GATE

2019

ELECTRICAL MACHINE

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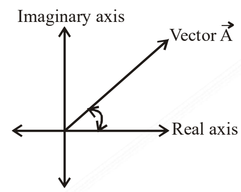
CONTENTS

CHAPTER - 1
TRANSFORMERS

1.1 PHASOR DIAGRAMS



Phasor Diagram of vector A

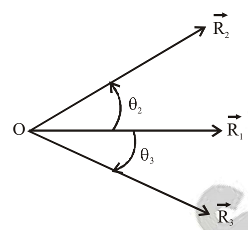
Phasor rotating vector

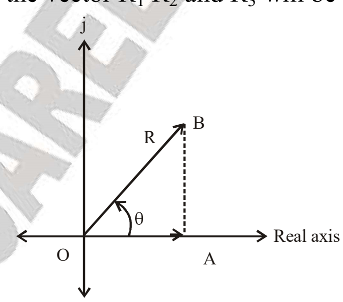
1. If all vectors are rotating at same frequency then only phase difference and amplitude of vector is to be known for vector operation.

2. Angle measured in counter clock- wise (ccw) direction are positive.

3. Angle measured in clock wise (cw) directions are negative.

4. If $\vec{R}_1$ is taken as reference then angle of $\vec{R}_1$ is Zero (0°). $\vec{R}_2$ vector is ahead or leading $\vec{R}_1$ by θ_2° and vector $\vec{R}_3$ is lagging $\vec{R}_1$ by θ_3°. And the vector R_1 R_2 and R_3 will be represented as :





$R_1 \angle 0°$, $R_2 \angle \theta_2°$ and $R_3 \angle -\theta_3°$

5. In phasor form always RMS values of amplitudes are taken.

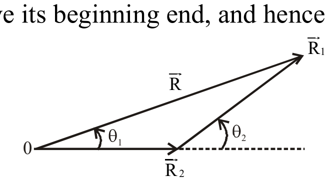
6. Adding or subtracting vectors.

Let $\vec{R} = \vec{R}_1 + \vec{R}_2$ is to be find out.

I. Place or draw $\vec{R}_1$

$$0 \longrightarrow \overline{R}_1$$

II. At the end of $\vec{R}_1$, $\vec{R}_2$ will have its beginning end, and hence join the ends of R_1 and R_2 as:



7. $|R| \angle\theta$ is represented on axis as the length of OB is equal to magnitude of $\vec{R} = |R|$

GATE QUESTIONS

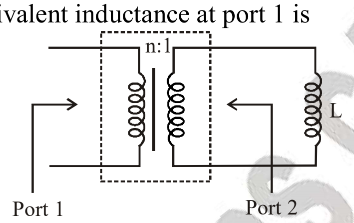
1. A three – phase, three winding Δ/Δ/Y (1.1 kV/6.6kV/400V) transformer is energized from AC mains at the 1.1 kV side. It Supplies 900 kVA load at 0.8 power factor lag from the 6.6 kV winding and 300 kVA load at 0.6 power factor lag from the 400V winding. The RMS line current in ampere drawn by the 1.1 kV winding from the mains is _____.

[GATE - 2017]

2. If the primary line voltage rating is 3.3 kV(Y side) of a 25 kVA, Y-Δ transformer (the per phase turns ratio is 5;1), then the line current rating of the secondary side (in Ampere) is _____.

[GATE - 2017]

3. If an ideal transformer has an inductive load element at port 2 as shown in the figure below, the equivalent inductance at port 1 is



[GATE - 2016]

(a) nL (b) n^2 L
(c) n/L (d) n^2/L

4. A single phase 400V, 50Hz transformer has no iron loss of 5000 W at the rated condition. When operated at 200V, 25Hz, the iron loss is 2000 W. when operated at 416V, 52Hz the value of the hysteresis loss divided by the eddy current loss is ____

[GATE - 2016]

5. A single – phase 22kVA, 220 V/220V, 50Hz, distribution transformer is to be connected as an auto transformer to get an output voltage of 2420V. Its maximum kVA rating as an auto- transformer is

[GATE - 2016]

(a) 22 (b) 24.2
(c) 242 (d) 2420

6. A single phase 2 kVA, 100/200 V transformer is reconnects as an auto – transformer such that its kVA rating is maximum. The new rating, in kVA, is ________.

[GATE - 2016]

7. Three single phase transformers are connected to form a delta – star three - phase transformer of 110 kV/11kV. The transformer supplies at 11 kV a load of 8 MW at 0.8p.f lagging to a nearby plant. Neglect the transformer losses. The ratio phase currents in delta side to star side is

[GATE - 2016]

(a) $1:10\sqrt{3}$ (b) $10\sqrt{3}:1$
(c) 1 : 10 (d) $\sqrt{3}:1$

8. For a specified input voltage and frequency, if the equivalent radius of the core of a transformer is reduced by half, the factor by which the number of turns in the primary should change to maintain the same no load current is

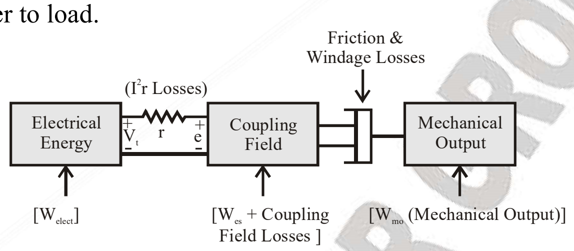
[GATE - 2014]

(a) 1/4 (b) 1/2
(c) 2 (d) 4

9. The core loss of a single phase, 230/115V, 50Hz power transformer is measured from 230 V side by feeding the primary (230 V side) from a variable voltage variable frequency source while keeping the secondary open circuit. The core loss is measured to be 1050 W for 230 V, 50 Hz input. The core loss is again measured to be 500W for 138 V, 30 Hz input. The hysteresis and eddy current losses of the transformer for 230 V, 30 Hz input. The hysteresis and eddy current losses of the transformer for 230 V, 50 Hz input are respectively.

CHAPTER - 2
BASICS OF ENERGY CONVERSION & ROTATING MACHINES

2.1 INTRODUTION
For conversion of energy from electrical to mechanical and mechanical to electrical, there must be coupling field, the coupling field must react in such a way that over all conversion draws energy from source and deliver to load.



$W_{elect} = W_{fld} + W_{mech.}$
$dW_{elect} = dW_{fld} + dW_{mech.}$

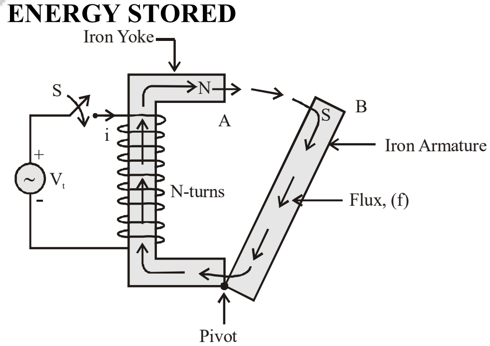
2.2 COUPLING FIELD
Coupling field is the link between electrical and mechanical system and energy stored in coupling field produces action and reaction on electrical and mechanical system.
This Coupling field may be magnetic or electrostatic field, but capacity of magnetic field to store energy is 25000 times more than electrostatic energy.Thus, magnetic field is used as coupling field.
Electrical input = e i dt

$$dW_{elec.} = i.e.dt\left[\because e = \frac{d\psi}{dt} \Rightarrow edt = d\psi\right]$$

$$dW_{elec.} = id\psi$$

Where ψ is flux linkage
$\psi = Li = N\phi$
$\Rightarrow$ d $w_{elec} = I\, d(N\,\phi) = iNd\phi$
$\Rightarrow$ d $W_{elec} = F\, d\phi$
Where F is magnetomotive force

2.3 MAGNETIC FIELD ENERGY STORED



GATE QUESTIONS

1. The flux linkage (λ) and current (i) relation for an electromagnetic system is $\lambda = -(\sqrt{i})/g$. When i = 2A and g (air gap length) = 10 cm, the magnitude of mechanical force on the moving part, in N, is_______

[GATE - 2016]

2. Match List-I with List-II and select the correct answer using the code given below the lists

List-I
A. Magnetic flux
B. Magneto motive force
C. Reluctance
D. Permeability

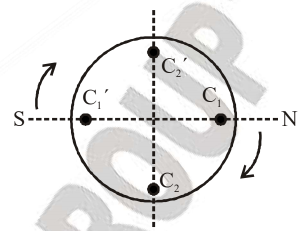
List-II
(i) Resistance
(ii) Electric current
(iii) Conductivity
(iv) Electromotive force

Codes: **[GATE - 2012]**
(a)A-ii, B-i, C-iv, D-iii
(b)A-iii, B-i, C-iv, D-ii
(c)A-ii, B-iv, C-i, D-iii
(d) A-iii, B-iv, C-i, D-ii

3. Distributed winding and short chording employed in AC machines will result in

[GATE - 2009]
(a) Increase in emf and reduction in harmonics
(b) Reduction in emf and increases in harmonics
(c) Increase in both emf and harmonics
(d) Reduction in both emf and harmonics

4. Two magnetic poles revolve around a stationary armature carrying two coil (c_1-c_1'.c_2-c_2') as shown in the figure. Consider the instant when the poles are in a position as shown .Identify the correct statement regarding the polarity of the induced emf at this instant in coil sides c_1 and c_2



[GATE - 2005]
(a) ⊙ in c_1 , no emf in c_2
(b) ⊗in c_1 , no emf in c_2
(c) ⊙ in c_2 , no emf in c_1
(d) ⊗ in c_2 , no emf in c_1

5. For a linear electromagnetic circuit , the following statement is true

[GATE - 2004]
(a) Field energy is equal to the co-energy
(b) Field energy is greater than the co- energy
(c) Field energy is lesser than the co-energy
(d) Co-energy is zero

6. A rotating electrical machine having its self inductances of both the stator and the rotor windings, independent of the rotor position will be definitely not develop.

[GATE - 2004]
(a) Starting torque
(b) Synchronizing torque
(c) Hysteresis torque
(d) Reluctance torque

7. When stator and rotor windings of a 2-pole rotating electrical machine are excited, each would produce a, sinusoidal mmf. Distribution in the air gap with peak value F_s and F_r respectively. The rotor mmf lags the stator

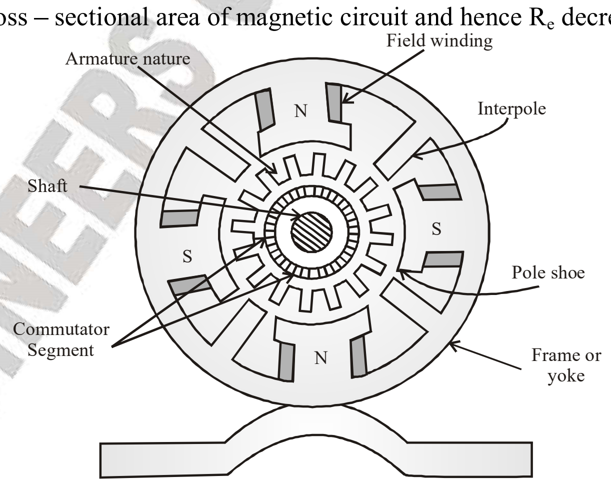
CHAPTER - 3
D.C MACHINE

3.1 BASIC STRUCTURE OF ELECTRIC MACHINE
1. Stator: Stationary part and normally is the outer frame of the machine.
2. Rotor: Rotating part and generally inner part of the machine.
3. Armature Winding: The winding in which voltage is induced.
4. Field Winding: The winding through which a current is passed to produce the main flux.

3.2 TYPES OF D.C MACHINE
1. D.C Generator: It convert mechanical energy into electrical energy.
2. D.C Motor: It converts electrical energy into mechanical energy.

3.3 D.C MACHINE CONSTRUCTION
D.C. Machine consists of three main parts:
1. Magnetic field system
2. Armature
3. Commutator and brush gear.

