EXPERIMENT NO.

Aim: To verify the Kirchhoff's law for the given network

Apparatus:	Range/Rating	Make
1. DC. Voltage source	0-32V, 5A	
2. Rheostat (3No.)	23Ω, 2.8A	
3. Three Ammeters (DC)	0-5A	
4. One voltmeter (DC)	0-30V	

Theory: Kirchhoff's laws

Kirchhoff's laws are particularly useful (a) in determining the equivalent resistance of a complicated network and (b) for calculating the currents flowing in the various conductors.

KIRCHHOFF'S VOLTAGE LAW

It states that "the algebraic sum of products of currents and resistances in each of the conductors in any closed path in a network plus the algebraic sum of the e.m.fs in that path is zero".

In other words, $\sum IR + \sum e.m.f. = 0$

It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

Following sign convention is suggested:

Sign Conventions

a) Battery e.m.f.:

A rise in voltage should be given a + ve sign and a fall in voltage a –ve sign. Keeping this in mind, it is clear that as we move from negative terminal of source to positive terminal, there is a rise in potential, hence this voltage should be given a +ve sign. If, on the other hand, we move from +ve terminal to –ve terminal of voltage source, then there is a fall in potential, hence it is to be considered as –ve.

Sign of IR Drop: -

Whenever we move in the direction of current there is a drop in voltage. Since the current always flows from point at higher potential to the point at lower potential. Hence Voltage drop in the current direction is taken as –ve. However, if we go in a direction opposite to that of the current, then there is a rise in voltage.

B) KIRCHHOFF'S CURRENT LAW (KCL)

It states that "in any electrical network, algebraic sum of the currents meeting a point is zero".

In another way, it simply means that the total current leaving a junction is equal to the total current entering that junction. It is obviously true because there is no accumulation or depletion of current at any junction of the network.
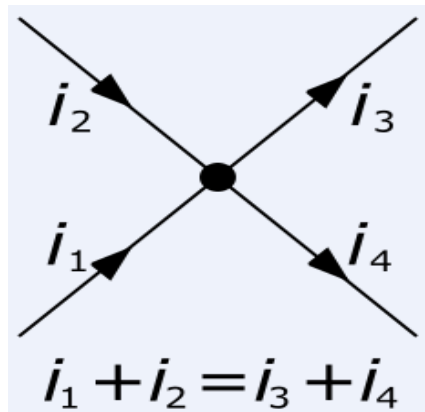
Consider the case of a few conductors meeting at a node as in fig.

$$i_1 + i_2 = i_3 + i_4$$

Some conductors have currents leading to node whereas some have currents leading away from node.

Assuming the incoming currents to be positive and the outgoing currents negative, applying KCL at node we have,

$$I_1 + I_2 - I_3 - I_4 = 0$$
Or
$$I_1 + I_2 = I_3 + I_4$$

Procedure:
1. Connect the circuit as per circuit diagram
2. Keep all the rheostats at maximum position.
3. Switch on the DC voltage supply, adjust the voltage to any suitable value.
4. Change the position of rheostats check that none of the ammeter reads excessive current.
5. Take the reading of all the ammeters.
6. Measure the voltages across all the rheostats.
7. Change the voltage of power supply and repeat step (5) and (6).
8. Verify Kirchhoff's laws.

Result & Conclusion:

Discussion Questions:
1. What are the sources of errors?
2. Can you apply Kirchhoff's laws to A.C circuit? If yes how the law will differ for A.C circuits?
3. What do you mean by a node and mesh?
4. The circuit consists of an A.C voltage source & the R-L-C combination in series with it. Draw the circuit and apply KVL to the loop formed?
5. While performing the experiment how will you note the direction of the circuit?
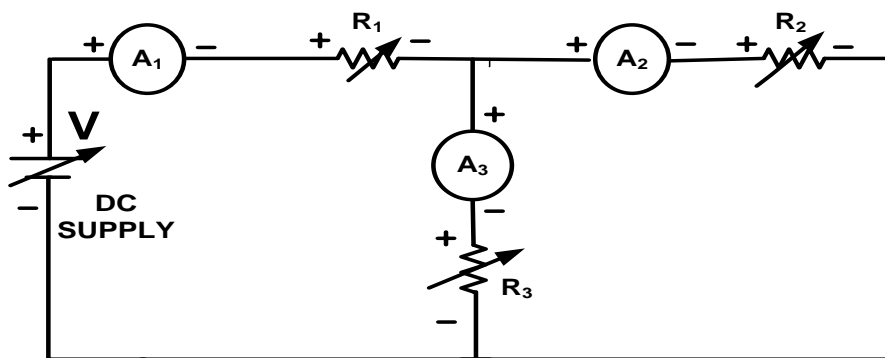
On LHS by Hand with Pencil

EXPERIMENT NO.

