SL NO. 3/Sem 4/I

MODEL QUESTION PAPER I

INDUCTION MACHINES

Time : 3 Hours Max.Marks : 75

PART A

I. Answer **all** questions in one word or one sentence **(9 x 1 = 9 Marks)**

1	List the two types of transformer based on construction.	M1.01	R
2	Write EMF equation of a transformer.	M1.02	R
3	Name the test used to measure the full load copper loss of the transformer.	M2.01	R
4	Define all day efficiency.	M2.02	R
5	Name the phenomenon in which a three phase induction motor has a tendency to run at very low speed compared to its synchronous speed	M3.02	R
6	List the two types of rotor construction used in three phase induction motors.	M3.01	R
7	Write the equation for calculating synchronous speed of rotating magnetic field.	M3.01	R
8	Name the test used to measure the no load losses in a three phase induction motor.	M4.01	R
9	List any two applications of three phase induction motor.	M4.04	R

PART B

II. Answer any ***eight*** questions from the following. Each question carries 3 marks.

(8x 3 = 24 Marks)

1	Explain the working principle of a transformer with a neat figure.	M1.01	R
2	An ideal transformer has a primary winding of 100 turns and secondary winding of 50 turns. The voltage applied to the primary winding of the transformer is 230V and the secondary winding is connected to an 1150W load. Calculate the current carried by the primary winding of the transformer.	M1.02	A
3	Sketch the equivalent circuit of a single phase transformer with resistance and leakage reactance and indicate the different parameters.	M1.04	R
4	Explain the working of a current transformer with the help of a neat sketch.	M2.03	U
5	Illustrate the connection diagram of a three phase star-delta transformer bank using three single phase transformers by indicating the polarity of the transformers.	M2.04	U
6	Explain the production of rotating magnetic field using neat figures.	M3.01	U
7	Illustrate the power flow diagram in a three phase induction motor.	M3.03	U
8	A 4 pole, 50Hz, 415V, three phase induction motor is running at a speed of 1450 rpm. Calculate the frequency of the EMF induced in the rotor in Hz.	M3.01	U
9	Draw the circuit diagram used to carry out a blocked rotor test on a three phase induction motor.	M4.01	R
10	Explain the various braking methods used in a three phase induction motor.	M0 4.03	U

PART C

Answer **ALL** questions. Each question carries 7 marks.

(6x 7 = 42 Marks)

III	Draw and explain the phasor diagram of a practical transformer connected to a capacitive load.	M1.03	U
	OR		
IV	A single-phase, 250kVA, 11kV/415V, 50Hz transformer has 80 turns on the secondary. Calculate the (a) approximate values of the primary (high voltage side) and secondary currents at full load (b) approximate number of primary turns and (c) maximum value of the flux.	M1.02	U
V	Derive the equation for saving copper in an autotransformer.	M2.03	R
	OR		
VI	Explain Open circuit Test and Short Circuit Test on single phase transformer with the help of circuit diagram.	M2.01	U
VII	In a 50kVA, 11kV/400V, single-phase transformer the iron and copper losses are 500 W and 600 W respectively under rated conditions. Calculate the (a) efficiency at unity power factor at full load (b) load at which maximum efficiency occurs and (c) iron and copper losses at this load	M2.02	A
	OR		
VIII	A 10kVA, 200V/400V, 50Hz, single-phase transformer has the following test results : OC test (HV winding open): 200 V, 1.3 A, 120 W. SC test (LV winding shorted): 22 V, 30 A, 200 W. Calculate (a) the magnetizing current, and (b) the equivalent resistance and leakage reactance as referred to the low voltage side.	M2.01	A

IX	Draw and explain the torque slip characteristics of three phase induction motor.	M3.02	U
	OR		
X	A 480V, 60 Hz, 50hp, three phase induction motor is drawing 60A at 0.85 PF lagging. The stator copper losses are 2 kW and the rotor copper losses are 700 W. The friction and windage losses are 600 W, the core losses are 1800 W, and the stray losses are negligible. Find the following quantities: 1. The air-gap power 2. The output power 3. The efficiency of the motor	M3.03	A
XI	Explain the various steps to construct circle diagram of three phase induction motor with the help of a neat sketch.	M4.01	U
	OR		
XII	Explain the working of a DOL starter with the help of a neat figure.	M4.02	U
XIII	Explain the constructional features and equivalent circuit of double cage induction motor.	M4.04	U
	OR		
XIV	Describe methods of speed control used for squirrel cage induction motor	M4.03	U

****************************END ********************************

QUESTION PAPER I PREPARED BY:	SCRUTINISED BY:
 Girish P R Lecturer in EEE GPTC Kottayam	 Jayaprakasan P Lecturer in EEE KGPTC Kozhikode

BLUE PRINT

Mark distribution

Module	**Hr / Module**	**(hi / ∑Hi) * 123**	**TYPE OF QUESTIONS**							
			PART A		**PART B**		**PART C**		**TOTAL**	
			No of Questions	Marks	No of Questions	Marks	No of Questions	Marks	No of Questions	Marks
I	14	29.69	2	2	3	9	2	14	**7**	**25**
II	15	31.81	2	2	2	6	4	28	**8**	**36**
III	14	29.69	3	3	3	9	2	14	**8**	**26**
IV	15	31.81	2	2	2	6	4	28	**8**	**36**
Total	**58**	**123**	**9**	**9**	**10**	**30**	**12**	**84**	**31**	**123**

Cognitive Level Wise Question Analysis

Mark Distribution

Cognitive Level	**% Marks**	**Marks**	**TYPE OF QUESTIONS**							
			PART A		**PART B**		**PART C**		**TOTAL**	
			No of Questions	Marks	No of Questions	Marks	No of Questions	Marks	No of Questions	Marks
R	30		9		3		1		**13**	
		36.9		9		9		7		**25**
U	50		0		6		8		**14**	
		61.5		0		18		56		**74**
A	20		0		1		3		**4**	
		24.6		0		3		21		**24**
Total	**100**		**9**		**10**		**12**		**31**	
		123		**9**		**30**		**84**		**123**

<u>Question Wise Analysis</u>

Q.No	**Module Outcome**	**Cognitive Level**	**Marks**	**Time**
I.1	M1.01	R	1	2
I.2	M1.02	R	1	2
I.3	M2.01	R	1	2
I.4	M2.02	R	1	2
I.5	M3.02	R	1	2
I.6	M3.01	R	1	2
I.7	M3.01	R	1	2
I.8	M4.01	R	1	2

I.9	M4.04	R	1	2
II.1	M1.01	R	3	7
II.2	M1.02	A	3	7
II.3	M1.04	R	3	7
II.4	M2.03	U	3	8
II.5	M2.04	U	3	8
II.6	M3.01	U	3	8
II.7	M3.03	U	3	7
II.8	M3.01	U	3	7
II.9	M4.01	R	3	7
II.10	M4.03	U	3	7
III.	M1.03	U	7	17
IV.	M1.02	U	7	17
V	M2.03	R	7	17
VI	M2.01	U	7	17
VII	M2.02	A	7	17
VIII	M2.01	A	7	17
IX	M3.02	U	7	17
X	M3.03	A	7	17
XI	M4.01	U	7	17
XII	M4.02	U	7	17
XIII	M4.04	U	7	17
XIV	M4.03	U	7	17
Total			**123**	**295**

SL NO. 3/Sem 4/II

MODEL QUESTION PAPER II

INDUCTION MACHINES

Time : 3 Hour ***Max.Marks : 75***

PART A

I. ***Answer all questions in one word or one sentence. Each question carries 1 mark.***

(9 x 1 = 9 Marks)

1	The transformer works on the principle of………………………	M1.01	R
2	Which material is used for making lamination of the transformer core?	M1.01	R
3	Define transformation ratio of the transformer.	M1.02	R
4	The open-circuit test in a transformer is used to measure ……...	M2.01	R
5	Define voltage regulation of transformers.	M2.02	R
6	The frame of an induction motor is usually made of …………	M3.01	R
7	Name the condition for maximum torque in the induction motor.	M3.02	R
8	For which induction motor, rotor resistance speed control method is not applicable.	M4.03	R
9	The advantage of the double squirrel cage induction motor over a single cage rotor is that its ……………	M4.04	R

PART B

I. Answer any *eight* questions from the following. Each question carries 3 marks.

(8 x 3 = 24 Marks)