1. Magnetic Field System
(i) It is the fixed or stationary part of the machine.
(ii) It produces the main magnetic flux.
(iii) The field winding is placed on poles, projected inward and hence they are called salient poles with poles with pole shoes.
(iv) Pole shoe serve two purposes:-
(a) It supports the field coils
(b) It increase the cross – sectional area of magnetic circuit and hence R_e decreases



Main part of the 4.pole DC. Machine

GATE QUESTIONS

1. A separately excited DC generator supplies 150A to a 145 VDC grid. The generator is running at 800 RPM. The armature resistance of the generator is 0.1Ω. If the speed of the generator is increased to 1000 RPM, the current in amperes supplied by the generator to the DC grid is ______.

[GATE - 2017]

2. A 220V DC series motor runs drawing a current of 30A fro mthe supply. Armature and field circuit resistances are 0.4Ω and 0.1Ω, respectively. The load torque varies as the square of the speed. The flux in the motor may be taken as being proportional to the armature current. To reduce the speed of the motor by 50% the resistance in ohms that should eb added in series with the armagure is _____. (Given the answer up to two decimal places)

[GATE - 2017]

3. A 120 V DC shunt motor takes 2 A at no load. It takes 7A on full load while running at 1200 rpm. The armauture resistance is 0.8Ω and the shunt field resistance is 240Ω. The no load speed, in rpm, is ________

[GATE - 2017]

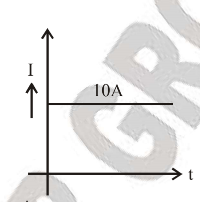
4. A 220V, 10 kW, 900 rpm separately excited DC motor has an armature resistance R_a = 0.02Ω. When the motor operates at rated speed and with rated terminal voltage, the electromagnetic torque developed by the motor is 70Nm. Neglecting the rotational losses of the machine, the current drawn by the motor from the 220V supply is

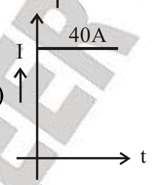
[GATE - 2017]

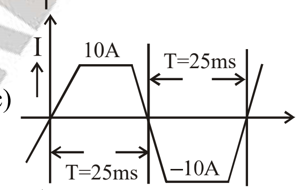
(a) 34.2 A (b) 30A
(c) 22A (d) 4.84 A

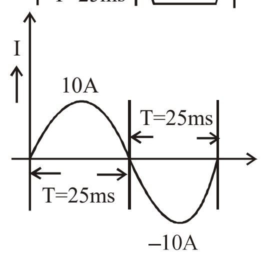
5. A 4-pole, lap – connected separately excited dc motor is drawing a steady current of 40A while running at 600 rpm. A good approximation for the waveshape of the current in an armature conductor of the motor is given by

[GATE - 2016]

(a)


(b)


(c)


(d)


6. A DC shunt generator delivers 45 A at a terminal voltage of 220 V. The armature and the shunt field resistances are 0.01Ω and 44Ω respectively. The stray losses are 375 W. the percentage efficiency of the DC generator is ____.

[GATE - 2016]

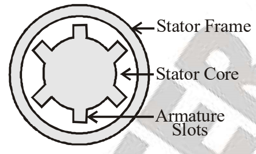
7. A three-phase, 50Hz salient-pole synchronous motor has a per – phase direct-axis reactance (X_d) of 0.8 pu and a per phase

CHAPTER - 4
SYNCHRONOUS MACHINE

4.1 INTRODUCTION
4.1.1 Construction and Working Principle
A synchronous machine essentially consists of two parts.
1. Armature (Rotor)
2. Field Magnet System

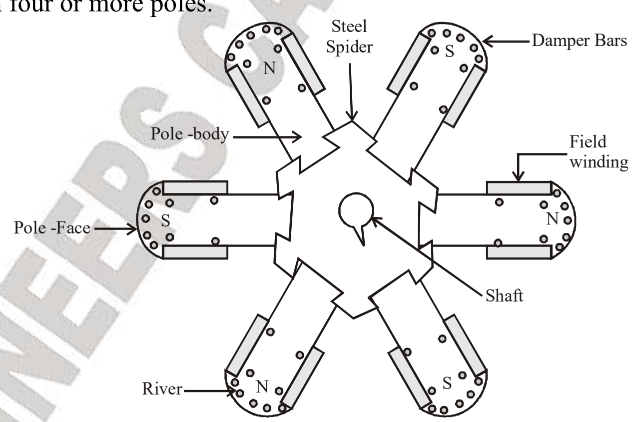
An alternation may be constructed with either the armature or the field structure as the revolving system. Stator is the stationary part of the machine it carries the armature winding in which the voltage is generated and hence output is taken from stator. The rotor is the rotating part of the machine. The rotor produces the main field flux.

1. *Stator Construction*
It includes the frame, stator core, stator windings and cooling arrangement, where frame may be of cast iron for small size machines.



2. *Rotor Construction*
There are two types of rotor constructions namely salient-pole type and cylindrical rotor type.

4.2 SALIENT POLE TYPE
Consists of poles projecting out from the surface of rotor core. Salient pole rotors are normally used for rotors with four or more poles.



Six Pole Salient Pole Rotor

4.2.1 Six Pole Salient Pole Rotor
Salient pole rotors have concentrated winding on the poles. And it has generally non-uniform air gap. And hence pole phases are so formed that this non-uniform flux becomes sinusodially which

GATE QUESTIONS

1. Two parallel connected, three - phase, 50Hz, 11kV, star - connected synchronous machines A and B, are operating as synchronous condensers. They together supply 50MVAR to a 11kV grid. Current supplied by both the machines are equal. Synchronous reactance's of machine A and machine B are 1Ω and 3Ω, respectively. Assuming the magnetic circuit to be linear, the ratio of excitation current of m machine A to that of machine B is _____.(given the answer up to two decimal places).

[GATE - 2017]

2. A three - phase, 50hz, star - connected cylindrical - rotor synchronous machine is running as a motor. The machine is operated from a 6.6kV grid and draws current at unity power factor (UPF). The synchronous reactance of the motor is 30Ω per phase. The load angle is 30°. The power delivered to the motor in kW is ________ (Give the answer up to one decimal place)

[GATE - 2017]

3. Two generating units rated 300MW and 400MW have governor speed regulation of 6% and 4% respectively from no load to full load. Both the generating units are operating in parallel to share a load of 600MW. Assuming free governor action, the load shared by the larger units is ____ MW.

[GATE - 2017]

4. A 25 kVA, 400V, Δ - connected, 3-phase, cylindrical rotor synchronous generator requires a field current of 5A to maintain the rated armature current under short – circuit condition. For the same field current, the open – circuit voltage is 360V. Neglecting the armature resistance and magnetic saturation, its voltage regulation (in % with respect to terminal voltage), when the generator delivers the rated load at 0.8 pf leading at rated terminal voltage is _____.

[GATE - 2017]

5. A 3-phase, 2-pole, 50hz, synchronous generator has a rating of 250 MVA, 0.8 pf lagging. The kinetic energy of the machine at synchronous speed is 100MJ. The machine is running steadily at synchronous speed and delivering 60MW power at a power angle of 10 electrical degrees. If the load is suddenly removed, assuming the acceleration is constant for 10 cycles, the value of the power angle after 5 cycles is _____ electrical degrees.

[GATE - 2017]

6. A star connected 400 V, 50 Hz, 4 pole synchronous machine gave the following open circuit and short circuit test results;'

Open circuit test : V_{∞} = 400V (rms, line –to – line) at field current,

$I_f = 2.3$ A

Short circuit test: I_{sc} = 10 A (rms, phase) at field current.

$I_f = 1.5$ A

The value of per phase synchronous impedance in Ω at rated voltage is ____.

[GATE - 2014]

7. A three phase synchronous generator is to be connected to the infinite bus. The lamps are connected as shown in the figure for the synchronization. The phase sequence fo bus voltage is R–Y–B and that of incoming generator voltage is R′ – Y′ – B′.

CHAPTER - 5
INDUCTION MOTOR

5.1 INTRODUCTION
5.1.1 Stator Emf
In general emf induced in coil
$E = K_w N_{phs} \phi_p \omega_r \sin(\omega_r t - \pi/2)$
E is Induced emf
K_w is Winding factor
N_{phs} is Number of seires turns per phase
ϕ_p is Flux per pole
ω_r is Relative angular velocity
$\sin(\omega_r t - \pi/2)$
$\therefore$ Induced emf in stator
$E_s = K_{ws} N_{phs} \phi_p \omega_s$
Induced emf in rotor, at stand still
$E_r = K_{ws} N_{phr} \phi_p \omega_r$
Instantaneous emf induced in rotor
$K_{wr} N_{phs} \phi(\omega_s - \omega_r)\sin[(\omega_s - \omega_r)t - \pi/2]$
Rotating field rotates at synchronous speed cuts the rotor bar conductors which generates emf and as rotor conductors are short circuited hence current will flow in it, which produces its own emf and interaction of these two emf. produces torque. As per Lenzes Law, the effect opposes the cause, here effect is rotation of rotor and causes is relative velocity between fields.
$\therefore$ Rotor rotates in direction as to decrease the relative velocity.
$\omega_s - \omega_r$ is slip speed
Where relative velocity = slip speed ,

$$S(\text{slip}) = \frac{\omega_s - \omega_r}{\omega_s} = \frac{N_s - N_r}{N_s} = \frac{\text{Relative speed}}{\text{Synchronous speed}}$$

$N_r = (1 - S) N_s$
$= K_{wr} N_{phs} \phi S \omega_s \sin[t - \pi/2]$
$\therefore$ Frequency and amplitude of rotor emp. Both becomes S-times the stator amplitude and frequency.
If (At stand still), S = 1, $E_r = E_2$, $f_r = f_2$ then at any slip say S, $E_r = SE_2$, $f_r = Sf_2$

5.2 CONSTRUCTIONAL FEATURES
5.2.1 Stator
Frame made-up of cost iron. Stator core made-up of laminated steel i.e., bearing, slip ring and shaft. 3– phase uniformly distributed winding electrically spread 120°.

GATE QUESTIONS

1. A 4 pole induction machine is working as an induction generator. The generator supply frequency is 60Hz. The rotor current frequency is 5Hz. The mechanical speed of the rotor in RPM is

[GATE - 2017]

(a) 1350 (b) 1650
(c) 1950 (d) 2250

2. A 3-phase, 50Hz generator supplies power of 3MW at 17.32 kV to a balanced 3-phae inductive load through an overhead line. The per phase line resistance and reactacne are 0.25Ω and 3.925Ω respectively. If the voltage at the generator terminal is 17.87 kV, the power factor of the load is ______.

[GATE - 2017]

3. A star – connected, 12.5 kW, 208V (line), 3-phase, 60hz squirrel cage induction motor has following equivalent circuit parameters per phase referred to the stator. R_1 = 0.3Ω, R_2 = 0.3Ω, X_1 = 0.41 Ω, X_2 = 0.41Ω. neglect shunt branch in the equivalent circuit. The starting current (in Ampere) for this motor when connected to an 80V (line), 20Hz, 3-phase, AC source is ______

[GATE - 2017]

4. A 3-Phase, 4-pole, 400V, 50Hz squirrel – cage induction motor is operating at a slip of 0.02. The speed of the rotor flux in mechanical rad/sec. Sensed by a stationary observer, is closest to

[GATE - 2017]

(a) 1500 (b) 1470
(c) 157 (d) 154

5. The starting line current of a 415 V, 3-phase delta connected induction motor is 120A, when the rated voltage is applied to its stator winding. The starting line current at a reduced voltage of 110V, in ampere, is ____

[GATE - 2016]

6. A 8-pole, 3-phase, 50 Hz induction motor is operating at a speed of 700 rpm. The frequency of the rotor current of the motor in Hz is ____.