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Apparatus:	**Range/Rating**	**Make**
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3. Three Ammeters (DC)	0-5A	
4. One voltmeter (DC)	0-30V	

Circuit diagram:

Observation table:

Sr. No.	Source Voltage V	Voltage Across R_1 V_{R1}	Voltage Across R_2 V_{R2}	Voltage Across R_1 V_{R3}	I_1	I_2	I_3
1							
2							
3							
4							

Calculations:

EXPERIMENT NO

Aim: To study RLC series circuit.

Apparatus	**Range/Rating**	**Make**

1. Single phase dimmerstat
2. Ammeter (AC)   0-5A
3. Voltmeter (AC)   0-300V
4. Rheostat   360Ω, 1.2A
5. Inductor   r= 67Ω, L= 1.88H
6. Capacitor (6 No. in Series)   100µF - 120µF
7. Multi Function Meter

Theory:

In this experiment, we are mainly interested in verification of Kirchhoff's voltage law for AC circuit.

When an A.C. voltage (Rms) is applied to RLC series circuit as shown in circuit diagram of series circuit, it establishes RMS current I given by equation

$$I = \frac{V}{Z}$$

$$Z = \sqrt{R^2 + (X_L + X_c)^2}$$

Where: Z-is the overall impedance of series combination.

In the circuit diagram the RMS value of supply voltage is equal to the vector addition of the voltage across inductor (V_L), voltage across resistance (V_R) & voltage across capacitor (V_c). The phasor diagram for the circuit can be drawn which shows the magnitude as well as the phase relationship between the various voltages (V_R, V_L, V_c & V_s) & the total current I. The phasor diagrams will be of different nature for the cases

XL > Xc (inductive circuit) &

Xc > X_L(Capacitive circuit)

X_L = Xc is said to be condition of resonance & the circuit will be resistive only. For the case when $X_L > X_c$, power factor of the circuit is lagging in nature, since the current I lags behind V by an angle ϕ.

Where

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{Z}\right)$$

In an inductor, the copper losses take place due to the internal resistance of its coil. In capacitor, the losses take place in the dielectric medium used for making it but usually it is ignored.

Procedure:

1. Make the connections as per circuit diagram
2. Set the rheostat for maximum resistance.
3. Set the dimmerstat to zero output & switch on the mains.
4. Adjust the variac so as to apply a suitable voltage to the circuit, measure the current I & voltages V_R, V_L, V_c, V_{RL} and supply voltage Vs at the output of variac.
5. Take different sets of reading by applying different voltage.
6. Make the calculations as shown in table.
7. Observe the waveform on CRO.

Note: Draw phasor diagram taking I (current) as reference vector.

Result & conclusion:

Discussion Questions:

1. What is RMS value, Average value?
2. Is KVL & KCL applicable to A.C circuit?
3. What do you understand by the term power factor?
4. What do you understand by impedance of series AC circuit? What is it unit?
5. Draw the phasor diagram for R-L-C circuit if $X_L = Xc$, $X_L > Xc$ & $Xc > X_L$?
6. What do you understand by series resonance? What is the condition?
7. If a sinusoidal voltage is applied to a resistor (R), inductor (L) & capacitor (C) separately, draw the wave form of currents (I_R, I_L, & Ic) each w.r.t. voltage reference?
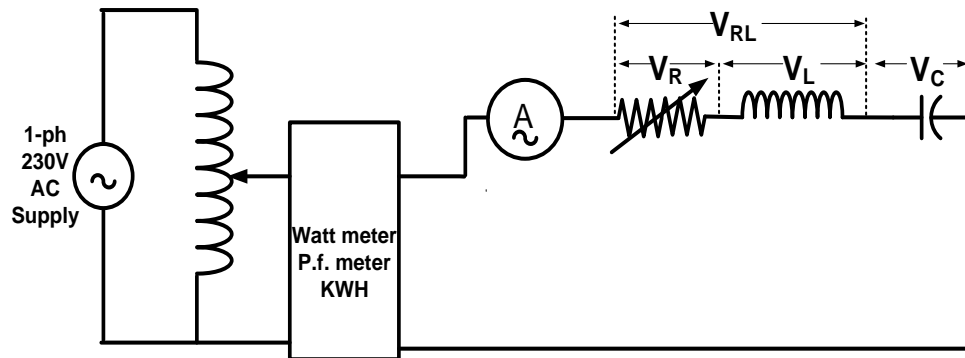8. What will be the power factor for a purely resistive load?

On LHS by Hand with Pencil

EXPERIMENT NO.

