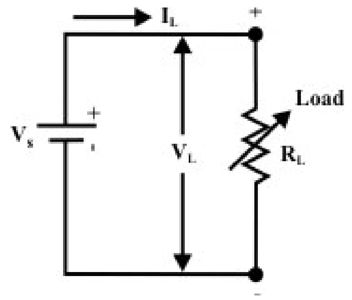
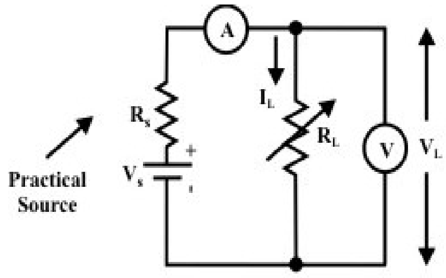
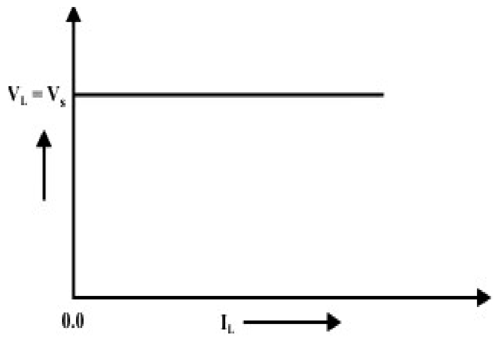
1	a)	Ideal voltage source	Practical Voltage source	Marks:
		-Terminal volts constant for all current values.	-Terminal volts falls for increasing current values.	1
		-Has Zero internal resistance.	-Has finite non zero internal resistance (low value preferably).	1
		-Figures:	-Figures:	



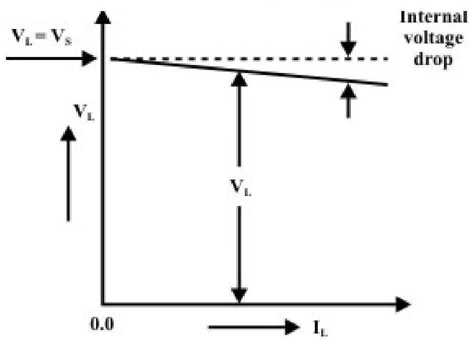


Practical dc voltage source model

1



V-I characteristics of ideal voltage source



1 V-I characteristics of practical voltage source

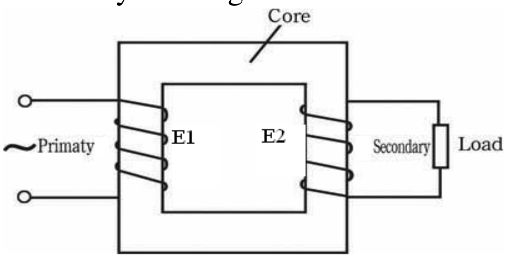
1

1	b)	A.C. system	D. C. System	
		- Specified by RMS/effective values	- Specified by actual values.	
		- Lines distinguished by phases (RYB)	- Lines distinguished by polarities (+, -).	
		- Single phase, two phase and poly-phase systems used.	- Only two polarities are obtained.	1 mark each point max. 04 marks
		- Characterized by impedances consisting of resistances, inductive / capacitive reactances.	- Characterized by resistances in steady state circuits.	
		-AC resistance is higher due to skin effect.	-DC resistance only present.	
		-fault current interruption is easy as the current passes through zero periodically	-fault current interruption difficult as current never becomes zero.	
		--more suitable for domestic supply	--more suitable for vehicular systems	
		-HVAC used in large industries	-not suitable at high voltages	

1 c) Principle of working of single phase transformer:

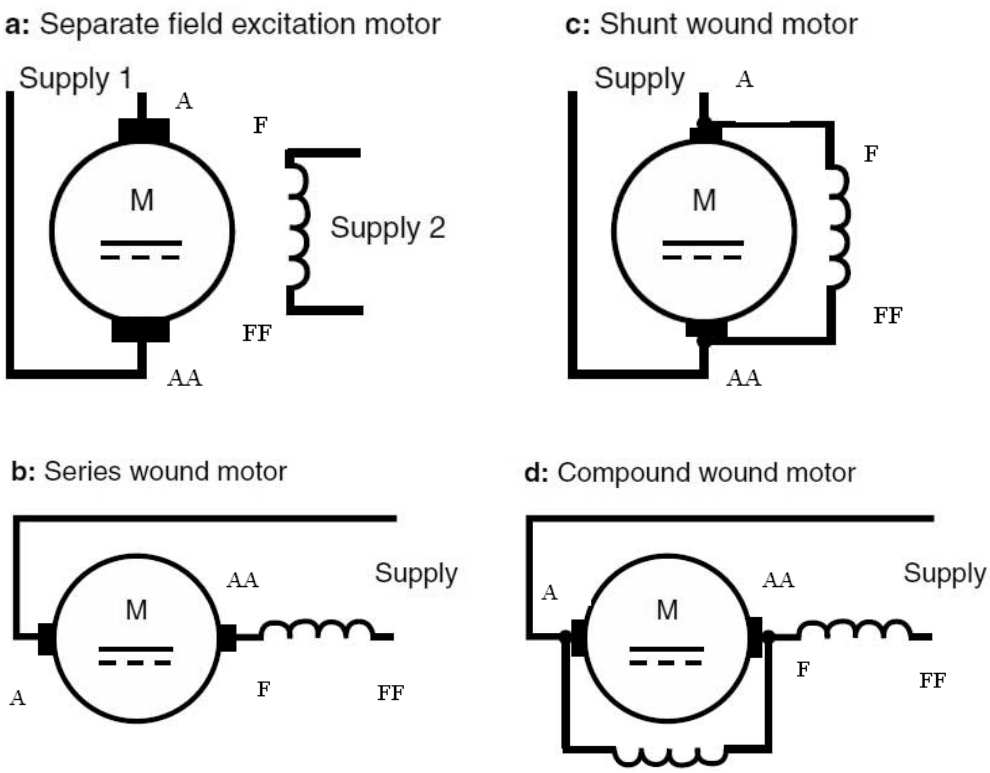
Mutual induction between two circuits / coils (in ac circuits).

