MADE EASY

MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2020 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-14: Full Syllabus Test

Paper-I

Name : ....

Roll No : | | | | | | | | | | | | |

Test Centres

Delhi ☐ Bhopal ☐ Noida ☐ Jaipur ☐ Indore ☐
Lucknow ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Patna ☐
Hyderabad ☐

Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

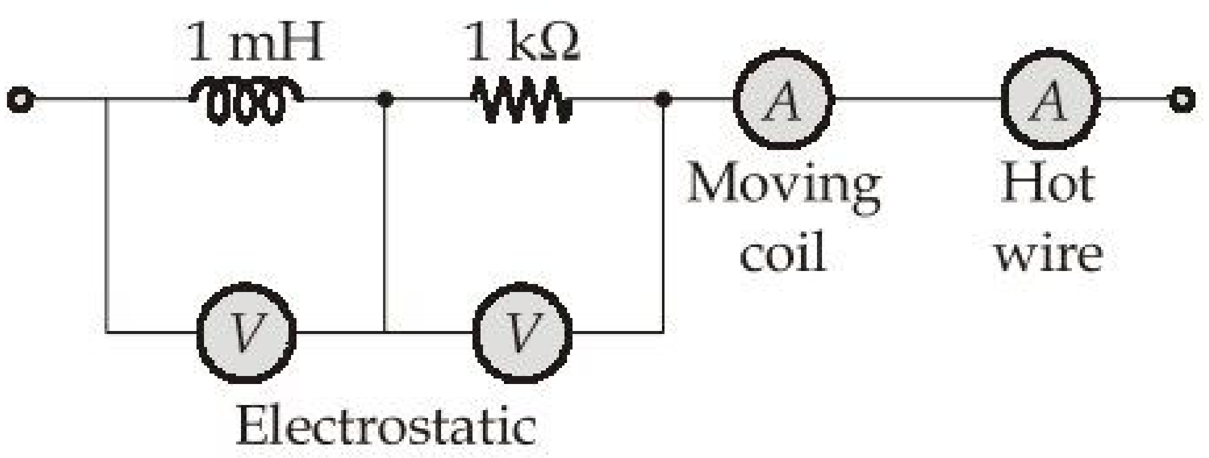
Signature of Evaluator .... Cross Checked by ....

Corp. office : 44 - A/1, Kalu Sarai, New Delhi-16 | **Ph:** 011-45124612, 9958995830 | **Web:** www.madeeasy.in

Do not write in this margin

Section-A

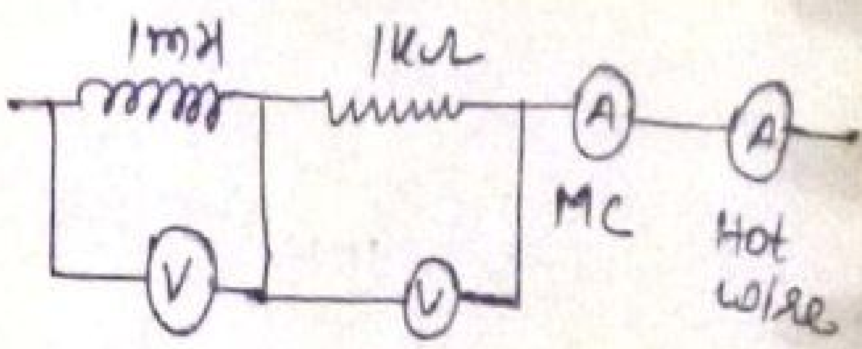
Q.1 (a) A current (in Amp) of $0.5 + 0.3 \sin\omega t - 0.2 \sin 2\omega t$ is passed through the circuit shown. Determine the reading of each instrument if $\omega = 10^6$ rad/s.



[12 marks]

Ans : (a) Given, $I = 0.5 + 0.3 \sin\omega t - 0.2 \sin 2\omega t$

$\omega = 10^6$ rad/sec.



Reading by Moving coil :→

∴ M.C. instrument read only DC value

So $I_{M.C.} = 0.5$ Amps.

Reading by Hot wire :→ Hot wire instrument read rms value of current so $I_{Hot\ wire} = \sqrt{0.5^2 + \frac{0.3^2}{2} + \frac{(0.2)^2}{2}}$ = 0.561 Amp

Electrostatic voltmeter reading across 1kΩ, $V_R = 0.561 \times 10^3 = 561$ Volts.

Instantaneous Voltage across inductor, $V_L = L\frac{di}{dt} = 10^{-3}\left[0.3\omega\cos\omega t - 0.2 \times 2\omega \cos 2\omega t\right]$

$\Rightarrow V_L = 10^{-3}\left[0.3 \times 10^6 \times \cos 10^6 t - 0.2 \times 2 \times 10^6 \cos 2 \times 10^6 t\right]$

$= 300 \cos 10^6 t - 400 \cos 2 \times 10^6 t$

So Electrostatic Voltmeter reading would be, $V_L = \sqrt{\left(\frac{300}{\sqrt{2}}\right)^2 + \left(\frac{400}{\sqrt{2}}\right)^2} = 353.55$ Volts

Q.1 (b) Suppose two 6-sided dices are rolled simultaneously. Consider the events:

A = 'odd on dice-1' B = 'odd on dice-2' C = 'odd sum'

Are A, B and C pairwise independent? Are they mutually independent?

[12 marks]

Ans: (b) $P(A) = P(B) = 1/2$ also $P(C) = 1/2$

for mutually independent $P(A \cap B) = P(A) \cdot P(B)$

Given $P(A \cap B) = P(A) \cdot P(B)$ also, $P(B \cap C) = P(B) \cdot P(C)$

and $P(A \cap C) = P(A) \cdot P(C)$

Now, $A \cap B = (1,1), (1,3), (1,5), (3,1), (3,3), (3,5), (5,1), (5,3), (5,5)$

$B \cap C = (2,1), (4,1), (6,1), (2,3), (4,3), (6,3), (2,5), (4,5), (6,5)$

$A \cap C = (1,2), (1,4), (1,6), (3,2), (3,4), (3,6), (5,2), (5,4), (5,6)$

If Both dice have odd value then sum won't be odd

Hence $P(A \cap B \cap C) = 0$ = Null $\neq P(A) \cdot P(B) \cdot P(C)$

Hence A, B, C are mutualy not independent events.

6

Q.1 (c) What are metamaterials? State characteristics of different types of metamaterials.

[12 marks]

Ans(c) The prefix 'meta' indicates that characteristics of material are beyond what we see in nature. Metamaterials are artifically crafted composite materials that derive their properties from internal micro-structure rather than chemical composition found in natural materials

- By engineering the arrangement of these nanoscale unit cell into desired architecture or geometry, one can tune the refractive index of the metamaterial to positive, near zero or negative refractive values.
- Thus metamaterials endowed properties and functionalities unattainable in natural materials

Characteristics of different type of metamaterials are :→

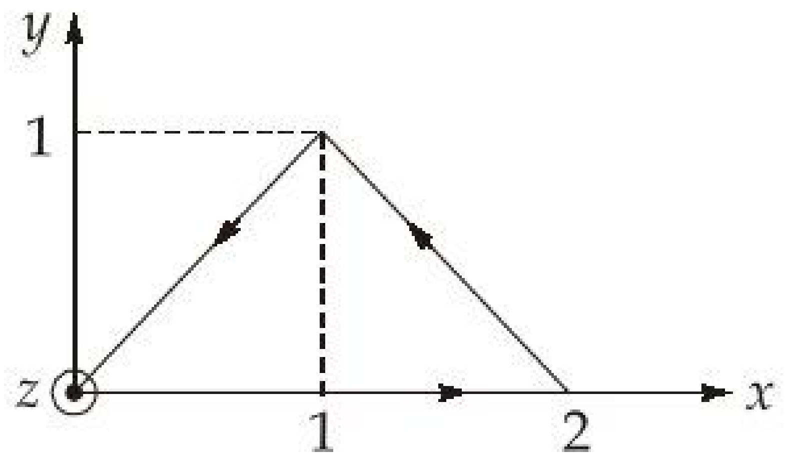
1. Negative Refraction :→ In some metamaterials, negative refraction occur such that light and other radiations gets bent backwards as it enters the structure.

2. Camouflage :→ optical invisibility camouflage is a technology to make an object seem invisible by causing incident light to avoid the object to avoid the object flow around the object and return undisturbed to its original trajectory

3 Super lens :→ A device that might provide light magnification at levels that dwarf any existing technology.
- Super lens allows to view object much smaller than the roughly 200 nm that regular optical lens would not permit.

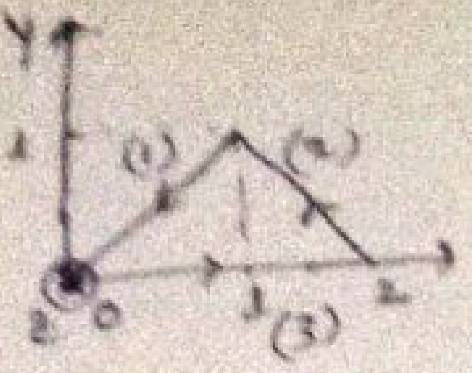
4. Acoustic meta material :→ Metamaterials that can be used to manipulate wave phenomena such as radar, sound, light
- Metamaterials are also able to control environmental sounds and structural vibrations, which have similar waveforms

Q.1 (d) A conducting triangular loop carries a current of 10 A. Find $\vec{H}$ at (0, 0, 5).



[12 marks]

Ans (d)



Point B = (0, 0, 5), I = 10 A, H = ?

$\vec{H}_B = \vec{H}_{B1} + \vec{H}_{B2} + \vec{H}_{B3}$

Now $\vec{H}_{B1} = \frac{I}{4\pi d_1}(\cos\alpha_2 + \cos\alpha_1)\left(\frac{-\hat{a}_x + \hat{a}_y}{\sqrt{2}}\right)$ A/m

where d_1 is perpendicular distance from straight wire

$d_1 = 5$ units. $\alpha_2 = 90$ and $\alpha_1 = \cos^{-1}\frac{\sqrt{2}}{\sqrt{(\sqrt{2})^2+5^2}} = \cos^{-1}\left(\frac{\sqrt{2}}{\sqrt{27}}\right)$

So $\vec{H}_{B1} = \frac{10}{4\pi 5}\left[\cos(90) + \frac{\sqrt{2}}{\sqrt{27}}\right]\left(\frac{-\hat{a}_x + \hat{a}_y}{\sqrt{2}}\right)$ A/m $= 0.0306(-\hat{a}_x + \hat{a}_y)$ A/m

Now similarly $\vec{H}_{B3} = \frac{I}{4\pi d_3}[\cos\alpha_2 + \cos\alpha_1](-\hat{a}_y)$ A/m where $\alpha_1 = 90$ and $\alpha_2 = \cos^{-1}\left[\frac{2}{\sqrt{29}}\right]$

$\Rightarrow \vec{H}_{B3} = \frac{10}{4\pi \times 5}\left[\frac{2}{\sqrt{29}} + \cos 90\right](-\hat{a}_y)$

$\vec{H}_{B3} = -0.0591\hat{a}_y$ A/m

Now from Biot savart law, $\vec{H}_{B2} = \frac{I}{4\pi}\int_{(2,0)}^{(1,1)} \frac{d\vec{l} \times \vec{R}}{R^3}$

$\Rightarrow \vec{H}_{B2} = \frac{I}{4\pi}\int_{(2,0)}^{(1,1)} \frac{(dx\,\hat{a}_x + dy\,\hat{a}_y) \times (-x\hat{a}_x - y\hat{a}_y + 5\hat{a}_z)}{(5^2+x^2+y^2)^{3/2}}$ also $y = 2-x$ — (1)
and $dy = -dx$ — (2)

So, $\vec{H}_{B2} = \frac{10}{4\pi}\int_2^1 \frac{(dx\,\hat{a}_x - dx\,\hat{a}_y) \times (-x\hat{a}_x - (2-x)\hat{a}_y + 5\hat{a}_z)}{(x^2+y^2+5^2)^{3/2}}$

$= \frac{10}{4\pi}\int_2^1 \frac{-5dx\,\hat{a}_x - 5dx\,\hat{a}_y - 2dx\,\hat{a}_z}{(2(x-1)^2+27)^{3/2}}$ [From Eq (1) & (2)]

$\vec{H}_{B2} = \frac{10}{4\pi}\left[\frac{-5(x-1)\hat{a}_x}{27\sqrt{2(x-1)^2+27}} + \frac{-5(x-1)\hat{a}_y}{27\sqrt{2(x-1)^2+27}} + \frac{-2(x-1)\hat{a}_z}{27\sqrt{2(x-1)^2+27}}\right]_2^1$

