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Detailed Solutions
SSC-JE 2018
Mains Test Series
(PAPER-II)
Electrical Engineering
Test No : 5

Q.1 (a) Solution:

We know that,

$$v_L(t) = L\frac{di_L(t)}{dt}$$

or,
$$i_L(t) = \frac{1}{L}\int v_L(t)\,dt = \frac{1}{2}\int 2\sin t\,dt$$

$$i_L(t) = -\cos t \text{ A}$$

also,
$$i_R(t) = 15\cos t \text{ A}$$

By KCL,

$$i_R(t) - i_C(t) + i_L(t) = 0$$

or,
$$i_C(t) = i_L(t) + i_R(t)$$
$$= 15\cos t - \cos t = 14\cos t \text{ A}$$

$$\text{RMS value of } i_C(t) = \frac{14}{\sqrt{2}} = 7\sqrt{2} \text{ A}$$

Q.1 (b) Solution:

When current coil on load side,

$$\text{Loss in current coil} = I^2R_C$$

$$\text{Loss in pressure coil} = \frac{V^2}{R_P}$$

For same error for two connection,

$$I^2 R_C = \frac{V^2}{R_P}$$

or,
$$I^2 = \frac{V^2}{R_C R_P} = \frac{(200)^2}{(0.04)(5000)} = 200$$

$$I = 14.14 \text{ A}$$

Q.1 (c) Solution:

Given,
$$\text{Turn ratio} = \frac{\text{No. of turns in H.V. winding}}{\text{No. of turns in L.V. winding}}$$

$$a = \frac{2750}{2500} = 1.1$$

Rating of two winding transformer;

$$S_{TW} = 25 \text{ kVA}$$

Rating of auto transformer;

$$S_{\text{auto}} = \left(\frac{a_{\text{auto}}}{a_{\text{auto}} - 1}\right) \times S_{TW}$$

$$= \frac{1.1}{1.1 - 1} \times 25 = 275 \text{ kVA}$$

Power transferred conductively

$$= \left(\frac{1}{a_{\text{auto}}}\right) s_{\text{auto}} = \frac{27.5}{1.1} = 250 \text{ kVA}$$

and power transferred inductively

$$= \left(1 - \frac{1}{a_{\text{auto}}}\right) = \left(1 - \frac{1}{1.1}\right) \times 275 = 25 \text{ kVA}$$

Q.1 (d) Solution:

Protective Relays : A protective relay is an automatic device which detects an abnormal condition in an electrical circuit and causes a circuit breaker to isolate the faulty element of the system.

Functional Characteristics : A protective relay is required to satisfy four basic functional characteristics.

Reliability : A protective relay must operate reliably when a fault occurs. The reliability of a protective relay should be very high, a typical value being 95%.

Sensitivity : A protective relay should be sensitive enough to operate when the magnitude of the actuating quantity exceeds its pick-up values.

Stability : This is the ability of the protective system to remain inoperative under all load conditions, and also in case of external faults.

The relay should remain stable when a heavy current due to an external fault is flowing through it.

Speed : A protective relay should neither be too slow which may result in damage to the equipment, nor should it be too fast which may result in undesired operation during transient faults.

Q.1 (e) Solution:

Given,

$$E_1 = \text{standard cell emf} = 1.6 \text{ V}$$

$$\text{Initial length} = 550 \text{ mm}$$

$$E_2 = \text{emf of new test cell} = 1.8 \text{ V}$$

Let the balance length be x

Voltage at a point on potentiometer is proportional to length of the slide wire.

$$E \propto l$$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$\frac{1.6}{550} = \frac{1.8}{x}$$

$$\text{Length, } x = 618.75 \text{ mm} \approx 619 \text{ mm}$$

Q.2 (a) Solution:

The current lags the voltage by 50° – 5° = 45°

$$\therefore \quad \omega L > \frac{1}{\omega C}$$

$$\tan 45° = 1 = \frac{\omega L - \frac{1}{\omega C}}{R}$$

and

$$\frac{V_m}{I_m} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = \sqrt{R^2 + R^2}$$

$$\frac{100}{10} = \sqrt{2}R$$

or $$R = 7.07\ \Omega$$

$\because$ $$R = \omega L - \frac{1}{\omega C}$$

$$\frac{1}{\omega C} = 314 \times 40 \times 10^{-3} - 7.07$$

$$\frac{1}{\omega C} = 12.56 - 7.07 = 5.49$$

or $$C = \frac{1}{314 \times 5.49} \approx 580\ \mu F$$

Q.2 (b) Solution:

Underground Cables :

- It consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.
- Used for transmission and distribution of power where it's impractical to make use of overhead construction.
- Cable installations are useful for submarines, crossings, railway yard, inside power station and in density populated areas.

Construction of Cable

An underground cable consists of following components:

(i) Conductor/core:

- A cable consists of one central core or more than one core made of tinned stranded copper or aluminium conductors.

(ii) Insulation:

- The conductor is provided with suitable thickness of insulation which withstands the operating voltage.
- Commonly used materials for insulation are varnished cambric, impregnated paper or rubber mineral compound.

(iii) Sheath:

- A metallic sheath of lead or alloy of aluminium is provided around the insulation to protect it against the moisture, gases or damaging liquids (acid or alkalies).

(iv) Bedding:

- A layer of bedding which consists of a fibrous material like (jute, cotton) is provided over metallic sheath against corrosion and from mechanical injury.

