GATE WALLAH

ESE-2024

MAIN EXAM DETAILED SOLUTION

ELECTRONICS AND COMMUNICATION ENGINEERING

PAPER-I

EXAM DATE - 23 JUNE 2024

9 : 00 AM TO 12 : 00 PM

SECTION-A

Q.1. (a) Consider an ideal pMOS capacitor of area 100 μm × 100 μm operated at $T = 300$ K. ϕ_M (work function for the metal) = 5.2 eV, x_o (oxide thickness) = 3 nm and $N_D = 10^{17}/\text{cm}^3$. Calculate the flat band voltage V_{FB} and the threshold voltage V_{TP}. Assume $E_{ox} = 3.43 \times 10^{-13}$ F/cm, V_T (thermal voltage) = 0.026 V, $n_i = 10^{10}/\text{cm}^3$, χ_{Si} (electron affinity of Si) = 4.05 eV, $E_G = 1.12$ eV and $E_{Si} = 10^{-12}$ F/cm.

Sol. Work function of the metal $\phi_m = 5.2$ eV

Oxide layer thickness $x_0 = 3 \text{ nm} = 3 \times 10^{-7}$ cm

$N_D = 10^{17}/\text{cm}^3$

Area A = 100 μm × 100 μm = 100×10^{-4} cm × 100×10^{-4} cm

$\in_{ox} = 3.43 \times 10^{-13}$F/cm

$V_T = 0.026$ V

$n_i = 10^{10}/\text{cm}^3$

Electron affinity of Si $X_{Si} = 4.05$ eV

$E_G = 1.12$ eV

$\in_{Si} = 10^{-12}$F/cm

What is flat band voltage V_{FB} = ? and , Threshold voltage V_{TP} = ?

Let is calculate the value of V_{FB} first:

Flat voltage is given by the relation

$$qV_{FB} = Q_{mSi} + \left(\frac{-Q_{ox}}{C_{ox}}\right) \quad \ldots\text{(i)}$$

Where $\phi_{mSi} = (\phi_m - \phi_{Si})$, $\phi_{Si} \rightarrow$ work furction of Si.

And $Q_{ox} \rightarrow$ is change in oxide layer

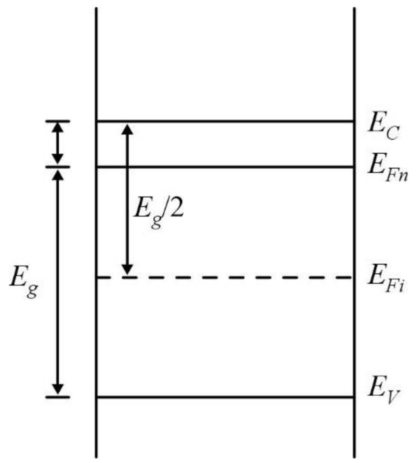
As there in no change in oxide layer, therefore $Q_{ox} = 0$

$$\therefore qV_{FB} = \phi_{mSi} + \frac{(-0)}{C_{ox}} = \phi_{mSi} = (\phi_m - \phi_{Si}) \quad \ldots\text{(ii)}$$

Lets find out the value of ϕ_{Si}

$$\phi_{Si} = X_{Si} + (E_c - E_{Fn}), \quad \ldots\text{(iii)}$$

Where E_{Fn} is fermi level of n-type substrate.



We know that shift in fermi level in n-type SC →

$$(E_{Fn}-E_{Fi})[\text{shift}]=kT\ln\left(\frac{N_D}{ni}\right)$$

$$(E_{Fn}-E_{Fi})=0.026\ln\left(\frac{10^{17}}{10^{10}}\right)$$

$$E_{Fn}-E_{Fi}=0.419eV$$

From the fermi level diagram

$$(E_c-E_{Fn})=\frac{E_g}{2}-(E_{Fn}-E_{Fi})$$

$$(E_c-E_{Fn})=\frac{1.12}{2}-0.419=0.141\text{eV} \qquad \text{........(iv)}$$

From equation (iii) and (iv)

$$\phi_{Si}=X_{Si}+(E_c-E_{Fn})=4.05+0.141$$

$$\phi_{Si}=4.191\text{ eV} \qquad \text{........(v)}$$

From equation (ii) and (v)

$$qV_{FB}=\phi_m-\phi_{Si}=5.2-4.191=1.009\text{ eV}$$

$$V_{FB}=\frac{1.009\text{eV}}{q}=1.009\text{V}\simeq 1\text{V}$$

Lets calculate threshold voltage V_{TP} = ?

Threshold voltage is given by :

$$V_{TP}=V_{FB}+\left(\frac{-Q_{dep}}{C_{ox}}+2\phi_f\right) \qquad \text{.........(vi)}$$

Where Q_{dep} is total charge in depletion region when depletion region thickness is maximum.

$$|\phi_f|(\text{fermi potential})=\frac{KT}{q}\ln\left(\frac{N_D}{ni}\right)=0.026\ln\frac{10^{17}}{10^{10}}=0.419\text{ Volt} \qquad \text{.......(vii)}$$

Lets calculate depletion region thickness to calculate Q_{dep}

$$W_{\max}=\sqrt{\frac{2\in_{Si}}{q}\left(\frac{1}{N_D}\right)\cdot 2|\phi_f|}=\sqrt{\frac{2\times10^{-12}}{1.6\times10^{-19}}\times\frac{1}{10^{17}}2\times0.419}$$

$$W_{\max}=\sqrt{\frac{4\times0.419}{1.6}}\times10^{-5}\text{cm}=3.236\times10^{-5}\text{cm}$$

$$Q_{\text{dep}}=+q\,N_D A.W_{\max}=1.6\times10^{-19}\times10^{17}\times100\times10^{-4}\times3.236\times10^{-5}$$

$$Q_{\text{dep}}=5.1776\times10^{-11}\text{ Coloumb.} \qquad \text{...............(viii)}$$

$$C_{ox}=\frac{\in_{ox}\cdot A}{x_o}=\frac{3.43\times10^{-13}\times100\times10^{-4}\times100\times10^{-4}}{3\times10^{-7}}$$

$$C_{ox}=1.143\times10^{-10}\text{ F} \qquad \text{.........(ix)}$$

From equation (vi), (vii), (viii) and (ix)

We get,

$$V_{TP} = V_{FB} + \left(\frac{-Q_{\text{dep}}}{C_{ox}}\right) + 2\phi_f$$

$$= 1.009 + \left(\frac{-5.1776\times10^{-11}}{1.143\times10^{-10}}\right) + 2(-0.419)$$

$= 1.009 - 0.4529 - 0.838 = -0.2819\text{V}$

$V_{TP} = -0.2819\text{V} \simeq -0.282$ Volt

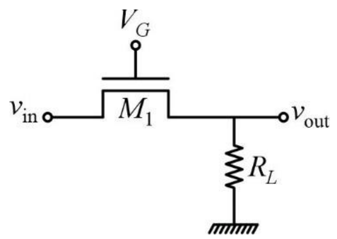
Find answer is $V_{FB} = 1.009\text{V} \simeq 1$ Volt

$V_{TP} = -0.282$ Volt

(b) In the circuit shown in the figure below, M_1 serves as an electronic switch. If V_{in} is very small, determine W/L such that circuit attenuates the signal by 5%.

Assume $V_G = 1.8$ V and $R_L = 100\ \Omega$.

$\mu_n C_{ox} = 200\frac{\mu A}{V^2}$ and $V_{TN} = 0.4$ V.

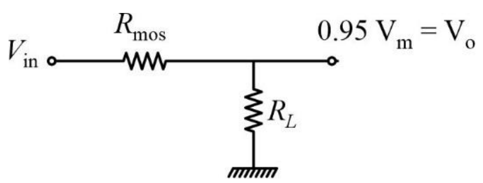


Sol. Since device work as a switch hence when it is on it will go into ohmic mode.

In ohmic mode the MOSFET can be replaced by a

$$\text{resistor of value} = \frac{1}{\mu_n C_{ox}\frac{\omega}{L}(V_{as} - V_{th})}$$

Since we need 5% dictation this the circuit will become



Thus $\frac{R_L}{R_L + R_{mos}} = .95$

$$\Rightarrow \frac{100}{100 + R_{mos}} = .95$$

$R_{mos} = 5.26\ \Omega$

$$\text{Now } 5.26\Omega = \frac{1}{\mu_n C_o \times \frac{\omega}{L}(V_{as} - V_{th})}$$

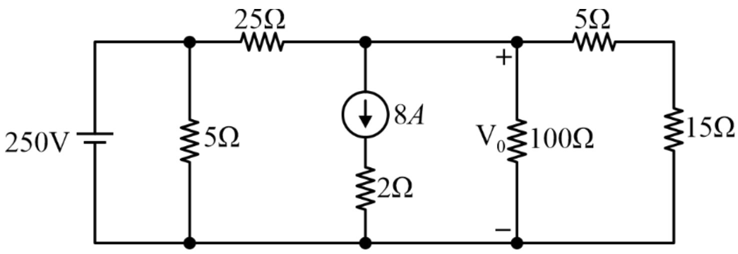
Since $V_G = 1.8$ V, $V_S = 0.95$ V_{in} $V_{th} = 0.4$

Since V_{in} is very small so $V_s \approx 0$

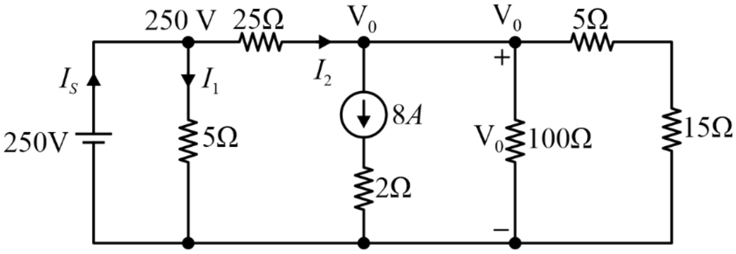
$$\Rightarrow 5.20 = \frac{1}{200\times10^{-6}\times\frac{\omega}{L}(1.8-0.4)}$$

So $\frac{\omega}{L}$ Ratio = 18785.

(c) Find the voltage v_0 in the circuit shown in the figure using source transformation. Also, find the power developed by the 250 V voltage source.

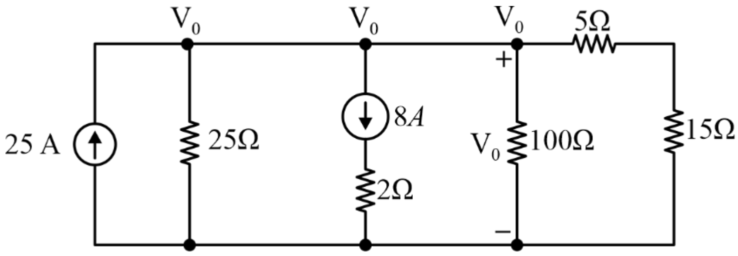


Sol.



5Ω resistance can be neglected

∴ Using source transformation circuit will be



Using KCL

$$25 = \frac{V_0}{25} + 8 + \frac{V_0}{100} + \frac{V_0}{20}$$

$$17 = V_0\left[\frac{4+1+5}{100}\right]$$

$V_0 = 170$ V and $I_S = I_1 + I_2 = \frac{250}{5} + \frac{250-170}{25}$

= 50 + 3.2 = 53.2

$P_{250V} = 250 \times 53.2 = 13.3\ kW$

(d) An electrical load absorbs an average power of 85 kW at lagging power factor of 0.85. If the load operates at 240 V rms, calculate the complex power and impedance of the load.

Sol. P_{avg} = 85 kW, P.F = 0.85 log $\rightarrow$ 4 = cos–1 (0.85) = 31.78°

V_L = 240 V,

$P = V_L I_L \cos\phi$

$$\therefore\ I_L = \frac{P}{V_L \cos\phi} = \frac{85\times10^3}{240\times0.85} = \frac{125°}{3} = 416.67\text{ A}$$

$Q_L = P\tan\phi = 85\times10^3\times\tan(31.78°)$

$$\therefore\ \vec{S}_L = P_L + jQ_L = (85 + j52.68)\text{ kVA}$$

$$Z_L = \frac{V_L}{I_L\angle-\phi} = \frac{240}{416.67\angle-31.78} = 0.576\angle31.78\ \Omega$$

(e) (i) Draw neat sketches of the edge and screw dislocation. Illustrate the Burger's vector on the sketches of dislocations.

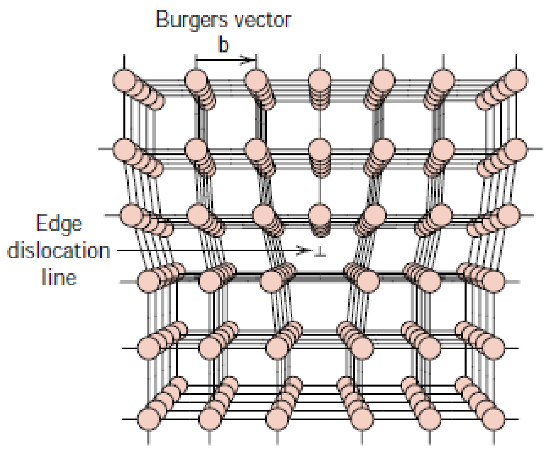
Sol.

Edge Dislocation:

A dislocation is a linear or one-dimensional defect around which some of the atoms are misaligned. An edge dislocation; it is a linear defect that centers around the line that is defined along the end of the extra half-plane of atoms. This is sometimes termed the dislocation line which is perpendicular to the plane of the page. Within the region around the dislocation line there is some localized lattice distortion.

The atoms above the dislocation line are squeezed together, and those below are pulled apart; this is reflected in the slight curvature for the vertical planes of atoms as they bend around this extra halfplane.

The magnitude of this distortion decreases with distance away from the dislocation line; at positions far removed, the crystal lattice is virtually perfect. Sometimes the edge dislocation is represented by the symbol _, which also indicates the position of the dislocation line. An edge dislocation may also be formed by an extra half-plane of atoms that is included in the bottom portion of the crystal; its designation is a _.