$= [27.36\hat{a}_x + 27.36\hat{a}_y + 10.95\hat{a}_z] \times 10^{-3}$ A/m

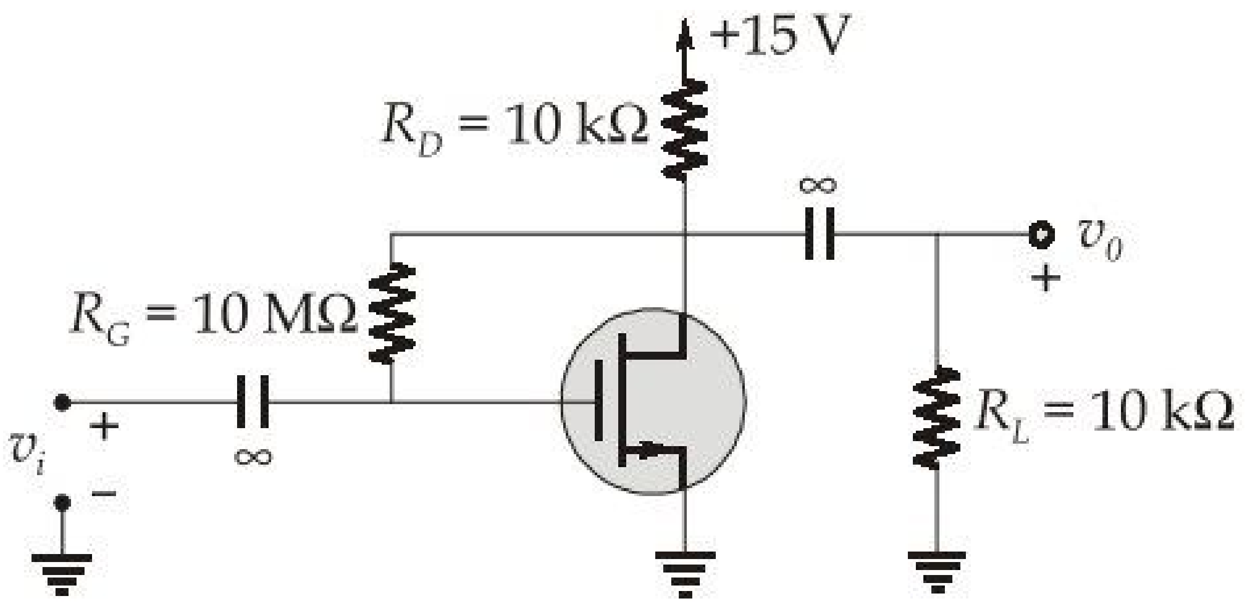
Hence

$H_B = \vec{H}_{B1} + \vec{H}_{B2} + \vec{H}_{B3}$

$= [-3.27\hat{a}_x - 1.11\hat{a}_y + 10.95\hat{a}_z] \times 10^{-3}$ A/m

11

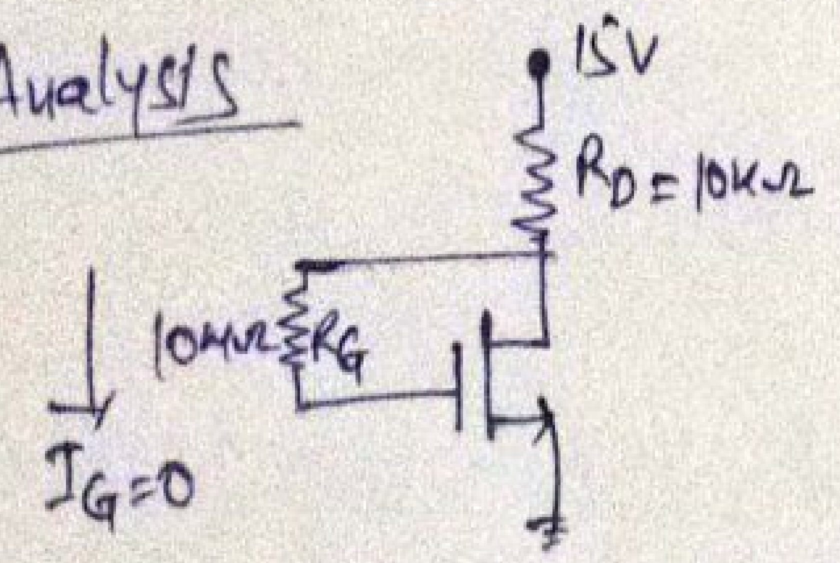
Q.1 (e) For the given amplifier circuit, determine the small-signal voltage gain $\frac{v_0}{v_i}$, input resistance and the largest allowable input signal. The transistor parameters are $V_t = 1.5$ V, $k_n'\left(\frac{W}{L}\right) = 0.25$ mA/V^2 and $V_A = 50$ V.



[12 marks]

Ans 1(e) Given, $V_t = 1.5$ V, $K_n'(W/L) = 0.25$ mA/V^2 and $V_A = 50$

DC Analysis



$\therefore V_{DS} = V_{GS}$

& $V_{DS} > V_{GS} - V_t$ Hence it is operating in saturation region

Also $I_D = \frac{1}{2} K_n'(W/L)(V_{GS} - V_t)^2 = \frac{1}{2} \times 0.25 \times 10^{-3} \times (V_{DS} - 1.5)^2$ ——— (1)

Do not write in this margin

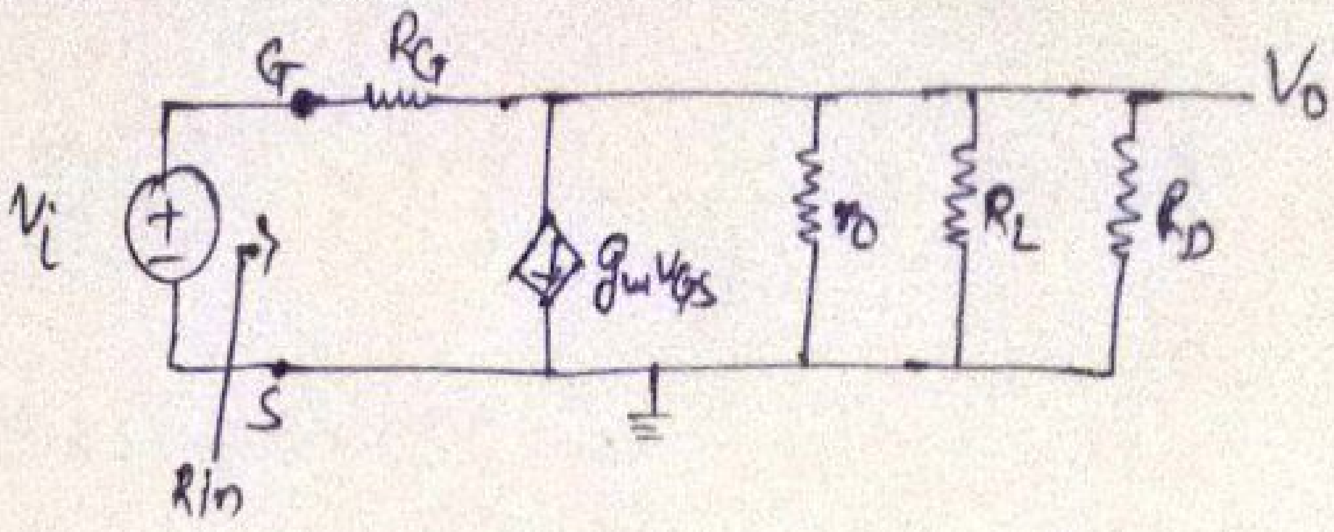
and $15 - I_D R_D = V_{DS} \Rightarrow V_{DS} = 15 - I_D \times 10 \times 10^3$ ⟵ (2)

From Eq (1) & (2) $I_D = 1.06\,mA$ and $V_D = 4.4V$

Now output resistance $r_o = \frac{V_A}{I_D} = \frac{50}{1.06} = 47.17\,k\Omega$

$g_m = k_n'\left(\frac{W}{L}\right)(V_{GS} - V_t) = 0.25\,(4.4 - 1.5) \times 10^{-3} = 0.725\,mA/V$

Small Signal Equivalent circuit



So, Voltage gain, $A_V = \frac{V_o}{V_i}$

But $V_{gs} = V_i$ So $A_V = -g_m\,(R_L \| r_o \| R_D)$

$\Rightarrow \frac{V_o}{V_i} = A_V = -0.725\,(10K \| 47.17K \| 10k\Omega)$

$= -3.27\ V/V$

Input resistance, $R_{in} = \frac{V_i}{I_i} \Rightarrow \frac{V_i}{\frac{V_i - V_o}{R_G}} \Rightarrow \frac{R_G}{1 - \left(\frac{V_o}{V_i}\right)} = \frac{10}{1-(-3.27)}$

$= 2.34\,M\Omega$

To keep MOSFET in saturation, $V_{DS} \geq V_{GS} - V_t$

$\Rightarrow \cancel{V_{DS}} + A_V V_{i_{max}} = \cancel{V_{GS}} + V_{i_{max}} - V_t$ $[\because V_{DS} = V_{GS}]$

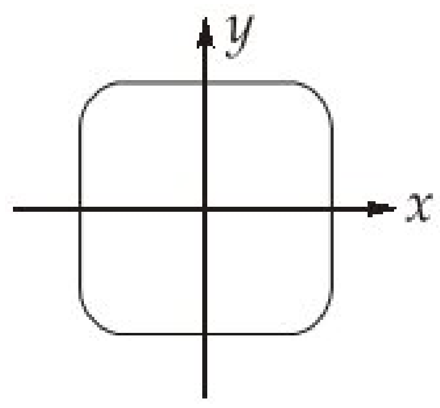
$\Rightarrow V_{i_{max}} = \frac{V_t}{1 - A_V} = \frac{1.5}{1 + 3.27} = 0.351\ Volt$

10

Do not write in this margin

Q.2 (a) **(i)** For the pseudo square $x^4 + y^4 = 1$, calculate the area A.

$\left(\Gamma\left(\frac{1}{4}\right) = 3.626\right)$



(ii) Use Euler's method to estimate the value at $x = 1.5$ of the solution of $\frac{dy}{dx} = y' = y^2 - x^2$ for which initial value of y is –1. Take step size 0.5.

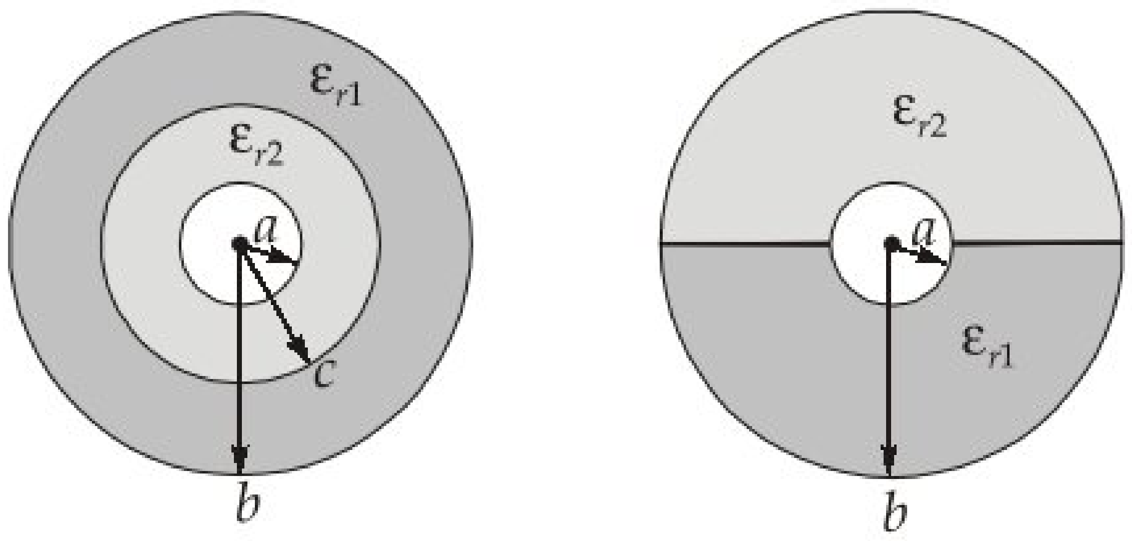
[14 + 6 marks]

Q.2 (b) **(i)** Given $\vec{H}_1 = 2\hat{a}_x + 6\hat{a}_y + 4\hat{a}_z$ A/m in the region $y - x \leq 2$ where $\mu_1 = 5\mu_0$. Calculate:

1. $\vec{M}_1$ and $\vec{B}_1$.
2. $\vec{H}_2$, $\vec{M}_2$ and $\vec{B}_2$ in region $y - x \geq 2$, where $\mu_2 = 2\mu_0$.

(ii) The figure represents the cross section of two spherical capacitors, determine their equivalent capacitance.