[GATE - 2016]

7. A 3-Phase , 50 Hz, six pole induction motor has a rotor resistance of 0.1Ω and reactance of 0.92Ω. Neglect the voltage drop in stator and assume that the rotor resistance is constant. Given that the full load slip is 3%, the ratio of maximum torque to full load torque is

[GATE - 2014]

(a) 1.567 (b) 1.712
(c) 1.948 (d) 2.134

8. A three – phase , 4 pole, self exited induction generator is feeding power to a load at a frequency f_1. If the load is partially removed, the frequency becomes f_2. If the speed of the generator is maintained at 1500 rpm in both the cases, then

[GATE - 2014]

(a) f_1, f_2 >: 50 Hz and $f_1 > f_2$
(b) $f_1 < 50$ Hz and $f_2 > 50$ Hz
(c) f_1, $f_2 < 50$ Hz and $f_2 > f_1$
(d) $f_1 > 50$ Hz and $f_2 < 50$ Hz

9. In a synchronous machine, hunting is predominantly damped by

[GATE - 2014]

(a) Mechanical losses in the rotor
(b) Iron losses in the rotor
(c) Copper losses in the stator
(d) Copper losses in the rotor

10. Leakage flux in an induction motor is

[GATE - 2013]

(a) Flux that leaks through the machine
(b)Flux that links both stator and rotor windings
(c)Flux that links none of the windings
(d)Flux that links the stator winding or the rotor winding but not both

SOLUTIONS

Sol.1. (c)

Supply frequency (f_1) = 60Hz & Pole = 4

$$\therefore\ N_s = \frac{120f}{P} = \frac{120\times 60}{4} = 1800\text{rpm}$$

Rotor frequency (f_2) = 5hz

We know tht $f_2 = sf_1$

$5 = (s)\,(60) \Rightarrow 0.0833$

But in induction generator, slip is a negative value

$$\Rightarrow\ -0.0833 = \frac{1800 - N_r}{1800}$$

$\Rightarrow N_r = 1950$ rpm

Sol.2. (0.8083)

$|V_s| = 17.87$ kV

$|V_r| = 17.32$ kV

$R = 0.25\Omega$

$X_L = 3.925\ \Omega$

$$Z = \sqrt{0.25^2 + 3.925^2}$$

$= 3.933\ \Omega$

$$P_r = \frac{17.87\times 17.32}{3.933}\cos(\theta-\delta) - \frac{0.25(17.32)^2}{3.933^2}$$

$$3 = \frac{17.87\times 17.32}{3.933}\cos(\theta-\delta) - \frac{0.25(17.32)^2}{3.933^2}$$

$\text{Cos}(\theta - \delta) = 0.0997$

$(\theta - \delta) = 84.276°$

$$Q_r = \frac{|V_s|\,|V_r|}{|Z|}\sin(\theta-8) - \frac{X\,|V_r|^2}{|Z|^2}$$

$$= \frac{1787\times 17.32}{3.933}\sin(84.276) - \frac{3.925\times 17.32^2}{3.933^2}$$

$= 2.18483$ VAR

$$pf = \cos\tan^{-1}\left(\frac{Q_r}{P_r}\right)$$

$$= \cos\tan^{-1}\left(\frac{2.18483}{3}\right)$$

$= 0.8083$ lag

Sol.3. (70.19 A)

Given parameters of star –connected SCIM at 60Hz are

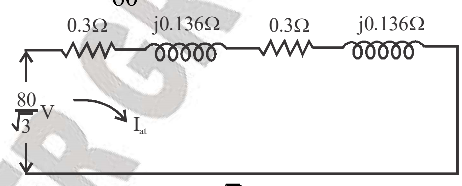
$r_1 = 0.3\Omega$, $r_2 = 0.3\Omega$

$X_1 = 0.41\Omega$, $X_2 = 0.41\ \Omega$

Now, if frequency changed to 20Hz, leakage reactance magnitude will change.

$$\therefore\ X_{1(\text{new})} = \frac{20}{60}(0.41) = 0.136\Omega$$

$$\therefore\ X_{2(\text{new})} = \frac{20}{60}(0.41) = 0.136\Omega$$



$$I_{st} = \frac{80/\sqrt{3}}{\sqrt{(0.3+0.3)^2 + (0.136+0+36)^2}}$$

$= 70.19$A

Sol.4. (c)

A 3–ϕ, 4 pole, 50Hz squirrel cage induction motor operating at a slip of 0.02

$$\text{Synchronous speed} = \frac{120F}{P}\text{rpm}$$

$$= \frac{120\times 50}{4} = 1500\text{rpm}$$

$\therefore$ rotor speed $= (1 - s)N_s$

$= (1 - 0.02)(1500)$

$= 1470$ rpm

The speed of rotor field with respect to rotor is

$$= \frac{120\times sF}{P} = 30\text{rpm}$$

The speed of rotor field with respect to stator is 1470 + 30 = 1500 rpm

$$= \frac{2\pi(1500)}{60}\text{rad/sec}$$

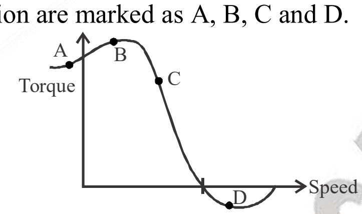
$= 157.07$ rad/sec

Sol.5. (31.8)

ESE OBJ QUESTIONS

1. Statement(I): A 3-phase induction motor is a self-starting machine.
Statement (II): A star-delta starter is used to produce starting torque for the induction motor.
[ESE - 2017]
(a)Both Statement (I) and Statements(II) are individually true and Statements (II) is the correct explanation of Statement (I)
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
(c)Statement (I) is true but Statement (II) is false.
(d)Statement (I) is false but Statement (II) is true

2. On the Torque /Speed curve of an induction motor shown in the figure, four points of operation are marked as A, B, C and D.



Which one of them represents the operation at a slip greater than 1?
[ESE - 2017]
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

3. A 3-phase, 460 v, 6 pole, 60 Hz cylindrical rotor synchronous motor has a synchronous reactance of 2.5Ω and negligible armature resistance. The load torque, proportional to the square of the speed, is 398N.m at 1200 rpm.
Unity power factor is maintained by excitation control. Keeping the V/f constant, the frequency is reduced to 36 Hz. The torque angle δ is
[ESE - 2017]
(a) 9.5° (b) 12.5°
(c) 25.5° (d) 30°

4. A 3-phase, induction motor operating at a slip of 5% develop 20 kW rotor power output. What is the corresponding rotor copper loss in this operating condition?
[ESE - 2016]
(a) 750 VV (b) 900 W
(c) 1050W (d) 1200W

5. Increasing the air gap of a squirrel-cage induction motor would result in
[ESE - 2016]
(a) Increasing in no-load speed
(b) Increase in full-load power factor
(c) Increase in magnetizing current
(d) Maximum available torque

6. For a 3-phase induction motor, what fraction/multiple of supply voltage is required for a direct on line starting method such that starting current is limited to 5 times the full load current and motor develops 1.5 times full load torque at starting time?
[ESE - 2016]
(a) 1.632 (b) 1.226
(c) 0.816 (d) 0.456

7. What is the material of slip rings in an induction machine?
[ESE - 2016]
(a) Carbon (b) Nickel
(c) Phosphor bronze (d) Manganese

8. The stator loss of a 3-phase induction motor is 2 kW. If the motor is running with a slip of 4% and power input of 90 kW, then what is the rotor mechanical power developed?
[ESE - 2016]
(a) 84.48 kW (b) 86.35 kW
(c) 89.72 kW (d) 90.52 kW

9. If a 3-phase slip ring induction motor is fed from the rotor side with stator winding short

CHAPTER - 6
SINGLE – PHASE INDUCTION MOTOR

6.1 SINGLE PHASE INDUCTION MOTOR

Alike 3 - ϕ I_M, 1 - ϕ IM is not self starting, and operates on poor p.f., lower capacity and reduced efficiency. It has pulsating air gap field.

For starting purposes an auxiliary winding is used and hence stator of a 1 - ϕ IM carries two windings:

1. Main or Running winding(S_M)
2. Auxiliary or starting winding(S_A)

In these motors, both main and auxiliary windings are in the circuit at the time of starting and a centrifugal switch is provided to disconnect the Auxiliary windings when rotor attains 70 to 80% of synchronous speed.

It must be noted that the space angle between (S_M) and (S_A) should be near about 90°.

6.2 REVOLVING FIELD THEORY OF SINGLE PHASE INDUCTION MOTOR

It is also called – double – revolving field theory of 1 - ϕ IM, basically states that a stationary pulsating magnetic field can be resolved into two rotating magnetic field, each of equal magnitude but rotating in opposite direction. And IM responds to each magnetic field separately, and net torque in motor is sum of the torques due to each the two magnetic fields.

Assume the stator mmf wave to be sinusoidally distributed in space and varying sinusoudally with time then,

$\therefore F_S = F_{s.max} \sin \omega t.\cos\alpha$

Where cosα is Distribution in space along the a is gap periphery

Where sinωt is Distribution in space alogn the a is gap periphery

Where $F_{s.max}$ is Peak maximum instantaneous altesnating M.M.F

Since, $\sin a \cos b = \frac{1}{2}\left[\sin(a-b)+\sin(a+b)\right]$

$$F_s = \frac{1}{2}F_{s.max.}\sin(\omega t-\alpha)+\frac{1}{2}F_{s.max.}\sin(\omega t+\alpha)$$

⇒ This shows that the pulsating stationary mmf wave of amplitude $F_{s.max.}$ can be resolved into, two counter rotating mmf. components of equal magnitudes as shown in figure.

At = 90° , $F_s = F_{s.max}$– At instant A and two components are = $\frac{1}{2}F_{s.max.}$

At instant B, $\omega t = \omega t_1$ from instant A

$$F_s = F_{s.max.}\sin(\omega t_1 + 90^\circ) = F_{s.max.}\cos\omega t_1$$

And pulsating mmf wave resolved into sinusoidal mmF. waves marked f and b, both mmf wave travelled through an angle wts to right and left respectively as :

GATE QUESTIONS

1. A 375 W, 230V, 50Hz, capacitor start single-phase induction motor has the following constants for the main and auxiliary windings (at starting): z_m = (12.50 + j15.75)Ω (main winding), Z_a = (24.50 + j12.75)Ω 9auxiliary winding). Neglecting the magnetizing branch, the value of the capacitance (in μF) to be added in series with the auxiliary winding to obtain maximum torque at staring is ____.

[GATE - 2017]

2. In a constant V/f induction motor drive, the slip at the maximum torque

[GATE - 2016]

(a)Is directly proportional to the synchronous speed.
(b)Remains constant with respect to the synchronous speed.
(c)Has an inverse relation with the synchronous speed.
(d)Has no relation with the synchronous speed.

3. The direction of rotation of a single – phase capacitor run induction motor is reversed by

[GATE - 2016]

(a)Interchanging the terminals of the AC supply.
(b)Interchanging the terminals of the capacitor.
(c)Interchanging the terminal of the auxiliary winding.
(d)Interchanging the terminals of both the windings.

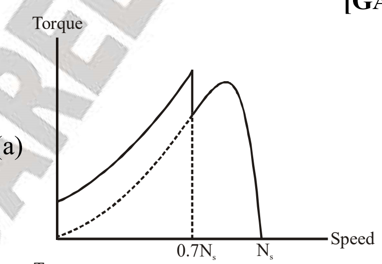
4. In a constant V/f control of induction motor, the ratio V/f is maintained constant from 0 to base frequency, where V is the voltage applied to the motor at fundamental frequency f. Which of the following statements relating to low frequency operation of the motor is TRUE?

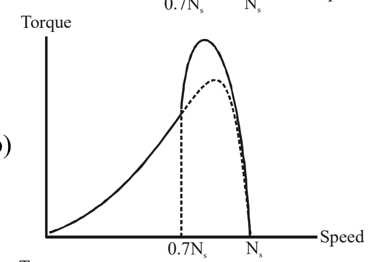
[GATE - 2014]

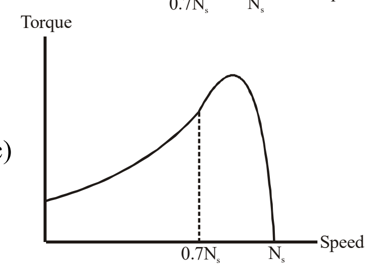
(a)At low frequency, the stator flux increases from its rated value.
(b)At low frequency, the stator flux decrease from its rated value.
(c)At low frequency, the motor saturates.
(d)At low frequency, the stator flux remains unchanged at its rated value.