1	Explain the concept of the ideal transformer.	M1.01	U
2	Explain the classification of transformer on the basis of construction.	M1.02	U
3	List the applications of Auto transformers.	M2.03	R
4	Explain the conditions for parallel operation of three phase transformers.	M2.04	U
5	Define starting torque and pull out torque of an induction motor.	M3.02	R
6	Illustrate the power stages of a three phase induction motor.	M3.03	U
7	Draw equivalent circuit of three phase induction motor.	M3.04	R
8	Explain the need of starters in the induction motor and list any two starters used for the induction motor	M4.02	U
9	Explain any two methods of braking of the induction motor.	M4.03	R
10	Explain the construction of a double cage induction motor.	M4.04	R

PART C

Answer *ALL* questions. Each question carries 7 marks. (6 x 7 = 42 Marks)

III	Derive the emf equation of a transformer	M1.02	U
	OR		
IV	Draw and explain the vector diagram of a transformer with resistance and leakage reactance on resistive load.	M1.03	U
V	A 3 phase, 50Hz, 11000/415V Delta/Star, 6kVA transformer is operating with a flux of 0.05Wb. Find (i) number of HV and LV turns per phase (ii) EMF per turn (iii) Full load HV and LV phase currents.	M1.02	A
	OR		
V1	A 25kVA 2200/220V, 50Hz single phase transformer has the following resistance and leakage reactance. $R_1 = 0.8\Omega$, $R_2 = 0.009\Omega$, $X_1 = 3.2\Omega$, $X_2 = 0.03\Omega$. Calculate equivalent resistance referred to primary and secondary and equivalent reactance referred to primary and secondary.	M1.04	A

VII	Identify a test to find the core loss of the transformer and explain it.	M2.01	A
	OR		
VIII	The following test results were obtained for a 50kVA transformer: Open-circuit test: primary voltage=3300 V; secondary voltage=400 V; power=430 W Short-circuit test: primary voltage=124 V; primary current=15.3 A; power=525W; secondary current = full-load current Calculate: (a) the efficiency at full load for 0.7 power factor; (b) the efficiency at half load for 0.7 power factor.	M2.01	A
IX	Explain with figure, the working of an autotransformer.	M2.03	U
	OR		
X	Explain the different cooling methods of transformer.	M2.04	U

X1	Explain the construction of three phase induction motor	M3.01	U
	OR		
XII	A 4 pole, 3 phase induction motor operates from a supply whose frequency is 50Hz. Calculate (i) the speed of the stator magnetic field (ii) rotor speed at 5% slip (iii) frequency of rotor currents when the slip is 2%.	M3.01	U
XIII	Explain the blocked rotor test of a 3-phase induction motor.	M4.01	U
	OR		
XIV	Describe methods of speed control used for slip ring induction motor.	M4.03	U

****************************END ******************************

QUESTION PAPER II PREPARED BY	SCRUTINISED BY:
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BLUE PRINT

Mark Distribution

Module	Hr / Module	(hi / ∑Hi) * 123	TYPE OF QUESTIONS							
			PART A		PART B		PART C		TOTAL	
			No of Questions	Marks	No of Questions	Marks	No of Questions	Marks	No of Questions	Marks
I	14	29.69	3	3	2	6	4	28	**9**	**37**
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III	14	29.69	2	2	3	9	2	14	**7**	**25**
IV	15	31.81	2	2	3	9	2	14	**7**	**25**
Total	**58**	**123**	**9**	**9**	**10**	**30**	**12**	**84**	**31**	**123**

Cognitive Level Wise Question Analysis

Mark Distribution

Cognitive Level	% Marks	Marks	TYPE OF QUESTIONS							
			PART A		PART B		PART C		TOTAL	
			No of Questions	Marks	No of Questions	Marks	No of Questions	Marks	No of Questions	Marks
R	30	36.9	9	9	5	15	0	0	**14**	**24**
U	50	61.5	0	0	5	15	8	56	**13**	**71**
A	20	24.6	0	0	0	0	4	28	**4**	**28**
Total	**100**	**123**	**9**	**9**	**10**	**30**	**12**	**84**	**31**	**123**

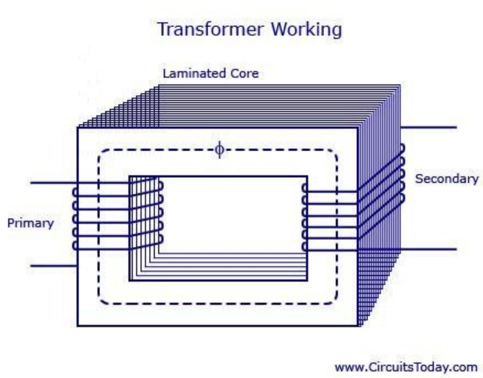
Question Wise Analysis

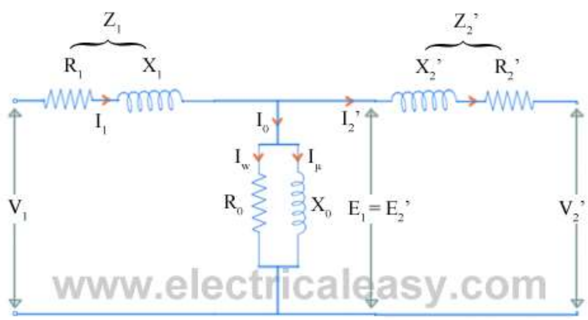
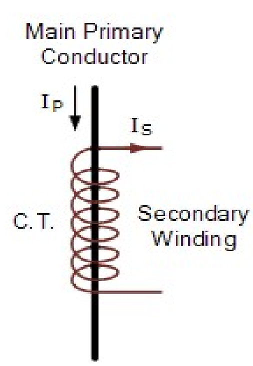
Q.No	Module Outcome	Cognitive Level	Marks	Time
I.1	M1.01	R	1	2
I.2	M1.01	R	1	2
I.3	M1.02	R	1	2
I.4	M2.01	R	1	2
I.5	M2.02	R	1	2
I.6	M3.01	R	1	2
I.7	M3.02	R	1	2
I.8	M 4.03	R	1	2
I.9	M4.04	R	1	2
II.1	M1.01	U	3	7
II.2	M1.02	U	3	7
II.3	M2.03	R	3	7
II.4	M2.04	U	3	8
II.5	M3.02	R	3	7
II.6	M3.03	U	3	7
II.7	M3.04	R	3	7
II.8	M4.02	U	3	7
II.9	M4.03	R	3	8
II.10	M3.04	R	3	8
III.	M1.02	U	7	17
IV.	M1.03	U	7	17

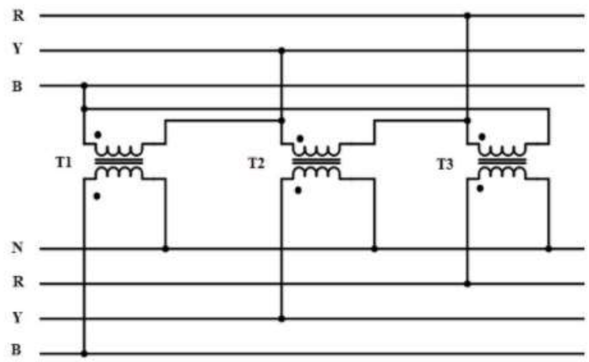
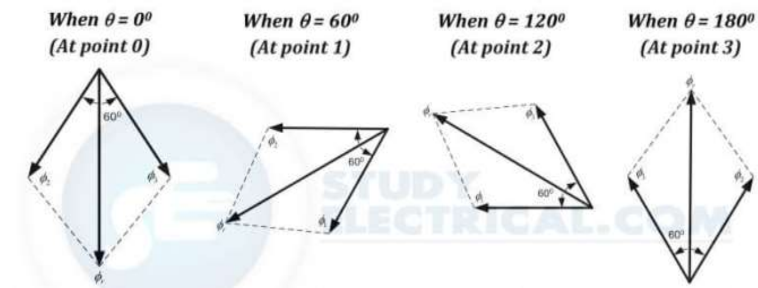
V	M1.02	A	7	16
VI	M1.04	A	7	14
VII	M2.01	A	7	17
VIII	M2.01	A	7	15
IX	M2.03	U	7	17
X	M2.04	U	7	20
XI	M3.01	U	7	20
XII	M3.01	U	7	14
XIII	M4.01	U	7	20
XIV	M4.03	U	7	17
Total			**123**	**295**

