Magnetic Circuit

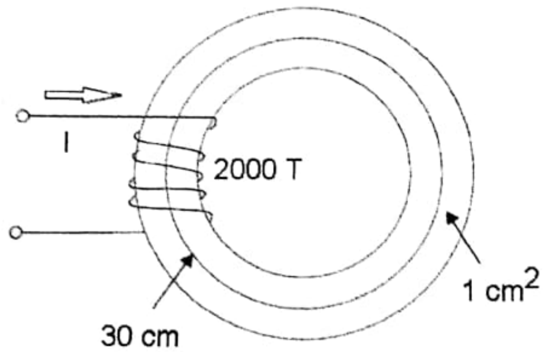
Problem1:

A magnetic core in the form of a closed circular ring has a mean length of 30 cm and a cross-sectional area of 1 cm^2. The relative permeability of iron is 2400.

Find the current that will be needed in the coil of 2000 turns uniformly wound around the ring to create a flux of 0.20 mWb in iron?

If an air-gap of 1 mm is cut through the core perpendicular to the direction of this flux, what current will now be needed to maintain the same flux in the air gap?

Hint:



Reluctance of the Core =

$$\frac{l}{\mu A} = \frac{l}{\mu_0 \mu_r A} = \frac{30\times10^{-2}}{4\pi\times10^{-7}\times2400\times1\times10^{-4}} = 994718\,H^{-1}$$

Given, flux = $0.2\times10^{-3}\,Wb$

mmf = flux × reluctance

So, mmf = $994718\times0.2\times10^{-3} = 199\,AT$

Given, turns = 2000

So, I = $\frac{199}{2000} = 0.0995A = 99.5mA$

For second case, in the case of air, l = $1\times10^{-3}\ m$

$$\frac{l}{\mu_0\mu_r A}(air)=\frac{1\times10^{-3}}{4\pi\times10^{-7}\times1\times1\times10^{-4}}=7957747\ H^{-1}$$

So, total reluctance = reluctance of iron+air = 994718+7957747 H^{-1}

Given, flux = $0.2\times10^{-3}Wb$

mmf = flux × reluctance

So, mmf = $8952465\times0.2\times10^{-3}=1790AT$

Given, turns = 2000

So, I = $\frac{1790}{2000}=0.895A=895mA$

Problem2:

For the magnetic circuit shown in fig the flux in the right limb is 0.24 mWb and the number of turns wound on the central-limb is 680.

*Calculate **(i)** flux in the central limb*

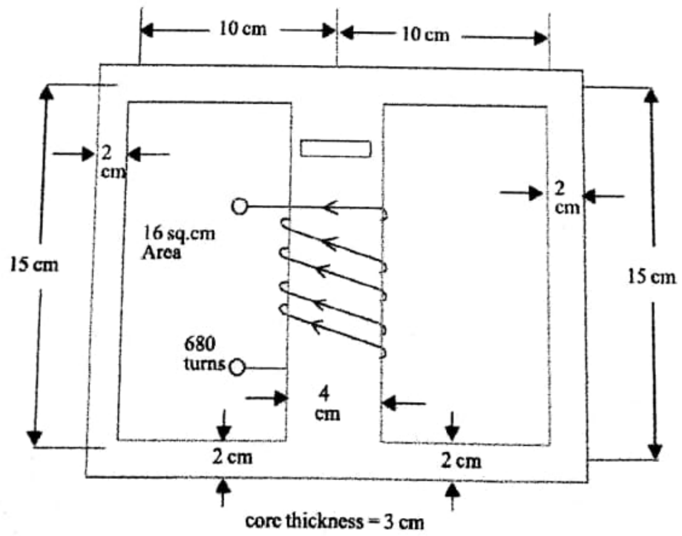
***(ii)** the current required.*

The magnetization curve for the core is given as below :

H (AT/m) :	200	400	500	600	800	1060	1400
B (Wb/m^2) :	0.4	0.8	1.0	1.1	1.2	1.3	1.4

Neglect Leakage and fringing.

Hint:



Given, flux in each side limb = $0.24\times10^{-3}Wb$

Since the coil is wound on the central limb and the magnetic circuit is symmetrical, (i) the flux in left limb = the flux in right limb and (ii) the flux in the central limb adds up from the side limbs

So, flux in central limb = $0.48\times10^{-3}Wb$

Area of cross-section of cent. limb = 4 × 3 = 12 sq.cm = $12\times10^{-4}\ m^2$

Flux density in central limb = $\dfrac{0.48\times10^{-3}}{12\times10^{-4}} = 0.4\,Wb/m^2$

From the provided chart, this flux density corresponds to H = 200 AT/m

This means, per meter of the central limb, 200 AT is required

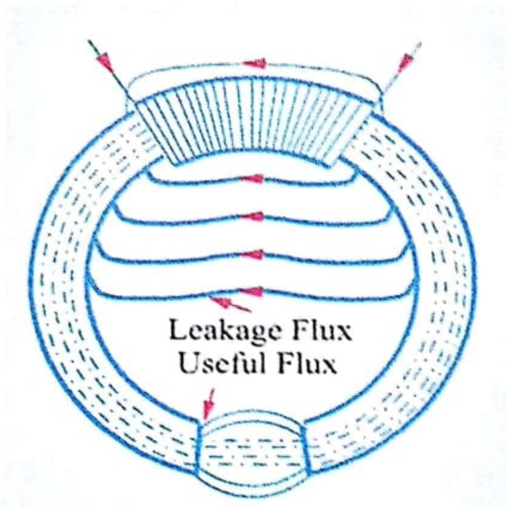
Central Limb has a path length of 15 cm

mmf required at central limb = (200 × 0.15) = 30 AT

Given, T = 680

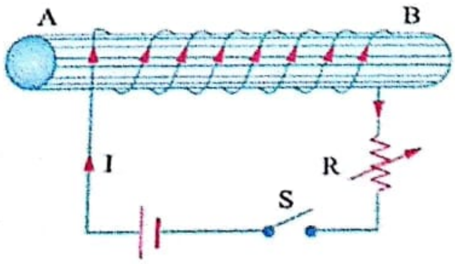
So, I = 44.1 mA

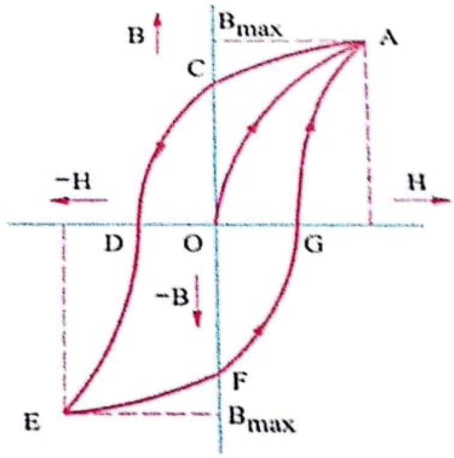
Leakage and Leakage Flux



$$\text{leakage coefficient } \lambda = \frac{\text{total flux}}{\text{useful flux}} \quad \text{or} \quad \lambda = \frac{\Phi_t}{\Phi}$$

Magnetic Hysteresis



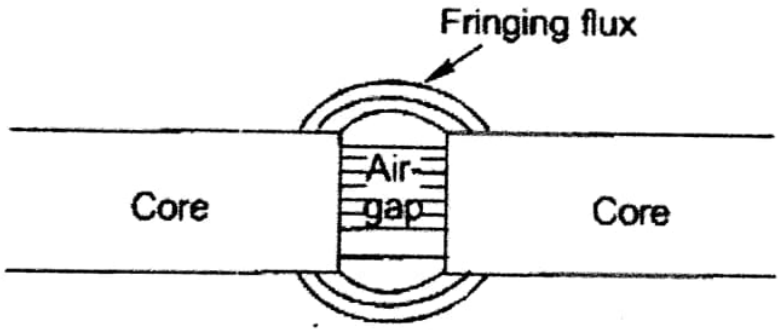


**Recall the terms: Magnetic Retentivity and Coercivity

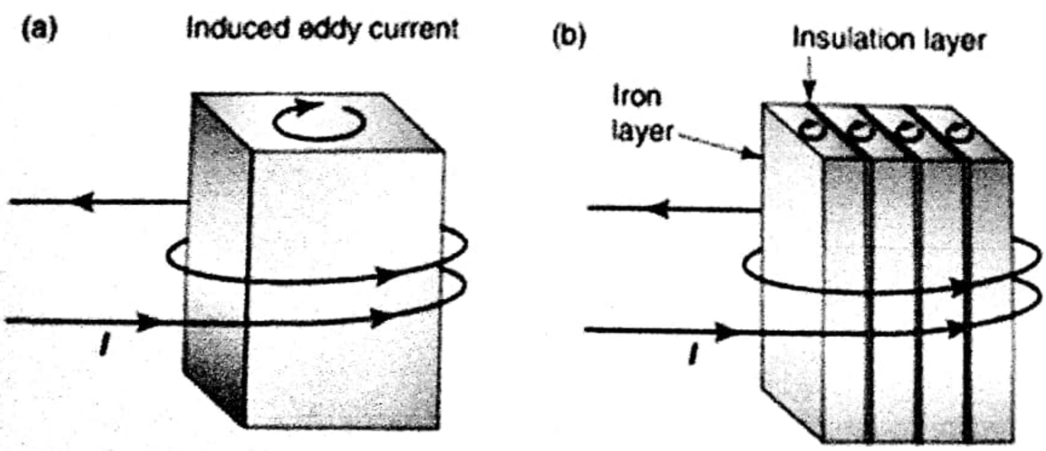
Fringing

- When flux enters into the air gap in the magnetic circuit, it passes through the air gap in terms of parallel flux lines.
- There exists a force of repulsion between the magnetic lines of force which are parallel and having the same direction.
- Due to this repulsion force there is tendency of the flux lines to bulge out at the edges of the air gap.
- This phenomenon is called magnetic fringing.

Effects:
- It increases the cross-sectional area of the air gap
- It reduces the flux density in the gap.



Eddy Current



•When an alternating magnetic field is applied to a magnetic material an emf is induced in the material itself according to Faraday's Law of Electromagnetic induction.

•Since the magnetic material is a conducting material, these EMFs circulates currents within the body of the material.

•These circulating currents are called Eddy Currents.

•They will occur when the conductor experiences a changing magnetic field.

Problem1:

The hysteresis loop for a certain magnetic material is drawn to the following scales :

1 cm = 200 AT/m and 1 cm = 0.1 Wb/m^2

The area of the loop is 48 cm^2

Assuming the density of the material to be 7.8×10^3 kg/m^3 Calculate the hysteresis loss in watt per kg of the material at 50 Hz.