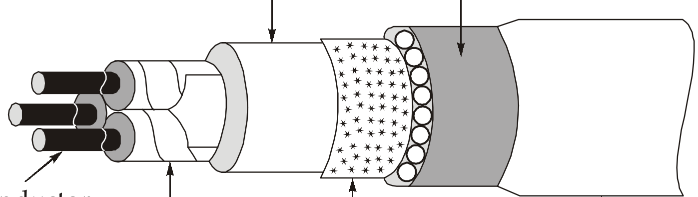
(v) Armouring:

- Over the bedding, armouring is provided, consisting of one or two layers of galvanised steel wire or steel tape to protect the cable from mechanical injury.

(vi) Serving:

- To protect the armouring, a layer of fibrous material similar to that of bedding called 'serving' is provided.

Single core cables for ac systems are not provided with armouring because eddy currents induced in the steel armour causes additional power loss. Such cables are provided plastic wrap for protection against mechanical injuries.



An underground cable

Classification of Cables

According to voltage, cables are classified as:

S.No.	Type of cable	Voltage level
1.	Low voltage cable (LT cable)	upto 1 kV
2.	High voltage cable (HT cable)	upto 11 kV
3.	Super tension cable (ST cables)	upto 33 kV
4.	Extra high tension cables (EHT cables)	upto 66 kV
5.	Extra super voltage cables	upto 132 kV

Q.2 (c) Solution :

Given,

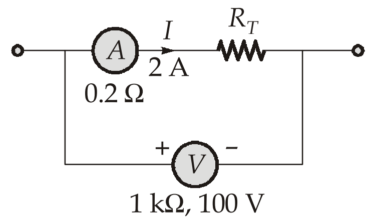
Internal resistance of ammeter = $0.2\ \Omega$

Internal resistance of voltmeter = $1\ k\Omega$

Voltmeter reading = 100 V

Ammeter reading = 2 A

Basic voltmeter-ammeter method layout for resistance measurement



Voltage drop across resistance,

$$R_T = IR = 2R_T$$

Applying KVL in loop, we get

$$100 = 2R_T + (0.2)\,2$$

$$R_T = \frac{100 - 0.4}{2}$$

True value of resistance, $R_T = 49.8\ \Omega$

Measured value of resistance,

$$R_M = \frac{100}{2} = 50\ \Omega$$

$$\text{Error, } \epsilon_r = \frac{R_M - R_T}{R_T} = \frac{50 - 49.8}{49.8} = 0.004$$

$$\text{Percentage error} = 0.4\%$$

Q.2 (d) Solution :

We know,

The deflection torque $T_d' \propto BI$

When magnet is replaced by another magnet having 3 times flux density to that of initial and current reduced to one-ninth of initial value.

New deflection torque $T_d' \propto (3B) \times \left(\frac{I}{9}\right)$

$$\propto \frac{BI}{3}$$

Hence new torque becomes one third of initial torque.

The new deflection reduces to one-third.

i.e. $\theta' = \frac{45}{3} = 15°$

Q.3 (a) Solution:

The input impedance is given by,

$$Z_{\text{in}} = 1 + \frac{1(j2)}{(1+j2)} = 1 + \frac{j2}{j2+1}$$

$$= 1 + \frac{j2(1-j2)}{5} = 1 + j0.4 + 0.8$$

For the input current to be in phase with the input voltage, the reactive part of the circuit impedance should be equal to zero.

$$\therefore \quad \frac{j}{\omega C} = 0.4j$$

or

$$C = \frac{1}{\omega \times 0.4} = \frac{1}{314 \times 0.4} = 7.96 \text{ mF}$$

Q.3 (b) Solution:

$$\text{Field current, } I_f = \frac{250}{125} = 2 \text{ A}$$

then armature current, $I_a = 16 - 2 = 14$ A

At no load;

$$E_b = 250 - (14 \times 0.2) = 247.2 \text{ V}$$

$$\text{No load losses} = 247.2 \times 14 - (14)^2 \times 0.2 \times 250 \times 2$$