Aim: To study R-L-C series circuits (AC)

Apparatus   **Range/Rating**   **Make**

1. Single phase dimmerstat
2. Ammeter (AC)   0-5A
3. Voltmeter (AC)   0-300V
4. Rheostat   360Ω, 1.2A
5. Inductor   r= 67Ω, L= 1.88H
6. Capacitor (6 No. in Series) 120μF
7. Multi Function Meter

Circuit diagram:

Observation table: RLC Series circuit:

r- internal resistance of coil =--------

| Sr. No.	Position of rheostat	Vs Volt	I Amp	V_R Volt	V_L Volt	Vc Volt	V_{RL} Volt	P.f. of circuit
1	Middle position	100V						
2.	Maximum position	100V						

On LHS by Hand with Pencil

Calculations -RLC Series circuit:

Sr No.	$R = \dfrac{V_R}{I}$	$Z_L = \dfrac{V_L}{I}$	$X_L = \sqrt{Z_L^2 - r^2}$	$\left\| Z = \dfrac{V_S}{I} \right\|$	ϕ from calculations $\phi = \cos{-1}$ $(\dfrac{R+r}{Z})$	ϕ from phasor dig	ϕ from p.f. meter

Procedure for Drawing Series circuit **phasor diagram:**

1. Choose suitable scale for voltages & voltage drops.
2. Take current I as reference & draw V_R in phase with I (V_R= OA)
3. Draw the arcs AB=V_L & OB =V_{RL} intersecting each other at point B
4. Join A with B & O with B.
5. Draw OD=V_C at an angle 90 lagging to I.
6. Draw a vertically downwards line from B i.e. BC = V_C= OD. Join OC=V_S
7. Find the p.f. angle ϕ between V_S & I.
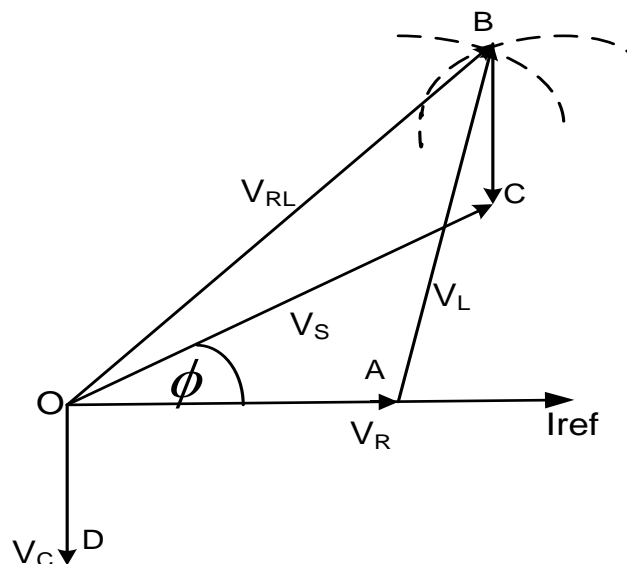
EXPERIMENT NO.

Aim: To study RLC parallel circuit.

Apparatus:	Range/Rating	Make

1. Single phase dimmerstat
2. Ammeter (AC)   0-5A
3. Voltmeter (AC)   0-300V
4. Rheostat 360Ω, 1.2A
5. Inductor   r= 31Ω, L= 0.79H
6. Capacitor (6 No. in Series) $120\mu F$
7. Multi Function Meter

Theory:

In this experiment, we are mainly interested in verification of Kirchhoff's voltage law for AC circuit.

The series combination of resistor & inductor is connected in parallel with capacitor as shown in the circuit diagram. The a.c. voltage of r.m.s. value v is applied to this parallel circuit. This applied voltage can be varied by the single phase dimmerstat.

The source current I will get divided into two branched as I_{RL} & I_C. But voltage across the two branches will be same.

Let I_1 be current passing through branches consisting of R&L in series while I_2 be current passing through the capacitance branch.

$I = I_1 + I_2$ (phasor sum)

Also $V_R + V_L = Vc = V$ (applied voltage)

Here we assume that our capacitance is pure, hence I_2 passing through C will lead V by 90, while the inductance is impure, therefore I_1 passing through L will lag V by an angle less than 90

Note that-

$V_R = I_1R$ (drop across resistance)

$V_L = I_1X_L$ (drop across inductance)

$Vc = I_2Xc$ (drop across capacitance)

Depending upon the impedance of the two branches the source current I will lag or lead the supply voltage by some angle which is called as the phase angle.