The circuits are linked by a common magnetic field produced in the electromagnetic core by one of the coils/circuits called as the primary winding 2 while the other is the secondary to which the load is connected. The induced emf produced in the secondary winding feeds the load through the terminals of the secondary winding.



2

1 d) D. C. Motors:



1 mark EACH DIAGRAM

1 e) Universal motor:

- Operating principle is the interaction of the main field and field due to current in the armature conductors to produce force/torque for motion.
- The force is directly proportional to the product of main flux and armature current.
- Small motors designed and constructed to operate on either DC or single phase AC supply of same voltage.
- Have nearly similar operating characteristics.
- The effect of inductance in AC adversely affects the operating characteristics which can be overcome by compensating winding.
- The armature is similar to that of the DC motor.

Approx coverage 2 marks

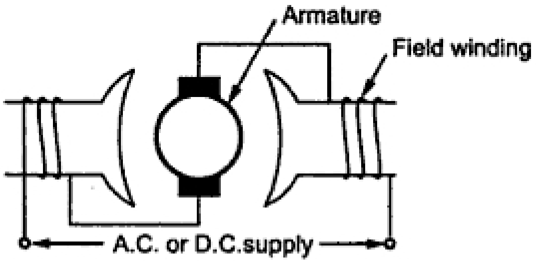


fig I

Fig I: 2 marks

OR

Fig II:

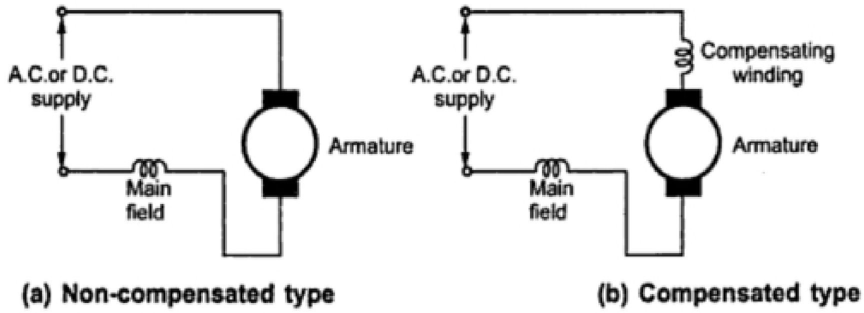


Fig II: 2 marks

OR

Fig III:

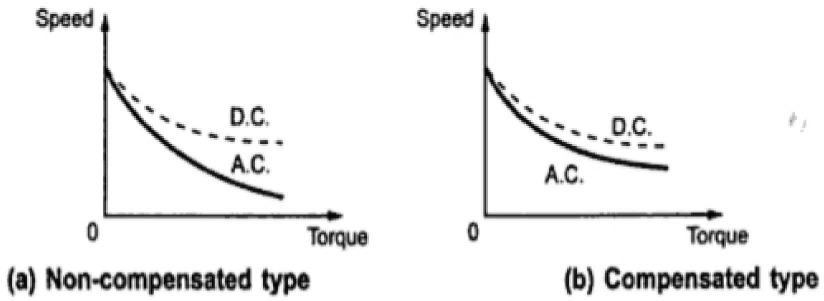
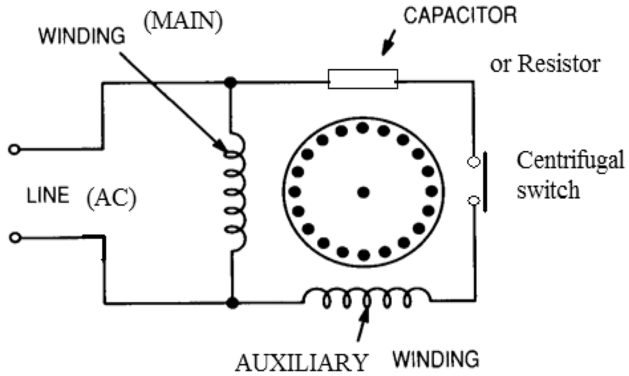


Fig III: 2 marks

1 f) Working of split phase motors:

- Have arrangement in the form of two windings placed with axes 90^0 apart in the stator.
- Single phase supply given to these windings results in phase diff. in the currents in these two windings due to the different impedances of the winding circuits.
- Resistance or capacitance is added in series to one of the coils (called as starting or auxiliary coil) to create the two currents that result in proportional magnetic fluxes with time phase difference (space phase is already created due to the winding/coil axes relative position) in the air gap resulting in the required starting torque in the required direction. The other coil is called as the main winding.
- The centrifugal switch is used to disconnect the starting winding once the motor picks up speed after which the motor continues to run.

