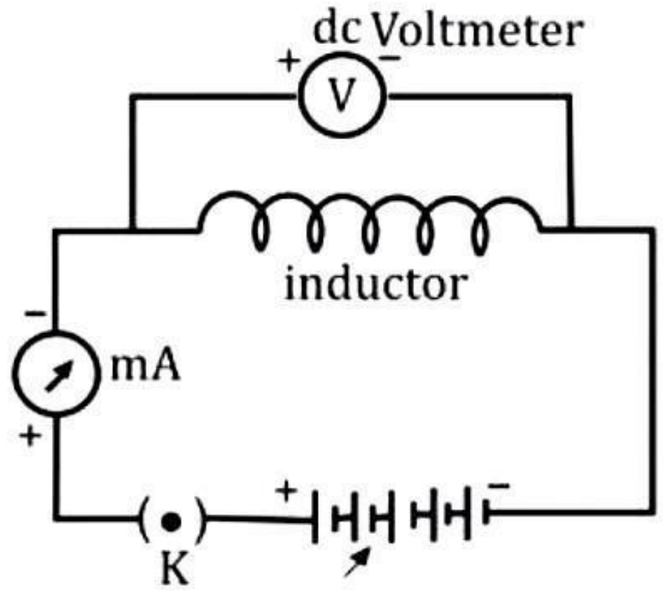
MATERIAL REQUIRED

A dc ammeter and voltmeter, ac ammeter and voltmeter, an ac source, a battery eliminator (0 – 15V), a resistance box, an induction coil or choke, a step-down transformer (≃ 12 V) with taping (0 – 6V, 50Hz), plug keys, connecting wires, an iron core and a multimeter.

DIAGRAM



Air cored inductor



Battery eliminator

Measurement of dc res is tance
an inductor without soft iron core

THEORY

Inductor: A hollow cylindrical coil of copper wire consisting of a large number of turns is known as an inductor or choke. The symbol of an air-cored inductor is shown in the figure.

The Resistance of an inductor or conductor in a *dc* circuit is defined as the ratio of the potential difference developed across its ends and the current flowing through it, mathematically,

$$\text{Resistance (R)} = \frac{V_{dc}}{I_{dc}}$$

where V_{dc} = dc voltage across inductor and I_{dc} = direct current through the inductor.

Reactance: Reactance of an inductor or inductive reactance is defined as the opposition to the flow of alternating current offered by it. It is denoted by X_L which is equal to ωL where L is the inductance of the coil and $\omega = 2\pi v$ where v is the frequency of ac.

Impedance: Impedance of an inductor is defined as the total effective opposition to the flowing current offered by a coil of resistance R and inductance L in ac circuit. Mathematically,

$$\text{Impedance (Z)} = \frac{V_{rms}}{I_{rms}} = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (\omega L)^2}$$

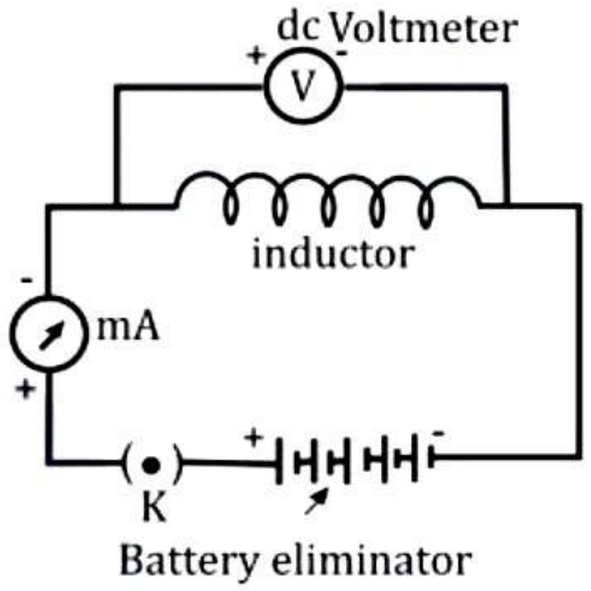
Where V_{rms} and I_{rms} are dc equivalents of ac voltage and current, respectively. What we measure by ac meters are rms values only.

NOTE: In practice, some ohmic resistance (R) is always associated with every coil of inductance (L). Therefore, the effective opposition to current (called impedance) in a coil, when it is put to an alternating current source, is given by $Z = \sqrt{R^2 + (\omega L)^2}$. But when a direct current (dc) is passed through the same induction coil then, the component ωL of impedance will be absent, and only ohmic resistance (R) will remain effective.

