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Detailed Solutions

SSC-JE 2018
Mains Test Series
(PAPER-II)

Electrical Engineering
Test No : 8

Q.1 (a) Solution:

$$Z_{\text{pu, new}} = Z_{\text{pu(old)}} \times \frac{(\text{MVA})_{\text{new}}}{(\text{MVA})_{\text{old}}} \times \left(\frac{\text{kV}_{\text{old}}}{\text{kV}_{\text{new}}}\right)^2$$

$$= 0.6 \times \frac{100}{25} \times \left(\frac{132}{132}\right)^2 = 2.4 \text{ pu}$$

Q.1 (b) Solution:

$$\text{Charge, } Q = CV = 4 \times 12 = 48 \text{ C}$$

After closing the switch,

$$\text{charge } Q = (C_1 + C_2)V_1$$

Where V_1 is common terminal voltage

$$48 = (4 + 2)V_1$$

$$V_1 = 8 \text{ V}$$

The energy stored after closing the switch

$$= \frac{1}{2}CV_1^2 = \frac{1}{2}(4+2)8^2 = 192 \text{ J}$$

Q.1 (c) Solution:

Given,

$$V = 230 \text{ V}$$

$$I = 4 \text{ A}$$

$$t = 6 \text{ hours}$$

$$\cos\phi = 1$$

$$\text{Energy consumed} = (VI\cos\phi) \times t = 230 \times 4 \times 1 \times 6 \times 10^{-3} = 5.52 \text{ kWh}$$

∴ Meter constant, $K = \dfrac{\text{No. of revolutions made by meter}}{\text{Energy consumed}}$

$$= \frac{2208}{5.52} = 400 \text{ rev/kWh}$$

When meter makes 1472 no. of revolutions, then

energy consumed by the meter $= \dfrac{1472}{400} = 3.68$ kWh

Now, actual energy consumed $= (VI \cos\phi) \times t \times 10^{-3}$

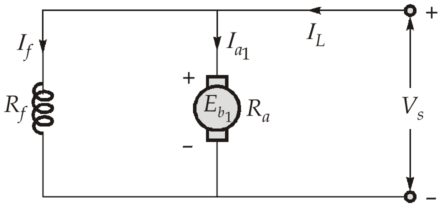
$$= 230 \times 5 \times \cos\phi \times 4 \times 10^{-3} = 3.68$$

or $\cos\phi = 0.8$

∴ Power factor of the load $= 0.8$

Q.1 (d) Solution:

Given that:



Supply voltage, $V_s = 500$ V

Speed, $N_1 = 250$ rpm

Armature current, $I_{a_1} = 200$ A

Armature resistance, $R_1 = 0.12\ \Omega$

$$E_{b_1} = V_s - I_{a_1} R_{a_1}$$

$$= 500 - 200 \times 0.12 = 476 \text{ V}$$

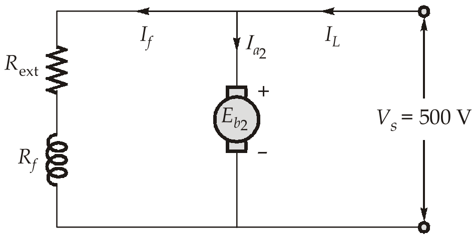
Now, when a resistance is inserted in the field,

Flux $\phi_2 = 0.8\ \phi_1$

Armature current, $I_{a_2} = 100$ A

Back emf, $E_{b_2} = V_s - I_{a_2} R_a$

$$= 500 - 100 \times 0.12 = 488 \text{ V}$$



Now, $E \propto N\phi$

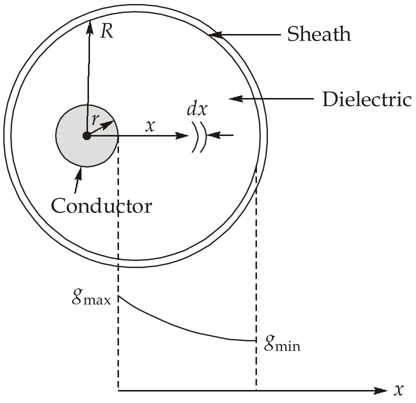
so, $$\frac{E_{b_2}}{E_{b_1}} = \frac{N_2}{N_1} \times \frac{\phi_2}{\phi_1}$$

$$N_2 = N_1 \times \frac{E_{b_2}}{E_{b_1}} \times \frac{\phi_1}{\phi_2} = 250 \times \frac{488}{476} \times \left(\frac{\phi_1}{0.8\phi_1}\right)$$

Speed, $$N_2 = 320.378 \text{ rpm}$$

Q.1 (e) Solution:

Capacitance of Single Core Cable



- Let consider a cable which have core surrounded by dielectric material as shown in figure.
- r = radius of conductor

  R = inner radius of sheath

  t = permittivity of dielectric

  q = charge in C/m

  V = potential of conductor w.r.t. sheath

  g = electric field intensity at a distance x from centre

$$g = \frac{q}{2\pi t x} \text{ V/m}$$

$$V = \int_r^R r \cdot dx = \frac{q}{2\pi t} \ln\left(\frac{R}{r}\right)$$

Capacitance between core and sheath is

$$C = \frac{2\pi t}{\ln\left(\frac{R}{r}\right)} \text{ F/m}$$

- g = potential gradient at a distance $x = \dfrac{V}{x\ln\left(\dfrac{R}{r}\right)}$

$$g_{\text{min}} = \frac{V}{R\ln\left(\dfrac{R}{r}\right)}\text{; occur at surface of sheath}$$

$$g_{\text{max}} = \frac{V}{r\ln\left(\dfrac{R}{r}\right)}\text{; occur at surface of conductor}$$

$$\frac{g_{\text{max}}}{g_{\text{min}}} = \frac{R}{r}$$

- For minimizing maximum dielectric stress (i.e. minimizing g_{max}),

$$\frac{d}{dr}\left[r\ln\left(\frac{R}{r}\right)\right] = 0$$

$\Rightarrow \quad \dfrac{R}{r} = e$ is condition for dielectric stress to be minimum at surface of conductor.

Q.2 (a) Solution:

Since the diode will only allow the positive half cycle of the input signal to flow, the output current will be the D.C. value of the half wave rectified output.