SL NO. 3/Sem 4/I

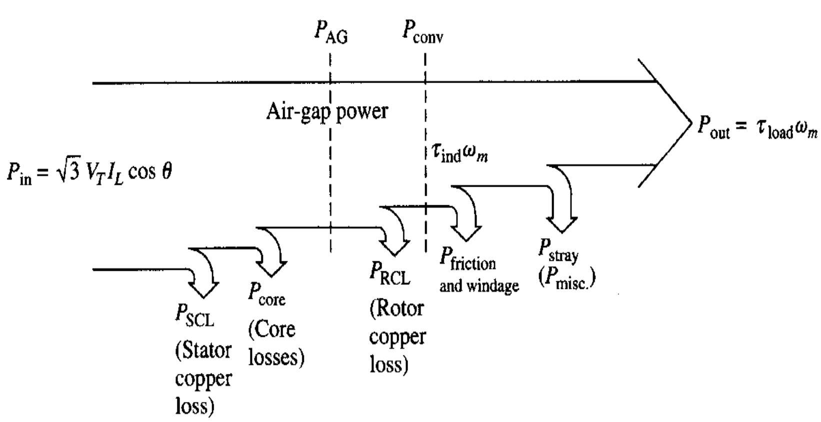
SCORING INDICATORS
MODEL QUESTION PAPER I
INDUCTION MACHINES

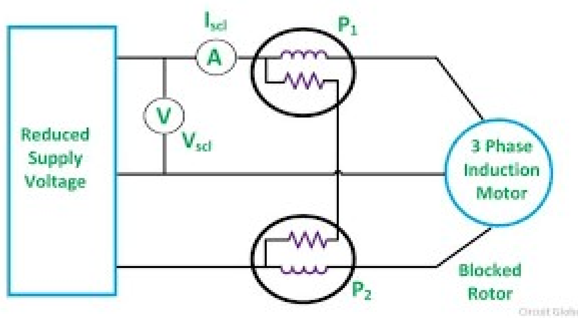
QUESTION NUMBER	SCORING INDICATORS	SPLIT UP MARKS	SUB TOTAL	TOTAL MARKS
	I. PART A			
I. 1	Core Type Transformer and shell type transformer	1		9
2	$E = 4.44 * f * \phi_M * N$	1		
3	Short Circuit Test	1		
4	All day efficiency is determined as total KWh at the secondary to the total KWh at the primary of the transformer for a long specific time period preferably 24 hrs.	1		
5	Crawling	1		
6	Squirrel Cage rotor and slip ring rotor	1		
7	$N_s = \frac{120 * f}{P}$	1		
8	No load test	1		
9	Pumps, conveyors, elevators, lathes etc (any two)	1		
	II. PART B			
II. 1	 (Reference: www.circuitstoday.com) Transformer is an electrical device which works on the principle of mutual induction. It consists of two or more coils of insulated wire wound on a laminated steel core. When voltage is introduced to one coil, called the primary, it magnetizes the iron core. A voltage is then induced in the other coil, called the	2(figure)+ 1(explanation)	3	24

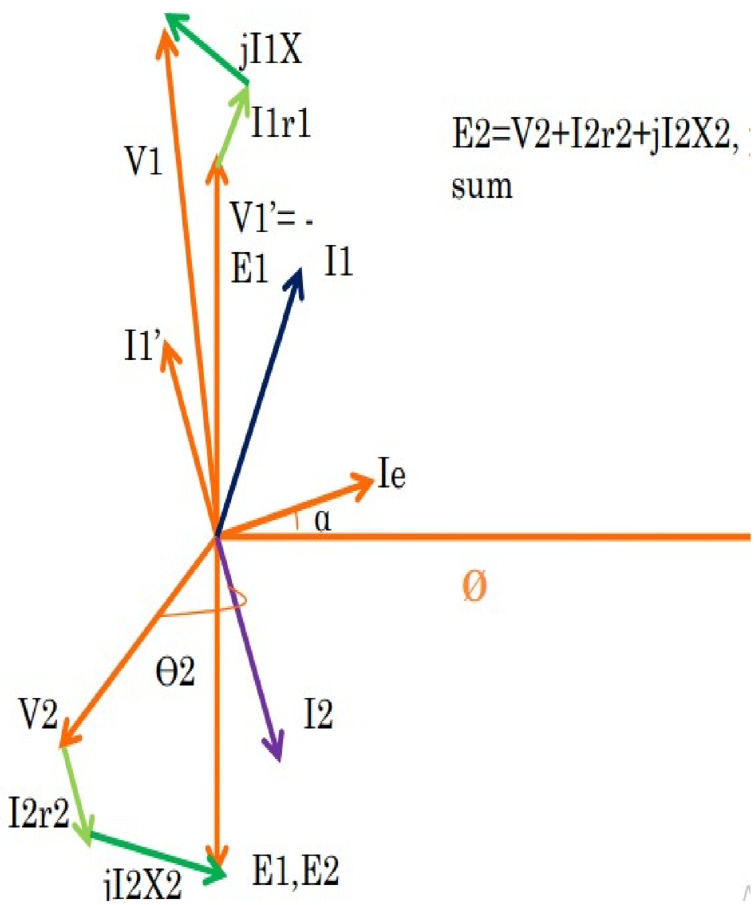
	secondary or output coil. The change of voltage (or voltage ratio) between the primary and secondary depends on the turns ratio of the two coils.			
2.	Secondary voltage, V2 =(N2/N1)*V1 V2=115V Secondary current ,I2= 1150/115=10A Primary current,I1 = (N2/N1)*I2=5A	2(for steps)+ 1(for I1)	3	
3.	 (Reference :www. electricaleasy.com) R0 and X0 Denotes core loss component and magnetizing component respectively R1 , X1 denotes primary side resistance and reactance respectively R2, X2 denotes secondary side resistance and reactance respectively	2(for circuit) + 1(for parameters)	3	
4.	Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The current transformer consists of only one or very few turns as its primary winding. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole.  (Reference : www.electrical4u.com)	2(figure) + 1 (explanation)	3	

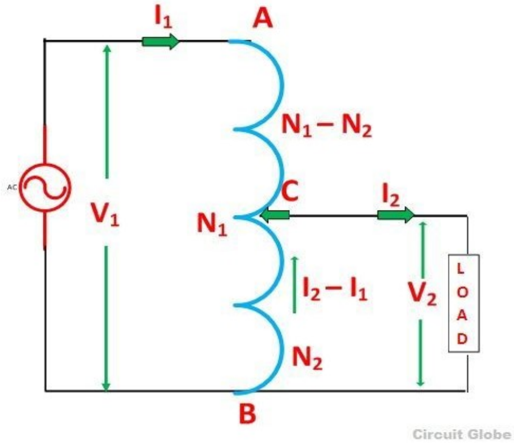
<table>
<tr><td>5.</td><td>
</td><td>3</td><td>3</td><td></td></tr>
<tr><td>6.</td><td>

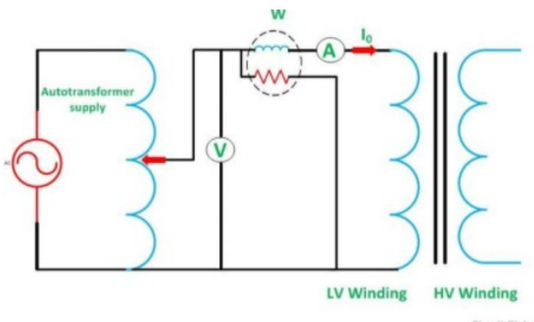
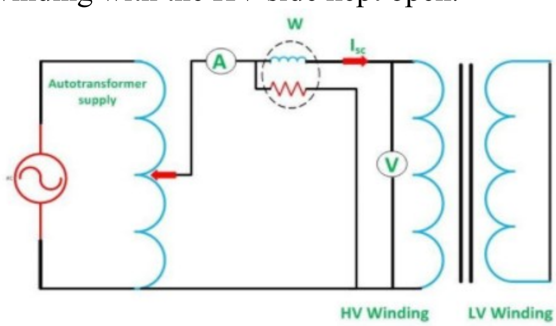
(Reference: studyelectrical.com)

