Register No. ☐☐☐☐☐☐☐☐☐☐☐☐

SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

AN AUTONOMOUS INSTITUTION

Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai

B.E/B.Tech Degree End Semester Exam, Nov/Dec 2024 – Answer Key

III Semester

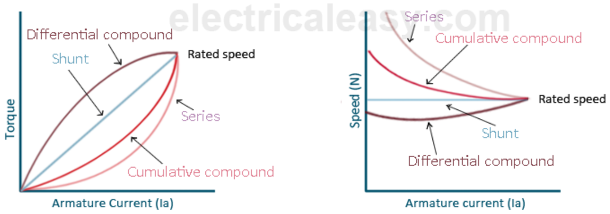
B.E-Electrical and Electronics Engineering

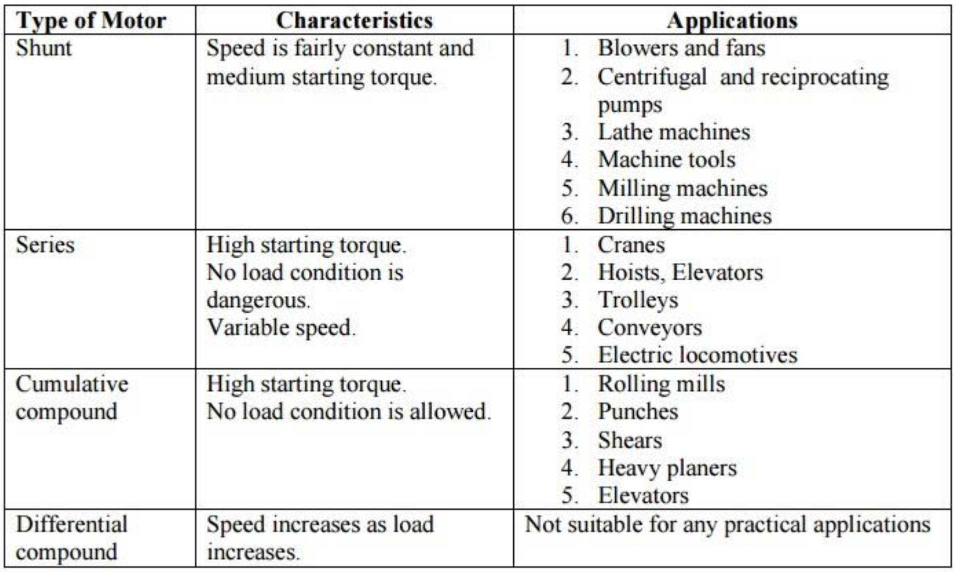
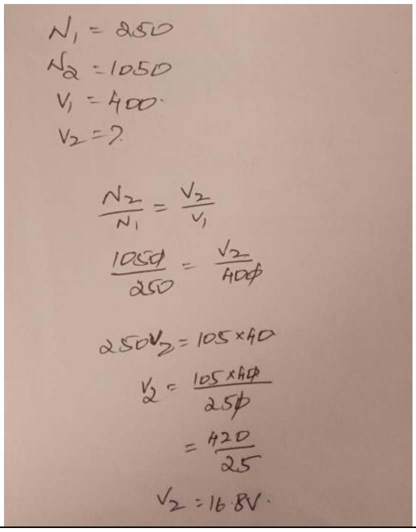
23EEB201- Theory of DC Machines and Transformers

Regulations 2023

Duration : 3 Hours **Maximum: 100 Marks**

Answer ALL questions

	PART A - (5 X 2 = 10 marks)			
Q.No	**Question**	**M**	**CO**	**BL**
1.	State the purpose of yoke in a DC machine. **Mechanical support :**The yoke provides mechanical support for the poles and protects the entire machine from dust and moisture. **Magnetic flux :**The yoke carries the magnetic flux produced by the poles and acts as a return path for the pole flux.	2	CO-1	L -1
2.	What do you mean by armature reaction in a DC machine? Mention its effects. Armature reaction in a DC machine is the impact of the armature's magnetic field on the main field, caused by the interaction between the armature flux and the main magnetic field. It can lead to several operational issues, including: **Reduced efficiency**: Armature reaction can reduce the efficiency of the machine. **Distorted flux patterns**: Armature reaction can distort the flux patterns within the machine. **Potential damage**: If not managed properly, armature reaction can potentially damage the machine. **Reduced voltage**: In a DC generator, armature reaction can reduce the generated voltage.	2	CO-1	L -2
3.	What is the significance of back emf in a DC motor? Back electromotive force (EMF) is important in a DC motor because it regulates the motor's speed, protects it from damage, and improves its efficiency	2	CO-2	L -2
4.	Plot the electrical and mechanical characteristics of DC compound motor.  Characteristics of DC compound motor	2	CO-2	L -1
5.	Mention the advantages and disadvantages of Hopkinson's test. Advantages. The various advantages of Hopkinson's test are, The power required for conducting the test is small compared to full load powers of the two machines. Disadvantages. The various disadvantages of Hopkinson's test are, There is difficulty in availability of two identical machines.	2	CO-3	L -1

<table>
<tr><td>6.</td><td>Summarize the applications of various types of DC motors.
<table><tr><th>Type of Motor</th><th>Characteristics</th><th>Applications</th></tr><tr><td>Shunt</td><td>Speed is fairly constant and medium starting torque.</td><td>1. Blowers and fans
2. Centrifugal and reciprocating pumps
3. Lathe machines
4. Machine tools
5. Milling machines
6. Drilling machines</td></tr><tr><td>Series</td><td>High starting torque.
No load condition is dangerous.
Variable speed.</td><td>1. Cranes
2. Hoists, Elevators
3. Trolleys
4. Conveyors
5. Electric locomotives</td></tr><tr><td>Cumulative compound</td><td>High starting torque.
No load condition is allowed.</td><td>1. Rolling mills
2. Punches
3. Shears
4. Heavy planers
5. Elevators</td></tr><tr><td>Differential compound</td><td>Speed increases as load increases.</td><td>Not suitable for any practical applications</td></tr></table></td><td>2</td><td>CO-3</td><td>L -2</td></tr>
<tr><td>7.</td><td>In a single-phase transformer, the number of turns in the primary and secondary are 250 and 1050 respectively. The primary side voltage is 400 V. Calculate the secondary side voltage of the transformer.

