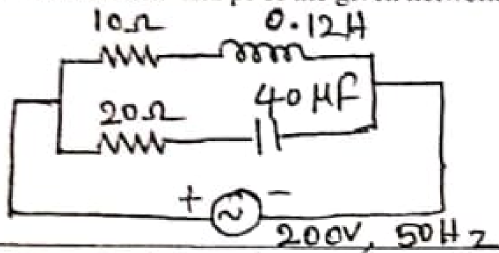
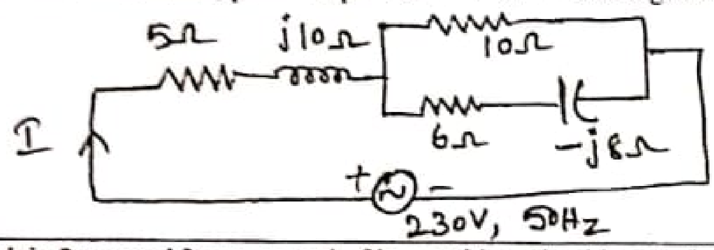
CMR INSTITUTE OF TECHNOLOGY									
Internal Assesment Test II – DEC 2018									
Sub:	BASIC ELECTRICAL ENGINEERING							Code:	18ELE13
Date:	05/12/2018	Duration:	90 mins	Max Marks:	50	Sem :	I	Section :	Physics cycle

Note: Answer any five **FULL** Questions

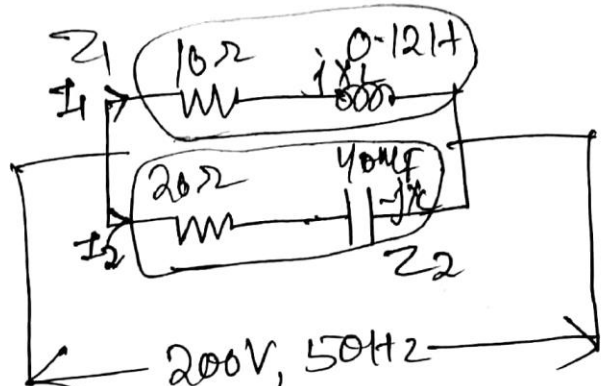
Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1 (a)	Find the current in each branch and pf of the given network 	[5]	CO2	L4
(b)	Find the total current, power & power factor of the circuit given 	[5]	CO2	L4
2	Explain 2way and 3way control of lamp with truth table and circuit diagram	[10]	CO5	L2
3 (a)	Obtain the expression for power factor using Two wattmeter method	[6]	CO3	L2
(b)	A 3 phase, 400 V supply is given to a balanced load which is star connected. Impedance in each phase of the load is 8 + j6 ohms. Determine the phase voltage, phase current.	[4]	CO3	L4
4 (a)	Describe briefly about the losses of a single phase transformer	[5]	CO4	L1
(b)	Obtain the EMF equation of a transformer	[5]	CO4	L2
5 (a)	What is efficiency? Derive the condition for max efficiency in a transformer.	[5]	CO4	L1
(b)	A 40 KVA Transformer has a core loss of 450 W and a full load copper loss of 850 W. If the load p.f is 0.8, calculate (a) efficiency at full load (b) load at which copper loss = iron loss	[5]	CO4	L4
6 (a)	A 10KVA single phase transformer has primary winding of 300 turns and secondary windings of 750 turns, cross sectional area of core is 64 cm^2 if the primary voltage is 440 volts at 50 Hz. Find maximum flux density in the core, EMF induced in the secondary of transformer. At 0.8 lagging pf, calculate the efficiency of transformer if full load copper loss is 400W & iron loss is 200W.	[6]	CO4	L4
(b)	What is phase sequence? What are the advantages of three phase power systems over single phase systems?	[4]	CO4	L1
7 a)	What is earthing? Explain any one type with neat diagram.	[5]	CO5	L2
b)	Explain the necessity and the operation of RCCB	[5]	CO5	L2
8 a)	Three phase 400V motor takes an input of 40KW at 0.45 pf lagging find the reading of each of two single wattmeters connected to measure input.	[5]	CO3	L4
b)	Explain delta connected 3 phase system and obtain the relationship between Line parameters and phase parameters.	[5]	CO3	L2

3/12/18

IAT-2 Solution (18ELE13)

1. a)



Ans: $Z_1 = 10 + jX_L$

$Z_2 = 20 - jX_C$

$X_L = \omega L = 2\pi f L$

$\Rightarrow X_L = 2\pi \times 50 \times 0.12 \Rightarrow X_L = 37.69$

$L = 0.12H$

$C = 40 \times 10^{-6} F$ 12

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 40 \times 10^{-6}}$

$\Rightarrow X_C = 79.57 \Rightarrow Z_1 = 10 + j37.69\ \Omega$

$Z_2 = 20 - j79.57\ \Omega$

(i) Current in each branch:

$I_1 = \frac{V}{Z_1} = \frac{200}{10 + j37.69} = 1.31 - 4.95j$ Amp.

$I_2 = \frac{V}{Z_2} = \frac{200}{20 - j79.57} = 0.59 + 2.36j$ Amp.

(ii) Total Impedance $= Z = \frac{V}{I} = Z_1 \parallel Z_2$

$$\Rightarrow Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{(10+j37.69)(20-j79.57)}{10+j37.69+20-j79.57}$$

$\Rightarrow Z = 36.822 + 50j$ $\Rightarrow$ In polar form

$\Rightarrow Z = 62.1 \angle 53.63°$ //

phase angle = pf angle $= \phi = \angle Z = 53.63°$ //

+ve so pf is lagging

$pf = \cos\phi = \cos(53.63) = 0.59$ lagging. //

1.(b)

