CMR INSTITUTE OF TECHNOLOGY	USN		

Internal Assessment Test –II

Sub:	Introduction to Electrical Engineering							Code:	1BESC104B
Date:	08/01/2026	Duration:	90 mins	Max Marks:	50	Sem:	II sem	Branch:	Chemistry cycle(I ,J,K and L)

Answer any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1 a)	Explain the following characteristics of a D.C. shunt motor and series motor. a)Torque vs armature current b)Speed vs armature current	5	CO3	L2
b)	In a residential house, the following loads are connected: (i) Six lamps of 40 W each, switched on for 5 hours a day ii) Two fans of 60W each, switched on for 12 hours a day (iii) One 1000 W heater working for 2 hours per day (iv) One refrigerator of 250 W working for 10 hours per day.If each unit of energy costs Rs. 6.50, what will be the total cost in the month of April?	5	CO5	L3
2a)	What is earthing? Explain about plate earthing with a neat diagram.	5	CO5	L2
b)	A 4 pole, short shunt compound generator has armature, shunt field and series field resistances of 0.4 Ω, 160 Ω and 0.2 Ω respectively. The armature is lap connected with 440 conductors and is driven at 600 rpm. Calculate the flux per pole when the machine is delivering 120 A at 400 V.	5	CO3	L3
3 a)	Explain with neat diagram the speed control of DC shunt motor.	5	CO3	L2
b)	A long shunt compound generator has an armature, series field and shunt field resistances of 0.04 Ω, 0.03 Ω and 200 Ω respectively. It supplies a load current of 180 A at 400 V. Calculate the generated e.m.f. Assume the contact drop per brush is 1 V.	5	CO3	L3
4 a)	What is transformer. Differentiate between Core and Shell type of transformer.	5	CO4	L2
b)	A 4 pole D.C. shunt motor takes 25A from a 250V supply. The armature and field resistances are 0.5Ω and 125Ω respectively. The wave wound armature has 30 slots and each slot	5	CO3	L3

	containing 10 conductors. If the flux per pole is 0.02wb, calculate i) speed ii) torque developed iii) power developed.			
5a)	Derive an expression for armature torque developed in a D. C. motor.	5	CO3	L1
b)	A 250KVA single phase transformer has 98.135% efficiency at full load and 0.8 lagging power factor. The efficiency at half load and 0.8 lagging power factor is 97.75%. Calculate full load iron loss and copper loss.	5	CO4	L3
6a)	Compare squirrel cage and slip ring types of induction motor with neat diagram	5	CO4	L2
b)	A transformer is rated at 100 kVA. At full load its copper loss is 1200W and its iron loss is 960W. Calculate: i) the efficiency at full load, UPF ii) the efficiency at half load, 0.8 p.f. iii) the load kVA at which maximum efficiency will occur iv) maximum efficiency at 0.85 p.f.	5	CO4	L3
7a)	With neat wiring diagram and truth table explain two way and three way control of lamp.	6	CO5	L2
b)	A 4 pole, 3phase, 50 Hz induction motor runs at a speed of 1470 rpm. Find the synchronous speed , the slip and frequency of the induced EMF in the rotor under this condition	4	CO4	L3

CI CCI HOD

Solutions

1a)

SPEED Vs ARMATURE CURRENT CHARACTERISTIC

Shunt Motor :-

$I_{sh} = \frac{V}{R_{sh}}$.

I_{sh} is constant with constant supply voltage and flux decreases slightly due to armature reaction. Thus flux is constant. (neglecting effect of armature reaction)

$$\text{Speed} = \frac{E_b}{K\phi}$$

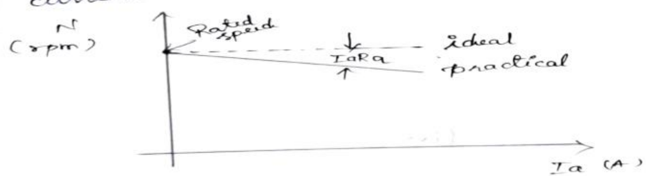
$$N = \frac{V - I_aR_a}{K\phi}$$

$$N \propto \frac{V - I_aR_a}{\phi}$$

$\boxed{N \propto V - I_aR_a}$ (flux constant)

↳ eqn of straight line with −ve slope.

i.e N decreases linearly with increase in armature current.



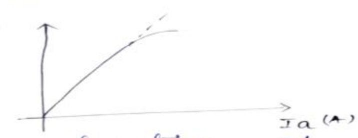
* The decrease in speed from no load to full load is very small ∴ the shunt motor may be taken as a constant speed motor.

$$T \propto \phi I_a$$

Thus the torque developed by a dc motor is directly proportional to the product of flux per pole and armature current.

⟹ Shunt motor :-
ϕ is nearly constant

∴ $\boxed{T \propto I_a}$



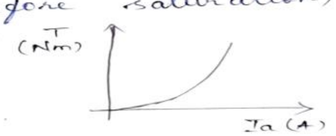
in high current region due to saturation of the core, the chac loses linearity.