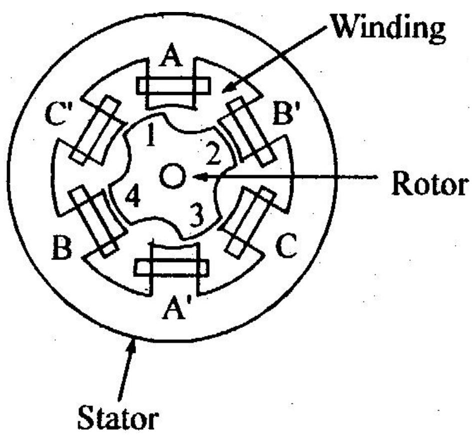
2 marks

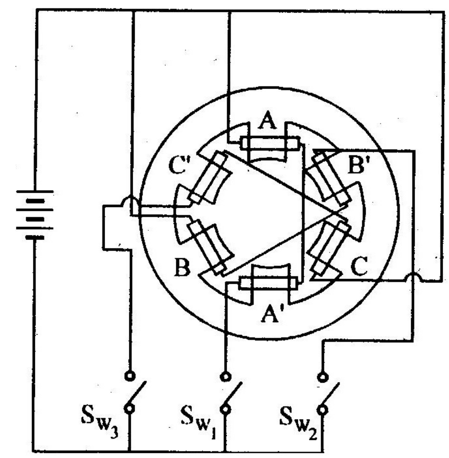


Labeled 2 marks, unlabeled 1 mark. (phasor diagram optional)

1 g) Working of stepper motor:

- Converts series of electrical pulses (input) into discrete angular movements (definite angular steps) i.e one step for each pulse input.
- Stator is constructed of laminated silicon steel.
- As shown the stator has six salient poles or teeth on which coils are placed with opposite poles having series connected coils to which voltage pulses are given through the switching circuit as shown.
- Rotor is also of laminated silicon steel with the no. of poles/teeth being four but has no coils. 1
- The switching is done sequentially to obtain rotation.
- When poles A & A' are excited by closing Switch S_{w1} the rotor teeth nearest to these align to have minimum reluctance between the A-A' stator poles. (poles A and A' are opposite in nature).
- Next if poles B & B' are excited by opening S_{w1} and closing Switch S_{w2} then the rotor moves anticlockwise angularly by 30^o to align with these poles.
- Thus if we provide 12 such voltage pulses sequentially by proper opening and closing of switches we get one full rotation in 12 equal steps.
- If the sequence of application of these pulses is A/A' – C/C' – B/B' then we obtain clockwise rotation. 1
- By changing the no of rotor teeth proportionally we can have smaller angular steps.





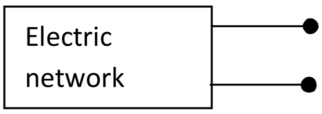
2

2 Attempt any two:

a) Open circuit:

i) Two points in an electric network are said to be open circuited when there is no electrical element connected between them nor there is a direct connection between them. In such cases the impedance (in AC) or the resistance (in DC) between the points is said to be infinite. The current in such open circuited paths is zero or nonexistent. 1 mark

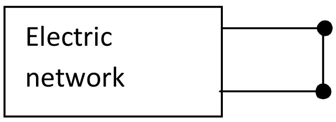
1 mark



Open circuit points

Short circuit:

Two points in an electric network are said to be short circuited when there is a low resistance (practically zero resistance/impedance) connection between them. The current in such open circuited paths depends on the other elements in the network coming in series with the path shorted. 1 mark



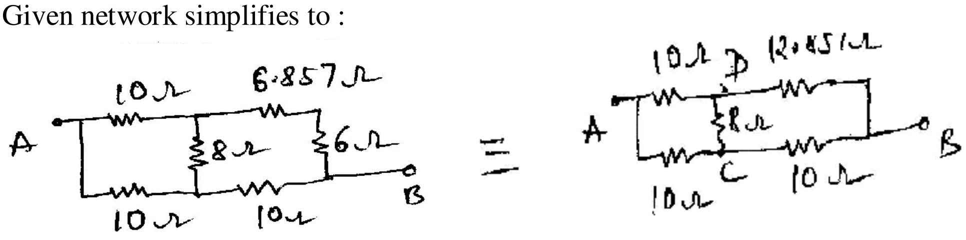
Short circuited points 1 mark

ii) 1) Power = V^2/R
$= 200^2/100 = 400$ W 1 mark

2) Energy consumed 1 mark
= power x time
= 400 x 10 W h.
= 4 kWh or 4000 Wh.
Or
= 400 (W) x 10 (hrs) x 3600(seconds/hr)
= 14400000 J or 14400 kJ. 2 marks

2 Given network simplifies to :

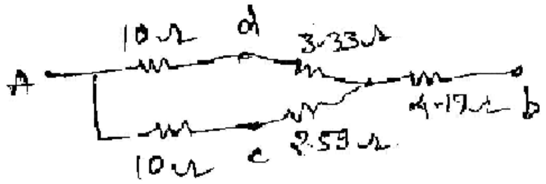
b)



2

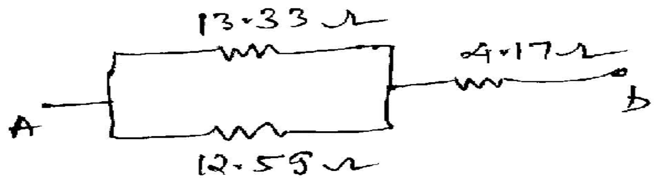
{For delta (A-B-C) to star (a-b-c) conversion between respective terminals we have Star values as $R_a = R_{AB} . R_{CA} / (R_{AB} + R_{BC+} R_{CA})$ etc.} 1

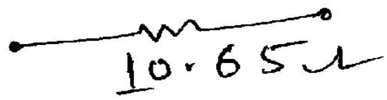
Hence for above network
R_b = 10 x 12.857/(10+12.857+8) = 128.57/30.857 = 4.17 ohms.
R_c = 8 x 10/(30.857) = 2.59 ohms.
R_d = 8 x 12.857/(30.857) = 3.33 ohms. 1



2

=> 1



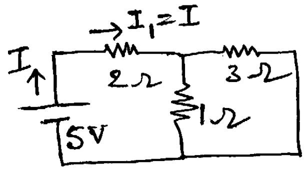


A B 1

Answer 10.65 ohms.