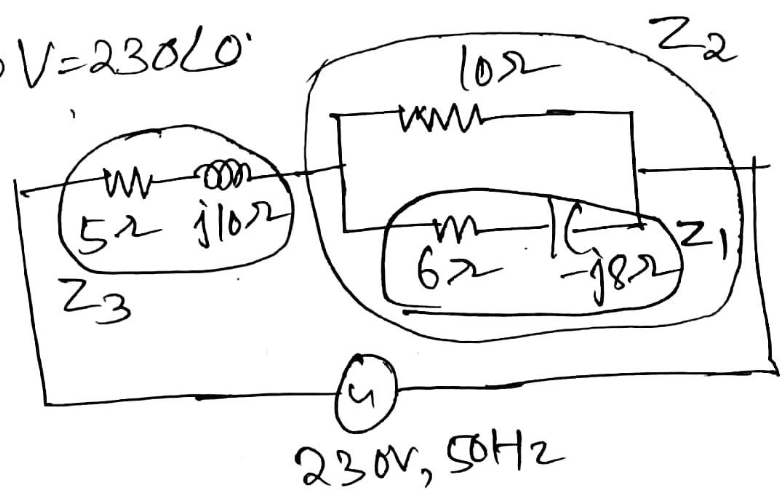
Ans:- $V_s = 230V$ (RMS) $\Rightarrow V = 230\angle 0°$

$Z_1 = 6 - j8\ \Omega$

$Z_2 = Z_1 \parallel R =$ ~~6-j8~~ $\frac{Z_1 R}{Z_1 + R}$

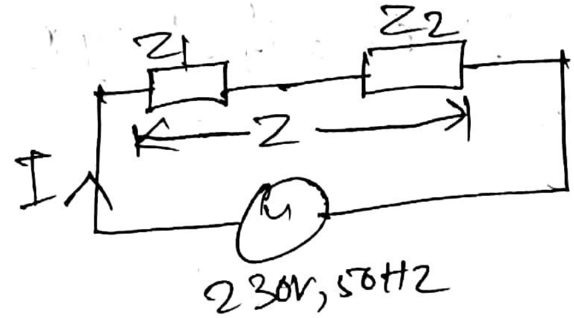
$$\Rightarrow Z_2 = \frac{(6-j8)\times 10}{(6-j8+10)}$$

$\Rightarrow Z_2 = 5 - 2.5j$



$Z_3 = 5 + j10\ \Omega$

Total Impedance:-



$Z = Z_1 + Z_2$

$= 5 - 2.5j + 5 + 10j$

$Z = 10 + 7.5j$ ⇒ Change into polar Form

$Z = 12.5 \angle 36.86$ //

So power factor angle of Circuit = angle of Impedance

⇒ $\phi = \angle Z = 36.86$ // (+ive so pf is lagging) (Inductive Circuit)

Power Factor = $pf = \cos\phi = \cos(36.86) = 0.8$ lagging //

~~Total Power~~ Current of Circuit = $I = \frac{V}{Z}$

⇒ $I = \frac{230 \angle 0}{12.5 \angle 36.86} = 18.4 \angle -36.86$ Amp //

Total Power = Complex Power = VI^*

⇒ ~~Q P~~ $S = 230 \angle 0 \times 18.4 \angle 36.86$

⇒ ~~S = 3386.03~~ +

$S = 3386.03 + 2538.61j$ VA //

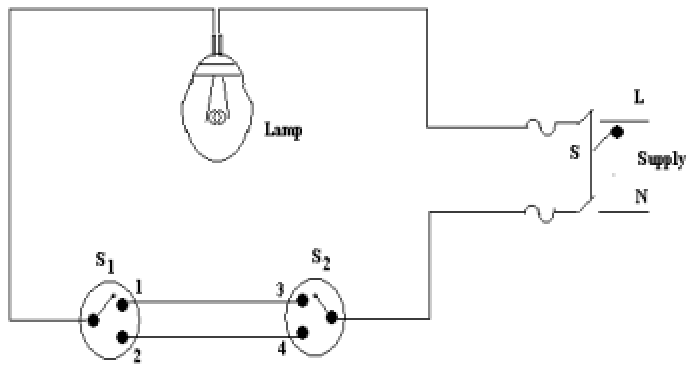
Average or Real Power = $Re[S] = 3386.03$ Watt //

2. 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 S_1 and S_2 are two-way switches with a pair of terminals 1&2, and 3&4 respectively.
- When the switch S_1 is in position**1** and switch S_2 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 S_1 is changed to position **2** the circuit gets completed and hence the lamp glows or is **ON**. N
- ow if S_2 is changed to position **3** with S_1 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:

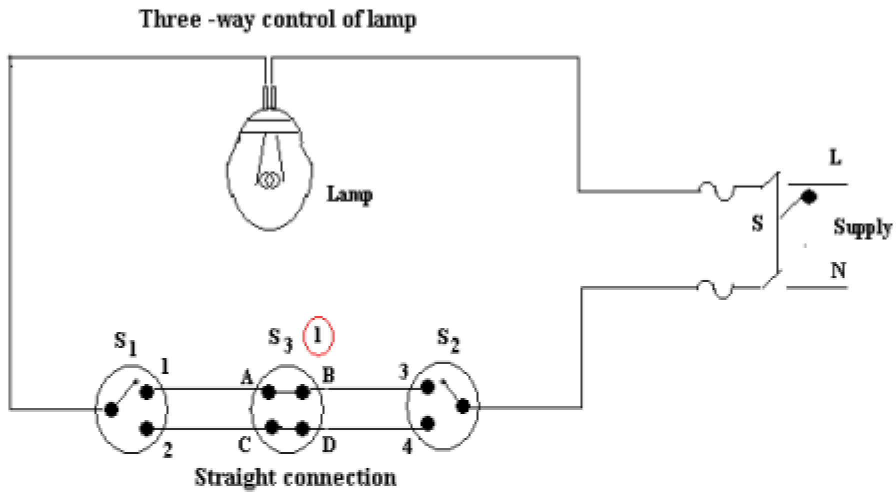
In case of very long corridors it may be necessary to control the lamp from 3 different points. In such cases, the circuit connection requires two; two-way switches S_1 and S_2 and an intermediate switch S_3. An intermediate switch is a combination of two, two way switches coupled together. It has 4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