⟹ Series motor :

$T \propto \phi I_a$

in series motor $\phi \propto I_a$ (before saturation)

∴ $T \propto I_a^2$ (parabolic)



At heavy loads, when core gets saturated ϕ is almost constant.

1 b)

6 lamps − 6×40 = 240 × 5hrs

= 1200 Wh

= 1.20 kwh

2 fans − 2×60 = 120 × 12 hrs.

= 1440 Wh

= 1.44 kwh

1 heater = 1 × 1000 = 1000 × 2 hrs

= 2000 Wh

= 2 kwh

1 Refrigerator = 1 × 250 = 250 w × 10 hrs

= 2500 Wh

= 2.5 kwh.

Total = 7.14 kwh.

1 unit = Rs 6.50/-

∴ 7.14 kwh = Rs 46.41/-

Total cost for April

= 46.41 × 30

= Rs 1392.30/-

2a)

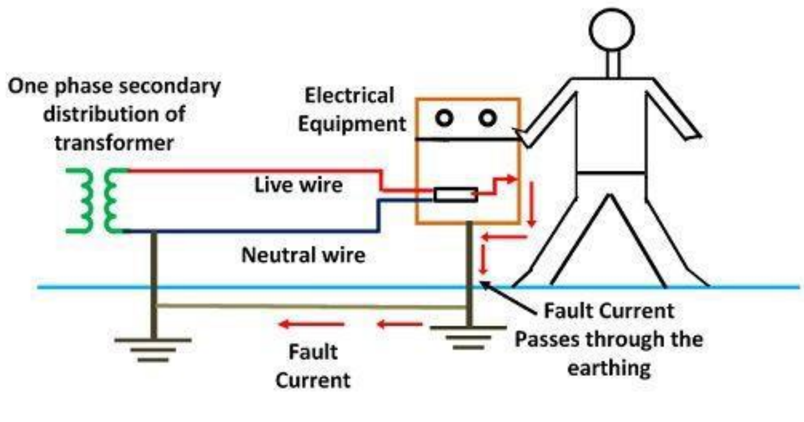
Earthing and Its Importance

•Theprocessoftransferringtheimmediatedischargeoftheelectricalenergydirectlytotheearthbythe helpofthelowresistancewireisknownastheelectricalearthing.

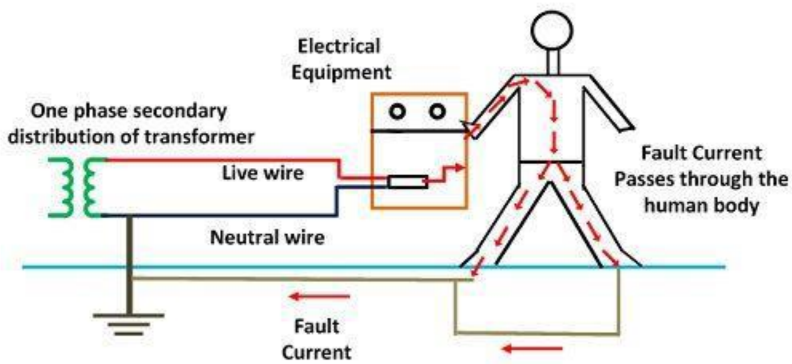
•Theearthingprotectsthepersonnelfromtheshortcircuitcurrent.

•Theearthingprovidestheeasiestpathtotheflowofshortcircuitcurrentevenafterthefailureoftheinsu lation.

•Theearthingprotectstheapparatusandpersonnelfromthehighvoltagesurgesandlightningdischarg e.