$$P_{NL} = 3921.6 \text{ W}$$

Assuming stray load losses will be ignored

at load, $I_a = 152 - 2 = 150$ A

$$\text{Losses} = I_a^2 \times R_a + P_{NL}$$

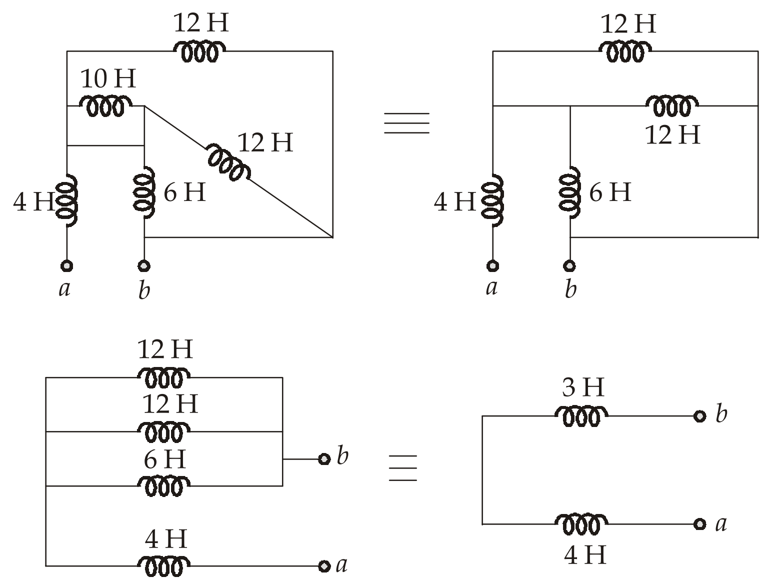
$$= (150)^2 \times 0.2 + 3921.6$$

$$= 8.4216 \text{ kW}$$

$$\text{Input power} = 250 \times 152 = 38 \text{ kW}$$

$$\text{Efficiency, } \%\eta = \frac{38 - 8.4216}{38} \times 100 = 77.83\%$$

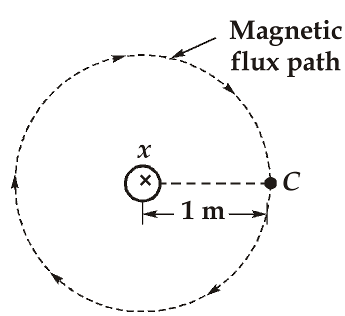
Q.3 (c) Solution:



$$L_{ab} = 7\text{ H}$$

Q.3 (d) Solution:

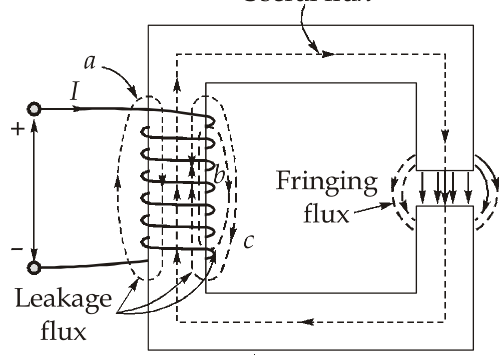
(i) Permeability of Free Space : Suppose a current *I* carrying conductor in a free space. As shown in figure.



- According to the right hand grip rule, around the current carrying conductor a magnetic flux path is generated.
- Suppose flux density at *C*, caused by magnetic field intensity *H* at *x* is *B* tesla and if *C* is one meter away from *x*, then permeability of free space μ_0 is given by

$$\mu_0 = \frac{B}{H} = 4p \times 10^{-7}$$

(ii) Leakage Flux : In Ideal magnetic circuits, all the flux produced by an exciting coil is confined to the desired magnetic path of negligible reluctance. But in practical magnetic circuits, a small amount of flux does follow a path through the surrounding air. Therefore, leakage flux may be defined as that flux which does not follow the intended path in a magnetic circuit. Leakage flux does exist in all practical ferromagnetic device. Its effect on the analysis of electrical machinery is carried out by replacing it by an equivalent leakage reactance.

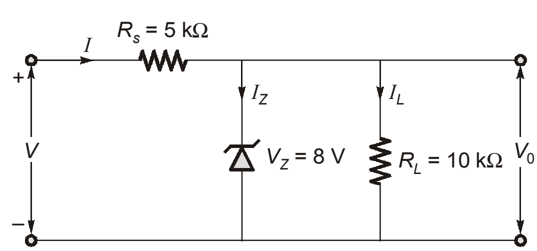


(iii) Fringing : At an air-gap in a magnetic core, the flux fringes out into neighboring air path as shown in the given. Longer the air gap, more is the flux fringing. The effect of fringing flux is to increase the effective cross-sectional area of the air gap. As a result, flux density in the air gap is not uniform and average flux density gets reduced,

$$\therefore \qquad B = \frac{\phi}{A}$$

If area of air gap increases then total area of core with consideration of air gap increases. Then average flux density gets reduced.

Q.4 (a) Solution:



$$I = I_Z + I_L$$

$$I_L = \frac{V_Z}{R_L} = \frac{8}{10} = 0.8 \text{ mA}$$

and
$$I = \frac{12-8}{5\text{k}} = \frac{4}{5\text{k}} = 0.8 \text{ mA}$$

$$I_Z = I - I_L = 0.8 - 0.8 = 0 \text{ mA}$$

(*i*) Output voltage, $V_0 = 10 \times 0.8 = 8$ V

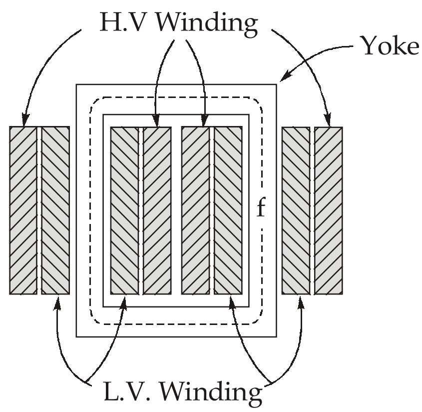
(*ii*) Voltage across, $R_s = 5 \times 0.8 = 4$ V

(*iii*) Current through zener diode,

$$I_Z = 0 \text{ mA}$$

Q.4 (b) Solution:

There are two general types of transformers, the core type and the shell type, differ from each other by the manner in which the windings are wound around the magnetic cores.