a) Straight connection

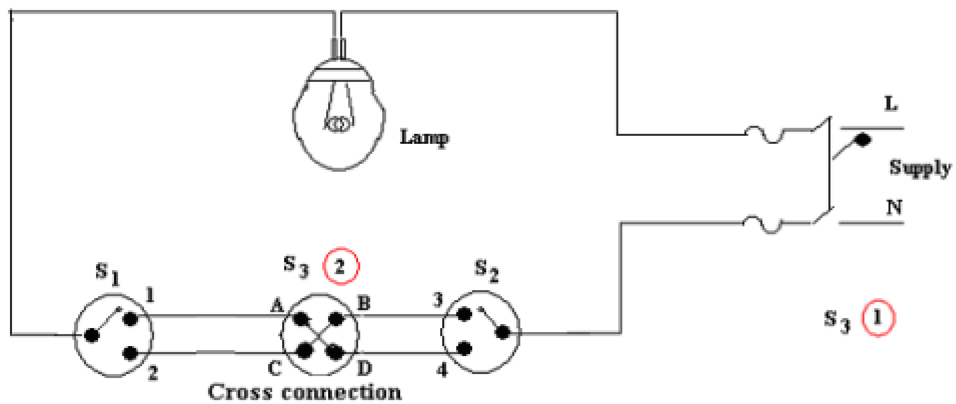
b) Cross connection

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.



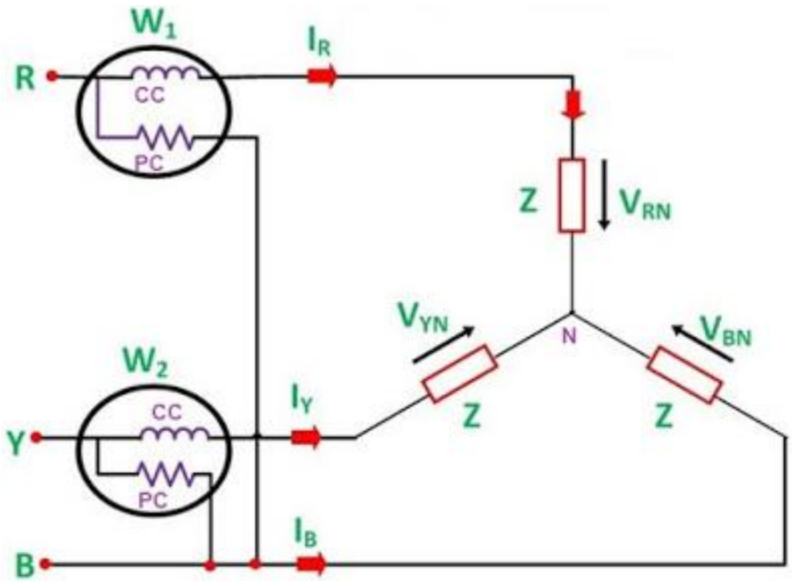
The condition of the lamp depends on the positions of the switches **S1**, **S2**, and **S3**.



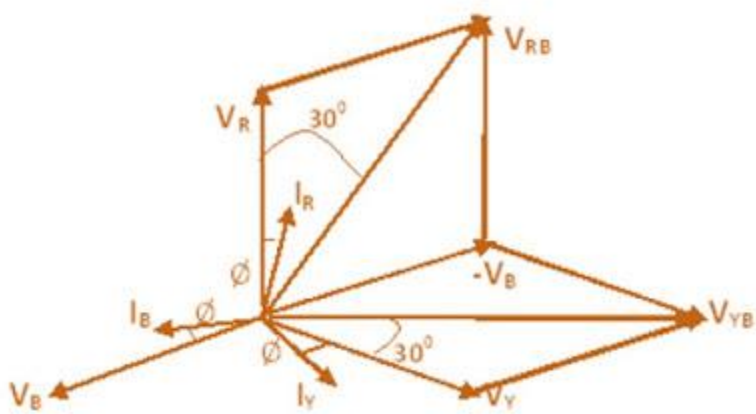
3. a) Two Wattmeter Method:

In two wattmeter method, a three phase balanced voltage is to a balanced three phase load where the current in each phase is assumed lagging by an angle of Ø behind the corresponding phase voltage.

The schematic diagram for the measurement of three phase power using two wattmeter method is shown below.



From the figure, it is obvious that current through the Current Coil (CC) of Wattmeter $W_1 = I_R$, current though Current Coil of wattmeter $W_2 = I_B$ whereas the potential difference seen by the Pressure Coil (PC) of wattmeter $W_1= V_{RB}$ (Line Voltage) and potential difference seen by Pressure Coil of wattmeter $W_2 = V_{BY}$. The phasor diagram of the above circuit is drawn by taking VR as reference phasor as shown below.



From the above phasor diagram,

Angle between the current I_R and voltage V_{RB} = (30° – Ø)

Angle between current I_Y and voltage V_{YB} = (30° + Ø)

Therefore, Active power measured by wattmeter $W_1 = V_{RB}I_R$ Cos (30° – Ø)

Similarly, Active power measured by wattmeter $W_2 = V_{YB}I_Y$Cos(30° + Ø)

As the load is balanced, therefore magnitude of line voltage will be same irrespective of phase taken i.e. V_{RY}, V_{YB} and V_{RB} all will have same magnitude. Also for Star / Y connection line current and phase current are equal, say $I_R = I_Y = I_B = I$

Let $V_{RY} = V_{YB} = V_{RB} = V_L$

Therefore,

$W_1 = V_{RB}I_R Cos\ (30° – Ø)$

$= V_L I Cos(30° – Ø)$

In the same manner,

$W_2 = V_L I Cos(30° + Ø)$

Hence, total power measured by wattmeters for the balanced three phase load is given as,

$W = W_1 + W_2$

$= V_L I×Cos(30° – Ø) + V_L I×Cos(30° + Ø)$

$= V_L I\ [Cos(30° – Ø) + Cos(30° + Ø)]$

$= 2V_L I×Cos30°CosØ$ ……………….[$CosC + CosD = 2Cos(C+D)/2×Cos(C-D)/2$]

$=\sqrt{3}V_L ICosØ$

Therefore, total power measured by wattmeters $W = \sqrt{3}V_L ICosØ$

Now, suppose you are asked to find the power factor of the load when individual power measured by the wattmeters are given, then we should proceed as