$a = 1$ mm, $b = 3$ mm, $c = 2$ mm, $\varepsilon_{r1} = 2.5$, $\varepsilon_{r2} = 3.5$



[12 + 8 marks]

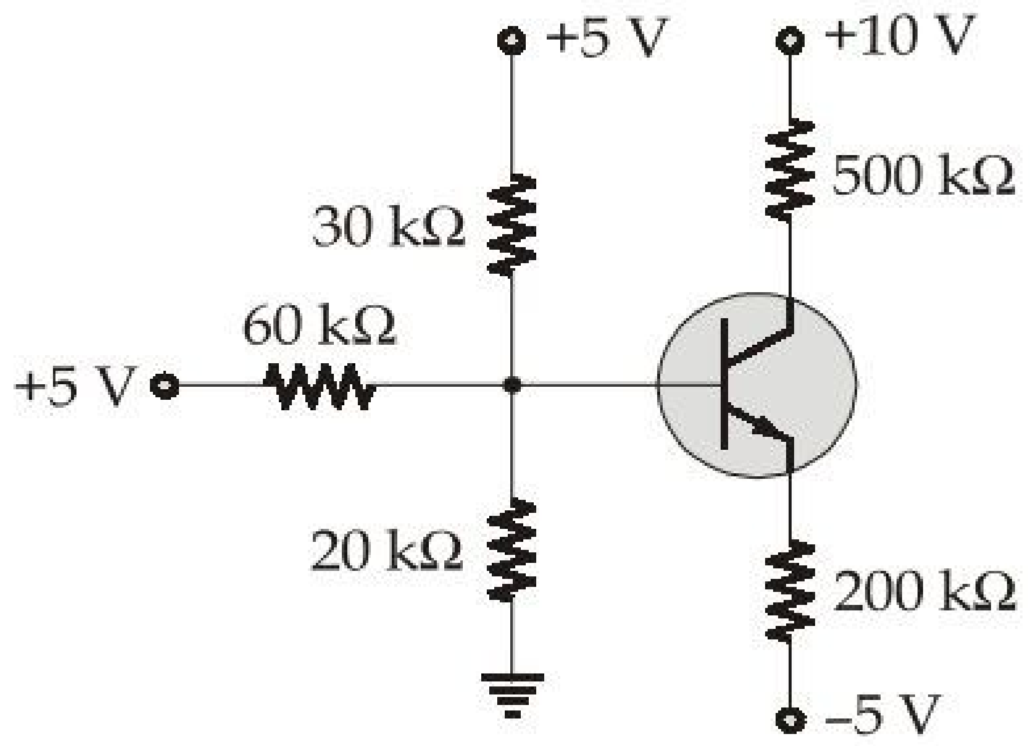
Do not write in this margin

Q.2 (c) A balanced, three-phase delta-connected load on a 400 V, 50 Hz supply has an impedance of $5 + j7\ \Omega$/phase. The current coil of a watthour meter W_1 is connected in the line R and that of a watthour meter W_2 in line Y. The volt coils of the two instruments have a common connection on line B, but have their terminals cross-connected, i.e. the volt coil of W_1 is connected to line Y and that of W_2 to line R. Show that the reactive kVAh of the load may be determined from the reading of either watt hour meter, and calculate the watthour meter reading and the total reactive kVAh if the time interval is 1 hour. Would this method apply to an unbalanced load?

[20 marks]

Do not write in this margin

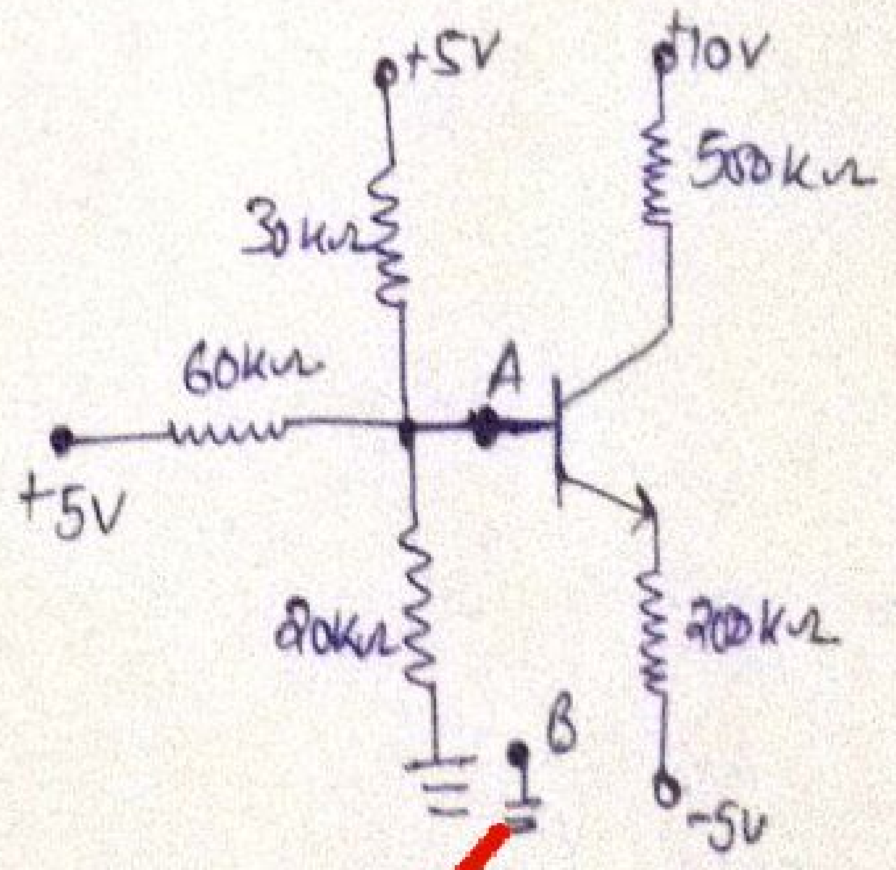
Q.3 (a) The transistor of the circuit, shown in the figure below, is made up of silicon and it has $\beta = 99$, and $V_{BE(active)} = 0.7$ V. Determine the value of I_{CQ}. Assume that the leakage current I_{CO} is negligible.

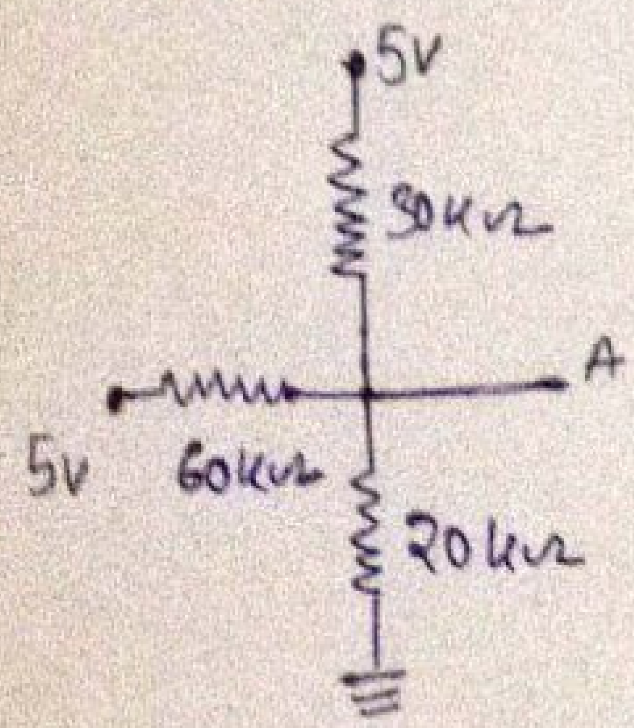


[20 marks]

Ans 3(a) Given, $\beta = 99$, $V_{BE} = 0.7V$, $I_{CQ} = ?$

Calculate thevenin Equivalent between terminal A-B.



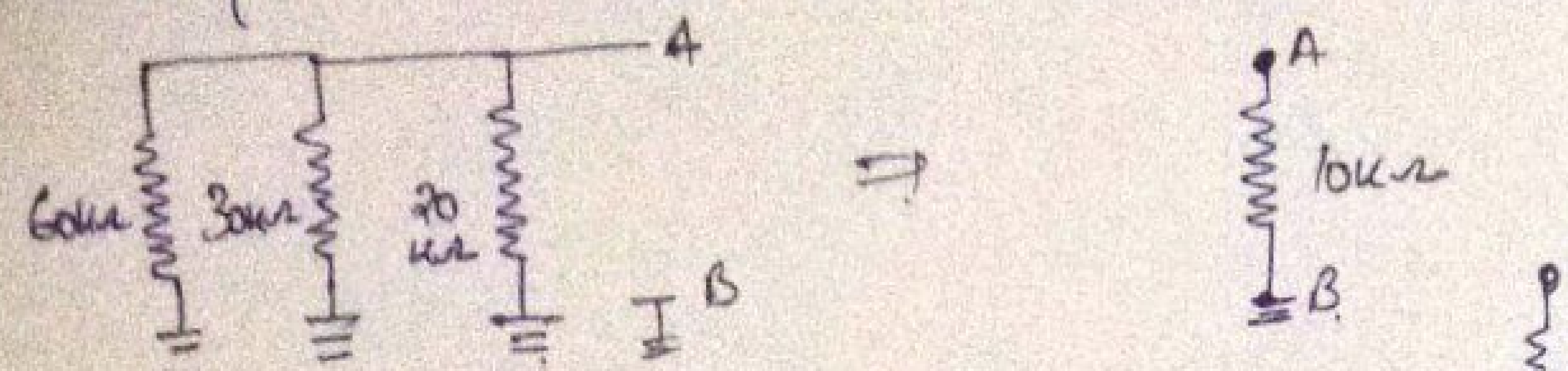


Applying KCL at Node A

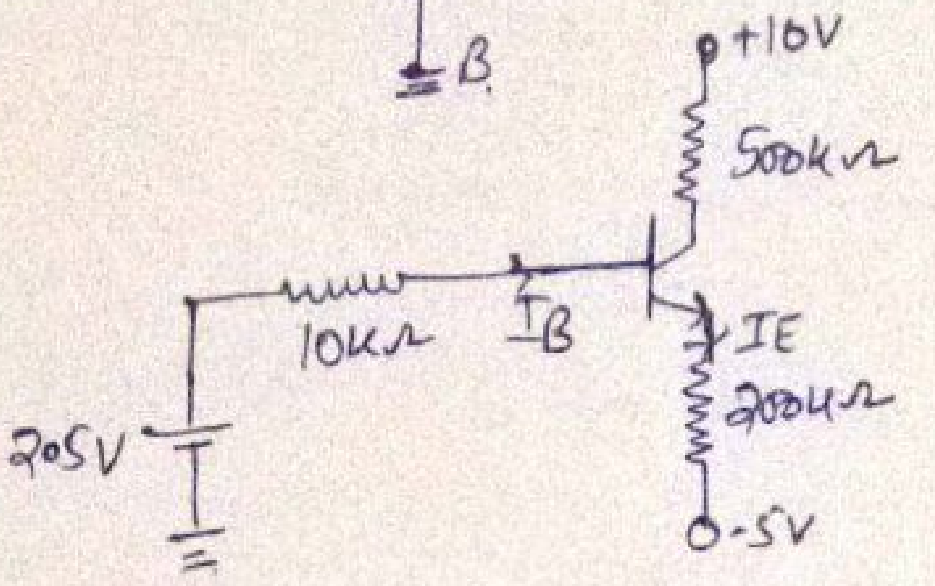
$$\frac{V_A - 5}{60k\Omega} + \frac{V_A - 0}{20k\Omega} + \frac{V_A - 5}{30k\Omega} = 0$$

$$\Rightarrow V_A\left[\frac{1}{60k\Omega} + \frac{1}{20k\Omega} + \frac{1}{30k\Omega}\right] = 5\left[\frac{1}{60k\Omega} + \frac{1}{30k\Omega}\right], \quad \boxed{V_A = 2.5V}$$

and Equivalent thevenin Resistance, $R_{th} = 10k\Omega$



Hence Equivalent Circuit would be



Applying KVL in the Base Emitter loop

$2.5 - 0.7 - (10k \times I_B) - (200k \times I_E) = -5V$

$\Rightarrow \quad 6.8 = (10 I_B + 200 \times I_E) \times 10^3 \quad —— (1)$

Also $I_E = I_B + I_C = I_B + \beta I_B = (\beta+1) I_B \quad —— (2)$

$\Rightarrow$ put this in Eq (1), $6.8 = [10 + 200 \times (99+1)] I_B \times 10^3$

$\Rightarrow \quad I_B = 3.398 \times 10^{-7}$ Amps $= 0.3398\ \mu A$.

$\Rightarrow$ So, Collector current $I_{C} = \beta \times I_B = 99 \times 0.3398 \times 10^{-6}$

$\boxed{I_C = 33.64\ \mu A}$

12

So, Collector, voltage $V_C = V_{CC} - I_C \times R_C$

$= 10 - 500 \times 10^3 \times 33.64 \times 10^{-6}$

$\boxed{V_C = -6.82 \text{ Volts}}$

Base Voltage $V_B = 2.5$ Volts

So $V_{CB} = V_C - V_B = -9.32$ Volts which in forward bias

So, BJT is in Saturation therefore $V_{CE} = 0.2$ Volts

Hence $10 - 500 \times 10^3 \times I_{CQ_{sat}} - 0.2 - 200 \times 10^3 \times I_{CQ_{sat}} = -5V$.

$\Rightarrow \quad \boxed{I_{CQ_{sat}} = 21.142\ \mu A}$

Hence BJT operating in Saturation Region with $I_{CQ_{sat}} = 21.142$ Amps.

Q.3 (b) Let $P(D) = D^2 + bD + 5$, where $D = \dfrac{d}{dt}$.

(i) For what range of the values of b will the solution to $P(D)y = 0$ exhibit oscillatory behavior?

(ii) For $b = 4$, solve the DE's.

1. $P(D)y = 4\,e^{2t} \sin t$ 2. $P(D)y = 4\,e^{2t} \cos t$

(iii) For $b = 2$, what ω does $P(D)y = \cos \omega t$ have the biggest response?