5. A single phase induction motor is provided with capacitor and centrifugal switch in series with auxiliary winding. The switch is expected to operate at a speed of 0.7 ns, but due to malfunctioning the switch fails to operate. The torque speed characteristic of the motor is represented by

[GATE - 2014]

(a)


(b)


(c)


ESE OBJ QUESTIONS

1. In a single-phase capacitor start induction motor, the direction of rotation

[ESE - 2016]

(a)Can be changed by reversing the main winding terminals.
(b)Cannot be changed.
(c)Is dependent on the size of the capacitor.
(d)Can be changed only in large capacitor motors.

2. For a given applied voltage and current , the speed of a universal motor will be

[ESE - 2015]

(a) Higher in dc excitation than in ac excitation
(b) Higher in ac excitation than in dc excitation
(c) Same in both dc and ac excitations
(d) Dangerously high in dc excitation

3. Consider the following statements :
1. Asynchronous motor has no starting torque but when started it always runs at a fixed speed
2. A single –phase reluctance motor is not self starting even if paths for eddy currents are provided in the rotor
3. A single –phase hysteresis motor is self –starting
Which of these statement(s) is /are correct ?

[ESE - 2013]

(a) 1, 2 and 3 (b) 1 only
(c) 1 and 2 only (d) 2 and 3 only

4. Why is centrifugal switch used in a 1–ϕ induction motor?

[ESE - 2008]

(a)To protect the motor from overloading
(b)To improve the starting performance of the motor.
(c)To cut off the starting winding at an appropriate instant.
(d)To cut in the capacitor during running condition.

5. An 8-pole, 1 - ϕ induction motor is running at 690 rpm. What is its slip w.r.t forward and backward fields, respectively.

[ESE - 2007]

(a) 0.08, 2.0
(b) 0.08, 1.92
(c) 1.92, 0.08
(d) 2.0, 0.08

6. Match List-I with List-II and select the correct answer using the code given below the lists :

List-I
A. General purpose split phase FHP motor
B. General purpose capacitor start FHP motor
C. Permanent split capacitor start FHP motor
D. Shaded pole FHP motor

List-II
(i) Refrigerator
(ii) Hair dryers
(iii) Unit Heaters
(iv) Fans, blowers

[ESE - 2007]

Codes:
(a) A-i, B-ii,C-iv, D-iii
(b) A-i, B-ii, C-iii, D-iv
(c) A-iv, B-i, C-ii, D-iii
(d) A-iv, B-i, C-iii, D-ii

7. A 1 - ϕ induction motor is running at N r.p.m. Its synchronous speed is N_s. If its slip with respect to forward field is S, what is the slip with respect to the backward field.

[ESE - 2007]

(a) s (b) -S
(c) (1-S) (d) (2-S)

8. Which one of the following is the type of 1 - ϕ induction motor having the highest power factor at full load?

CHAPTER - 7
SERVO AND STEPPER MOTOR

7.1 INTRODUCTION
A servo system mainly consists of three basic components - a controlled device, a output sensor, a feedback system. This is an automatic closed loop control system. Here instead of controlling a device by applying the variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal. When reference input signal or command signal is applied to the system, it is compared with output reference signal of the system produced by output sensor, and a third signal produced by a feedback system. This third signal acts as an input signal of controlled device.
This input signal to the device presents as long as there is a logical difference between reference input signal and the output signal of the system. After the device achieves its desired output, there will be no longer the logical difference between reference input signal and reference output signal of the system. Then, the third signal produced by comparing theses above said signals will not remain enough to operate the device further and to produce a further output of the system until the next reference input signal or command signal is applied to the system. Hence, the primary task of a servomechanism is to maintain the output of a system at the desired value in the presence of disturbances.

7.1.1 Working Principle of Servo Motor
A servo motor is basically a DC motor(in some special cases it is AC motor) along with some other special purpose components that make a DC motor a servo. In a servo unit, you will find a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate according to our wishes. As we know, a small DC motor will rotate with high speed but the torque generated by its rotation will not be enough to move even a light load. This is where the gear system inside a servomechanism comes into the picture. The gear mechanism will take high input speed of the motor (fast) and at the output, we will get an output speed which is slower than original input speed but more practical and widely applicable.
Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. This output port of the potentiometer is connected with one of the input terminals of the error detector amplifier. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from external source, will be amplified in the error detector amplifier and feeds the DC motor. This amplified error signal acts as the input power of the DC motor and the motor starts rotating in desired direction. As the motor shaft progresses the potentiometer knob also rotates as it is coupled with motor shaft with help of gear arrangement. As the position of the potentiometer knob changes there will be an electrical signal produced at the potentiometer port. As the angular position of the potentiometer knob progresses the output or feedback signal increases. After desired angular position of motor shaft the potentiometer knob is reaches at such position the electrical signal generated in the potentiometer becomes same as of external electrical signal given to amplifier. At this condition, there will be no output signal from the amplifier to the motor input

GATE QUESTIONS

1. In a steeper motor , the detent torque means **[GATE - 2009]**

(a) Minimum of the static torque with the phase winding excited
(b) Maximum of the static torque with the phase winding excited
(c) Minimum of the static torque with the phase winding unexcited
(d) Maximum of the static torque with the phase winding unexcited

2. A three-phase, three stack, variable reluctance step motor has 20 poles on each rotor and stator stack .The step angle of this motor is **[GATE - 2007]**

(a) 3°   (b) 6°
(c) 9°   (d) 18°

3. For a given stepper motor , the following torque has the highest numerical value **[GATE - 2004]**

(a) Detent torque   (b) Pull in torque
(c) Pull- out torque   (d) Holding torque

4. The following motor definitely has a permanent magnet rotor **[GATE - 2004]**

(a) DC commulator motor
(b) Brushless dc motor
(c) Stepper motor
(d) Reluctance motor

5. For a 1.8°, 2-phase bipolar stepper motor, the stepping rate is 100 steps /second. The rotational speed of the motor in rpm is **[GATE - 2004]**

(a) 15   (b) 30
(c) 60   (d) 90

ESE OBJ QUESTIONS

1. A permanent magnet steeper motor with 8 poles in stator and 6 poles in rotor will have a step angle of

[ESE - 2017]

(a) 7.5° (b) 15°
(c) 30° (d) 60°

2. Which one of the following types of motors is most suitable for a computer printer drive

[ESE - 2004]

(a) Reluctance motor
(b) Hysteresis motor
(c) Shaded pole motor
(d) stepper motor

3. A certain R-L series combination is connected across a 50Hz single phase a.c supply. If the instantaneous power drawn was found to be negative for 2 milliseconds in one cycle, the 'power factor angle' of the current must be

[ESE - 2002]

(a) 9° (b) 18°
(c) 36° (d) 45°

SOUTIONS

Sol.1. (b)

Given $N_s = 8$, $N_r = 6$

Then step angle $(\beta) = \frac{(N_s - N_r)}{N_s.N_r} \times 360°$

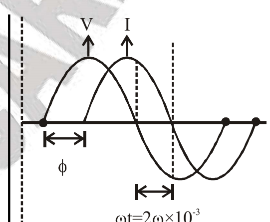
$= \frac{(8-6)}{8\times 6}\times 360°$

$= \frac{2}{48}\times 360° = \frac{1}{24}\times 360$

$= \beta = 15°$

Sol.2. (d)

Sol.3. (c)



$\phi = \omega t = 2\times\pi\times 50\times 2\times 10^{-3} = \frac{\pi}{5} = 36°$

GATE 2018

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CONTENTS

CHAPTER - 1
MEASUREMENTS AND MEASUREMENT SYSTEMS

1.1 MEASUREMENTS
Measurement of quantity is result of comparison of the quantity under measurement, also called as measurand, with perfect standard. The result is expressed in numerical values.
There are two methods to measure:
1. Direct Method
The measurement is compared directly with the standard.
Example. Measurement of length by tape.
2. Indirect Method
The measurand is measured by use of measuring instruments.

1.1.1 Measurement Instruments
1.Mechanical Instruments
They are good for static measurement i.e. measurand is not varying with time. Due to inertia, mechanical instruments are not suitable for dynamic measurement.
2. Electrical Instruments
They are better than mechanical instruments for dynamic measurements. However electrical systems use mechanical parts.
3. Electronic Instruments
Because the mass of electron is very less, the electronic systems are fastest.
In these, amplification of the signal can be done, hence very weak signals can also be measured.

1.1.2 Properties
1. Highest sensitivity
2. Power consumption is least
3. Most reliable
4. Fastest response
5. Low weight

1.1.3 Classification of Instruments
1. Absolute Instruments
The magnitude of measurand is measured in terms of the instruments constants. For eg: Tangent Galvanometer, rayleigh current balance. They are used for caliberating secondary instruments.

2. Secondary Instruments
They are caliberated with absolute instruments. The measurand is observed by output indication.

3. Deflection – Type Instruments
The measurand produces force or torque for deflection. Opposing torque to this deflection is produced externally. At the point of balance,
Deflection torque = controlling torque.

ESE OBJ QUESTIONS

1. A resistance of 108 Ω is specified using significant figures as indicated below:
1. 108 Ω
2. 108.0 Ω
3. 0.00108 Ω

[EE ESE - 2011]

Among these:
(a)1 represents greater precision than 2 and 3.
(b)2 represent greater precision but 1 and 3 represents same precision.
(c)2 and 3 represent greater precision than 1
(d)1, 2 and 3 represents same precision

2. A resistance of 105 ohms is specified using significant figures as indicated below:
1. 105 ohms
2. 105.0 ohms
3. 0.000105 MΩ

[EE ESE - 2010]

Among these
(a) 1 represents greater precision than 2 and 3.
(b) 2 and 3 represent greater precision than 1.
(c) 1, 2 and 3 represent same precision.
(d) 2 represents greater precision but 1 and 3 represent same precision.

3. What is the prefix tera equivalent to?

[EE ESE - 2008]

(a) 10^3 (b) 10^6
(c) 10^9 (d) 10^{12}

4. For defining the standard meter, wavelength of which material is considered?

[EE ESE - 2006]

(a) Neon (b) Krypton
(c) Helium (d) Xenon

5. Which one of the following is the most stable frequency primary atomic standard for frequency

[EC ESE - 2005]

(a) Caesium beam standard
(b) Hydrogen maser standard
(c) Rubidium vapour standard
(d) Quartz crystal standard

6. Match List-I (Accuracy) with List-II (Type of the standard) and select the correct answer:
List-I
A. Least accurate
B. More accurate
C. Much more accurate
D. Highest possible accurate
List-II
(i) Primary
(ii) Secondary
(iii) Working
(iv) International

[EE ESE - 2004]

Codes:
(a) A-iii, B-iv, C-i, D-ii
(b) A-i, B-iv, C-iii, D-ii
(c) A-iii, B-ii, C-i, D-iv
(d) A-i, B-ii, C-iii, D-iv

7. For time and frequency, the working standard is

[EE ESE - 2003]

(a) Microwave oscillator
(b) Crystal controlled oscillator
(c) Laser
(d) ARF oscillator

8. The most suitable primary standard for frequency is

[EC ESE - 2002]

(a) Rubudium vapour standard
(b) Quartz standard
(c) Hydrogen maser standard
(d) Ceasium beam standard

9. The modern standard of time

[EE ESE - 2001]

(a) A second defined as 1/86400 of a mean solar day.

(b) A second defined as time constant of an RC series circuit having R = 2 MΩ, C = 500 pF.
(c) A second which is duration of 9192631770 periods of radiation corresponding to the transition between the two hyperfine levels of the fundamental state of the atom cesium 133.
(d) A second defined as 1/31556925.9747 of the time required by the earth to orbit the sun in the year 1900.