$W_1 + W_2 = \sqrt{3}V_L ICosØ$ ……………………………..(1)

Similarly,

$W_1 – W_2= V_L I×Cos(30° – Ø) + V_L I×Cos(30° + Ø)$

$= V_L I\ [Cos(30° – Ø) + Cos(30° + Ø)]$

$= 2V_L I×Sin30°SinØ$ ………[$CosC – CosD = 2Sin(C+D)/2×Sin(D-C)/2$]

$= V_L ISinØ$

Hence,

$W_1 – W_2 = V_L ISinØ$ ………………………………(2)

Dividing equation (2) by equation (1),

$(W_1 – W_2) / (W_1 + W_2) = V_L ISinØ / \sqrt{3}V_L ICosØ$

$(W_1 – W_2) / (W_1 + W_2) = (tanØ) /\sqrt{3}$

Hence,

$$\tan\text{Ø} = \sqrt{3}[(W_1 - W_2) / (W_1 + W_2)]$$

From the above equation, we can find the value of Ø and hence the power factor Cos Ø of the load.

4. a) Losses In Transformer

In any electrical machine, 'loss' can be defined as the difference between input power and output power. An electrical transformer is a static device, hence mechanical losses (like windage or friction losses) are absent in it. A transformer only consists of electrical losses (iron losses and copper losses). Transformer losses are similar to losses in a DC machine, except that transformers do not have mechanical losses. **Losses in transformer** are explained below -

(I) Core Losses Or Iron Losses

Eddy current loss and hysteresis loss depend upon the magnetic properties of the material used for the construction of core. Hence these losses are also known as **core losses** or **iron losses**.

- **Hysteresis loss in transformer**: Hysteresis loss is due to reversal of magnetization in the transformer core. This loss depends upon the volume and grade of the iron, frequency of magnetic reversals and value of flux density. It can be given by, Steinmetz formula:
  $W_h = \eta B_{max}^{1.6} f V$ (watts)
  where, η = Steinmetz hysteresis constant
  V = volume of the core in m^3
- **Eddy current loss in transformer**: In transformer, AC current is supplied to the primary winding which sets up alternating magnetizing flux. When this flux links with secondary winding, it produces induced emf in it. But some part of this flux also gets linked with other conducting parts like steel core or iron body or the transformer, which will result in induced emf in those parts, causing small circulating current in them. This current is called as eddy current. Due to these eddy currents, some energy will be dissipated in the form of heat.

(Ii) Copper Loss In Transformer

Copper loss is due to ohmic resistance of the transformer windings. Copper loss for the primary winding is $I_1^2R_1$ and for secondary winding is $I_2^2R_2$. Where, I_1 and I_2 are current in primary and secondary winding respectively, R_1 and R_2 are the resistances of primary and secondary winding respectively. It is clear that Cu loss is proportional to square of the current, and current depends on the load. Hence copper loss in transformer varies with the load.

4(b) EMF equation for 1ø transformer:-

Consider ac sinusoidal flux,

Ø=Øm sinwt

By faraday's law of electromagnetic induction EMF induced is, for a single turn.

$e = -d\text{Ø}/dt$

For N, number of turn

$e = -N d\emptyset/dt = N(-d(\emptyset_m \sin wt)/dt) = N\emptyset_m (\cos wt) w = -N\emptyset_m 2\pi f \cos wt = \emptyset_m N.2\pi \sin(wt - \pi 2) e_{max}$

$N.\emptyset_m 2\pi f = E_{RMS} = e_{max}/\sqrt{2} = 4.44 N N\emptyset_m f$

Primary induced emf, $E_1 = 4.44 N_1 \emptyset_m f$

$E_2 = 4.44 N_2 \emptyset_m f$

5. a) Transformer Efficiency

The **Efficiency** of the transformer is defined as the ratio of useful power output to the input power. The input and the output power are measured in the same unit. Its unit is either in Watts (W) or KW. Transformer efficiency is denoted by η.

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\text{output power}}{\text{output power} + \text{losses}}$$

$$\eta = \frac{\text{output power}}{\text{output power} + \text{iron losses} + \text{copper losses}}$$

$$\eta = \frac{V_2 I_2 \cos\varphi_2}{V_2 I_2 \cos\varphi_2 + P_i + P_c}$$

Where,

- V_2 – Secondary terminal voltage
- I_2 – Full load secondary current
- $\cos\phi_2$ – power factor of the load
- P_i – Iron losses = hysteresis losses + eddy current losses
- Pc – Full load copper losses = $I_2^2 Res$

Maximum Efficiency Condition of a Transformer

The efficiency of the transformer along with the load and the power factor is expressed by the given relation.

$$\eta = \frac{V_2 I_2 \cos\varphi_2}{V_2 I_2 \cos\varphi_2 + P_i + I_2^2 R_{es}} = \frac{V_2 \cos\varphi_2}{V_2 \cos\varphi_2 + P_i/I_2 + I_2 R_{es}} \dots\dots\dots (1)$$

The value of the terminal voltage V_2 is approximately constant. Thus, for a given power factor the Transformer efficiency depends upon the load current I_2. In the equation (1) shown above the numerator is constant and the transformer efficiency will be maximum if the denominator with respect to the variable I_2 is equated to zero.

$$\frac{d}{dI_2} = \left(V_2 \, Cos\varphi_2 + \frac{P_i}{I_2} + I_2 R_{es} \right) = 0 \qquad or \qquad 0 - \frac{P_i}{I_2^2} + R_{es} = 0$$

Or

$$I_2^2 R_{es} = P_i \; \ldots \ldots \ldots . . (2)$$

i.e Copper losses = Iron losses

Thus, the transformer will give the maximum efficiency when their copper loss is equal to the iron loss.

$$\eta_{max} = \frac{V_2 I_2 Cos\varphi_2}{V_2 I_2 Cos\varphi_2 + 2P_i} \qquad as \, (P_c = P_i)$$

$$I_2 = \sqrt{\frac{P_i}{R_{es}}}$$

5. (b)

5 (b) 40 KVA Transformer ⇒ Full Load $E_2 I_2 = 40 \times 10^3$ VA

Full Load Core Loss = $W_i = 450W$ (Iron loss)