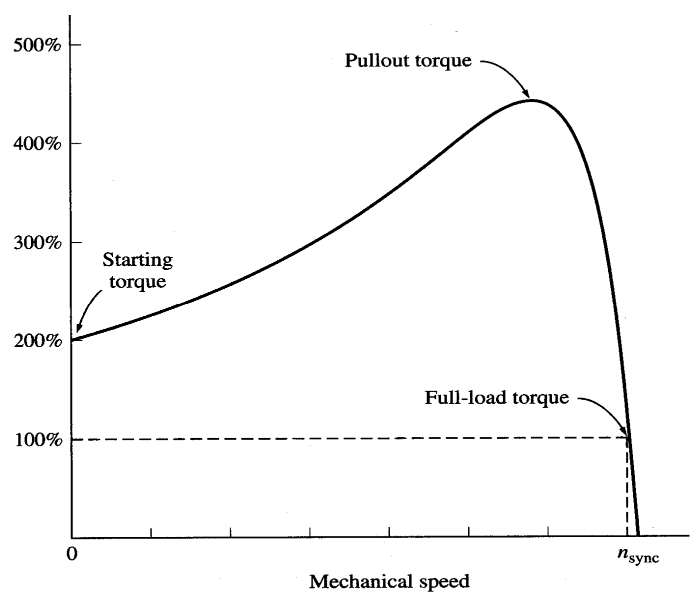
When a 3-phase winding is energized from a balanced 3-phase supply, a rotating magnetic field is produced. This field is such that its poles do no remain in a fixed position on the stator but go on shifting their positions around the stator. The speed of the RMF is constant and is known as synchronous speed.</td><td>2(for figures) + 1(for explanation)</td><td>3</td><td></td></tr>
<tr><td>7.</td><td>
</td><td>3</td><td>3</td><td></td></tr>
</table>

8.	Synchronous speed of RMF, Ns= 120*f/P=1500rpm Slip=(Ns-Nr)/Ns=0.033 Rotor EMF frequency = s*f=1.67Hz	1(for Ns)+ 1(for slip)+ 1(for rotor EMF frequency)	3	
9.	 (Reference: www.circuitglobe.com)	2(for instruments)+ 1(for showing blocked rotor)	3	
10.	Regenerative Braking • If the rotor speed becomes greater than synchronous speed, then the relative speed between the rotor conductor and air gap rotating field reverse and the power will be fed back to supply. Plugging or reverse voltage braking • When the phase sequence of supply of the motor running at speed is reversed by interchanging the connection of any two phases of the stator on the supply terminal. Dynamic Braking • The stator of induction motor is connected across the DC supply, which produces a stationary magnetic field. The machine therefore works as a generator and the generated energy is dissipated in the rotor circuit resistance, thus giving the dynamic braking.	1*3=3	3	

PART C				
III.	 (Reference:www.electricalbaba.com)	4(for figure) + 3(for explanation)	7	42
OR				
IV	Primary current , I1= 250*/11=22.7A Secondary current, I2= 250*1000/415= 602A Number of primary turns, N1=(V1/V2)*N2=2120 Maximum value of flux, =V2/(4.44*f*N2)=23.4mWb	1(for I1)+ 1(for I2)+ 2(for N1)+ 3(for flux)	7	

V	 (Reference: www.circuitglobe.com) The weight of the copper is proportional to the length and area of a cross-section of the conductor. The length of the conductor is proportional to the number of turns, and the area of cross-section is proportional to the product of current and number of turns. Weight of autotransformer is proportional to: $W_a \propto I_1 (N_1 - N_2) + (I_2 - I_1) N_2$ $W_a \propto I_1 N_1 + I_2 N_2 - 2 I_1 N_2$ Weight of ordinary transformer is proportional to: $W_o \propto I_1 N_1 + I_2 N_2$ the ratio of the weight of the copper in an auto transformer to the weight of copper in an ordinary transformer is given as $\frac{W_a}{W_o} = \frac{I_1 N_1 + I_2 N_2 - 2 I_1 N_2}{I_1 N_1 + I_2 N_2}$ OR $\frac{W_a}{W_o} = \frac{I_1 N_1 + I_2 N_2}{I_1 N_1 + I_2 N_2} - \frac{2 I_1 N_2}{I_1 N_1 + I_2 N_2}$ $\frac{W_a}{W_o} = 1 - \frac{2 I_1 N_2 / I_1 N_1}{I_1 N_1 / I_1 N_1 + I_2 N_2 / I_1 N_1} = 1 - K$ OR $W_a = (1 - K) W_o$ Saving of copper = $W_O - W_a = W_o - (1 - K) W_0 = K W_O$	2(for figure) + 5 (for derivation)	7	

OR				
VI	 (Reference: www.circuitglobe.com) OC Test: The purpose of the open-circuit test is to determine the no-load current and no load losses of the transformer. This test is normally performed on the Low voltage side of the transformer. The wattmeter, ammeter and the voltage are connected to the LV winding. The nominal rated voltage is supplied to the LV winding with the HV side kept open.  (Reference: www.circuitglobe.com) SC Test: The purpose of the short circuit test is to determine the full load copper losses of the transformer. The short circuit test is performed on the high voltage winding of the transformer. The measuring instrument like wattmeter, voltmeter and ammeter are connected to the high voltage winding of the transformer. The low voltage winding is short-circuited by the help of thick strip.	2(for figure) + 2(for explanation and equation) 2(for figure) + 1(for explanation and equation)	7	
VII	At full load upf, output power = 50*1=50kW At full load input= output power + core loss+ copper loss Input power= 50+0.5+0.6=51.1kW Efficiency at full load upf = output power/input power= 50/51.1= 97.85% Load for maximum efficiency = $\sqrt{\frac{coreloss}{copperloss}} * 50 = \sqrt{\frac{500}{600}} * 50 = 45.6kVA$	1(for input power) + 2(for efficiency)+ 2(load for maximum	7	

	Iron loss and copper loss at this load = 500W	efficiency)+ 2(for iron and copper loss)		
	OR			
VIII	Turns ratio, k=2 No load power factor = (120/(200*1.3))= 0.46 Working current= I0* no load pf=1.3*0.46=0.6A Magnetizing current = $I_m = \sqrt{I_0^2 - I_w^2}$ =1.15A HV side Resistance = 200/(30*30)= 0.22ohm LV side resistance = 0.22/(k^2)=0.055ohm HV side impedance= V/I=22/30=0.73ohm HV side reactance= $\sqrt{0.73^2 - 0.22^2}$ =0.696 ohm LV side reactance = 0.696/k^2=0.174 ohm	1(for no load pf)+ 2(for magnetizing current)+ 2(for LV side resistance)+ 2(for LV side reactance)	7	
IX	 The induced torque is zero at synchronous speed. The curve is nearly linear between no-load and full load. In this	4(For figure)+ 3(for explanation)	7	

	range, the rotor resistance is much greater than the reactance, so the rotor current, torque increase linearly with the slip. There is a maximum possible torque that can't be exceeded. This torque is called *pullout torque* and is 2 to 3 times the rated full-load torque. The torque of the motor for a given slip varies as the square of the applied voltage.			
	OR			
X	Input power, $P_{in} = \sqrt{3} V_L I_L \cos\theta$ $= \sqrt{3} \times 480 \times 60 \times 0.85 = 42.4\,\text{kW}$ Air gap power. $P_{AG} = P_{in} - P_{SCL} - P_{core}$ $= 42.4 - 2 - 1.8 = 38.6\,\text{kW}$ Converted power , $P_{conv} = P_{AG} - P_{RCL}$ $= 38.6 - \frac{700}{1000} = 37.9\,\text{kW}$ Output power , $P_{out} = P_{conv} - P_{F\&W}$ $= 37.9 - \frac{600}{1000} = 37.3\,\text{kW}$ Efficiency of the motor $\eta = \frac{P_{out}}{P_{in}} \times 100\%$ $= \frac{37.3}{42.4} \times 100 = 88\%$	1(for input power) + 2(for airgap power) + 2(for output power) + 2(for efficiency)	7	