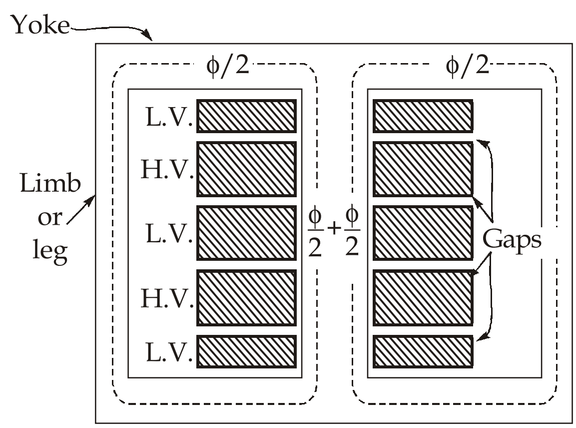


Core type transformer

Core Type Transformer :

- The windings surround a considerable part of steel core.
- For a given output and voltage rating, it requires less iron but more conductor material.
- Most of the flux is confined to high permeability core but some leakage flux flows through the core legs and non-magnetic material surrounding the core. For avoiding it, half of the low voltage (L.V.) winding is placed over one leg and other half over the second leg or limb. Similarly for high voltage.
- L.V. windings are placed adjacent to steel core and H.V. winding outside, in order to minimize the amount of insulation required.
- It performs better for high voltage, high power levels.

Shell Type Transformer : In this type of transformer the L.V. and H.V. windings are wound over the central limb and are inter leaved or sandwiched. It performs better for low-voltage, low power levels, whereas core type construction is used for high voltage, high power transformers.



Shell type transformer

Q.4 (c) Solution:

For alternator, we can write,

$$E_f^2 = (V_t \cos\phi + I_a r_a)^2 + (V_t \sin\phi + I_a X_s)^2$$

For $r_a = 0$

and $X_s = 0.2$ p.u.

or $$E_f^2 = V_t^2 \cos^2\phi + (V_t \sin\phi + I_a X_s)^2$$

$$E_f^2 = V_t^2 \left[\cos^2\phi + \left(\sin\phi + \frac{I_a X_s}{V_t}\right)^2\right]$$

$\therefore$ $$\frac{I_a X_s}{V_t} = X_{s\,(\text{p.u.})} = 0.2 \text{ p.u.}$$

$$E_f^2 = V_t^2\left[(0.8)^2 + (0.8)^2\right]$$

$$E_t = 1.131 V_t \quad \text{...(i)}$$

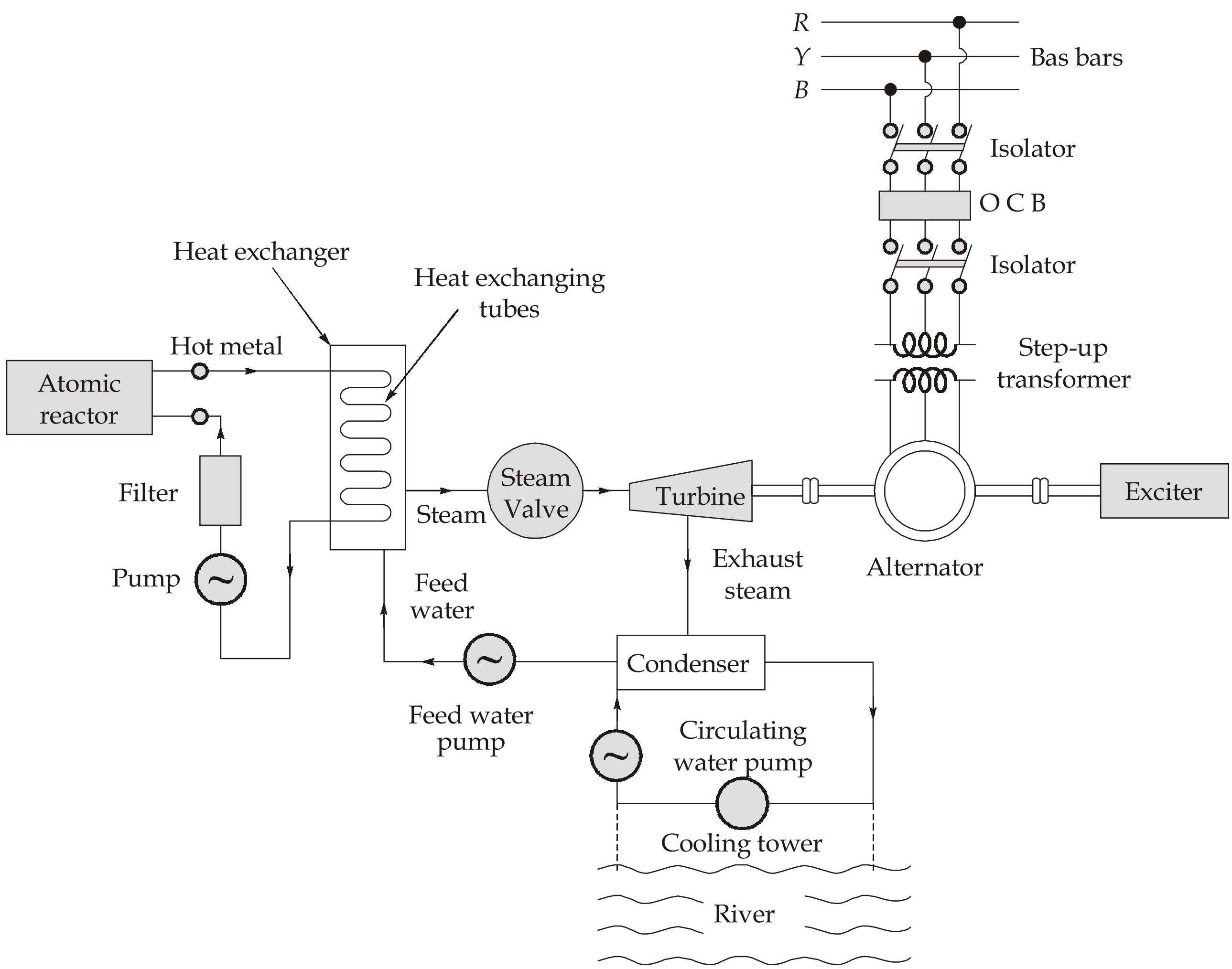
Voltage regulation; $$\text{V.R.} = \frac{E_f - V_t}{V_t} = \frac{1.13\,V_t - V_t}{V_t} \times 100$$

$$= 13.1\%$$

Q.4 (d) Soltuion:

Nuclear Power Plant :

- **Need:** As the reserves of fossil fuels like coal, oil, gas are fast depleting. Thus the nuclear energy is only alternative source which can meet the future energy demands of world.