[4 + 10 + 6 marks]

Ans 3 (b) Given $P(D) = D^2 + bD + 5$ where $\frac{d}{dt} = D$

(i) Solution of $P(D)y = 0$ for oscillatory behaviour

$$D = \frac{-b \pm \sqrt{b^2 - 4\times1\times5}}{2} = -\frac{b}{2} \pm \frac{1}{2}\sqrt{b^2-20}$$

So, for real solution of D, $b^2 \geq 20$

or $b \geq 4.472$

Hence for oscillatory behaviour $b < 4.472$

also $b > 0$

Hence range for oscillatory behaviour $0 < b < 4.472$

(ii) (i) $P(D)y = 4e^{2t}\sin t$ given, $b = 4$

Complementary Solution

$P(D)y = 0$, $\Rightarrow D^2 + 4D + 5 = 0$

$D = -2-i, -2+i$

Hence complementary solution be $y = e^{-2t}[C_1 \cos t + C_2 \sin t]$ —— ①

Particular Solution

$$y = \frac{4e^{2t}\sin t}{D^2+4D+5} \Rightarrow 4e^{2t}\frac{\sin t}{(D+2)^2 + 4(D+2) + 5}$$

$$y = 4e^{2t}\frac{\sin t}{D^2+4+4D+4D+8+5} \Rightarrow 4e^{2t}\frac{\sin t}{D^2+8D+17}$$

$$y = 4e^{2t}\frac{\sin t}{-1+17+8D} \Rightarrow 4e^{2t}\frac{\sin t}{8D+16} \Rightarrow \frac{1}{2}e^{2t}\frac{\sin t}{(D+2)} \times \frac{D-2}{(D-2)}$$

Do not write in this margin

$\frac{1}{2} e^{2t} \frac{(D-2)\sin t}{D^2-4} \Rightarrow \frac{1}{2} e^{2t} \frac{(D-2)\sin t}{-1-4}$ $(\because D^2=-1)$

$\Rightarrow -\frac{1}{10} e^{2t}[\cos t - 2\sin t] \Rightarrow \frac{1}{10} e^{2t}[2\sin t - \cos t]$

So, complete solution, $y = C.I. + P.I.$

$y = e^{-2t}[C_1\cos t + C_2 \sin t] + \frac{1}{10} e^{2t}[2\sin t - \cos t]$

(ii) complementary solution would be same as in part (i) — Given $P(D)y = 4e^{2t}\cos t$

So $y = e^{-2t}[C_1 \cos t + C_2 \sin t]$

Particular solution

$P(D)y = 4e^{2t}\cos t \Rightarrow y = \frac{4 e^{2t}\cos t}{D^2+4D+5}$

$\Rightarrow y = 4e^{2t}\frac{\cos t}{(D+2)^2 + 4(D+2)+5} = 4e^{2t}\frac{\cos t}{D^2+4+4D+4D+8+5}$

$\Rightarrow y = 4e^{2t}\frac{\cos t}{D^2+8D+17} \Rightarrow 4e^{2t}\frac{\cos t}{-1+8D+17} \Rightarrow \frac{1}{2}e^{2t}\frac{\cos t}{(D+2)}$

$y = \frac{1}{2}e^{2t}\frac{(D-2)}{D^2-4}\cos t \Rightarrow \frac{1}{2}e^{2t}\frac{(D-2)\cos t}{-1^2-4} = \frac{-1}{10}e^{2t}(D-2)\cos t$

$\Rightarrow y = \frac{-1}{10}e^{2t}[-\sin t - 2\cos t] \Rightarrow \frac{1}{10}e^{2t}[\sin t + 2\cos t]$

So complete solution, $y = P.I. + C.I.$

$\Rightarrow y = e^{-2t}[C_1\cos t + C_2 \sin t] + \frac{1}{10}e^{2t}[\sin t + 2\cos t]$

(iii) for $b=2$, $P(D)y = \cos\omega t$ taking $y = Re[z]$

So $P(D)z = e^{j\omega t} \Rightarrow z = \frac{e^{j\omega t}}{D^2+2D+5} = \frac{e^{j\omega t}}{-\omega^2+5+2j\omega}$

$\Rightarrow z = \frac{e^{j\omega t}}{(5-\omega^2)+2j\omega} = \frac{e^{j\omega t}}{\sqrt{(5-\omega^2)^2+(2\omega)^2}\angle \tan^{-1}\frac{2\omega}{5-\omega^2}}$

So, Magnitude $x = \frac{1}{\sqrt{(5-\omega^2)^2+(2\omega)^2}}$

To find maximum so $\frac{dx}{d\omega} = 0 = \frac{d}{d\omega}\frac{1}{\sqrt{(5-\omega^2)^2+4\omega^2}}$

$\Rightarrow \boxed{\omega = \sqrt{3}\ \text{rad/s}}$

Do not write in this margin

Q.3 (c) **(i)** Consider a solid containing N identical atoms per m^3, the polarizability of the atoms is 'α' Farad m^2. Assuming a Lorentz internal field, derive the Clausius-Mossotti relation.

(ii) A specimen of pure annealed copper has a resistivity of 1.56×10^{-8} ohm-m at 300 K. If nickel is added to copper, the resistivity increases by 1.25×10^{-8} ohm-m per added atomic percent nickel. Similarly, silver increases the resistivity of copper by 0.14×10^{-8} ohm-m per added atomic percent. For an alloy of 0.2 atomic percent nickel and 0.4 atomic percent silver in copper, what is the theoretical resistivity of the alloy at 300 K and 4 K ?

[10 + 10 marks]

Ans 3 (c) (i) As we know that $\vec{P} = N\alpha \vec{E_i}$ —— ①

where, α = Polarizibility of atom, N = No. of atom/m^3

and $\vec{E_i}$ = Lorentz internal field and $\vec{P}$ = Polarization.

Also, we know $\vec{E_i} = \vec{E} + \frac{\vec{P}}{3\varepsilon_0}$, where $\vec{E}$ = Electric field external —— ②

So from Eq ① & ② Put Value of E_i from ② put in Eq ①

$\vec{P} = N\alpha\left[\vec{E} + \frac{\vec{P}}{3\varepsilon_0}\right] \Rightarrow \vec{P} = N\alpha\vec{E} + \frac{N\alpha\vec{P}}{3\varepsilon_0}$

$\Rightarrow \vec{P}\left[1 - \frac{N\alpha}{3\varepsilon_0}\right] = N\alpha\vec{E} \Rightarrow \frac{\vec{P}}{\vec{E}} = \frac{N\alpha}{1 - \frac{N\alpha}{3\varepsilon_0}} = \varepsilon_0(\varepsilon_r - 1)$

$\Rightarrow \varepsilon_r - 1 = \frac{N\alpha/\varepsilon_0}{1 - \frac{N\alpha}{3\varepsilon_0}}$ —— ③ where ε_r = relative permittivity.

Now Add 3 both sides in Eq ③

$\varepsilon_r - 1 + 3 = \frac{\frac{N\alpha}{\varepsilon_0}}{1 - \frac{N\alpha}{3\varepsilon_0}} + 3 \Rightarrow \varepsilon_r + 2 = \frac{\frac{N\alpha}{\varepsilon_0} + 3 - \frac{N\alpha}{\varepsilon_0}}{1 - \frac{N\alpha}{3\varepsilon_0}}$

$\Rightarrow \varepsilon_r + 2 = \frac{3}{1 - \frac{N\alpha}{3\varepsilon_0}}$ —— ④

Divide Eq ③ by Eq ④ we get

$$\boxed{\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N\alpha}{3\varepsilon_0}} \rightarrow \text{Clausius Mosotti Equation.}$$

(ii) $\rho_{Cu} = 1.56 \times 10^{-8}$ Ω-m at 300K, $\rho_{Ni\text{-}Cu} = 1.25 \times 10^{-8}$ ohm-m / % Ni

$\rho_{Si\text{-}Cu} = 0.14 \times 10^{-8}$ ohm-m / added % Silver

$\therefore \rho_{Total} = \rho_{Cu} + \rho_{Ni-Cu} + \rho_{Si-Cu}$

$\rho_{Total}\big|_{300K} = 1.56 \times 10^{-8} + 1.25 \times 10^{-8} \times 0.2 + 0.14 \times 10^{-8} \times 0.4$

$\boxed{\rho_{Total}\big|_{300K} = 1.866 \text{ ohm-m}}$

$\therefore \rho_R$ = Residual resistivity independent of temp $= 1.25 \times 10^{-8} \times 0.2 + 0.14 \times 10^{-8} \times 0.4$

$\boxed{\rho_R = 0.306 \times 10^{-8} \ \Omega\text{-m}}$

As temperature coefficient of Cu $= \alpha = 0.004/°C$

and $\rho_{CuT_1} = \rho_{CuT_2} [1 + \alpha(\Delta T)]$

$\Rightarrow \rho_{Cu}\big|_{4K} = \rho_{Cu\,300K} [1 + 0.004 [-242]]$

$\rho_{Cu\,4K} = 1.56 \times 10^{-8} [0.032] = 0.04992 \times 10^{-8} \ \Omega\text{-m}$

Hence $\rho_{Total\ at\ 4K} = \rho_{Cu4K} + \rho_R$

$= (0.04992 + 0.306) \times 10^{-8} \ \Omega\text{-m}.$

$\boxed{\rho_{4K} = 0.356 \times 10^{-8} \ \Omega\text{-m}}$

Hence resistivity at 4K is less than resistivity at 300K

$\therefore$ Cu is metal and its resistivity increases at temperature increase and residual resistivity independent of temp.

12

Q.4 (a) **(i)** What is an operating system? What all tasks does it perform?

(ii) Consider a pipeline having 4 phases with duration 60, 50, 90 and 80 nS. Given latch delay is 10 ns.

Calculate:

1. Speed up ratio.
2. Pipeline and non-pipeline time to perform 1000 tasks.
3. Throughput for pipelined execution.

[8 + 12 marks]

Ans4 (a) Operating System:→ It is a software installed in the computer which interfaces between user and hardware. If it's not install then user have to write seperate program for each & individual operation he/she has to perform on the hardware.

It also facilitates Memory management, Process management etc.

Task performs by OS are:→

1> Creation:→ It help user to provide various editing and debugging facility by providing an interface to create a program.

2> File Management:→ It maintains file table system and manage hard disk storage and keep file in a systematic way.

3> Memory management:→ To speed up the performance of CPU, OS regulates the memory so that CPU utilization increase also it ensures that CPU won't be overloaded also.

4> I/O Access:→ OS takes care of I/O by providing required control signal to I/O in which each require it's own set of control signals.

Error detection & correction :→ OS detects various error which would be generated in the computer and acknowledge user necessary information and also provide required solution for the same.

Ans 4 (b) (ii)

Cycle time for Non Pipeline , $T_{NP} = 60ns + 50ns + 90ns + 80ns$
$= 280ns$

And cycle time for pipeline , $T_p = Max(60, 50, 90, 80)ns$ + Delay time

$T_p = 90ns + 10ns = 100ns$

So Speed up $= \frac{T_{NP}}{T_p} = \frac{280ns}{100ns} = 2.8$

Non pipeline execution time for 1000 tasks ⇒ $ET_{NP} = 1000 \times 280 \times 10^{-9}$
$= 280 \mu s$

for Pipeline execution time for 1000 tasks ⇒ ET_p = Time taken for 1st task + Time taken for 999 task

$ET_p = 1 \times 4T + 999 \times T$
$= 4 \times 100 \times 10^{-9} + 999 \times 100 \times 10^{-9} = 100.3 \mu s$

3. Through put for pipeline execution = $\frac{\text{No. of instruction executed}}{\text{Time taken}}$

$= \frac{1000}{100.3 \mu s} = 9.97$ task/µsec.

6

 Do not write in this margin

Q.4 (b) **(i)** A current transformer with a bar primary has 300 turns in its secondary winding. With 5 A flowing in the secondary winding, the magnetizing mmf is 100 A and iron loss is 1.2 W. Determine the ratio and phase angle errors. Given that the resistance and reactance of the secondary circuit are 1.5 Ω and 1 Ω respectively, including the transformer winding.

(ii) Discuss methods and design features to reduce errors in C.T.

[12 + 8 marks]

Ans 4 (b) Given $\frac{N_s}{N_p} = 300$

Secondary burden, $z = \sqrt{1.5^2 + 1^2} = 1.803\ \Omega$

and $\cos\delta = \frac{1.5}{1.803} = \frac{\text{Resistance}}{\text{Impedance}} = 0.832$

So $\sin\delta = \sqrt{1 - \cos^2\delta} = 0.554$

Given secondary current = 5 Ampe

So voltage across secondary circuit, $V_s = I_s \times Z = 5 \times 1.803 = 9.01V$

So, Primary induced Emf, $V_p = \frac{V_s \times N_p}{N_s} = \frac{9.01}{300} = 0.03V$

Therefore ∴ Iron loss $= V_p \cdot I_c \Rightarrow 1.2 = 0.03 \times I_c$

$\Rightarrow I_c = \frac{1.2}{0.03} = 40A$

Given magnetizing MMF = 100 AT So $I_m = \frac{MMF}{N_p} = \frac{100}{1} = 100A$

So Actual Ratio, $R = n + \frac{I_c \cos\delta + I_m \sin\delta}{I_s}$

$\Rightarrow R = 300 + \frac{40 \times 0.832 + 100 \times 0.554}{5} = 317.736$

and Nominal Ratio, $K_n = 300$

So Ratio error $= \frac{K_n - R}{R} \times 100 = \frac{-317.736 + 300}{317.736} \times 100$

$\Rightarrow$ Ratio error $= -5.582\%$

Now, Phase angle error $= \theta = \frac{180}{\pi}\left(\frac{I_m \cos\delta - I_c \sin\delta}{n I_s}\right)$

$\Rightarrow \theta = \frac{180}{\pi}\left(\frac{100 \times 0.832 - 40 \times 0.554}{300 \times 5}\right) = 2.33°$

(ii) Methods and design to reduce CT errors are:→

1) Reduce leakage reactance by increasing linkage between primary and secondary winding.