Hint:

Hysteresis loss = xy (area of B/H loop) J/m^3/cycle

Now, 1 cm = 200 AT/m ; 1 cm = 0.1 Wb/m^2

$\therefore$ x = 200, y = 0.1, area of loop = 48 cm^2

$\therefore$ loss for this area (a) = $200 \times 0.1 \times 48 = 960$ J/m^3/cycles

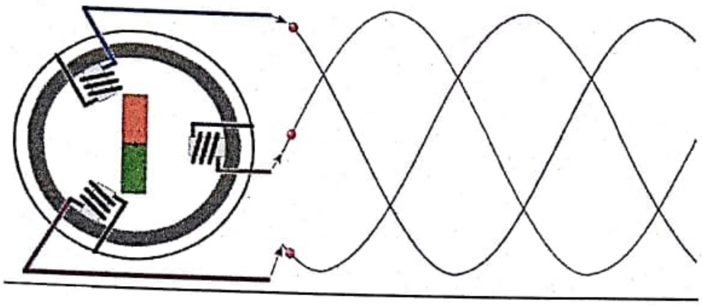
Now, density = 7.8×10^3 kg/m^3

Volume of 1 kg of material = mass/density = $1/(7.8 \times 10^3)$ m^3

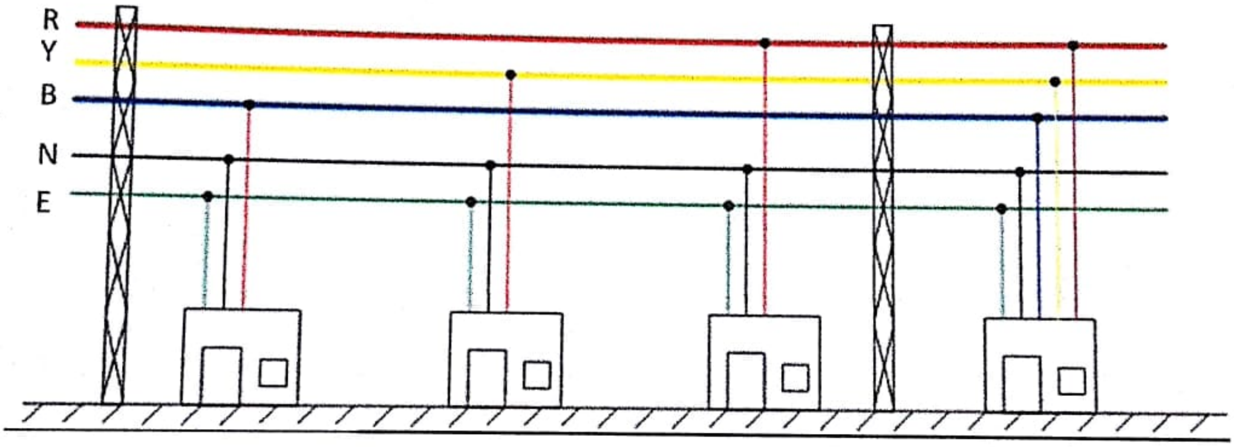
$\therefore$ loss = a × volume × cycles per sec
= **6.15 watt** per kg of the material

Concept of Three Phase Alternating Current

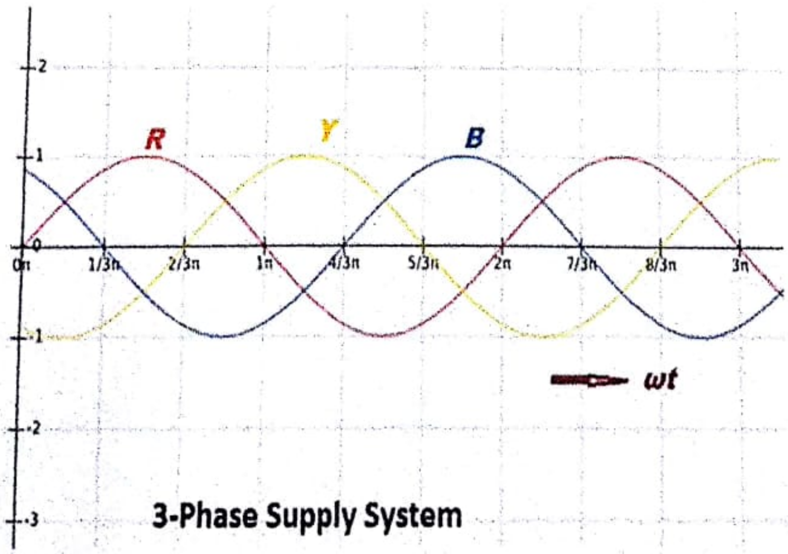
Generation:



Distribution:



Supply:



Advantages of three phase system:

Generation:

- The output of 3-phase machine is always greater than single phase machine of same size.
- The output is approx. 1.5 times than single phase machine.
- So for given V and VA, 3-phase electrical machines occupy less space and less cost compared to single phase machine
- Parallel operation of three phase generators is simple compared to single phase generators, for delivering more power

Transmission:

- 3-phase requires less conducting material than that of single phase system for given VA and voltage ratings
- More economical compared to single phase system

Consumption:

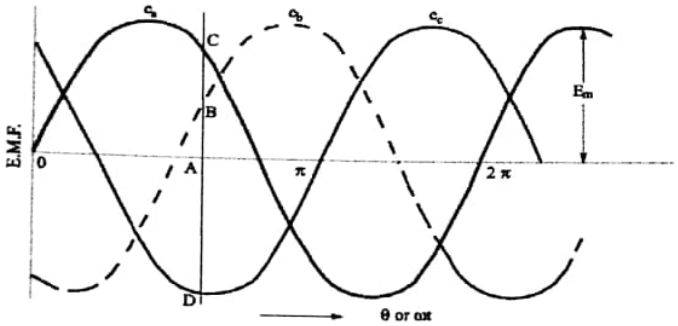
- 3-phase machines are self starting due to rotating magnetic field. In order to start a single phase machine auxiliary devices are required
- Power factor of single phase machines is poor compared to three phase machines
- Single phase system can be obtained from 3-phase supply system, vice-versa is not possible
- For converting systems like rectifiers, the dc voltage waveform becomes more smoother
- Three phase motors will have uniform torque whereas single phase motors will have pulsating torque

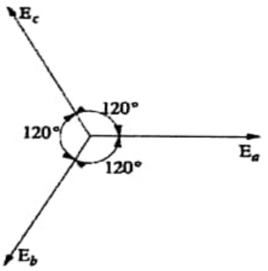
Their equations are :

$$e_a = E_m \sin \omega t \qquad \text{... (i)}$$

$$e_b = E_m \sin(\omega t - 120°) \qquad \text{... (ii)}$$

$$e_c = E_m \sin(\omega t - 240°) \qquad \text{... (iii)}$$



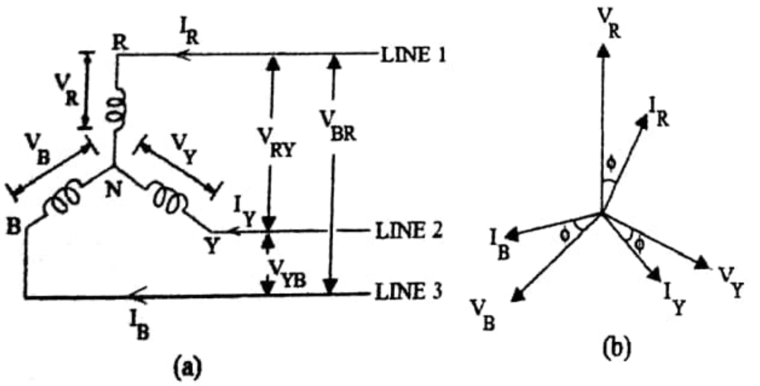


Interconnection of Three Phases

(*a*) Star or Wye (Y) connection and

(*b*) Mesh or Delta (Δ) connection.

Voltages and Currents in Y-Connection



$V_R = V_Y = V_B = V_{Ph}$

$V_{RY} = V_{YB} = V_{BR} = V_L$

and

$I_R = I_Y = I_B = I_L$

and

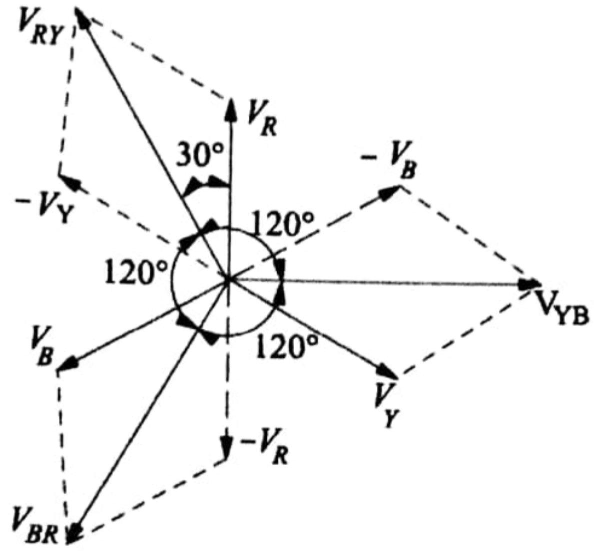
$I_L = I_{Ph}$

Fig. 1. where a balanced system has been assumed.

Line voltage V_{RY} between line 1 and line 2 is the vector difference of V_R and V_Y.
Line voltage V_{YB} between line 2 and line 3 is the vector difference of V_Y and V_B.
Line voltage V_{BR} between line 3 and line 1 is the vector difference of V_B and V_R.

(a) Line Voltages and Phase Voltages

The p.d. between line 1 and 2 is $V_{RY} = V_R - V_Y$



$$V_L = \sqrt{3} \cdot V_{ph}$$

1. Line voltages are 120° apart.
2. Line voltages are 30° ahead of their respective *phase* voltages.
3. The angle between the line currents and the corresponding line voltages is $(30 + \phi)$ with current lagging.

(b) Line Currents and Phase Currents

It is seen from Fig. 1. (a) that each line is in series with its individual phase winding, hence the line current in each line is the same as the current in the phase winding to which the line is connected.