2 c) By superposition theorem:
Total current in 2 ohms is the algebraic sum of currents in it with each source; i.e 5 V. and 10 V. acting alone. 1 mark

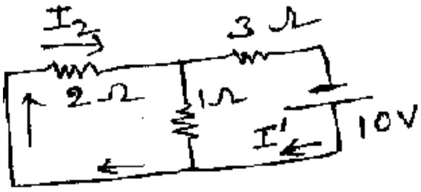
I_1 = current in it with 5 V in circuit and 10 V removed (with only its internal resistance in place)



1 mark

For I_1:
Current from source of 5 V. = I = 5/(2+ ¾) = (20/11) A.
But I_1 = I = 20/11 A. 2 marks

I_2 = current in it with 10 V in circuit and 5 V removed (with only its internal resistance in place).



Current from source of 10 V. = I' = 10/(3+ 2/3) = 30/11 A.
I_2 = I' x [1/(1+2)] = (30/11) x (1/3) = 10/11 A.
(division of current in parallel circuit) 2 marks

Required current in 2 ohms is (I_1 + I_2)
= 20/11 +10/11
= 30/11 A. or 2.72 A. 2 marks

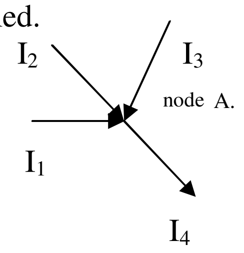
3 Attempt any two:

a)

i) Kirchoff's current law:
The algebraic sum of all branch currents meeting at a junction (or node) in an electric network is always zero. 2 marks

$\sum I = 0$, OR $I_1 + I_2 + I_3 + \ldots\ldots + I_n = 0$. 2 marks (figure optional)

Where $I_1, I_2, I_3, \ldots\ldots, I_n$ are the currents in branches connected to the node at which the law is applied.

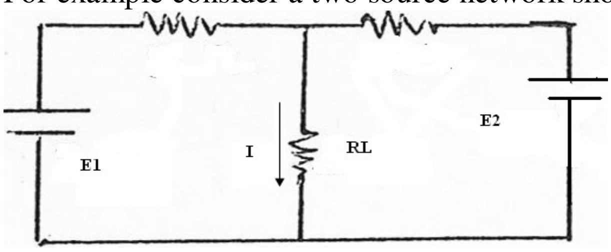


At node A $I_1 + I_2 + I_3 - I_4 = 0$

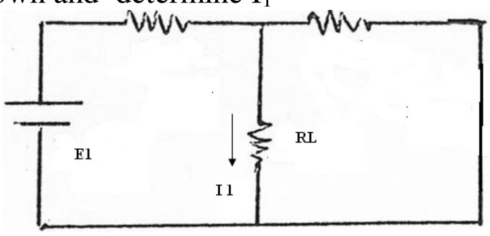
ii)

Superposition theorem:
In a linear bilateral electric network the resultant current in any branch is the algebraic sum of the currents that would be produced in that branch by each one of the sources acting seperately while all the remaining sources are replaced by their respective internal resistances /impedances(optional). 1 mark

For example consider a two source network shown:

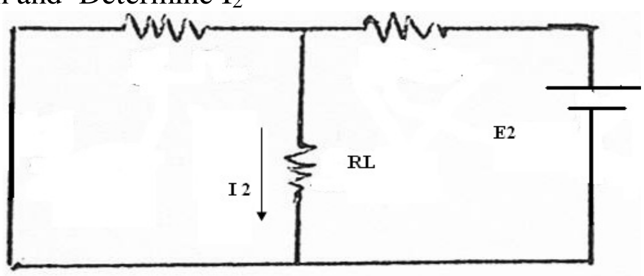


Remove E_2 as shown and determine I_1



1 mark

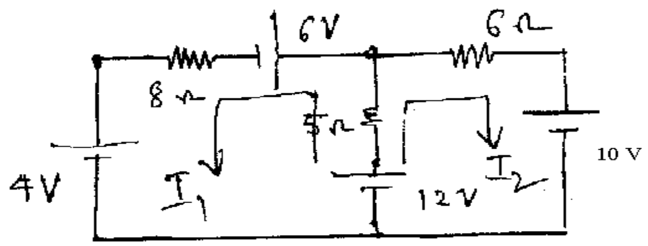
Remove E_1 as shown and Determine I_2



1 mark

The current in resistance R_L is I_L given by,
$I_L = I_1 + I_2$. 1 mark

3 b)



1 mark

Current in 8 ohms is I_1, and current in 6 ohms is I_2.

KVL: $\sum E = \sum I.R$, in a closed loop. 1 mark

Apply KVL to loop 1,
$12 - 6 - 4 = 13\ I_1 + 5\ I_2$,
$2 = 13\ I_1 + 5\ I_2$, ----------------- (A) 1 mark
Apply KVL to loop 2,
$12 - 10 = 5\ I_1 + 11\ I_2$,
$2 = 5\ I_1 + 11\ I_2$, --------------------(B)
1 mark

Solve (A) and (B) simultaneously,
$2 = 13\ I_1 + 5\ I_2$,
$2 = 5\ I_1 + 11\ I_2$,
To get;

$I_1 = 0.101$ A. and 2 marks

$I_2 = 0.135$ A. 2 marks

3 c) Given $v = 141.4 \sin(628t - \pi/6)$ volts. Marks
Compare $v = V_{max} \sin(\omega t - \Phi) = V_{max} \sin(2\pi f t - \Phi)$.

i) RMS value = $V_{max} / \sqrt{2} = 141.4/\sqrt{2} = 100$ V. 1

ii) Max value = $V_{max} = 141.4$ V 1

iii) Angular frequency = $\omega = 628$ rad/ s. 1

iv) Frequency $f = (\omega/2\pi) = 100$ c/s or hertz 1

v) Form factor = (RMS value)/(Average value). 1
{Average value of sinusoidal waveform is $[2V_{max} /(\pi)]$
$= (2 \times 141.4)/(\pi) = 90.$ V} 1
Hence Form factor = 100/90 = 1.11.

vi) At t = 0.015 sec.
$v = 141.4 \sin(628 \times 0.015 - \pi/6)$ volts 1
$= 21.86$ Volts. 1

4 Attempt any two:

a) i)

1) True power or real power is given by 1

$P = V\, I \cos\Phi$ in single phase circuits and

$P = \sqrt{3}\, V\, I \cos\Phi$ in balanced three phase circuits.