2) Excitation MMF should be small in comparision to primary MMF. Hence single turn primary winding is used i.e. $N_p = 1$.

3) Provision for turn compensation so that nominal ratio and actual ratio should be as close as possible to reduce ratio error i.e. $\boxed{K_n \approx R}$

4) Widlar Compensation:→ Here auxillary secondary turns passed through hole of core and it is in series with secondary winding. It provides improved phase or phase error reduced.

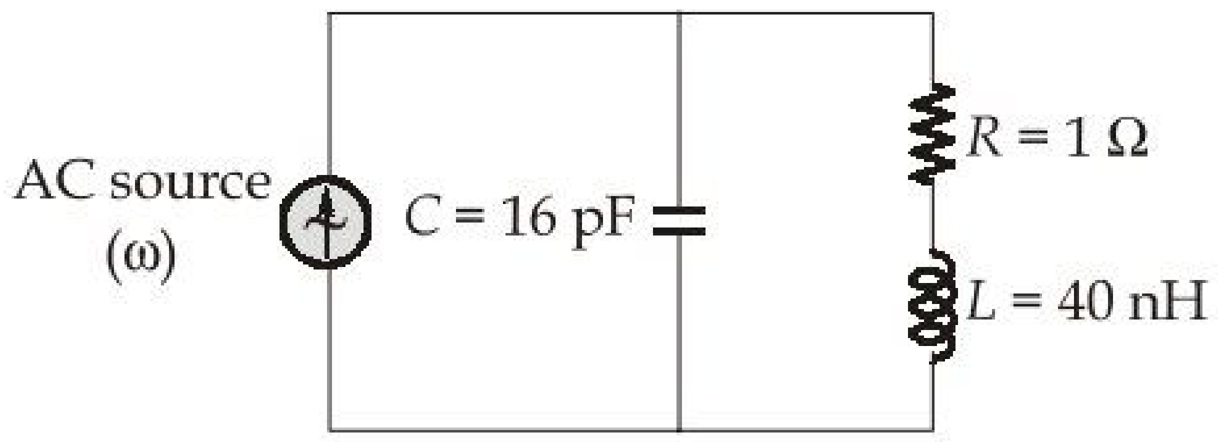
5) High permeability material is used such as Mumetal (76% Ni) So that less magnetizing current is needed.

6) Toroidal cores should be used to get high flux linkage between primary and secondary.

15

Q.4 (c) **(i)** For the given RLC circuit.

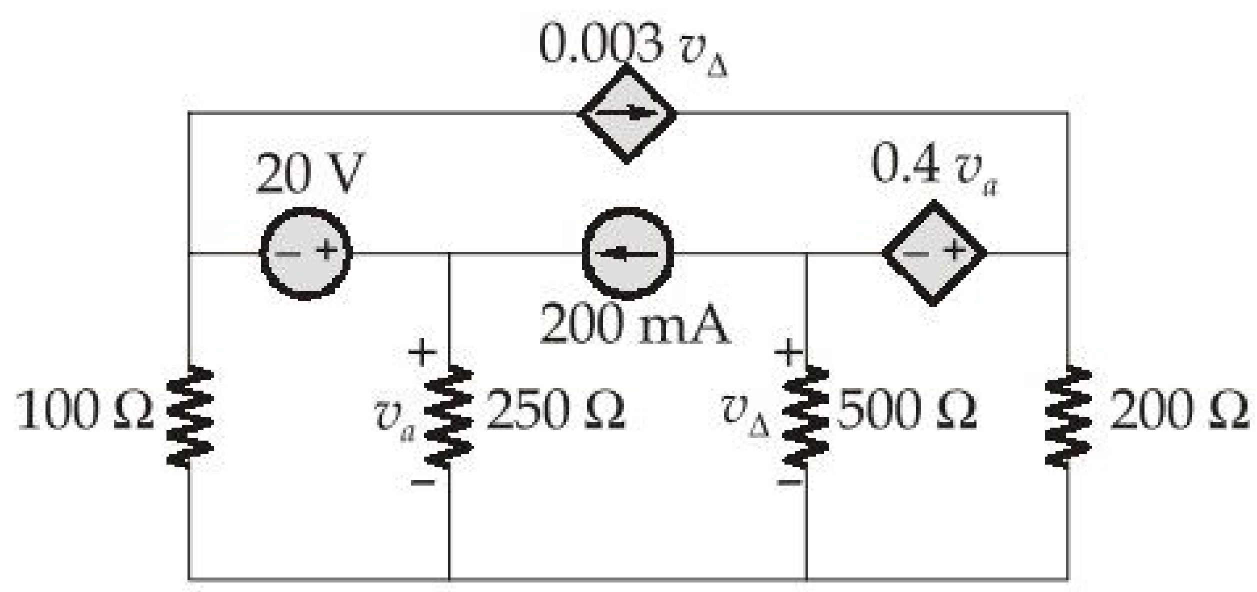
1. Plot the real and imaginary part of impedance Z_{eq} of the circuit as a function of frequency ω.
2. Find the frequency at which real part of the impedance reaches its maximum and also $\{R_{eq}\}_{max}$ value.
3. Find the quality factor Q.



(ii) For the given circuit, determine the power absorbed by the independent voltage source using

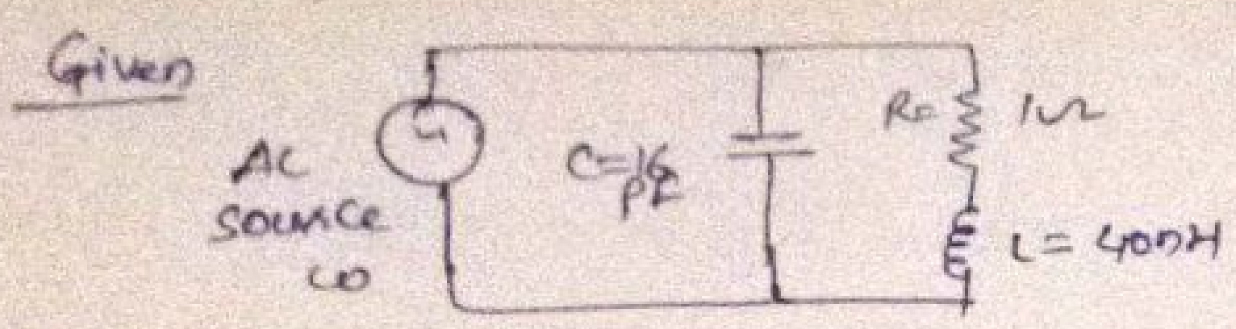
(a) Mesh current method

(b) Node voltage method.



[12 + 8 marks]

Ans 4(c)(i) Given



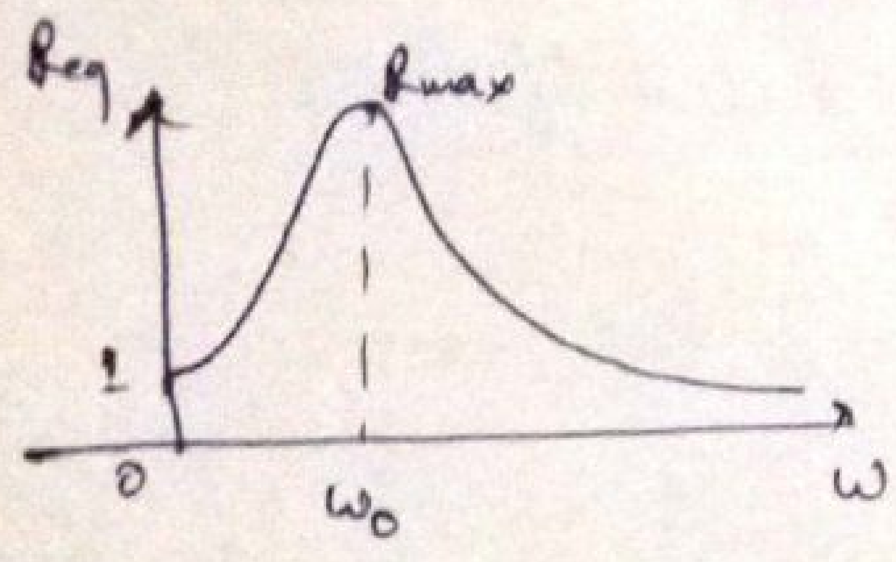
$\Rightarrow X_C = \frac{1}{j\omega C}\,\Omega$ & $X_L = j\omega L$ so $Z_{RL} = R + j\omega L$

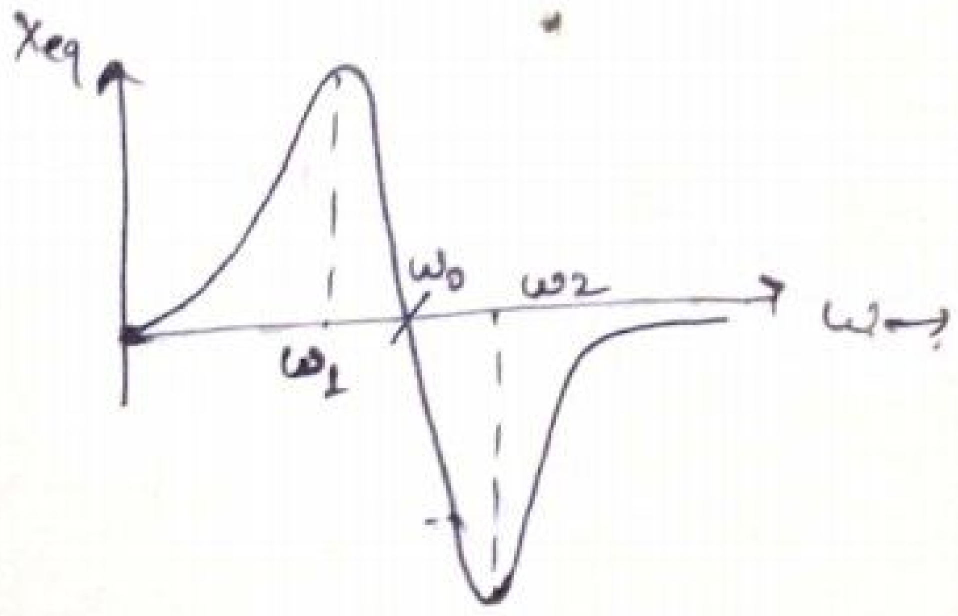
So, $Z_{eq} = \dfrac{(R+j\omega L)\times\frac{1}{j\omega C}}{R+j\omega L+\frac{1}{j\omega C}} \Rightarrow \dfrac{R+j\omega L}{(R+j\omega L)j\omega C+1}$

$\Rightarrow Z_{eq} = \dfrac{(R+j\omega L)}{(1-\omega^2 LC)+j\omega RC} \times \dfrac{(1-\omega^2 LC)-j\omega RC}{(1-\omega^2 LC)-j\omega RC}$

$\Rightarrow Z_{eq} = \dfrac{(1-\omega^2 LC)R+\omega^2 LRC}{(1-\omega^2 LC)^2+(\omega^2 R^2 C^2)} + j\,\dfrac{\omega L(1-\omega^2 LC)-\omega R^2 C}{(1-\omega^2 LC)^2+(\omega RC)^2}$

$Z_{eq} = \underbrace{\dfrac{\left(\frac{1}{\omega^2}-LC\right)R + LCR}{\omega^2\left(\frac{1}{\omega^2}-LC\right)^2+(RC)^2}}_{\text{Real part}} + j\,\underbrace{\dfrac{\frac{L}{\omega}(1-\omega^2 RC) - R^2C}{\omega^2\left(\frac{1}{\omega^2}-LC\right)^2+(RC)^2}}_{\text{Imaginary part}}$





At resonance frequency $\omega = \omega_0$, $Re[Z]|_{max}$ So put $X_{eq}(\omega=\omega_0) = 0$

$$\Rightarrow \omega_0 = \sqrt{\frac{L - R^2C}{L^2C}} = \sqrt{\frac{40\times10^{-9} - 1\times16\times10^{-12}}{(40\times10^{-9})^2\times16\times10^{-12}}}$$

$$\omega_0 = 1.24975\times10^{9}\ HZ = 1.24795\ GHZ$$

Put $\omega=\omega_0$, $Re(Z) \Rightarrow (R_{eq})_{max} = \frac{R}{(1-\omega^2LC)^2 + (\omega RC)^2}$

$$\Rightarrow R_{eq} = \frac{1}{\left(1-(1.24795\times10^9)^2\times40\times10^{-9}\times16\times10^{-12}\right)^2 + \left(1.24795\times10^9\times1\times16\times10^{-12}\right)^2}$$

$$\Rightarrow R_{eq} = 2500\,\Omega$$

3. Quality factor $= \frac{\omega_0}{\Delta\omega} = \frac{\omega_0}{\omega_2-\omega_1}$ — (1)

Now At ω_1 or ω_2, $|Z| = \frac{R_{eq\,max}}{\sqrt{2}} = \frac{2500}{\sqrt{2}}$

$$\Rightarrow \sqrt{\frac{1+(\omega\times4\times10^{-8})^2}{(1-\omega^2\times64\times10^{-20})^2+(\omega\times16\times10^{-12})^2}} = \frac{2500}{\sqrt{2}}$$