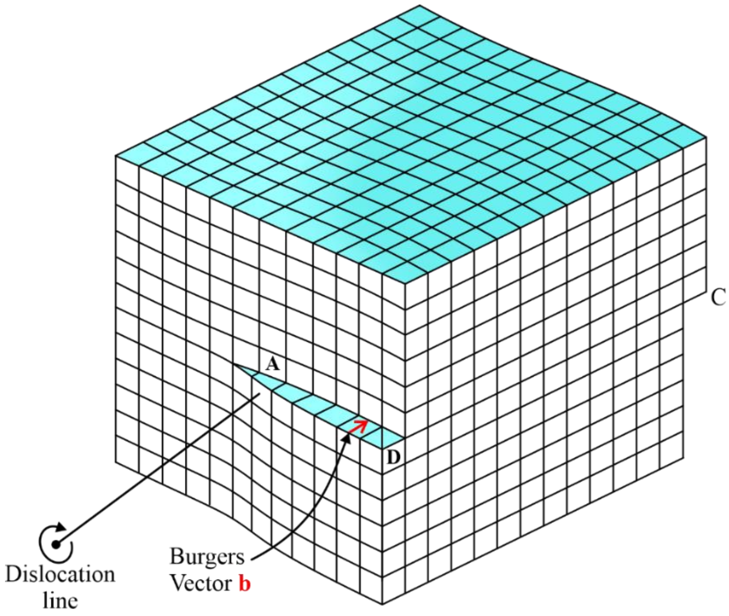


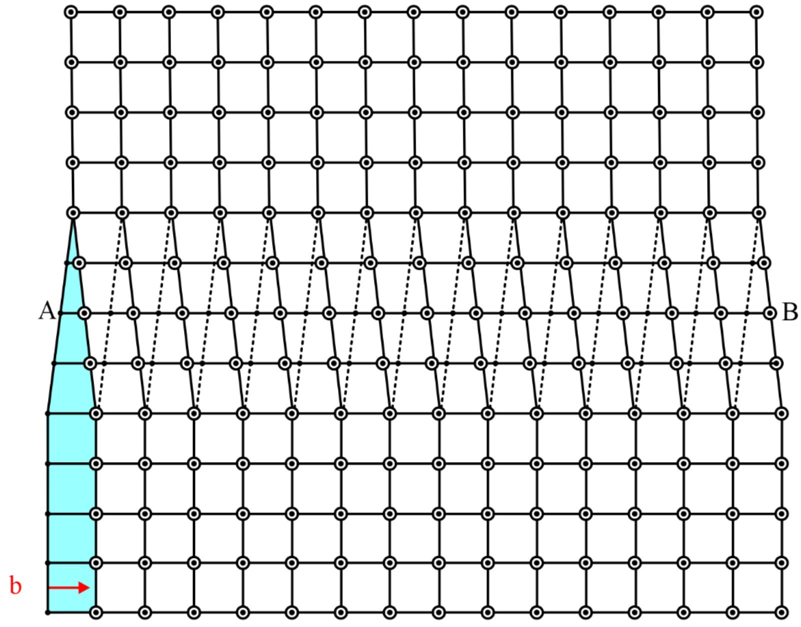
Screw Dislocation:

A screw dislocation may be thought of as being formed by a shear stress that is applied to produce the distortion in the upper front region of the crystal is shifted one atomic distance to the right relative to the bottom portion. The atomic distortion associated with a screw dislocation is also linear and along a dislocation line, line AB in Figure.

The screw dislocation derives its name from the spiral or helical path or ramp that is traced around the dislocation line by the atomic planes of atoms.

Sometimes the ↻ symbol is used to designate a screw dislocation.





(b)

(ii) Calculate the line energy of dislocation in BCC iron if the shear modulus and lattice parameter of BCC iron are 80.2 GN/m^2 and 2.87Å, respectively.

Sol.

Line energy of dislocation $= \frac{1}{2} G b^2$

Where, G is the shear modulus.

b is the magnitude of burger vector

$$b = \frac{k}{2}\left(a^2 + b^2 + c^2\right)^{1/2}$$

$k = 2.87 A°$, $a = b = c = 1$

$$b = \frac{2.87}{2}\left(1^2 + 1^2 + 1^2\right)^{1/2} \times 10^{-10}$$

$b = 2.485 \times 10^{-10}$

Hence, Line energy of dislocation $= \frac{1}{2} \times 80.2 \times 10^9 \times \left(2.485 \times 10^{-10}\right)^2$

$$= 247.6 \times 10^{-12}\ J/m = 2.476 \times 10^{-9}\ J/m$$

Q.2. **(a)** A p-n junction solar cell is fabricated using silicon and has the following important parameters:

$N_A = 3 \times 10^{18}/\text{cm}^3$, $N_D = 2 \times 10^{16}/\text{cm}^3$

$D_n = 25\ \text{cm}^2/\text{s}$, $D_p = 10\ \text{cm}^2/\text{s}$

$\tau_{n0} = 4 \times 10^{-7}$ s, $\tau_{p0} = 10^{-7}$ s

The photocurrent density $J_L = 20\ \text{mA/cm}^2$. Calculate the open circuit voltage of the solar cell at $T = 300$ K. Assume $n_i = 1.5 \times 10^{10}/\text{cm}^3$.

Sol.

Given data,

$N_A = 3 \times 10^{18}/\text{cm}^3$, $N_D = 2 \times 10^{16}\ \text{cm}^{-3}$

$D_n = 25\ \text{cm}^2/\text{s}$, $D_p = 10\ \text{cm}^2/\text{s}$

$\tau_{n_0} = 4\times10^{-7}\ s$, $\tau_{p_0} = 10^{-7}\ s$

$J_L = J_{\text{solar}} = 20\ \text{mA/cm}^2$, $n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$

$T = 300\ k$

$$V_T = \frac{T}{11,600} = \frac{300}{11,600} \cong 26mV$$

Consider the formula of open-circuit voltage of solar cell,

$$V_{OC} = V_T \ln\left[\frac{J_{solar}}{J_0} + 1\right] \quad ....(i)$$

$$J_0 = qn_i^2\left[\frac{D_p}{N_D L_p} + \frac{D_n}{N_A L_n}\right]$$

$$J_0 = qn_i^2\left[\frac{D_p}{N_D\sqrt{D_p \tau_{p_0}}} + \frac{D_n}{N_A\sqrt{D_n \tau_{n_0}}}\right]$$

$$J_0 = qn_i^2\left[\frac{1}{N_D}\sqrt{\frac{D_p}{\tau_{p_0}}} + \frac{1}{N_A}\sqrt{\frac{D_n}{\tau n_0}}\right]$$

$$J_0 = (1.6\times10^{-19})(1.5\times10^{10})^2\left[\frac{1}{2\times10^{16}}\sqrt{\frac{10}{10^{-7}}} + \frac{1}{3\times10^{18}}\sqrt{\frac{25}{4\times10^{-7}}}\right]$$

$$J_0 = 36\left[(500\times10^{-15}) + (2.64\times10^{-15})\right]$$

$$J_0 = 36\times502.64\times10^{-15} \simeq 18.095\,pA$$

Substitute the values in equation (i),

$$V_{OC} = 26\ln\left[\frac{20\times10^{-3}}{18.095\times10^{-12}} + 1\right]mV$$

$$V_{OC} = 26\times20.82mV = 0.54V$$

(b) (i) What are the two functions of commutator in DC machines?

Sol. In DC machines, Commutator serves two main functions:

1. Rectification:

The commutator converts alternating current induced in armature windings of DC machine into direct current. Commutator reverses the direction of current in armature winding in every half cycle and hence the current supplied to the load in case of generator and the current taken from the supply in motor remains unidirectional.

2. To keep rotor or armature mmf stationary in space when armature conductors rotate, commutator reverses the direction of current in each coil. It makes armature mmf stationary in space.

(ii) Explain how the commutator keeps the armature mmf stationary in space, along the interpolar axis, even though the armature rotates.

Sol. In a DC machine, the commutator plays a crucial role in ensuring that the armature MMF remains stationary in space along the interpolar axis, despite the physical rotation of the armature. Here's how this works:

1. Coil Current Reversal:

- As the armature rotates, different coils come into contact with different commutator segments. The commutator segments are connected to the armature windings in such a way that the current in each coil reverses direction when it passes through the neutral plane.
- This reversal happens at precise intervals, ensuring that at any given moment, the direction of current in the armature windings is such that the resulting MMF is always directed along the interpolar axis.

2. Spatial Position of the Armature MMF:

- The armature MMF is the result of the combined effect of the currents flowing through the armature windings. When the current in a coil reverses as it crosses the neutral plane, it effectively creates a continuous magnetic field in a fixed spatial position relative to the stator poles.
- Although the individual coils are physically rotating with the armature, the systematic reversal of current by the commutator ensures that the overall magnetic field (the resultant armature MMF) does not rotate with the armature. Instead, it remains stationary in space along the interpolar axis.

3. Interpolar Axis Alignment:

- The interpolar axis is the axis midway between the poles of the machine. The armature MMF aligns along this axis due to the symmetry and timing of the commutation process.
- As each coil enters the influence of a different pole, the commutator switches the current direction to maintain a consistent direction of the magnetic field produced by the armature. This consistent field direction aligns with the interpolar axis, thus keeping the armature MMF stationary.

(c) (i) Explain why end-centred tetragonal geometry does not exist in Bravais crystal structures.

Sol. An end-centered lattice has additional lattice points at the center of each face of one pair of opposite faces of the unit cell. For the tetragonal system, this would mean having lattice points in the centers of the top and bottom faces of the unit cell.

When we try to construct an end-centered tetragonal lattice, we find that it can be transformed into a body-centered tetragonal lattice.

Specifically, if we consider the end-centered tetragonal lattice, it can be seen as a distorted body-centered tetragonal lattice. The lattice points at the centers of the top and bottom faces effectively double the number of lattice points along the c-axis, making it indistinguishable from a body-centered tetragonal lattice with a different choice of unit cell.

This redundancy means that the end-centered tetragonal lattice does not offer any unique arrangement of points that cannot already be described by the body-centered tetragonal lattice.

Therefore, the reason an end-centered tetragonal geometry does not exist in the Bravais crystal structures is due to its redundancy with the body-centered tetragonal lattice. The body-centered arrangement already covers the possible unique configurations of lattice points for the tetragonal system, rendering the end-centered tetragonal unnecessary and non-distinct. This consolidation maintains the minimal set of 14 unique Bravais lattices.

(ii) Differentiate between different types of magnetic materials on the basis of magnetic dipoles and hysteresis loops.

Sol. On the basis of magnetic dipole arrangement and hysteresis loops, magnetic materials are classified in to five different type as follows :

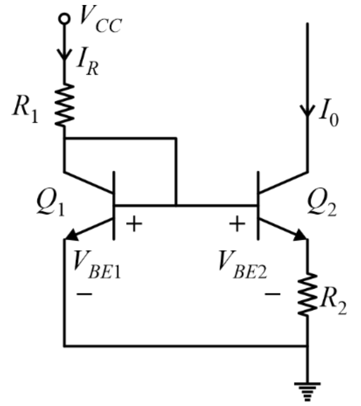
1. Diamagnetic materials
2. Paramagnetic materials
3. Ferromagnetic materials
4. Ferrimagnetic materials
5. Anti-ferromagnetic materials

1. **Diamagnetic materials:** There is no any permanent magnetic dipoles in diamagnetic materials. Dipoles are induced in opposite direction when it is kept in magnetic field. Its B-H curve is linear. There is no any hysteresis loop.

2. **Paramagnetic materials:** There are permanent magnetic dipoles in paramagnetic materials. The dipoles are weakly aligned when kept in magnetic field. Its B-H curve is linear.

3. **Ferromagnetic materials:** There are permanent magnetic dipoles in ferromagnetic materials. The dipoles are strongly aligned when kept in magnetic field. Ferromagnetic materials exhibit a large and wide hysteresis loop.
4. **Ferrimagnetic materials:** Ferrimagnetic materials have permanent dipoles, but they align in anti-parallel having unequal magnitude resulting in net magnetization. Its hysteresis loop is wide but retentivity is less as compared to ferromagnetic materials.
5. **Anti-ferromagntetic materials:** Anti-ferromagnetic materials have permanent dipoles, but they align in anti-parallel having equal magnitude resulting in net magnetization equal to zero. It exhibits very narrow hysteresis loop.

Q.3. **(a)** (i) Design a Widlar current source shown in the figure below to give $I_o = 5\ \mu A$ and $I_R = 1$ mA. The parameters are $V_{CC} = 30$ V, $V_{BE1} = 0.7$ V, $V_T = 25$ mV and $\beta_F = 100$.



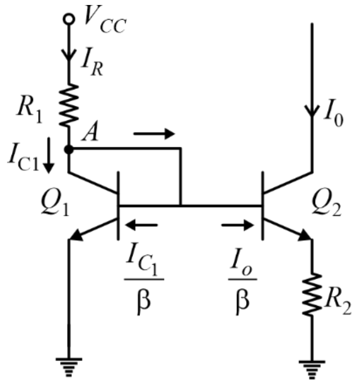
Sol. $I_R = 1$ mA

$I_0 = 5\ \mu A$

$V_{BE1} = 0.7$ V

$V_T = 25$ mV

$V_{CC} = 30$ V



Lets apply KCL at node A

$$I_{C1} + \frac{I_{C1}}{\beta} + \frac{I_0}{\beta} = I_R$$

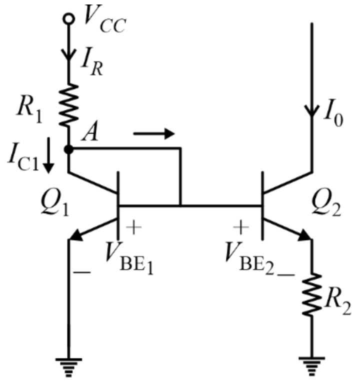
$$I_{C1} + \frac{I_{C1}}{100} + \frac{5\ \mu A}{100} = 1\text{ mA}$$

$I_{C1} = 0.9900$ mA

Since $V_{BE1} = 0.7$ V

Thus, $I_R R_1 = 30 - 0.7$

So, $R_1 = 29.3$ kΩ



We can see that,

$$V_{BE1} = V_{BE2} + \frac{I_0}{\alpha} R_2$$

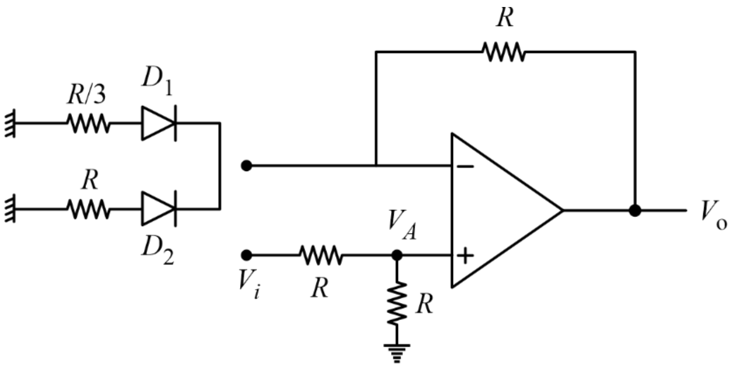
$$\Rightarrow \; V_T \ln\left(\frac{I_{C1}}{I_3}\right) = V_T \ln\left(\frac{I_0}{I_3}\right) + \frac{I_0}{\alpha} R_2$$

$$\Rightarrow \; V_T \ln\left(\frac{I_{C1}}{I_0}\right) = \frac{I_0}{\alpha} R_2$$

$R_2 = 27.773$ kΩ

(ii) Design an amplifier that has a voltage gain of 2 if $V_{IN} < 0$ and 1, if $V_{IN} > 0$. Assume ideal diodes and ideal op amps are available.

Sol. We will design non inverting amplifier.



We can see that, $V_A = \dfrac{V_i}{2}$

and when $V_i > 0$ then D_2 will be on and $V_0 = V_A\left(1 + \dfrac{R}{R}\right)$

= 2 VA

$$= 2\,\frac{Vi}{2} = \text{V}$$

and when $V_i < 0$ then D_1 will be on and $V_A\left(1+\frac{R}{R/3}\right)$

= 4 VA

= 2 V_i

So, this circuit will work as designed.