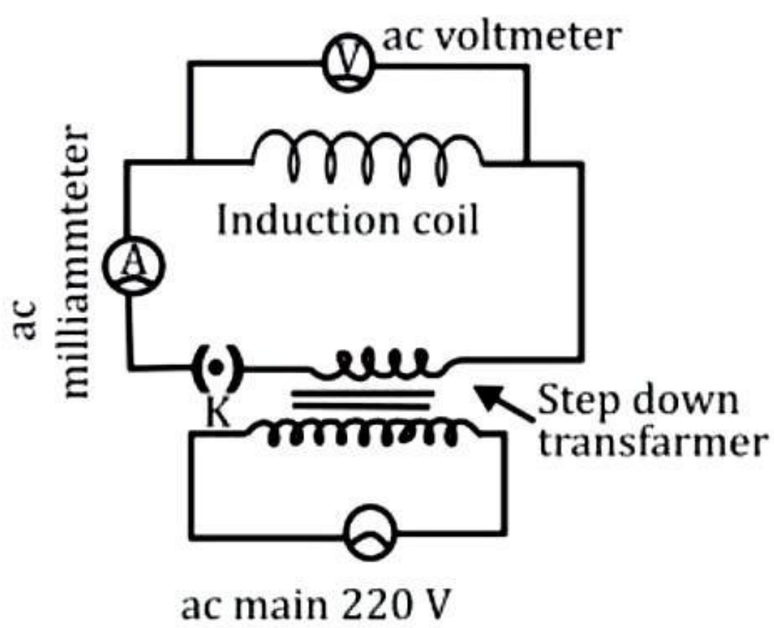
PROCEDURE

1. Measurement of resistance of an inductor without a soft iron core:
   - **(i)** Draw a circuit diagram as shown in Fig. and make electrical connections according to the circuit diagram. Find the least count of all electrical measuring instruments.
   - **(ii)** Connect the inductor in parallel to *dc* voltmeter.
   - **(iii)** The connections should be clean and tight.
   - **(iv)** Now adjust the value of the battery eliminator to 2V and put the plug-in key K.
   - **(v)** Observe and record the *dc* ammeter and *dc* voltmeter readings.
   - **(vi)** Repeat the experiment for at least two more settings of a battery eliminator.
2. Measurement of resistance of inductor with soft iron core:
   - **(i)** Now insert the soft iron core fully inside the induction coil. The circuit will look like Fig.
   - **(ii)** Repeat steps (iv) to (vi) of step 1.

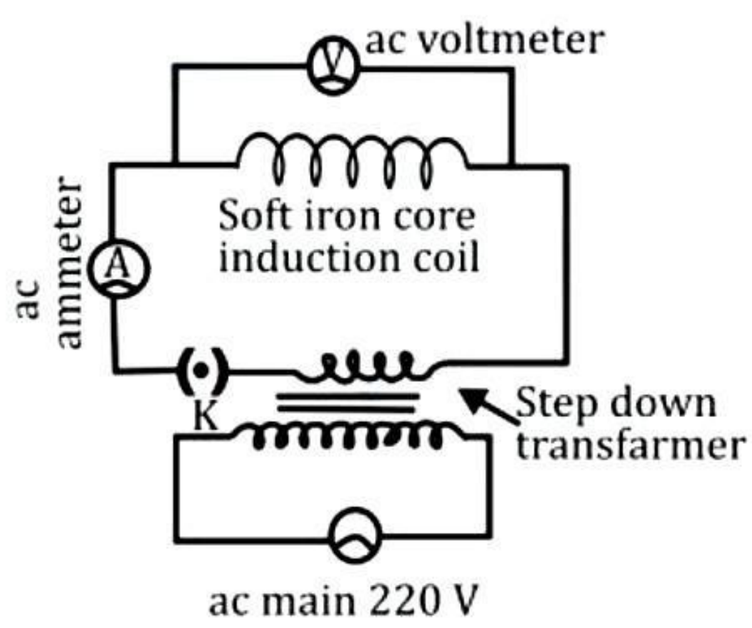
   NOTE. In particular, observe and record if there is any change in the current through the inductor when the soft iron core is introduced.
3. Measurement of the impedance of an induction coil without soft iron:
   - **(i)** Draw a circuit diagram as shown in Fig. and make electrical connections according to the circuit diagram.
   - **(ii)** Connect the induction coil, *ac* ammeter, a step-down transformer, and *ac* voltmeter as shown in Fig.
   - **(iii)** Repeat steps (iv) to (vi) of step 1.
4. Measurement of the impedance of an induction coil with a soft iron core:
   - **(i)** Now, introduce the soft iron core fully inside the induction coil so that the circuit diagram now becomes as shown in Fig.
   - **(ii)** Repeat steps (iv) to (vi) of 1.



Measurement of dc res is tance an inductor without soft iron core



Measurement of impedance of an induction coil without soft iron core



Measurement of impedance of an induction coil without soft iron core

OBSERVATION

Variation of resistance across a coil in a dc circuit without soft iron core and with soft iron core

Without soft iron Core				With Soft Iron Core		
No. of obser-vations	Voltage V (volt)	Current, I (ampere)	Resistance R (ohm)	Voltage, V (volt)	Current I (ampere)	Resistance R (ohm)
1.						
2.						
3.						

Variation of resistance across a coil in an ac circuit without soft iron core and with soft iron core

Without soft iron Core				With Soft Iron Core		
No. of obser-vations	Voltage V (volt)	Current, I (ampere)	Resistance R (ohm)	Voltage, V (volt)	Current I (ampere)	Resistance R (ohm)
1.						
2.						
3.						