Procedure:

1. Make the connections as shown in the circuit diagram.
2. Set the Dimmerstat (variac) to zero output.
3. Set the rheostat to maximum.
4. Switch on the supply.
5. Adjust the variac to give a suitable voltage to the circuit.
6. Note down the voltage across R, L, C, & R-L with a.c. voltmeter.
   Note down the reading of all the meters.
7. Take different readings for different another position of rheostat.

Note: Draw phasor diagram for each reading.

Result & conclusion:

Discussion Questions:
1. Define following terms with their units-
   i. Admittance ii. Conductance iii. Susceptance
2. What is meant by lagging and leading current in AC circuit? Show it by phasor diagram and waveform diagram.
3. Define following powers- i. Active power ii. Re-active power
   iii. Apparent power
4. Draw the power triangle for inductive load and capacitive load.
5. What is phasor diagram? What is difference between vector diagram and phasor diagram?
6. Two branches are connected in parallel. One branch consists of R-L series combination while other branch consists of R-C series combination. Draw the phasor diagram showing all the voltages & all the currents.
7. What do you mean by parallel resonance? What is the condition?

On LHS by Hand with Pencil

EXPERIMENT NO.

Aim: To study R-L-C parallel circuits (AC).

Apparatus: Range/Rating   Make
1. Single phase dimmerstat
2. Ammeter (AC)   0-5A
3. Voltmeter (AC)   0-300V
4. Rheostat   360Ω, 1.2A
5. Inductor   r= 31Ω, L= 0.79H
6. Capacitor (6 No. in Series)   120μF
7. Multi Function Meter

Circuit Diagram :
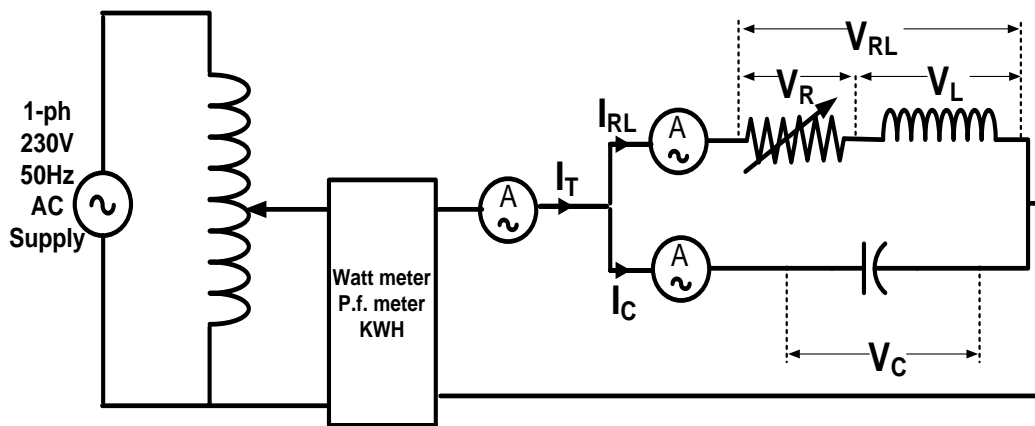
Observation table:-RLC parallel circuit:

Sr. No	P.f. of ckt	Vs volt	I Amp	I_{RL} Amp	I_C Amp	V_R Volt	V_L Volt	Vc Volt	V_{RL} Volt
1									
2									

On LHS by Hand with Pencil

Calculations -RLC parallel circuit:

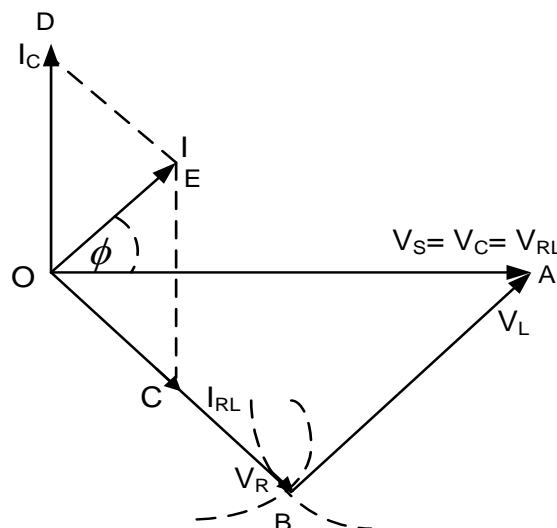| Sr. No.	$R = \dfrac{V_R}{I_{RL}}$	$X_L = \dfrac{V_L}{I_{RL}}$	$X_c = \dfrac{V_c}{I_C}$	$Z_{eq} = Z_1 \mid\mid Z_2$ $Z_1 = R + jX_L$ $Z_2 = -jXc$ $Z_{eq} = R_{eq} + jX_{eq}$	ϕ from calculations $\phi = \cos{-1}\left(\dfrac{R_{eq}}{Z_{eq}}\right)$	ϕ from phasor diagram	ϕ from p.f. meter