(b) (i) Discuss the points of similarities between a transformer and induction machine. Explain, why an induction machine is called a generalized transformer.

Sol. Similarities Between Transformers and Induction Machines

Transformers and induction machines (induction motors and generators) share several similarities, Both devices operate based on the principle of electromagnetic induction. In transformers, a varying current in the primary winding induces a voltage in the secondary winding. In induction machines, a rotating magnetic field induces currents in the rotor.

1. **Core Structure:** Both typically use laminated iron cores to reduce eddy current losses and enhance magnetic coupling. The cores are designed to provide a low-reluctance path for magnetic flux.
2. **Windings:** Both have windings made of conductive materials like copper or aluminum. Transformers have primary and secondary windings, while induction machines have stator and rotor windings.
3. **AC Operation:** Both operate with alternating current (AC). Transformers transfer AC power between different voltage levels, while induction machines convert electrical energy to mechanical energy (motors) or vice versa (generators).
4. **Flux Linkage:** In both devices, magnetic flux links the windings. In transformers, the flux links the primary and secondary windings. In induction machines, the flux from the stator links with the rotor windings.

Why the Induction Machine is Called a Generalized Transformer

The induction machine is often referred to as a generalized transformer because it extends the principles of transformer operation to include relative motion between the magnetic field and the windings.

Transformer Action in Induction Machines: In an induction machine, the stator winding (analogous to the primary winding of a transformer) creates a rotating magnetic field when connected to an AC supply. This rotating field induces a voltage in the rotor winding (analogous to the secondary winding of a transformer).

1. **Relative Motion:** Unlike a stationary transformer, the rotor in an induction machine can rotate. The induced voltage and the resulting current in the rotor create a magnetic field that interacts with the stator's rotating field to produce torque. This aspect of relative motion between the magnetic field and the windings is a key distinction from a static transformer.

2. **Frequency Difference:** In a transformer, the primary and secondary windings are linked by a common magnetic flux, and the frequency of the induced voltage in the secondary is the same as that in the primary. In an induction machine, the frequency of the induced voltage in the rotor (slip frequency) is different from the supply frequency due to the relative motion between the rotor and the stator's magnetic field.

3. **Energy Conversion:** While a transformer is primarily an energy transfer device (transferring electrical energy between circuits), an induction machine performs energy conversion (converting electrical energy to mechanical energy in motors or mechanical energy to electrical energy in generators).

4. **Impedance Transformation:** Like a transformer, an induction machine can also transform impedances. The rotor impedance referred to the stator side is affected by the slip, which is analogous to the impedance transformation ratio in a transformer.

(ii) A 10 kVA/2500/250 V, single-phase transformer has the following parameters:

Primary winding (h.v. side): Resistance $r_1 = 2.4\ \Omega$

Leakage Reactance, $x_1 = 6.00\ \Omega$

Secondary winding (l.v. side): Resistance $r_2 = 0.03\ \Omega$

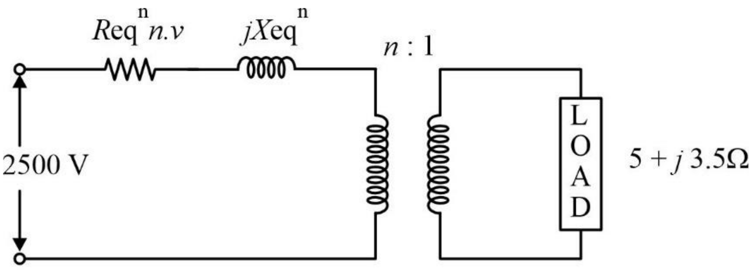
Leakage Reactance, $x_2 = 0.07\ \Omega$

With primary supply voltage held constant at 2500 V, calculate the secondary terminal voltage, when the low voltage winding is connected to a load impedance of 5 + j 3.5 Ω and the transformer delivers its rated current at 0.8 p.f. lagging on the low voltage side.

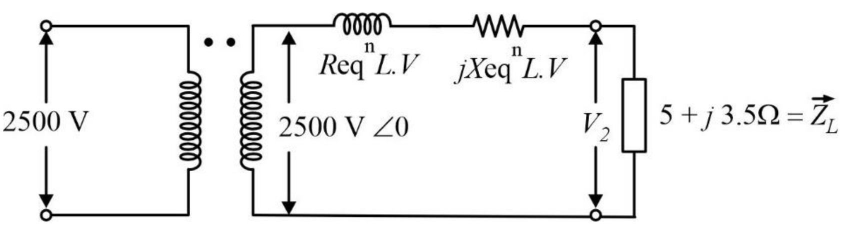
Sol. 10 kVA, 2500/250 volts.

H.V side :- $R_1 = 2.4\ \Omega$; $X_1 = 6.0\ \Omega$

L.V side :- $R_2 = 0.03\ \Omega$; $X_2 = 0.07\ \Omega$



2500/250



$$R_{eqL.V}^{n} = 0.03 + \left[\frac{250}{2500}\right]^2 \times 2.4 = 0.054\Omega$$

$$X_{eqL.V}^{n} = 0.07 + \left[\frac{250}{2500}\right]^2 \times 6.0 = 0.13\Omega$$

$$\vec{I}_2 = \left[\frac{250\angle 0}{0.054 + j0.13 + 5 + j3.5}\right] = 40.617\angle -34.8028\text{A}$$

Secondary terminal voltage

$$\vec{V}_2 = \vec{I}_2 \times \vec{Z}_L = 247.89\angle 0.189°$$

Secondary terminal voltage when transformer delivers load of rated current at 0.8 p.f lag.

$$R_{p.u} = \frac{R_{eqL.V}^{n}}{Z_{Base(L.V)}} = 8.64 \times 10^{-3}$$

$$\left\{\because Z_{Base(L.V)} = \frac{(0.25)^2}{9.01} = 6.25\Omega\right\}$$

$$X_{p.u} = \frac{X_{P_{L.V}^{n}}}{Z_{Base(L.V)}} = 0.0208$$

$$V.R = R_{p.u} \cos \phi_2 + X_{p.u} \sin \phi_2 = 0.01939$$

$$V_2 = 250 \times [1 - V.R]$$

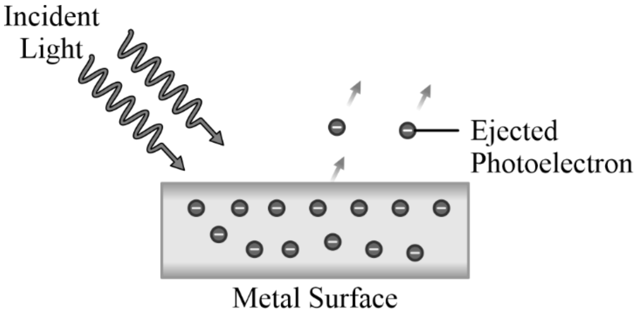
$$= 245.15 \text{ volts.}$$

(c) (i) Discuss photoelectric effect and find out the number of photoelectrons emitted per unit time from a transmitter operated at a frequency of 800 kHz and 10 kW power.

Sol.

Photoelectric effect:

The photoelectric effect is a phenomenon in which electrons are ejected from the surface of a metal when light is incident on it. These ejected electrons are called photoelectrons. It is important to note that the emission of photoelectrons and the kinetic energy of the ejected photoelectrons is dependent on the frequency of the light that is incident on the metal's surface. The process through which photoelectrons are ejected from the surface of the metal due to the action of light is commonly referred to as photoemission.



Number of photoelectrons emitted per

With time $\dfrac{10\times10^{3}}{6.6\times10^{-34}\times800\times10^{3}}$

$\left\{=\dfrac{P}{hV}\right\}$

$= 1.89 \times 10^{31}$ per second.

(ii) Define dielectric strength. Discuss different types of dielectric breakdowns in solids.

Sol. Solid dielectric materials are used in all kinds of electrical circuits and devices to insulate one current carrying part from another when they operate at different voltages. A good dielectric should have low dielectric loss, high mechanical strength, should be free from gaseous inclusion, and moisture, and be resistant to thermal and chemical deterioration. Solid dielectrics have higher breakdown strength compared to liquids and gases.

The mechanism of breakdown is a complex phenomenon in the case of solids, and varies depending on the time of application of voltage as shown in diagram.

The various breakdown mechanisms can be classified as follows:

(a) Intrinsic or ionic breakdown,

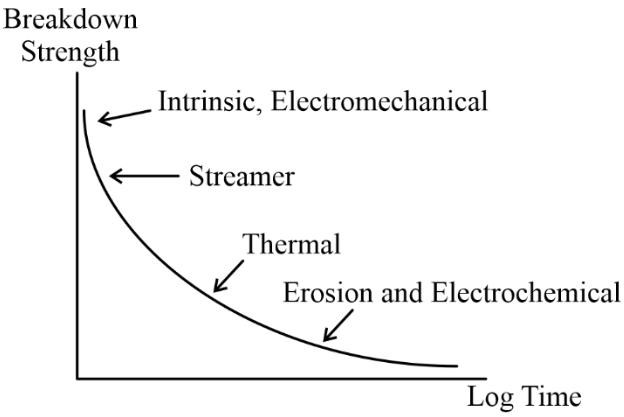
(b) electromechanical breakdown,

(c) failure due to treeing and tracking,

(d) thermal breakdown,

(e) electrochemical breakdown, and

(f) breakdown due to internal discharges



(a) Intrinsic Breakdown

When voltages are applied only for short durations of the order of 8 10 sthe dielectric strength of a solid dielectric increases very rapidly to an upper limit called the intrinsic electric strength.

Intrinsic breakdown depends upon the presence of free electrons which are capable of migration through the lattice of the dielectric. Usually, a small number of conduction electrons are present in solid dielectrics, along with some structural imperfections and small amounts of impurities. The impurity atoms, or molecules or both act as traps for the conduction electrons up to certain ranges of electric fields and temperatures. When these ranges are exceeded, additional electrons in addition to trapped electrons are released, and these electrons participate in the conduction process. Based on this principle, two types of intrinsic breakdown mechanisms have been proposed.

(i) Electronic Breakdown Intrinsic breakdown occurs in time of the order of 10-8 s and therefore is assumed to be electronic in nature. The initial density of conduction (free) electrons is also assumed to be large, and electron-electron collisions occur.

(ii) Avalanche or Streamer Breakdown This is similar to breakdown in gases due to cumulative ionization. Conduction electrons gain sufficient energy above a certain critical electric field and cause liberation of electrons from the lattice atoms by collision. Under uniform field conditions, if the electrodes are embedded in the specimen, breakdown will occur when an electron avalanche bridges the electrode gap.

(b) Electromechanical Breakdown

When solid dielectrics are subjected to high electric fields, failure occurs due to electrostatic compressive forces which can exceed the mechanical compressive strength. If the thickness of the specimen is d0 and is compressed to thickness d under an applied voltage V, then the electrically developed compressive stress is in equilibrium.

(c) Thermal Breakdown

The breakdown voltage of a solid dielectric should increase with its thickness. But this is true only up to a certain thickness above which the heat generated in the dielectric due to the flow of current determines the conduction.

When an electric field is applied to a dielectric, conduction current however small it may be, flows through the material. The current heats up the specimen and the temperature rise. The heat generated is transferred to the surrounding medium by conduction through the solid dielectric and by radiation from its outer surfaces. Equilibrium is reached when the heat used to raise the temperature of the dielectric, plus the heat radiated out, equals the heat generated. The heat generated under d. c. stress E is given as

$W_{d.c.} = E^2 \sigma$ W/cm^3 (4.4) where σ is the d.c. conductivity of the specimen.

Under a.c. fields, the heat generated.

$W_{a.c.} = \frac{E^2 f_{er} \tan\delta}{1.8\times10^{12}}$ W/cm^3 (4.5) where, f = frequency in Hz, δ = loss angle of dielectric material, and E = rms value. The heat dissipated (W_r) is given by $W_r = C_v \frac{dT}{dt} + div$ (K grad T) (4.6) where, C_v = specific heat of the specimen,

T = temperature of the specimen, K = thermal conductivity of the specimen, and t = time over which the heat is dissipated.

Equilibrium is reached when the heat generated ($W_{d.c}$ or $W_{a.c}$) becomes equal to the heat dissipated (W_r). In actual practice there is always some heat that is radiated out.

Breakdown occurs when $W_{d.c.}$ or $W_{a.c.}$ exceeds W_r. The thermal instability condition is shown in Figure. Here, the heat lost is shown by a straight line, while the heat generated at field E_1 and E_2 is shown by seperate curves. At field E_2 breakdown occurs both at temperature T_A and T_B heat generated is less than the heat lost for the field E_2, and hence the breakdown will not occur.

(d) Chemical and Electrochemical Deterioration and Breakdown

In the presence of air and other gases some dielectric materials undergo chemical changes when subjected to continuous stresses. Some of the important chemical reactions that occur are: -Oxidation: In the presence of air or oxygen, material such as rubber and polyethylene undergo oxidation giving rise to surface cracks. -Hydrolysis: When moisture or water vapor is present on the surface of a solid dielectric, hydrolysis occurs and the material loses their electrical and mechanical properties. Electrical properties of materials such as paper, cotton tape, and other cellulose materials deteriorate very rapidly due to hydrolysis. Plastics like polyethylene undergo changes, and their service life considerably reduces. -Chemical Action: Even in the absence of electric fields, progressive chemical degradation of insulating materials can occur due to a variety of processes such as chemical instability at high temperatures, oxidation and cracking in the presence of air and ozone, and hydrolysis due to moisture and heat.

(e) Breakdown Due to Treeing and Tracking

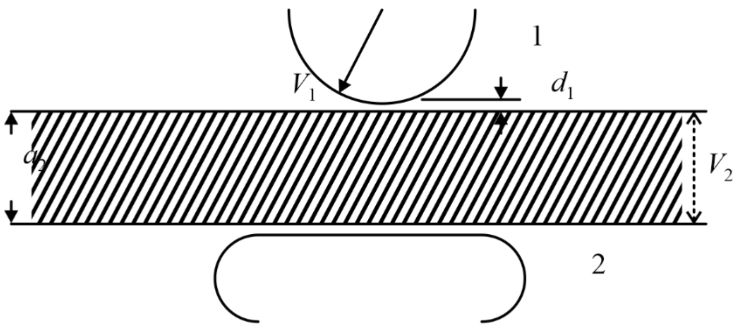
When a solid dielectric subjected to electrical stresses for a long time fails, normally two kinds of visible markings are observed on the dielectric material. They are:

(i) the presence of a conducting path across the surface of the insulation:

(ii) a mechanism whereby leakage current passes through the conducting path finally leading to the formation of a spark. Insulation deterioration occurs as a result of these sparks.

The spreading of spark channels during tracking, in the form of the branches of a tree is called treeing.