Full load Copper loss = $[W_{cu}]_{FL} = 850W$

pf = $\cos\phi = 0.8$

(i) $$\eta = \frac{E_2 I_2 \cos\phi}{E_2 I_2 \cos\phi + W_i + [W_{cu}]_{FL}} = \frac{40\times10^3 \times 0.8}{40\times10^3\times0.8 + 450 + 850}$$

$\Rightarrow \eta = 0.9609 \Rightarrow$ $\boxed{\eta = 96.09\%}$

(ii) Load at which $[P_{cu}] = W_i = 450W$

$$P_{cu} = x^2 [P_{cu}]_{FL} = 450 \Rightarrow x^2 \times 850 = 450$$

$\Rightarrow x^2 = \frac{9}{17} \Rightarrow$ $\boxed{x = 0.727}$ Load is 72.7% of FL

6.(a)

Ans: $N_1 = 300$, $N_2 = 750$, $A = 64\,cm^2 = 64 \times 10^{-4}\,m^2$

$E_1 = 440V$, $f = 50Hz$, $KVA = 10 \times 10^3$, $pf = \cos\phi = 0.8$

EMF Equation is $E_1 = 4.44 N_1 \phi_m f$

$$\Rightarrow \phi_m = \frac{E_1}{4.44 N_1 f} = \frac{440}{4.44 \times 300 \times 50}$$

$$\Rightarrow \phi_m = 6.6 \times 10^{-3}\,Wb$$

* Maximum Flux Density, $B_m = \frac{\phi_m}{A} = \frac{6.6 \times 10^{-3}}{64 \times 10^{-4}}$

$$\Rightarrow B_m = \frac{33}{32} \Rightarrow B_m = 1.031\,Wb/m^2 \quad //$$

* Emf Induced in secondary is E_2

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K = \frac{750}{300} \Rightarrow K = 2.5$$

$$\Rightarrow E_2 = KE_1 \Rightarrow E_2 = 2.5 \times 440 \Rightarrow E_2 = 1100\,V \quad //$$

* $KVA = E_2 I_2 = 10 \times 10^3$

Output Power $= P_o = E_2 I_2 \cos\phi = 10 \times 10^3 \times 0.8$

Copper Loss $= P_{cu} = 400W$

Iron Loss $= P_c = 200W$

Total Loss $= P_{cu} + P_c = 400 + 200 = 600W$

Input Power $= P_i = P_o + \text{Losses} = 10 \times 10^3 \times 0.8 + 600$

$$\Rightarrow P_i = 8600W$$

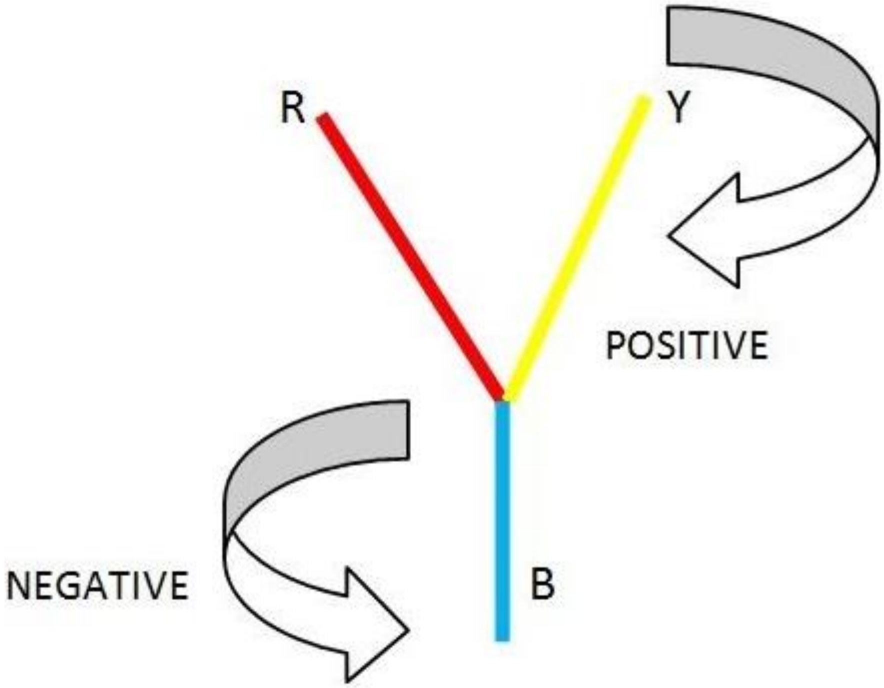
$$\Rightarrow \text{Efficiency} = \eta = \frac{P_o}{P_i} = \frac{10 \times 10^3 \times 0.8}{8600} = 0.93$$

$$\Rightarrow \%\eta = 93\% \quad //$$

6. b)

In three phase system the order in which the voltages attain their maximum positive value is called *Phase Sequence.*

Taking an example, if the phases of any coil are named as R, Y, B then the Positive phase sequence will be RYB, YBR, BRY also called as clockwise sequence and similarly the *Negative* ***phase sequence will be RBY, BYR, YRB respectively and known as an anti-clockwise sequence.***



Advantages of three-phase system over single phase systems

The advantages of polyphase system over single phase systems are given below:

1. Power delivered is constant. In single phase circuit the power delivered is pulsating and objectionable for many applications.
2. For a given frame size a polyphase machine gives a higher output than a single phase machine.
3. Polyphase induction motors are self starting and are more efficient. Single phase motor has no starting torque and requires an auxiliary means for starting.
4. Comparing with single phase motor, three phase induction motor has higher power factor and efficiency.
   Three phase motors are very robust, relatively cheap, generally smaller, have self-starting properties, provide a steadier output and require little maintenance compared with single phase motors.
5. For transmitting the same amount of power at the same voltage, a three phase transmission line requires less conductor material than a single phase line. The three phase transmission system is so cheaper.
   For a given amount of power transmitted through a system, the three phase system requires conductors with a smaller cross-sectional area.
   This means a saving of copper and thus the original installation costs are less.
6. Polyphase motors have uniform torque whereas most of the single phase motors have pulsating torque.