Unit is Watts.

2) Reactive power or imaginery power is given by

$Q = V\, I \sin\Phi$ in single phase circuits and

$Q = \sqrt{3}\, V\, I \sin\Phi$ in balanced three phase circuits. 1

Unit is Volt-ampere reactive or VAR.

3) Apparent power or total power is given by, 1

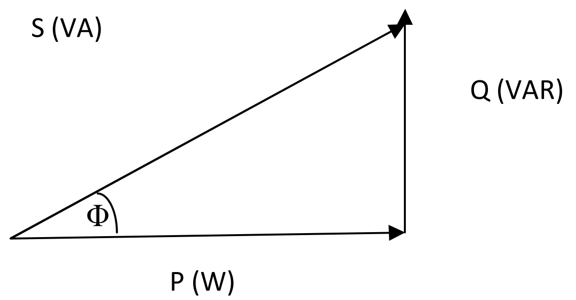
$S = V\, I$. in single phase circuits and

$S = \sqrt{3}\, V\, I$. in balanced three phase circuits.

Unit is Volt-ampere or VA.

Where V, I, are the line values of the voltage and current respectively while Φ is the time phase angle between them OR cos Φ power factor of the load for which the power is calculated.

Power triangle: 1



4 a) ii) Admittance: it is the reciprocal of the impedance of an electric circuit. 1

Given by $Y = 1/Z$. unit is "mhos". 1

Given $Z = (7 + j\,9)$ ohms.

Admittance is $Y = 1/Z = 1/(7 + j\,9) = 1/11.4\angle 52.18^o = 0.00877\angle -52.18^o$ mhos (2 for polar) else

OR Rationalising the denominator,

$Y = (7 - j\,9)/(49 + 81) = (7 - j\,9)/(130)$ 1

$= [(7/130) - j\,(9/130)] = (0.0538 - j\,0.0692)$ mhos. 1

4 b) i) Resistance = voltage across resistance / current in resistance

= 100/5 = 20 ohms. 1

ii) Voltage across inductance $V_L = \sqrt{(V^2 - V_R^2)}$., (V= total voltage, V_R = voltage across resistance)

$= \sqrt{(250^2 - 100^2)} = 229$ V. 1

iii) Inductance L:

Inductive reactance X_L = voltage across inductance/current in it 1

$= V_L / I = 229/5 = 45.8$ ohms.

But $X_L = 2 \pi f L$. hence $L = X_L / (2 \pi f)$ 1

$= 45.8/(2 \pi \times 50) = 0.1457$ H.

iv) Power factor = R/Z. 1

$Z = \sqrt{(R^2 + X_L^2)} = \sqrt{(20^2 + 45.8^2)} = 50$ ohm or 1

Z = V/I = 250/5 = 50 ohms.

Therefore power factor (PF) = 20 / 50 = 0.4 lagging as it is inductive circuit. 1

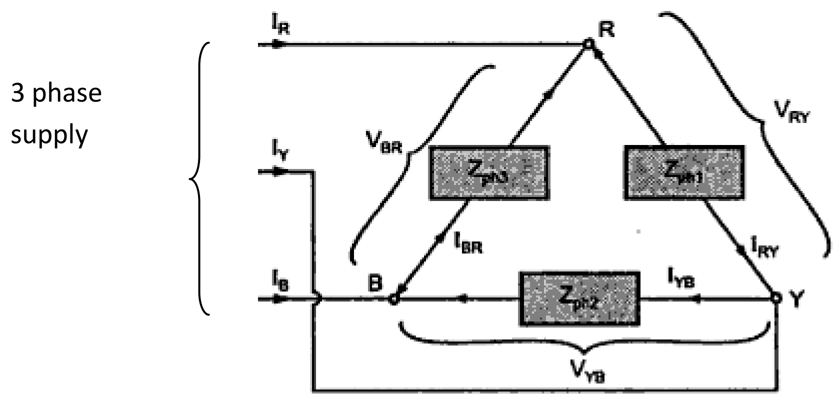
v) Active power = V I (PF) = 250 x 5 x 0.4 = 500 W.

vi) Reactive power = $V I \sqrt{[1 - (PF)^2]} = 250 \times 5 \times \sqrt{[1 - 0.16]}$ 1

=1146 VAR.

4 c)

i)



2 marks

Line voltages = Phase voltages: are V_{RY}, V_{YB}, and V_{BR}. 1 mark

Line currents = I_R, I_Y, and I_B.

Phase currents = I_{RY}, I_{YB}, and I_{BR}. 1 mark

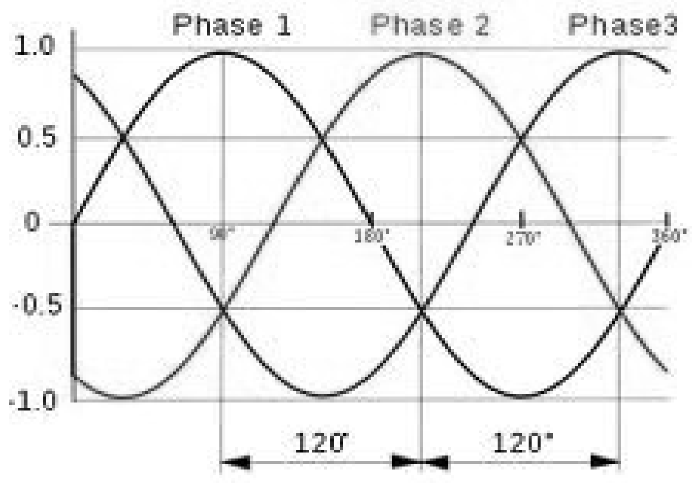
For balanced supply and loads:

All the line voltages are equal in magnitude and so are line currents.