$N_1 = 250$
$N_2 = 1050$
$V_1 = 400.$
$V_2 = ?$
$\frac{N_2}{N_1} = \frac{V_2}{V_1}$
$\frac{105\cancel{0}}{250} = \frac{V_2}{40\cancel{0}}$
$250V_2 = 105 \times 40$
$V_2 = \frac{105 \times 4\cancel{0}}{25\cancel{0}}$
$= \frac{420}{25}$
$V_2 = 16.8V.$</td><td>2</td><td>CO-4</td><td>L -2</td></tr>
<tr><td>8.</td><td>List the characteristics of an ideal transformer.
Zero winding resistance: The primary and secondary windings have zero resistance.
Infinite core permeability: The core of an ideal transformer has infinite permeability, so no magnetizing current is required to magnetize it.
No leakage flux: The entire flux from the primary winding links with the secondary.
100% efficiency: An ideal transformer has no losses, so the output power is exactly equal to the input.</td><td>2</td><td>CO-4</td><td>L -2</td></tr>
<tr><td>9.</td><td>Discuss the reasons why the transformers are rated in KVA.
Transformers are rated in KVA (kilo-volt-amperes) because their internal losses, primarily copper losses (dependent on current) and iron losses (dependent on voltage), are primarily determined by the apparent power (kVA) and not the power factor of the connected load, meaning their capacity is best described by this combined value regardless of the type of load connected to it</td><td>2</td><td>CO-5</td><td>L -2</td></tr>
<tr><td>10.</td><td>Define all-day efficiency.
All-day efficiency is a term used in electrical engineering to describe the overall efficiency of a transformer over a 24-hour period.
$$\text{All day efficiency, } \eta_{\text{all day}} = \frac{\text{output in kWh}}{\text{input in kWh}} \quad \text{(for 24 hours)}$$</td><td>2</td><td>CO-5</td><td>L -2</td></tr>
</table>

PART B - (2 X 13 = 26 marks)

11.	(a)	(i) Illustrate the construction of a DC Machine with a neat diagram.	8	CO-1	L-2

An electromechanical device which can convert direct current (dc) electricity into mechanical energy or mechanical energy into direct current (dc) electricity is known as a **DC machine**.

If the DC machine converts DC electrical energy into mechanical energy, it is known as **DC motor**. If the machine converts mechanical energy into DC electrical energy, then it is known as a **DC generator**. Both DC motor and DC generator have the similar construction.

A typical DC machine consists of the following major parts −

Yoke or Frame
Armature
Field System
Commutator
Brushes
Bearings

The schematic diagram of a DC machine is shown below −

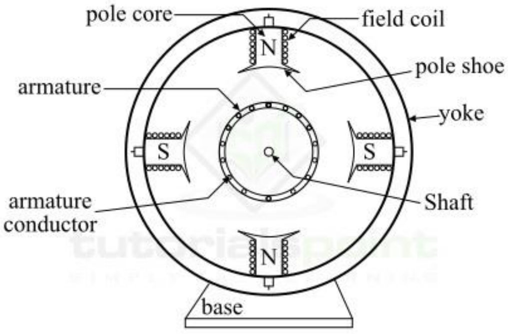


Figure - DC Machine Construction

Yoke or Frame
The yoke is the outer frame of the DC machine. It is made up of such materials that have high permeability and high mechanical strength. In practice, the yoke of DC machine is made up of cast steel.
The yoke or frame of the DC machine serves the following main purposes −
It protects the internal machine parts like armature, windings, field poles, etc. against mechanical damages.
The yoke houses the magnetic field system.
It provides a low reluctance path to the working magnetic flux.
It supports the rotor or armature through bearings.

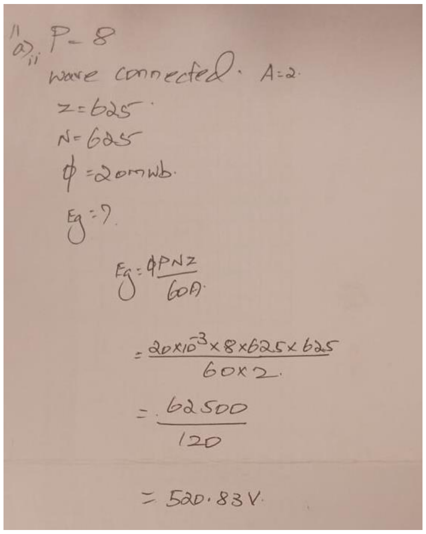
Armature

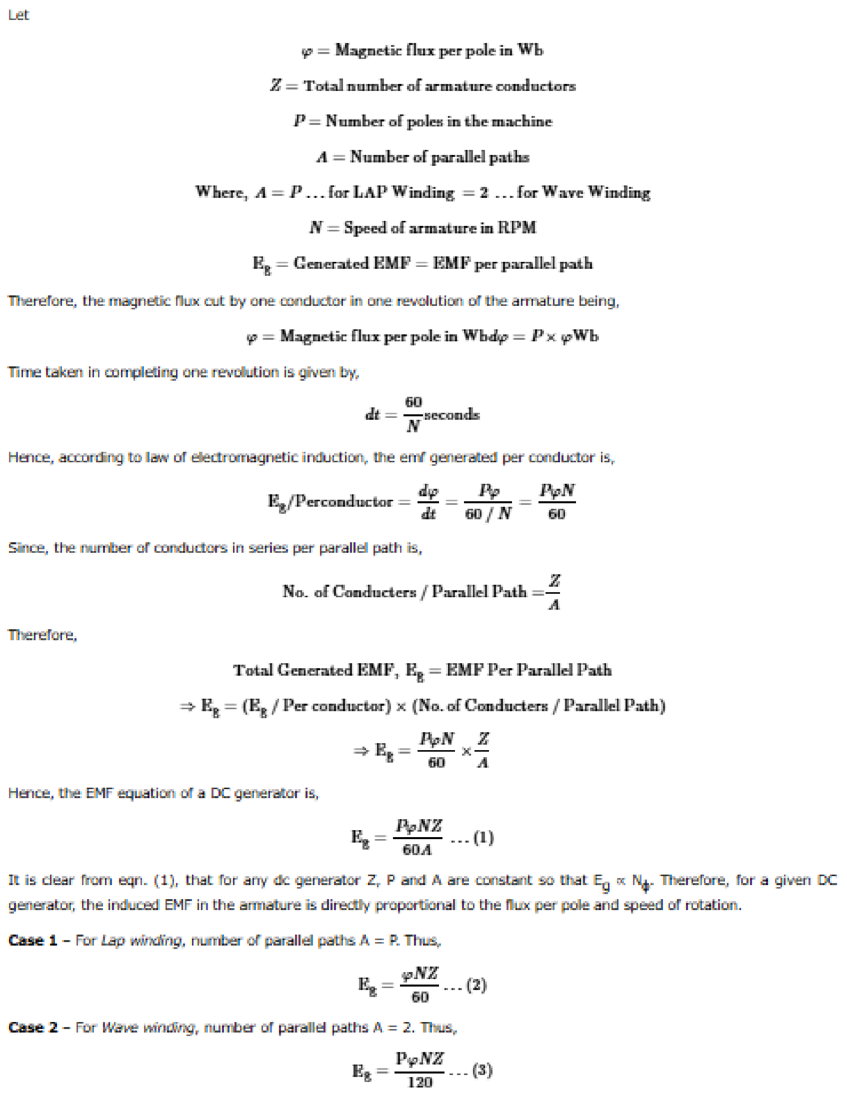
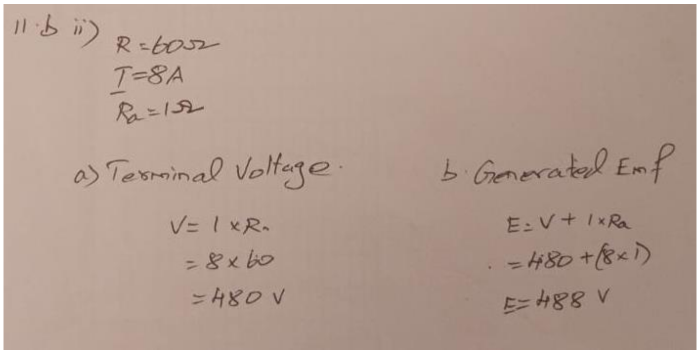
In DC machines (motor or generator), armature is a system of conductors or coils that can rotate freely on the supporting bearings. The working torque and EMF are developed in coils of the armature. The armature consists of two main parts namely, **armature core** and **armature winding**.