Consider a system of a solid dielectric having a conducting film and two electrodes on its surface. In practice, the conducting film very often is formed due to moisture. On application of voltage, the film starts conducting, resulting in generation of heat, and the surface starts becoming dry. The conducting film becomes separate due to drying, and so sparks are drawn damaging the dielectric surface. With organic insulating materials such as paper and bakelite, the dielectric carbonizes at the region of sparking, and the carbonized regions act as permanent conducting channels resulting in increased stress over the rest of the region. This is a cumulative process, and insulation failure occurs when carbonized tracks bridge the distance between the electrodes. This phenomenon, called tracking is common between layers of bakelite, paper and similar dielectrics built of laminates. On the other hand treeing occurs due to the erosion of material at the tips of the spark. Erosion results in the roughening of the surfaces, and hence becomes a source of dirt and contamination. This causes increased conductivity resulting either in the formation of conducting path bridging the electrodes or in a mechanical failure of the dielectric.

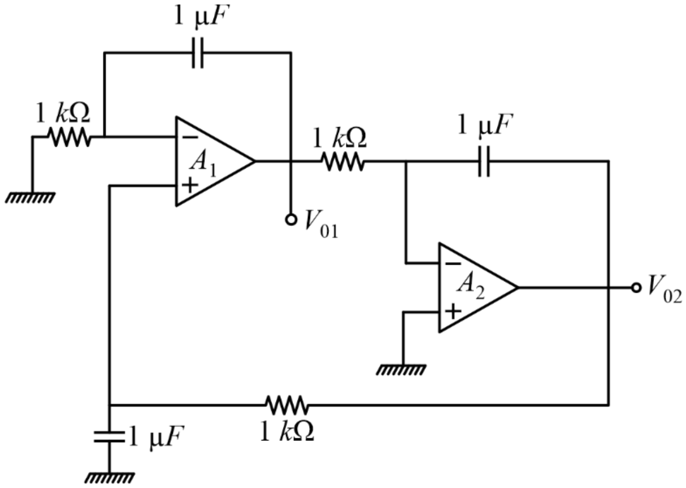


$$V_1 = \frac{V.d_1}{d_1 + \left(\frac{\varepsilon_1}{\varepsilon_2}\right) d_2}$$

(f) Breakdown Due to Internal Discharges

Solid insulating materials, and to a lesser extent liquid dielectrics contain voids or cavities within the medium or at the boundaries between the dielectric and the electrodes. These voids are generally filled with a medium of lower dielectric strength, and the dielectric constant of the medium in the voids is lower than that of the insulation. Hence, the electric field strength in the voids is higher than that across the dielectric. Therefore, even under normal working voltages the field in the voids may exceed their breakdown value, and breakdown may occur.

Q.4. **(a)** For the circuit shown in the figure below, determine the frequency of oscillation f_0 and overall voltage gain A_v. Also identify the type of oscillator. (Assume op amps are ideal).



Sol. Let $R = 1$ kΩ

$C = 1$ μF

So by simple volta divisional

$$\Rightarrow V_A = \frac{V_{O2}}{R_{SC} + 1}$$

Since opamp1 is a non Inv. Amplifier

$$\Rightarrow V_{O1} = V_A\left(1 + \frac{1}{R_{SC}}\right)$$

And opamp2 form a 1nv. Amp

So $V_{O2} = V_{O1}.(-1/R_{SC})$

So the loop gain is $\frac{1}{R_{SC}+1} \times \left(1 + \frac{1}{R_{SC}}\right) \cdot (-Y_{RSC})$

$$\Rightarrow \frac{-1}{(R^2S^2C^2)} \qquad (S = j\omega)$$

Overall doop gain $\Rightarrow \frac{1}{R^2\omega^2C^2}$

By barkhausen criteua

Doop gain = 1 $\Rightarrow \frac{1}{R^2\omega_o^2C^2} = 1$

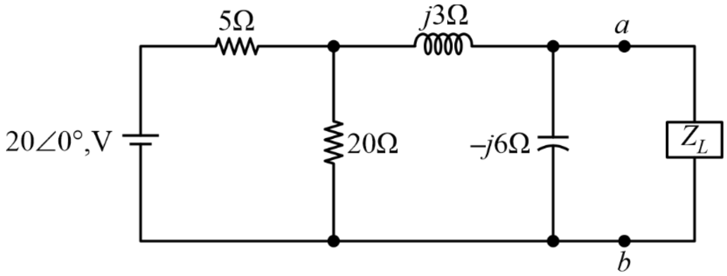
$$\Rightarrow \omega_o = \frac{1}{RC}$$

So oscellation frequency is $= \frac{1}{RC}$

This osullator is called Quad action oscillator.

(b) (i) Determine the impedance Z_L that results in maximum average power transferred to Z_L for the circuit shown in the figure.

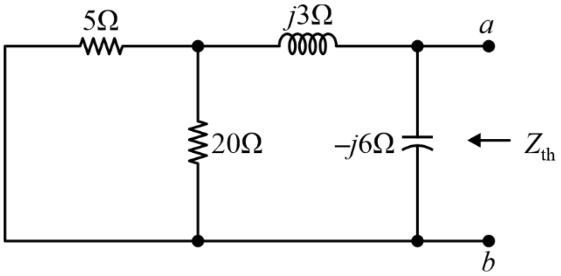
Calculate the maximum average power transferred to the load impedance determined.



Sol. For max power

$$Z_L = Z_{th}^*$$

∴ To find Z_{th}, SC the voltage source and open the load.



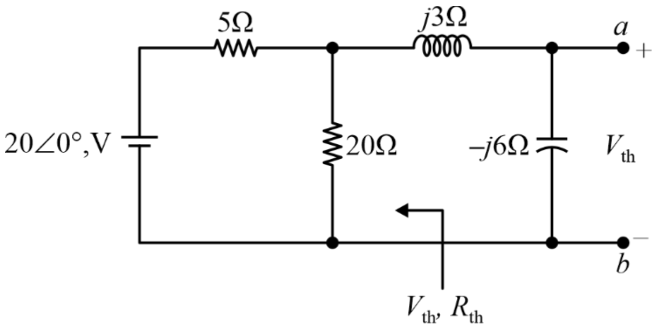
$$Z_{th} = (-j6) \| (j3 + (5 \| 20))$$

$$= (-j6) \| (j3 + 4)$$

$$= \frac{(-j6) \times (j3+4)}{-j6 + j3 + 4} = (5.76 - j1.68)\Omega$$

$$\therefore Z_L = Z_{th}^* = (5.76 + j1.68)\Omega$$

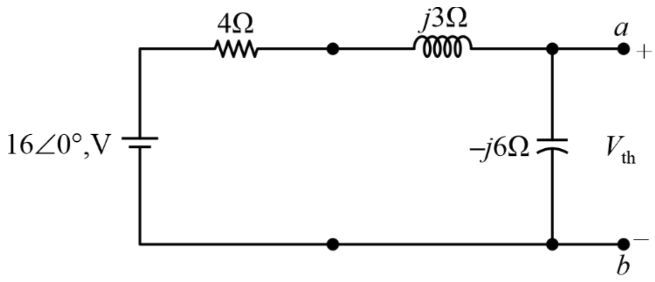
To find V_{th} open the load,



$$R_{th} = 5 \| 20 = 4\Omega$$

$$V_{th} = \frac{20 \times 20}{25} = 16V$$

∴ Circuit will be;



Using voltage division;

$$V_{th} = \frac{16\times(-j6)}{(4+j3-j6)} = 19.2\angle -53.13°\text{V}$$

$$P_{max} = \frac{V_{th}^2}{4R_L} = \frac{(19.2)^2}{4\times 5.76} = 16W$$

(ii) What are the major factors that have led to the acceleration and development of solar and wind power?

Sol. There are following different major factors that have led to acceleration and development of solar and wind power :

1. **Technological Innovations**

- **Advanced Materials:** Development of new materials, such as perovskites for solar cells and carbon fiber for wind turbine blades, has improved efficiency and durability.
- **Automation and AI:** Use of artificial intelligence and automation in manufacturing and maintenance has increased efficiency and reduced costs.
- **Hybrid Systems:** Integration of solar and wind systems with other renewable sources and energy storage solutions has enhanced overall system reliability and efficiency.

2. **Economic Viability**

- **Cost Parity:** Solar and wind power have reached or are approaching cost parity with traditional fossil fuels in many regions, making them economically competitive without subsidies.
- **Job Creation:** The renewable energy sector has become a significant source of job creation, providing economic benefits that encourage investment and development.
- **Investment Appeal:** Renewable energy projects have become attractive to investors due to their stable returns and low operational costs.

3. **Environmental and Health Benefits**

- **Biodiversity Conservation:** Unlike fossil fuel extraction, solar and wind energy have a smaller footprint on local ecosystems, helping to preserve biodiversity.

- **Water Use Reduction:** Solar and wind power require minimal water for operation, reducing the strain on water resources compared to thermal power plants.
- **Public Health:** Reduced air and water pollution from renewable energy sources has significant public health benefits, decreasing healthcare costs and improving quality of life.

4. Policy and International Agreements

- **Global Climate Agreements:** International agreements like the Paris Agreement have set binding targets for emissions reductions, pushing countries to adopt renewable energy.
- **Renewable Portfolio Standards (RPS):** Many countries and states have implemented RPS, mandating that a certain percentage of electricity must come from renewable sources.
- **Carbon Pricing:** Implementation of carbon taxes or cap-and-trade systems has made fossil fuel-based energy more expensive, enhancing the competitiveness of renewables.

5. Financial Mechanisms

- **Risk Mitigation Instruments:** Financial tools such as insurance and guarantees for renewable projects have reduced investment risks.
- **Innovative Financing:** Models like pay-as-you-go solar and community-owned wind farms have democratized access to renewable energy, enabling wider adoption.
- **Public-Private Partnerships:** Collaborations between governments and private companies have accelerated the development and deployment of renewable energy projects.

6. Infrastructure and Grid Modernization

- **Distributed Generation:** Growth in distributed solar generation (rooftop solar) has reduced the need for large-scale transmission infrastructure and increased grid resilience.
- **Energy Storage Integration:** Advances in battery technology and other storage solutions have mitigated the intermittency of solar and wind power, ensuring a stable energy supply.
- **Dynamic Grid Management:** Modern grid management techniques, such as demand response and real-time energy management, have improved the integration of renewable energy.

7. Geopolitical and Security Considerations

- **Energy Independence:** Countries are adopting renewables to reduce dependence on imported fossil fuels, enhancing energy security and geopolitical stability.

- **Decentralized Energy:** Renewable energy systems, particularly distributed generation, offer resilience against natural disasters and cyberattacks, enhancing national security.

(c) To produce a p-type semiconductor, the boron is doped in pure silicon. Doping is done through a B_2O_3 vapour phase of a surface concentration equivalent to 3.3×10^{26} boron atoms/m^3. Calculate the time required to get a boron content of 10^{23} atoms/m^3 at a depth of 2 µm. The doping temperature is 1000°C and D_B in Si at this temperature is 4×10^{-17} m^2/s.

Given: erf (0.95) = 0.8209

erf (1.0) = 0.8427

erf (2.4) = 0.9993

erf (2.6) = 0.9998

Sol. Given data,

$N_0 = 3.3 \times 10^{26}$ boron atoms/m^3

$x = 2$ µm

$D_B = 4 \times 10^{-17}$ m^2/s

$N(x, t) = 10^{23}$ boron atoms/m^3

Consider the following formula,

$$N(x,t) = N_0 \text{ erfc}\left(\frac{x}{2\sqrt{D_{B^+}}}\right) \qquad \ldots(1)$$

Substitute the values in equation (1),

$$10^{23} = 3.3\times10^{26}\text{erfc}\left(\frac{2\times10^{-6}}{2\sqrt{4\times10^{-17}\times t}}\right)$$

$$\frac{1}{3300} = \text{erfc}\left(\frac{10^{-6}}{2\sqrt{10^{-17}\times t}}\right)$$

$$1-\frac{1}{3300} = 1-\text{erfc}\left(\frac{10^{-6}}{2\sqrt{10^{-17}t}}\right)$$

$$\frac{3299}{3300} = \text{erf}\left(\frac{10^{-6}}{2\sqrt{10^{-17}t}}\right) \qquad [\because \text{erf}(x) = 1 - \text{erfc}(x)]$$

$$0.9997 = \text{erf}\left(\frac{10^{-6}}{2\sqrt{10^{-17}t}}\right)$$

$$\text{erf}(2.6) = \text{erf}\left(\frac{10^{-6}}{2\sqrt{10^{-17}t}}\right) \qquad [\because \text{Given, erf}(2.6) = 0.9998]$$

$$\frac{10^{-6}}{\sqrt{10^{-17}t}} = 5.2 \quad \Rightarrow \frac{10^{-12}}{10^{-17}\times t} = (5.2)^2$$

$t = 3698$ sec $\simeq 1.03$ hours

SECTION-B

Q.5. **(a)** Assume an ideal 10 bit ADC with V_{REF} = 5 V is used to sample 1 V_{p-p} sinusoidal signal that has a 2.5 V offset. What percent of error can be expected in the peak voltage measurement due to quantization effect of the ADC? (The error is relative to the magnitude of the sinusoid).

Sol.

(a) $V_{in} = 2.5 + 0.5 \sin(u(t)) \rightarrow |V_{in}|_{max} = 3\text{V}$

$$V_{LSB} = \frac{V_{REF}}{2^{10}} = 4.883\text{mV}$$

$$\text{Output}\left[\frac{3V}{V_{LSB}}\right] = 614 = (1001100110)_2$$

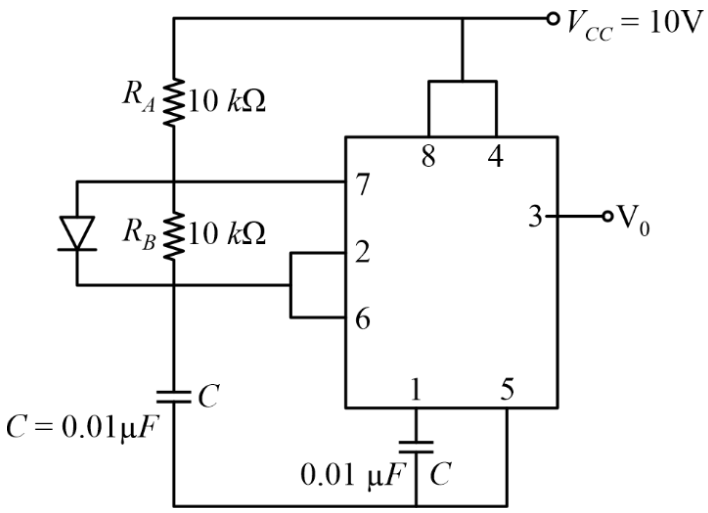
$$\text{Error} = \frac{3 - 614.V_{LSB}}{3} = 0.067\%$$

(b) $V_{in} = 2.5 + 2.5 \sin(\omega t) \rightarrow |V_{in}|_{max} = \text{V}$

$$\text{Output}\left[\frac{5V}{V_{LSB}}\right] = 2^{10} = 1024$$

$$\text{Error} = \frac{5 - 1024.V_{LSB}}{5} = 0.$$

(b) A 555 IC is connected as shown in the figure below. Determine the frequency of oscillation and the duty cycle. (Assume that diode is an ideal diode).