10. The resistivity of the wire material can be expressed in terms of LMTI system of dimensional parameter as

[EC ESE - 2001]

(a) $ML^2T^{-2}I^{-2}$
(b) $ML^2T^{-3}I^{-2}$
(c) $ML^3T^{-3}I^{-2}$
(d) $ML^3T^{-2}I^{-2}$

11. "The current internationally recognized unit of time and frequency is based on the cesium clock, which gives an accuracy better 1μs per day ". This statement is related to

[EC ESE - 1999]

(a) Working standards
(b) International standards
(c) Primary standards
(d) Secondary standards

SOLUTIONS

Sol. 1. (b)
1. 108 Ω has 3 significant figures.
2. 108.0 Ω has 4 significant figures.
3. 0.000108 MΩ can be written has 108 Ω.
So, it has 3 significant figures.
The more the significant figures, the greater the precision of measurement.
Hence, option (b) is correct.

Sol. 2. (d)

Sol. 3. (d)

Sol. 4. (b)

Sol. 5. (b)
The hydrogen maser is the most stable frequency source currently known , having a frequency of 1420405751.73± 0.03Hz. However, due to its relatively large size, its use is limited to area where stability is critical, and size is not a consideration

Sol. 6. (c)

Sol. 7. (b)

Sol. 8. (d)

Sol. 9. (c)

Sol. 10. (c)
$R = \frac{\rho l}{A} \Rightarrow \rho = \frac{RA}{l}$

But $R = \frac{V}{i}$ where $V = \frac{W}{Q}$

So, $\rho = \frac{W}{Q} \cdot \frac{1}{i} \cdot \frac{A}{l}$

Where
W = work
Q = charge
I = current
A = area
l = length
Considering dimensions

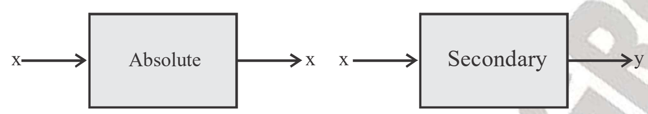
$\rho = \frac{ML^2T^2}{IT} \cdot \frac{1}{I} \cdot \frac{L^2}{L}$

Or $\rho = ML^3T^{-3}I^{-2}$
So, the dimension of resistivity is $ML^3T^{-3}I^{-2}$

Sol. 11. (c)

CHAPTER - 2
CHARACTERISTICS OF INSTRUMENTS AND MEASUREMENT SYSTEMS

2.1 STATIC CHARACTERISTICS
1. Calibration Curve
In this process, a known quantity is given as an input to instrument and output is seen. If output varies then instrument is adjusted accordingly using absolute instruments.



Adjust instrument so that output is x

2. Accuracy
Confirmity to truth, or true value. True value is impossible to calculate. However, most agreed value by experts may be considered as true value.
Measured in terms of its error.
Static error = Measured value – True value
$\delta A = A_m - A_t$
Absolute error/static error (δA) = $E_0 = A_m - A_t$
Relative error,
$$E_r = \frac{\delta A}{A_t}$$
(i) Accuracy is specified in three ways
(a) Point Accuracy
Only for a particular value the instrument is accurate to measure
(b) Accuracy as percentage of scale range i.e., x% of full scale deflection.
(c) Accuracy as percentage of true value i.e., x% of true value.

3. Static Correction
$\delta C = -(\delta A)$
Error is corrected in opposite to the error.

4. Scale Range
The range from minimum to maximum that instrument can measure.

5. Scale Span
$X_{max} - X_{min}$ = Scale Span

6. Reproducibility and Drift
The degree of closeness with which a given value can be measured repeatedly at different times in reproducibility.
If there is perfect reproducibility over time that is called No Drift.

GATE QUESTIONS

1. Two magnetically uncoupled inductive coils have Q factors q_1 and q_2 at the chosen operating frequency. Their respective resistances are R_1 and R_2. When connected in series. Their effective Q factor at the same operating frequency is

[GATE - 2013]

(a) $q_1 + q_2$
(b) $(1/q_1) + (1/q_2)$
(c) $(q_1R_1 + q_2R_2)/(R_1 + R_2)$
(d) $(q_1R_2 + q_2R_1)/(R_1 + R_2)$

SOLUTIONS

Sol. 1. (c)
The quality factor of the inductances are given by

$q_1 = \frac{\omega L_1}{R_1}$ and $q_2 = \frac{\omega L_2}{R_2}$

So, in series circuit, the effective quality factor is given by

$$Q = \frac{|X_{Leq}|}{R_{eq}} = \frac{\omega L_1 + \omega L_2}{R_1 + R_2}$$

$$= \frac{\frac{\omega L_1}{R_1R_2} + \frac{\omega L_2}{R_1R_2}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{\frac{q_1}{R_2} + \frac{q_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{q_1R_1 + q_2R_2}{R_1 + R_2}$$

CHAPTER - 3
ERRORS IN MEASUREMENTS AND THEIR STATISTICAL ANALYSIS

3.1 INTRODUCTION
3.1.1 Limiting Errors/ Guarantee Errors

Limiting error is the deviation from nominal value guaranteed by manufacturer.

$A_a = A_s \pm \delta A$

Where A_a is Actual value

Relative limiting Error(E_r) = $\dfrac{\text{Actual Value} - \text{Nominal Value}}{\text{Nominal Value}} = \dfrac{\delta A}{As}$

Example A wattmeter has fsd 1000W and error ± 1% fsd. What will be the range of value if we measure 100W if error was specified as percentage of true value.

Solution.

Magnitude of limiting error at fsd = $\pm\dfrac{1}{100}\times 1000 = \pm 10W$

$\Rightarrow$ 100 ± 10W i.e., Between 90W to 110W

Percentage of E_r = $\pm\dfrac{10}{100}\times 100 = \pm 10\%$

If error given as percentage of true value

Magnitude = $\pm\dfrac{1}{100}\times 100 = \pm 1W$

Hence, meter will read from 99 to 101 W

Example A 0 – 150V voltmeter has guaranteed accuracy of 1% of fsd. At = 75V. what is the limiting error ?

Solution.

$\delta A = \dfrac{1}{100}\times 150 = 1.5$

$A_t = 75V$

Percentage of E_r = $\dfrac{1.5}{75}\times 100 = 2\%$

3.1.2 Limiting error of components/combination of quantities

1. Addition

$x = x_1 + x_2$

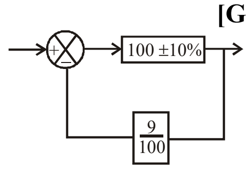
$$\frac{dx}{x} = \pm\frac{d(x_1 + x_2)}{x}$$

$$\frac{dx}{x} = \pm\left[\left(\frac{\partial x_1}{x_1}.\frac{x_1}{x}\right) + \left(\frac{\partial x_2}{x_2}.\frac{x_2}{x}\right)\right]$$

GATE QUESTIONS

1. As shown in the figure, a negative feedback system has an amplifier of gain 100 with + 10% tolerance in the forward path, and an attenuator of value 9/100 in the feedback path. The overall system gain is approximately

[GATE - 2010]



(a) $10 \pm 1\%$ (b) $10 \pm 2\%$
(c) $10 \pm 5\%$ (d) $10 \pm 10\%$

2. A variable *w* is related to three other variables *x,y,z* as *w= xy/Z,* The variables are measured with meters of accuracy ±0.5% reading, ±1% of full scale value and ±1.5% reading. The actual readings of the three meters are 80, 20 and 50 with 100 being the full scale value for all three. The maximum uncertainty in the measurement of *w* will be

[GATE - 2006]

(a) ±0.5% rdg (b) ±5.5% rdg
(c) ±6.7 rdg (d) ±7.0 rdg

SOLUTIONS

Sol. 1. (a)

Overall gain of the system is

$$g = \frac{100}{1+100\left(\frac{9}{100}\right)} = 10\,(\text{zero error})$$

Gain with error

$$g = \frac{100+10\%}{1+(100+10\%)\left(\frac{9}{100}\right)}$$

$$= \frac{110}{1+\frac{110\times 9}{100}} = 10.091$$

error Δg = 10.091 – 10 □ 0.1

Similarly

$$g = \frac{100-10\%}{1+(100-10\%)\frac{9}{100}} = \frac{90}{1+90\times\frac{9}{100}} = 9.89$$

Error Δg = 9.89 – 10 □ –0.1

So gain g = 10 ± 0.1 = 10 ± 1%

Sol. 2. (d)

Given that $\omega = \frac{xy}{2}$

logω = log x + logy – logz

Maximum error in ω

$$\%\frac{d\omega}{\omega} = \pm\frac{dx}{x} \pm \frac{dy}{y} \pm \frac{dz}{z}$$

$$\frac{dx}{x} = \pm 0.5\%\,\text{readings}$$

$$\frac{dy}{y} = \pm 1\%\,\text{full scale} = \pm\frac{1}{100}\times 100 = \pm 1$$

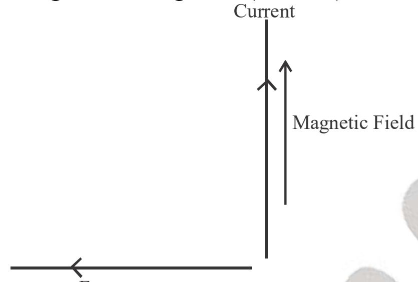
$$\frac{dy}{y} = \pm\frac{1}{20}\times 100 = \pm 5\%\ \text{reading}$$

$$\frac{dz}{z} = 1.5\%\ \text{reading}$$

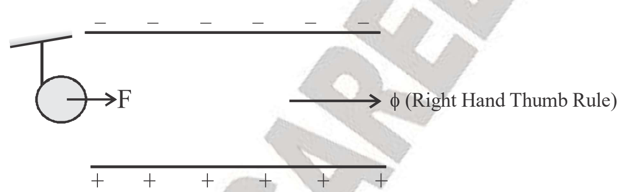
So $\%\frac{d\omega}{\omega} = \pm 0.5\% \pm 5\% \pm 1.5\% = \pm 7\%$

CHAPTER - 4
ANALOG INSTRUMENTS

4.1 INTRODUCTION
4.1.1 Fleming's Left Hand Rule
This rule is used in Permanent Magnet Moving Coil (PMMC)



When an iron piece is placed near magnetic field then magnetic energy acts in such a way so as to reduce reluctance.