The armature core is a solid cylindrical structure, made up of high permeability thin silicon steel laminations. On the outer periphery of the core slots are cut to carry the armature winding.

Field System

Field system is the part of a DC machine which produces the working magnetic flux in the machine. It is basically a system of electromagnets which is excited by a DC supply. In case

		of DC machine, the field system is a stationary part of the machine and it is bolted to the yoke or frame of the machine. There are three main parts of a field system in dc machines namely **pole core, pole shoes**, and **field coils**. Commutator The commutator is one of the important parts of the DC machine. It is basically mechanical rectifier. It is a cylindrical shaped device and is made up of copper. The outer periphery of the commutator has V-shaped slots to carry commutator segments. Where, the commutator segments are copper bars inserted in the slots. These segments are insulated from each other by mica. The commutator is mounted on the shaft of the DC machine on one side of the armature. The armature conductors are connected to the commutator segments with the help of copper lugs. The commutator performs the following two major functions − In a DC generator, it collects the current from the armature conductor. In a DC motor, it supplies the current to the armature conductors. It converts the alternating current of the armature into unidirectional current in the external circuit with the help of brushes, and *vice-versa*. Brushes Brushes are used to make an electrical connection with the rotating commutator. These collect (or supply) current from (or to) the moving commutator. Brushes are usually made up of carbon. They are housed in brush holders and are in contact with the commutator surface with the help of spring pressure.			
		(ii) Compute the emf generated by an 8 Pole, wave connected armature that has 625 conductors and driven at 625 rpm. The fulx per pole is 20 mWb.  11 a) ii P = 8 wave connected. A=2. Z=625. N=625 ϕ =20mWb. Eg=?. $E_g = \frac{\phi PNZ}{60A}$ $= \frac{20\times10^{-3}\times8\times625\times625}{60\times2}$ $= \frac{62500}{120}$ = 520.83V.	5	CO-1	L-3
OR					
	(b)	(i) Derive the emf equation of a DC generator.	8	CO-1	L-2

		 Let φ = Magnetic flux per pole in Wb Z = Total number of armature conductors P = Number of poles in the machine A = Number of parallel paths Where, $A = P \ldots$ for LAP Winding $= 2 \ldots$ for Wave Winding N = Speed of armature in RPM E_g = Generated EMF = EMF per parallel path Therefore, the magnetic flux cut by one conductor in one revolution of the armature being, $\varphi = \text{Magnetic flux per pole in Wb} d\varphi = P \times \varphi \text{Wb}$ Time taken in completing one revolution is given by, $dt = \frac{60}{N}\text{seconds}$ Hence, according to law of electromagnetic induction, the emf generated per conductor is, $E_g/\text{Perconductor} = \frac{d\varphi}{dt} = \frac{P\varphi}{60 / N} = \frac{P\varphi N}{60}$ Since, the number of conductors in series per parallel path is, $\text{No. of Conducters / Parallel Path} = \frac{Z}{A}$ Therefore, Total Generated EMF, E_g = EMF Per Parallel Path $\Rightarrow E_g = (E_g / \text{Per conductor}) \times (\text{No. of Conducters / Parallel Path})$ $\Rightarrow E_g = \frac{P\varphi N}{60} \times \frac{Z}{A}$ Hence, the EMF equation of a DC generator is, $E_g = \frac{P\varphi NZ}{60A} \ldots (1)$ It is clear from eqn. (1), that for any dc generator Z, P and A are constant so that $E_g \propto N\phi$. Therefore, for a given DC generator, the induced EMF in the armature is directly proportional to the flux per pole and speed of rotation. **Case 1** – For *Lap winding*, number of parallel paths A = P. Thus, $E_g = \frac{\varphi NZ}{60} \ldots (2)$ **Case 2** – For *Wave winding*, number of parallel paths A = 2. Thus, $E_g = \frac{P\varphi NZ}{120} \ldots (3)$			
		(ii) A DC generator is connected to a load of 60 Ω and delivers a current of 8 A. If the armature resistance is 152, determine (a) the terminal voltage (b) the generated emf..  11·b ii) $R = 60\Omega$ $I = 8A$ $R_a = 1\Omega$ a) Terminal Voltage. $V = I \times R_L$ $= 8 \times 60$ $= 480$ V b. Generated Emf $E = V + I \times R_a$ $= 480 + (8 \times 1)$ $E = 488$ V	5	CO-1	L-3
12.	(a)	Outline the various methods of speed control employed for DC shunt motors. Back emf E_b of a DC motor is nothing but the induced emf in armature conductors due to rotation of the armature in magnetic field. Thus, the magnitude of E_b can be given by EMF equation of a DC generator. $E_b = {}^{PØNZ}/_{60A}$ (where, P = no. of poles, Ø = flux/pole, N = speed in rpm, Z = no. of armature conductors, A = parallel paths) E_b can also be given as,	13	CO-2	L-2

$E_b = V - I_aR_a$

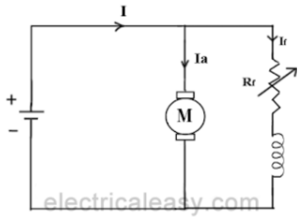
thus, from the above equations
$N = {}^{E_b\,60A}/_{P\text{Ø}Z}$

but, for a DC motor A, P and Z are constants

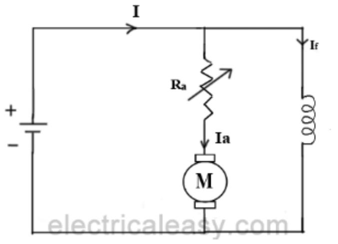
Therefore, $N \propto K\,{}^{E_b}/_{\text{Ø}}$ (where, K=constant)

This shows the **speed of a dc motor** is directly proportional to the back emf and inversely proportional to the flux per pole.