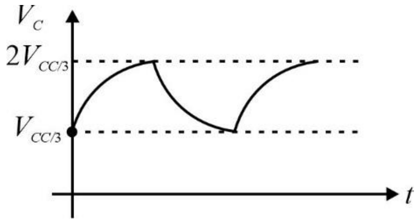


Sol. The circuit work as an as table multivibrator

When the capacitor is charging then diode is an and capacitor charge using R_A only so charging term constant of capacitor is R_{AC}

When the discharge terminal therefore node 7 is active then capacitor discharge through R_B, So discharging time constant in R_{BC}

Now we know that capacitor voltage changer between $V_{cc/3}$ and $2V_{cc/3}$.



The charge equation of capacitor is

$$V_c(t) = V_{cc} - \left(V_{cc} - \frac{V_{cc}}{3}\right)^{e^{-t/R_{AC}}}$$

So capacitor charger up to $\frac{2V_{cc}}{3}$ so

$$\frac{2V_{cc}}{3} = V_{cc} - \frac{2V_{cc}}{3}e^{-\text{Ton}/\text{R}_{\text{AC}}}$$

So Ton = $R_A(L_n(2))$

Similarly for discharging case

$$V_c(t) = 2\frac{V_{cc}}{3}e^{-t/R_BC}$$

Since capacitor discharge up to $\frac{V_{cc}}{3}$

So $\frac{V_{cc}}{3} = \frac{2V_{cc}}{3}e^{-T_DFF/R_BC}$

$T_{OFF} = R_BCL_n(2)$

Since $R_B = R_A$ thus $T_{OFF} = T_{on}$

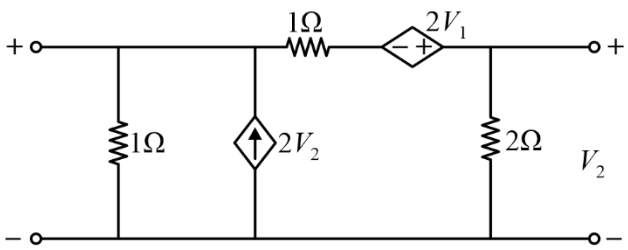
Thus duty cycle = $\frac{1}{2}$

And total time peuod = $T_{on} + T_{OFF} = 2\ L_n(2)R_C$

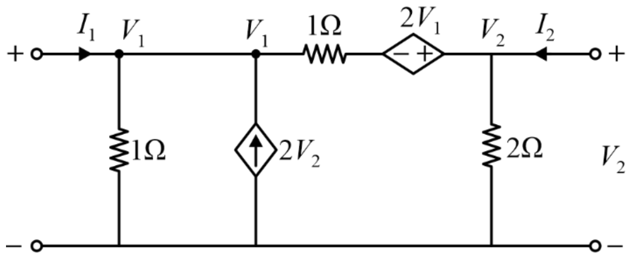
$\Rightarrow 1.3862 \times 10^{-5}$

Frequency of output = 72134 Hz.

(c) (i) The network of the figure contains both a dependent voltage source and a dependent current source. Determine the y and z parameters.



Sol.



Using KCL at V_1

$$I_1 = \frac{V_1}{1} - 2V_2 + \frac{V_1 + 2V_1 - V_2}{1}$$

$I_1 = V_1 - 2V_2 + 3V_1 - V_2$

$I_1 = 4V_1 - 3V_2$ ...(1)

Using KCL at V_2

$$I_2 = \frac{V_2}{2} + \frac{V_2 - 2V_1 - V_1}{1}$$

$I_2 = 0.5V_2 + V_2 - 2V_1 - V_1$

$I_2 = -3V_1 + 1.5V_2$ ...(2)

From (1) and (2)

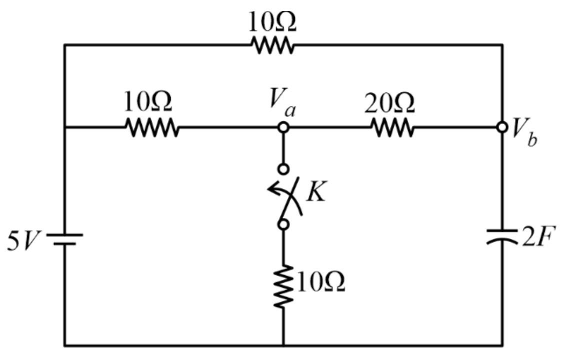
$$[Y] = \begin{bmatrix} 4 & -3 \\ -3 & 1.5 \end{bmatrix}$$

$$Z = [Y]^{-1} = \begin{bmatrix} 4 & -3 \\ -3 & 1.5 \end{bmatrix}^{-1}$$

$$= \frac{1}{6-9}\begin{bmatrix} 1.5 & 3 \\ 3 & 4 \end{bmatrix}$$

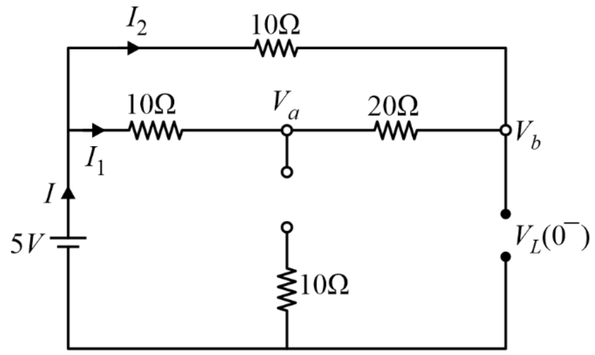
$$[Z] = \begin{bmatrix} -0.5 & -1 \\ -1 & -4/3 \end{bmatrix}$$

(ii) In the figure shows, a network with a steady state is reached with switch K open. At $t = 0$, the switch is closed. For the element values given, determine the value of $v_a(0^-)$ and $v_a(0^+)$.



Sol. Initially K open →

C will also open



Here, 5V source is opened

∴ $I = I_1 = I_2 = 0$

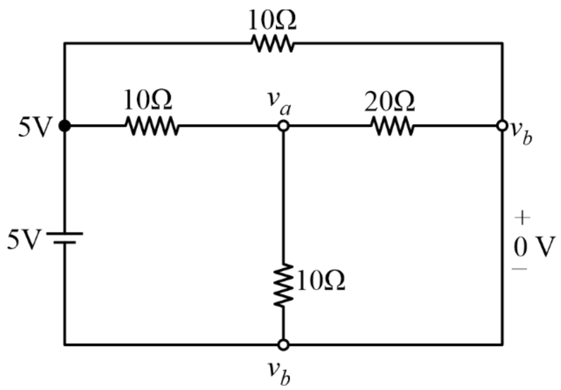
So, $V_a\ (0^-) = 0$ V

$V_C\ (0^-) = 0$ V

Hence, $V_C\ (0^+) = 0$V

Hence, VC $(0^+) = 0$ V

Now, at $t = 0^+$, switch is closed.



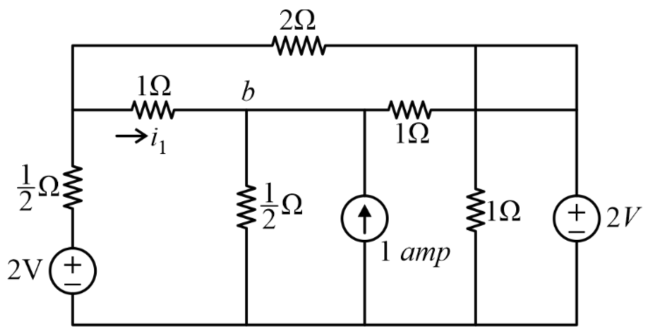
Here 20 Ω and 10 are in parallel between V_a and V_b

Assume $V_b = 0$ V (GND)

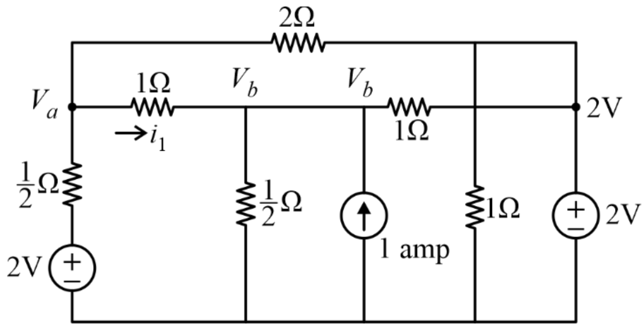
Using voltage division rule

$$V_0(0^+) = \frac{5 \times (20 \| 10)}{10 + (20 \| 10)} = 2\text{ V}$$

(d) (i) For the figure shown, find i_1.



Sol.



Using KCL at V_a

$$\frac{V_a-2}{1/2}+\frac{V_a-2}{2}+\frac{V_a-V_b}{1}=0$$

$2V_a - 4 + 0.5\ V_a - 1 + V_a - V_b = 0$

$3.5V_a - V_a = 5$ ....(i)

Using KCL at V_b

$$\frac{V_b-V_a}{1}+\frac{V_b}{1/2}+\frac{V_b-2}{1}=1$$

$V_b - V_a + 2V_b + V_b - 2 = 1$

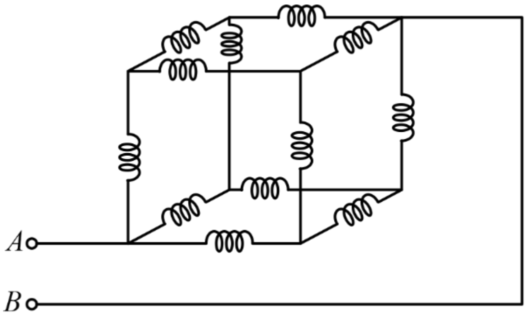
$-V_a + 4V_b = 3$ ....(ii)

From (i) and (ii),

$$V_a=\frac{23}{13}V;V_b=\frac{31}{26}V$$

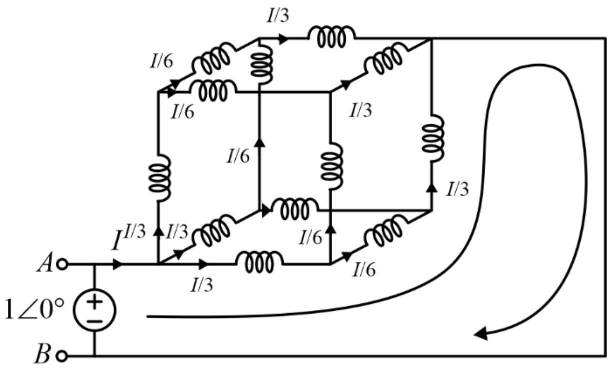
$$\therefore I_1=\frac{V_a-V_0}{1}=V_a-V_b=\frac{23}{13}-\frac{31}{26}=\frac{15}{26}=0.577A$$

(ii) The network of inductors in the figure below is composed of a 1 H inductor on each edge of a cube with the inductors connected to the vertices of the cube as shown. Find out the $L_{equivalent}$ between the terminals A-B.



Sol. Let source frequency ω rad/sec

$\therefore\ X_L = \omega \times 1 = \omega\Omega$



Using KVL;

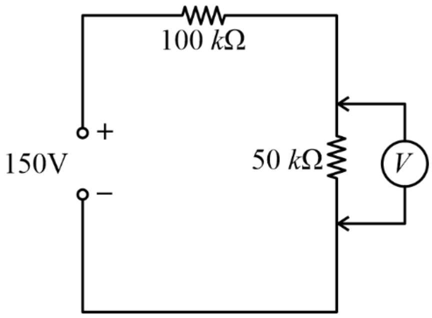
$$-1+\frac{I}{3}(j\omega)+\frac{I}{6}(j\omega)+\frac{I}{3}(j\omega)=0$$

$$\frac{5I}{6}j\omega=1$$

$$\frac{1}{I}=\frac{5}{6}j\omega=j\omega\angle eq$$

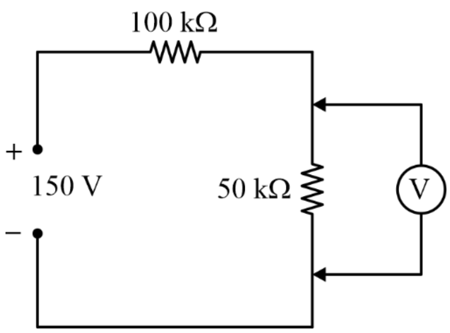
$$\angle eq=\frac{5}{6}\text{ H}$$

(e) It is desired to measure the voltage across the 50 kΩ resistor in the circuit shown in the figure. Two voltmeters are available for this measurement: Voltmeter 1 with sensitivity of 1000 Ω/V and Voltmeter 2 with a sensitivity of 20,000 Ω/V. Both meters are used on their 50 – V range. Calculate the reading of each meter.



Sol. Voltmeter-1 S_1 = 1000 Ω/V, Range = 50 V

Voltmeter-2 S_2 = 2000 Ω/V, Range = 50 V



Resistance of meter (1)

$$R_{m_1}=1000\ \Omega/\text{V}\times 50=50\text{ k}\Omega$$

Parallel combination R_{m_1} and 50 kΩ

$$R_{e_1} = \frac{50 \times 50}{(50+50)} = \frac{2500}{100} = 25 \text{ k}\Omega$$

Resistance of meter (2)

$$R_{m_2} = 20{,}000\ \Omega/\text{V} \times 50$$

$$= 100 \text{ k}\Omega$$

Parallel combination of R_{m_2} and 50 kΩ

$$R_{e_2} = \frac{100 \times 50}{150} = 33.33 \text{ k}\Omega$$

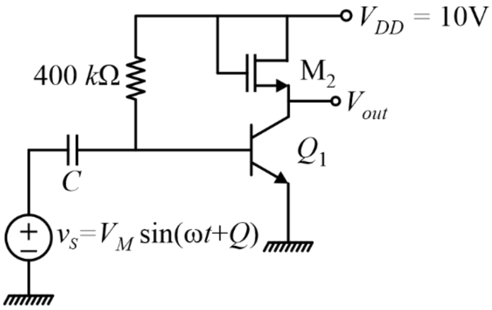
Voltmeter (1) reading

$$V_1 = 150 \times \frac{25}{(100+25)} = 150 \times \frac{25}{125} = 30 \text{ V}$$

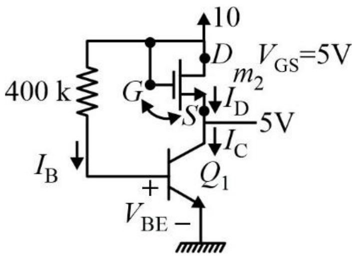
Voltmeter (2) reading

$$V_2 = 150 \times \frac{33.33}{(100+33.33)} = 37.5 \text{ V}$$

Q.6. **(a)** For the circuit shown in the figure below, MOS and BJT are operating in saturation and active mode, respectively. The capacitor C is very large and V_M is small. The parameters of the transistors are : $\mu_n C_{ox} = 100\ \mu\text{A/V}^2$, $V_{TN} = 1$ V, $L = 2\ \mu$m, $V_T = 25$ mV, $\beta_F = 100$, $V_{BE} = 0.7$ V and quiescent output voltage is 5 V. Size the MOSFET and calculate the small signal voltage gain $A_V = \frac{V_{ow}}{V_s}$