Schematic arrangement of a nuclear power plant

- **Operation:** A nuclear plant consists of nuclear reactor (for generating the heat), heat exchanges (for converting water into steam by using heat generated in nuclear reactor), steam turbine, alternator, condenser, etc.
- Excess amount of heat energy is produced by fission process in reactor.
- The heat exchanger exchanges the produced heat in the reactor by circulation.

- It heat exchanger, steam is produced which is utilized to drive gas turbine/steam turbine coupled to an alternator thus producing electrical energy.

Main Components of Nuclear Reactor

1. **Reactor core :**
   - It consists of number of fuel rods made of fossil material i.e. Uranium (U^{235}).
2. **Moderator :**
   - Neutrons produced by fission process have very high kinetic energy.
   - The moderator in core have purpose to reduce the neutron speed to a value that increases the probability of fission.
   - Moderate material: (Heavy water), He, Li, B, C, etc.
3. **Control rods:**
   - The rate of fission of U-235 is controlled by means of control rods.
   - With help of control rod, the nuclear fission process can be shut down automatically under emergency conditions such as natural calamities.
   - Control rods are made of B(Boron), Cd(Cadmium), Hafnium
4. **Coolant:**
   - Heat generated in reactor is transferred to the heat exchanger with help of medium called coolant.
   - Coolant flows through and around the reactor core.
   - Materials used as coolant are:
     (i) Gases: Air, Helium, Hydrogen and CO_2
     (ii) Liquid: Light and Heavy water
     (iii) Metals: Molten sodium and Lithium

   Liquid metals (Na and K) are used as coolant in fast reactors.
5. **Reflector:** If completely surrounds the reactor core within the thermal shielding arrangement and bounces back most of the neutrons that escape from the fuel core.
6. **Biological shield:**
   - Load iron or concrete shields are used to enclose the whole of the reactor to prevent escape or leakage of fast neutrons.

Q.5 (a) Solution:

$$\text{Frequency, } f = \frac{PN}{120} = \frac{6 \times 1000}{120} = 50 \text{ Hz}$$

$$\text{slots per pole} = m = 3$$

$$\text{No. of slots} = \frac{360°}{20} = 18$$

$$\text{No. of turns/phase} = \frac{18 \times 12}{2} = 108$$

$$\text{Slot angle, } \beta = 20°$$

then, distribution factor,
$$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \beta / 2}$$

$$K_d = \frac{\sin \frac{3 \times 20°}{2}}{3 \times \sin \frac{20°}{2}} = 0.9598$$

$$\text{Emf generated per phase} = 4.44 f \phi N_{ph} \cdot K_d$$
$$= 4.44 \times 50 \times 3 \times 10^{-2} \times 108 \times 0.9598$$
$$E_p = 690.36 \text{ V}$$

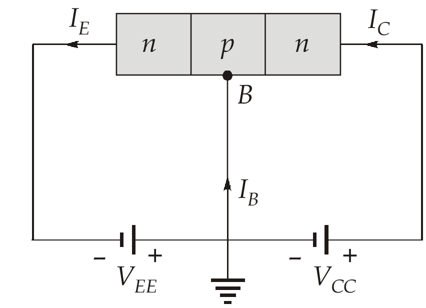
Q.5 (b) Solution:

An NPN (Negative-Positive-Negative) type BJT.

A Bipolar NPN Transistor Configuration:

- The terminology used for denoting the three basic transistor configurations indicates the transistor terminal that is common to both input and output circuits. This gives rise to the three terms: common base, common collector and common emitter.
- The term grounded, i.e. grounded base, grounded collector and grounded emitter may also be used on occasions because the common element signal is normally grounded.
- The three different transistor configurations are:

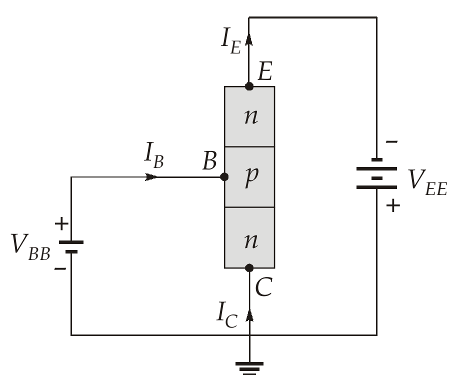
  Common base: This transistor configuration provides a low input impedance while offering a high output impedance. Although the voltage is high, the current gain is low and the overall power gain is also low when compared to the other transistor configurations available. The other salient feature of this configuration is that the input and output are in phase.



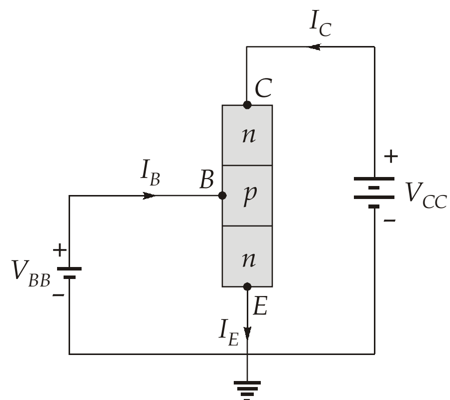
In the active region the base emitter junction is forward biased, where as the collector base junction is reverse biased.