<table>
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<td>XI</td>
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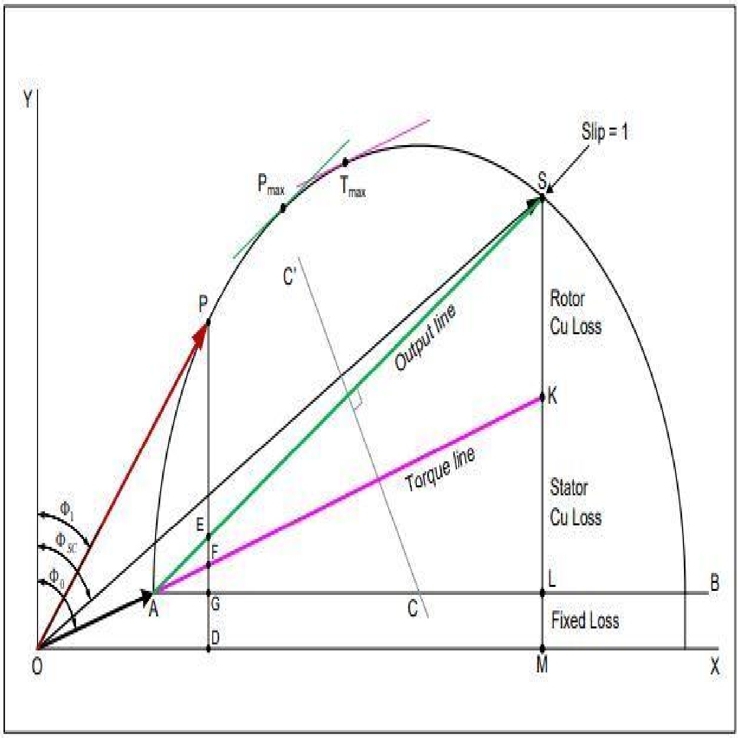

Select a suitable scale and first draw Io at an angle Φo from the vertical.
Using the same scale draw Isn at an angle Φsc from the vertical. Name the end points as OS.
Join A and S to obtain the output line.
Draw a horizontal line from A.
Draw a perpendicular bisector to AS. The meeting point of this bisector with the horizontal line from A is the centre of the circle. (Name the meeting point as C)
Draw a semi-circle with radius equal to distance from centre to A (Draw a circle with Centre at C and radius AC).
Draw a perpendicular SM from S to the x axis.
Divide SL such that SK is equal to rotor copper loss and KL is equal to stator copper loss. (Normally divide in half if nothing is mentioned).
Join AL to obtain the torque line.
The operating point of this induction lies in the circle.
</td>
<td>4(for figure)

+
3(for steps)</td>
<td>7</td>
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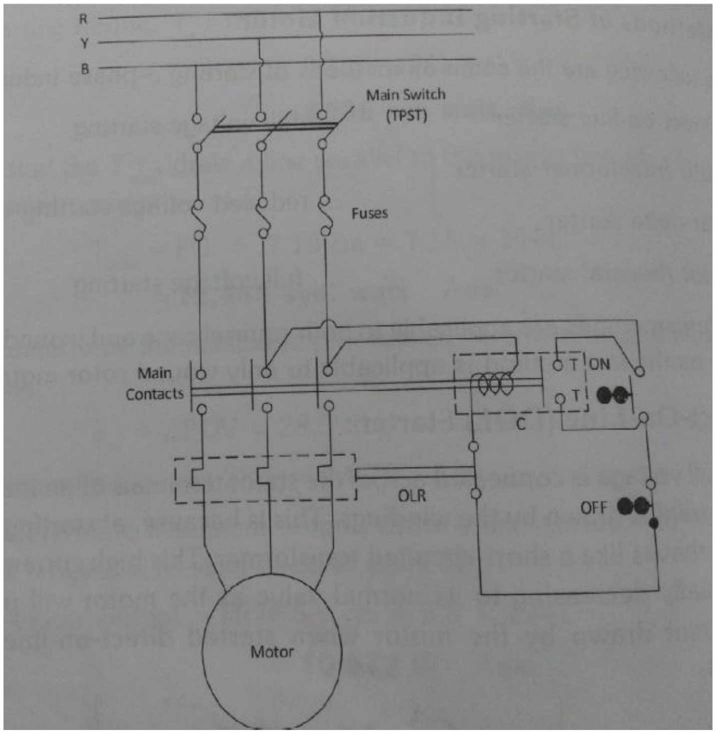
<tr><td colspan="5">OR</td></tr>
<tr>
<td>XII</td>
<td>


It consists of a contactor controlled by a relay.
2 push buttons are used for ON and OFF function of which the ON switch is Normally open (NO) and OFF switch is Normally Closed (NC)
The relay terminals are connected to auxiliary contact such that once the relay coil is energized it maintains the supply through auxiliary contact (Terminal T-T in circuit).
When the motor is to be turned ON, the ON is switch is pressed making the relay circuit complete.
Due to this the main contactor gets closed and motor starts running.
Even after the ON switch goes back to Normally Open condition the main contact remains in the same position due to auxiliary contact supply.
When the motor is to be turned OFF, the OFF is switch is pressed making the relay circuit open and there by opening the main contractor.
Similarly in case of any overload, the overload relay opens the relay circuit, thereby turning OFF the motor.
Normally used for motors below 5 hp

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<td>4(for figure) +

3(for explanation)</td>
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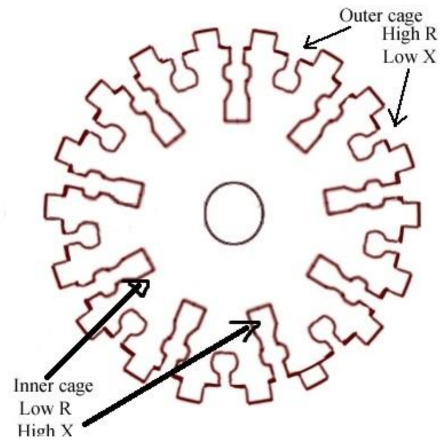
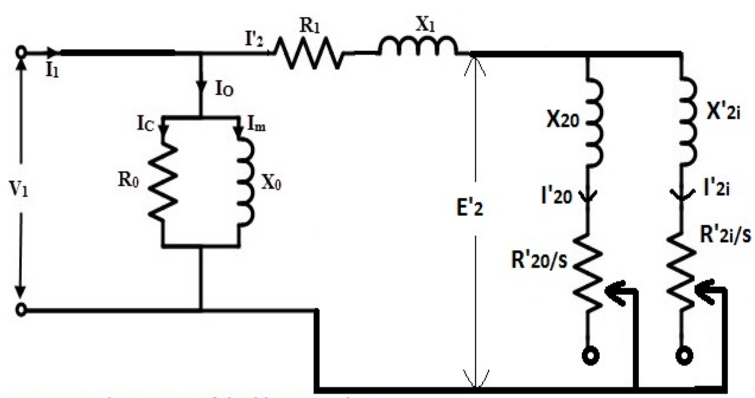
XIII	 (Reference:www.electricaleasy.com) A rotor of double cage motor carries two squirrel cage windings embedded in two rows of slots. The outer slots contain high resistance and low reactance conductors and inner cage have low resistance and high reactance conductors. At starting rotor has the same frequency as that of stator. Hence reactance of inner cage winding becomes higher than that of the outer cage. Thus rotor current is forced to flow through the outer cage to produce sufficiently high starting torque. At normal speed since frequency of rotor reduces to a low value the reactance of inner cage and hence impedance reduces to a very low value. Then rotor current is forced to flow through the inner cage to produce sufficiently high running torque.  Fig: Equivalent circuit of double cage induction motor	4(for constructional features) + 3(for equivalent circuit)	7	

OR				
XIV	1. Changing Applied Voltage This method, even though easiest, it is rarely used. The reasons are (a) for a small change in speed, there must be a large variation in voltage. (b) This large change in voltage will result in large change in flux density 2. Changing Applied Frequency The synchronous speed of the induction motor is given by Ns = 120f/P. So from this relation, it is evident that the synchronous speed and thus the speed of the induction motor can by varied by the supply frequency. 3. Changing Number Of Stator Poles The number of poles is inversely proportional to the speed of the motor. This change of number of poles can be achieved by having two or more entirely independent stator windings in the same slots. Each winding gives a different number of poles and hence different synchronous speed. 4. V/f control: The voltage and frequency are varied in proportion so that the flux density remains constant.	1(for voltage control) + 2(for frequency control) + 2(for pole changing)+ 2(V/f control)	7	