Sol. Given that V_{out} = 5V, lets solve the circuit at dc



So $I_B = \frac{10 - V_{BE}}{400u} = 0.02325$ mA

So $I_C = 100\ I_B = 2.325$ mA

Since $I_C = I_D$ and MOSFET is in saturation mode

So $I_D = \frac{1}{2} u_n C_O \times \frac{\omega}{L}(V_{GS} - V_{th})^2$

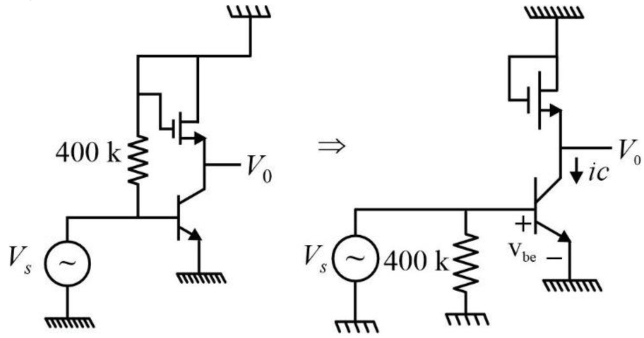
$2.325 \times 10^{-3} = \frac{1}{2} \times 100 \times 10^{-6} \times \frac{\omega}{L}(5-1)^2$

So $\frac{\omega}{L} = 2.90625$

$\omega = 5.8125$ μm

Now lets solue the circuit to find gain ⇒

The ac analysis circuit is

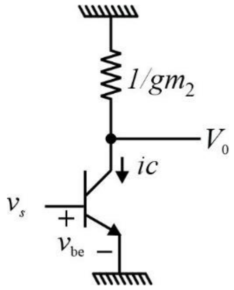


We know that D–G shorted MOSFET can be replaced by resistor of value

$\frac{1}{gm_2} \| R_{O_2} \Rightarrow$ Since R_{O_2} is not given so MOSFET ⇒

$gm_2 = \mu_n Co_x \frac{\omega}{L}(V_{gs} - V_{th}) \Rightarrow 100 \times 10^{-6} \times 2.90625 \times (5-1) = 1.1625 \times 10^{-3}$

So the circuit becomes,



So $\theta be = \theta_s$

$I_c = g_{m1}\, \theta\, \text{be} = g_{m1}\, \theta_s$

So $V_o = -i_c \times \frac{1}{g_{m_2}}$

$V_o = -g_{m1} V_S / g_{m2}$

$g_{m1} = g_m \text{ of BJT} = \frac{I_C}{Y_T} = \frac{2.325}{25}$

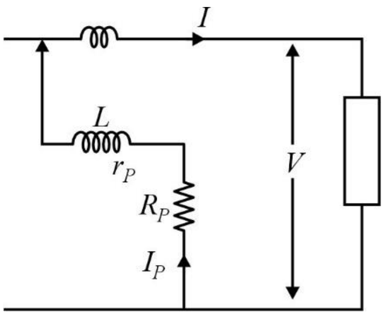
So $V_O = \frac{-g_{m1}}{g_{m2}} V_s$

$V_0 = 0.80 V_s$

So, gain = 0.80

(b) **(i)** Prove that the true power $= \dfrac{\cos\phi}{\cos\phi \cdot \cos(\phi-\beta)} \times$ actual watt meter reading for electrodynamometer type of watt meters, where, $\cos\phi$ = power factor of the circuit, $\beta = \tan^{-1} \omega L/R$ where, L and R are the inductance and resistance of the pressure coil of the circuit.

Sol.



Let,

r_P = the resistance of pressure coil.

L = the inductance of pressure coil.

R_P = the resistance in series with pressure coil.

$R = r_P + R_P$ = total resistance of pressure coil = $r_P + R_P$

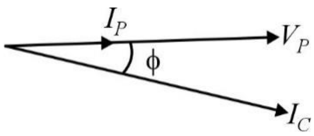
I = Current in the current coil circuit.

I_P = Current in the pressure coil circuit.

Z_P = Total impedance of pressure coil.

$$= \sqrt{(R_P + r_P)^2 + (\omega L)^2}$$

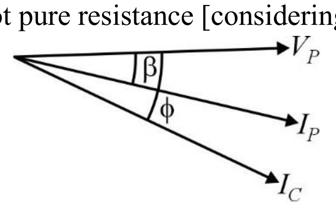
If pressure coil is pure Resistance



For ideal wattmeter, the true power is given

$$\text{True power } \theta = \frac{VI\cos\phi}{KR} \cdot \frac{dm}{d\theta}$$

If pressure coil is not pure resistance [considering inductance]



$$\text{Actual power, } \theta = \frac{VI}{KR}\cos\beta \cdot \cos(\phi-\beta) \cdot \frac{dm}{d\theta}$$

$$\frac{\text{True power}}{\text{Actual power}} = \frac{\cos\phi}{\cos\beta . \cos(\phi-\beta)}$$

$$\text{Ture power} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}$$

$$\text{Ture power} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}\times\text{Actual power}$$

(ii) Explain why errors are large when the power factor is low.

Sol. $\text{True power} = \frac{VK\cos\phi}{KR}\cdot\frac{dm}{d\theta}$

$$\text{Actual power} = \frac{VI}{KR}\cdot\cos\beta\cdot\cos(\phi-\beta)\cdot\frac{dm}{d\theta}$$

$$\frac{\text{True power}}{\text{Actual power}} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}$$

$$\text{True power} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}\times\text{Actual power}$$

Error = Actual power – True power

$$\text{Correction Factor} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}$$

For lagging power factor

$$\text{Correction factor} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi+\beta)}$$

For lagging power factor.

For lagging P.F. [Inductor]

$$\text{Correction factor} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi-\beta)}$$

$\therefore$ For lagging P.F,

The wattmeter reads high, i.e. the indicted power will be were true actinal power so error is more

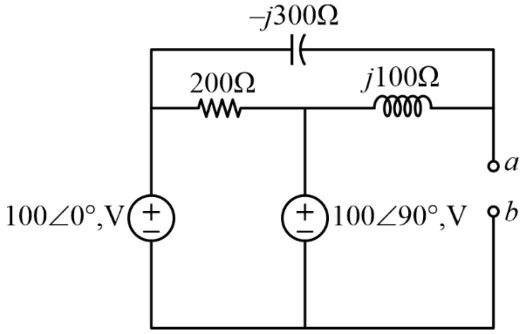
For leading P.F.[caput]

$$\text{Correction factor} = \frac{\cos\phi}{\cos\beta\cdot\cos(\phi+\beta)}$$

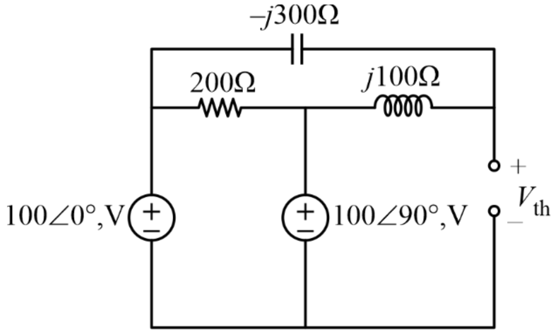
$\therefore$ For lagging P.F

The wattmeter reads, low that means the indicators power will be less than actual power so error less.

(c) **(i)** Find the Thevenin's equivalent for the circuit at terminals a – b.



Sol. V_{th}



$$\frac{V_{th}-100\angle 90^\circ}{j100}+\frac{V_{th}-100\angle 0^\circ}{-j300}=0$$

$$\frac{V_{th}-j100}{j100}-\left(\frac{V_{th}-100}{j300}\right)=0$$

$$-j\frac{V}{100}-1+j\frac{V}{300}-j\frac{1}{3}=0$$

$$\frac{jV}{300}-j\frac{V}{100}=1+\frac{j}{3}$$

$$\frac{jV-j3V}{3}=\frac{300+j100}{3}$$

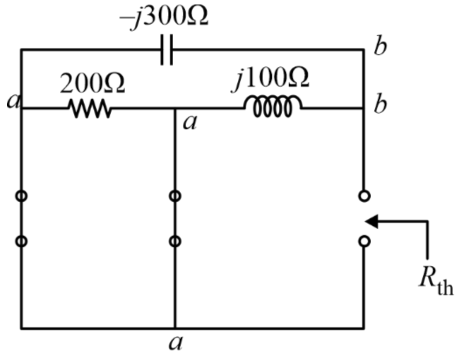
$$-j2V=300+j100$$

$$V=\frac{300+j100}{-2j}$$

$$V=+j150-50$$

$$V=-50+j150$$

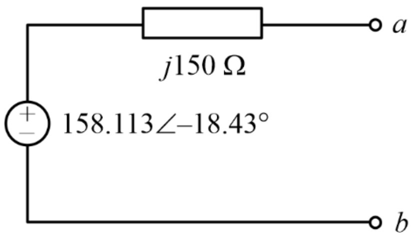
$$V=158.113\angle -18.43^\circ V$$



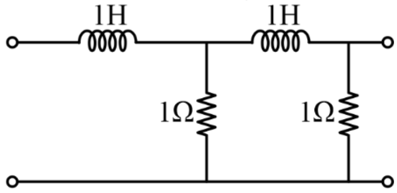
$$Z_{th}=(-j300)\,||\,j100$$

$$= \frac{(-j300)\times(j100)}{j100 - j300}$$

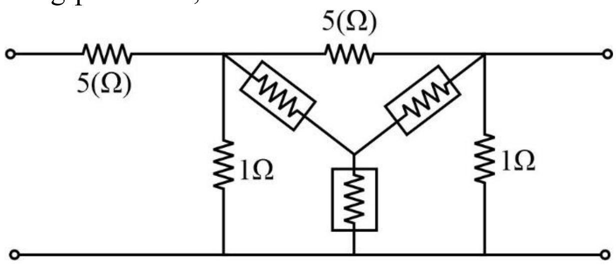
$$= \frac{300,00}{-j200} = j150\Omega$$



(ii) For the ladder network determine the g parameters in the s domain.

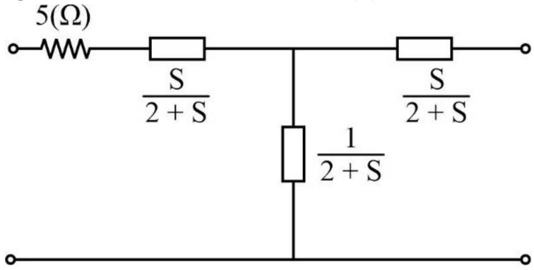


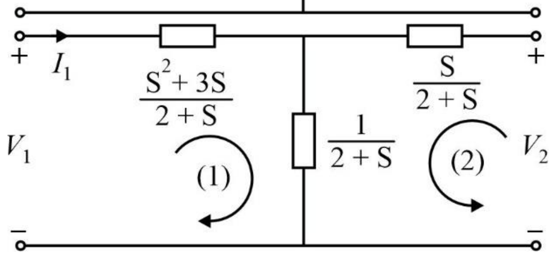
Sol. Equation of g-parameter;



$I_1 = g_{11}V_1 + g_{12}I_2$ ....(1)

$V_1 = g_{21}V_1 + g_{22}I_2$ ....(2)





Apply KVL in loop (1);

$$V_1 + I_1\left(\frac{s^2+3s}{2+s}\right) + (I_1+I_2)\left(\frac{1}{2+s}\right)$$

$$V_1 + I_1\left(\frac{s^2+3s+1}{2+s}\right) + I_2\left(\frac{1}{2+s}\right)$$

$$I_1\left(\frac{s^2+3s+1}{2+s}\right)=V_1-I_2\left(\frac{1}{2+s}\right)$$

$$I_1=\left(\frac{2+s}{s^2+3s+1}\right)V_1-I_2\left(\frac{1}{s^2+3s+1}\right) \qquad ....(1)$$

Apply KVL in loop (2);

$$-V_2+I_2\left(\frac{s}{2+s}\right)+I_1+I_2\left(\frac{1}{2+s}\right)$$

$$V_2+I_1\left(\frac{s}{2+s}\right)+I_1+I_2\left(\frac{1}{2+s}\right)$$

From equation (1)

$$V_2=\left[\left(\frac{2+s}{s^2+3s+1}\right)V_1-I_2\left(\frac{1}{s^2+3s+1}\right)\right]$$

$$\left(\frac{1}{2+s}\right)+I_2\left(\frac{s+1}{s+2}\right)$$

$$V_2=V_1\left(\frac{1}{s^2+3s+1}\right)-I_2\left(\frac{1}{s^2+3s+1}\right)$$

$$\left(\frac{1}{2+s}\right)+I_2\left(\frac{s+1}{s+2}\right)$$

$$V_2=V_1\left(\frac{1}{s^2+3s+1}\right)+I_2$$

$$\left[\left(\frac{s+1}{s+2}\right)-\frac{1}{(s+2)(s^2+3s+1)}\right]$$

$$V_2=V_1\left(\frac{1}{s^2+3s+1}\right)+I_2\left[\frac{(s+1)(s^2+3s+1)-1}{(s+2)(s^2+3s+1)}\right]$$

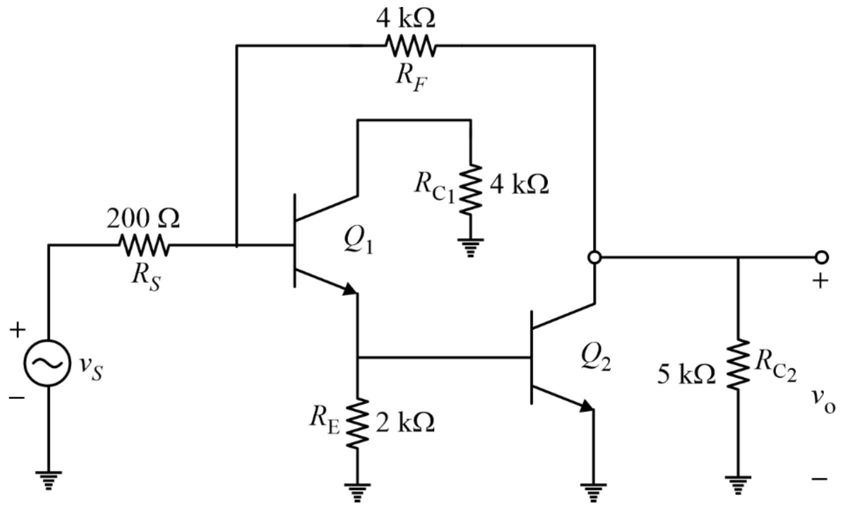
$$V_2=V_1\left(\frac{1}{s^2+3s+1}\right)+I_2\left[\frac{s^3+4s^2+4s+1-1}{(s+2)(s^2+3s+1)}\right]$$

$$V_2=V_1\left(\frac{1}{s^2+3s+1}\right)+I_2\left[\frac{s(s^2+4s+4)}{(s+2)(s^2+3s+1)}\right]$$