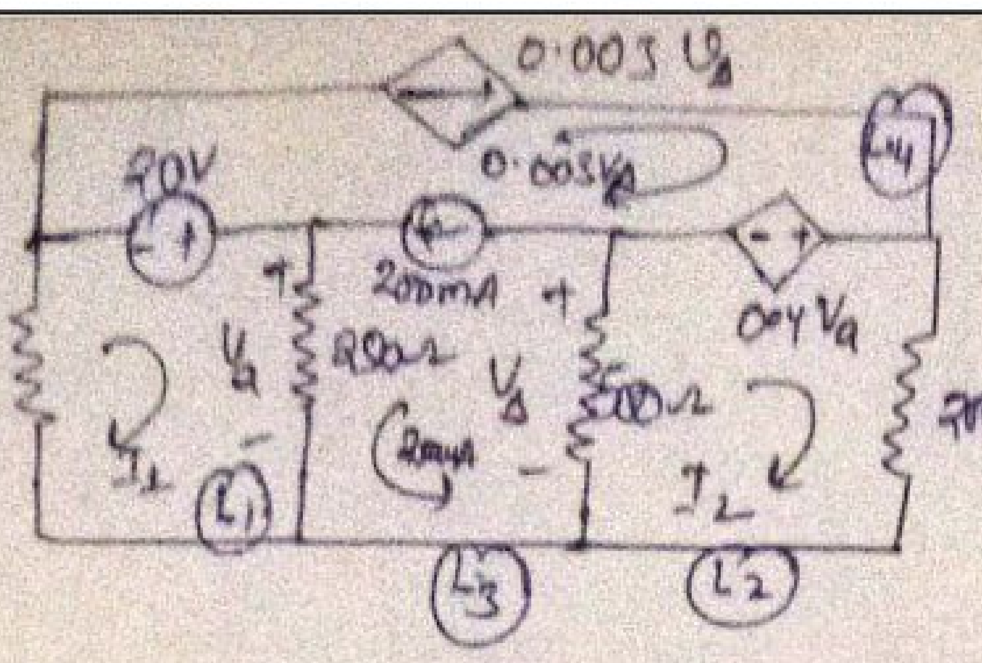
$\Rightarrow$ On Calculation, $\omega_2 = 1.26257\times10^{9}\ HZ$

and $\omega_1 = 1.23756\ GHZ$

So from Eq (1) Quality factor $= \frac{1.24795}{1.26257 - 1.23756}$

$$\Rightarrow \boxed{Q = 49.89}$$

Ans 4 (c)(ii) Given



(a) Mesh Method

Applying KVL in loop 1 we get

$20 = V_a + 100 I_1$ — (1)

Also $V_a = 250\Omega(I_1 + 200\,mA)$ — (2)

Put value of V_a from Eq (2) in Eq (1) we get

$20 = 250 I_1 + 50 + 100 I_1 \Rightarrow$ $\boxed{I_1 = -\frac{3}{35}\text{ Amps}}$

Applying KVL in loop 2

$0.4 V_a = 200 \times I_2 + 500(I_2 + 200\,mA)$

$\Rightarrow 0.4 V_a = 700 I_2 + 100$ — (3)

Put value of I_1 in Eq (2) we get $V_a = 250\left(\frac{-3}{35} + 200\times10^{-3}\right)$

$\Rightarrow$ $\boxed{V_a = 28.57\text{ Volts}}$ — (4)

Put V_a in Eq (3) we get $\Rightarrow 0.4 \times 28.57 = 700 I_2 + 100$

$\Rightarrow I_2 = -0.1265$ Amps

So, $V_\Delta = -(200\times10^{-3} + (-0.1265)\times 500) = -36.75$ Volts.

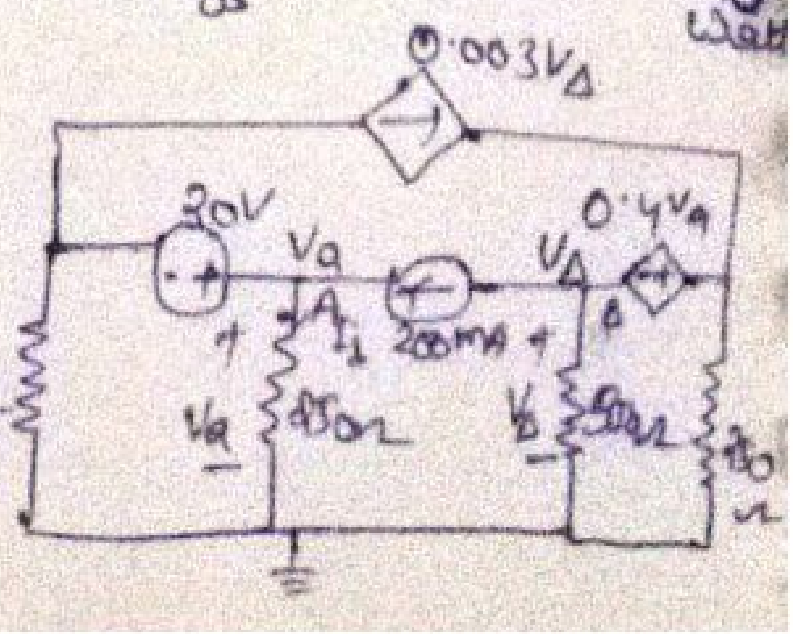
Hence

Power absorbed by 20V source $= 20V \times$ [redacted] $=$ [redacted] $=$ [redacted]

$(-I_1 + 0.003V_\Delta)$ $= 20\left(\frac{3}{35} - 0.003\times36.75\right) = -0.481$ Watt

Hence Power absorbed by 20V source $= -0.0481$ Watts

(b) Node voltage method



Applying KCL at Node A

$\frac{V_a}{250} + \frac{V_a - 20}{100} + 0.003 V_\Delta = 200\times10^{-3} \Rightarrow V_a[250^{-1} + 100^{-1}] = 200\times10^{-3} - 0.03 V_\Delta + 1/5$

$\Rightarrow V_a = \frac{200}{7} - \frac{15}{7} V_\Delta$ —(1)

Applying KCL at Node B, $\frac{V_\Delta}{500} + \frac{V_\Delta + 0.04 V_a}{200} + 200\times10^{-3} = 0.003 V_\Delta$

$\Rightarrow V_\Delta[500^{-1} + 200^{-1} - 0.003] + 200\times10^{-3} = -2\times10^{-3} V_a$

$\Rightarrow V_\Delta + 50 = -0.5 V_a$ —(2)

from Eq (1) & (2).

$V_a =$ 44 Volts and $V_\Delta = -$ 2.75 Volts

So current $I_1 = \frac{V_a}{250\Omega} = \frac{28.57}{250} = 0.11428$ Amps

So current absorbed/taken by 20 V source $= 0.2 - \frac{V_a}{250}$

So, Power absorbed by 20V Source $= 20\left(0.2 - \frac{V_a}{250}\right)$

$= 20\left(0.2 - \frac{44}{250}\right) = 0.48$ watts

Hence Power absored by Independent voltage Source = 0.48 watt.

Section-B

Q.5 (a) $M = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 2 & -1 & -1 \end{bmatrix}, M^{-1} = \frac{1}{12}\begin{bmatrix} 1 & 1 & 4 \\ a & 7 & -8 \\ b & -5 & 4 \end{bmatrix}.$

(i) Compute the determinant of M.

(ii) Find a and b for the matrix M^{-1}.

(iii) Find the solution $\vec{r} = < x, y, z >$ to

$$x + 2y + 3z = 0$$
$$3x + 2y + z = t$$
$$2x - y - z = 3$$

as a function of t.

(iv) Compute $\vec{v} = \frac{d\vec{r}}{dt}$.

[2 + 4 + 4 + 2 marks]

Ans 5 (a) $M = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 2 & -1 & -1 \end{bmatrix}$, $M^{-1} = \frac{1}{12}\begin{bmatrix} 1 & 1 & 4 \\ a & 7 & -8 \\ b & -5 & 4 \end{bmatrix}$

(a) determinant of M, $|M| = \begin{vmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 2 & -1 & -1 \end{vmatrix} = 1[-2+1] - 2[-3-2] + 3[-3-4]$

$= -1 + 10 - 21 \Rightarrow -12$

(b) $\because [M][M^{-1}] = [I]$ where I is identity matrix

So $\frac{1}{12}\begin{bmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 2 & -1 & -1 \end{bmatrix}\begin{bmatrix} 1 & 1 & 4 \\ a & 7 & -8 \\ b & -5 & 4 \end{bmatrix} = \frac{1}{12}\begin{bmatrix} 1+2a+3b & 0 & 0 \\ 0 & 12 & 0 \\ 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

So $1 + 2a + 3b = 12 \Rightarrow$ — (1)

Also $|M^{-1}| = -\frac{1}{12}$ So, $|M^{-1}| = \frac{1}{12}\left[1[28-40] - 1[4a+8b] + 4[-5a-7b]\right]$

$\Rightarrow |M^{-1}| = \frac{1}{12}\left[-12 - 4a - 8b - 20a - 28b\right] \Rightarrow -\frac{1}{12}$

First row first column

$\Rightarrow \frac{1}{12}\left[-12 - 24a - 36b\right] = \frac{-1}{\cdot} \Rightarrow 1 + 2a + 3b = 12$ — (1)

and 2nd row 1st column

$\Rightarrow \frac{3+2a+b}{12} = 0 \Rightarrow 2a + b = -3$ — (2)

from Eq (1) & (2) $\boxed{a = -5,\ b = 7}$

(iii) $\vec{r} = \langle x, y, z \rangle$ Given, $x + 2y + 3z = 0$
$3x + 2y + z = t$
$2x - y - z = 3$

So $[A|B]$ composite matrix $= \begin{bmatrix} 1 & 2 & 3 & | & 0 \\ 3 & 2 & 1 & | & t \\ 2 & -1 & -1 & | & 3 \end{bmatrix}$ $R_2 \to 3R_1 - R_2$, $R_3 \to 2R_1 - R_3$

$\Rightarrow \begin{bmatrix} 1 & 2 & 3 & | & 0 \\ 0 & 4 & 8 & | & -t \\ 0 & 5 & 7 & | & -3 \end{bmatrix}$ $R_3 \to 4R_3 - 5R_2$ $\begin{bmatrix} 1 & 2 & 3 & | & 0 \\ 0 & 4 & 8 & | & -t \\ 0 & 0 & -28 & | & -12+5t \end{bmatrix}$

So, $-28z = -12 + 5t \Rightarrow z = \frac{3}{7} - \frac{5}{28}t$ — (1)

Now, $4y + 8z = -t \Rightarrow 4y + \frac{24}{7} - \frac{40}{28}t = -t$ [from Eq (1)]

$\Rightarrow y = -\frac{6}{7} + \frac{3}{28}t$ — (2)

Now, $x + 2y + 3z = 0 \Rightarrow x = -2y - 3z$ from Eq (1) & (2)

$x = -2\left[-\frac{6}{7} + \frac{3t}{28}\right] - 3\left[\frac{3}{7} - \frac{5}{28}t\right]$

$\boxed{x = \frac{3}{7} + \frac{9}{28}t}$ — (3)

Hence $\vec{r} = x\hat{a}_x + y\hat{a}_y + z\hat{a}_z$

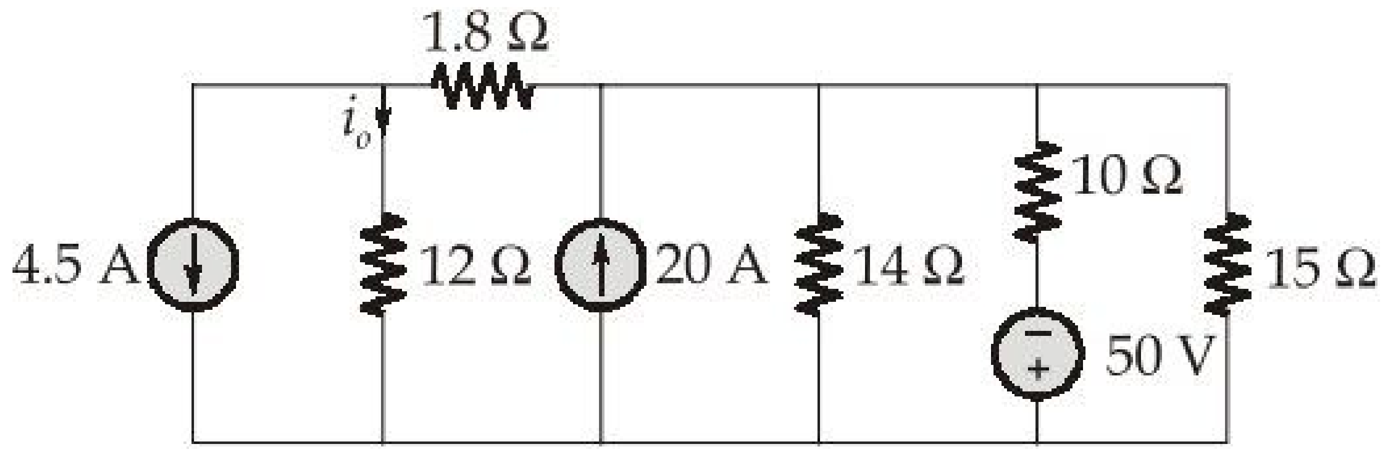
$\boxed{\vec{r} = \left(\frac{3}{7} + \frac{9}{28}t\right)\hat{a}_x + \left(-\frac{6}{7} + \frac{3}{28}t\right)\hat{a}_y + \left(\frac{3}{7} - \frac{5}{28}t\right)\hat{a}_z}$