7. Parallel operation of three-phase generators is simpler then that of single phase generator.
8. Polyphase system can set up rotating magnetic field in stationary windings.

7. a) **Necessity of Earthing**:

1. To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. To maintain the line voltage constant under unbalanced load condition.
3. Protection of the equipments
4. Protection of large buildings and all machines fed from overhead lines against lightning

Methods of Earthing:

The important methods of earthing are the plate earthing and the pipe earthing. The earth resistance for copper wire is 1 ohm and that of G I wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the earth potential. The typical value of the earth resistance at powerhouse is 0. 5 ohm and that at substation is 1 ohm.

1. Plate earthing 2. Pipe earthing

1. Plate Earthing:

In this method a copper plate of 60cm x 60cm x 3.18cm or a GI plate of the size 60cm x 60cm x 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.

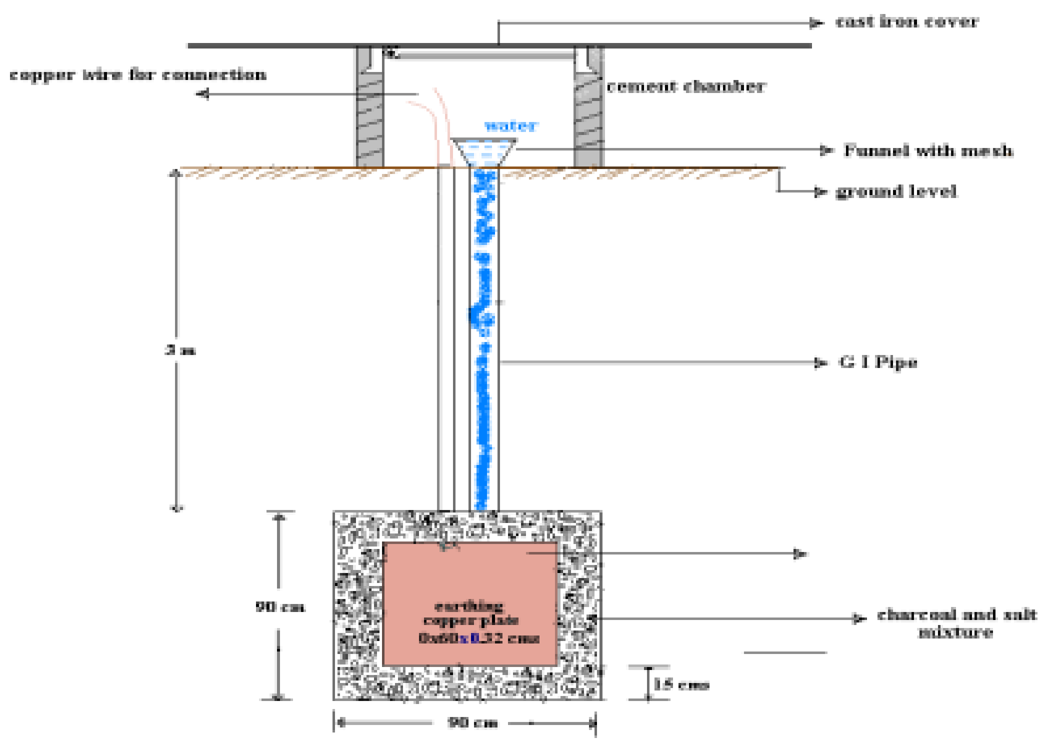
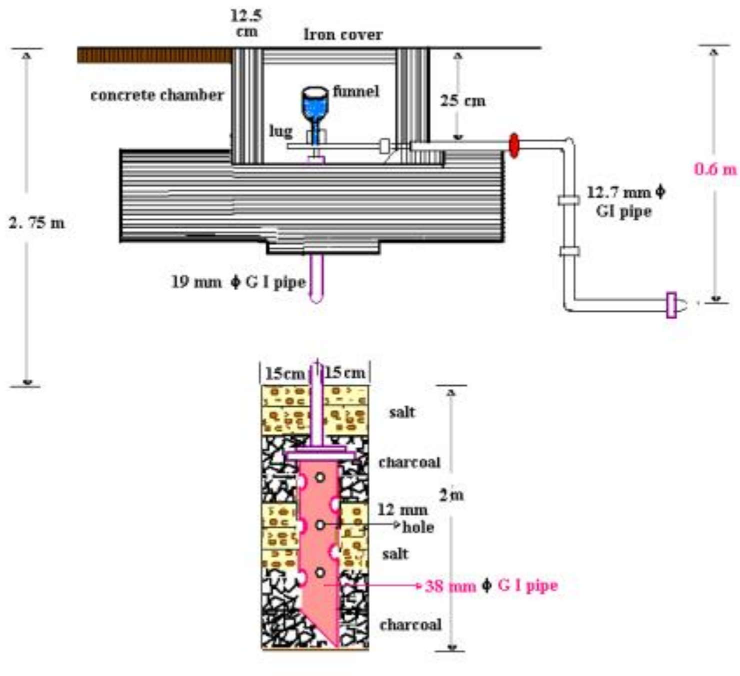


PLATE EARTHING

Pipe Earthing:

Earth electrode made of a GI (galvanized) iron pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cms) surrounding the GI pipe is filled with a mixture of salt and coal.. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the following figure.



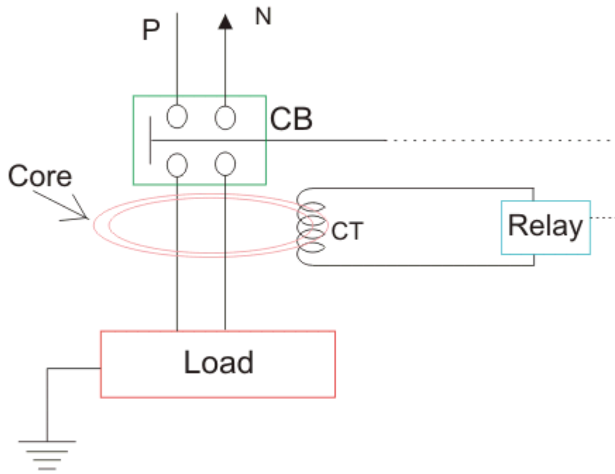
PIPE EARTHING

When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.