Reluctance = $\frac{\text{mmf}}{\text{flux}} = \frac{NI}{\phi}$

Where mmf is Magneto Motive Force
emf is Electro Motive Force

4.1.2 Ampere's Law
$\oint H.d\ell = I_{enclosed}$

where H is Magnetic Field Intensity
$\oint$ is magnetic path enclosed

$H \times \ell_m = NI$

Where ℓ_m is length of magnetic path

4.1.3 Right Hand Thumb Rule
Thumb is the direction of current and curl of fingers is the direction of flux.

GATE QUESTIONS

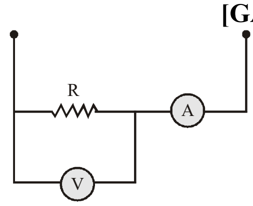
1. A current of $-8+6\sqrt{2}(\sin\omega t+30°)$ A is passed through three meters. They are a centre zero PMMC meter, a true rms meter and a moving iron instrument. The respective reading (in A) will be

[GATE - 2006]

(a) 8, 6, 10 (b) 8, 6, 8
(c) –8,10,10 (d) –8, 2, 2

2. The set-up in the figure is used to measure resistance *R*. The ammeter and voltmeter resistances are 0.01Ω and 2000 Ω, respectively. Their readings are 2 A and 180 V, respectively, giving a measured resistances of 90 Ω The percentage error in the measurement is

[GATE - 2005]



(a) 2.25% (b) 2.35%
(c) 4.5% (d) 4.71%

3. A moving coil of a meter has 100 turns, and a length and depth of 10 mm and 20 mm respectively. It is positioned in a uniform radial flux density of 200 mT. The coil carries a current of 50 mA, The torque on the coil is

[GATE - 2004]

(a) 200 μNm (b) 100 μNm
(c) 2 μNm (d) 1 μNm

4. A dc A-h meter is rated for 15 A, 250 V. The meter constant is 1.4,4 A-sec/rev, The meter constant at rated voltage may be expressed as

[GATE - 2004]

(a) 3750 rev/kWh (b) 3600 rev/kWh
(c) 1000 rev/kWh (d) 960 rev/kWh

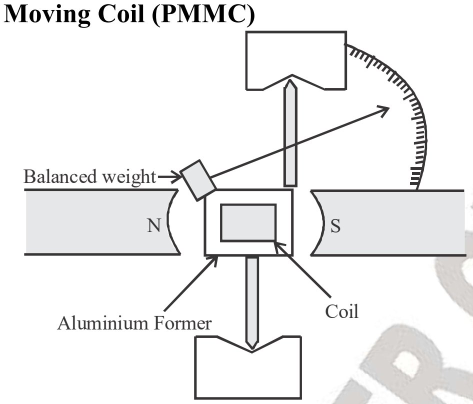
5. A moving iron ammeter produces a full scale torque of 240 μNm with a deflection of 120° at a current of 10 A. The rate of change of self induction (μH/radian) of the instrument at full scale is

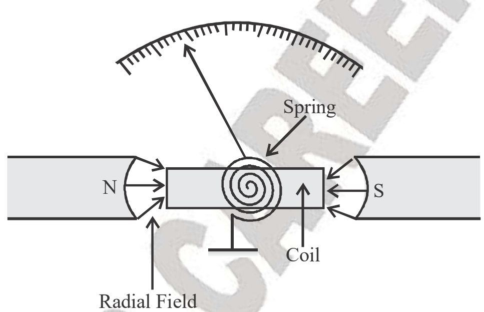
[GATE - 2004]

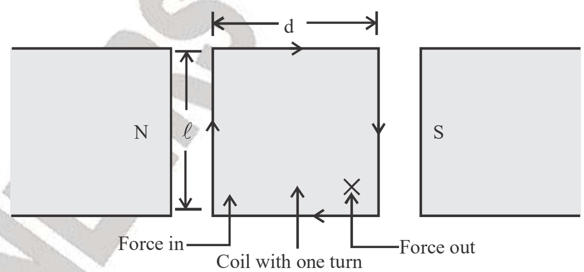
(a) 2.0 μH/radian (b) 4,8 μH/radian
(c) 12.0 μH/radian (d) 114.6 μH/radian

CHAPTER - 5
ANALOG AMMETER, VOLTMETER AND OHMETER

5.1 INTRODUCTION
5.1.1 Permanent Magnet Moving Coil (PMMC)





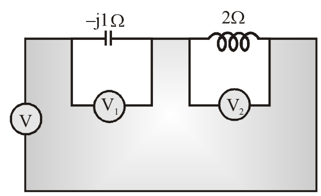


$F = NIBl \sin\theta$
For radial field; $\theta = 90^0$
$T_d = F.d$
$F = NIB\ ld$
$\because\ A = ld$
$F = NIBA$
$\because\ G = NBA$

GATE QUESTIONS

1. Three moving iron type voltmeter are connected as shown below. Voltmeter readings are V, V_1 and V_2 as indicated. The correct relation among the voltmeter readings is

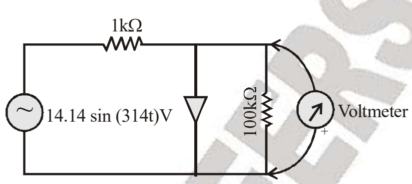
[GATE - 2013]



(a) $V = \frac{V_1}{\sqrt{2}} + \frac{V_2}{\sqrt{2}}$
(b) $V = V_1 + V_2$
(c) $V = V_1 V_2$
(d) $V = V_2 - V_1$

2. The input impedance of the permanent magnet moving coil (PMMC) voltmeter is infinite. Assuming that the diode shown in the figure below is ideal, the reading of the voltmeter in Volts is

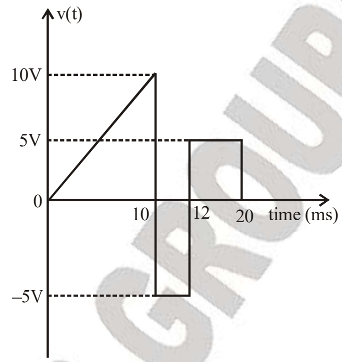
[GATE - 2013]



(a) 4.46 (b) 3.15
(c) 2.23 (d) 0

3. A periodic voltage waveform observed on an oscilloscope across a load is shown. A permanent magnet moving coil (PMMC) meter connected across the same load reads

[GATE - 2012]



(a) 4V (b) 5V
(c) 8V (d) 10V

4. An analog voltmeter uses external multiplier settings. With a multiplier setting of 20 kΩ, it reads 440V and with a multiplier setting of 80 kΩ, it reads 352V, For a multiplier setting of 40 kΩ, the voltmeter reads

[GATE - 2012]

(a) 371V (b) 383V
(c) 394 V (d) 406V

5. An ammeter has a current range of 0.5 A, and its internal resistance is 0.2 Ω. In order to change the range to 0-25 A, we need to add a resistance of

[GATE - 2010]

(a) 0.8 Ω in series with the meter
(b) 1.0 Ω in series with the meter
(c) 0.04 Ω in parallel with the meter
(d) 0.05 Ω in parallel with the meter

6. The Q-meter works on the principle of

[GATE - 2005]

(a)Mutual inductance (b)Self inductance
(c)Series resonance (d)Parallel resonance

7. A PMMC voltmeter is connected across a series combination of DC voltage source $V_1 = 2$ V and AC voltage source $V_2(t) = 3 \sin(4t)$ V, The meter reads

ESE OBJ QUESTIONS

1. A $3\frac{1}{2}$ digit digital voltmeter is accurate to ±0.5% of reading ±2 digits. What is the percentage error, when the voltmeter reads 0.10V on its 10V range?

[EC ESE - 2017]

(a) 0.025% (b) 0.25%
(c) 2.05% (d) 20.5%

2. A PMMC instrument if connected directly to measure alternating current, it indicates

[EC ESE - 2017]

(a) The actual value of the subject AC quantity
(b) Zero reading
(c) $\frac{1}{\sqrt{2}}$ of the scale value where the pointer rests
(d) $\frac{\sqrt{3}}{2}$ of the scale value where the pointer rests.

3. Consider the following statements:
Sphere gap method of voltage measurement is used
1. For measuring r.m.s. value of a high voltage
2. For measuring peak value of a high voltage
3. As the standard for calibration purposes
Which of the above statements are correct ?

[EC ESE - 2017]

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

4. A voltmeter having a sensitivity of 1000 Ω/V reads 100 V on its 150 V scale when connected across at resistor of unidentified specifications in series with a milliammeter. When the milliammeter reads 5 mA, the error due to the loading effect of the voltmeter will be nearly

[EC ESE - 2017]

(a) 13% (b) 18%
(c) 23% (d) 33%

5. Statement (I): Moving iron instruments are used in ac circuits only.
Statement (II): The deflecting torque in moving iron instruments depends on the square of the current.

[EE ESE - 2017]

(a) Both statement (I) and statement (II) are individually true and statement (II) is the correct explanation of statement (I).
(b) Both statement (I) and statement (II) are individually true but statement (II) is not the correct explanation of statement (I).
(c) Statement (I) is true but statement (II) is false.
(d) Statement (I) is false but statement (II) is true.

6. Statement (I): PMMC instruments are suitable in aircraft and air space applications.
Statement (II): PMMC instruments use a core magnet which possesses self– shielding property.

[EE ESE - 2017]

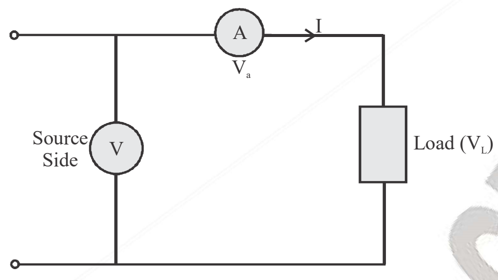
(a) Both statement (I) and statement (II) are individually true and statement (II) is the correct explanation of statement (I).
(b) Both statement (I) and statement (II) are individually true but statement (II) is not the correct explanation of statement (I).
(c) Statement (I) is true but statement (II) is false.
(d) Statement (I) is false but statement (II) is true.

7. Statement (I): An instrument manufacture as an ammeter should not be used as voltmeter
Statement (II): The high resistance winding of an ammeter will suffer serious damage if connected across a high voltage source.

[EE ESE - 2017]

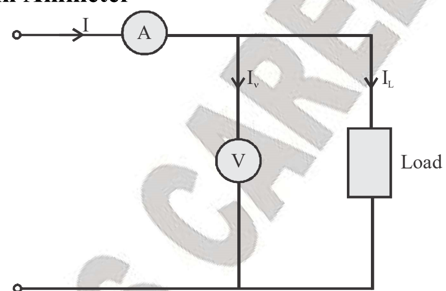
CHAPTER - 6
MEASUREMENT OF POWER

6.1 DC CIRCUITS
1. Voltmeter – Ammeter method



Power indicated by the instrument is = VI
= $(V_a + V_L).I = V_a.I + V_L.I$
$= V_L I + I^2 Ra$

2. Actual Power and Loss in Ammeter



$I = I_L + I_v$
$\Rightarrow (I_L + I_v)V$
$\Rightarrow VI_L + I_v V$
$\Rightarrow VI_L + VI_v$

Actual Power and Loss in voltmeter = $V \cdot I_L + \frac{V^2}{R_V}$

Power indicated by the instrument is actual power and loss in the instrument placed near load.

6.2 AC CIRCUITS
Here we use ED type Wattmeter
Fixed coils are connected in series so that they carry load current. Hence fixed coils are also called cc coils(current carrying coils). Moving coil depends on source on load and current carried by moving coils is proportional to voltage. They are also called potential coils or pressure coils.

GATE QUESTIONS

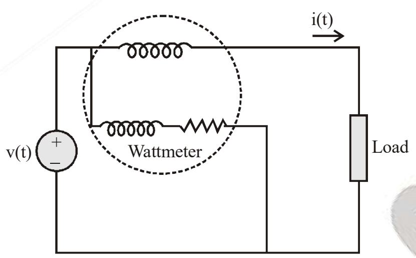
1. The bridge method commonly used for finding mutual inductance is

[GATE - 2012]

(a) Heaviside Campbell bridge
(b) Schering bridge
(c) De Sauty bridge
(d) Wien bridge

2. For the circuit shown in the figure, the voltage and current expressions are $V(t) = E_1 \sin(\omega t) + E_3\sin(3\omega t)$ and $i(t) = I_1\sin(\omega t - \phi_1) + I_3\sin(3\omega t - \phi_3) + I_5\sin(5\omega t)$
The average power measured by the wattmeter is

[GATE - 2012]



(a) $\frac{1}{2}E_1I_1\cos\phi_1$

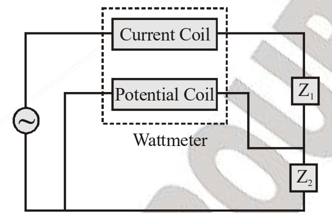
(b) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_1I_3\cos\phi_3 + E_1I_s]$

(c) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_3\cos\phi_3)$

(d) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_1\cos\phi_1]$

3. A wattmeter is connected as shown in figure. The wattmeter reads.

[GATE - 2010]



(a) Zero always
(b) Total power consumed by Z_1 and Z_2
(c) Power consumed by Z_1
(d) Power consumed by Z_2

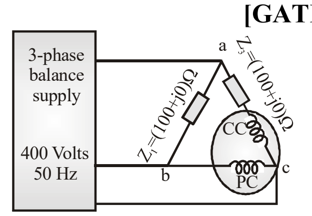
4. The pressure coil of dynamometer type wattmeter is