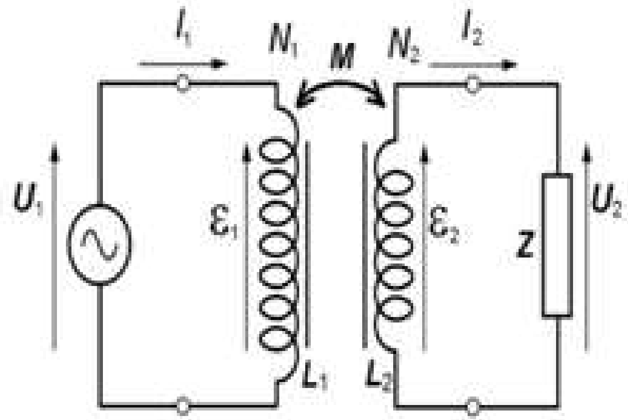
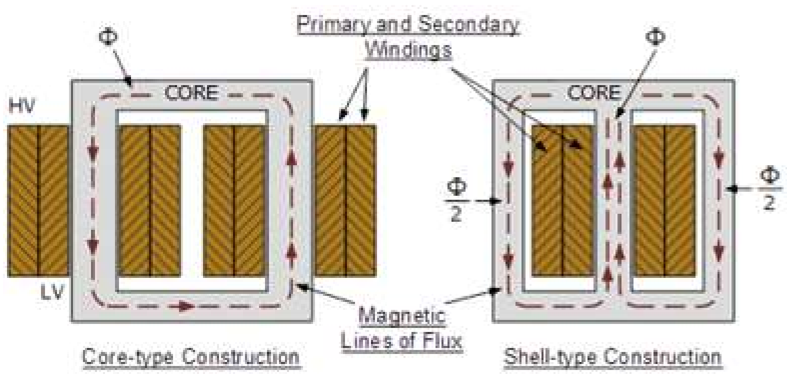
SL NO. 3/Sem 4/II

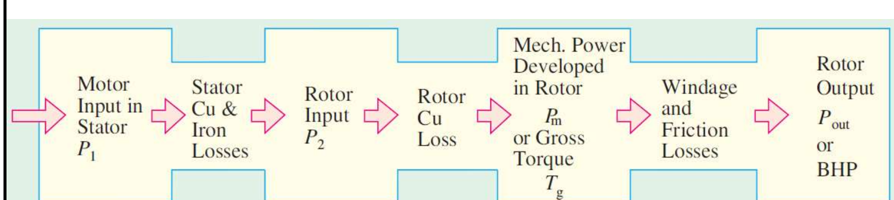
Scoring Indicators

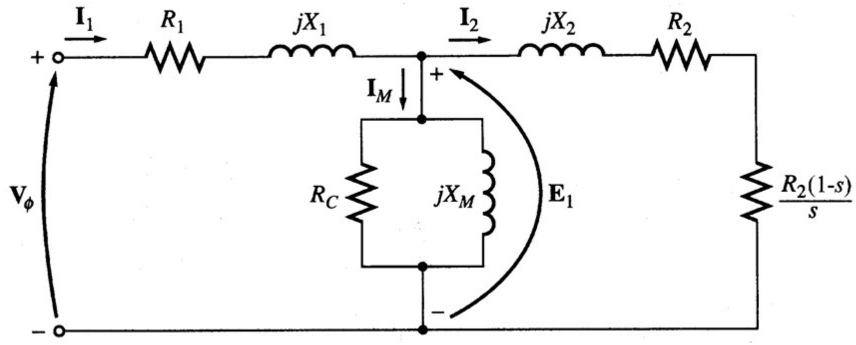
Model Question Paper II

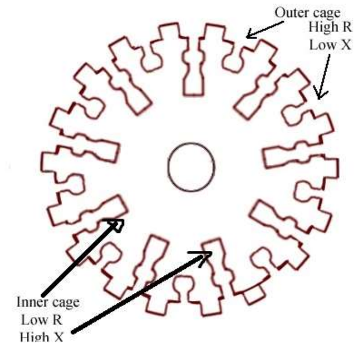
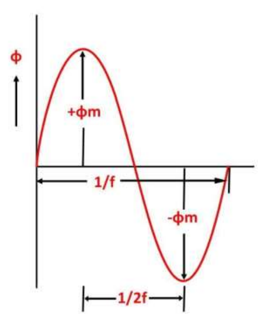
INDUCTION MACHINES

Revision: 2021 **INDUCTION MACHINES**				
Qs No	**Scoring indicator**	**Split up score**	**Sub Total**	**Total**
I	**PART A**			**9**
1	Electromagnetic induction	**1**		
2	Silicon Steel	**1**		
3	Transformation ratio of a transformer is the ratio of secondary voltage to primary voltage.	**1**		
4	Core loss	**1**		
5	Voltage Regulation of transformers is the percentage change in its secondary terminal voltage compared to its original no-load voltage under varying secondary load conditions.	**1**		
6	Cast iron	**1**		
7	$S \times X_2 = R_2$	**1**		
8	Squirrel cage induction motor	**1**		
9	Starting current is low.	**1**		
PART B				
II **1**	A transformer that doesn't have any losses like copper and core is known as an ideal transformer. In this transformer, the output power is equivalent to the input power. The efficiency of this transformer is 100%, which means there is no loss of power within the transformer. The properties of an ideal transformer include the following. ● · The two windings of this transformer have small resistance. ● · Because of the resistance, eddy current and hysteresis	**Fig-1** **Explanation-2**	**3**	**24**

	there are no losses in the transformer. ● · The efficiency of this transformer is 100% ● · The total flux generated in the transformer has restricted the core & connects with the windings. Therefore, its flux & inductance leakage is zero. 			
2	The two most common and basic designs of transformer construction are the Closed-core Transformer and the Shell-core Transformer. 	**Fig-1.5 Explanation-1.5**	**3**	
3	(1) Inter connecting transformers e.g. 400kv/220kv transformers, 220kv/132kv transformers where turns ratio is not so great. (2) As *variacs*. Wherever we need variable voltage LT supply, an auto transformer is used with toroidal core winding. This gives a cheap and compact design. (3) Used for fan speed control and lamp dimmers (4)Used in electrical apparatus testing labs since the voltage can be smoothly and continuously varied. (5)They find application as boosters in AC feeders to increase the voltage levels.	**3×1=3**	**3**	

4	The following conditions are to be fulfilled before paralleling two three phase Transformers:- 1. The voltage transformation ratio of the both transformer must be same. 2. The polarity must be same. 3. The phase sequence must be same.	**3**	**3**	
5	Starting torque is the torque produced by an inductionmotor when it starts. The Starting Torque is the torque, an electrical motor develops when starting at zero speed. A high Starting Torque is more important for application or machines hard to start - like positive displacement pumps, cranes etc. A lower Starting Torque can be accepted for centrifugal fans or pumps where the start load is low or close to zero. The starting torque is also known as Standstill Torque. At the start condition the value of s = 1. Therefore, the starting is $$T_{dst} = \frac{3\, E_{20}^2 R_2}{2\pi\, n_s\, (R_2^2 + X_{20}^2)}$$ The maximum or pull-out torque of the three-phase induction motor three-phase induction motor is the extreme bearable torque which motor can produce without any sudden decrease in its regular speed but for a short time interval. If the motor stays to work at its maximum or pull out torque, it will produce serious damage for the rotor of the motor and in conclusion, the speed of the motor will steadily slow down and motor stops to work. $$T_{d\,max} = \frac{k\, E_{20}^2}{2X_{20}}$$	**1.5** **1.5**	**3**	
6	 	**3**	**3**	