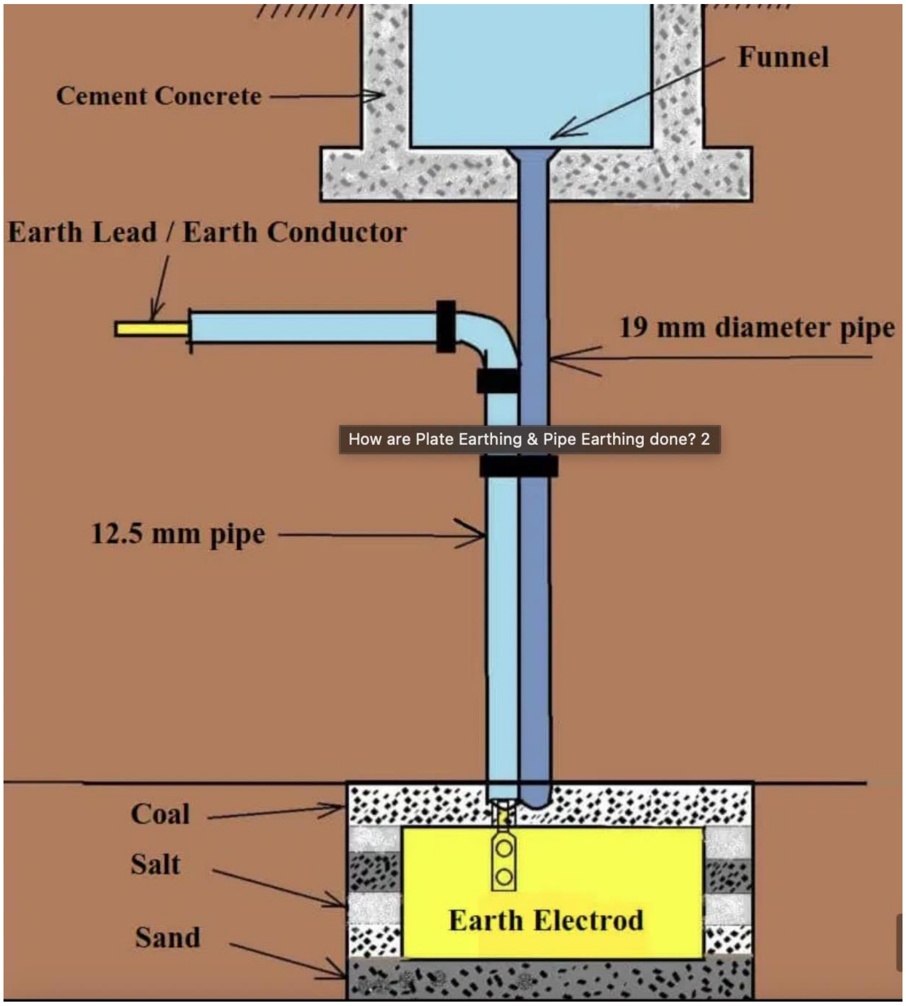


Electrical System With Earthing



Electrical System Without Earthing

Plate Earthing

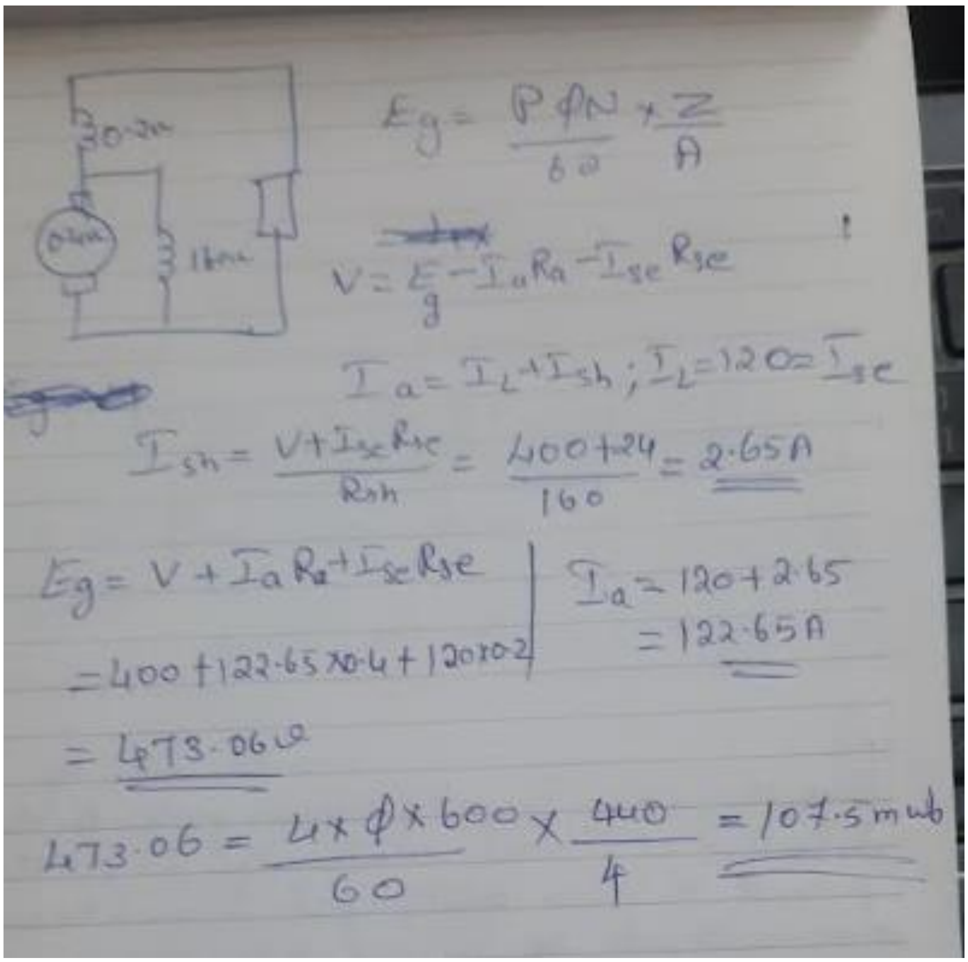


In that pit, 60 cm long × 60 cm wide and 3.15 mm thick copper Plate or 60 cm long × 60cm wide and 6.3 mm thickness G.I. Plate is used as a main electrode. Two Pipes of diameter 19 mm and 12.7 mm are added to that Plate. A funnel is attached at the top end of the Pipe with a diameter of 19 mm. An open copper / G.I. for connection to the Earth electrode. The wire comes out of the ground via a 12.7 mm diameter Pipe.A layer of sand, salt and coal of 15 cm each is laid around the electrode. Such layer is laid up to 90 cm. After the rest of the pit is filled with black soil, usually after 2.5 meters, the Pipe with earth conductor gets out, where the connection of Earthing is to be done. The Pipe which has a funnel on the top end. A 30cm × 30cm cement concrete tank is built around the ground around the Pipe, and is covered with a lid made of cast iron. In this way Earthing is done by conveying the Plate to the main switch and from there to the earth conductor to the required location. This type of Earthing is done in generating stations and sub stations.

Salt and Coal are poured around the earth electrode. Because salt soaks the ground alkali. And coal makes the ground moisture ashes. Which increases the conductivity of the ground. The conductivity of the land will be high, only then the leakage current will easily go into the ground.

The ground dries up during the summer season. Due to which the conductivity of the ground is reduced. To increase the moisture in the ground, water is poured through the funnel into the Earthing. A cast iron lid is placed over the Earthing funnel so that the path of pouring water into the earring is not closed.

2b)



$E_g = \frac{P\phi N}{60} \times \frac{Z}{A}$

$V = E_g - I_a R_a - I_{se} R_{se}$