Current in line 1 = I_R : Current in line 2 = I_Y: Current in line 3 = I_B

Since $\quad I_R = I_Y = I_B$ = say, I_{ph} – the phase current

$\therefore$ line current $I_L = I_{ph}$

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(c) Power

The total active or true power in the circuit is the sum of the three phase powers. Hence, total active power = 3 × phase power or $P = 3 \times V_{ph} I_{ph} \cos\phi$

Now

$$V_{ph} = V_L / \sqrt{3} \quad \text{and} \quad I_{ph} = I_L$$

Hence, in terms of line values, the above expression becomes

$$P = 3 \times \frac{V_L}{\sqrt{3}} \times I_L \times \cos\phi \quad \text{or} \quad P = \sqrt{3}\, V_L\, I_L \cos\phi$$

It should be particularly noted that ϕ is the angle between ***phase*** voltage and ***phase*** current and not between the line voltage and line current.

Similarly, total reactive power is given by $\mathbf{Q} = \sqrt{3}\, V_L\, I_L \sin\phi$

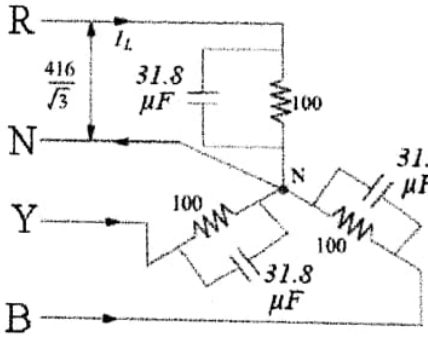
The total apparent power of the three phases is

$S = \sqrt{3}\, V_L I_L$ Obviously, $S = \sqrt{P^2 + Q^2}$

Problem:

Each phase of a star-connected load consists of a non-reactive resistance of 100 Ω in parallel with a capacitance of 31.8 μF.

Calculate the line current, the power absorbed, the total kVA and the power factor when connected to a 416-V, 3-phase, 50-Hz supply.



Solution.

$$V_{ph} = (416/\sqrt{3})\angle 0° = 240\angle 0°$$

Admittance of each phase is

$$\mathbf{Y}_{ph} = \frac{1}{R} + j\omega C = \frac{1}{100} + j314 \times 31.8 \times 10^{-6}$$

$$= 0.01 + j0.01 = 0.01\angle 45°$$

$$\therefore\ \mathbf{I}_{ph} = \mathbf{V}_{ph} \times \mathbf{Y}_{ph} = 240\angle 0° \times 0.01\angle 45° = 2.4\angle 45°$$

Since $I_{ph} = I_L$ for a star connection $\therefore\ I_L = 2.4\ \mathbf{A}$

Power factor = cos 45° = **0.707 (leading)**

Now $\mathbf{V}_{ph} = 240\text{V}$

$\therefore\ \mathbf{P} = 240 \times 2.4 \times \cos 45° = 407\text{ W}$ ... per phase

Total Power = 3 × 407 W = 1221 W = 1.2 kW

Total VA = 3 × 240 × 2.4 = **1728 VA = 1.7 kVA**

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Three phase alternators

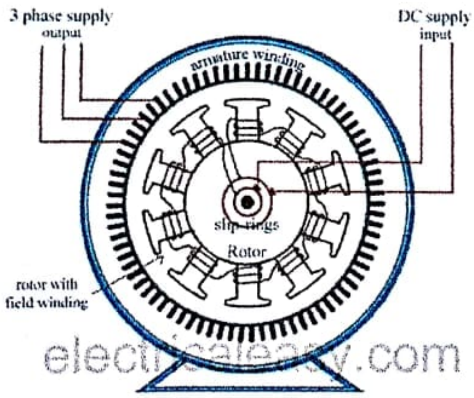
•The operation of a synchronous generator is based on Faraday's law of electromagnetic induction
•In an AC synchronous generator the generation of emf's is by relative motion of conductors and magnetic flux.

•These machines can be used as either motors or generators but their predominant use is in generation.

There are a number of sources of energy used to turn the turbines:-

(a) Gas
(b) Steam
(c) Combined cycle
(d) Nuclear
(e) Hydro
(f) Wind
(g) Wave
(h) Photovoltaic

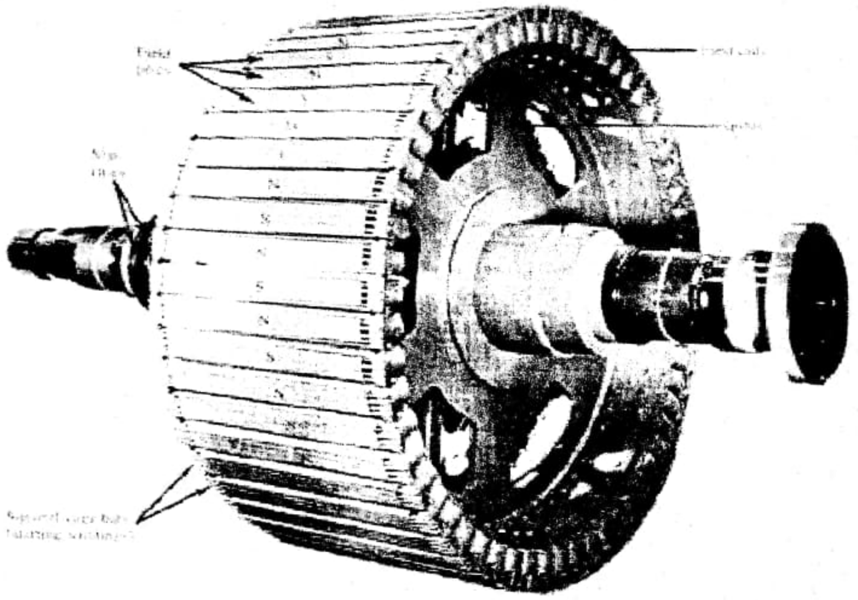
•In constructing a synchronous machine a point to note is that the stator is fixed and the poles rotate.

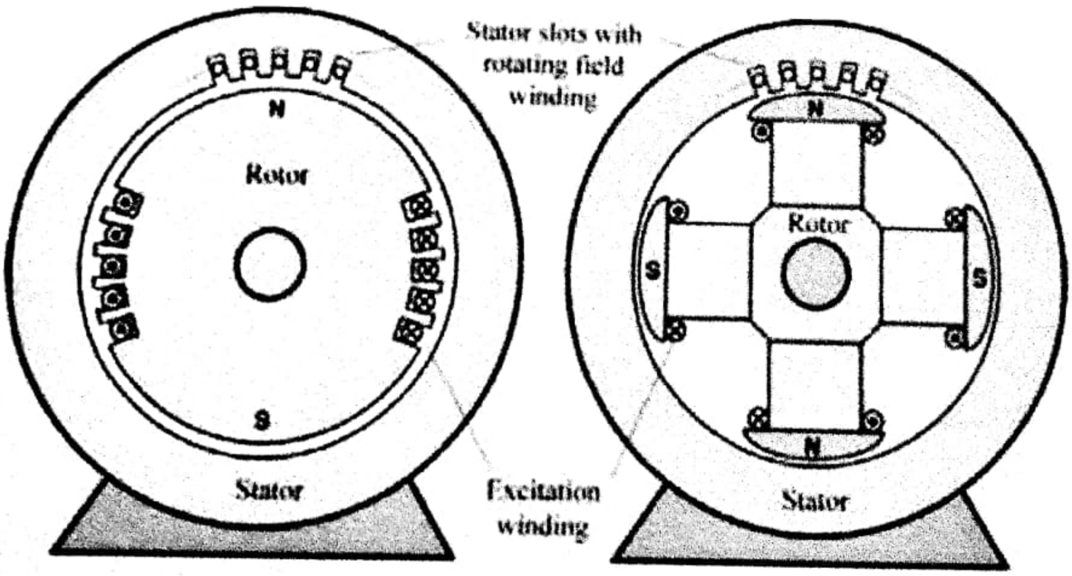


•There are two categories of Synchronous machines:

(a) those with salient or projecting poles

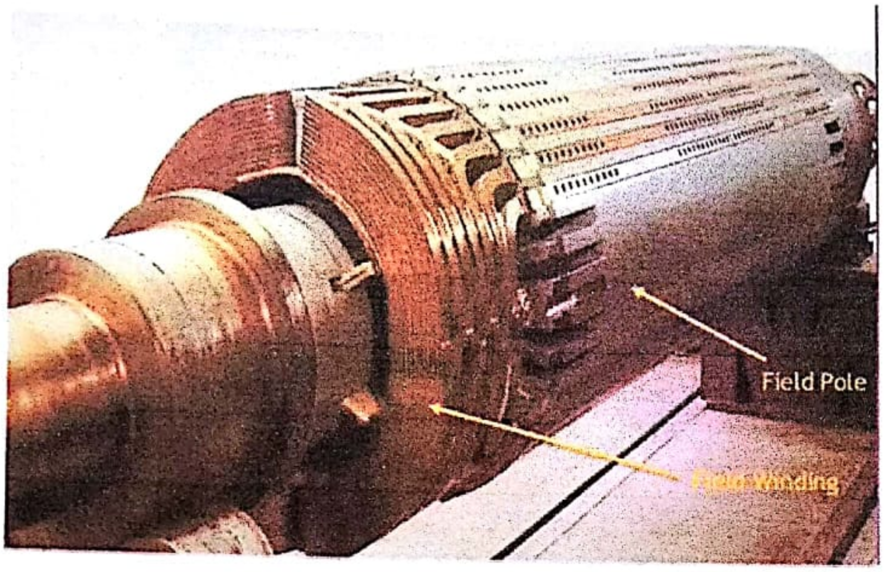
(b) those with cylindrical rotors



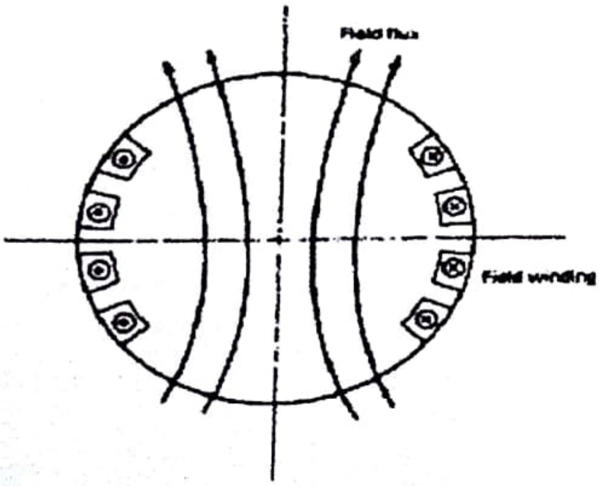


Cylindrical Rotor

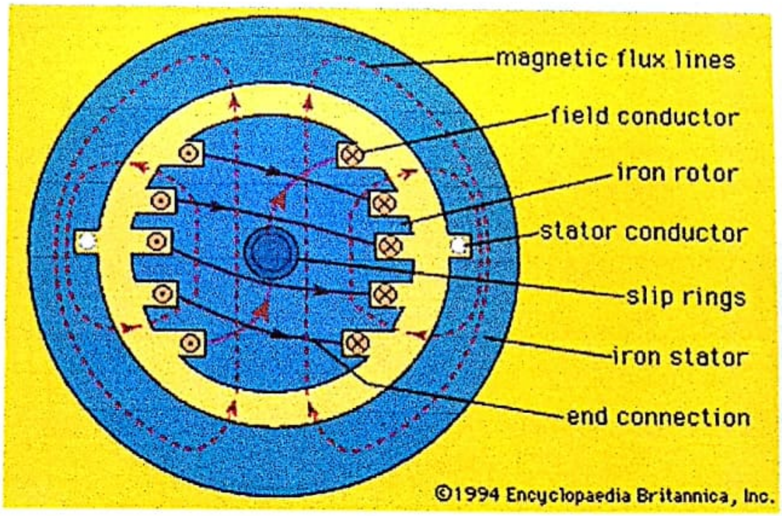
Salient Pole Rotor

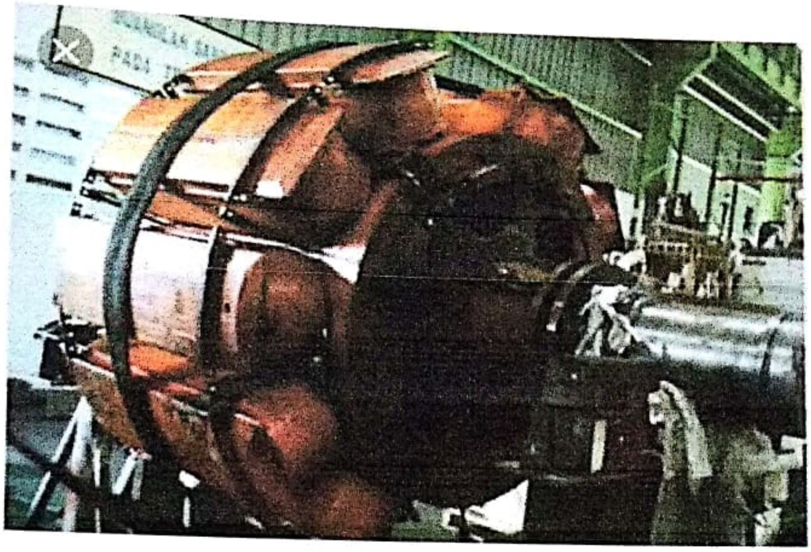


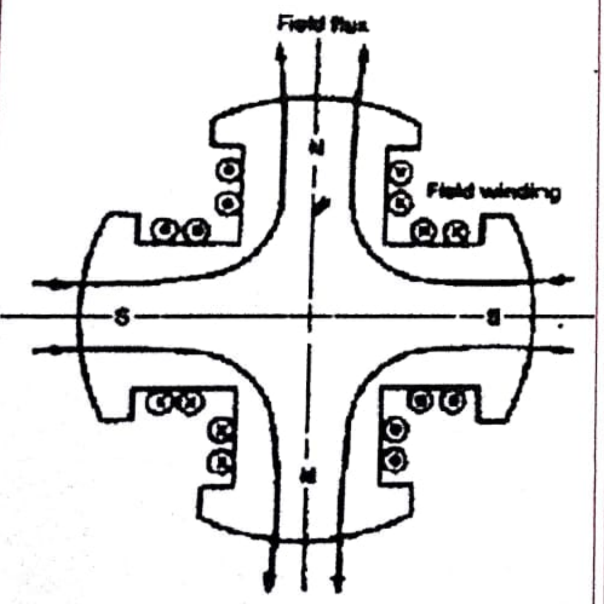
2-pole Cylindrical Rotor



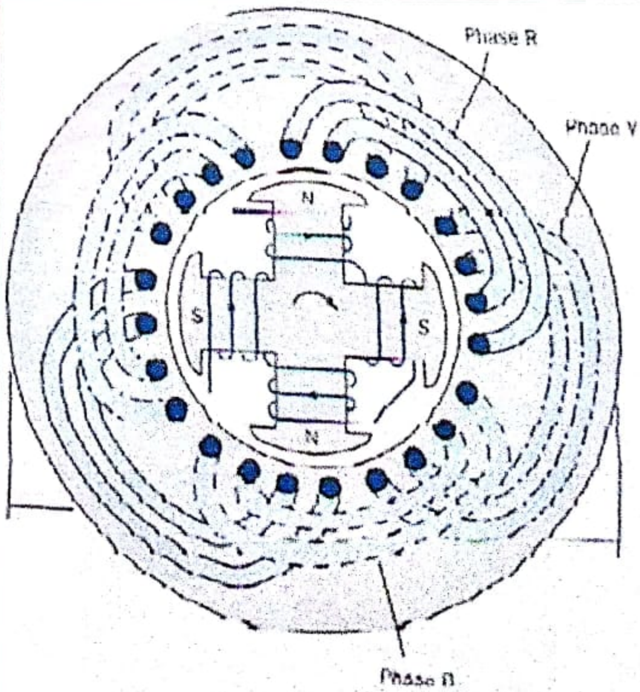
A Cylindrical Rotor





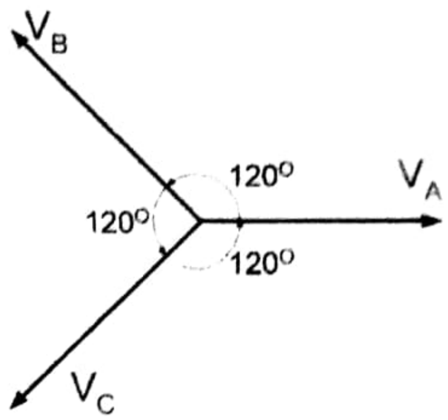


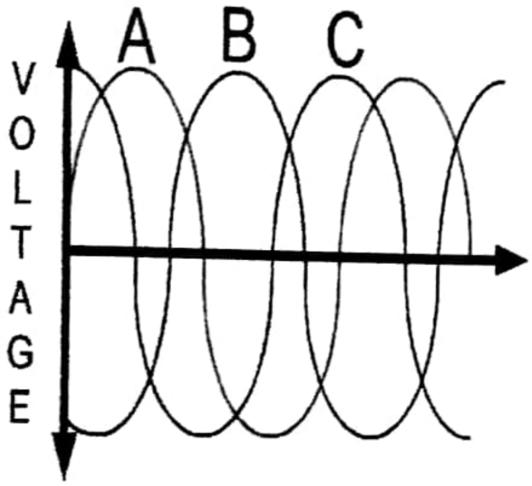
4-Pole Salient Rotor



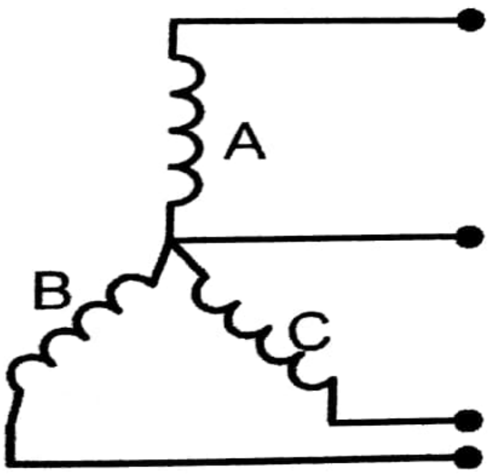
A Salient Pole Rotor

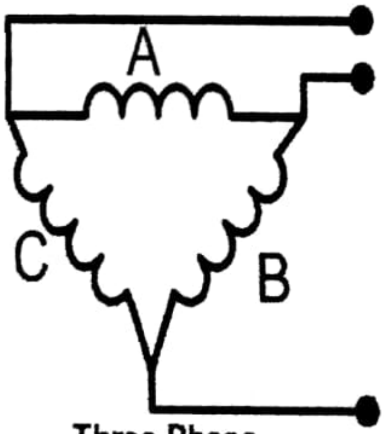
The three-phase alternator has three single-phase windings spaced so that the voltage induced in any one is phase-displaced by 120 degrees from the other two.





The voltage waveforms generated across each phase are drawn on a graph phase-displaced 120 degrees from each other.





•The frequency of the AC generated by an alternator depends upon the number of poles and the speed of the rotor

•When a rotor has rotated through an angle so that two adjacent rotor poles (a north and a south) have passed one winding, the voltage induced in that one winding will have varied through a complete cycle of 360 electrical degrees.

•A two pole machine must rotate at twice the speed of a four-pole machine to generate the same frequency.

•The magnitude of the voltage generated by an alternator can be varied by adjusting the current on the rotor which changes the strength of the magnetic field.