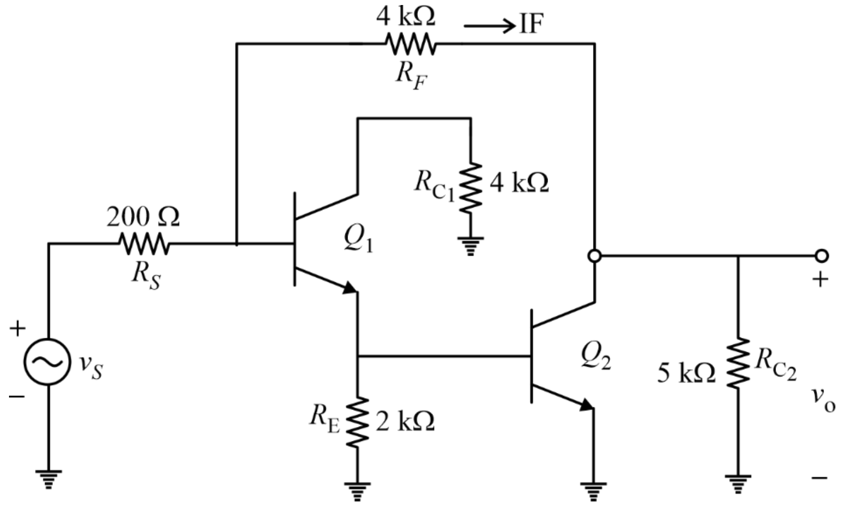
g-parameter

$$\begin{bmatrix}\dfrac{2+s}{s^2+3s+1} & \dfrac{1}{s^2+3s+1}\\ \dfrac{1}{s^2+3s+1} & \dfrac{s(s^2+4s+4)}{(s+2)(s^2+3s+1)}\end{bmatrix}$$

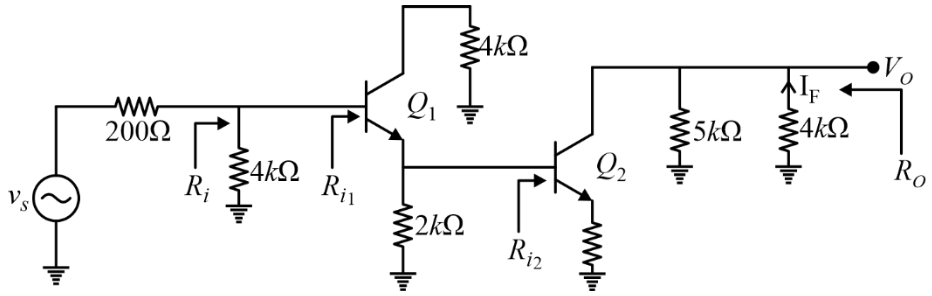
Q.7. (a) The parameters of the amplifier shown in the figure below are $R_{C_1}=4\,\text{k}\Omega$, $R_E=2\Omega$, $R_{C_2}=5\,\text{k}\Omega$, $R_F=4\ \text{k}\Omega$ and $R_S=200\ \Omega$. The DC bias currents of the transistor are $I_{C_1}=0.5\,\text{mA}$, $I_{C_2}=1\,\text{mA}$. The transistor parameters are $h_{fe}=h_{fe1}=h_{fe2}=150$. Use the techniques of feedback analysis to calculate the input resistance R_{IF}, the output resistance R_{OF} and the closed loop transresistance gain A_f. Assume $V_T=25$ mV.



Sol. We can see that the circuit has voltage sample and current mix hence the feedback signal will be If/V_0



- The circuit without feedback will be



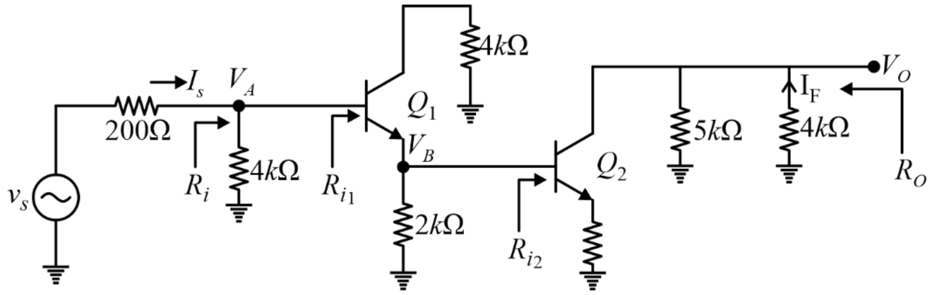
- So $\beta = \frac{I_E}{V_0} = -\frac{1}{4000}$

- $R_{i_2} = r_{\pi_2} = \frac{\beta}{I_{C_2}}.V_T \Rightarrow \frac{150}{1} \times 25 = 3750\Omega$

- $R_{i_1} = \left(r_{e_1} + 2k\Omega \,||\, R_{i_2}\right)(\beta + 1)$

$$= \left(\frac{V_T}{I_{C_1}} + 2k\Omega \,||\, R_{i_2}\right)(\beta + 1)$$

- $R_{i_1} = 204.50b\ k\Omega$
- Now $R_i = R_{i1} \| 4k\Omega = 3.92\ k\Omega$
- And $R_0 = 5\ k\Omega \| 4k\Omega = 2.22\ k\Omega$



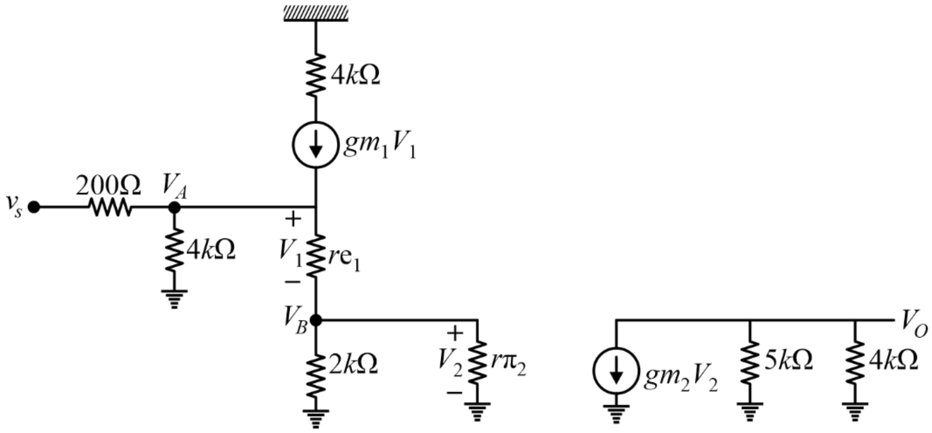
Now lets find the gain of circuit without feedback V_0/I_s

$$I_s = \frac{V_s}{200 + R_i} = \left(\frac{V_s}{4.12k\Omega}\right)$$

$$\text{Now } V_A = V_S \times \frac{R_i}{R_i + 200} = .9514V_s$$

Now if we draw small signal model of circuit we get

T model for Q_1 and π model for Q_2



$re_1 = V_T / I_{C_1} = 50\Omega$

$r_{\pi_2} = 3.75k\Omega$, by voltage division

$$\text{So } V_B = VA \times \frac{2k\Omega \| r\pi_2}{re_1 + (2k\Omega \| r\pi_2)} = .9630\ VA$$

Since $V_2 = V_B$

$V_0 = -gm_2V_2(5k\Omega \| 4k\Omega)$

$$g_{m_2} = \frac{I_{C_2}}{V_T} = \frac{1}{25}$$

$$V_0 = -\frac{1}{25} \times .9630\ VA \times 2222$$

$V_0 = -85.59$ VA

Since VA = .9514 Vs

So $V_0 = -81.43$ Vs

Now Vs = 4.12 kΩ Is

So $V_0 = -(81.42 \times 4120)$ Is

$$\frac{V_0}{I_s} = -335498.58$$

So open loo gain = – 335498.58 = A_{OL}

and $\beta = -\frac{1}{4000}$

Thus closed loop gain $= \frac{A_{OL}}{1+\beta A_{OL}} = 3952$

Thus closed loop $R_{in} = R_{if} = \frac{R_i}{1+A_{OL}\beta} = \frac{3920}{1+A_{OL}\beta} = 46.18\Omega$

Thus clsoed loop $R_O = R_{OF} = \frac{R_O}{1+A_{OL}\beta} = \frac{2222}{1+A_{OL}\beta} = 26.17\Omega$

(b) **(i)** Explain at least five advantages and disadvantages of LVDT. State at least two uses of LVDTs.

Sol. **Advantages:**

1. High Sensitivity: S = 40V/mm, for small vartaions in the displacement, LVDT provides a high output of 40V.
2. Low Hysterisis: LVDT high repeatable due to their extremly low hysterisis.
3. Low power consumption: Lass power consuption compared to other transducers.
4. Infinite Life: No physical contact between core and coils hence the lifetime is more.
5. Best secondary transducer: By attaching LVDT to primary transducers like bourdon tube, rotatnetion bellences parameters like force, pressure measurable

Disadvantage of LVDT:

1. As at is a inductive transducer it is sensitive to the stray magnetic field, hence an exite setup is required to prottect from stray aeldr.
2. As LVDT is electro magnetic device, it is affected by vibrations and temperature.
3. Signal conditioning molecules like demodulation, felts circuits are necessary to get proper output.
4. LVDT is bulk in size
5. the temperature can effect the performance of two condition.

Application [oses] of LVDT:

- It is mostly used in insustries in the field of automation, aircraft, turbines, Turbines, Satellite, Hydraulics etc.
- LVDT is used to measure physical quantitiy which as Force, Tension, Pressure, Weight etc. LVDT acts as best secondary transucer.
- LVDT plays important role in geotechnical instrumentation, as it is used for monitering ground morements, landslides and structural stability.
- LVDT plays a important role in the marine and offshere industry by monitering the movements and positions of ships and under water structure.

LVDT plays a important role in power eneration as it monitors the critical companes in turbines and generators.

(ii) The output of an LVDT is connected to a 5 V voltmeter through an amplifier whose amplification factor is 200. An output of 2 mV appears across the terminals of LVDT when the core moves through a distance of 0.5 mm. Calculate the sensitivity of the LVDT and that of the whole set-up. The milli voltmeter scale has 100 divisions. The scale can be read to 1/5 of a division. Calculate the resolution of the instrument in mm.

Sol. Given that,

Range of voltmeter = 5V

Amplification factor = 200

Output voltage = 2 mV

Displacement = 0.5 mm

Number of divisions = 100

$$\text{Sensitivity of LVDT} = \frac{V_{out}}{\text{Displacement}} = \frac{2\times10^{-3}}{0.5\times10^{-3}} = 4\,\text{V/m}$$

= 4 mV/mm

Sensitivity of instrument

= (Sensitivity of LVDT) (Amplification factor)

= (4 mV/mm) × 200 = 800 mV/mm

$$\text{Smallest division of scale} = \frac{\text{Range of voltmeter}}{\text{Number of divisions}}$$

$$= \frac{5}{100} = 0.05V$$

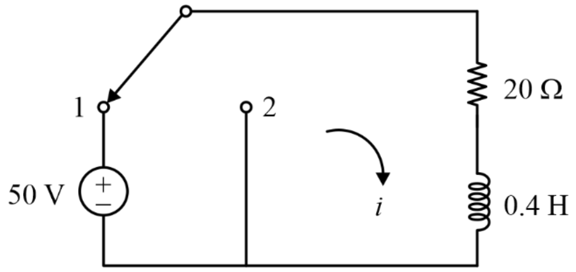
$$\text{Minimum voltage that can be read on voltmeter} = \frac{1}{5}\times 0.05 = 0.01\text{V} = 10\text{mV}$$

Hence,

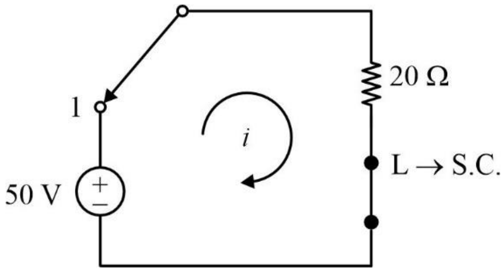
$$\text{Resolution of instrument} = \frac{\text{Minimum voltage reading}}{\text{Sensitivy}}$$

$$= \frac{10}{800} = 0.025$$

(c) **(i)** In the series RL circuit, the switch is in position 1 long enough to establish the steady state and is switched to position 2 at $t = 0$. Find the current i.



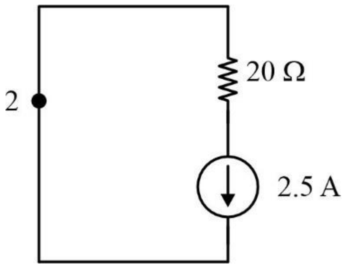
Sol. At $t = 0^-$



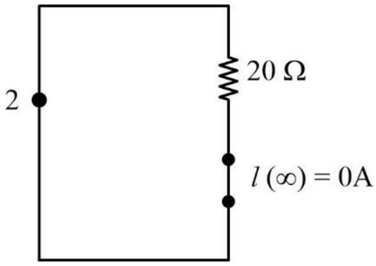
$$i_L(0^-) = i(0^-) = \frac{50}{20} = 2.5\text{A}$$

at $t = 0^+$

$i(0^-) = i(0^+) = 2.5$ A



At $t = \infty$ circuit is source free

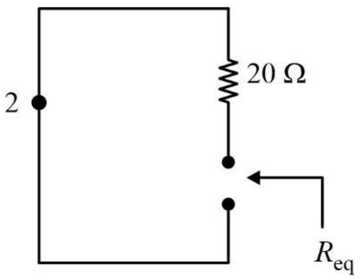


$i(t) = i(\infty) + (i_L(0) - i(\infty))\, e^{-t/\tau}$

$i(t) = 2.5\ e^{-t/\tau}$

$$\tau = \frac{L}{R}$$

$R_{eq} = 20\ \Omega$

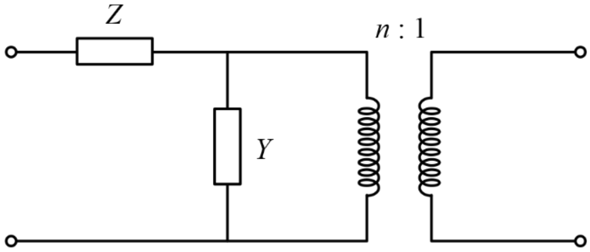


$$\tau = \frac{0.4}{20} = 0.02$$

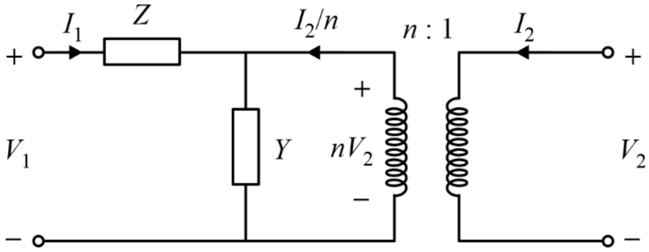
$$i(t) = 2.5e^{-t/0.02}$$

$$i(t) = 2.5e^{-50t}\text{ A}$$

(ii) Obtain the overall ABCD parameters of the circuit.