$I_a = I_L + I_{sh}$; $I_L = 120 = I_{se}$

$I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}} = \frac{400+24}{160} = 2.65A$

$E_g = V + I_a R_a + I_{se} R_{se}$

$= 400 + 122.65 \times 0.4 + 120 \times 0.2$

$= 473.06V$

$I_a = 120 + 2.65 = 122.65A$

$473.06 = \frac{4 \times \phi \times 600}{60} \times \frac{440}{4} = 107.5 mwb$

3a)

Speed control of DC Motors

For a dc motor, w.k.T, $E_b \propto \phi N$

Re-arranging

$$N \propto \frac{E_b}{\phi}$$

$$N = \frac{E_b}{K\phi}$$

where K is the motor constant.

DC SHUNT MOTOR

$$\therefore N = \frac{V - I_a R_a}{K\phi} \leftarrow \boxed{\because E_b = V - I_a R_a}$$

Therefore the speed can be varied by varying

* voltage of the armature (V)
* resistance in the armature circuit (R_a)
* the flux per pole.

Change in the armature voltage and external resistance involves a change that affects the armature circuit while flux involves change in the magnetic field.

Thus the speed control of DC motor can be classified into,

1. Armature control method
2. Field control method.

Armature control of DC Shunt Motor.

* Armature voltage control
* Armature resistance control

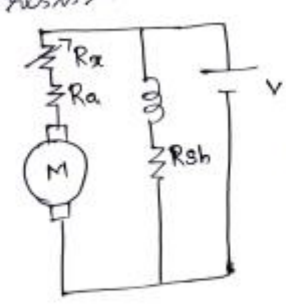
Armature voltage control:

In this method of speed control, the flux is maintained constant and the armature voltage is varied to vary the speed. i.e the field winding receives a fixed voltage and armature gets a variable voltage. Therefore it involves the use of switchgear mechanism to provide a variable voltage to armature.

Since $N \propto V - I_a R_a$, the speed can be controlled from 0 to rated value by varying armature voltage from 0 to V.

Armature Resistance Control:-

This method uses a variable resistance in series with armature circuit to vary the armature voltage which in turn controls the speed. Since it involves power loss in the resistor, it is not the preferred one.

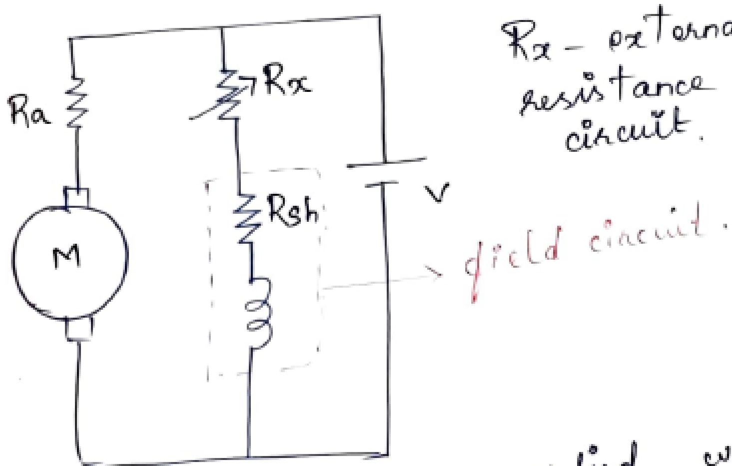


⇐ armature R control.