(iv) Now, Given $\boxed{\vec{v} = \frac{d\vec{r}}{dt} = \frac{9}{28}\hat{a}_x + \frac{3}{28}\hat{a}_y - \frac{5}{28}\hat{a}_z}$

$\therefore \frac{d\vec{r}}{dt} = \frac{d}{dt}\left[\left(\frac{3}{7} + \frac{9}{28}t\right)\hat{a}_x + \left(-\frac{6}{7} + \frac{3}{28}t\right)\hat{a}_y + \left(\frac{3}{7} - \frac{5}{28}t\right)\hat{a}_z\right]$

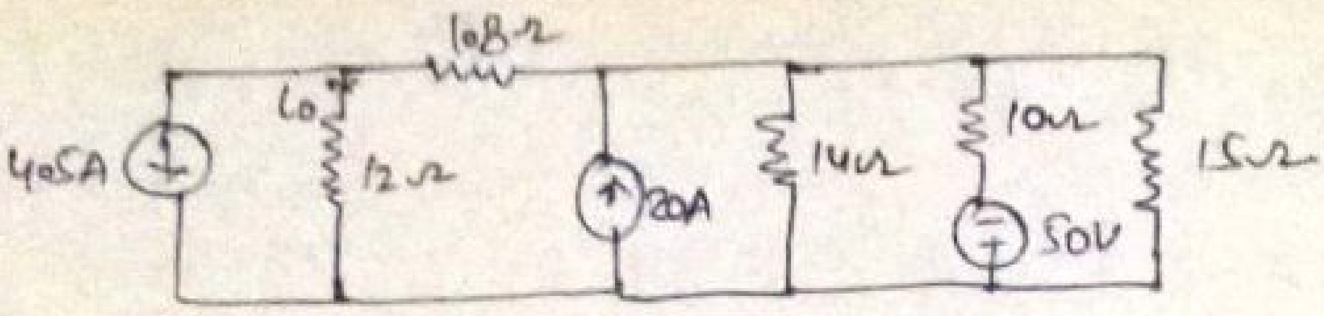
7

Q.5 (b) Use superposition method to find the current i_0 in the circuit.



[12 marks]

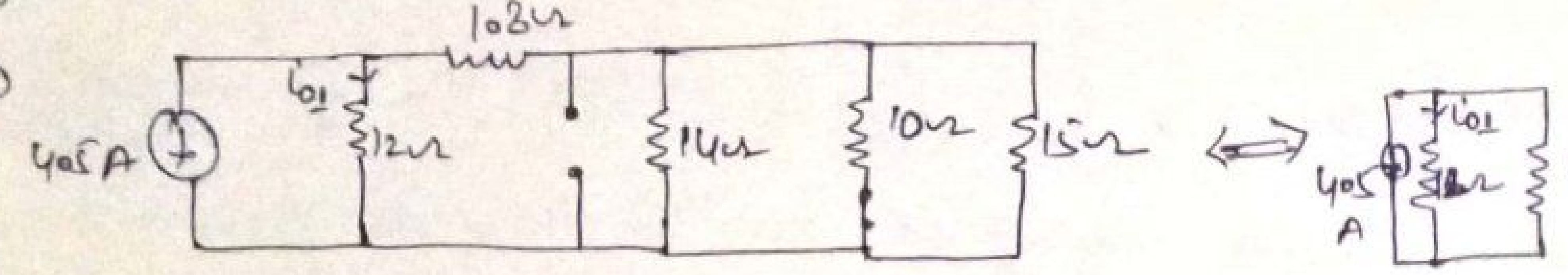
Ans 5(b) Given,



Case 1

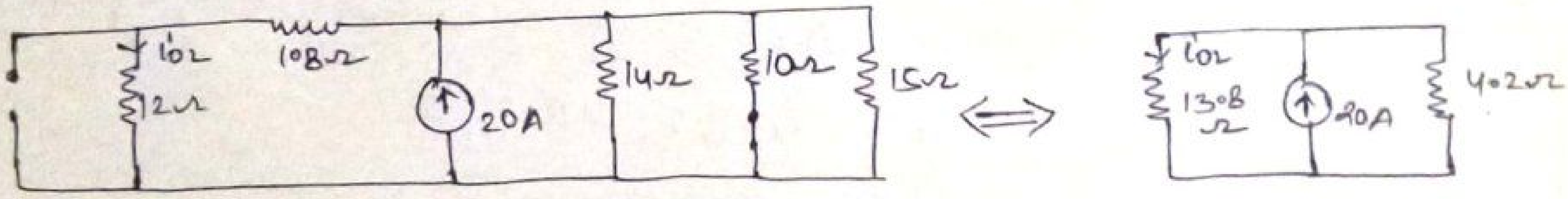
Let only 4.5 Amps current source is active only replace other source by their respective internal resistance

So



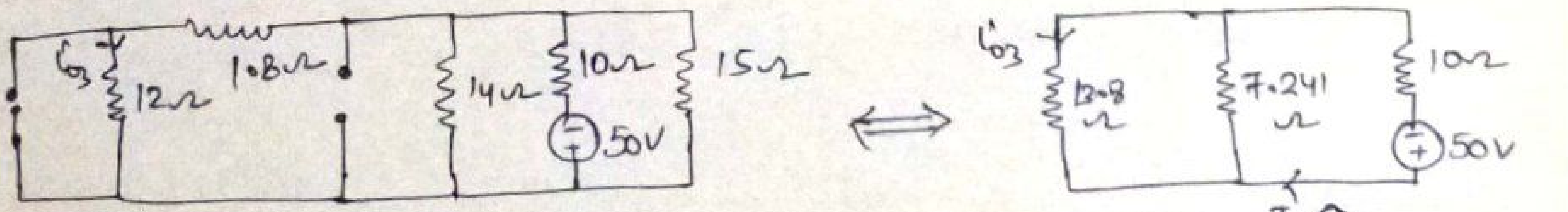
So by current division rule $i_{01} = -4.5\left[\frac{6}{6+12}\right] = -1.5$ Amps.

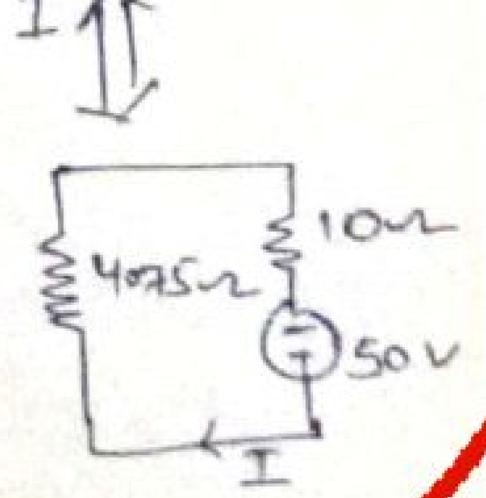
Case 2 Let only 20 Amp source is active replace other source by their internal resistance.



By current division rule $i_{02} = 20 \times \left[\frac{4.2}{4.2+13.8}\right] = 15.33$ Amps.

Case 3 Let only 50V source is active replace other source by their internal resistance.





Here current $I = \frac{50V}{10+4.75} = 3.39$ Amps

Now i_{03} from current division rule $= I \times \frac{7.241}{(7.241+13.8)}$

$i_{03} = -3.39 \times \frac{7.241}{(7.241+13.8)} = -1.167$ Amps

By the principle of Super position, $i_0 = I_{01} + I_{02} + I_{03}$

So $i_0 = -1.5A + 15.33A - 1.167A = 12.663A$

Hence current i_0 calculated is 12.663 Amps

5

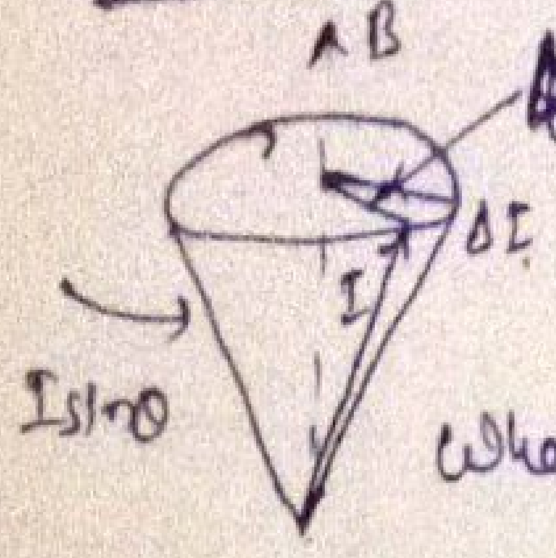
Q.5 (c) What is the Larmor frequency and its role in MRI? Calculate the larmor frequency for a ^1H nuclei in a magnetic field of 1.41 T. The magnetogyric ratio is $2.6752 \times 10^8\ T^{-1}\ s^{-1}$.

[12 marks]

Ans 5(c) Larmor frequency, $f_L = \frac{\gamma}{2\pi} \cdot B$ where γ = Gyromagnetic ratio

MRI (Magnetic resonance imaging) is used in the field of science where concept of nuclear spin transition is used.

Derivation for Larmor frequency



Torque $= \frac{\Delta I}{\Delta t} = \frac{I \sin\theta\, \Delta\phi}{\Delta t}$ — (1)

where torque is rate of change of nuclear spin angular momentum

So Also, Torque, $T = \mu \times B = \mu B \sin\theta$ — (2)

where $\mu = \frac{ge}{2m_p} I$

Angular Velocity $\omega_{larmor} = \frac{d\phi}{dt} = \frac{ge}{2m_p} \cdot B = \gamma B$

So $f_{larmor} = \frac{ge}{2m_p} \frac{B}{2\pi} = \frac{\gamma}{2\pi} B$

Given ^1H nuclei, $B = 1.41T$

So $f_{larmor} = \frac{2.6752 \times 10^8}{2\pi} \times 1.41 = 60\ MHz$

Hence larmor frequency = 60 MHz.

10

Do not write in this margin

Q.5 (d) The coil of a 150 V moving iron voltmeter has a resistance of 400 Ω and an inductance of 0.75 H. The coil is made of copper which has a resistance temperature coefficient of 0.004 per °C. The current consumed by the instrument when placed on a 150 V dc supply is 0.05 A. The series resistance of the voltmeter is of Manganin with a resistance temperature coefficient 0.00015 per °C. Estimate the

(i) temperature coefficient of the instrument.

(ii) alteration of the reading between direct current and alternating current at 100 Hz.

(iii) capacitance necessary to eliminate this frequency error.

[4 + 6 + 2 marks]

Ans 5 (d) Given supply voltage $V_{dc} = 150V$ and $I = 0.05A$, $L = 0.75H$

So Total input resistance $= \frac{150}{0.05} = 3000\Omega$

and given M.I. resistance $= 400\Omega$ So, Series Resistance $= 3000 - 400 = 2600\Omega$

Given $\alpha_{coil} = 0.004/°C$ So ΔR_{coil} for 1°C rise $= 0.004 \times 400 \times 1 = 1.60\Omega$

and $\alpha_{swamping} = 0.00015/°C$ So $\Delta R_{swamping}$ for 1°C rise $= 0.00015 \times 2600 \times 1 = 0.39\Omega$

So Total change in resistance $\Delta R = 0.39 + 1.60 = 1.99\Omega$

Hence temperature coefficient of instrument $= \frac{\Delta R/°C}{R}$

$= \frac{1.99}{3000} = 6.63 \times 10^{-4}/°C$

ii) At 100Hz, $X_L = 2 \times \pi \times 100 \times 0.75 = 471.24\Omega$

So Impedance, $Z = \sqrt{R^2 + X_L^2} = \sqrt{3000^2 + 471.24^2} = 3036.78\Omega$

So Current drawn at 100Hz, $I = \frac{150}{3036.78}$ Amp $= 0.0494$ A

So Reading at 100Hz, $V = 0.0494 \times \frac{150}{0.05} = 148.2$ Volts

So % error $= \frac{148.2 - 150}{150} \times 100 = -1.2\%$ Hence low value

(iii) Capacitance to eliminate frequency error,

$C = 0.41 \frac{L}{R_s^2} = 0.41 \times \frac{0.75}{2600^2} = 0.0455\mu F$.

10

Do not write in this margin

Q.5 (e) A platinum resistance thermometer has a resistance of 100 Ω at 25°C. Find its resistance at 50°C. The resistance temperature coefficient of platinum is 0.00392 Ω/Ω/°C. If the thermometer has a resistance of 200 Ω, calculate the value of temperature in °K.

[12 marks]

Ans 5(e) Given $R_{25^\circ C} = 100\Omega$ at $T = 25^\circ C$, $R_{50^\circ C} = ?$, $\alpha = 0.00392\ \Omega/\Omega/^\circ C$

$\therefore$ $$R_{50^\circ C} = R_{25^\circ C}[1 + \alpha \Delta T]$$

where α = temperature coefficient
ΔT = Change in temperature

So, $R_{50^\circ C} = 100[1 + 0.00392 \times [50 - 25]]$

$\Rightarrow$ $R_{50^\circ C} = 109.8$ ohms.

Hence an increase of $9.8\ \Omega$ from Resistance at 25°C to resistance at 50°C.