Procedure for drawing <u>Parallel circuit</u> phasor diagram:

1. Choose suitable scale for voltages & suitable scale for currents.
2. Take OA =V_S = V_C = V_{RL} as reference.
3. Since V_S = V_C = V_{RL} =V_R + V_L, draw the arcs OB= V_R from O & AB= V_L from A intersecting each other at point B. Jion OB = V_R & AB = V_L.
4. Draw OC= I_{RL} in phase with V_R & OD = I_C at an angle 90 leading to V_S.
5. Draw OE= I = I_C + I_{RL} by vector addition (completing the parallelogram).
6. Find the p.f. angle ϕ between V_S & I.

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Shri Ramdeobaba College of Engineering and Management, Nagpur 440013
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Sample Calculations-

If $R = \dfrac{V_R}{I_{RL}}$, $X_L = \dfrac{V_L}{I_{RL}}$, $X_c = \dfrac{V_c}{I_C}$

Then $Z_1 = R + jX_L$,   and $Z_2 = -jXc$

Then $Z_{eq} = Z_1 || Z_2 = = \dfrac{Z_1 Z_2}{Z_1 + Z_2} = \dfrac{(R + jX_L)(-jXc)}{R + j(X_L - Xc)} = Z_{eq} \angle \phi$

$Z_{eq} = R_{eq} + jX_{eq}$

EXPERIMENT NO

Aim-To trace hysteresis loop for different magnetic materials.

Apparatus:
    B-H curve tracer kit, CRO, Patch Cords, Trace paper
    Magnetic Materials: Nail, Hack Saw Blade, Ferrite Rod, Steel rod

Theory:
Magnetic hysteresis may be defined as the lagging of magnetization (or flux density B) behind magnetizing force H. It is that property of material due to which energy is dissipated in it on the reversal of its magnetism.

The magnetizing force H can be produced by passing current through the coil wound on iron core. It can be increased or decreased by increasing or decreasing the current through the coil.

Consider a circuit consisting of a battery "E" an ammeter, variable resistance R and reversible switch shown in the **fig.1.**

i)   Initially variable resistance is kept at maximum position so current through the circuit is very low. The field strength H=NI /l is also very low .So as current increased, for low values of field strength, flux density do not increase rapidly. But after the knee point flux density increases rapidly up to certain point .This point is called **point of saturation** .There after any change in current do not have an effect on the flux density .This curve is nothing but the magnetization curve (B-H curve). This is the initial part of hysteresis loop.

ii)   After the saturation point, now current is again reduced to zero. Due to this field strength also reduces to zero. But it is observed that flux density do not trace the same curve back but falls back as compared to previous magnetization curve .This phenomenon of falling back of flux density while demagnetization cycle is called hysteresis. Hence due to this effect, when current becomes exactly zero, there remains some magnetism associated with a coil and hence the flux density .The core does not get completely demagnetized though current through coil becomes zero. This value of flux density when exciting current through the coil and magnetic field strength is reduced to zero is called **residual flux density**/ *residual magnetism* of the core. The magnitude of this residual flux or magnetism depends on the nature of the material of the core. And this property of the material is called *retentivity.*

iii)   But now if it is required to demagnetize the core entirely then it is
    necessary to reverse the direction of the current through the coil.   This is possible with the help of the intermediate switch.The value of magnetic field strength required to wipe out the residual flux density is   called the coercive force .It is measured in terms of **coercivity.**

iv)   If now this reversed current is increased, core will get saturated but in opposite direction. At this point flux density is maximum but with opposite direction.

v)   If this current is reduced to zero, again core shows a hysteresis property and does not get fully demagnetized. It shows same value of residual magnetism but with opposite direction.

vi)   If current is reversed again, then for a certain magnitude of field strength, complete demagnetization of the core is possible.

vii)   And if it is increased further, then saturation in the original direction is achieved completing one cycle of magnetization and demagnetization.

The curve plotted for such one cycle turns out to be closed loop which is called **hysteresis loop**. Its nature is shown in the **Fig.2.**

In the conventional techniques of tracing the B-H loop, one has to wind a primary and a secondary coil on the specimen and experiment with it. This method is not convenient for quick study of the shapes of B-H loop of different materials.

The present technique can be used to study B-H loop by simply inserting the specimen in a magnetizing coil .It makes use of a specially designed integrated circuit probe to measure the flux density B. The current flow through the magnetizing coil develops a potential difference across the resistance R, which deflects the beam in the X –direction. The deflection is proportional to the magnetic field H which is given by;

$$H = \frac{N * V_X}{R * L} \text{ ampere turns/meter}$$

where N is the no. of turns of the coil (300),R the resistance in series with the coil, and L is the coil length in meters(0.033m). Vx is the voltage applied to the X-input of the CRO. The probe has a sensitivity of 5mV per Gauss. Hence B=0.5VyWeber/sq m, Where V_y is the voltage applied to the Y input of the CRO.