R_x - ext resistance in armature to vary the armature voltage.

Field or flux control

In this method, the armature voltage is kept constant and field current (flux) is varied by using a variable resistor in series with the field winding resistor.



Rx - external variable resistance in field circuit.

When the rated voltage is applied with Rx at minimum position, the rated current flows through field winding and the speed is at rated range. When the Rx is increased gradually, the field flux decreases and the speed of the motor increases beyond its rated value.

$$N \propto \frac{1}{\phi}$$ → in case of flux control

3b)

$$E_g = V + I_a(R_a + R_{se}) + 1 \times 2$$

~~Eg~~ $I_L = 180A$

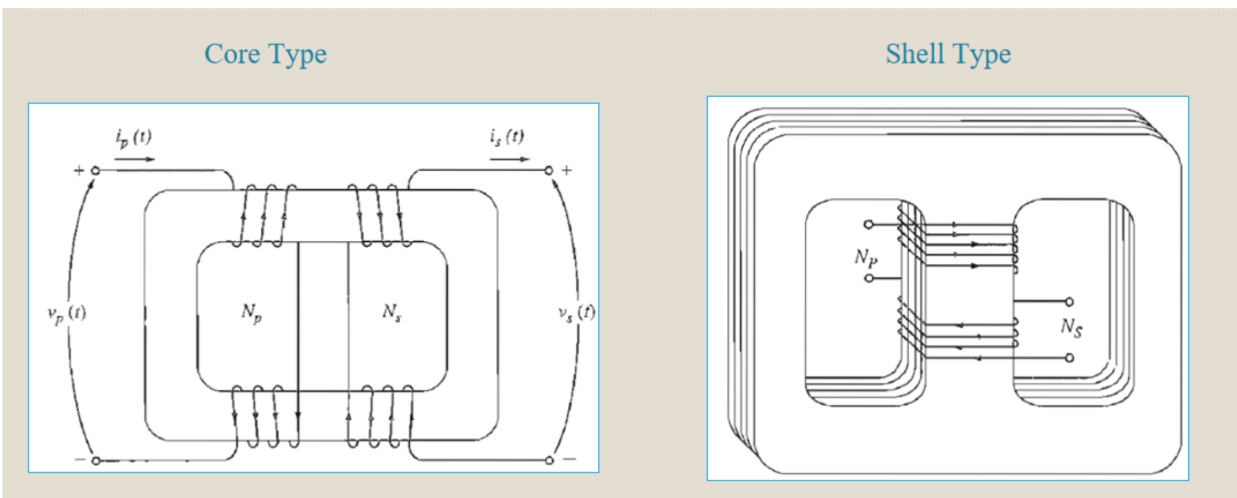
$$I_a = I_{sh} + I_L$$

$$I_{sh} = V/R_{sh} = 400/200 = \underline{\underline{2A}}$$

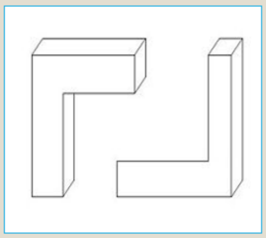
$$I_a = 2 + 180 = \underline{\underline{182A}}$$

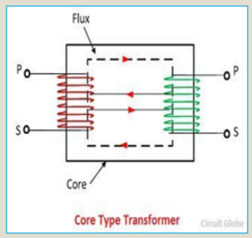
$$E_g = 400 + 182(0.04 + 0.03) + 2$$
$$= 414.74V$$

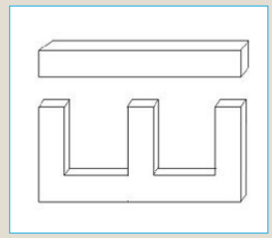
4a)

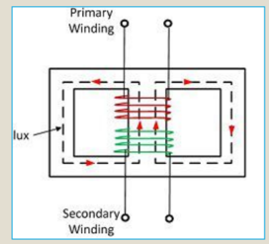


Core Type	Shell Type
1. The winding encircles the core	1. The core encircles the winding
2. The lamination is cut in the form of the L strips.	2. Lamination are cut in the form of the long strips of E and L.
3. Cross-section may be square, cruciform and three stepped	3. The cross section is rectangular in shape.
4. Two limbs	4. Three limbs
5. The primary and secondary winding are placed on the side limbs.	5. Primary and secondary windings are placed on the central limb

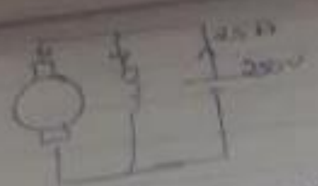








4b)



$I_{sh} = \frac{250}{125} = 2A$

$I_a = 25 - 2 = 23A$

$E_b = V - I_a R_a - 2$

$= 250 - 23 \times 0.5 - 2 = 236.5V$

$E_b = \frac{P\phi N}{60} \frac{Z}{A}$

$236.5 = \frac{4 \times 0.02 \times 30 \times 10}{60} \times \frac{N}{2}$

1) $N = 1183$ rpm

2) $T = \frac{E_b I_a}{\omega} = \frac{E_b \times I_a \times 60}{2\pi N} = \frac{236.5 \times 23 \times 60}{2\pi \times 1183}$