CALCULATION

1. Resistance of given coil without soft iron core, $R = \_\_\_\_\ \Omega$

2. Resistance of given coil with a soft iron core, $R' = \_\_\_\_\ \Omega$

3. The impedance of the given coil without soft iron core, $Z = \_\_\_\_\ \Omega$

4. The impedance of the given coil with a soft iron core, $Z' = \_\_\_\_\ \Omega$

RESULTS

1. In dc circuit, an inductor has ohmic resistance only and the insertion of a soft iron core does not affect its ohmic resistance.

2. In an ac circuit, the impedance of a given coil increases on insertion of the soft iron core.

PRECAUTIONS

1. All the connections should be clean and tight enough.

2. The ends of connecting wires should be cleaned with sandpaper.

3. Close the key only when you are taking an observation.

4. A soft iron core must be inserted fully inside the induction coil.

5. The least count of all instruments should be determined before the start of the experiment.

SOURCES OF ERROR

The least count of ac voltmeter and ac ammeter (mA) may not be small enough to record the difference in impedance accurately on inserting the iron core.

VIVA- VOCE

Q 1. What do you mean by reactance?

Ans. The effective opposition to the flow of alternating current offered by a capacitor or inductor is known as reactance.

Q 2. Define inductive reactance.

Ans. The resistance offered by an inductor to the passage of alternating current is called inductive reactance.

Q 3. Do you know the expression for inductive reactance?

Ans. Inductive reactance $(X_L) = \omega L = 2\pi vL$, where L is the self-inductance of the coil and v is the frequency of the alternating current.

Q 4. Tell the expression for capacitive reactance.

Ans. Capacitive reactance $(X_C) = \frac{1}{\omega C} = \frac{1}{2\pi vC}$, where C is the capacitance of the capacitor.

Q 5. Define the term impedance.

Ans. The total effective resistance offered by resistance, capacitor, and inductor to the passage of alternating current is called impedance.

Q 6. What is the SI unit of impedance?

Ans. Ohm (Ω).

Q 7. Write an expression for impedance.

Ans. Impedance $(Z) = \sqrt{R^2 + (X_L - X_C)^2}$

or $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

where symbols have their usual meaning.

Q 8. What is the impedance of an LR circuit?

Ans. The impedance of an LR circuit $(Z) = \sqrt{R^2 + (\omega L)^2}$ or $Z = \sqrt{R^2 + (2\pi vL)^2}$, where L is the self-inductance of the coil and v is the frequency of ac and R is the resistance associated with the coil.

Q 9. Define the self-inductance (L) of a coil.

Ans. The coefficient of self-induction or inductance is defined as the emf induced in a coil due to the unit rate of change of current through it.

Q 10. Is there any inductance of a coil in a direct current?

Ans. No, as no change of magnetic flux is involved with direct current.

Q 11. What is the SI unit of inductance or self-inductance of a coil?

Ans. Henry (H).

Q 12. Write henry in terms of volt and ampere.

Ans. $1 \text{ henry} = \frac{1 \text{ volt}}{1 \text{ ampere/second}}$.

Q 13. Dc ammeters and voltmeters can't be used in ac. Why?

Ans. In alternating current, the direction of current changes 100 times per second due to which the needle of these devices cannot follow direction change. Hence, the pointer will not be deflected and will remain at rest.

Q 14. What is the frequency of domestic alternating current supply? How many times does it become zero in one second?

Ans. 50 Hz. It becomes zero twice in each cycle and so it becomes zero 100 times per second.

Q 15. Is there any device that may control the alternating current without dissipating energy?

Ans. Yes, pure inductor and pure capacitor.

Q 16. What will be the effect on inductive reactance X_L if the frequency of ac source is increased?

Ans. Since $X_L = 2\pi\nu L$, hence X_L will increase.

Q 17. What will be the effect on capacitive reactance X_C if the frequency of ac source is increased?

Ans. X_C decreases as $X_C = \frac{1}{2\pi\nu C}$; $X_C \propto \frac{1}{\nu}$.

Q 18. What is an ideal inductor?

Ans. An ideal inductor is an inductor that has only self-inductance. It does not have any ohmic resistance or any kind of capacitive reactance.

Q 19. Is it possible to have an ideal inductor in the laboratory?

Ans. No, it is not possible to have an ideal inductor without any ohmic resistance since the inductor is made up of some material.

Q 20. How can you have a resistor without inductance?

Ans. If a wire wound resistor has non-inductive winding, it has no inductance.

Q 21. Distinguish between resistor and resistance.

Ans. A resistor is a body that offers resistance, but resistance is the property of the body due to which it resists the passage of current.

Q 22. What is the reciprocal of resistance?

Ans. Conductance.

Q 23. What is the reciprocal of reactance?

Ans. Susceptance (of an AC circuit).

Q 24. What is the reciprocal of impedance?

Ans. Admittance