Sol.



Using, KVL,

$$V_1 = I_1 Z + nV_2 \quad \ldots(1)$$

Using KCL,

$$I_1 = nV_2 Y - \frac{I_2}{n} \quad \ldots(2)$$

Put I_1 in (1)

$$V_1 = \left(nV_2 Y - \frac{I_2}{n}\right)Z + nV_2$$

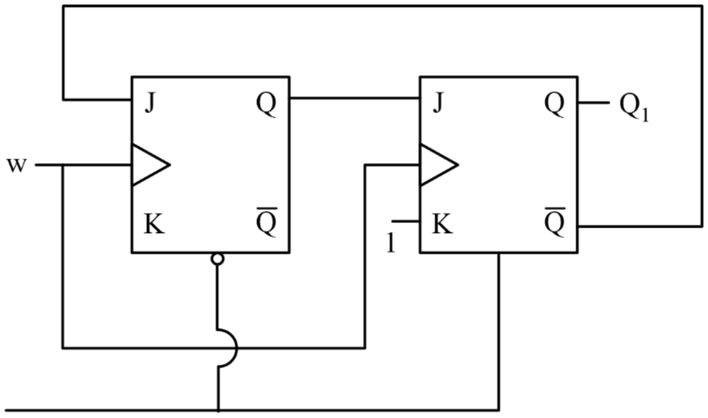
$$= nYZV_2 + nV_2 - \frac{I_2}{n}Z$$

$$V_1 = (nYZ + n)V_2 - \frac{Z}{n}I_2$$

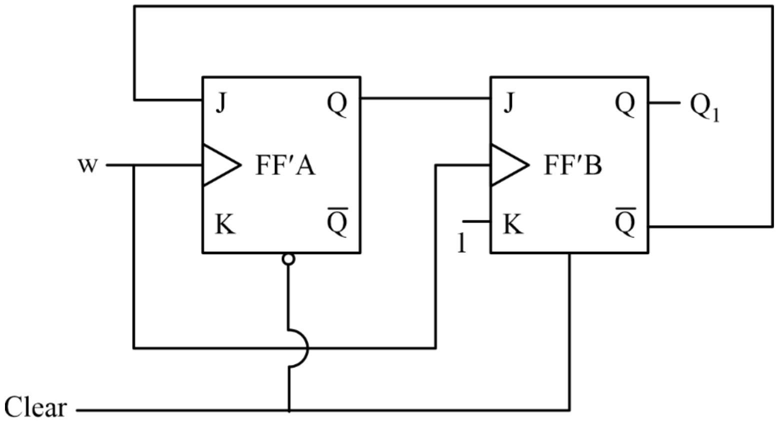
$$I_1 = nYV_2 - \frac{1}{n}I_2$$

$$[T] = \begin{bmatrix} nYZ + n & \frac{Z}{n} \\ nY & \frac{1}{n} \end{bmatrix}$$

Q.8. **(a)** **(i)** Determine the function behaviour of the circuit. Assume that input w is driven by a square wave signal.



Sol.



Writing connections:

$J_A = \bar{Q}_B$

$J_B = Q_A$

$Q_1 = Q_B$ = Output

J-K flip-flop standard operation

J	*K*	*Q*
0	0	Hold
0	1	Reset
1	0	Set
1	1	Toggle

FF-B Analysis:

$K_B = 1$

$J_B = Q_A$

$Q_1 = Q_B$

For Q_A high $\rightarrow J_B = 1$ i.e., Toggle mode

$K_B = 1$

For Q_A low $\rightarrow J_B = 0$ i.e., Reset mode

$K_B = 1$

FF-A Analysis:

$K_A = *$ (0 or 1)

$J_A = \bar{Q}_B$

For Q_B high $\rightarrow J_A = 0$

$K_A = *$

Case-I: $K_A = 0$, i.e., Hold mode

Case-II: $K_A = 1$, i.e., Reset mode

For Q_B low $\rightarrow J_A = 1$

$K_A = *$

Case-I: $K_A = 0$, i.e., Set mode

Case-II: $K_B = 1$, i.e., Toggle mode

When clear = 0

FF-A connected is negative logic (OFF)

FF-B connected is positive logic (ON)

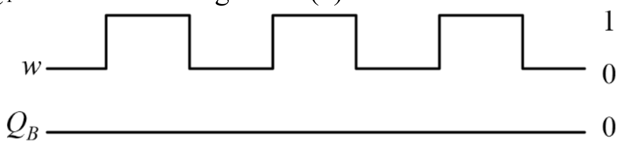
$Q_A = 0$

$J_B = 0$

$K_B = 1$

FF-B is reset mode

So, Q_1 will remain at logic low (0)



When clear = 1

FF-A connected is negative logic (ON)

FF-B connected is positive logic (OFF)

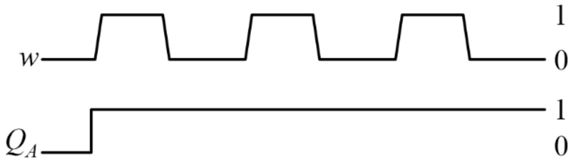
$Q_B = 0$

$J_A = \bar{Q}_B = 1$

$K_A = *$

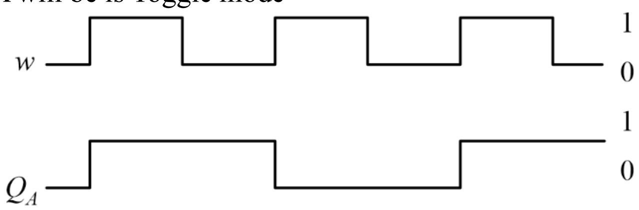
Case-I: $K_A = 0$

FF-A will be is Set mode



Case-II: $K_A = 1$

FF-A will be is Toggle mode

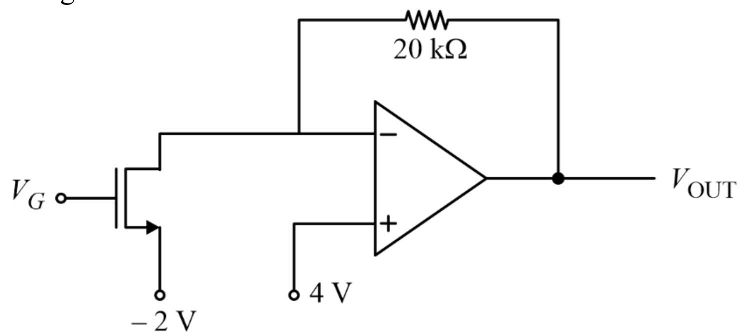


Functional description of Circuit

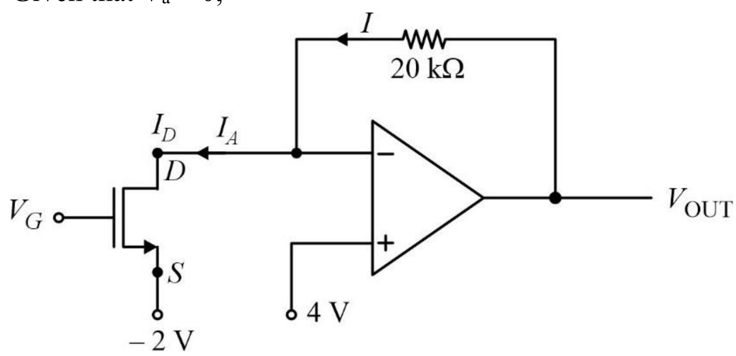
For Clear = 0 both Q_A and Q_B will be permanently 0 i.e circuit will be at 00 state permanently for any no. of clock pulses(W).

When clear = 1 then in one case output will be at 10 permanently and in second case it will go through the states 00-10 after application of clock pulses(W) i.e it will work like MOD-2 counter.

(ii) In the circuit shown in the figure below, the gate voltage V_G is very small. Assume op amp is an ideal op amp, $V_{TN} = 1V$ and $\frac{\mu_n C_{ox} w}{L} = \frac{200 \mu A}{V^2}$. Calculate output voltage.



Sol. Given that $V_a \approx 0$,



By virtual short $V_A = 4$,

Since $V_a = 0$, $V_D = 4$ So MOSFET is in saturation mode

So $I_D = \frac{1}{2} V_n C_o \times \frac{\omega}{L}(V_{as} - V_{th})^2$

$= \frac{1}{2} \times 200 \times 10^{-6} (2-1)^2$

$I_D = 100\ \mu A$

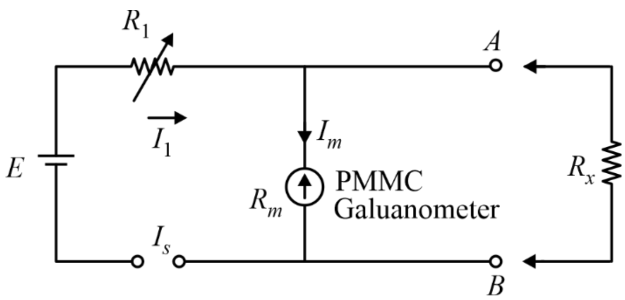
So $I = I_D = 100\ \mu A$

$\Rightarrow 4 + 2$

$\Rightarrow 6V$

(b) **(i)** Describe the construction and working of a shunt type ohmmeter. Write down its design equation.

Sol.

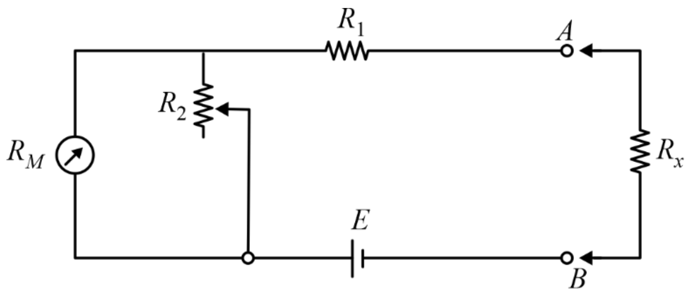


If the resistor's value is unknown and to be measured by placign it in parallel (shunt) witht eh ohmmeter, then that ohmmeter is called shunt ohmmeter.

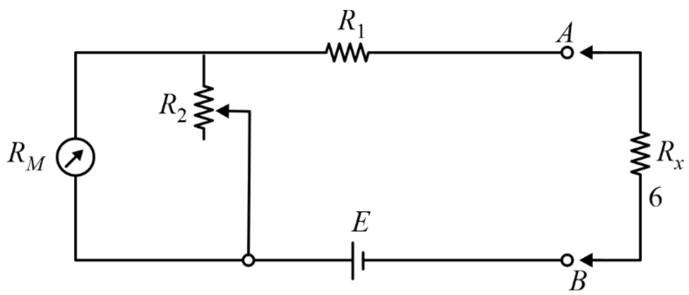
The part of the circuit which is left side of terminals A & B is shunt ohmmeter. So the unknown resistance can be measured by placing it to the right side terminals A & B.

Close the switch, S of above circuit white inverse
If $R_x = 0\Omega$, then the terminals A and B will be short circuited with each other. Due to this the entire current, I, flows through the terminals A, B. In this case, no current flows through PMMC.
Hence the null defection of PMMC galvanometer can be represented as 0Ω.
If $R_x = \infty$, then the terminals A & B will be open circuited with each other. So no current flow through terminals A & B. In this case the entire current I flows through PMMC. If required vary (adjust) the value of resistor, R_1 untit the PMMC shown full scale deflection current. Hence the full scale deflection current of PMMC represented as ∞Ω.

(ii) The ohmmeter shown in the figure uses a 100 Ω basic movement requiring a full-scale current of 1 mA. The internal battery voltage is 3 V. The desired scale marking for half-scale deflection is 2000 Ω. Calculate the value of R_1 and R_2, and the maximum value of R_2 to compensate for a 10% drop in the battery voltage.



Sol.



$V = IR$
$R_n = 2000\Omega$; V = 5V
$R_m = 100\Omega$; $I_{fm} = 1$ mA
Value of R_{se}, R_{sb}

$$R_{se} = R_h = \frac{I_{fm} R_m R_n}{E}$$

$$= 2000 - \frac{(1\times10^{-3})(00)\times(200)}{3}$$

= 2000 – 200/3
= 2000 – 66.66Ω = 1934Ω

$$R_{sh} = \frac{I_{fm}R_mR_h}{E - I_{fm}R_h}$$

$$= \frac{1\times10^{-3}\times100\times2000}{3(1\times10^3\times2000)} = \frac{200}{1} = 200\Omega$$

Percentage in SV $\rightarrow \frac{10}{100}\times3 = 0.3 \rightarrow (3-0.3) = 2.7V$

$$R_{sh} = \frac{I_{fm}R_mR_h}{E - I_{fm}R_h} = \frac{1\times10^{-3}\times100\times2000}{2.7[1\times10^{-3}\times2000]} = \frac{200}{2.7-1} = \frac{200}{2.7} = 74\Omega$$

(c) A series resonant network consists of a 50 Ω resistor, a 4 mH inductor and a 0.1 μF capacitor. Calculate values for: (a) ω_0, (b) f_0, (c) Q_0, (d) BW, (e) ω_1, (f) ω_2, (g) Z_{in} at 45 k rad/sec, and (h), the ratio of magnitude of the capacitor impedance to resistor impedance at 45 k rad/sec.

Sol. (a) $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4\times10^{-3}\times0.1\times10^{-6}}} = 50{,}000$ r/s

(b) $f_0 = \frac{\omega_0}{2\pi} = \frac{50{,}000}{2\pi} = 795.7$ kHz

(c) $Q_0 = \frac{1}{K}\sqrt{\frac{L}{C}} = \frac{1}{50}\sqrt{\frac{4\times10^{-3}}{0.1\times10^{-6}}} = 4$

(d) $BW = \frac{\omega_0}{Q} = \frac{50{,}000}{4} = 12{,}500$ r/s

(e) $\omega_2 - \omega_1 = BW = 12{,}500$ r/s …(1)

$\sqrt{\omega_1\omega_2} = \omega_0 = 50{,}000$ r/s

$(\omega_2+\omega_1)^2 = (\omega_2-\omega_1)^2 + 4\omega_1\omega_2$

$= (12{,}500)^2 + 4\times(50{,}000)^2$

$\omega_2+\omega_1 = \sqrt{10156250000}$

$\omega_2+\omega_1 = 100778.2$ r/s …(2)

From (1) and (2)

$\omega_1 = 44139.11$ r/s

(f) $\omega_1 = 56639.11$ r/s

(g) $Z_{in} = R + j(X_L - X_C)$

$X_L = \omega L = 2\pi fL = 2\times\pi\times45\times10^3\times4\times10^{-3} = 1130.9\ \Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC} = \frac{1}{2\times\pi\times45\times10^3\times0.1\times10^{-6}} = 35.37\ \Omega$

$\therefore\ Z_{in} = 50 + j\,(1130.9 - 35.37)$

$= (50 + j\,1095.53)\ \Omega$

(h) $\frac{X_C}{R} = \frac{35.37}{50} = 0.707$

❑❑❑

THANK YOU!