All the phase voltages are equal in magnitude and so are phase currents.

$V_{Line} = V_{Phase}$, and $I_{Line} = \sqrt{3}\, I_{Phase}$.

4 c) ii)



$90^o = \pi/2$ radians

$180^o = \pi$ radians

$270^o = 3\pi/2$ radians

$360^o = 2\pi$ radians

$120^o = 2\pi/3$ radians

Unlabeled 1 mark

Partially labeled 2 marks

Fully labeled 4 marks

(labeled in radians/degrees is acceptable)

5 Attempt any two:

a) i) It is star connected circuit:

Phase current = phase voltage(V_{PH}) / phase impedance(Z_{PH}).

Phase voltage = line voltage/ $\sqrt{3}$ = 400/$\sqrt{3}$ = 231 V

Phase impedance $Z_{PH} = \sqrt{(3^2 + 6^2)} = 45^{1/2}$ = 6.7 ohms. 1

Therefore phase current I_{PH} = 231/6.7 = 34.47 amps.

ii) Phase voltage = 231 V as calculated above in i). 1

iii) Power factor = R/Z = 3 / 6.7 = 0.4477 lag. 1

iv) Total active power = $\sqrt{3} V_L I_L$ (pf)

= $\sqrt{3}$ x 400 x 34.47 x .4477

= 10691.441 W = 10.691 kW. 1

v) Total reactive power: $\sqrt{3} V_L I_L \sqrt{[1 - (pf)^2]}$

= $\sqrt{3}$ x 400 x 34.47$\sqrt{[1 - (0.4477)^2]}$ 1

= 21354 VAR = 21.35 kVAR. 1

vi) Total apparent power = $\sqrt{3} V_L I_L$ 1

= $\sqrt{3}$ x 400 x 34.47 = 23881 VA = 23.881 kVA. 1

5 b)

(Primary voltage V_1)/(secondary voltage V_2) =

(Primary turns N_1)/(secondary turns N_2) 1

Hence secondary voltage V_2 = (V_1/N_1) x N_2 = (230/500) x 250

$V_2 = 115$ V.

R_L = load resistance across the secondary terminals = 10 ohm.

i) Secondary current $I_2 = V_2/R_L = 115/10 = 11.5$ amps. 2
ii) Primary current $I_1 = V_2 I_2 / V_1 = 115 \times 11.5 / 230 = 5.75$ A. 2
iii) Secondary voltage $V_2 = 115$ V. 1
iv) kVA = $V_1 I_1 \times 10^{-3} = V_2 I_2 \times 10^{-3} = 230 \times 5.75 \times 10^{-3} = 1.3225$ kVA. 2

5 c)

i) Losses in transformers:

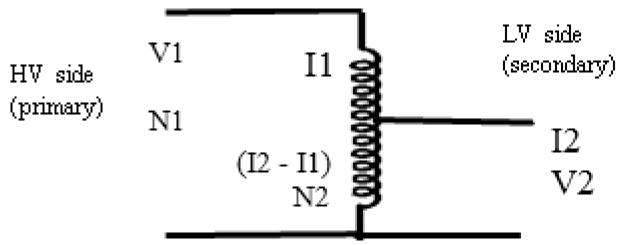
1) Copper losses in the primary and secondary windings given by $\sum I^2R$ where I and R take up primary and secondary side values related to the windings respectively. These losses depend on the current drawn by the load. Higher current leads to higher losses. 2
2) Iron losses in the electromagnetic path (core limbs, yoke); that consist of hysteresis and eddy current losses. These losses are dependent on applied voltage and frequency on the primary side. Higher values result in higher iron losses. 2

5 c) ii) Working of single phase auto transformer:

These are single winding transformers with laminated electromagnetic core. They can be used as step down or step up transformers with limitations and advantages.

The input voltage given to it results in input current (primary side current) that creates the flux. The flux induces (self induced) emf in the winding which is utilized to supply to the secondary side loads. Depending on the connections we have step down and step up autotransformers. 1

Auto transformer (step down) ($N_2 < N_1$)

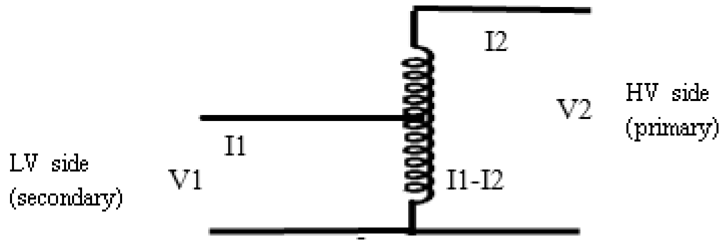


(1

OR

OR

Auto transformer (step up) ($N_1 < N_2$)



1)

Advantages of auto transformers:

1) Results in saving in copper winding requirement compared to 2 winding transformers of same rating.
2) Gives better voltage regulation compared to 2 winding transformers of same rating.
3) Efficiency is higher compared to 2 winding transformers of same rating.
4) Can be used easily for interconnecting systems of same voltage levels.
5) Is used for short time applications with high currents involved such as starters for ac motors.