$= 43.93$ Nm

3) Power developed $= 5.439$ kW

5a)

Torque Equation of a dc motor :-

Voltage eqn of dc motor

$V = E_b + I_a R_a$ — (1)

×Ia, $V I_a = E_b I_a + I_a^2 R_a$ — (2)

VI_a → elec i/p to arm

$E_b I_a$ → elec equivalent of gross mech power

$I_a^2 R_a$ → cu loss in arm

i.e input = output + losses

$E_b I_a$ - electrical equivalent of gross mech power — (3)

Let T be the average electro-magnetic torque developed by armature in Nm (newton metres)

Mechanical power developed by armature

$$P_m = \omega \times T \quad — (4)$$

where $\omega = \frac{2\pi N}{60}$

i.e $P_m = \frac{2\pi N}{60} \times T$

Using (3) and (4),

$$E_b I_a = \omega T$$

$$\boxed{T = \frac{E_b I_a}{\omega}} \quad — (5)$$

W.K.T $E_b = \frac{P\phi N Z}{60 A}$

Sub E_b in (5), $T = \frac{P\phi Z N}{60 A} \times \frac{I_a}{2\pi N} \times 60$

$$\boxed{T = \frac{1}{2\pi} \frac{P\phi Z}{A} I_a} \quad — (6)$$

eqn (5) represents the torque eqn of dc motor

Considering eqn (6), P, Z and A are constant for given dc machine, $\therefore$ $T = K_t \phi I_a$

where $K_t = \frac{PZ}{2\pi A}$

5b)

$$\eta = \frac{x V_2 I_2 \cos\phi_2}{x V_2 I_2 \cos\phi_2 + P_i + x^2 P_{cu}}$$

At F.L

$$0.9814 = \frac{1 \times 250 \times 10^3 \times 0.8}{1 \times 250 \times 10^3 \times 0.8 + P_i + 1^2 \times P_{cu}}$$

$$P_i + P_{cu} = 3790.50 \quad \text{---(1)}$$

At half F.L

$$0.9775 = \frac{0.5 \times 250 \times 10^3 \times 0.8}{0.5 \times 250 \times 10^3 \times 0.8 + P_i + (0.5)^2 P_{cu}}$$

$$P_i + 0.25 P_{cu} = 2301.79 \quad \text{---(2)}$$

$$P_{cu} = 1984.95 \text{ W}$$

$$P_i = 1805.55 \text{ W}$$

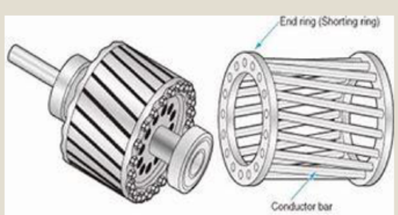
6a)

Rotor

- The rotor is also built of thin laminations of the same material as the stator. The laminated cylindrical core is mounted directly on the shaft. These laminations are slotted on the outer side to receive the conductors. There are two types of rotor.
- (i) Squirrel Cage Rotor
- (ii) Phase Wound Rotor