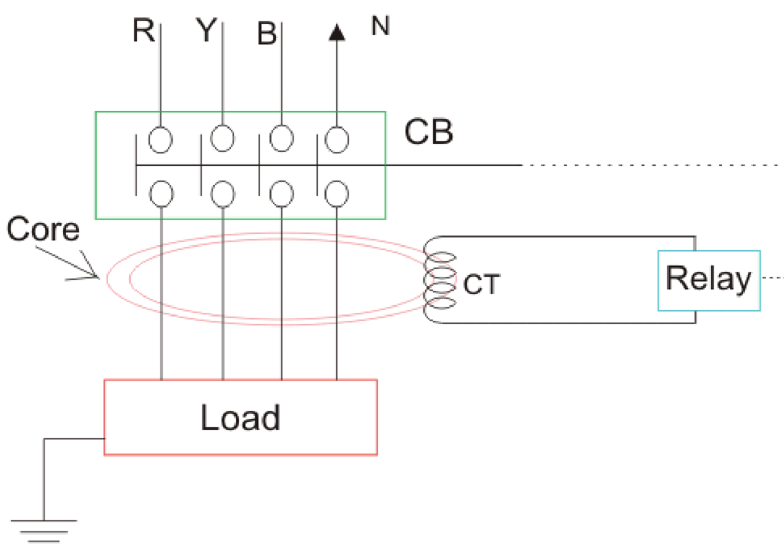
7. (b) **Current ELCB or RCCB or Residual Current Circuit Breaker**

The working principle of current earth leakage circuit breaker or RCCB is also very simple as voltage operated ELCB but the theory is entirely different and residual current circuit breaker is more sensitive than ELCB.

Current based ELCB is referred as RCD or RCCB. Here one CT core is energized from both phase wise and neutral wire.

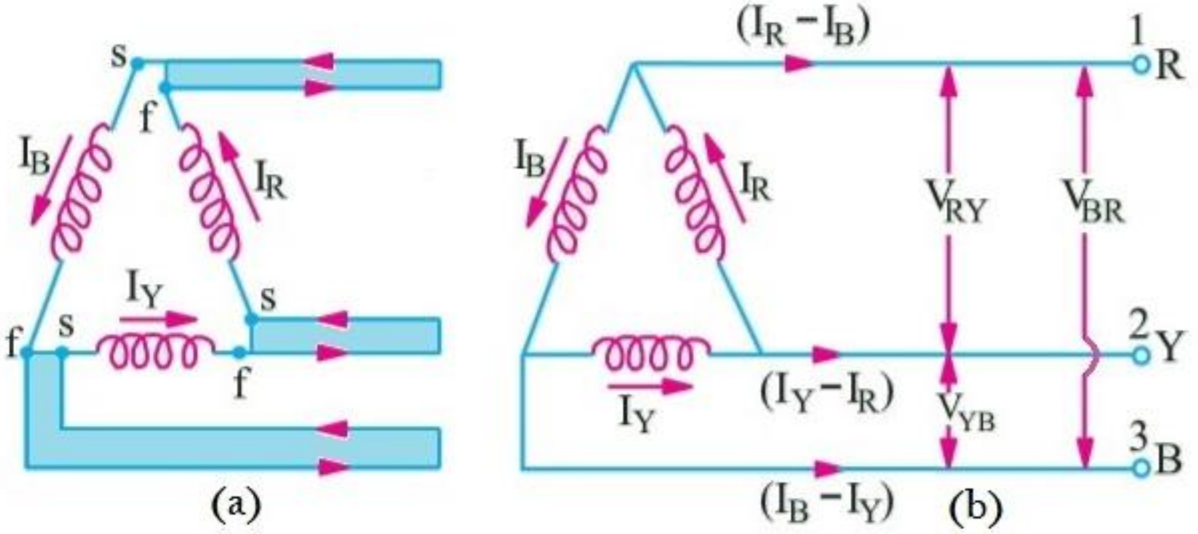


Single Phase Residual Current ELCB:
The polarity of the phase winding and neutral winding on the core is so chosen that, in normal condition mmf of one winding opposes that of another. As it is assumed that, in normal operating conditions the current goes through the phase wire will be returned via neutral wire if there's no leakage in between. As both currents are same, the resultant mmf produced by these two currents is also zero-ideally. The relay coil is connected with another third winding wound on the CT core as secondary. The terminals of this winding are connected to a relay system. In normal operating condition there would not be any current circulating in the third winding as here is no flux in the core due to equal phase and neutral current. When any earth leakage occurs in the equipment, there may be part of phase current passes to the earth, through the leakage path instead of returning via mental wire. Hence the magnitude of the neutral current passing through the RCCB is not equal to phase current passing through it.



8. b) **Delta or Mesh Connection** (**Δ**) System is also known as **Three Phase Three Wire System** (**3-Phase 3 Wire**) and it is the most preferred system for AC power transmission while for distribution, Star connection is generally used.

In **Delta** (also denoted by **Δ**) system of interconnection, the starting ends of the three phases or coils are connected to the finishing ends of the coil. Or the starting end of the first coil is connected to the finishing end of the second coil and so on (for all three coils) and it looks like a closed mesh or circuit as shown in fig (1).



Delta Connection (Δ): 3 Phase Power, Voltage & Current Values

Line Voltages (V_L) and Phase Voltages (V_{Ph}) in Delta Connection

It is seen in fig 2 that there is only one phase winding between two terminals (i.e. there is one phase winding between two wires). Therefore, **in Delta Connection, the voltage between (any pair of) two lines is equal to the phase voltage of the phase winding** which is connected between two lines.

Since the phase sequence is R → Y → B, therefore, the direction of voltage from R phase towards Y phase is positive (+), and the voltage of R phase is leading by 120°from Y phase voltage. Likewise, the voltage of Y phase is leading by 120° from the phase voltage of B and its direction is positive from Y towards B.