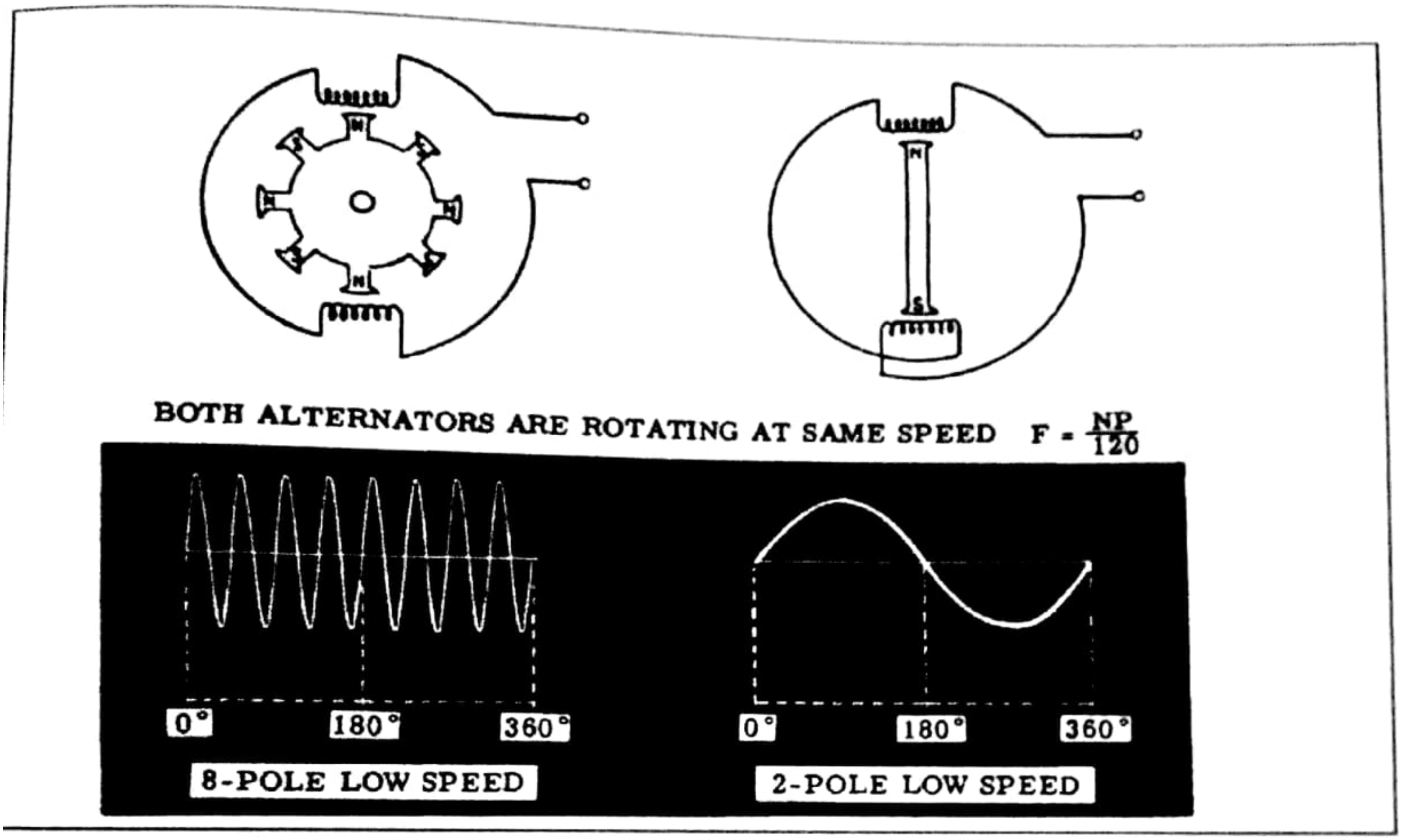
•A two pole alternator produces one electrical cycle for each complete mechanical rotation.

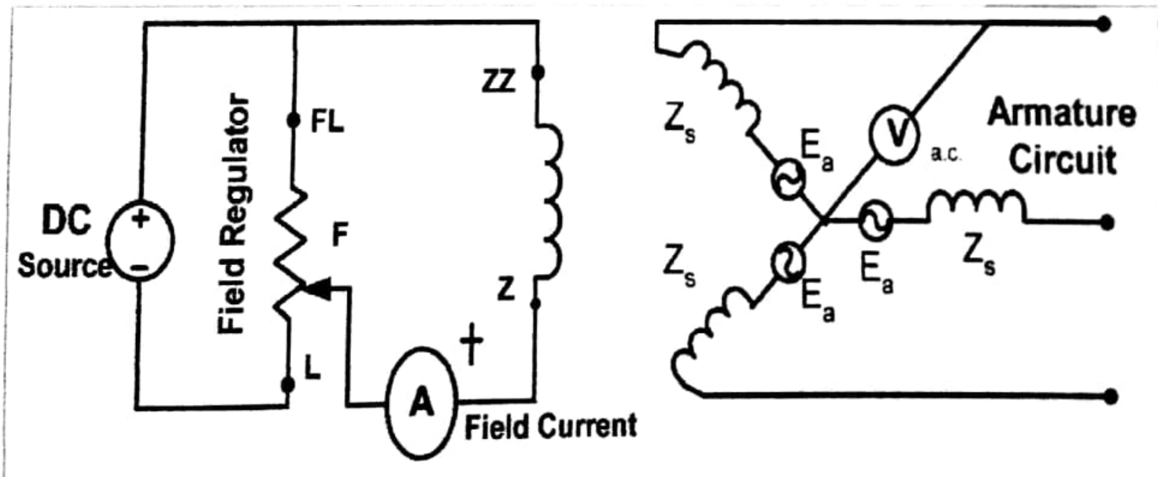
•A four pole alternator will produce two electrical cycles for each mechanical rotation because two north and two south poles move by each winding on the stator for one complete revolution of the rotor.

$$f = N_S \times \frac{P}{2} \times \frac{1}{60} = \frac{N_S \times P}{120}$$

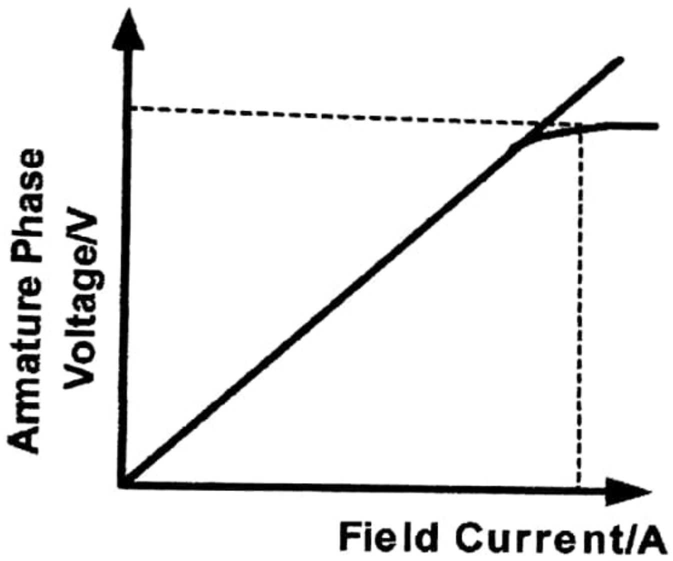
where N_S is the synchronous speed of the rotor in revolutions per minute, P is the number of poles and f is the electrical line frequency produced by the alternator.

The speed of the rotor must be divided by 60 to change from revolutions per minute to revolutions per second.





To obtain the open circuit characteristics the machine is driven at rated speed without the load. Readings of the line-to-line voltage are taken for various values of field current. The voltage, except in very low voltage machines, is stepped down by the means of a potential transformer.



If not for the magnetic saturation of the iron, the open circuit characteristics would be linear as represented by the air gap line

Let Φ = Flux per pole, in Wb
P = Number of poles
N_s = Synchronous speed in r.p.m.
f = Frequency of induced e.m.f. in Hz

Consider a single conductor placed in a slot.

The average value of e.m.f. induced in a conductor

$$\frac{d\Phi}{dt}$$

For one revolution of a conductor,

e_{avg} per conductor =

(Flux cut in one revolution)/(time taken for one revolution)

Total flux cut in one revolution is $\Phi \times P$

Time taken for one revolution is $60/N_s$ seconds.

$$\therefore \quad e_{avg} \text{ per conductor} = \frac{\Phi P}{60/N_S} = \frac{\Phi P N_S}{60}$$

As we have already found that

$$f = \frac{PN_S}{120}$$

Thus e_{avg} per conductor = $2 f \Phi$ volts

Now, for sine wave, e_{rms}/e_{avg} = form factor = 1.11

So, rms e.m.f = average e.m.f × 1.11

So, rms e.m.f. per conductor = $2.22 f \Phi$ volts

If total number of conductors per phase = Z, then

So, rms e.m.f. per phase = $2.22 f \Phi Z$ volts

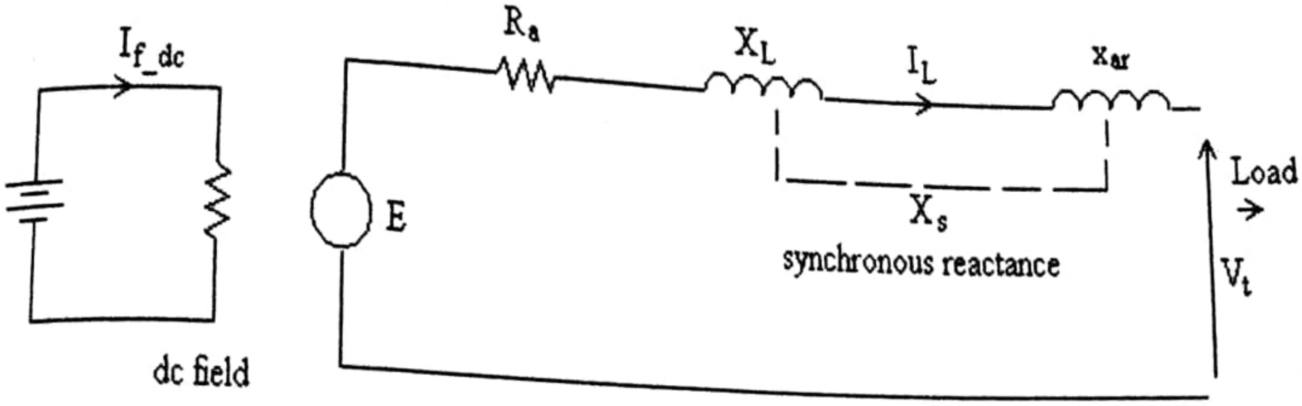
Since 1 Turn = two conductors,

So, e.m.f. per turn = 2 × (e.m.f. per conductor)

If total number of turns per phase = T, then

rms e.m.f. per phase = $2 \times 2.22 f \Phi T$ volts

= $4.44 f \Phi T$ volts



Per Phase Equivalent Circuit

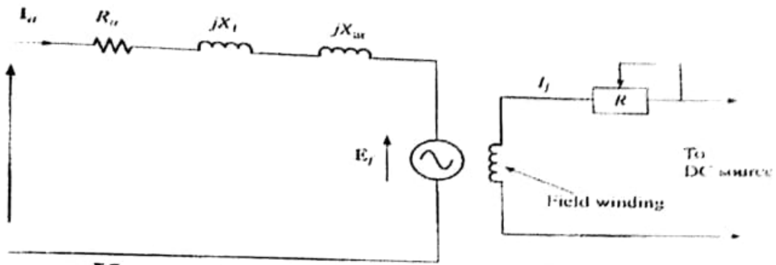
R_a => armature resistance per phase
X_L => leakage reactance.

Synchronous Motors

- Constant-speed machine; rotor rotating at a speed synchronized with the supply frequency
- The actual speed depends on the number of stator poles
- The rotor is either a permanent magnet for small motors or electromagnet for large motors
- Construction
    - Stator identical to that of a three-phase alternator
    - Energize from a three-phase supply and develop the rotating magnetic field
    - Rotor needs a DC voltage excitation through slip rings
- Operation
    - Magnetic field of the rotor "locks" with the rotating magnetic field – rotor turns at synchronous speed
- Starting

- Get motor to maximum speed (usually with no load) with the help of external motor or short circuited specialized rotor windings
- Remove the short and energize the rotor (field) with a DC voltage
- Wait for the rotor to increase its speed and get locked with the speed of rotating magnetic field.