Flux control method



Armature control method



Voltage Control Method

a) **Multiple voltage control**
b) **Ward-Leonard System**

Speed control of series motor

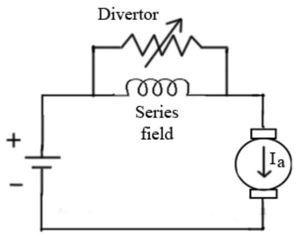


fig (a) Field Divertor

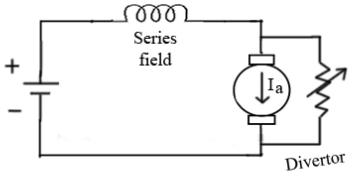


fig (b) Armature Divertor

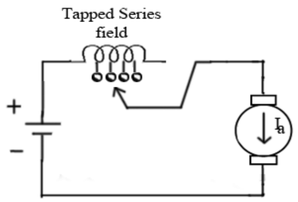


fig (c) Tapped field

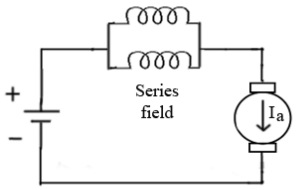


fig (d) Paralleling Field coils

OR

	(b)	Examine the electrical, mechanical and other major characteristics of D.C. Series motors. Draw the performance curve of D.C. Series Motor.	13	CO-2	L-2

1. Electrical Characteristics:

1. **High Starting Torque:**
    - The torque (T) is proportional to the square of the armature current (I_a):

$$T \propto \phi I_a \quad \text{and} \quad \phi \propto I_a \quad \rightarrow \quad T \propto I_a^2$$

    - At low speeds, high currents produce a large torque.
2. **Speed-Torque Relationship:**
    - The speed (N) of the motor is inversely proportional to the flux (ϕ):

$$N \propto \frac{1}{\phi}$$

    - At high loads (low speed), flux is high, and at light loads, speed increases significantly.
3. **Current-Voltage Relationship:**
    - The motor draws large current during starting, which can be controlled using external resistances.

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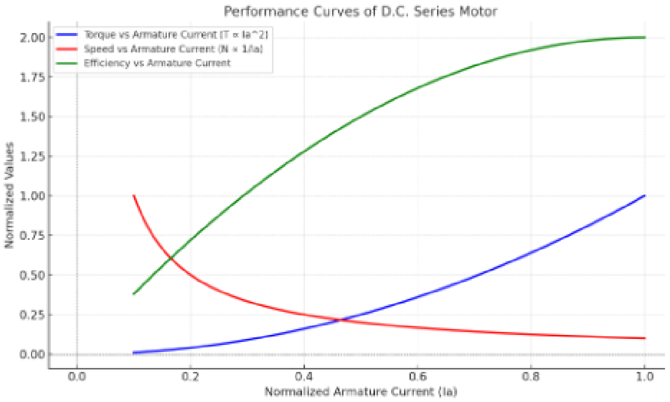
2. Mechanical Characteristics:

1. **Torque-Speed Characteristic:**
    - At low speeds, the torque is very high, which decreases as speed increases.
    - This makes it ideal for applications requiring high initial torque.
2. **Efficiency:**
    - Efficiency is lower at low speeds due to high I^2R losses in the armature.
    - It improves as speed increases under load.
3. **Mechanical Stress:**
    - High starting torque can cause mechanical stress on the components like shafts and bearings.

3. Other Major Characteristics:

1. **No Load Operation:**
    - A D.C. series motor should never run without a load because at no load, the flux becomes very small, causing the motor speed to increase excessively (runaway condition).
2. **Applications:**
    - Suitable for applications requiring variable speed and high torque, such as electric trains, hoists, and rolling mills.
3. **Regulation:**
    - Poor voltage regulation due to high variation in current with load changes.



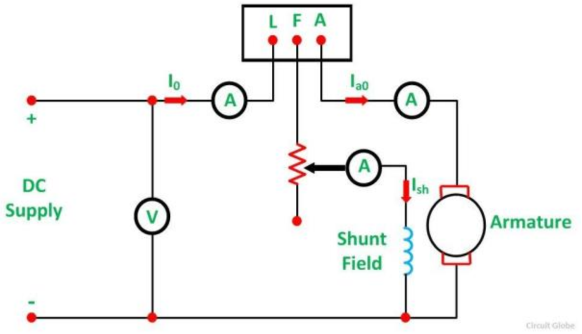
Here are the performance curves of a D.C. series motor:

1. **Torque vs. Armature Current (blue):** A parabolic curve showing that torque increases significantly with an increase in armature current.
2. **Speed vs. Armature Current (red):** A hyperbolic curve indicating that speed decreases as armature current increases.
3. **Efficiency vs. Armature Current (green):** A bell-shaped curve showing efficiency rises with current, peaks at an optimal point, and then decreases due to increased losses.

13	(a)	Illustrate the Swinburne's test on a D.C. Motor. What are its advantages and disadvantages?	13	CO-3	L-2

Swinburne’s Test is an indirect method of testing of DC machines. In this method, the losses are measured separately and the efficiency at any desired load is predetermined. Machines are tested for finding out losses, efficiency and temperature rise.

For small machines direct loading test is performed. For large shunt machines, indirect methods are used like Swinburne’s or Hopkinson’s test. The machine is running as a motor at rated voltage and speed. The connection diagram for DC shunt machine is shown in the figure below:



Advantages of Swinburne’s Test

The main advantages of Swinburne’s test are as follows:

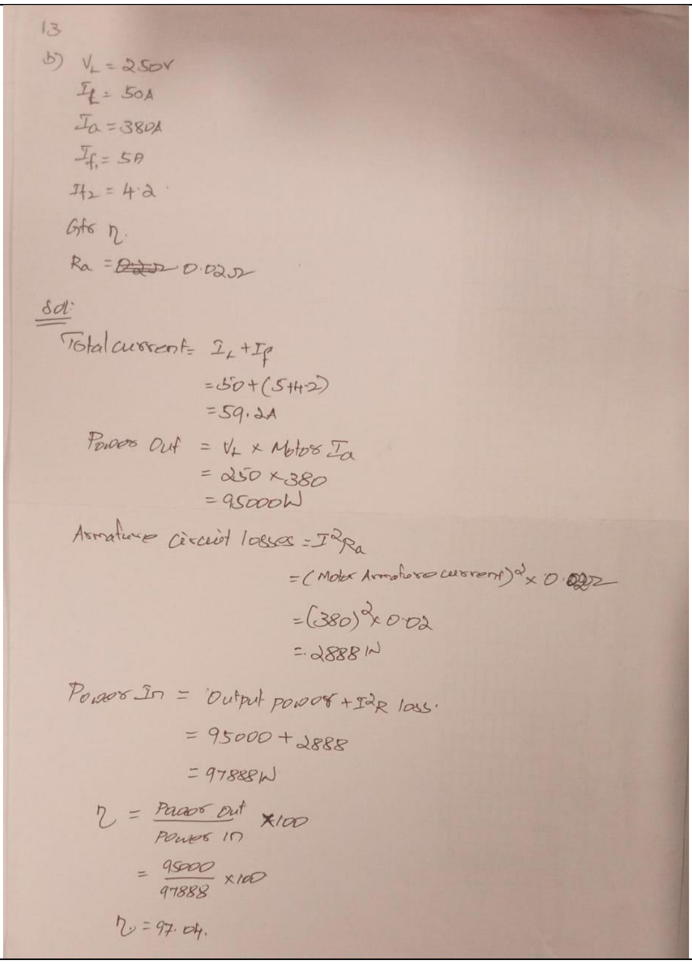
- The power required to test a large machine is small. Thus, this method is an economical and convenient method of testing of DC machines.
- As the constant loss is known the efficiency can be predetermined at any load.