As can be seen from the diagram, in this transistor configuration, the base electrode is common to both input and output circuits.

Common collector: This transistor configuration is also known as the emitter follower because the emitter voltage follows that of the base. Offering a high input impedance and a low output impedance it is widely used as a buffer. The voltage gain is unity, although current gain is high. The input and output signals are in phase. As can be seen from the diagram, in this transistor configuration, the collector electrode is common to both input and output circuits.



Common emitter: This transistor configuration is probably the most widely used. The circuit provides a medium input and output impedance levels. Both current and voltage gain can be described as medium, but the output is the inverse of the input, i.e. 180° phase change. This provides a good overall performance and as such it is often thought of as the most widely used configuration.

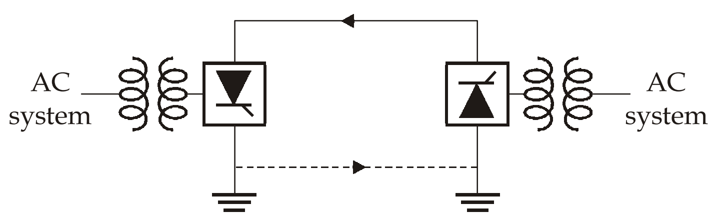


In active region of a common emitter amplifier, the base emitter junction is forward biased, where as collector base junction is reverse biased. As can be seen from the diagram, in this transistor configuration, the emitter electrode is common to both input and output circuits.

Q.5 (c) Solution:

Types of DC Links : The dc links can be classified into the following types:

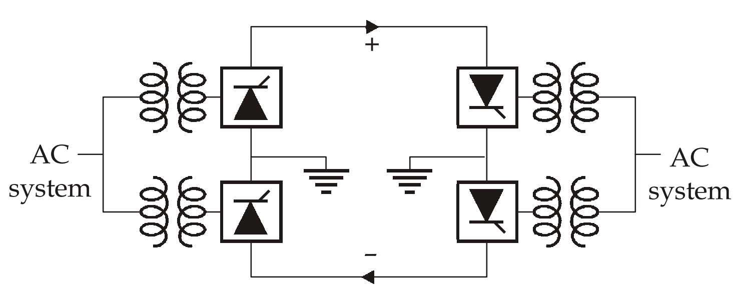
Monopolar Link :



Monopolar link

- This link has only one conductor, usually of negative polarity and uses ground or sea water as the return conductor.
- The negative polarity is preferred on overhead lines due to lesser radio interference.

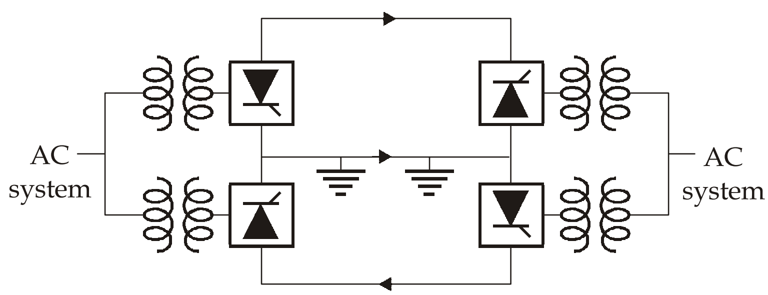
Bipolar Link :



Bipolar link

- This link has two conductors, one positive and the other negative.
- At each terminal, two converters of equal rated voltages are connected in series on the dc side. The neutral points (i.e., the junctions between converters) are grounded.
- If a fault develops on one conductor, the other conductor (along with ground return) can supply half of the rated load.

Homopolar :

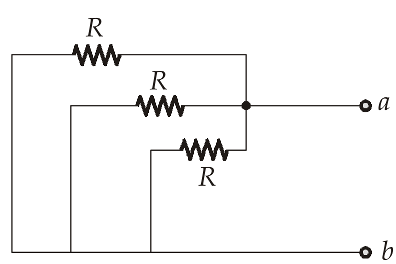


Homopolar link

- A homopolar link has two (or more) conductors, all having the same polarity (usually negative) and always operates with ground as the return conductor.

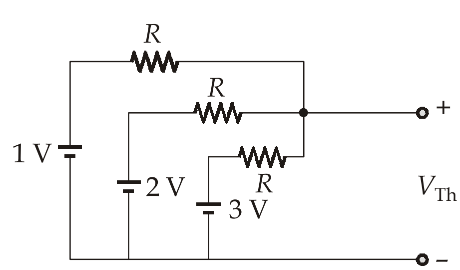
Q.5 (d) Solution:

For finding R_{Th} across terminal a and b:



$$R_{Th} = \frac{R}{3}\ \Omega$$

For finding V_{Th}:



Using KCL, we get,

$$\frac{V_{Th}-1}{R}+\frac{V_{Th}-2}{R}+\frac{V_{Th}-3}{R} = 0$$

$$3V_{Th} = 6$$

$$V_{Th} = 2\text{ V}$$

∴ Maximum power transferred will be given by

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

$$5 \times 10^{-3} = \frac{2\times 2}{4\times\frac{R}{3}}$$

$$\frac{R}{3} = \frac{10^3}{5}$$

or $$R = \frac{3}{5}\times 10^3 = 600\ \Omega$$

Q.6 (a) Solution:

(i) Compact Fluorescent Lamp (CFL)

- A compact fluorescent lamp (CFL), are also known as a compact fluorescent light bulb. Compared to incandescent lamps of the same luminous flux, CFLs use less energy and longer rated life. The purchase price of CFL is higher than of an incandescent lamp of the same luminous output, but this cost is recovered in energy savings and replacement costs over the bulb's life time.
- The modern Compact Fluorescent Lamp (CFL's) typically have a life span between 6000 and 15000 hours, where as incandescent lamps are usually manufactured to have a life span of 750 to 1000 hours. The life time of any lamp depends on many factors including manufacturing defects, exposure to voltage spikes, mechanical shock and ambient operating temperature, among other factors.
- CFL lamps give less light later in their life than they did at the start.
- CFL's are produced for both a.c. and d.c. input. D.C. CFLs are operated with car batteries.
- CFLs can also be operated with solar powered street lights, using solar panels located on the top or sides of a pole and luminaires that are specially wired to use the lamps.

Salient Features of CFL

1. Voltage limits AC 220 V - 240 V, 50/60 Hz
2. Long life
3. High brightness
4. Low power consumption
5. Quick starting
6. No interference to TV or Radio
7. Not fit for turning light

Precautions :

Never use with following fixtures :

1. Emergency light fixtures.
2. Direct current fixtures.
3. Never install where water may drop on the lamp.
4. Never install where the ambient temperature may rise above 400°C.
5. Unsuitable for applications where the lamp must be turned on and off frequently.
6. Never use where there is frequent fluctuations of voltage

CFL Comparison with Incandescent Lamps

1. CFL has life between 6000 and 15,000 hours, whereas incandescent lamps are usually manufactured to have a life span of 750 to 1000 hours.
2. CFLs give less light later in their life than they did at the start.
3. For a given light output, CFLs use between one fifth and one quarter of the power of an equivalent incandescent lamp. So use of CFLs could save 7% energy from house hold usage.
4. CFLs are currently 7% to 8% efficient than incandescent lamp.
5. Cost to CFLs is 3 to 10 times greater than that of an equivalent incandescent lamp.
6. CFLs emit much more high picthed buzzing sound where as incandescent do not.
7. Compared to incandescent lamps of the same luminous flux, CFLs uses less energy.

(ii) Modes of Transfer of Heat

There are three different modes by which heat is transferred :

1. Conduction; 2. Convection; 3. Radiation

1. **Conduction :**

- In this mode of transfer of heat, one molecule of the substance gets heated and transfer the heat to the adjacent one so on. Thus heat is transferred through a substance from one part to another.
- In a plate of thickness '*t*' meters, having X-sectional area of its two parallel faces A square metrs and temperature of its two faces T_1 and T_2 °C absolute, the quantity of heat passed through it during T hours is given by

$$Q = \frac{kA}{t}(T_1 - T_2)\,T$$

where, k is the coefficient of thrermal conductivity for the materials.

2. **Convection :** Heat is transferred by convection in case of

(i) Immersion type water heater

(ii) Room heating

- The air in contact with a heated radiator element in a room receives heat from contact with the element. The heated air expands and rises, cold air flowing into take its place. Thus there is a constant flow of air upwards across the heating element, this process is called convection.
- A similar action takes place in an electric water heater, a continuous flow of water passing upwards across the immersed heater element, with the result that the whole water becomes hot.

Heat dissipation is given by the following expression,

$$H = a(T_1 - T_2)^b \ \text{W/m}^2$$

where, a and b are constants whose value depends up on the heating surface facilities, T_1 and T_2 are the temperatures of the heating surface and the fluid in °C absolute respectively.

3. **Radiation**

- In this method of heating, the heat reaches the substance to be heated from the source of heat without heating the medium in between.

(iii) Induction Heating

- The induction heating works on the transformer principle. More over it is also known as eddy current heating.
- The currents are induced by the principle of electromagnetic induction.
- The induction heating may be low frequency as in case of core type induction furnace or high frequency as the case with coreless induction furnace.

Types of Induction Heating

(i) Direct Induction Heating

(ii) Indirect Induction Heating

(i) Direct Induction Heating :

- In direct induction heating the eddy currents are produced with in the material itself that is to be heated.
- The examples of direct induction heating are the high frequency eddy current heating used for case hardening or tempering of various machine parts, annealing of steel strip and soldering.
- The core type induction furnace used for melting non-ferrous metals such as copper, zinc, brass.

(ii) Indirect Induction Heating :

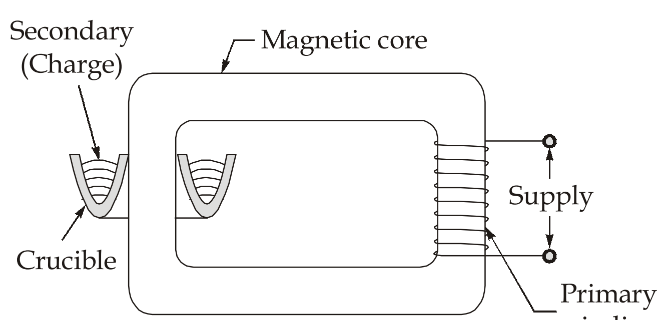
- The example of indirect induction heating is the indirect induction oven which is in direct competition with resistance oven and is preferred over it due to its fine temperature control.
- In the indirect induction heating method the eddy current are induced in the heating elements by electromagnetic induction which produces heat in heating elements. The heat thus produced is transferred to the body to be heated by radiation.