½ mark each any four = 2 marks

6 Attempt any two:

a) i) Need of starter in DC motor:

The armature current in the DC motor is given by

$I_A = (V_A - E_B)/R_A$,

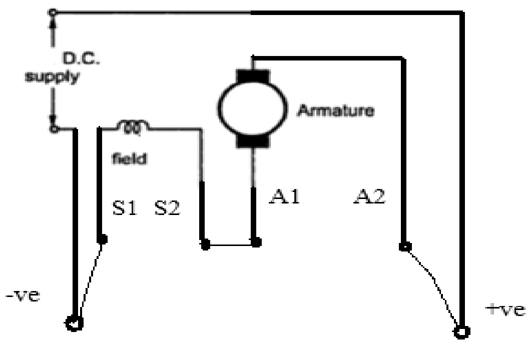
where V_A is the applied voltage to armature, E_B is the back emf produced in the armature and R_A is the armature resistance. Under normal working speed E_B differs from V_A by a very small magnitude. Hence I_A is small. 2

At start $E_B = 0$ as it is directly proportional to speed, hence if full voltage gets applied to the armature at start, I_A reaches a dangerously high value (because R_A is very low). This high current damages the armature winding (burning of insulation). 1
Also, the torque in dc motors is directly proportional to the product of the field flux and armature current; hence the starting torque will be so high due to high armature current that it results in mechanical damage to the motor. (damage to bearings and supports etc) 1

6 a) ii) Reversal of rotational direction of DC series motor:

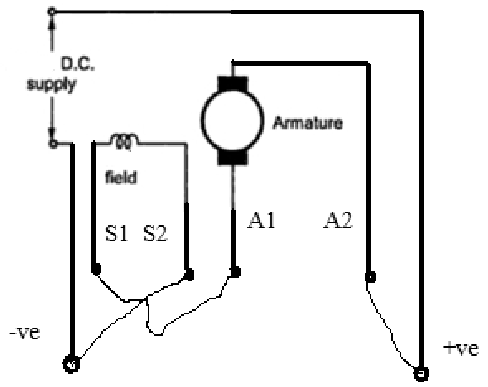
Reversal is achieved by reversing the connections of either the field or armature terminals with respect to the supply polarity. 1

Initial running connections:



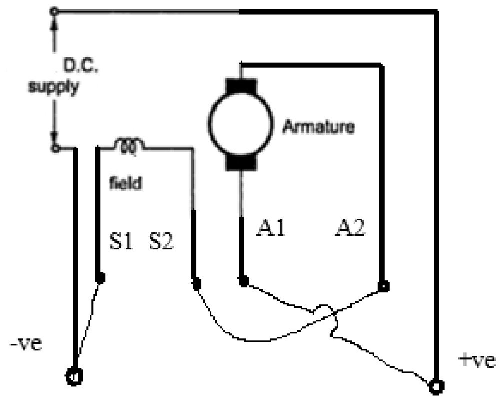
1

Reversal by changing only field connections:



1

Reversal by changing only armature connections



1

6 b) i) Constructional difference between 3 phase slip ring and squirrel cage induction motor.

	Slip ring motor	Squirrel cage motor	
1	The secondary / rotor is wound with copper winding.	The secondary / rotor is of squirrel cage type (die cast).	
2	The rotor phase windings terminate at hard copper slip rings.	The rotor is short circuited by end rings.	
3	Brushes are used over the slip rings to connect to the rotor circuit.	No external connection to the rotor is possible as rotor is shorted.	1 mark each point max 4 marks
4	The terminal box contains the rotor winding terminals coming through the brushes on the slip rings.	The terminal box does not contain any rotor section termination.	
5	Rotor winding connected in star	The rotor is short circuited by end rings.	

6 b) ii) P=2, f = 50 Hz., slip = 5 %.

1) Synchronous speed $N_S = 120f/P$ 1

$= 120 \times 50/2$

$= 3000$ RPM 1

2) Rotor speed $= N_R = N_S(1 - s)$, {s = 5 % = 0.05 pu} 1

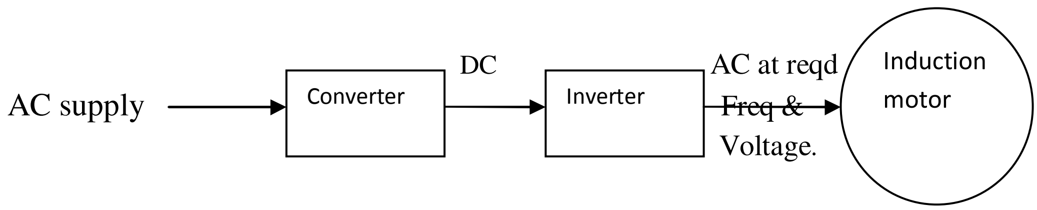
$= 3000 \times (1 - 0.05)$

$= 2850$ RPM. 1

6 c) i) Methods of speed control of 3 phase induction motor expected: Any one method

1. Supply frequency control, 2. Pole changing, 3. Voltage control, 4. Rotor resistance control in slip ring motors, 5. Cascade operation connection.

1. Supply frequency control:



2

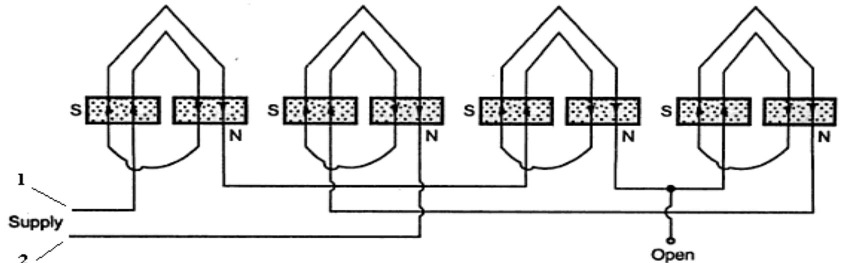
By changing freq. syn. speed is changed hence rotor speed changes.