7		**3**	**3**	
8	If normal voltage is applied to Three phase Induction motor at starting then a starting current of 5 to 7 times the full load current is taken from the supply. Hence it is not advisable to start induction motors of large capacity directly. So starters are used. Types of starters are DOL (Direct Online Starters), Primary Resistance Starters, Star Delta Starters, Auto transformer Starter, Rotor Resistance Starters (Applicable for slip ring)	**2** **1**	**3**	
9	(1)Regenerative braking: If the rotor speed becomes greater than synchronous speed, then the relative speed between the rotor conductor and air gap rotating field reverse and the power will be fed back to supply. (2)Plugging: When the phase sequence of supply of the motor running at speed is reversed by interchanging the connection of any two phases of the stator on the supply terminal. The reversal of phase sequence reverses the direction of a rotating field. (3)Dynamic method: In this method, the stator of induction is connected across the DC supply. The direct current flow through the stator produces a stationary magnetic field, and the motion of the rotor in this field induces voltage in the stationary windings. The machine therefore works as a generator and the generated energy is dissipated in the rotor circuit resistance, thus giving the dynamic braking.	**1.5×2 = 3**	**3**	
10	A rotor of double cage motor carries two squirrel cage windings embedded in two rows of slots as shown in figure. The outer slots contain high resistance and low reactance conductors and inner cage have low resistance and high reactance conductors. At starting rotor has the same frequency as that of stator. Hence reactance of inner cage winding becomes higher than that of the	**Fig-1 Explanation-2**	**3**	

	outer cage. Thus rotor current is forced to flow through the outer cage to produce sufficiently high starting torque. At normal speed since frequency of rotor reduces to a low value the reactance of inner cage and hence impedance reduces to a very low value. Then rotor current is forced to flow through the inner cage to produce sufficiently high running torque.  			
	PART C			
III	Let · ϕ_m be the maximum value of flux in Weber · f be the supply frequency in Hz · N_1 is the number of turns in the primary winding · N_2 is the number of turns in the secondary winding Φ is the flux per turn in Weber  	**7**	**7**	**42**

As shown in the above figure that the flux changes from + ϕ_m to – ϕ_m in half a cycle of 1/2f seconds.

By Faraday's Law

Let E_1 be the emf induced in the primary winding

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

Where $\Psi = N_1\phi$

Therefore, $E_1 = -N_1 \frac{d\varphi}{dt}$ ....(2)

Since ϕ is due to AC supply $\phi = \phi_m$ Sinwt

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

$$E_1 = -N_1 \, w\varphi_m \text{ Coswt}$$

$$E_1 = N_1 w\varphi_m \text{ Sin}(wt - \pi/2) \dots \dots \dots . (3)$$

Maximum valve of emf

$$E_1 max = N_1 w\varphi_m \dots \dots \dots . (4)$$

But w = 2πf

$$E_1 max = 2\pi f N_1 \varphi_m \dots \dots \dots . (5)$$

Root mean square RMS value is

$$E_1 = \frac{E_{1max}}{\sqrt{2}} \dots \dots \dots . . (6)$$

Putting the value of E_1max in equation (6) we get

$$E_1 = \sqrt{2}\pi f N_1 \varphi_m \text{ ....(7)}$$

<table>
<tr>
<td>IV</td>
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Putting the value of π = 3.14 in the equation (7) we will get the value of E_1 as

$$E_1 = 4.44 f N_1 \varphi_m \dots\dots\dots (8)$$

Similarly

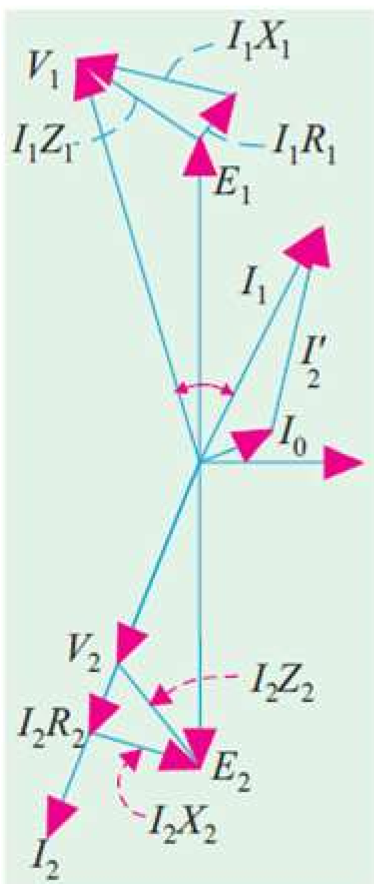
$$E_2 = \sqrt{2}\pi f N_2 \varphi_m$$

Or

$$E_2 = 4.44 f N_2 \varphi_m \dots\dots\dots (9)$$

($\phi m = B_m \times A_i$) where A_i is the iron area and B_m is the maximum value of flux density.

$$E_1 = 4.44 N_1 f B_m A_i \text{ Volts} \quad \text{and} \quad E_2 = 4.44 N_2 f B_m A_i \text{ Volts}$$



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<td>Diagram-5 Explanation-2</td>
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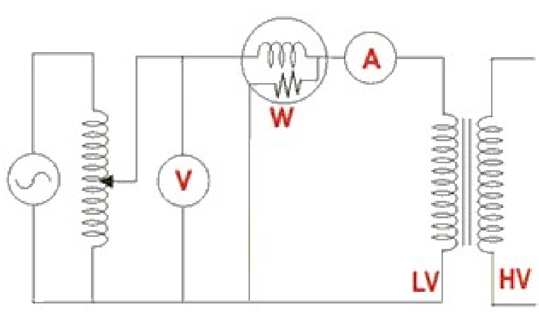
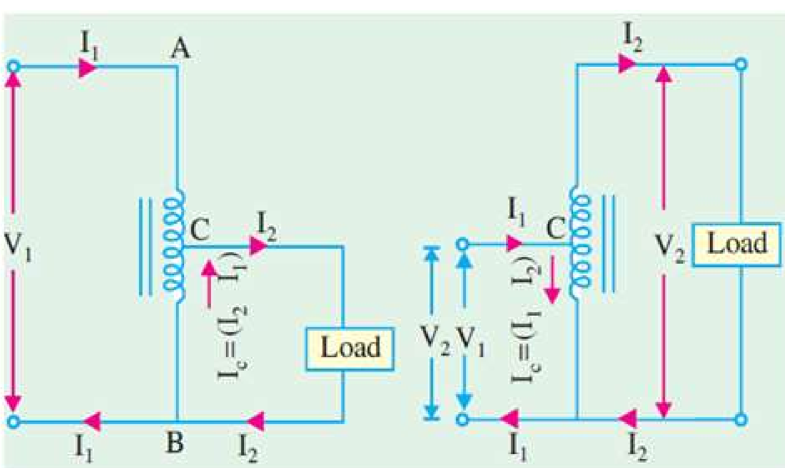
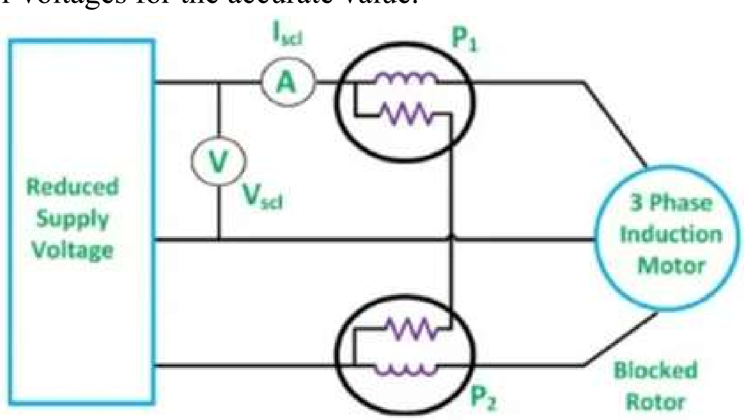
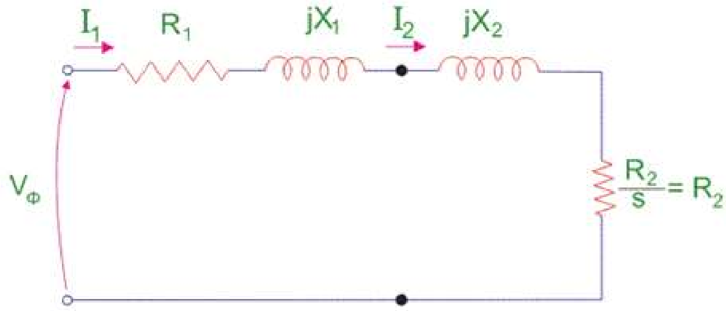
V	Maximum value of flux, $\phi m = 0.05Wb$ (ii) EMF per turn = $4.44f\,\phi m = 11.1V$ Voltage per phase on delta connected primary winding = 11000V Voltage per phase on star connected secondary winding = 415/1.732 = 239.6V (i) N_1 = Number of turns on primary per phase = voltage per phase/emf per turn = 11000/11.1 = 991 N_2 = Number of turns on secondary per phase = voltage per phase/emf per turn = 21.6 = 22 (iii) Full load HV and LV phase currents Output per phase = 6kVA/3 = 2kVA HV phase current = 2000/11000 = 0.182A LV phase current = 2000/239.6 = 8.35A	**2** **1** **1** **1** **1** **1**	**7**	
VI	K = V2/V1 = 220/2200 = 0.1 R01 = R1 + (R2/K^2) = 1.7Ω X01 = X1 + (X2/K^2) = 6.2 Ω R02 = R2 + (K^2×R1) = 0.017 Ω X02 = X2 + (K^2×X1) = 0.062 Ω	**1** **1.5** **1.5** **1.5** **1.5**	**7**	
VII	The connection diagram for **open circuit test on transformer** is shown in the figure.  Open Circuit Test on Transformer The voltage at rated frequency is applied to that LV side. The ammeter reading gives the no load current I_e. As the transformer is open circuited, there is no output, hence the input power here	**Fig-3 Explanation-4**	**7**	