Equivalent Circuit of a Synchronous Motor Armature (One Phase)



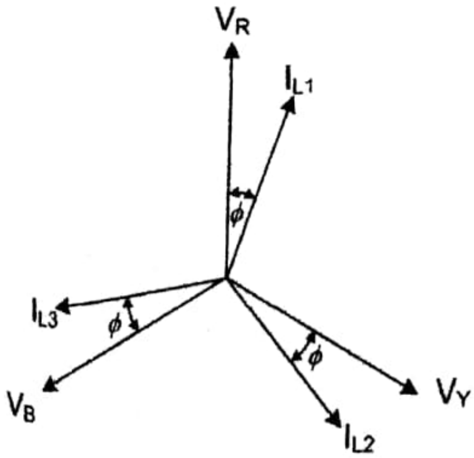
$$V_T = I_a R_a + I_a jX_l + I_a X_{ar} + E_f$$

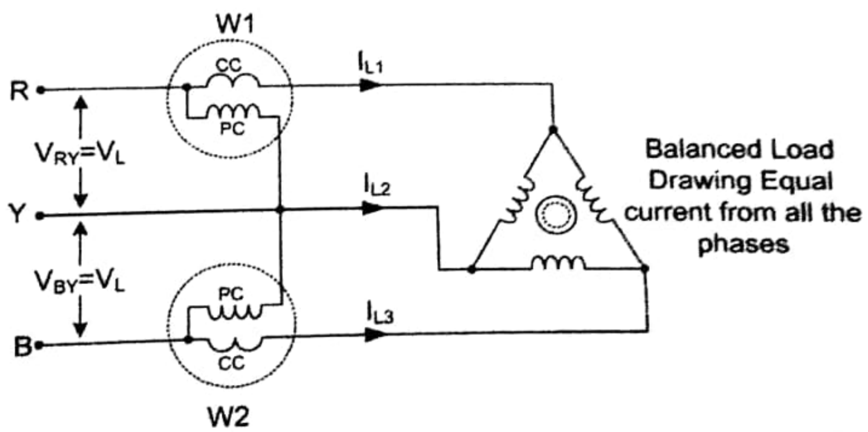
$$X_s = X_l + X_{ar}$$

$$V_T = E_f + I_a(R_a + jX_s)$$

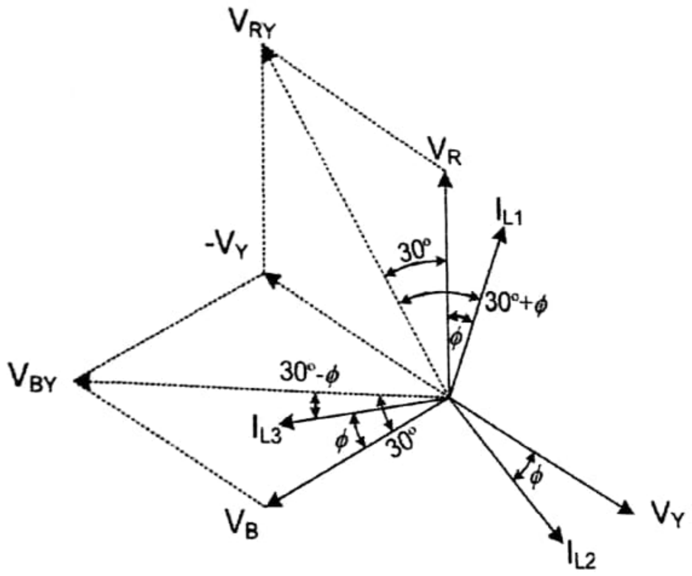
$$V_T = E_f + I_a Z_s$$

Three Phase Balanced Load Power Measurement by Two-Wattmeter Method





Phasor Diagram



$$W1 = V_{RY} I_{L1} \cos(30° + \phi)$$

$$W2 = V_{BY} I_{L3} \cos(30° - \phi)$$

$$\begin{aligned} W1+W2 &= V_{RY} I_{L1} \cos(30° + \phi) + V_{BY} I_{L3} \cos(30° - \phi) \\ &= V_L I_L [\cos(30° + \phi) + \cos(30° - \phi)] \\ &= \sqrt{3} V_L I_L \cos\phi \end{aligned}$$

Thus it can be proved that in a three phase system, for balanced load, two wattmeters are sufficient to calculate the total power consumed in the system

METERS

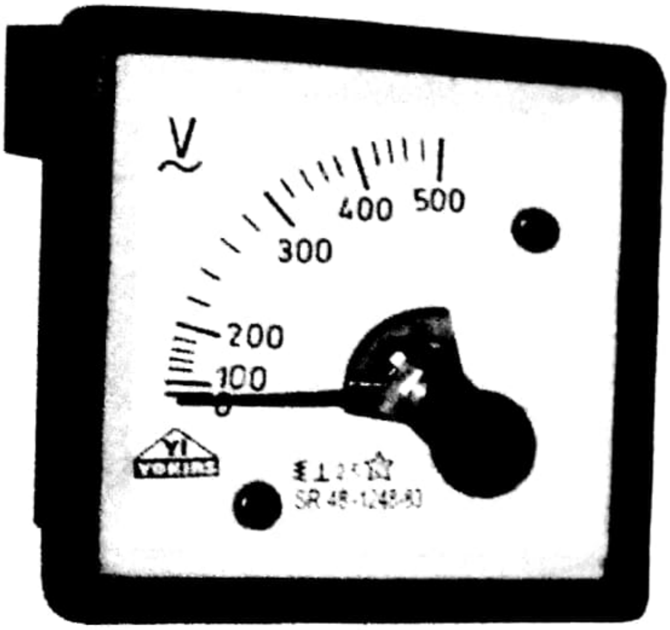
The various electrical instruments may, in a very broad sense,

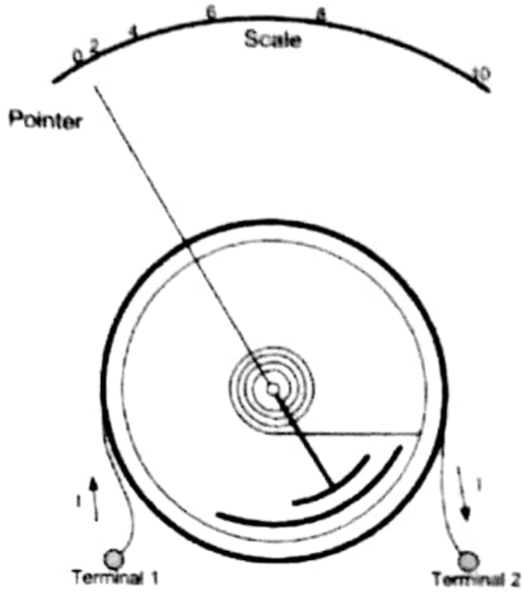
be divided into

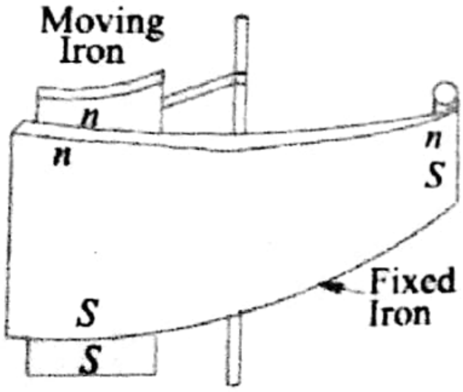
(i) ***absolute instruments and***

(ii) ***Secondary* instruments.**

Moving-iron Instrument (AC/DC)







$\therefore \quad T_d \propto I^2$

and for spring control $T_c \propto \theta$

As $\quad T_c = T_d$

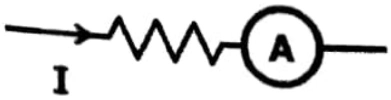
$\therefore \quad \theta \propto I^2$

****

Measuring current, voltage, and resistance

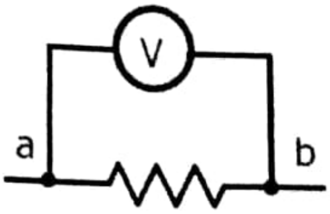
Ammeter:

- measures current (A)
- connected **in series**
  (current must go through instrument)



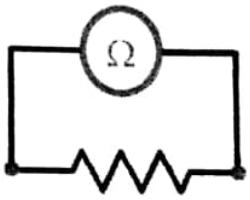
Voltmeter:

- measures potential difference (V)
- connected **in parallel**



Ohmmeter:

- measures resistance of an isolated resistor (not in a working circuit)

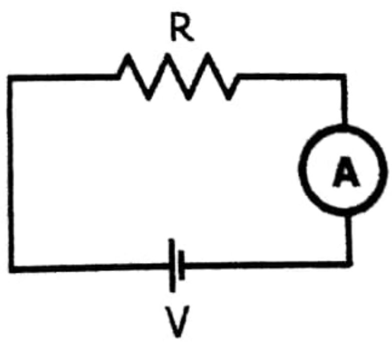


Effect of ammeter on circuit

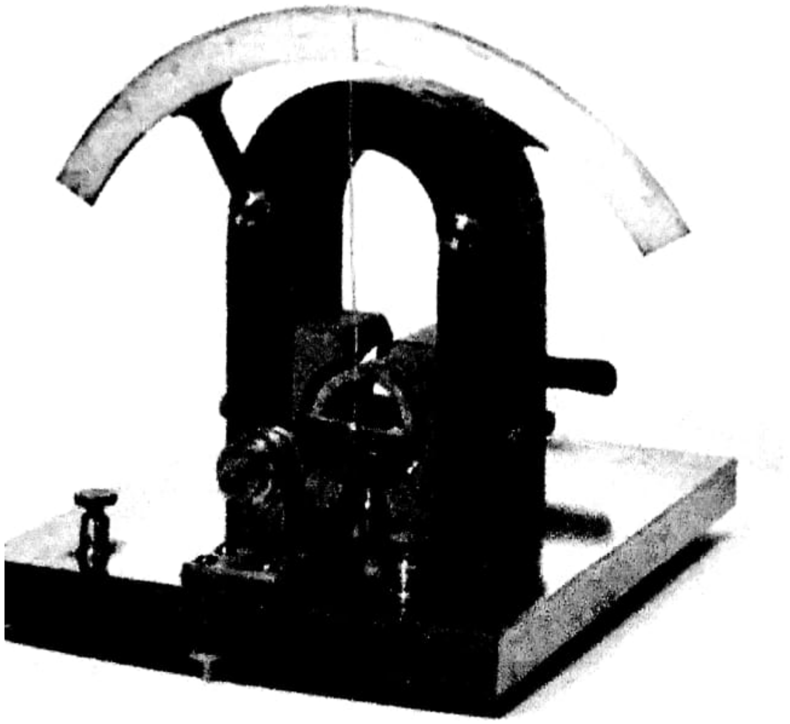
Measuring current in a simple circuit:

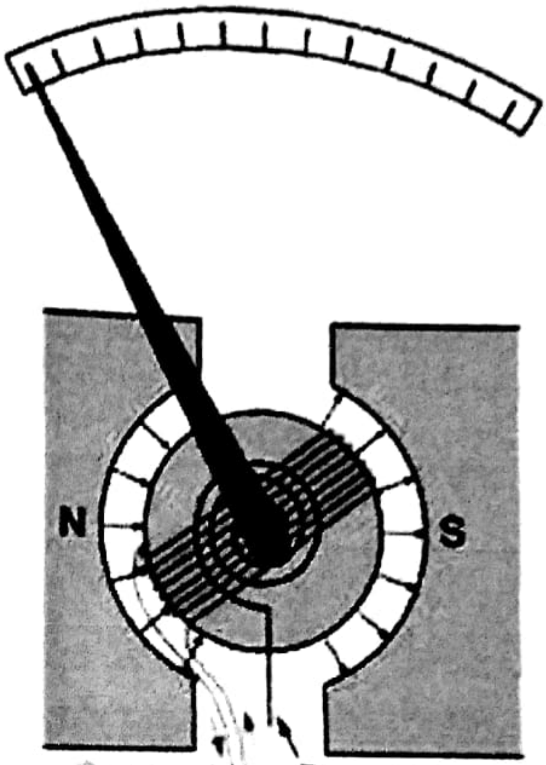
- connect ammeter in series

Are we measuring the correct current?
(the current in the circuit without ammeter)



Moving Coil Instrument (Only DC)





$\therefore \quad T_d \propto I$

and for spring control $T_c \propto \theta$

As $\quad T_c = T_d$

$\therefore \quad \theta \propto I$

Absolute instruments are those which give the value of the quantity to be measured, in terms of the constants of the instrument and their deflection only. No previous calibration or comparison is necessary in their case.

Secondary instruments are those, in which the value of electrical quantity to be measured can be determined from the deflection of the instruments, only when they have been precalibrated by comparison with an absolute instrument. Without calibration, the deflection of such instruments is meaningless.

It is the secondary instruments, which are most generally used in everyday work; the use of the absolute instruments being merely confined within laboratories, as standardizing instruments.

Another way to classify secondary instruments is to divide them into ***(i) indicating instruments (ii) recording instruments and (iii) integrating instruments.***

Indicating instruments are those which indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured.

Their indications are given by pointers moving over calibrated dials. Ordinary ammeters, voltmeters and wattmeters belong to this class.

Recording instruments are those, which records the variations of a quantity over a selected period of time. The moving system of the instrument carries an inked pen which continuously records on a moving chart or graph.

Integrating instruments are those which measure and register the summation of a quantity for a given time. Ampere-hour and watt-hour meters fall in this class.

Essentials of Indicating Instruments

1. A deflecting (or operating) torque

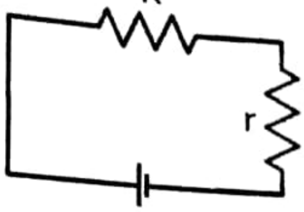
2. A controlling (or restoring) torque

3. A damping arrangement.

Effect of ammeter on circuit

Measuring current in a simple circuit:

- connect ammeter in series



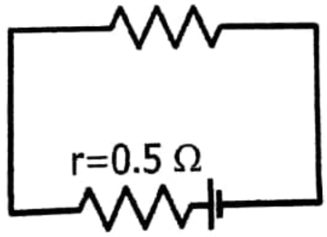
Are we measuring the correct current?
(the current in the circuit without ammeter)

- any ammeter has **some resistance r.**
- current in presence of ammeter is $I = \frac{V}{R+r}$.
- current without the ammeter would be $I = \frac{V}{R}$.

To minimize error, ammeter resistance r must be very small.
(ideal ammeter would have zero resistance)

Example: an ammeter of resistance 10 mΩ is used to measure the current through a 10 Ω resistor in series with a 3 V battery that has an internal resistance of 0.5 Ω. What is the relative (percent) error caused by the ammeter?

Actual current **without** ammeter:



You might see the symbol ε used instead of V.

$$I = \frac{V}{R+r}$$

$$I = \frac{3}{10+0.5} A$$

$$I = 0.2857 \text{ A} = 285.7 \text{ mA}$$

Current with ammeter:

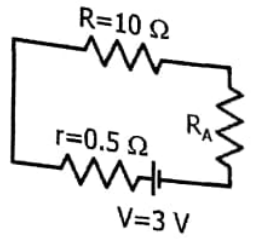
$$I = \frac{V}{R + r + R_A}$$

$$I = \frac{3}{10 + 0.5 + 0.01} A$$

$$I = 0.2854 \text{ A} = 285.4 \text{ mA}$$

$$\% \text{ Error} = \frac{0.2857 - 0.2854}{0.2857} \times 100$$

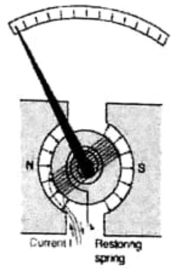
$$\% \text{ Error} = 0.1 \%$$



Designing an ammeter

- ammeter can be based on moving coil instrument
- simplest case: send current directly through a moving coil instrument, observe deflection of needle

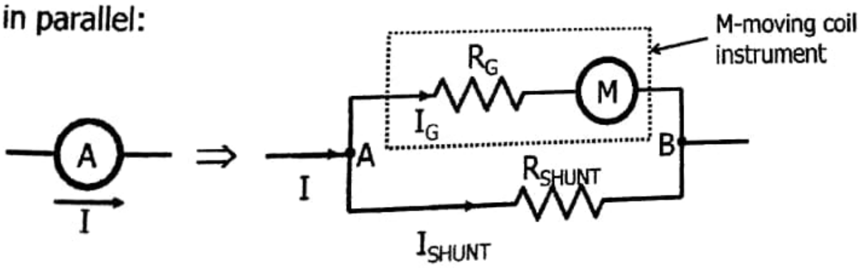
> Recall that needle deflection is proportional to current. Each instrument has a certain maximum current corresponding to full needle deflection.



What if you need to measure a larger current?

- use **<u>shunt</u>** resistor

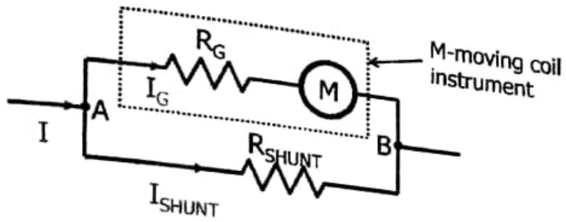
Ammeter uses a moving coil instrument and a shunt, connected in parallel:



Everything inside the dotted box is the ammeter.

- Current I gets split into I_{shunt} and I_G

> Homework hint:
> If your moving coil unit reads 1A full scale but you want the ammeter to read 5A full scale, then R_{SHUNT} must result in I_G=1A when I=5A. What are I_{SHUNT} and V_{SHUNT}?



Shunt also reduces resistance of the ammeter:

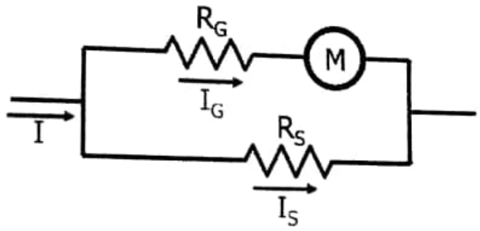
$$\frac{1}{R_A} = \frac{1}{R_G} + \frac{1}{R_{SHUNT}}$$

$$R_A = \frac{R_G\, R_{SHUNT}}{R_G + R_{SHUNT}}$$

Example: what shunt resistance is required for an ammeter to have a resistance of 10 mΩ, if the moving coil resistance is 60 Ω?

$$\frac{1}{R_A} = \frac{1}{R_G} + \frac{1}{R_S}$$

$$\frac{1}{R_S} = \frac{1}{R_A} - \frac{1}{R_G}$$



$$R_S = \frac{R_G\, R_A}{R_G - R_A} = \frac{(60)(.01)}{60 - .01} = 0.010\ \Omega$$

(actually 0.010002 Ω)

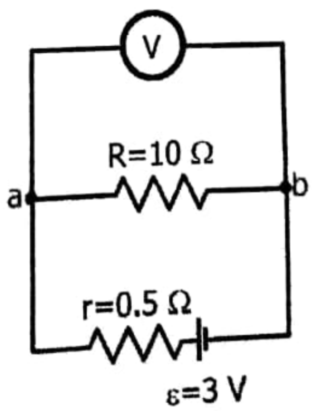
To achieve such a small resistance, the shunt is probably a large-diameter wire or solid piece of metal.

Effect of voltmeter on circuit

Measuring voltage (potential difference) V_{ab} in a simple circuit:

- connect voltmeter in parallel

Are we measuring the correct voltage?
(the voltage in the circuit without voltmeter)



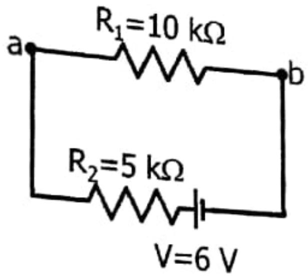
Example: a moving coil of resistance 60 Ω is used to measure the voltage drop across a 10 kΩ resistor in series with an ideal 6 V battery and a 5 kΩ resistor. What is the relative error caused by the nonzero resistance of the moving coil?

Actual voltage drop without instrument:

$$R_{eq} = R_1 + R_2 = 15\times10^3\ \Omega$$

$$I = \frac{V}{R_{eq}} = \frac{6\ \text{V}}{15\times10^3\ \Omega} = 0.4\times10^{-3}\ \text{A}$$

$$V_{ab} = IR = \left(0.4\times10^{-3}\right)\left(10\times10^3\ \Omega\right) = 4\ \text{V}$$



The measurement is made with the moving coil instrument.

60 Ω and 10 kΩ resistors in parallel are equivalent to 59.6 Ω resistor.