Thus, $$I_0 = \frac{I_{\text{max}}}{\pi}$$

$$I_{\text{max}} = \frac{10}{10\times10^3}\text{A} = 1\text{ mA}$$

$\therefore$ $$I_0 = \frac{1}{\pi}\text{mA}$$

$$I_0 = 0.318\text{ mA}$$

Q.2 (b) Solution:

(i) Electrostatic Instruments:

Electrostatic instruments are mainly used to measure high voltages in laboratories.

Principle

The basic principle behind electrostatic instruments is that the deflecting torque is produced by action of electric field on charged conductors. The force or torque is due to the fact that mechanism tends to move the moving electrode to such a position where the energy stored is maximum.

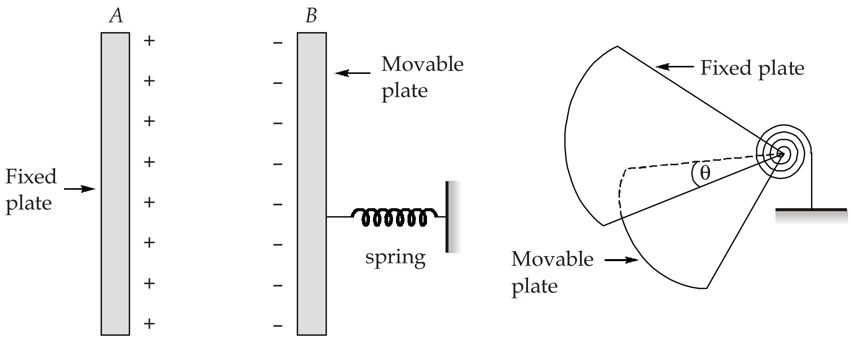


Figure (a) **Figure (b)**

Figure-1 : Linear and Rotary motion of electrostatic instruments (a) and (b)

Figure--1 shows the linear and rotary motion of electrostatic instruments

Energy stored by the capacitor (Figure (a)) is $\frac{1}{2}cv^2$

where, v = voltage applied between plates

Let the capacitance and voltage changes to ($c + dc$) and ($v + dv$) from initial value of c and v respectively

$$\therefore \quad \text{Change in stored energy} = \frac{1}{2}(c+dc)(v+dv)^2 - \frac{1}{2}cv^2 \qquad \text{...(i)}$$

$$\text{Also,} \quad \text{input energy} = vIdt$$

$$I = \frac{dq}{dt} = \frac{d}{dt}(cv) = \frac{vdc}{dt} + \frac{cdv}{dt}$$

$$\therefore \quad \text{Input energy} = v\left(\frac{vdc}{dt} + \frac{cdv}{dt}\right) \cdot dt = v^2dc + cvdv \qquad \text{...(ii)}$$

work done in moving the plate by $d\theta$ (deflection) is w = $T_d \times d\theta$ ...(iii)

Now, input energy = change in stored energy + work done

using equations (i), (ii), and (iii), we have

$$v^2dc + cvdv = \left(\frac{1}{2}(c+dc)(v+dv)^2 - \frac{1}{2}cv^2\right) + T_d \cdot d\theta$$

$$\text{or,} \quad T_d = \frac{1}{2}V^2\frac{dc}{d\theta} \text{ ... equation of deflecting torque}$$

$$\text{Also,} \quad T_c = k\theta \text{ ... equation of controlling torque}$$

$$\text{At equilibrium,} \quad T_c = T_d$$

$$\therefore \quad k\theta = \frac{1}{2}V^2\frac{dc}{d\theta} \text{ or } \theta \propto V^2$$

$$\text{or} \quad \theta = \frac{1}{2k}V^2\frac{dc}{d\theta} \text{ ...deflection}$$

Electrostatic instrument is used to measure rms value of voltage as deflection, $\theta \propto V^2$, [$\theta \propto (\text{voltage})^2$]

- Scale is non-uniform (compressed at the lower end) due to square law response.
- **Advantage of electrostatic instruments:**
  - (a) Power consumption is less
  - (b) They can be used on both ac and dc
  - (c) There is no frequency and waveform error
  - (d) No error due to stray magnetic field
  - (e) Used at high voltage
- **Disadvantage of electrostatic instruments:**
  - (a) These are used in ac circuits of relatively high voltage
  - (b) It is expensive and larger in size
  - (c) It has non-uniform scale
  - (d) The operating forces are small

(ii) Electrothermic Instruments:

Electrothermic instruments are used for the measurement of current at high frequencies. They can also be used for the measurement of voltage at moderate frequencies.

Principle

The principle used in these instruments is indication on some property of a circuit element due to the heating effect produced by the flow of current.

Classification

These instruments are classified as

1. Hot wire instruments
2. Thermocouple Instruments

1. Hot wire instruments

Figure-2 below shows the construction of a hot wire instrument

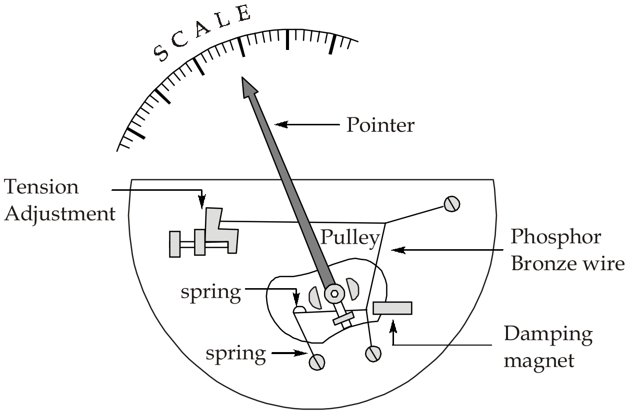


Figure-2 : Hot wire instrument

Hot wire instrument is made up of platinum-Irridium wire.

The current to be measured is passed through the platinum Iridium wire.

Principle of operation:

When the current to be measured is passed through the platinum-Irridium wire, the wire expands due to heating effect. The expansion is taken up by the spring. This causes the pulley to rotate and the pointer to deflect, indicating the value of current. The expansion is proportional to the heating effect of the current and hence the square of the rms value of the current. The meter is calibrated in terms of rms value of the current.