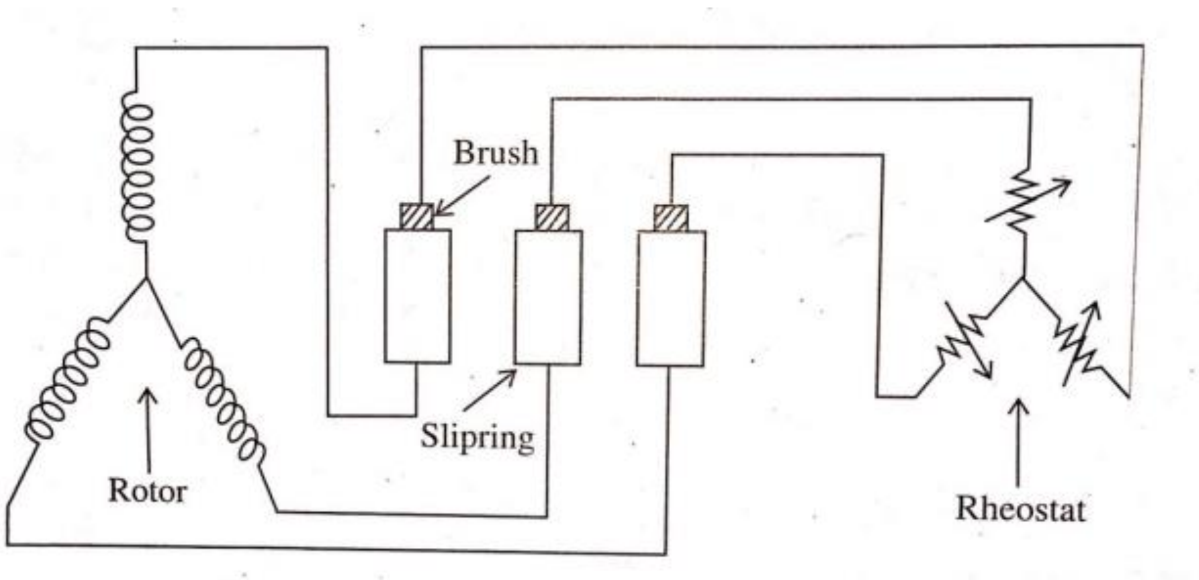
Squirrel cage rotor

- **Squirrel Cage Rotor**
- A squirrel cage rotor consists of a laminated cylindrical core. The circular slots at the outer periphery are semi-closed. Each slot contains uninsulated bar conductor of aluminium or copper. At the end of the rotor the conductors the short-circuited by a heavy ring of copper or aluminum. The rotor slots are usually not parallel to the shaft but are skewed.



Slip ring (wound) rotor

- **Phase Wound Rotor**
- The Phase wound rotor is also called as Slip Ring Rotor. It consists of a cylindrical core which is laminated. The outer periphery of the rotor has a semi-closed slot which carries a 3 phase insulated windings. The rotor windings are connected in star. The slip rings are mounted on the shaft with brushes resting on them. The brushes are connected to the variable resistor. The function of the slip rings and the brushes is to provide a means of connecting external resistors in the rotor circuit.



Comparison of Phase wound and Squirrel cage rotor IM

S.No	Phase Wound or Slip Ring IM	Squirrel Cage IM
1	Construction is complicated due to presence of slip ring and brushes	Construction is very simple
2	The rotor winding is similar to the stator winding	The rotor consists of rotor bars which are permanently shorted with the help of end rings
3	We can easily add rotor resistance by using slip ring and brushes	Since the rotor bars are permanently shorted, it is not possible to add external resistance
4	Due to presence of external resistance high starting torque can be obtained	Staring torque is low and cannot be improved
S.No	Slip ring and brushes are present	Slip ring and brushes are absent
5	This motor is rarely used only 10 % industry uses slip ring induction motor	Due to its simple construction and low cost. The squirrel cage induction motor is widely used
6	Rotor copper losses are high and hence less efficiency	Less rotor copper losses and hence high efficiency
7	Slip ring induction motor are used where high starting torque is required i.e. in hoists, cranes, elevator etc.	Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc.

6b)

2) $\eta_{HFL} = \dfrac{0.5 \times 100 \times 10^3 \times 0.8}{0.5 \times 100 \times 10^3 \times 0.8 + (0.5)^2 \times 1200 + 960} = 96.95\%$

3 $x^2 P_{cu} = P_i$

$x^2 \times 1200 = 960$

$x^2 = 960/1200 \Rightarrow x = \sqrt{\dfrac{960}{1200}} = 0.894$

$kVA_{max\,\eta} = 0.894 \times 100 \times 10^3 = 89.4\ kVA$

4) $\eta_{max} = \dfrac{0.894 \times 100 \times 10^3 \times 0.85}{0.894 \times 100 \times 10^3 \times 0.85 + (0.894)^2 \times 1200 + 960}$

$= 97.54\%$

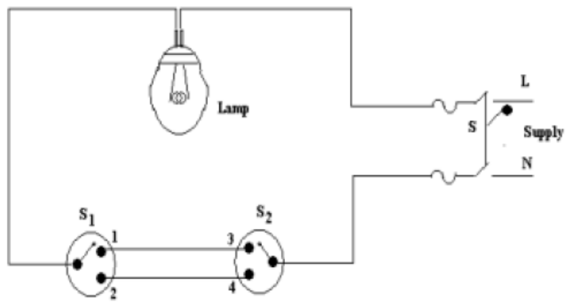
7a)

Two- way and Three- way Control of Lamps:

The domestic lighting circuits are quite simple and they are usually controlled from one point. But in certain cases it might be necessary to control a single lamp from more than one point (Two or Three different points). For example: staircases, long corridors, large halls etc.

(i)Two-way Control of lamp:

Two-way control is usually used for staircase lighting. The lamp can be controlled from two different points: one at the top and the other at the bottom - using two- way switches which strap wires interconnect. They are also used in bedrooms, big halls and large corridors. The circuit is shown in the following figure.



Two -way control of lamp

- Switches **S₁** and **S₂** are two-way switches with a pair of terminals 1&2, and 3&4 respectively.
- When the switch **S₁** is in position**1** and switch **S₂** is in position **4**, the circuit does not form a closed loop and there is no path for the current to flow and hence the lamp will be **OFF.**
- When **S₁** is changed to position **2** the circuit gets completed and hence the lamp glows or is **ON**. N

- ow if **S₂** is changed to position **3** with **S₁** at position **2** the circuit continuity is broken and the lamp is off.
- Thus the lamp can be controlled from two different points.