[GATE - 2009]

(a) Highly inductive
(b) Highly resistive
(c) Purely resistive
(d) Purely inductive

5. The figure shows a three-phase delta connected load, supplied from a 400V, 50 Hz, 3-phase balanced source. The pressure coil (PC) and current coil (CC) of a wattmeter are connected to the load as shown, with the coil polarities suitably selected to ensure a positive deflection. The wattmeter reading will be

[GATE - 2009]



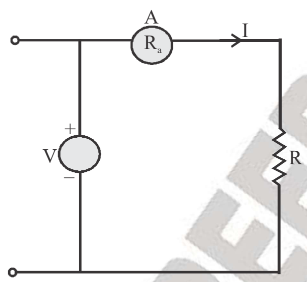
(a) 0
(b) 1600 Watt
(c) 800 Watt
(d) 400 Watt

6. A sampling wattmeter (that computes power from simultaneously sampled values of voltage and current) is used to measure the average power of a load. The peak to peak voltage of the square wave is 10 V and the current is a triangular wave of 5 A p-p as shown in the figure. The period is 20 ms. The reading in W will be

CHAPTER - 7
MEASUREMENT OF RESISTANCE

7.1 THREE CATEGORY FOR MEASUREMENT OF RESISTANCE
(i) Low R: of order of 1Ω or less
(ii) Medium R: of order of 1 Ω – 100 kΩ
(iii) High R: R > 100kΩ

7.2 METHOD TO CALCULATE RESISTANCE
Type-I. Ammeter Voltmeter Method
This method is suitable for measuring high resistance

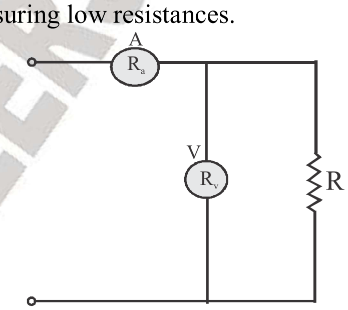


Measured value of $R_m = \frac{V}{I}$

If R_a then, $R_m = \frac{V}{I} = \frac{I_R + R_a}{I} = R + R_a$

Percentage error = $\frac{R_a}{R}$

Type-II.
This method is suitable for measuring low resistances.



$R_m = \frac{V}{I} = \frac{V}{I_v + I_R}$

$I_v = \frac{V}{R_v}$ and $I_R = \frac{V}{R -}$

CHAPTER - 8
AC BRIDGES

8.1 INTRODUCTION

AC bridges are used for measurement of inductance, capacities, quality factor of coils and dissipation factor of capacitances etc.

Source is an electronic oscillator with controllable frequencies.

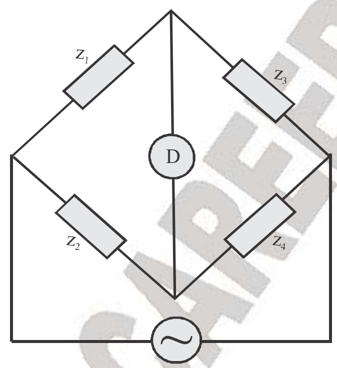
1. Detectors are

1. Headphones: 250Hz to 4 kHz
2. Vibration galvanometer: This is most sensitive for 5Hz to 200 Hz.
3. Wide frequency range, tunable amplifier: 100Hz to 10 kHz

At balance, $\overline{z}_1\overline{z}_4 = \overline{z}_2\overline{z}_3$

$|z_1||z_4| = |z_2||z_3|$ …(i)

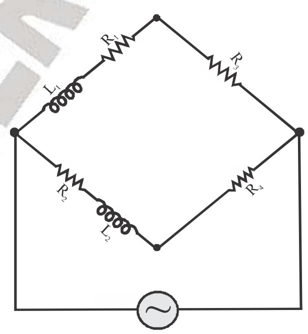
$\angle\theta_1 + \theta_4 = \angle\theta_4 + \theta_3$



Two equations: two unknown variable can be known in terms of known variable. For quick balance, the known variables shall not come in the equation.

$(R_1 + j\omega L_1)R_4 = (R_2 + j\omega L_2)R_3$

$R_1R_4 = R_2R_3$



And $L_1R_4 = L_2R_3$

$$R_1 = \frac{R_2R_3}{R_4}$$

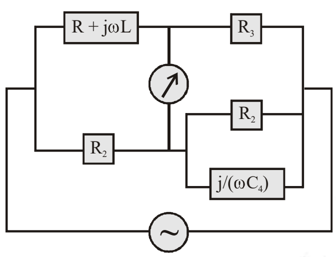
GATE QUESTIONS

1. Consider the following statement
(1) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the current coil.
(2) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the voltage coil circuit.

[GATE - 2011]

(a) (1) is true but (2) is false
(b) (1) is false but (2) is true
(c) Both (1) and (2) are true
(d) Both (i) and (2) are false

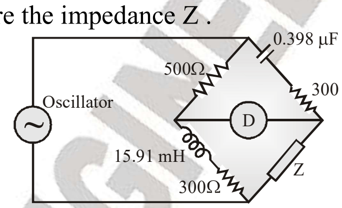
2. The Maxwell's bridge shown in the figure is at balance. The parameters of the inductive coil are.



[GATE - 2010]

(a) $R = R_2R_3/R_4$, $L = C_4R_2R_3$
(b) $L = R_2R_3/R_4$, $R = C_4R_2R_3$
(c) $R = R_4/R_2R_3$, $L = 1/(C_4R_2R_3)$
(d) $L = R_4/R_2R_3$, $R = 1/(C_4R_2R_3)$

3. The ac bridge shown in the figure *is* used to measure the impedance Z .



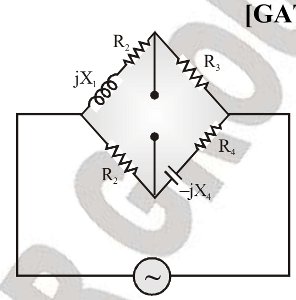
If the bridge is balanced for oscillator frequency f = 2 kHz, then the impedance *Z* will be

[GATE - 2008]

(a) (260 + J0)Ω (b) (0 + j200)Ω
(c) (260 – j200)Ω (d) (260 + j200) Ω

4. A bridge circuit is shown in the figure below. Which one of the sequence given below is most suitable for balancing the bridge ?

[GATE - 2007]



(a) First adjust (b) First adjust
(c) First adjust (d) First adjust

5. R_1 and R_4 are the opposite arms of a Wheatstone bridge as are R_2 and R_1. The source voltage is applied across R_1 and R_3. Under balanced conditions which one of the following is true

[GATE - 2006]

(a) $R_1 = R_3R_4/R_2$
(b) $R_1 = R_2R_3/R_4$
(c) $R_1 = R_2R_4/R_3$
(d) $R_1 = R_2 + R_3 + R_4$

6. The items in Group-I represent the various types of measurements to be made with a reasonable accuracy using a suitable bridge. The items in Group-II represent the various bridges available for this purpose. Select the correct choice of the item in Group-II for the corresponding item in Group-I from the following

List-I
A. Resistance in the milli-ohm range
B. Low values of Capacitance
C. Comparison of resistance which are nearly equal
D. Inductance of a coil with a large time-constant

SOLUTIONS

Sol. 1. (c)
The compensation coil compensation the effect of impedance of current coil.

Sol. 2. (a)
At balance condition

$$(R + j\omega L)\left(R_4 \parallel \frac{-j}{\omega C_4}\right) = R_2R_3$$

$$(R + j\omega L)\frac{\frac{-jR_4}{\omega C_4}}{\left(R_4 - \frac{j}{\omega C_4}\right)} = R_2R_3$$

$$\frac{-jRR_4}{\omega C_4} + \frac{\omega LR_4}{\omega C_4} = R_2R_3R_4 - \frac{jR_2R_3}{\omega C_4}$$

Comparing real & imaginary parts.

$$\frac{RR_4}{\omega C_4} = \frac{R_2R_3}{\omega C_4}$$

$$R = \frac{R_2R_3}{R_4}$$

Similarly, $\frac{LR_4}{C_4} = R_2R_3R_4$

$L = R_2R_3C_4$

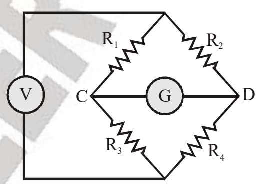
Sol. 3. (a)
Impedance of different branches is given as
$Z_{AB} = 500\Omega$

$$Z_{BC} = \frac{1}{j\times 2\pi\times 2\times 10^3\times 0.398\mu F} + 300\Omega$$

□ $(-200\,J + 300)\,\Omega$
$Z_{AD} = j \times 2\pi \times 2 \times 10^3 \times 15.91\text{ mH} + 300\Omega$
□ $(200\,j + 300)\Omega$
To balance the bridge
$Z_{AB}Z_{CD} = Z_{AD}Z_{BC}$
$500Z = (200\,j + 300)\ 9–200\,j + 300)$
$500\,Z = 130000$
$Z = (260 + j0)\Omega$

Sol. 4. (a)
To balance the bridge
$(R_1 + jX_1)(R_4 - jX_4) = R_2R_3$
$(R_1R_4 + X_1X_4) + j(X_1R_4 - R_1X_4) = R_2R_3$
Comparing real and imaginary parts on both sides of equations
$R_1R_4 + X_1X_4 = R_2R_3$ … (i)
$X_1R_4 - R_1X_4 = 0 \Rightarrow \frac{X_1}{X_4} = \frac{R_1}{R_4}$ …(ii)
From eq(1) and (2) it is clear that for balancing the bridge first balance R_4 and then R_1.

Sol. 5. (b)



In balanced condition there is no current in CD arm so $V_C = V_D$
Writing node equation at C and D

$$\frac{V_C - V}{R_1} + \frac{V_C}{R_3} = 0 \Rightarrow V_C = V\left(\frac{R_3}{R_1 + R_3}\right)$$

$$\frac{V_0 - V}{R_2} + \frac{V_D}{R_4} = 0 \Rightarrow V_D = V\left(\frac{R_4}{R_2 + R_4}\right)$$

So $V\left(\frac{R_3}{R_1 + R_3}\right) = V\left(\frac{R_4}{R_2 + R_4}\right)$

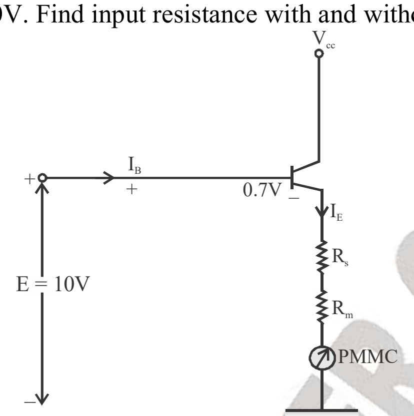
$R_2R_3 + R_3R_4 = R_1R_4 + R_3R_4$
$R_1 = R_2R_3/R_4$

Sol. 6. (a)
Kelvin Double bridge is used for measuring low values of resistances. ($P \rightarrow 2$)
Low values of capacitances is precisely measured by Schering bridge ($Q \rightarrow 3$)
Inductance of a coil with large time constant or high quality factor is measured by hay's bridge ($R \rightarrow 5$)

CHAPTER - 9
ELECTRONIC MEASUREMENTS

9.1 ELECTRONIC MEASUREMENT

Example Find I_m when E = 10V. Find input resistance with and without transistor.



$R_s + R_m = 9.3\ k\Omega$

$I_{fsd} = 1mA$

$\beta = 100$

Solution.