Disadvantages of Hot wire Instruments:

(a) It consumes high power

(b) It has sluggish response

(c) It can't with stand overloads and mechanical shocks

2. Thermocouple Instruments

- Thermocouple instruments works on the principle of Thermocouple. i.e. an emf is developed at the junction due to heating effect produced by an auxiliary circuit carrying current to be measured.
- **Thermocouple:** When two metals having different work functions are placed together, a voltage is generated at the junction which is proportional to the temperature. This junction is called a Thermocouple. Heat energy get converted into electrical energy at the junction.

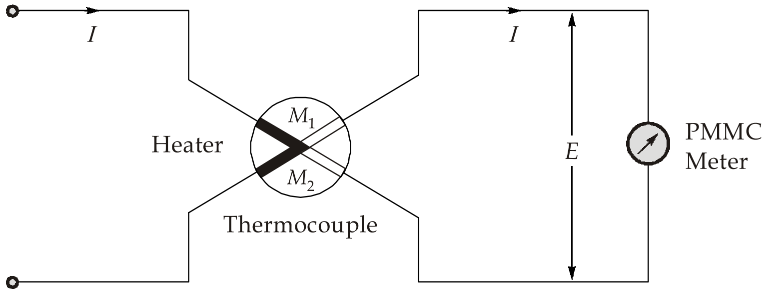


Figure-3 : Basic circuit of a thermo-couple

- The thermocouple produces an emf at it's output terminal which is measured by the help of a PMMC instrument.
- The emf is proportional to the temperature and hence to the rms value of the current.
- The thermocouple type of instruments can be used for both ac and dc applications.
- These instruments are used for the measurement of voltage and current at high frequencies.
- It gives accurate results upto a frequency of 50 MHz.
- It's sensitivity is high and are not affected by stray magnetic field.

Q.2 (c) Solution:

Provisions Applicable to Medium, High or Extra High Voltage Installations

The following provisions shall be observed where energy at medium, high or extra high voltage is supplied, converted, transformed or used:

1. (a) All conductors (other than those of overhead lines) shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanically continuous and adequately protected against mechanical damage unless the said conductors arc accessible only to an authrorised person or are installed and protected of the satisfaction of the inspector so as to prevent danger.
   (b) All metal work enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall if considered necessary by the inspector, by connected with earth.
   (c) Every main switch board shall comply with the following provisions, namely:
      (i) a clear space of not less than 0.144 m or 3 feet in width shall be provided in front of the switchboard.
      (ii) if there are any attachments or bare connections at the back of switchboard, the space (if any) behind the switchboard shall be either less than 0.286 m or 9 inches, or more than 0.762 m or 30 inches in width, measured from the further outstanding part of any attachment or conductor.
      (iii) if the space behind the switchboard exceeds 0.762 m or 10 inches in width, there shall be a passage-way from either end of the switchboard clear to a height of 1.828 inches or 6 feet.
2. Where an application has been made to supplier for supply of energy to any installation, he shall not commence, or where the supply has been discontinued, recommence the supply unless he is satisfied that the consumer has complied in all respects with the conditions of supply set out in sub-rule (1) of this rule, rules 50 and 64.
3. Where a supplier propose to supply or use energy at medium voltage or to recommence supply after it has been discontinued for a period of six months, he shall before connecting or reconnecting the supply, give notice in writing of such intention to the inspector.
4. If at any time after connecting the supply the supplier is satisfied that any provision of sub-rule (1) of this rule, or of rules 50 and 64 is not being observed, he shall give notice of the same in writing to the consumer and the inspector specifying how the provision has not been observed, and may discontinue the supply if the inspector so directs.

Q.2 (d) Solution:

$$I = \frac{100\sqrt{2}\cos 3000t}{1+j\omega_1 L} + \frac{10\sqrt{2}\sin 1000t}{1+j\omega_2 L}$$

$$I = \frac{100\sqrt{2}\cos 3000t}{1+j3} + \frac{10\sqrt{2}\sin 1000t}{1+j1}$$

$$I = \frac{100\sqrt{2}\cos 3000t}{\sqrt{10}\angle\tan^{-1}3} + \frac{10\sqrt{2}\sin(1000t)}{\sqrt{2}\angle\tan^{-1}1}$$

$$I_{\text{rms}} = \sqrt{\frac{1}{2}\left[\frac{10000\times 2}{10} + \frac{100\times 2}{2}\right]} = \sqrt{1050}\ \text{A}$$

So, power dissipated is, $P = I_{\text{rms}}^2 \times R = 1050\ \text{W}$

Q.3 (a) Solution:

Given,

$$S_{\text{rated}} = 20\ \text{kVA},$$
$$R_{\text{pu}} = 0.015\ \text{p.u.}$$

Full load current at *l.v.* side $= \frac{20\ \text{kVA}}{200} = 100\ \text{A}$

∴ Since maximum efficiency occurs at 90 A load current.

At maximum efficiency;

core loss = copper loss

$$\%\ \text{load} = \frac{90}{100} = 0.9$$

Full load copper loss in p.u. $= R_{pu} = 0.015$

Core loss $= (0.9)^2 \times 0.015$

Half rated load efficiency at 0.8 p.f. lagging

$$\%\ \eta = \frac{\frac{1}{2}\times 1.0\times 0.8\times 100}{\frac{1}{2}\times 1.0\times 0.8 + \left[(0.9)^2 + (0.5)^2\right]0.015}$$

$$= \frac{0.4\times 100}{0.4 + [0.81 + 0.25]\times 0.015} = \frac{0.4\times 100}{0.4159}$$

$$\%\ \eta = 96.177\%$$

Q.3 (b) Solution:

(i) Method of Measurement:

Direct Measurement

- In this method, the measured or the unknown quantity is directly compared against a standard.
- This method of measurement sometimes produces human errors and hence gives inaccurate results.

Indirect Measurement

- This method of measurement is more accurate and more sensitive.
- These are more preferred over direct measurement.

Mechanical, Electrical and Electronic Instruments

Mechanical

- This instruments are used for stable and static conditions:
- They are unable to respond rapidly to measurements of dynamic and transient conditions because of having moving parts that are bulky, heavy are rigid possessing high inertia.

Electrical

- Electrical methods of indicating the output of detectors are more rapid than mechanical methods, but they are limited time response.

Electronic

- These instruments require use of semiconductor devices. The response time of these instruments are extremely small as a very small inertia of electron is only involved. The sensitivity of these instruments are also very high. Faster response, lower weight, lower power consumption are some of the advantages of an electronic instrument.