Disadvantages of Swinburne’s Test

- Change in iron loss is not considered at full load from no load. Due to armature reaction flux is distorted at full load and, as a result, the iron loss is increased.
- As the Swinburne’s test is performed at no load. Commutation on full load cannot be determined whether it is satisfactory or not and whether the temperature rise is within the specified limits or not.

OR

	(b)	Hopkinson's test on two machines gave the following results for full load; line voltage 250V, line current excluding field current 50A, motor armature current 380A, field currents 5 and 4.2A. Calculate the efficiency of each machine. The armature resistance of each machine is 0.02 Ω. State the assumptions made.	13	CO-3	L-3



13

b) $V_L = 250V$

$I_L = 50A$

$I_a = 380A$

$I_{f_1} = 5A$

$I_{f_2} = 4.2$

Gts η.

$R_a =$ ~~0.2Ω~~ 0.02Ω

Sol:

Total current $= I_L + I_f$

$= 50 + (5 + 4.2)$

$= 59.2A$

Power Out $= V_t \times$ Motor I_a

$= 250 \times 380$

$= 95000W$

Armature circuit losses $= I^2 R_a$

$=$ (Motor Armature current)$^2 \times 0.02Ω$

$= (380)^2 \times 0.02$

$= 2888W$

Power In = Output power + I^2R loss.

$= 95000 + 2888$

$= 97888W$

$$\eta = \frac{\text{Power out}}{\text{Power in}} \times 100$$

$$= \frac{95000}{97888} \times 100$$

$\eta = 97.04$.

14	(a)	(i) Derive an expression for the e.m.f. equation of a single-phase transformer.	8	CO-4	L-2

The induced EMF (E) in any winding having (N) number of turns is given by:

$$E_{rms} = 4,44 \times f \times N \times \Phi_{max}$$

Where,

f → frequency Hz

N → number of turns of winding

Φ → Flux density in Wb

N1 is the number of turns in the primary winding

N2 is the number of turns in the secondary winding

By Faraday's Law the flux changes from + ϕm to – ϕm in half a cycle of 1/2f seconds

Emf induced in the primary winding is the E1

$$E_1 = -\frac{d\psi}{dt} \dots\dots\dots (1)$$

Where $\Psi = N1\phi$

So,

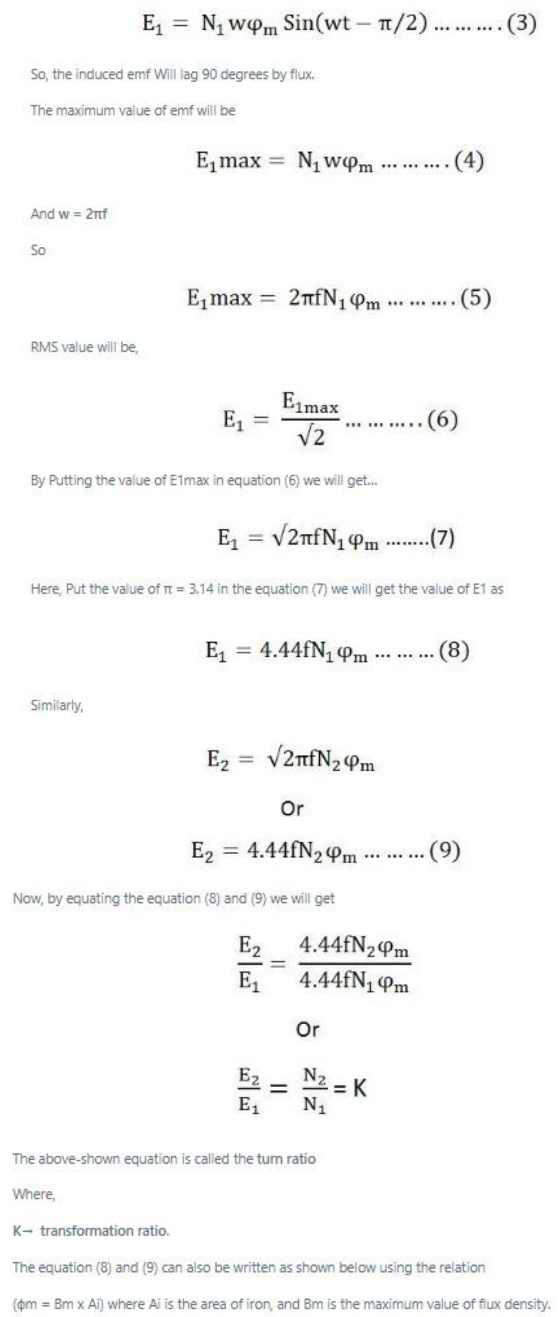
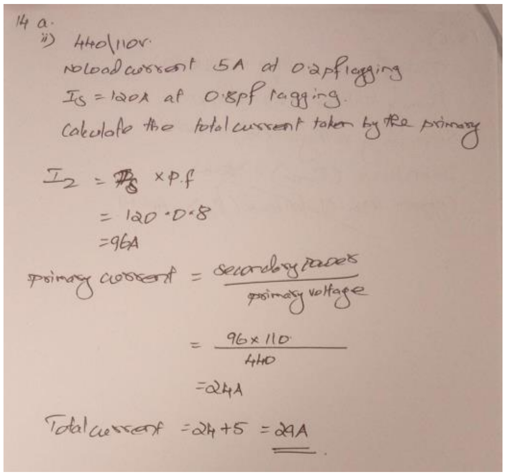
.....(2)

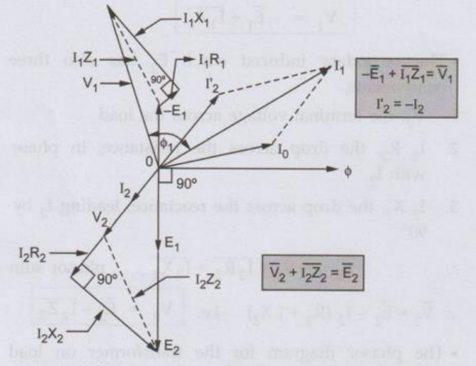
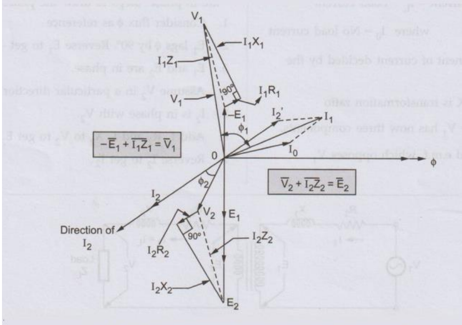
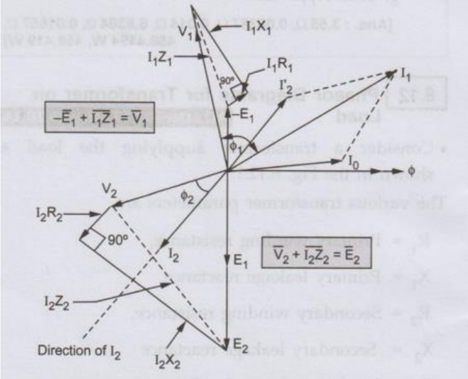
$$E_1 = -N_1 \frac{d\varphi}{dt}$$