VIII	consists of core losses in transformer and copper loss in transformer during no load condition. But the no-load current in the transformer is quite small compared to the full load current. So the copper loss can be neglected due to the no-load current. Hence the wattmeter reading as equal to the core losses in the transformer. Let wattmeter reading is Po. $$P_o = \frac{V_1^2}{R_m}$$ Where, Rm is shunt branch resistance of transformer. If, Zm is shunt branch impedance of transformer. $$Z_m = \frac{V_1}{I_e}$$ Core loss = 430 W Copper loss on full-load = 525 W ∴ Total loss on full load = 955 W = 0.955 kW Efficiency at full-load = {(50×0.7)/[(50×0.7)+0.955)}×100 = 97.3% Copper loss on half load = 525 × $(0.5)^2$ = 131 W ∴ Total loss on half load = 430 + 131 = 561 W = 0.561 kW Efficiency at half-load = {(25×0.7)/[(25×0.7)+0.561)}×100 = 96.9%	1 2 1 1 2	7	
IX	 It is a transformer with one winding only, part of this being common to both primary and secondary.But its theory and	Fig-3 Explanation-4	7	

	operation are similar to those of a two-winding transformer. Because of one winding, it uses less copper and hence is cheaper. It is used where transformation ratio differs little from unity.As shown in Fig, AB is primary winding having N1 turns and BC is secondary winding having N2 turns. Neglecting iron losses and no-load current. $$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$$ The current in section CB is vector difference of I2 and I1. But as the two currents are practically in phase opposition, the resultant current is (I2 − I1) where I2 is greater than I1. As compared to an ordinary 2-winding transformer of same output, an auto-transformer has higher efficiency but smaller size. Moreover, its voltage regulation is also superior.			
X	The following cooling types are in common use : (a) oil-filled self-cooled (b) oil-filled water-cooled (c) air-blast type	1	7	
	Small and medium size distribution transformers–so called because of their use on distribution systems as distinguished from line transmission–are of **type (a)**. The assembled windings and cores of such transformers are mounted in a welded, oil-tight steel tank provided with steel cover. After putting the core at its proper place, the tank is filled with purified, high quality insulating oil. The oil serves to convey the heat from the core and the windings to the case from where it is radiated out to the surroundings.	2		
	Construction of very large self-cooled transformers is expensive, a more economical form of construction for such large transformers is provided in the **oil-immersed, water-cooled type**. The windings and the core are immersed in the oil, but there is mounted near the surface of oil, a cooling coil through which cold water is kept circulating. The heat is carried away by this water. The large transformers such as those used with high-voltage transmission lines, are constructed in this manner. Oil-filled transformers are built for outdoor duty and as these require no housing other than their own, a great saving is thereby effected. These transformers require only periodic inspection.	2		
	For voltages below 25,000 V, transformers can be built for cooling by means of an **air-blast**. The transformer is not immersed in oil,	2		

	but is housed in a thin sheet-metal box open at both ends through which air is blown from the bottom to the top by means of a fan or blower.			
XI	A 3 phase induction motor has two main parts (i) stator and (ii) rotor. The rotor is separated from the stator by a small air-gap which ranges from 0.4 mm to 4 mm, depending on the power of the motor.	1		
	(1)Stator : It consists of a steel frame which encloses a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses. A number of evenly spaced slots are provided on the inner periphery of the laminations. The insulated connected to form a balanced 3-phase star or delta connected the circuit. The 3-phase stator winding is wound for a definite number of poles as per requirement of speed.	1	7	
	(2)Rotor: The rotor, mounted on a shaft, is a hollow laminated core having slots on its outer periphery. The winding placed in these slots (called rotor winding) may be one of the following two types: (i) Squirrel cage type (ii) Wound type	1		
	(i) Squirrel cage rotor: It consists of a laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal rings called end rings. This forms a permanently short circuited winding which is indestructible. The entire construction (bars and end rings) resembles a squirrel cage and hence the name. The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors. Most of 3 phase induction motors use squirrel cage rotor as it has a remarkably simple and robust construction enabling it to operate in the most adverse circumstances. However, it suffers from the disadvantage of a low starting torque. It is because the rotor bars are permanently short-circuited and it is not possible to add any external resistance to the rotor circuit to have a large starting torque.	2		
	(ii) Wound rotor: It consists of a laminated cylindrical core and carries a 3-phase winding, similar to the one on the stator. The	2		

	rotor winding is uniformly distributed in the slots and is usually star-connected. The open ends of the rotor winding are brought out and joined to three insulated slip rings mounted on the rotor shaft with one brush resting on each slip ring. The three brushes are connected to a 3-phase star-connected rheostat. At starting, the external resistances are included in the rotor circuit to give a large starting torque. These resistances are gradually reduced to zero as the motor runs up to speed. The external resistances are used during starting period only. When the motor attains normal speed, the three brushes are short-circuited so that the wound rotor runs like a squirrel cage rotor.			
XII	$P = 4, f = 50Hz$ $Ns = 1500rpm$ Rotor speed at $S = 5\% = 0.05$ $Nr = Ns \times (1-S) = 1425rpm$ $fr = S \times f = 1Hz$	**2** **2** **3**	**7**	
XIII	In the blocked rotor test, the applied voltage on the stator terminals should be low otherwise normal voltage could damage the winding of the stator. In block rotor test, the low voltage is applied so that the rotor does not rotate and its speed becomes zero and full load current passes through the stator winding. The slip is unity related to zero speed of rotor hence the load resistance becomes zero. Slowly increase the voltage in the stator winding so that current reaches to its rated value. At this point, note down the readings of the voltmeter, wattmeter and ammeter to know the values of voltage, power and current. The test can be repeated at different stator voltages for the accurate value. 	**Fig-3** **Explanation-4**	**7**	



In blocked rotor test, core loss is very low due to the supply of low voltage and frictional loss is also negligible as rotor is stationary, but stator cupper losses and the rotor cupper losses are reasonably high.

Let copper loss is W_{cu}.

Therefore,

$$W_{cu} = W_s - W_c$$

Where, W_c = core loss

$$W_{cu} = 3I^2 R_{01}$$

Where, R_{01} = Motor winding of stator and rotor as per phase referred to stator.

Thus,

$$R_{01} = \frac{W_{cu}}{3I_s^2}$$

Now let us consider

I_s = short circuit current

V_s = short circuit voltage

Z_0 = short circuit impedance as referred to stator

Therefore,

$$Z_{01} = \frac{short\ circuit\ voltage\ per\ phase}{short\ circuit\ current} = \frac{V_s}{I_s}$$

X_{01} = Motor leakage reactance per phase referred to stator can be calculated as

$$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$$

XIV	**1.** Changing Applied Voltage This method, even though it is the easiest, is rarely used. The reasons are (a) for a small change in speed, there must be a large variation in voltage. (b) This large change in voltage will result in large change in flux density **2.**Changing Applied Frequency The synchronous speed of the induction motor is given by Ns = 120f/P. So from this relation, it is evident that the synchronous speed and thus the speed of the induction motor can be varied by the supply frequency. **3.**Rotor resistance control By varying the rotor resistance, slip can be controlled and thereby speed can be controlled. **4.**V/f control: The voltage and frequency are varied in proportion so that the flux density remains constant.	1(for voltage control) +2(for frequency control) +2(for rotor resistance control) +2(V/f control)	**7**	