(ii) Types of Instruments:

- **Absolute Instruments**

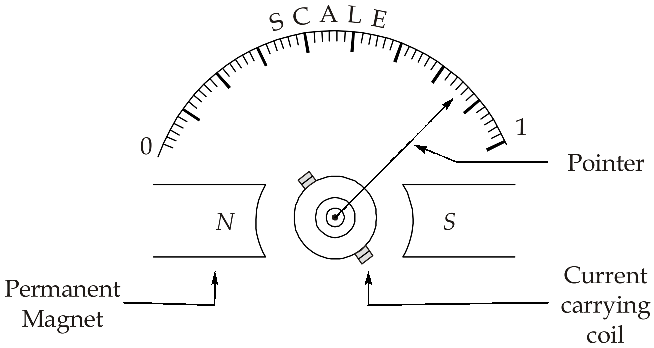
  These instruments give the magnitude of the quantity under measurement in terms of physical constants of the instruments i.e. Tangent Galvanometer, Rayleigh's current balance.

- **Secondary Instruments**

  In these type of instruments, the quantity being measured can only be measured by observing the output indicated by the instrument. These instruments are calibrated by comparing with an absolute instrument.

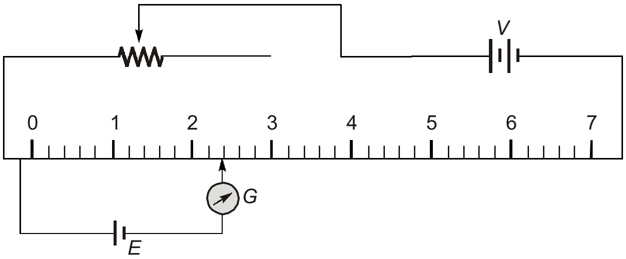
Deflection and Null Type Instruments:

- **Deflection Type:** The deflection of the instrument provides a basis for determining the quantity under measurement i.e. PMMC Ammeter, Electrodynamometer and moving iron instruments. They are less accurate, less sensitive and have faster response.



PMMC (Deflection Type Instrument)

- **Null Type Instruments:** In null type instruments, a zero or null indication leads to determination of the magnitude of measured quantity. Null type instruments are more accurate, highly sensitive and are less suited for measurements under dynamic conditions than deflection type instruments.



(Unknown voltage)

Q.3 (c) Solution:

Vacuum Circuit Breaker

- In these type of CBs, vacuum is used as dielectric medium.
- In this CB, fixed and moving contact is enclosed in a permanently sealed vacuum interrupts.
- It is mainly used for medium voltage range.
- Multi-unit VCBs arc employed at voltage upto 72.5 kV.
- VCB has high insulating medium for arc extinction as compared to other CBs.
- Figure shows basic constructional features of a VCB.
- VCBs requires small space than OCBs and arc employed both for indoors and outdoor purposes.
- VBCs arc used for interrupting high current and low voltages.

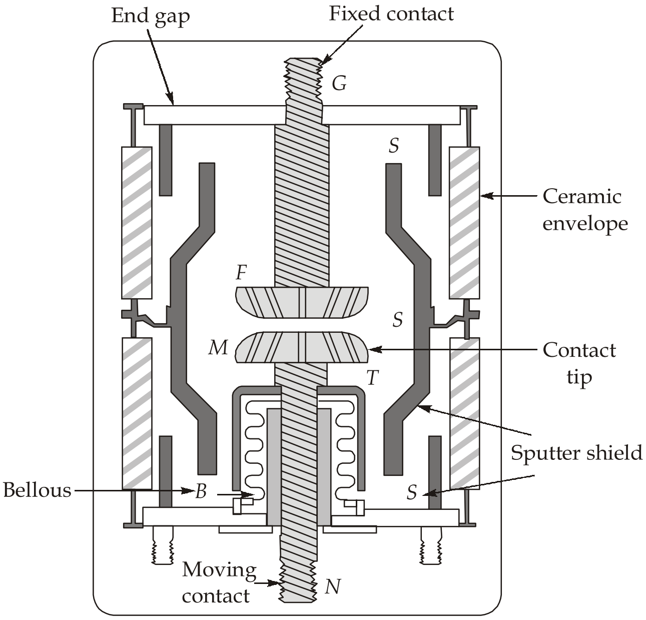
- VCBs arc ideally suited for capacitor switching restrike free operation due to which it is capable of chopping small currents.

Advantages of VCB:

- VCB do not need periodic refilling.
- Compact and self-contained breaker unit.
- Rapid recovery of high dielectric strength on current interruption.

Disadvantages of VCB:

- Cost of breaker becomes high at higher voltages.
- Loss of vacuum due to transit damage or failure makes the entire interrupter useless.

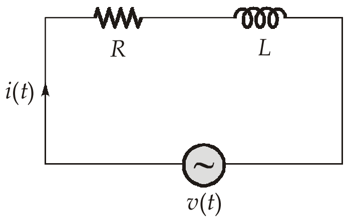


G-Fixed electrode; N-Moving electrode; F, M-Arcing contacts;
E-Ceramic or Glass bottle; B-Bellows; T-Bellows shield

Vacuum circuit breaker

Q.3 (d) Solution:

Consider a RL circuit as shown below.



$v(t)$ = instantaneous supply voltage = $V_m \sin\omega t$

current i will lag v by an angle,

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

Instantaneous current $i = I_m \sin(\omega t - \phi)$

Instantaneous power, $P = v.i = [V_m \sin\omega t]\,[I_m \sin(\omega t - \phi)]$

$$= V_m I_m \sin\omega t \times \sin(\omega t - \phi)$$

$$= \frac{V_m I_m}{2}[\cos\phi - \cos(2\omega t - \phi)]$$

$$= V_{\text{rms}}\, I_{\text{rms}}\, [\cos\phi - \cos(2\omega t - \phi)$$

Average power, $$P_{\text{avg}} = \frac{1}{T}\int_0^T P \cdot d(\omega t)$$

$$P_{\text{avg}} = \frac{1}{2\pi}\int_0^{2\pi} V_{\text{rms}}\, I_{\text{rms}}\, [\cos\phi - \cos(2\omega t - \phi)]\, d(\omega t)$$

$$= \frac{V_{\text{rms}}\, I_{\text{rms}}}{2\pi}\left[\cos\phi(\omega t) - \frac{\sin(2\omega t - \phi)}{2}\right]_0^{2\pi}$$