Procedure:

a) Connect one terminal of the magnetizing coil to point C of main unit and the other terminal marked V_I (6Volts ac).connect H to the horizontal input of the CRO and V to vertical input of the CRO. Operate the CRO in X-Y mode.

b) Connect the IC probe to the "IC" marked on main unit.

c) Switch ON the kit. To get proper loop vary the resistance to the maximum value with the help of knob P on the panel.

d) With no specimen through the coil, adjust the horizontal gain of the CRO until a convenient X deflection is obtained. Note down this reading as S_H.

e) Insert the magnetic specimen(a 5' nail), through the magnetizing coil such that it touches the probe at the centre .**Make sure that sample is touching I C only and conducting tracks should not be shorted in any case**. Adjust the oscilloscope vertical gain (Y gain) until a trace showing the B-H loop conveniently fills the screen. Note down this reading as Sv. If the curve is back to front, reverse the connection of the magnetizing coil.

f) Trace the area of the loop on butter paper from the screen of CRO and retrace it on graph paper.

g) Note down the X intercept V_x and Y intercept V_y from the graph paper. Calculate the coercivity H using relation 1and retentivity B using relation 2.

h) Measure the area of the loop with the help of graph paper .

The energy loss = $\dfrac{(0.5 \text{ x N x } S_v \text{ x } S_H \text{ x area of the loop})}{(R \text{ x L})}$

Joules/second/unit volume

Where S_v and S_H are vertical and horizontal sensitivities of the CRO for that particular setting of the gains.

(i) Repeat the experiment by varying the a.c. voltage by connecting coil between points C& V_2(9Volts)andV_3(12V).The part of the curve showing saturation changes in length.

j) Repeat the experiment with different specimen and note your comments on the properties of different materials.

Precautions:

(a) The specimen should touch the probe.

(b) If the area of the loop is expressed in cm^2, the sensitivities should be expressed in volts/cm. If the area of the loop is expressed in sq.meter the sensitivities should be expressed in volts/meter. The length of the coil should be in meter.

Conclusion:-

Discussion Questions:-

1) Draw and briefly explain the hysteresis loop.
2) What is saturation in magnetic material?
3) What is residual magnetism?
4) What is relative permeability and absolute permeability?
5) Why B-H curve is different for different material?
6) Plot B-H curve for non magnetic material?

7) Draw hysteresis loop for hard steel, cast and alloyed sheet, laminated sheet on the same graph paper and compare.
8) Why hysteresis loop is thin /small for transformer stamping.

On LHS by Hand with Pencil

EXPERIMENT NO

Aim-To trace hysteresis loop for different magnetic materials.
Apparatus:
    B-H curve tracer kit, CRO, Patch Cords, Trace paper
    Magnetic Materials: Nail, Hack Saw Blade, Ferrite Rod, Steel rod
Circuit Diagram:
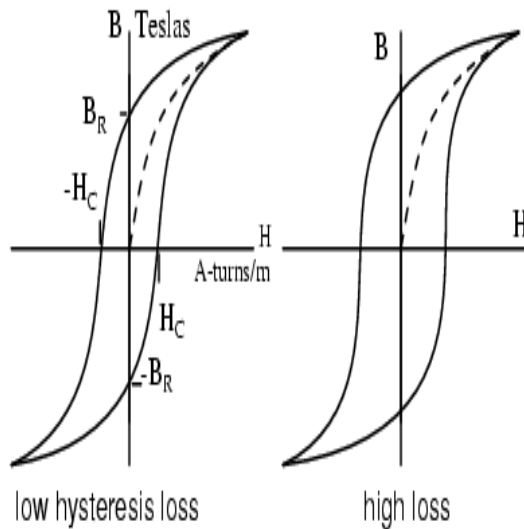
Figure 1 Hysteresis Loop
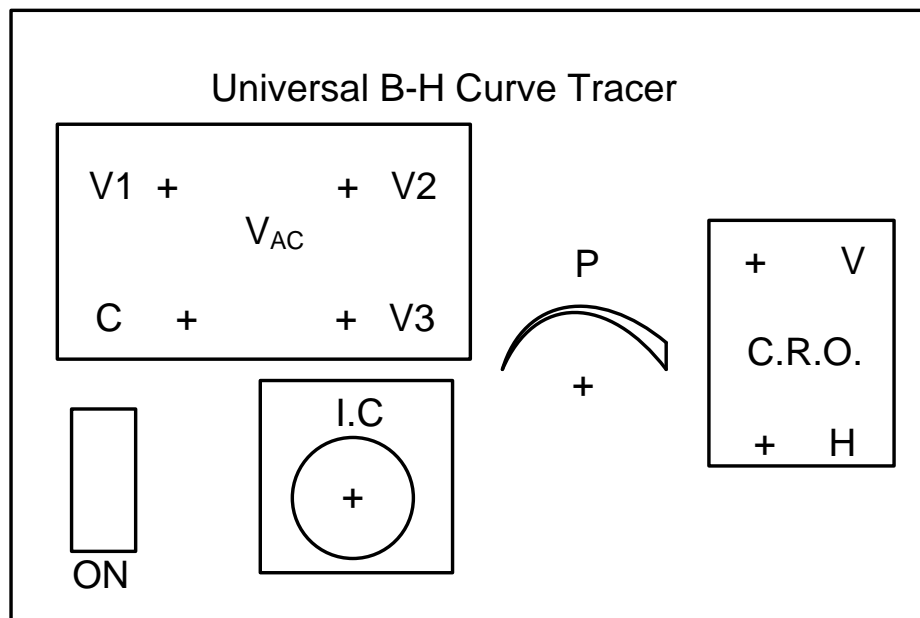
Figure 2   Details of the Instrument