Position of S1	Position of S2	Condition of lamp
1	3	ON
1	4	OFF
2	3	OFF
2	4	ON

(ii)Three- way Control of lamp:

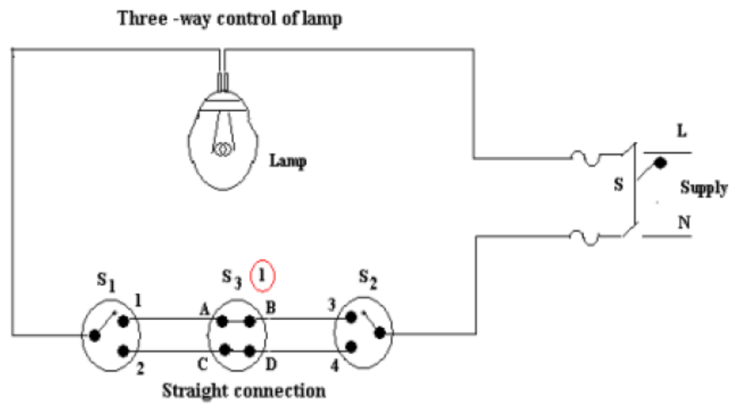
In case of very long corridors it may be necessary to control the lamp from 3 different points. In such cases, the circuit connection requires two; two-way switches **S_1** and **S_2** and an intermediate switch **S_3**. An intermediate switch is a combination of two, two way switches coupled together. It has 4 terminals ABCD. It can be connected in two ways:

a) Straight connection

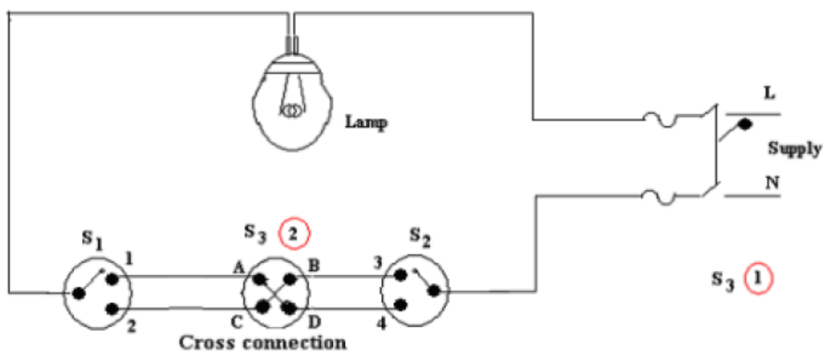
b) Cross connection

In case of straight connection, the terminals or points AB and CD are connected as shown in figure 1(a) while in case of cross connection, the terminals AB and CD is connected as shown in figure 1(b).

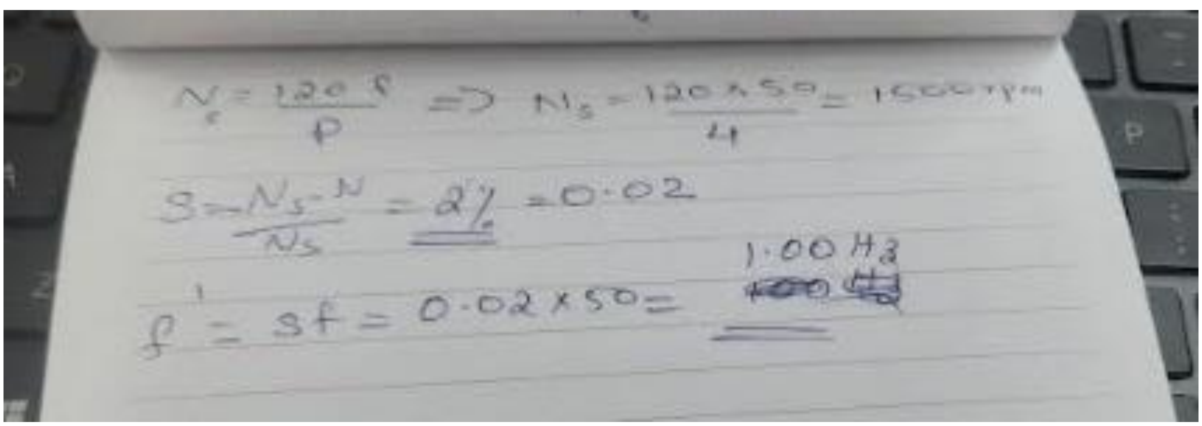
As explained in two ways control the lamp is ON if the circuit is complete and is OFF if the circuit does not form a closed loop.



The condition of the lamp depends on the positions of the switches **S1**, **S2**, and **S3**.



7b)



$N_s = \frac{120 f}{P} \Rightarrow N_s = \frac{120 \times 50}{4} = 1500 \text{ rpm}$

$S = \frac{N_s - N}{N_s} = 2\% = 0.02$

$f' = sf = 0.02 \times 50 = 1.00 \text{ Hz}$