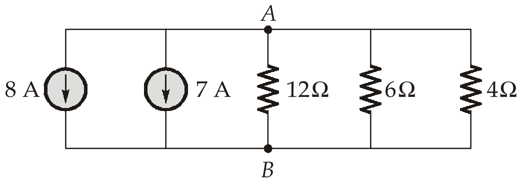
$$= \frac{V_{\text{rms}}\, I_{\text{rms}}}{2\pi}[\cos\phi(2\pi - 0) - 0]$$

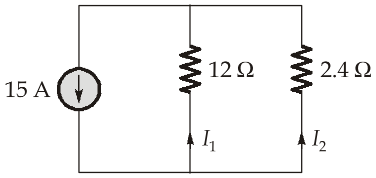
$$= \frac{1}{2\pi} V_{\text{rms}}\, I_{\text{rms}}\,(2\pi\cos\phi)$$

$$P = V_{\text{rms}}\, I_{\text{rms}}\cos\phi = \text{Active power (Real power)}$$

Q.4 (a) Solution:

Circuit can be drawn as





$$I_1 = 15 \times \frac{2.4}{14.4} = 2.5\text{ A}$$

$$P_{\text{absorbed}} = (2.5)^2 \times 12 = 75\text{ W}$$

Q.4 (b) Solution:

Given $$M = -6\cos(\theta + 30°)\text{ mH}$$

For a dc ammeter in Electrodynamometer type instrument, deflecting torque, T_d is given by

$$T_d = I^2 \frac{dM}{d\theta}$$

$$\frac{dM}{d\theta} = 6 \sin (\theta + 30°) \text{ mH/degree}$$

For $\theta = 60°$,
$$\frac{dM}{d\theta} = 6 \sin (60° + 30) = 6 \sin 90° = 6 \times 10^{-3} \text{ mH/degree}$$

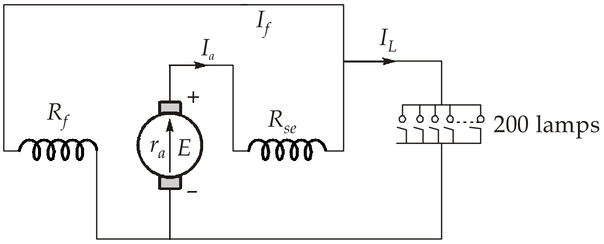
$\therefore$ For current , $I = 50$ mA, deflecting torque, T_d is

$$T_d = (50 \times 10^{-3})^2 \times 6 \times 10^{-3} = 15 \text{ µN-m}$$

Q.4 (c) Solution:

(i) For long shunt

Given, $E = 110$ volt, $r_a = 0.06\ \Omega$, $R_{sh} = 25\ \Omega$, $R_{se} = 0.05\ \Omega$



Each lamp rated at 55 W, 100 V

$$\because \quad P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{(100)^2}{55} = 181.8\ \Omega$$

200 lamps with parallel

Then,

Total load resistance of lamp

$$R_L = \frac{181.8}{200} = 0.91\ \Omega$$

$\because$ Compound generator voltage,

$$V = 110 \text{ volt,}$$

Load current,
$$I_L = \frac{V}{R_L} = \frac{110}{0.91} = 120.8 \text{ A}$$

Field current for long shunt,

$$I_f = \frac{V}{R_f} = \frac{110}{25} = 4.4 \text{ A}$$

Then,

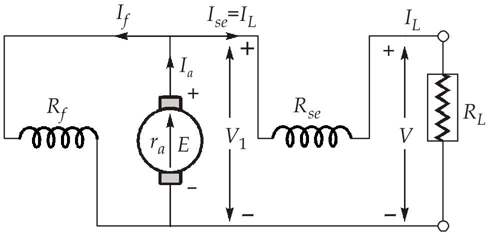
$$\because \quad I_a = I_f + I_L = 120.8 + 4.4 = 125.2 \text{ A}$$

From figure,

$$\because \quad E = V + I_a(r_a + R_{se}) = 110 + 125.2(0.06 + 0.05)$$

$$E = 123.77 \text{ volt}$$

(ii) For short shunt d.c. generator



From figure,

$$E = I_a r_a + V_1$$

Where,

$$V_1 = V + I_L R_{se}$$

$$= 110 + 120.8 \times 0.05 = 116.04 \text{ volt}$$

Then,

$$E = V + I_a r_a + I_L R_{se}$$

$$\because \quad I_f = \frac{V_1}{R_f} = \frac{116.04}{25} = 4.64$$

Then,

$$I_a = I_f + I_L$$

$$= 4.64 + 120.8 = 125.44 \text{ A}$$

$$E = V + I_L R_{se} + I_a r_a$$

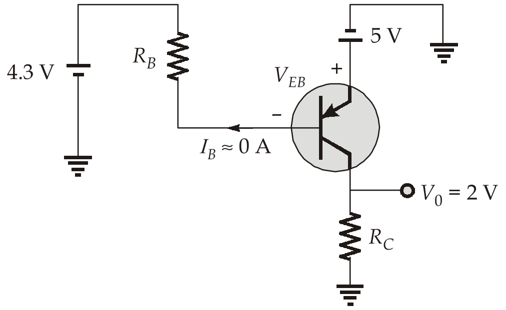
$$= 116.04 + 125.44(0.06)$$

$$E = 123.56 \text{ volt}$$

Q.5 (a) Solution:

Since β is very large, base current I_B can be neglected.

Thus



Applying KVL in base loop, we get,

$$V_{EB} + 4.3 = 5 \text{ V}$$

$$\therefore \quad V_{EB} = 0.7 \text{ V}$$

Thus $V_B = 0.7$

Now $V_C = 2\text{ V}$

Hence $V_{CB} = 2 - 0.7 = 1.3\text{ V}$

Hence, emitter base junction ⇒ forward biased and collector base junction ⇒ reverse biased.

Thus the transistor is working in forward active region or active region.