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OBSERVATON TABLE

N= 300 turns   R= 55 Ω   L=0.033 meters

Sr.No	Type of material	S_V(V) CM	S_H(V)CM	$EnergyLoss = \dfrac{0.5 * N * S_v * S_H * areaofloop}{R * L}$

Calculation:

Sample calculation for-

a) 5'' nail

S_V=0.5v/CM

S_H=2 V/CM

Area of the loop=445x10^{-2}cm^2

Energy loss=367.76 J/cycle/unit volume

b) Ferrite Rod

R=

S_V=

S_H=

Area of the loop=

Energy loss=

c) Hacksaw Blade

R=

S_V=

S_H=

Area of the loop=

Energy loss=

d) Transformer stamping

R=

S_V=

S_H=

Area of the loop=

Energy loss=

Experiment No.

Aim: To study speed control of D.C. shunt motor by:
a) Armature Voltage Control method.
b) Field current control method.

Apparatus: **Range/Rating**   **Make**
1. Ammeter (DC)   0-5A
2. Voltmeter (DC)   0-300V
3. DC motor   1HP, 230V, 1500rpm
4. Rheostats
5. Tachometer (to measure the speed in RPM)

Theory:
The speed of the d.c. shunt motor is given by the relation:

$$N \propto \frac{V - I_a R_a}{\phi}$$

Where   V=applied voltage in volts.

I_a = current in armature in amps.

R_a = armature resistance in ohms.

ϕ = Flux per pole

Z = Number of armature conductors

N = Speed of motor

A = Number of parallel paths

From above expression it is clear that the speed can be varied by changing
        a) The resistance in the armature circuit.
        b) The flux (ϕ)

(a) Armature voltage control method

In this method the external resistance is connected in series with the armature winding.
The back emf for dc shunt motor (Eb) is given by,

$$E_b = \frac{\phi ZNP}{60 * A}$$

Therefore,

$$N \propto \frac{Eb}{\Phi}$$

If flux of motor is constant then,
$$N \propto V\text{-}I_aR_a$$
If the resistance is increased then the back emf will decrease. As this term is proportional to the speed, the speed also decreases

(b) Field Current Control Method

In D.C. shunt motor flux (ϕ) is proportional to the current in the field winding of motor. Since

$$N \propto \frac{Eb}{\Phi}$$

But, Back emf (Eb)   Eb = V-IaRa

Therefore, $N \propto \dfrac{V - I_a R_a}{\phi}$

This expression indicates that the speed is inversely proportional to the flux per pole. External resistance is connected in series with shunt field winding. If resistance is increased then the current in the shunt field winding decreases. So, the flux produced also decreases. As the speed is inversely proportional to the flux, the speed increases. This method is used for obtaining speeds above normal speed.

Procedure:
(a) Armature voltage control method
1. Connect the circuit as shown in circuit diagram.
2. Set the rheostats in the armature circuit to maximum and field
3. Set the rheostats in the armature circuit to maximum and field circuit to minimum resistance position.
4. Switch on the D.C. supply and start the motor using the starter resistance.
5. Keep the field rheostat constant at suitable value of field current.
6. Note the reading of tachometer, voltmeter & ammeter
7. Now change the resistance in the armature circuit by changing armature rheostat & note down the readings of meters.
8. Plot armature voltage Vs speed graph.