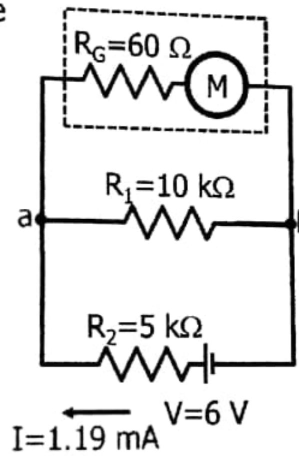
Total equivalent resistance: 5059.6 Ω

Total current: $I=1.186\text{x}10^{-3}$ A

V_{ab} = 6V − IR_2 = 0.07 V.

The relative error is:

$$\%\ \text{Error} = \frac{4-.07}{4}\times100 = 98\%$$

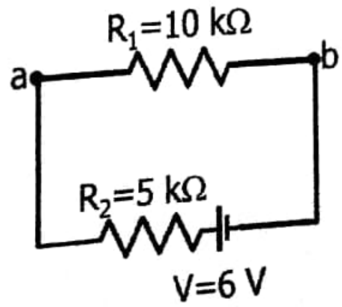


Would you pay for this voltmeter?
We need a better instrument!

Example: a voltmeter of resistance 100 kΩ is used to measure the voltage drop across a 10 kΩ resistor in series with an ideal 6 V battery and a 5 kΩ resistor. What is the percent error caused by the nonzero resistance of the voltmeter?

We already calculated the actual voltage drop (2 slides back).

$$V_{ab} = IR = \left(0.4\times10^{-3}\right)\left(10\times10^3\ \Omega\right) = 4\ \text{V}$$



The measurement is now made with the "better" voltmeter.

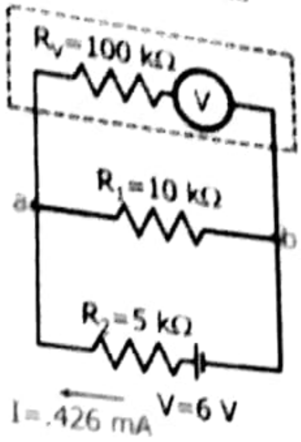
100 kΩ and 10 kΩ resistors in parallel are equivalent to an 9090 Ω resistor.
Total equivalent resistance: 14090 Ω

Total current: $I=4.26\times10^{-4}$ A

The voltage drop from a to b:
$6-(4.26\times10^{-4})(5000)=3.87$ V.

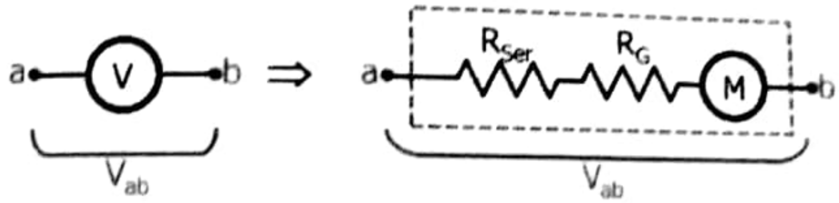
The percent error is.

$$\% \text{Error} = \frac{4-3.87}{4}\times 100 = 3.25\%$$



Not great, but much better.

- voltmeter must have a very large resistance
- voltmeter can be made from moving coil instrument in series with a large resistance



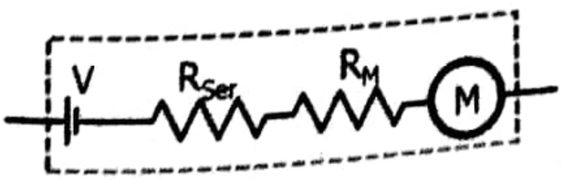
Everything inside the blue box is the voltmeter.
This series resistance is called Voltmeter **Multiplier**.

Homework hints: "the moving coil reads 1A full scale" would mean a current of $I_G=1A$ would produce a full-scale deflection of the needle.

If you want the voltmeter shown to read 10V full scale, then the selected R_{Ser} must result in $I_G=1A$ when $V_{ab}=10V$.

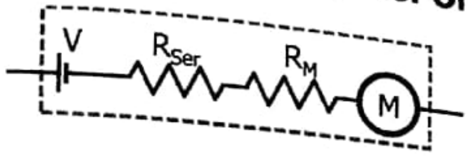
Measuring Instruments: Ohmmeter

- Ohmmeter measures resistance of isolated resistor
- Ohmmeter can be made from a moving coil instrument, a series resistance, and a battery (active device).

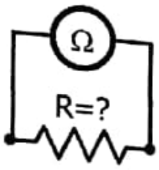


Everything inside the blue box is the ohmmeter.

Measuring Instruments: Ohmmeter



- Terminals of ohmmeter are connected to unknown resistor
- battery causes current to flow and moving coil to deflect
- $V=I\ (R_{ser} + R_G + R)$ solve for unknown R

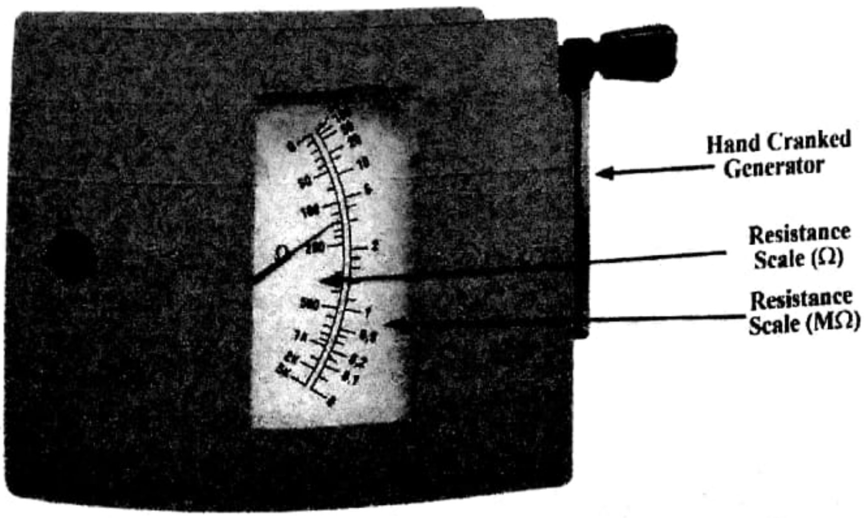


Homework: For direct reading ohmmeter, how will be the scale markings of the moving coil instrument?

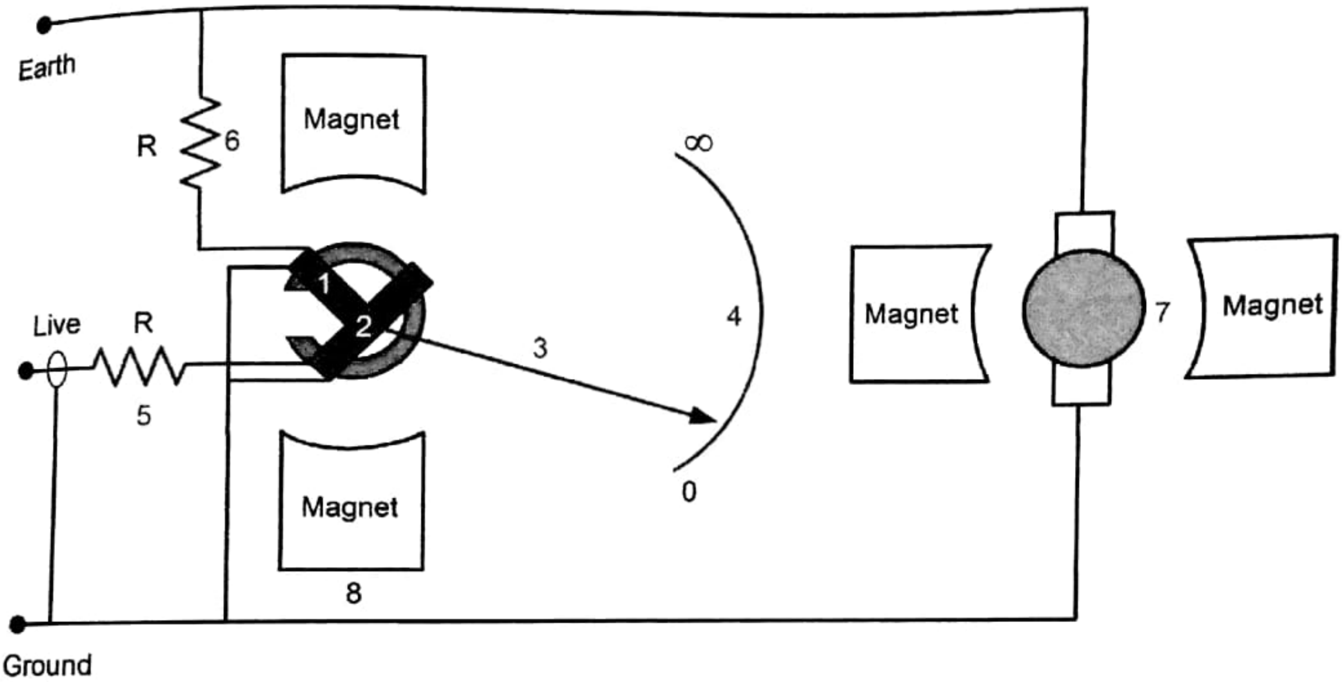
How to measure the insulation resistances in the order of tens of megaohm?

The current through the moving coil will be so less that the pointer will not deflect!!!

- A special instrument called insulation resistance tester
- It is commonly called "**Megger**" or "Megohmmeter" because Megger was the company who first invented it to measure very high insulation resistances.
- A high voltage source is required to pass a measurable current through such resistances. Thus, the megger is essentially an ohmmeter with a sensitive deflection instrument and a high voltage source. As illustrated in figure (1), the voltage is usually produced by a hand-cranked generator. The generated voltage may range from 100 V to 2.5 kV



Megohmmeter Circuit Diagram



1 and 2: Control and Deflecting Coil

They are typically mounted to each other at an angle of 90 degrees and linked to the generator in a parallel manner. The polarities are in such a way that the torque developed by these coils is in opposite direction.

3 and 4: Scale and Pointer

A pointer is tied to the coils and end of the pointer moves on a meter scale having a range between "zero" and "infinity". The scale is calibrated in "ohms".

5 and 6: Pressure Coil and Current Coil resistances

They provide protection against any damage in case of low external resistance under test.

7: D.C generator or battery connection

In manually operated megger, a DC generator provides test voltage while in digital typemegger, this is done by battery or voltage charger.

8: Permanent Magnets

Permanent magnets generate a magnetizing effect in order to deflect the pointer.

How to use Megohmmeter

1. Isolate the equipment to be tested from all power circuits
2. Connect leads to the appropriate terminals for insulation testing
3. Set the function switch to the desired voltage the meter will induce into the electrical component