Q.5 (b) Solution:

Voltage across capacitor, $V = \left[\frac{10}{10+20} - \frac{2}{2+8}\right] \times 30 = 4\text{ V}$

Energy stored in the capacitor,

$$= \frac{1}{2}CV^2 = \frac{1}{2} \times 1 \times 10^{-6} \times 4^2 = 8\ \mu\text{J}$$

Q.5 (c) Solution:

The equivalent resistance of the given circuit is

$$R_{\text{eq}} = \left(\frac{xr}{2} + \frac{r}{x}\right) = \frac{x^2 r + 2r}{2x}$$

Now, $I = \frac{V}{R_{\text{eq}}}$

Hence, for current I to be maximum, R_{eq} should be minimum

i.e. $\frac{dR_{\text{eq}}}{dx} = 0$

or, $\frac{2x(2xr+0) - (x^2 r + 2r) \times 2}{(2x)^2} = 0$

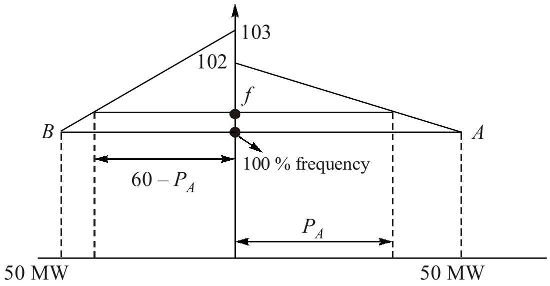
$$2x\,(2xr) - 2(x^2 r + 2r) = 0$$

$$4x^2 - 4 - 2x^2 = 0$$

$$x^2 = 2$$

$$x = \sqrt{2}$$

Q.5 (d) Solution:



(i)
$$\frac{P_A}{50} = \frac{102 - f}{102 - 100} \qquad \ldots(i)$$

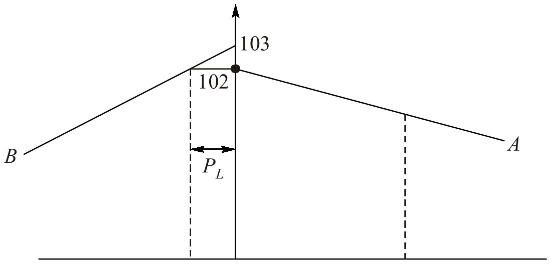
$$\frac{60 - P_A}{50} = \frac{103 - f}{103 - 100} \qquad \ldots(ii)$$

From (i) and (ii),
$$P_A = 34 \text{ MW}$$
$$f = 100.96\ \%$$
$$P_B = 26 \text{ MW}$$

(ii) Calculate the max. load at which one of the machine would become unloaded.

$$\frac{P_L}{50} = \frac{103 - 102}{103 - 100}$$

$$P_L = \frac{50}{3}\text{MW}$$



Q.6 (a) Solution:

(i) Types of Errors

Error: Deviation of the measured value from the true value of the quantity being measured is called an error.

A study of errors is a first step in finding ways to reduce them. Errors may arise from different sources and are classified as under:

1. Gross error
2. Systematic error
3. Random error

Gross Error	Systematic Error	Random Errors
1. These types of error mainly comprises of human mistakes in reading instruments and recording and calculating measurement results. 2. The experimenter is mainly responsible for these errors. 3. Some gross errors are easily detected while some are difficult to detect. 4. These errors can be avoided by taking great care in reading and recording the data. Also, two or three or even more readings should be taken for the quantity under measurement. 5. Computational mistakes, incorrect adjustment and improper application of instruments can lead to gross errors.	1. Systematic errors are classified into three types: (i) **Instrument Errors:** • Occurs due to short coming in the instrument • Misuse of the instrument • Loading effect of the instrument (ii) **Environmental Errors:** • These errors occurs due to external environment factors like humidity, dust, vibrations or external magnetic field etc. (iii) **Observation Errors:** • Different experimenters may produce different results, when sound and light measurements are involved since no two observers possess the same physical response.	1. Random errors are those errors whose causes can't be established because of random variations in the parameters or the system of measurement. 2. The happenings or disturbances about which we are unaware are lumped together and called "Random" or "Residual" and error caused due to these happenings are called "Random" error.

(ii) **Double Field Revolving Theory:** Though double revolving field theory is not simpler in application than the cross-field theory, but once this theory is understood, the fundamental concepts are more readily grasped. This theory is based on the idea that pulsating field produced in a single phase motor can be resolved into two components of half its amplitude and rotating in opposite directions with synchronous speed.

It may perhaps simplify the visual picture by placing these two rotating fluxes in two separate motors mounted on the same shaft. This is equivalent of replacing a single phase motor by two identical three phase motors whose rotors are fitted on a common shaft, and whose stator windings are so connected in series that the magnetic fields developed by them rotate in space in opposite directions. These two motors, in turn, are equivalent to one three phase motor with two identical series connected three phase windings creating fields rotating in opposite directions. Under stationary rotor condition (i.e. when speed $N = 0$ or slip $s = 1$), the two rotating fields slip past the rotor at the same slip, $s = 1$ and inducing equal currents in the squirrel cage rotor. The two rotating fields are of the same strength and develop equal and opposite electromagnetic torques resulting in net torque of zero value. Thus the starting torque is zero and the single phase induction motor is non-self starting. Further, the two rotating fields induce a resultant emf in the stator which balances the applied voltage assuming low leakage impedance of the stator winding.

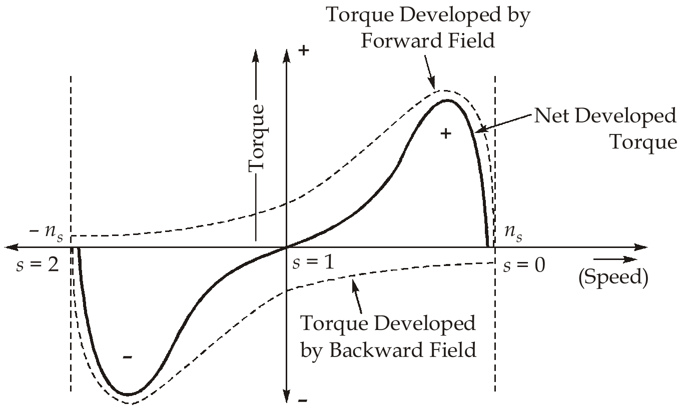
If, however, the rotor is made to run at speed N by some external means in any direction, say in the direction of forward field, the two slips are now s and $(2 - s)$, as shown below:

The slip of the rotor with respect to the forward rotating field F_f,

$$s_f = \frac{N_s - N}{N_s} = s \qquad \text{...(i)}$$

The slip of the rotor with respect to the backward rotating field F_b,

$$s_b = \frac{N_s - (-N)}{N_s} = \frac{2N_s - (N_s - N)}{N_s} = (2 - s) \qquad \text{...(ii)}$$



For normal operation $(2 - s) >> s$ and as a consequence the backward field rotor currents are much larger than at standstill and have a low power factor.