We know that ϕ is due to AC supply $\phi = \phi m \, Sin(wt)$

$$E_1 = -N_1 \frac{d}{dt} (\varphi_m \, Sinwt)$$

$$E_1 = -N_1 \, w \varphi_m \, Coswt$$

		 $E_1 = N_1 w \varphi_m \sin(wt - \pi/2) \ldots\ldots\ldots(3)$ So, the induced emf Will lag 90 degrees by flux. The maximum value of emf will be $E_1 max = N_1 w \varphi_m \ldots\ldots\ldots(4)$ And w = 2πf So $E_1 max = 2\pi f N_1 \varphi_m \ldots\ldots\ldots(5)$ RMS value will be, $E_1 = \frac{E_{1max}}{\sqrt{2}} \ldots\ldots\ldots(6)$ By Putting the value of E1max in equation (6) we will get... $E_1 = \sqrt{2}\pi f N_1 \varphi_m \ldots\ldots(7)$ Here, Put the value of π = 3.14 in the equation (7) we will get the value of E1 as $E_1 = 4.44 f N_1 \varphi_m \ldots\ldots\ldots(8)$ Similarly, $E_2 = \sqrt{2}\pi f N_2 \varphi_m$ Or $E_2 = 4.44 f N_2 \varphi_m \ldots\ldots\ldots(9)$ Now, by equating the equation (8) and (9) we will get $\frac{E_2}{E_1} = \frac{4.44 f N_2 \varphi_m}{4.44 f N_1 \varphi_m}$ Or $\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$ The above-shown equation is called the **turn ratio** Where, **K→ transformation ratio.** The equation (8) and (9) can also be written as shown below using the relation (ϕm = Bm x Ai) where Ai is the area of iron, and Bm is the maximum value of flux density.			
		(ii) A single-phase transformer with a ratio of 440/110V takes a no-load current is 5A at a p.f. of 0.2 lag. If the second. Supplies a current of 120A at 0.8pf lag, calculate the total current taken by the primary.  14 a. ii) 440\110V. Noload current 5A at 0.2pf lagging I_S = 120A at 0.8pf lagging. Calculate the total current taken by the primary $I_2 = I_S \times p.f$ = 120 ·0·8 =96A primary current = $\frac{\text{secondary power}}{\text{primary voltage}}$ = $\frac{96 \times 110}{440}$ =24A Total current = 24+5 = 29A	5	CO-4	L-3
OR					

	(b)	Draw the complete phasor diagram of a single-phase transformer on load at leading, lagging and unity power factors. Indicate the various quantities.  **Fig. 6.12.2 Phasor diagram for unity power factor load**  **Fig. 6.12.3 Phasor diagram for lagging power factor load**  **Fig. 6.12.4 Phasor diagram for leading power factor load**	13	CO-4	L-2
15	(a)	In a 25kVA, 1000/400V single-phase transformer, the iron and copper losses at full load are 300W and 400W respectively. Calculate the load (in kVA) for maximum efficiency.	13	CO-5	L-2

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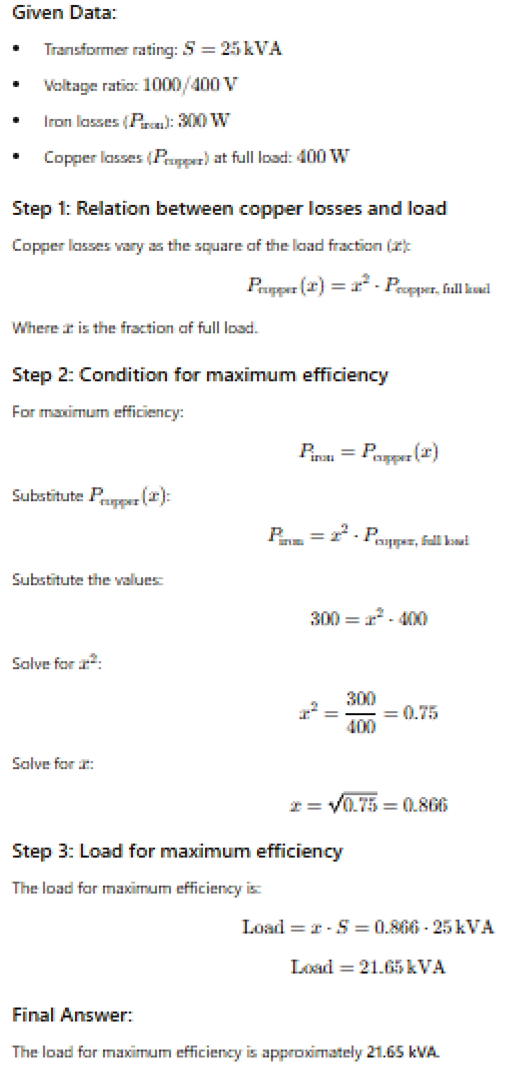

Given Data:

- Transformer rating: $S = 25\,\mathrm{kVA}$
- Voltage ratio: $1000/400\,\mathrm{V}$
- Iron losses (P_{iron}): $300\,\mathrm{W}$
- Copper losses (P_{copper}) at full load: $400\,\mathrm{W}$

Step 1: Relation between copper losses and load

Copper losses vary as the square of the load fraction (x):

$$P_{\text{copper}}(x) = x^2 \cdot P_{\text{copper, full load}}$$

Where x is the fraction of full load.

Step 2: Condition for maximum efficiency

For maximum efficiency:

$$P_{\text{iron}} = P_{\text{copper}}(x)$$

Substitute $P_{\text{copper}}(x)$:

$$P_{\text{iron}} = x^2 \cdot P_{\text{copper, full load}}$$

Substitute the values:

$$300 = x^2 \cdot 400$$

Solve for x^2:

$$x^2 = \frac{300}{400} = 0.75$$

Solve for x:

$$x = \sqrt{0.75} = 0.866$$

Step 3: Load for maximum efficiency

The load for maximum efficiency is:

$$\text{Load} = x \cdot S = 0.866 \cdot 25\,\mathrm{kVA}$$

$$\text{Load} = 21.65\,\mathrm{kVA}$$

Final Answer:

The load for maximum efficiency is approximately **21.65 kVA**.

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<td colspan="6">OR</td>
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<td>(b)</td>
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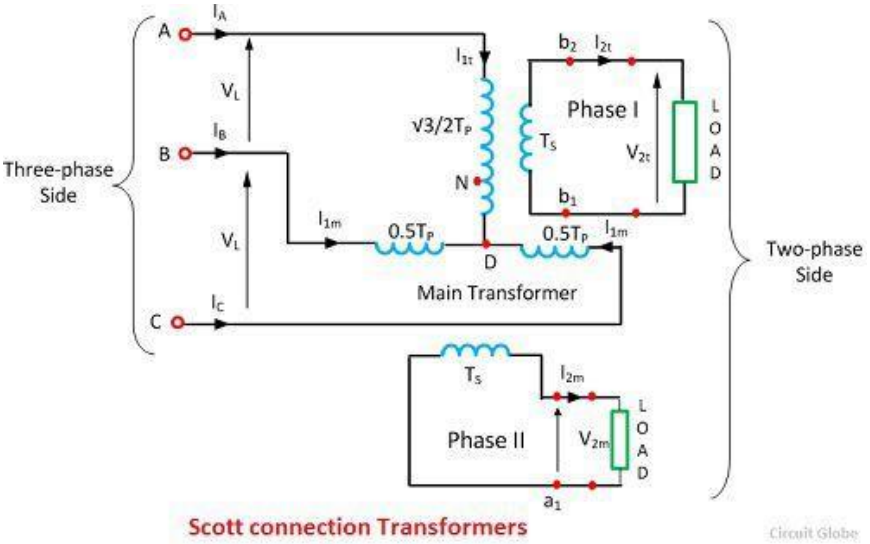
Illustrate with the help of relevant diagrams, the Scott connection of single-phase transformers.