If the line voltage between;

- Line 1 and Line 2 = V_{RY}
- Line 2 and Line 3 = V_{YB}
- Line 3 and Line 1 = V_{BR}

Then, we see that V_{RY} leads V_{YB} by 120° and V_{YB} leads V_{BR} by **120°**.

Let's suppose,

$V_{RY} = V_{YB} = V_{BR} = V_L$ …………… (Line Voltage)

Then

$\mathbf{V_L = V_{PH}}$

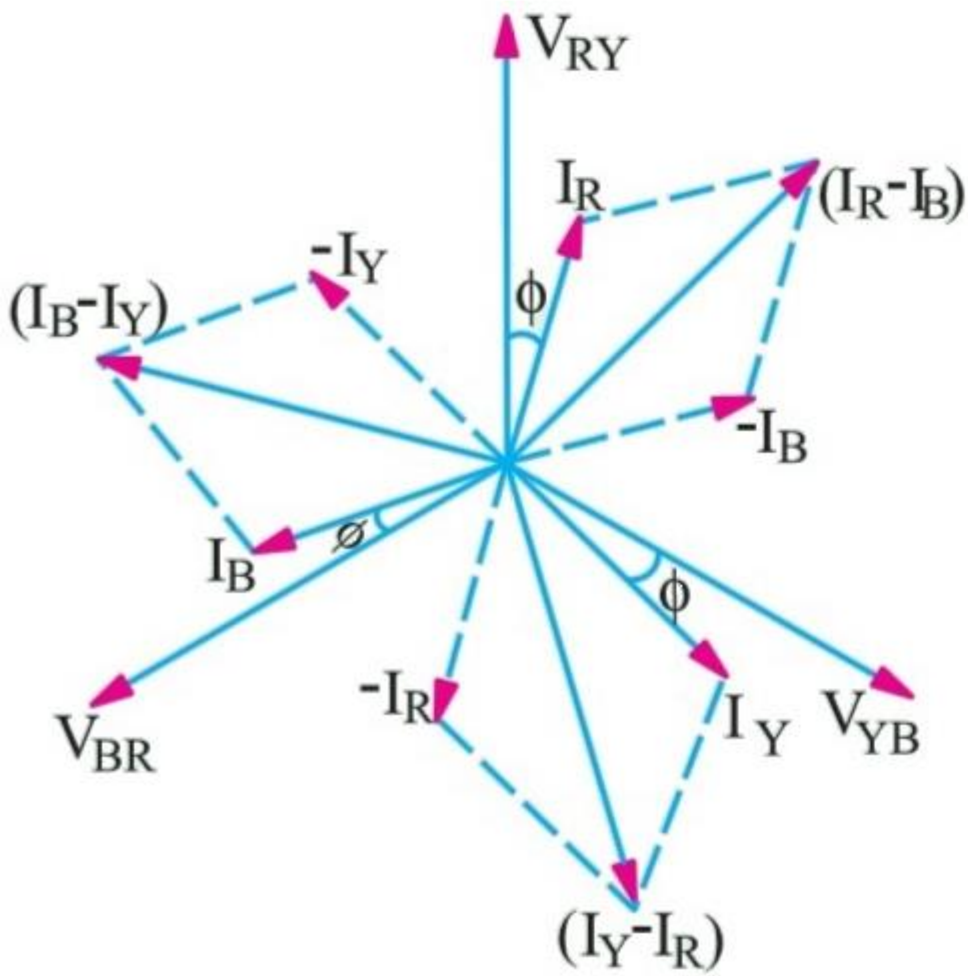
I.e. **in Delta connection, the Line Voltage is equal to the Phase Voltage**.

Line Currents (I_L) and Phase Currents (I_{Ph}) in Delta Connection

It will be noted from the below (fig-2) that the **total current of each Line is equal to the vector difference between two phase currents in Delta connection** flowing through that line. i.e.;

- Current in Line 1= $I_1 = I_R - I_B$
- Current in Line 2 =$I_2 = I_Y - I_R$
- Current in Line 3 =$I_3 = I_B - I_Y$

{Vector Difference}



Line & Phase Current and Line & Phase Voltage in Delta (Δ) Connection

The current of Line 1 can be found by determining the vector difference between I_R and I_B and we can do that by increasing the I_B Vector in reverse, so that, I_R and I_B makes a parallelogram. The diagonal of that parallelogram shows the vector difference of I_R and I_B which is equal to current in Line 1= I_1. Moreover, by reversing the vector of I_B, it may indicate as ($-I_B$), therefore, the angle between I_R and $-I_B$ (I_B, when reversed = $-I_B$) is 60°. If,

$I_R = I_Y = I_B = I_{PH}$ …. The phase currents

Then;

The current flowing in Line 1 would be;

I_L or $I_1 = 2 \times I_{PH} \times \text{Cos}\ (60°/2)$

$= 2 \times I_{PH} \times \text{Cos}\ 30°$

$= 2 \times I_{PH} \times (\sqrt{3}/2)$ …… Since $\text{Cos}\ 30° = \sqrt{3}/2$

$I_L = \sqrt{3}\ I_{PH}$

i.e. **In Delta Connection, The Line current is √3 times of Phase Current.**

8.(b)

$V_L = 400V$, $Pf = 0.45 \Rightarrow \cos\phi = 0.45 \rightarrow \phi = 63.256^\circ$

Input total Power $P = 40kW = 40\times10^3 W$

$P = \sqrt{3} V_l I_l \cos\phi \Rightarrow I_l = P / \sqrt{3} V_l \cos\phi$

$\Rightarrow I_l = \dfrac{40\times10^3}{\sqrt{3}\times400\times0.45} \Rightarrow \underline{I_l = 128.3 A}$ ✓

Wattmeter Readings are

$W_1 = V_l I_l \cos(30-\phi) = 400\times128.3\times\cos(30-63.256)$

$\Rightarrow W_1 = 42915.2\ W = 42.9152 kW$

$W_2 = V_l I_l \cos(30+\phi) = 400\times128.3\times\cos(30+63.256)$

$\Rightarrow W_2 = -2915.2\ W = -2.9152\ kW$

To check $\Rightarrow W_1 + W_2 = 42.9152 - 2.9152$

$\Rightarrow P = W_1 + W_2 = 40\ kW$