The corresponding opposing rotor mmf, owing to stator impedance, causes the backward field to be greatly reduced in strength. On the other hand, the low-slip forward rotating field induces smaller currents of a high power factor in the rotor than at standstill. This leads to greatly strengthening of the forward field.

Thus weakening of backward field and strengthening of forward field depends upon the slip (or speed of rotor) and the difference increases with the decrease in slip with respect to the forward field or with the increase in rotor speed in forward direction. In fact, at near about the synchronous speed, the forward field may be several times the backward field. As a result there is a net running torque.

Let us assume that the torque developed by forward field in the direction of rotor rotation is positive. Then the torque developed by the backward field will be negative and, evidently, be a braking torque.

The torque-slip curve of actual motor may be obtained by applying the principle of superposition to the hypothetical constituent motors. Their individual torque-slip curves will be of the form shown in figure by dotted line curves. The net or resultant torque at different slips is the algebraic sum of individual torques and is shown by the full-line curve in figure.

From figure it is noted that the curve of the resultant torque passes through zero at a slip of unity (or at standstill), thus showing that no starting torque is developed and the motor cannot start rotating independently. However, for other values of slip, the motor develops a net torque in the direction of rotation and the operating conditions with the rotor running in either direction at a certain speed are identical. The breakdown or maximum torque is also less than that what is expected in a 3-phase induction motor. A further point is that the resultant developed torque drops to zero at a speed slightly below synchronous speed whereas in a polyphase induction motor the torque does not drop to zero until synchronous speed is attained.

The fact is that the torque developed at synchronous speed is negative. This is due to the torque developed by the backward field.

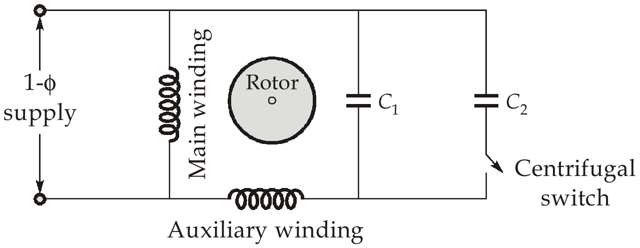
The effect of increasing rotor resistance is rather different in a single phase induction motor than in a 3-phase induction motor. In the case of a 3-phase induction motor the value of the maximum torque is not affected by the change in rotor resistance, the only change being the value of slip at which maximum torque occurs. In a single phase machine, the increase in rotor resistance increases the effectiveness of the backward field, which reduces the breakdown torque, lowers the efficiency and increases the slip corresponding to maximum torque. Double squirrel cages and deep rotor bars are also impractical for the same reasons, and some other means must be adopted to obtain high starting torque.

The performance characteristics of a single phase induction motor, in general, are of the same nature as those for polyphase induction motor. However, the performance of a single phase induction motor, in every respect, is somewhat inferior to that of a 3-phase induction motor for the given frame size. This is due to the presence of backward rotating field. It has a lower breakdown torque at larger slip and increased power losses. Further, it has greater power (true as well as apparent) input because of their consumption in the backward rotating field. Even the copper losses occuring in the stator winding of a single phase induction motor are higher because all the current flows through a single winding. As a consequence, efficiency is lowered and temperature rise is increased. Further, the speed regulation of a single phase induction motor tends to be poorer than that for a polyphase motor. The normal slip of a single phase induction motor under load conditions is rather greater than that of the corresponding 3-phase motor and, therefore, power factor of a single phase motor tends to be lower. For a given power and speed rating, a single phase motor must, therefore, have a larger frame size than that of a 3-phase motor.

The forward field and the rotor's backward reaction field and also the backward field and the rotor's forward reaction field move in opposite directions with relative speeds of double the synchronous speed and develop second harmonic pulsating torques with zero average value. As a consequence single phase motors tend to be somewhat noisier than three-phase ones, which have no such pulsating torque.

(iii) Capacitor Start Capacitor Run single-phase induction motor:

It is also called two value capacitor motor.



The capacitor start capacitor run motor is similar to capacitor start motor except that the auxiliary winding and a capacitor remain connected in the circuit at all times.

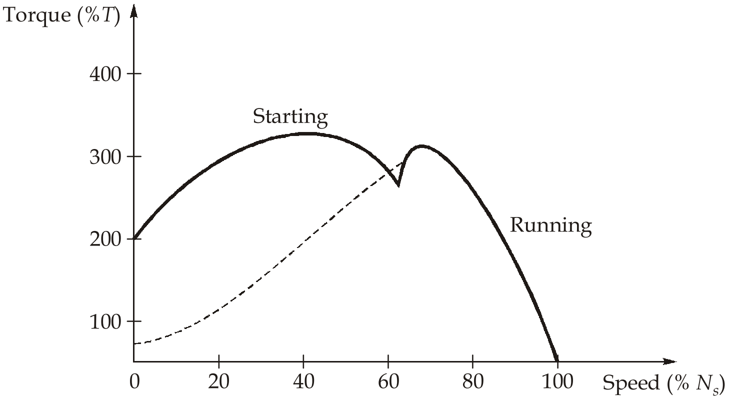
When the centrifugal switch is closed during the starting period the two capacitor C_1 and C_2 are in parallel. So that total capacitance in the auxiliary winding circuit is sum of their values. After the centrifugal switch opens only the capacitor C_1 remain in the auxiliary winding circuit.

In practice starting capacitor C_2 is about 10-15 times as large as the running capacitor C_1. Such a motor operates as a two-phase motor from single-phase supply therefore producing a constant torque.

Besides their ability to start heavy loads they are extremely quiet in operation, have better efficiency (55-65%) and power factor (0.8-0.95) when loaded and developed up to 25% greater over load capacity. When the motor attains 75% of synchronous speed the starting capacitor C_2 is taken out of circuit by the operation of centrifugal switch. This motor is use in refrigerators, compressors, pumps, conveyors etc.