The Scott-T Connection is the method of connecting two single phase transformer to perform the 3-phase to 2-phase conversion and vice-versa. The two transformers are connected electrically but not magnetically.One of the transformers is called the main transformer, and the other is called the auxiliary or teaser transformer.



Scott connection Transformers

</td>
<td>13</td>
<td>CO-5</td>
<td>L-2</td>
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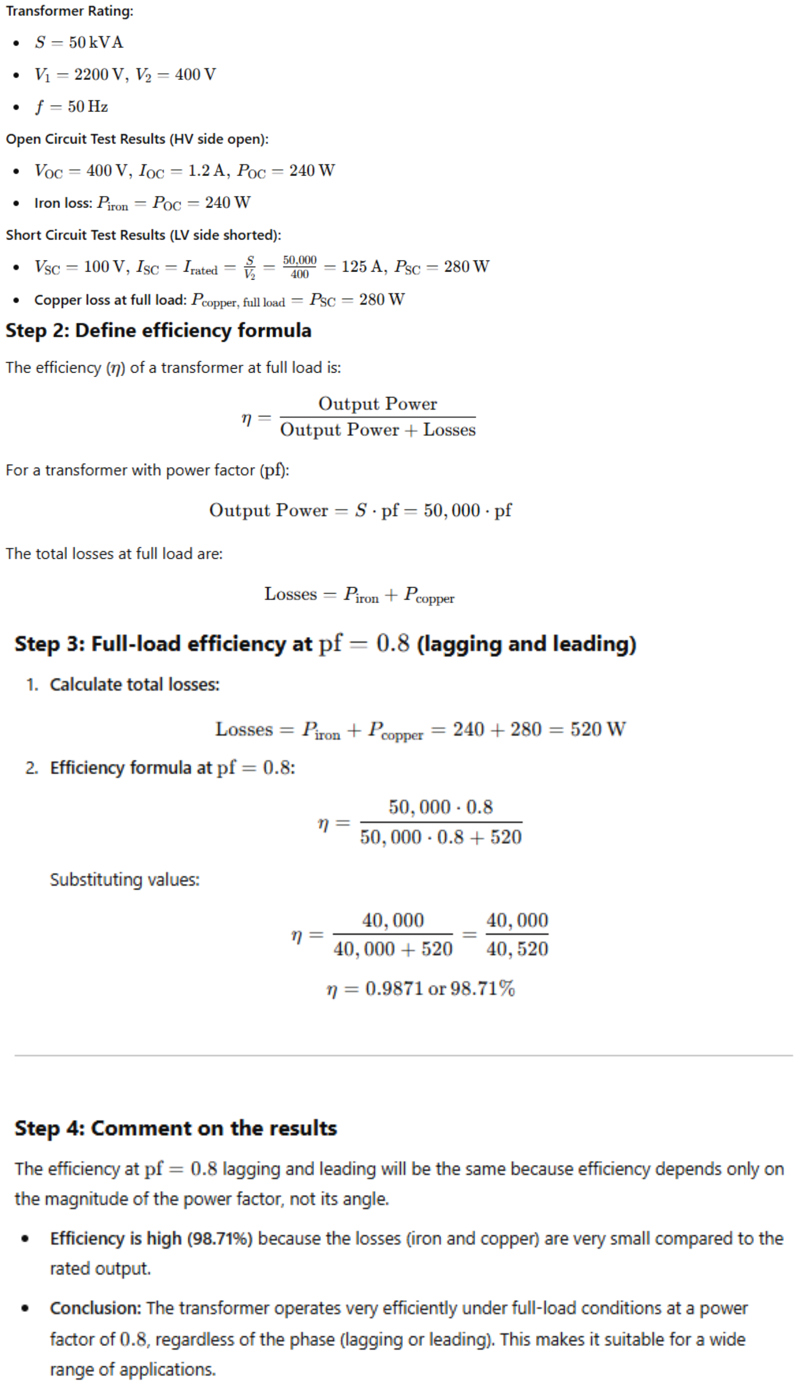
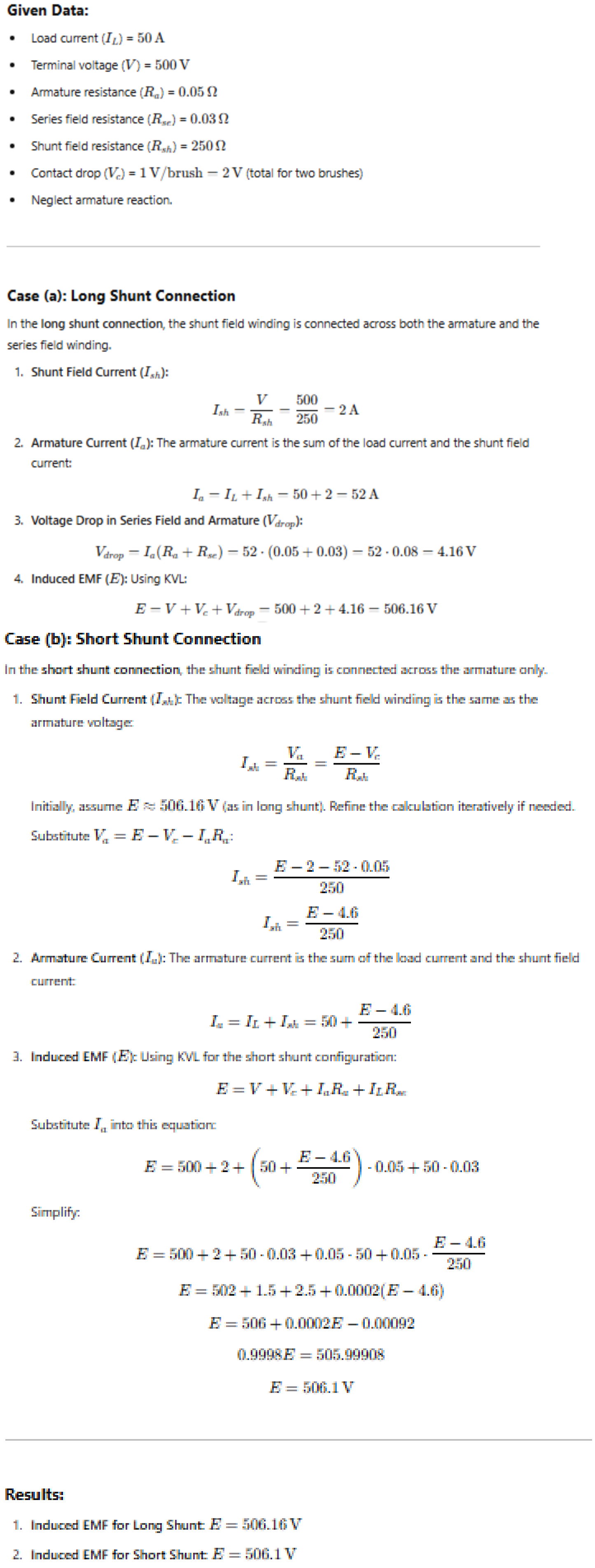
PART C - (1 X 15 = 15 marks)					
16.	(a)	A single phase, 50kVA, 2200V/400V, 50Hz transformer is tested for open and short circuit test with the following test details. O.C: Vo=400V, Io= 1.2A, Woc=240 W (HV open circuited) S.C: Vsc 100V, Isc= rated current, Wsc = 280W(LV short circuited) Calculated the full load efficiency of the transformer at 0.8 pf (lead) and 0.8 pf (lagging). Comment on the results.  **Transformer Rating:** - $S = 50\,\text{kVA}$ - $V_1 = 2200\,\text{V},\ V_2 = 400\,\text{V}$ - $f = 50\,\text{Hz}$ **Open Circuit Test Results (HV side open):** - $V_{\text{OC}} = 400\,\text{V},\ I_{\text{OC}} = 1.2\,\text{A},\ P_{\text{OC}} = 240\,\text{W}$ - Iron loss: $P_{\text{iron}} = P_{\text{OC}} = 240\,\text{W}$ **Short Circuit Test Results (LV side shorted):** - $V_{\text{SC}} = 100\,\text{V},\ I_{\text{SC}} = I_{\text{rated}} = \frac{S}{V_2} = \frac{50{,}000}{400} = 125\,\text{A},\ P_{\text{SC}} = 280\,\text{W}$ - Copper loss at full load: $P_{\text{copper, full load}} = P_{\text{SC}} = 280\,\text{W}$ **Step 2: Define efficiency formula** The efficiency (η) of a transformer at full load is: $\eta = \frac{\text{Output Power}}{\text{Output Power} + \text{Losses}}$ For a transformer with power factor (pf): $\text{Output Power} = S \cdot \text{pf} = 50,000 \cdot \text{pf}$ The total losses at full load are: $\text{Losses} = P_{\text{iron}} + P_{\text{copper}}$ **Step 3: Full-load efficiency at $\text{pf} = 0.8$ (lagging and leading)** 1. **Calculate total losses:** $\text{Losses} = P_{\text{iron}} + P_{\text{copper}} = 240 + 280 = 520\,\text{W}$ 2. **Efficiency formula at $\text{pf} = 0.8$:** $\eta = \frac{50,000 \cdot 0.8}{50,000 \cdot 0.8 + 520}$ Substituting values: $\eta = \frac{40,000}{40,000 + 520} = \frac{40,000}{40,520}$ $\eta = 0.9871 \text{ or } 98.71\%$ **Step 4: Comment on the results** The efficiency at $\text{pf} = 0.8$ lagging and leading will be the same because efficiency depends only on the magnitude of the power factor, not its angle. - **Efficiency is high (98.71%)** because the losses (iron and copper) are very small compared to the rated output. - **Conclusion:** The transformer operates very efficiently under full-load conditions at a power factor of 0.8, regardless of the phase (lagging or leading). This makes it suitable for a wide range of applications.	15	CO-5	L-4
OR					
	(b)	A compound generator devices a load current of 50A at 500V. The resistance are Ra=0.05 2, Rse = 0.03 2, Rsh = 250 2. Find the induced emf if contact drop is 1V/brush. Neglect armature reaction. Assume (a) Long shunt (b) short shunt connection.	15	CO-1	L-3