(b) Field Current Control Method
1. First three steps are same as part (a).
2. Keep the armature voltage constant.
3. Now increase the resistance in the field circuit. Note that the speed & current readings.
4. Repeat step (3) for different field currents.
5. Plot field current Vs speed graph.

Precautions:
1. Do not put on the supply until the circuit is checked by the concerned   teacher.
2. Do not touch the live part of the circuit.
3. Polarity and ratings of the meters must be correct.
4. Ensure that initially the starter handle is at its maximum resistance position (left hand side).

Plot the graphs-
i) Armature voltage V^s Speed
ii) Field current V^s Speed

Result and Conclusion:

Discussion Questions:-
1) What are the types of dc motors? Draw it's circuit diagram.
2) What is Back Emf? Write the equation for the same.
3) When and why Field Current Control Method is preferred, below rated speed or above rated speed.
4) When and why Armature voltage control method is preferred, below rated speed or above rated speed.
5) Explain the need of starter.
6) What are the types of starter?
7) Draw diagram of three point starter.
8) Explain with rough graph effect of change in the Field Current and Armature voltage on the speed of D C motor.

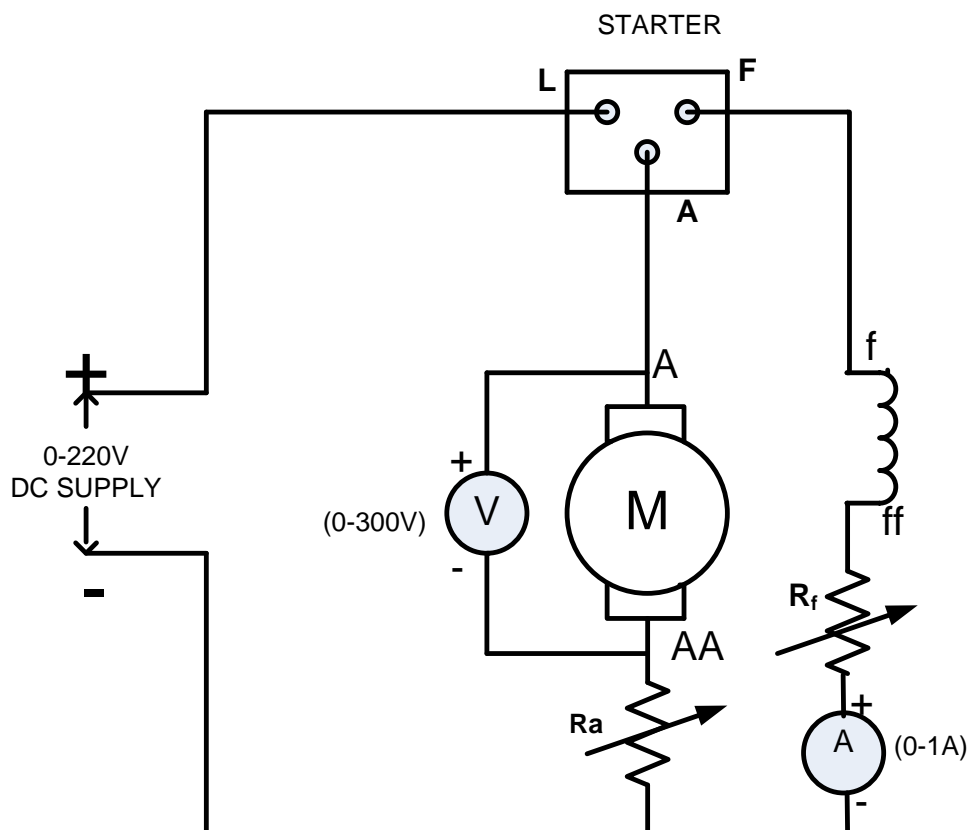# On LHS by Hand with Pencil

Experiment No.

Aim: To study speed control of D.C. shunt motor by:
   a) Armature Voltage Control method.
   b) Field current control method.

Apparatus: Range/Rating   Make
1. Ammeter (DC)   0-5A
2. Voltmeter (DC)   0-300V
3. DC motor   17HP, 230V, 1500rpm
4. Rheostats
5. Tachometer (to measure the speed in RPM)

On LHS by Hand with Pencil

Observation table:-

a) Armature Voltage Control method.

Sr. No.	field current (constant) (A)	Armature Voltage (V)	Speed of Motor (in RPM)
1			
2			
3			
4			
5			
6			
7			

b) Field current control method.

Sr. No.	Armature Voltage (constant) (V)	field current (A)	Speed of Motor (in RPM)
1			
2			
3			
4			
5			
6			
7			