E = 10V = V

I_m = ImA

$10 - 0.7 = (9.3 \times 10^3)\ I_m$

$I_m = 1mA$

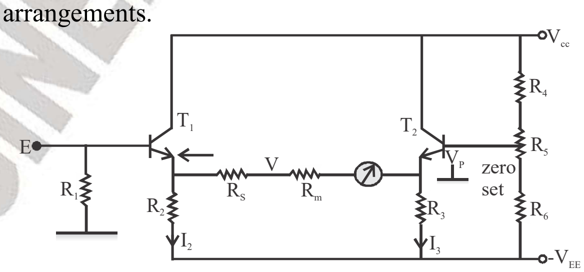
$Z_{in} = (h_{fe} + 1)Re.$

$$Z_{in} = \frac{E}{I_B} \Rightarrow Z_{in} = \frac{10}{0.1\mu A} = 100M\Omega$$

$$I_B \approx \frac{I_E}{B} = 0.1\mu A$$

$Z_{in} = R_s + R_m = R_E$

Input impedance should be high to avoid loading effect. Thus, to eliminate the error due to V_{BE}, we will make certain arrangements.



No two transistors can be same.

GATE QUESTIONS

1. An average-reading digital multi-meter reads 10 V when fed with a triangular wave, symmetric about the time-axis. For the same input an rms reading meter will read

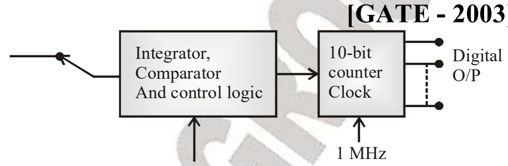
[GATE - 2009]

(a) $\frac{20}{\sqrt{3}}$ (b) $\frac{10}{\sqrt{3}}$

(c) $20\sqrt{3}$ (d) $10\sqrt{3}$

2. The simplified block diagram *of* a 10-bit A/D converter of dual slope Integrator type is shown In figure. The 10-bit counter at the output is clocked by a 1 MHz clock. Assuming negligible timing overhead for the control logic, the maximum frequency of the analog signal that can be converted using this A/D converter is approximately

[GATE - 2003]



(a) 2 kHz (b) 1 kHz

(c) 500 Hz (d) 250 Hz

SOLUTIONS

Sol. 1. (d)

Average value of a triangular wave

$V_{av} = \frac{V_m}{3}$

rms value $V_{ms} = \frac{V_m}{\sqrt{3}}$

Given that $V_{av} = \frac{V_m}{3} = 10V$

So $V_{rms} = \frac{V_m}{\sqrt{3}} = \sqrt{3}\,V_{av} = 10\sqrt{3}\,V$

Sol. 2. (b)

Maximum frequency of input in dual slope A/D converter is given as

$T_m = 2^n T_C$

Where $f_m = \frac{1}{T_m} \rightarrow$ maximum frequency of input

$f_C = \frac{1}{T_C} \rightarrow$ clock frequency

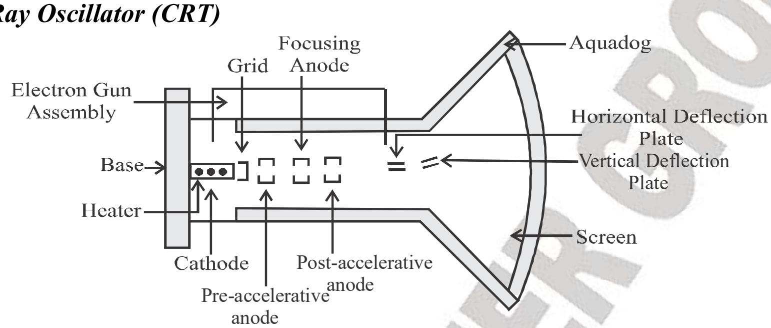
So $f_m = \frac{f_c}{2^{n'}}$ n = 10

$= \frac{10^6}{1024} = 1\text{kHz(approx)}$

CHAPTER - 10
CATHODE RAY OSCILLOSCOPE (CRO)

10.1 INTRODUCTION
Cathode Ray Oscillator is basically a XY plotter, the CRO can measure frequency upto 1GHz. CRO is basically voltage meter.

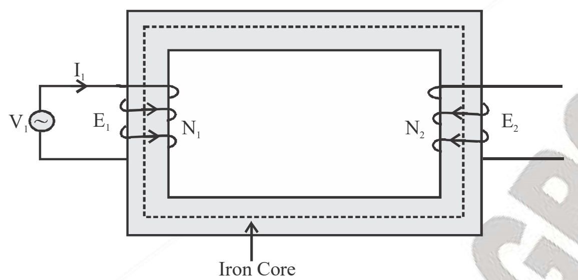
10.1.1 Part of CRO
1. Cathode Ray Oscillator (CRT)



Electron gun assembly produces sharp beam of accelerated electrons.
(i) ***Cathode:*** It produces electrons when heated. A layer of stromdium oxide is placed over cathode to increase efficiency. Cathode is cylindrical with a hole in it.
(ii) ***Grid:*** The intensity/ brightness spots on screen depends on no. of electrons. This can be controlled by putting a negative bias on grid.
(iii) ***Pre – Accelerative Anode:*** By placing positive high voltage, speed of electron increases.
(iv) ***Focusing Anode:*** The scattered beam is focused by electrostatic focusing in CRO and by magnetic focusing in TV sets.
(v) ***Post –Accelerative Anode:*** It is required to accelerate the electrons.
(vi) ***Horizontal Deflection Plate :*** Its function is to move electrons beam horizontally on the screen.
(vii) ***Vertical Deflection Plate:*** Its function is to move electrons beam vertically on the screen.
(viii) ***Screen:*** It is made of glass coated with phosphor. When electrons strike on phosphor, the energy is increased and it produces light that is called cathode luminance.
(ix) ***Gratiule:*** Horizontal and vertical divisions on screen for measurement.
(x) ***Aquadog:*** When electrons strike over screen, they cause emission of electrons from screw which is called secondary emission. Aquadog is aqueous summation of device which collect through secondary emitted electrons.

CHAPTER - 11
INSTRUMENT TRANSFORMERS

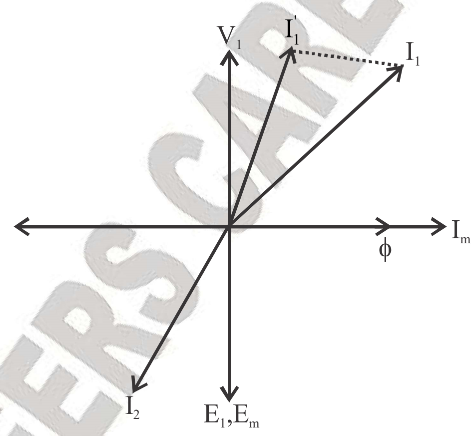
11.1 INTRODUCTION



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

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$$



The above graph is phasor diagram of ideal transformer without any load.

If we put some load on transformer, and we get a path for current to flow. So the current produced will be to oppose the flux here,

$E_1 = 4.44\ \phi_m\ fN_1$

$E_2 = 4.44\ \phi_m\ fN_2$

$V_1 = -E_1 = 4.44\ \phi\ f\ N$

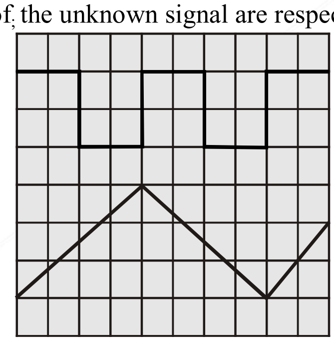
When V_1, f and N are not changing then even ϕ we cannot change.

I_2 causing ϕ decreases. But ϕ cannot on decreasing

Then transformer drives more current from supply to maintain the ϕ such that

GATE QUESTIONS

1. The time/div and voltage/div axes of an oscilloscope have been erased. A student connects a 1 kHz, 5 V p-p square wave calibration pulse to channel-1 of the scope and observes the screen to be as shown in the upper trace of the figure. An unknown signal is connected to channel-2 (lower trace) of the scope. It the time/ div and V/div on both channels are the same, the amplitude (p-p) and period of the unknown signal are respectively



[GATE - 2006]

(a) 5 V. 1 ms (b) 5 V, 2 ms
(c) 7,5 V, 2 ms (d) 10 V, 1 ms

2. 200/1 Current transformer (CT) is wound with 200 turns on the secondary on a toroidal core. When it carries a current of 160 A on the primary, the ratio and phase errors of the CT are found to be – 0.5% and 30 minutes respectively. If the number of secondary turns is reduced by 1 new ratio-error(%) and phase error(min) will be respectively

[GATE - 2006]

(a) 0.0, 30 (b) -0.5, 35
(c) -1.0, 30 (d) -1.0, 25

3. A 50 Hz, bar primary CT has a secondary with 500 turns. The secondary supplies 5 A current into a purely resistive burden of 1 Ω. The magnetizing ampere-turns is 200. The phase angle between the primary and second current is

[GATE - 2004]

(a) 4.6° (b) 85.4°
(c) 94.6° (d) 175.4°

CHAPTER-12
PRIMARY SENSING ELEMENTS AND TRANSDUCERS

12.1 INTRODUCTION

TYPE	OPERATION
Contacting spindle, pin or figure	displacement to displacement
Proving ring	Force to displacement
Bourdon tube	Pressure to displacement
Bellows	Pressure to displacement
Diaphragm	Pressure to displacement
Spring	Force to displacement
Siesmic mass	Forcing function to displacement
Pendulum scale	Force to displacement
Monometer	Pressure to displacement
Thermocouple	Temperature to electric current
Bi-metallic strip	Temperature to displacement
Temp – stick	Temperature to phase
Float	Fluid level to displacement
Hydrometer	Specific gravity to displacement
Quefis	Fluid velocity to pressure
Venturi tube	Fluid velocity to pressure
Pitot tube	Fluid velocity to pressure
Vanes	Fluid velocity to force

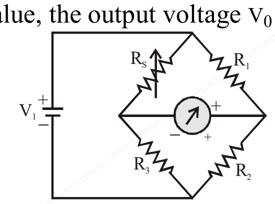
12.2 CLASSIFICATION OF TRANSDUCERS
1. Principle of Transduction used
(i) Resistive Transducers

Transducer	Operation	Typical Use
(a) Potentiometer device	Positioning of slider changes	Measurement of displacement
	the resistance	and pressure
(b) Strain Gauge	Resistance of conductors and	Force, troque, displacement
	semi – conductor changes by	
	tensile or compressive stress.	
(c) Pirani Gauge	Resistance of heating element	Gas flow, gas pressure
	is changed by connection cooling	
(d) Thermometer	Resistance changes with	Temperature
	temperature with positive α.	
(e) Thermistor	Resistance changes with	Temperature, gas flow, water flow
	temperature with negative α.	
(f) Photoconductive Cell	Resistance changes by light	Photosensitive relay

(ii) Capacitive Transducers

GATE QUESTIONS

1. A strain gauge forms one arm of the bridge shown in the figure below and has a nominal resistance without any load as R_s = 300 Ω, Other bridge resistances are $R_1 = R_2 = R_3$= 300 Ω. The maximum permissible current through the strain gauge is 20mA, During certain measurement when the bridge is excited by maximum permissible voltage and the strain gauge resistance is increased by 1% over the nominal value, the output voltage V_0 in mV is



[GATE - 2013]

(a) 56.02 (b) 40.83
(c) 29.85 (d) 10.02

2. A $4\frac{1}{2}$ digit DMM has the error specification as: 0.2% of reading + 10 counts. If a dc voltage of 100 V is read on its 200 V full scale, the maximum error that can be expected in the reading is

[GATE - 2011]

(a) ±0.1% (b) ±0.2%
(c) ±0.3% (d) ±0.4%

3. Two 8-bit ADCs, one *of* single slope integrating type and other of successive approximate type, take T_A and T_B times to convert 5V analog input signal to equivalent digital output. If the input analog signal is reduced to 2.5 V, the approximate time taken by the two ADCs will respectively, be

[GATE - 2008]

(a) T_A. T_B (b) $T_A/2$, T_B
(c) T_A, $T_B/2$ (d) $T_A/2$, $T_B/2$

4. A digital-to-analog converter with a full-scale output voltage of 3.5 V has a resolution close to 14 mV. Its bit size is

[GATE - 2005]

(a) 4 (b) 8
(c) 16 (d) 32