Induction Furnaces : There are basically two types of induction furnaces:

(i) Core type induction furnace

(ii) Corelss induction furnace

Core type induction furance:



Core Type Furnace

- Core type furnace is essentially a transformer with the charge of metal to be heated as single turn short-circuited secondary and magnetically coupled to the primary winding by iron core.

- The current flowing through the charge is very high may be of the order of several thousand ampres.
- The main disadvantages is that electromagnetic forces produces greater turbulence of the molten metal which is useful to a certain point, but it becomes too severe unless frequency is kept low.
- Another disadvantages of this furnace is that a crucible is of inconvenient shape from metallurgical point of view is used.

Q.6 (b) Solution:

For given energy meter, shows 30 revolutions in 40 seconds.

$$\text{Number of revolutions in 1 sec} = \frac{30}{40}$$

$$\text{So, number of revolutions in an hour} = \frac{30 \times 60 \times 60}{40}$$

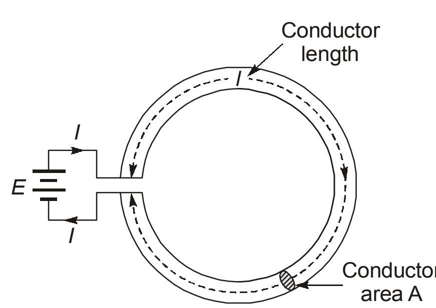
Number of revolutions for connected constant load of 4 kW = 2700

$$\text{For per kilowatt} = \frac{2700}{4} = 675 \text{ rev/kW hr}$$

$$\text{Meter constant} = 675 \text{ rev/kWhr}$$

Q.6 (c) Solution :

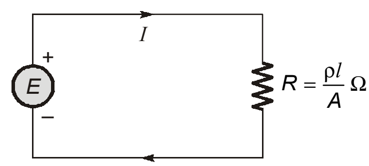
Electrical Circuit : A torodial copper ring of length l, cross-sectional area A is connected to emf E so that current I flows.



Similarities:

1. Closed path for electrical current is called an electric circuit.
2. Driving force is emf E, volts.
3. Resistance : $R = \frac{\rho \cdot l}{A}$ V/A or Ω

4. Equivalent circuit.



5. Circuit : $I = \frac{\text{Driving force}}{\text{Resistance}} = \frac{E}{R} A$

6. Current density : $J = \frac{I}{A}$ A/m^2

7. Electric field intensity, $\varepsilon = \frac{E}{l}$ V/m

Also, $e = \frac{E}{l} = \frac{IR}{l} = \frac{I}{l} \cdot \frac{\rho l}{A} = \rho \cdot \frac{I}{A} = \rho \cdot J$ V/m

8. Conductivity of current path,

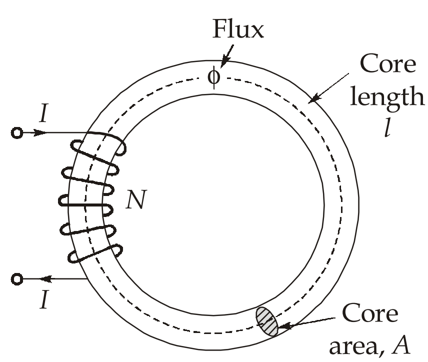
$$\sigma = \frac{1}{\rho}$$

So that, $J = \sigma \cdot \varepsilon$ A/m^2

Dissimilarities:

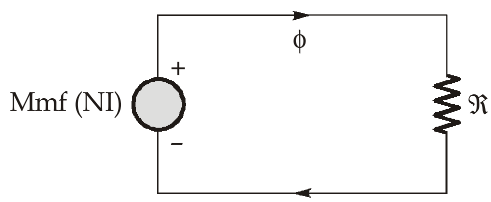
1. The electrical current actually flows in an electric circuit. For the existence of this current, energy is drawn from the source continuously. This energy gets dissipated in resistance in the form of heat.
2. Electrical insulator confine the current to well defined paths.

Magnetic Circuit : A torodial iron ring of length l, cross area A is excited by a coil of N turns carrying I amperes so that flux ϕ is produced.



Similarities:

1. Closed path for the magnetic flux is called a magnetic circuit.
2. Driving force is Mmf = IN ATs
3. Reluctance, $\mathfrak{R} = \frac{l}{\mu A}$ AT/Wb
4. Equivalent circuit,



5. Magnetic flux : $\phi = \frac{\text{Driving force}}{\text{Reluctance}} = \frac{\text{Mmf}}{\mathfrak{R}}$ Wb
6. Magnetic flux density: $B = \frac{\phi}{A} T$ (or Wb/m^2)
7. Magnetic field intensity: $H = \frac{NI}{l}$ At/m

   Also, $H = \frac{NI}{l} = \frac{Mmf}{l} = \frac{\phi \cdot Rl}{l} = \frac{\phi}{l}\frac{l}{\mu A} = \frac{1}{\mu}\cdot\frac{\phi}{A} = \frac{1}{\mu}\cdot B$ At/m
8. Conductivity of current path, μ

   So that, $B = \mu H$ Wb/m^2 or T

Dissimilarities:

1. Strictly speaking, magnetic flux does not flow. Energy is needed for establishing the required flux. Once the requisite flux is created, no more energy is needed in maintaining it.
2. There are no magnetic insulators. Even in the best known magnetic insulator air, the flux can be established.

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