To maintain air gap flux to normal value under varying freq. the ratio V/f is to be maintained constant. 1

The frequency changing is now done electronically using SCRs etc. 1

OR

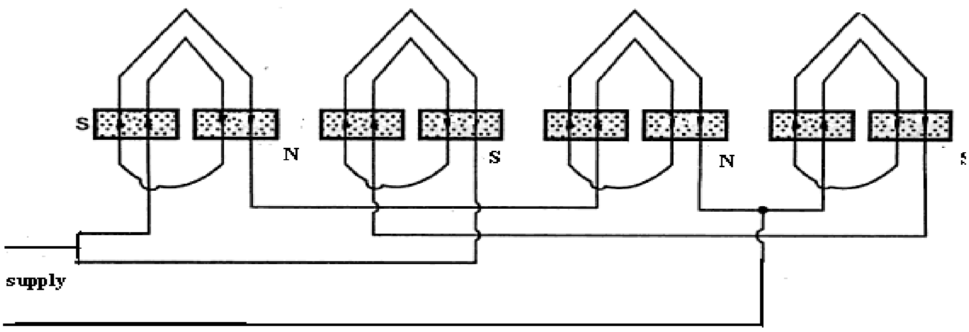
2. Pole changing:



1

Connection for one phase of the three similar motor phases
Stator winding connections get changed in the ratio 2:1,
Three terminals of stator are provided and only two (1, 2) are connected across the supply, the third kept open gives 8 poles as seen. 1

Now if the open terminal is connected to one of the supply lines and the earlier motor terminals are connected together (which were across supply earlier) to the remaining supply line the no. of poles formed will be 4. 1



1

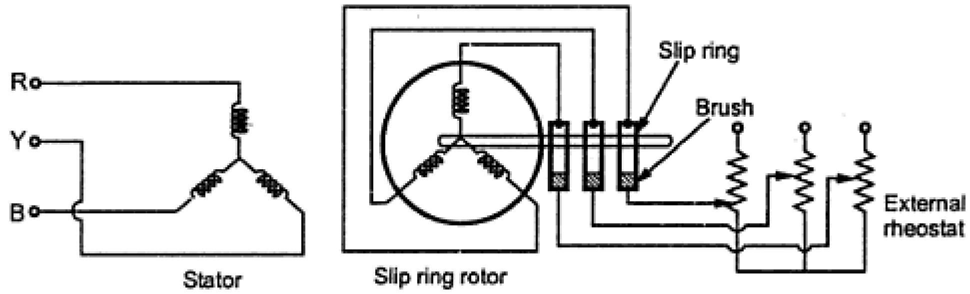
4 pole winding.

OR

3. Voltage control:
At near full load condition torque T α s V^2, 1
For constant torque, slip 's' α $1/V^2$, hence changing the voltage applied results in change in the speed. 1
But the change in speed is not very much considerable for small voltage changes.
Also if the voltage increase is larger (to get greater speed variation) the magnetic losses increase to create more heat as they are dependent on the voltage. 1
Further if the voltage is dropped by large values the current drawn increases heavily to cater to the torque and power requirements resulting in heavy copper losses and line drops. 1

OR

4. Rotor resistance control in slip ring motors:



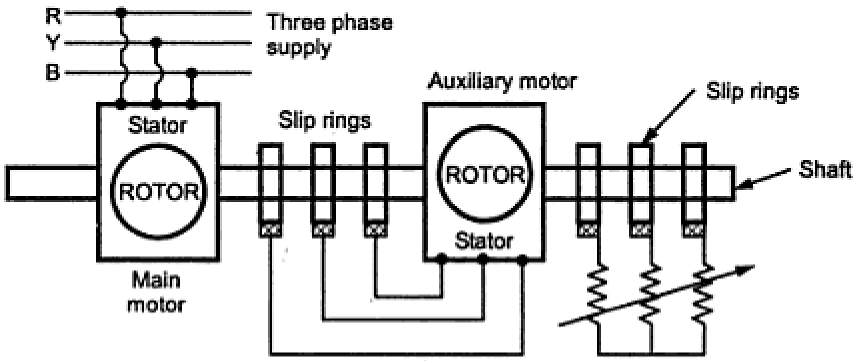
2

1

The rotor circuit resistance is varied (external rheostat) to get different speeds for particular torques. Around rated speed of motor the slip's' α R_2 , the rotor circuit resistance. Hence inserting resistance in the rotor circuit by external means such as rheostat results in increase in slip and hence decrease in the speed. 1

5. Cascade control:

OR



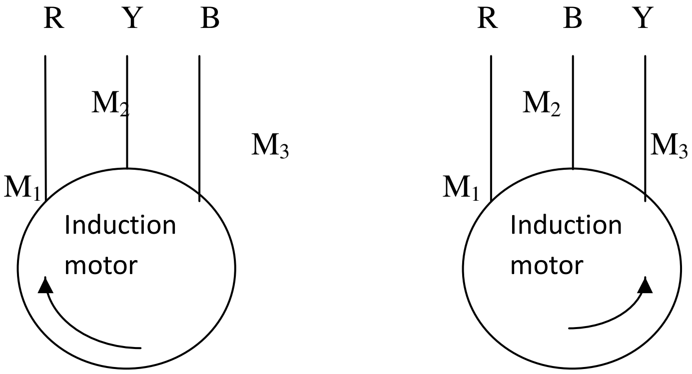
2

Cascade control of two induction motors

Here two motors of which at least one is a slip ring type are used.
The connections are made as shown ie one of the motors is fed from the mains while the other is fed from the emf generated at slip rings of the main motor. 1
Depending upon the connections with respect to phases four diff. syn. speeds are possible. (if p_1, and p_2 are the no of poles of the two motors)
$N_{S1} = 120f/p_1$, $N_{S2} = 120f/p_2$, $N_{S3} = 120f/(p_1 + p_2)$ (cumulative), $N_{S4} = 120f/(p_1 - p_2)$ (differential). 1

6 c) ii) Reversal of rotation in three phase induction motors:

By interchanging any two of the supply phase lines to the motor the direction of stator rotating field is reversed resulting in reversal of the rotor direction. 2



Reversal of any two lines 2 marks.

M_1, M_2, M_3 are the stator three winding terminals of the motor to be connected to the supply lines.