The direction of rotation of motor may be reversed by interchanging the connections to the supply of either the main or auxiliary winding.

Disadvantage → The cost of this motor is high.



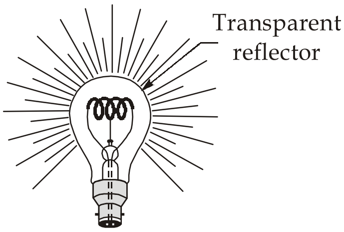
Q.6 (b) Solution:

Types of Lighting Schemes:

The interior lighting schemes may be classified as:

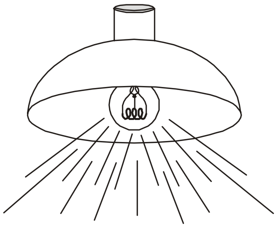
1. Direct lighting
2. Semi-direct lighting
3. Semi-indirect lighting
4. Indirect lighting and
5. General lighting

1. **Direct lighting:** It is most commonly used type of lighting scheme. In this lighting scheme more than 90 percent of total light flux is made to fall directly on the working plane with the help of deep reflectors. Though it is most efficient but causes hard shadows and glare. It is mainly used for industrial and general out door lighting.



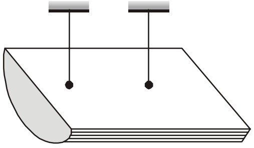
Direct lighting

2. **Semi-direct lighting:** In this lighting scheme 60 to 90 percent of the total light flux is made to fall downwards directly with the help of semi-direct reflectors, remaining light is used to illuminate the ceiling and walls. Such a lighting system is best suited to rooms with high ceilings where a high level of uniformally distributed illumination is desirable. Glare in such units is avoided by employing diffusing globes which not only improve the brightness towards the eye but improve the efficiency of the systems with reference to working plane.



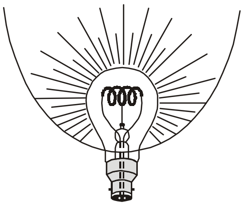
Semi-direct lighting

3. **Semi-indirect lighting:** In this lighting scheme 60 to 90 percent of total light flux is thrown upwards to the ceiling for diffuse reflection and the rest reaches the working plane directly except for some absorption by the bowl. This lighting scheme is with shoft shadows and glare free. It is mainly used for indoor light decoration purposes.



Semi-indirect lighting

4. **Indirect lighting:** In this light scheme more than 90 percent of total light flux is thrown upwards to the ceiling for diffuse reflection by using inverted or bowl reflectors. In such a system the ceiling acts as the light source, and the glare is reduced to minimum. The resulting illumination is softer and more diffused, the shadows are less prominent and the appearance of the room is much improved over that which results from direct lighting. It is used for decoration purposes in cinemas theatres and hotels etc. and in workshops where large machines and other obstructions would cause trouble some shadows of direct lighting is employed.



Indirect lighting

5. **General lighting:** In this scheme lamps made of diffusing glass are used which give nearly equal illumination in all directions.

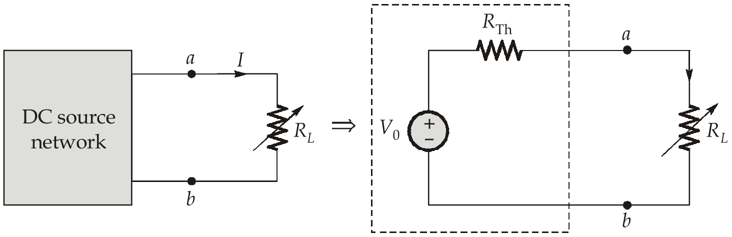
Q.6 (c) Solution:

Statement:

A resistive load, being connected to a dc network, receives maximum power when the load resistance is equal to the internal resistance of the source as seen from the load terminals.

Explanation:

A variable resistance R_L is connected to a dc source network as shown in figure.



Thevenin equivalent of DC source network

Current,
$$I = \frac{V_0}{R_{Th} + R_L}$$

while the power delivered to the resistance load R_L is

$$P_L = I^2 \cdot R_L = \left(\frac{V_0}{R_{\text{Th}} + R_L}\right)^2 \cdot R_L \qquad \text{...(i)}$$

P_L can be maximized by varying R_L and hence maximum power can be delivered when $\left(\frac{dP_L}{dR_L}\right) = 0$.

$\therefore$ Differentiating equation (*i*) w.r.t. to R_L.

$$\frac{dP_L}{dR_L} = \frac{(R_{\text{Th}} + R_L)^2 \cdot V_0^2 - V_0^2 R_L\{2(R_{\text{Th}} + R_L)\}}{(R_{\text{Th}} + R_L)^4}$$

$$= \frac{V_0^2(R_{\text{Th}} + R_L - 2R_L)}{(R_{\text{Th}} + R_L)^3} = \frac{V_0^2(R_{\text{Th}} - R_L)}{(R_{\text{Th}} + R_L)^3}$$

$$\frac{dP_L}{dR_L} = 0$$

So, $$\frac{V_0^2(R_{\text{Th}} - R_L)}{(R_{\text{Th}} + R_L)^3} = 0 \Rightarrow R_{\text{Th}} - R_L = 0 \Rightarrow R_L = R_{\text{Th}} \quad (\text{Condition for } P_{L\max})$$

Again with, $R_L = R_{\text{Th}}$

$$P_{\max} = \frac{V_0^2}{(R_{\text{Th}} + R_L)^2} \cdot R_L = \frac{V_0^2}{(R_{\text{Th}} + R_{\text{Th}})^2} \cdot R_{\text{Th}} = \frac{V_0^2}{4R_{\text{Th}}}$$

Since, the power transfer by the source would be $\frac{V_0^2}{4R_{\text{Th}}}$, the load power and source power being the same.

The total power supplied is,

$$P = 2 \cdot \left(\frac{V_0^2}{4R_{\text{Th}}}\right) = \frac{V_0^2}{2R_{\text{Th}}} = 2P_{\max}$$

During maximum power transfer the efficiency,

$$\%\eta = \frac{P_{\max}}{P} \times 100 = 50\%$$

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