Given Data:

- Load current (I_L) = $50\,\mathrm{A}$
- Terminal voltage (V) = $500\,\mathrm{V}$
- Armature resistance (R_a) = $0.05\,\Omega$
- Series field resistance (R_{se}) = $0.03\,\Omega$
- Shunt field resistance (R_{sh}) = $250\,\Omega$
- Contact drop (V_c) = $1\,\mathrm{V/brush} = 2\,\mathrm{V}$ (total for two brushes)
- Neglect armature reaction.

Case (a): Long Shunt Connection

In the **long shunt connection**, the shunt field winding is connected across both the armature and the series field winding.

1. **Shunt Field Current (I_{sh}):**

$$I_{sh} = \frac{V}{R_{sh}} = \frac{500}{250} = 2\,\mathrm{A}$$

2. **Armature Current (I_a):** The armature current is the sum of the load current and the shunt field current:

$$I_a = I_L + I_{sh} = 50 + 2 = 52\,\mathrm{A}$$

3. **Voltage Drop in Series Field and Armature (V_{drop}):**

$$V_{drop} = I_a(R_a + R_{se}) = 52 \cdot (0.05 + 0.03) = 52 \cdot 0.08 = 4.16\,\mathrm{V}$$

4. **Induced EMF (E):** Using KVL:

$$E = V + V_c + V_{drop} = 500 + 2 + 4.16 = 506.16\,\mathrm{V}$$

Case (b): Short Shunt Connection

In the **short shunt connection**, the shunt field winding is connected across the armature only.

1. **Shunt Field Current (I_{sh}):** The voltage across the shunt field winding is the same as the armature voltage:

$$I_{sh} = \frac{V_a}{R_{sh}} = \frac{E - V_c}{R_{sh}}$$

Initially, assume $E \approx 506.16\,\mathrm{V}$ (as in long shunt). Refine the calculation iteratively if needed.

Substitute $V_a = E - V_c - I_a R_a$:

$$I_{sh} = \frac{E - 2 - 52 \cdot 0.05}{250}$$

$$I_{sh} = \frac{E - 4.6}{250}$$

2. **Armature Current (I_a):** The armature current is the sum of the load current and the shunt field current:

$$I_a = I_L + I_{sh} = 50 + \frac{E - 4.6}{250}$$

3. **Induced EMF (E):** Using KVL for the short shunt configuration:

$$E = V + V_c + I_a R_a + I_L R_{se}$$

Substitute I_a into this equation:

$$E = 500 + 2 + \left(50 + \frac{E - 4.6}{250}\right) \cdot 0.05 + 50 \cdot 0.03$$

Simplify:

$$E = 500 + 2 + 50 \cdot 0.03 + 0.05 \cdot 50 + 0.05 \cdot \frac{E - 4.6}{250}$$

$$E = 502 + 1.5 + 2.5 + 0.0002(E - 4.6)$$

$$E = 506 + 0.0002E - 0.00092$$

$$0.9998E = 505.99908$$

$$E = 506.1\,\mathrm{V}$$

Results:

1. **Induced EMF for Long Shunt:** $E = 506.16\,\mathrm{V}$
2. **Induced EMF for Short Shunt:** $E = 506.1\,\mathrm{V}$