Now, Given, $R = 200\ \Omega$, let temperature be T

from $R = R_T[1 + \alpha \Delta T] \Rightarrow 200 = 100[1 + 0.00392[T - 25]]$

$\Rightarrow 255.102 = T - 25 \Rightarrow$ $T = 280.102^\circ C$

So value of temperature in kelvin °K $= T_{^\circ K} = 280.102^\circ C + 273$

$= 553.102^\circ K$

Hence value of temperature calculated is $= 553.102^\circ K$.

10

Q.6 (a) **(i)** Differentiate between the following:

1. Anisotropy and isotropy.
2. Crystalline and Amorphous.
3. Allotropy and catenation.

(ii) State the types of point defects in solid solutions. What are the factors that determine the degree of impurity in a solid?

(iii) Germanium forms a substitutional solid solution with Silicon. Compute the weight percent of Germanium that must be added to Silicon to yield an alloy that contains 2.43×10^{21} Ge atoms per cubic centimeter: The densities of pure Ge and Si are 5.32 and 2.33 g/cm^3, respectively.

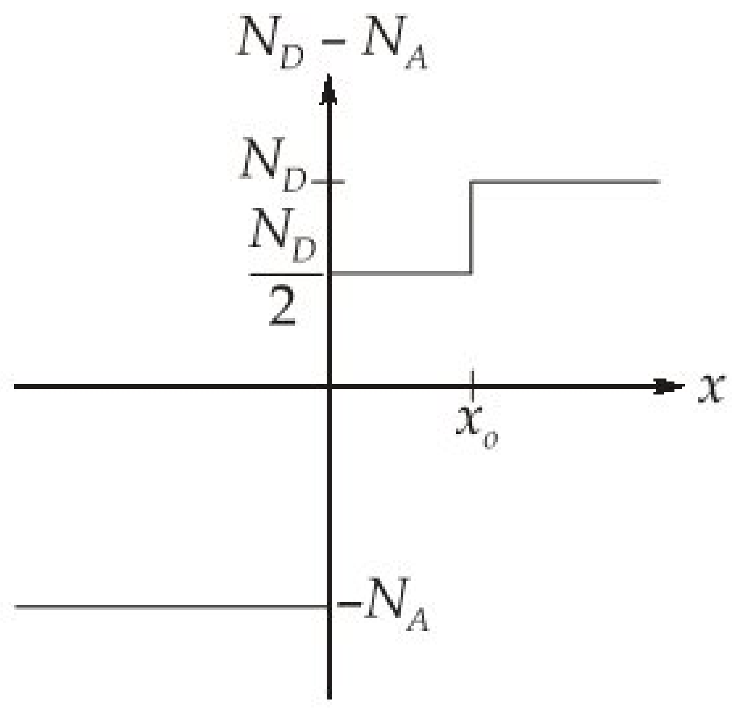
(Atomic wt. Ge = 72.61 g/mol, Atomic wt. Si = 28.08 g/mol)

[6 + 8 + 6 marks]

Q.6 (b) **(i)** A germanium diode is operated at 20° C. A reverse bias of –1.5 volts results in a current of 70 μA. What is the current flow for a forward bias of 0.2 volts at 20° C and at 40° C.

(ii) A *pn*-junction diode has the doping profile shown. Assume $x_n > x_0$.

1. What is the built-in voltage across the junction?
2. Invoking the depletion approximation, sketch the charge density ρ versus x inside the diode.
3. Obtain an analytical solution for the electric field, $E(x)$, inside the depletion region.



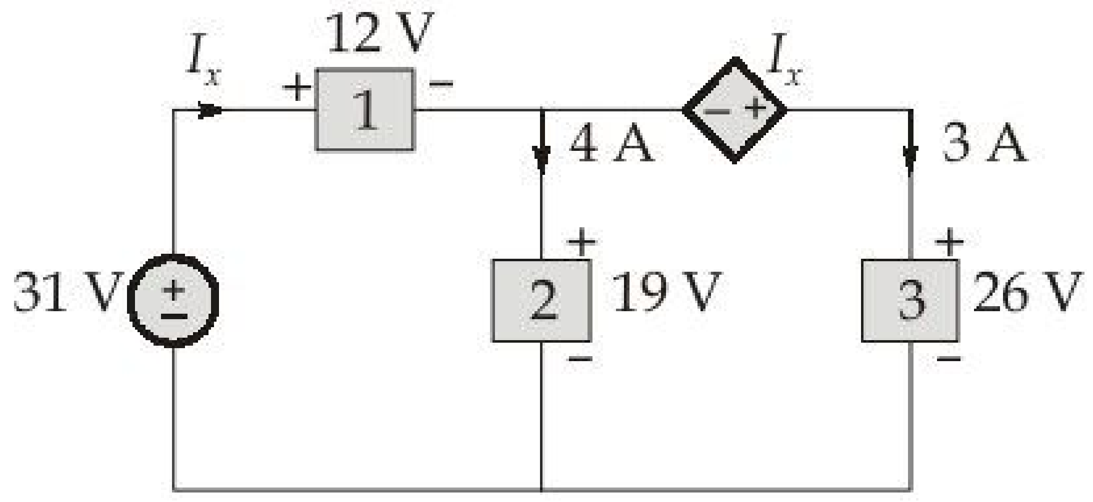
[6 + 14 marks]

Q.6 (c) **(i)** With the help of a block diagram, explain the principle of operation of a digital multimeter.

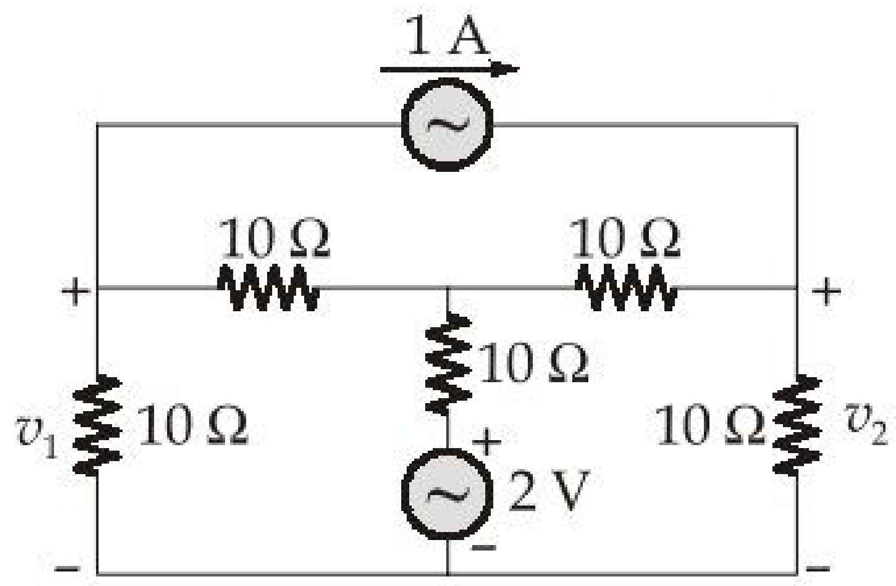
(ii) An eight-bit D/A converter has a full-scale output of 5 mA and a full scale error of ±0.25% of full scale. Determine the range of expected analog output for a digital input of 1000 0010.

[15 + 5 marks]

Q.7 (a) **(i)** State the Tellegen's theorem. Find I_x in the network using the theorem. Also find the power absorbed by element 1.



(ii) Draw the oriented graph of the network. Determine incidence matrix and find the v_1 and v_2.

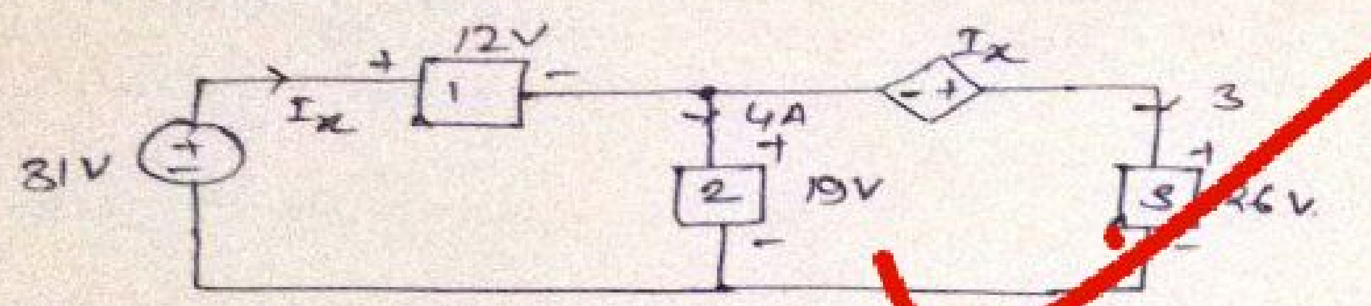


[6 + 14 marks]

Ans 7 (a) Tellegen's theorem :→ In a system summation of total Power generated is equal to total Power absorbed by the system assuming no external influence.

i.e. $\sum_{i=1,2,3}^{\infty} V_i \cdot I_i = 0$

Given



Hence using telegan's theorem $\sum V_i \cdot I_i = 0$

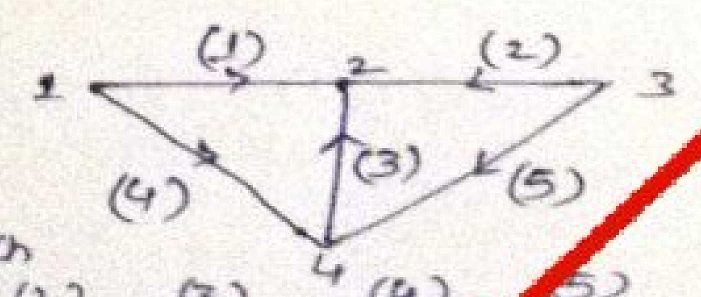
$\Rightarrow 31 \times I_x - 12 \times I_x - 4 \times 19 + 3I_x - 3 \times 26 = 0$

$\Rightarrow 22 I_x = 154 \Rightarrow \boxed{I_x = 7 \text{ Amps}}$

So, I_x in the network is 7 Amps.

Now Power absorbed by the element 1 $= 12 \times I_x$
$= 12 \times 7 = 84$ watts.

(ii) Oriented graph of the circuit



Augmented matrix, [AM] =

Node \ Branch	(1)	(2)	(3)	(4)	(5)
1	1	0	0	1	0
2	-1	-1	-1	0	0
3	0	1	0	0	1
4	0	0	1	-1	-1

So, Incidence Matrix $Q = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix}$ Node 4 taken as reference.

Branch admittance $Y_b = \begin{bmatrix} 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 \\ 0 & 0 & 0 & 0.1 & 0 \\ 0 & 0 & 0 & 0 & 0.1 \end{bmatrix}$, Source $V_s = \begin{bmatrix} 0 \\ 0 \\ 2 \\ 0 \\ 0 \end{bmatrix}$

Source current $i_s = \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$

Now:- $Q Y_b Q^T V_n = i_s - Q Y_b V_s$ —— ①

$$Q Y_b Q^T = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 \\ 0 & 0 & 0 & 0.1 & 0 \\ 0 & 0 & 0 & 0 & 0.1 \end{bmatrix} \begin{bmatrix} 1 & -1 & 0 \\ 0 & -1 & 1 \\ 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.2 & -0.1 & 0 \\ -0.1 & 0.3 & -0.1 \\ 0 & -0.1 & 0.2 \end{bmatrix}$$

and
$$Q Y_b V_s = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 \\ 0 & 0 & 0 & 0.1 & 0 \\ 0 & 0 & 0 & 0 & 0.1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ -0.2 \\ 0 \end{bmatrix}$$

So, from Eq ①
$$\begin{bmatrix} 0.2 & -0.1 & 0 \\ -0.1 & 0.3 & -0.1 \\ 0 & -0.1 & 0.2 \end{bmatrix} \begin{bmatrix} V_{N1} \\ V_{N2} \\ V_{N3} \end{bmatrix} = \begin{bmatrix} -1 \\ +0.2 \\ 1 \end{bmatrix}$$

$\Rightarrow V_{N1} = V_1 = -4.5V$, $V_{N2} = 1V$ and $V_{N3} = V_2 = 5.5V$.

Hence $V_1 = -4.5V$ and $V_2 = 5.5V$

17

Scanned with CamScanner

Q.7 (b) **(i)** Compare horizontal and vertical micro-programmed control unit.

(ii) Consider a hypothetical control unit which supports 4 K words. The hardware contains 64 control signals and 16 flags. What is the size of control word used in bits and control memory in byte using horizontal programming and vertical programming?

(iii) Show a flowchart algorithm to find the largest among three different numbers entered by the user.

[4 + 8 + 8 marks]

Ans 7(b)

Horizontal micro programmed control unit	Vertical micro programmed
① Decoded Binary form of control signal.	① Encoded Binary form of control signal.
② It supports longer control word	② It support shorter control word
③ No need of external decorders	③ External decorders are required
④. faster than vertical micro program-med control unit.	④ It is slower than Horizontal microprogrammed control unit.

(ii) Given, 4K words, 64 control signals, 16 flags

(a) Horizontal Programmed

Flags = 16 ⇒ $\log_2 16 = 4$ bits, 64 control signals = 64 bits/CS

Memory bits $\log_2 2^{12} = 12$ bits

Control word = | Branch | Flag | Control field | Control Memory address |

So Size of Control word = 0 + 4 + 64 + 12 = 80 bits

and Control Memory = 4 K words = $\frac{4 \times 80 \text{ bits}}{8} K = 40 KB$

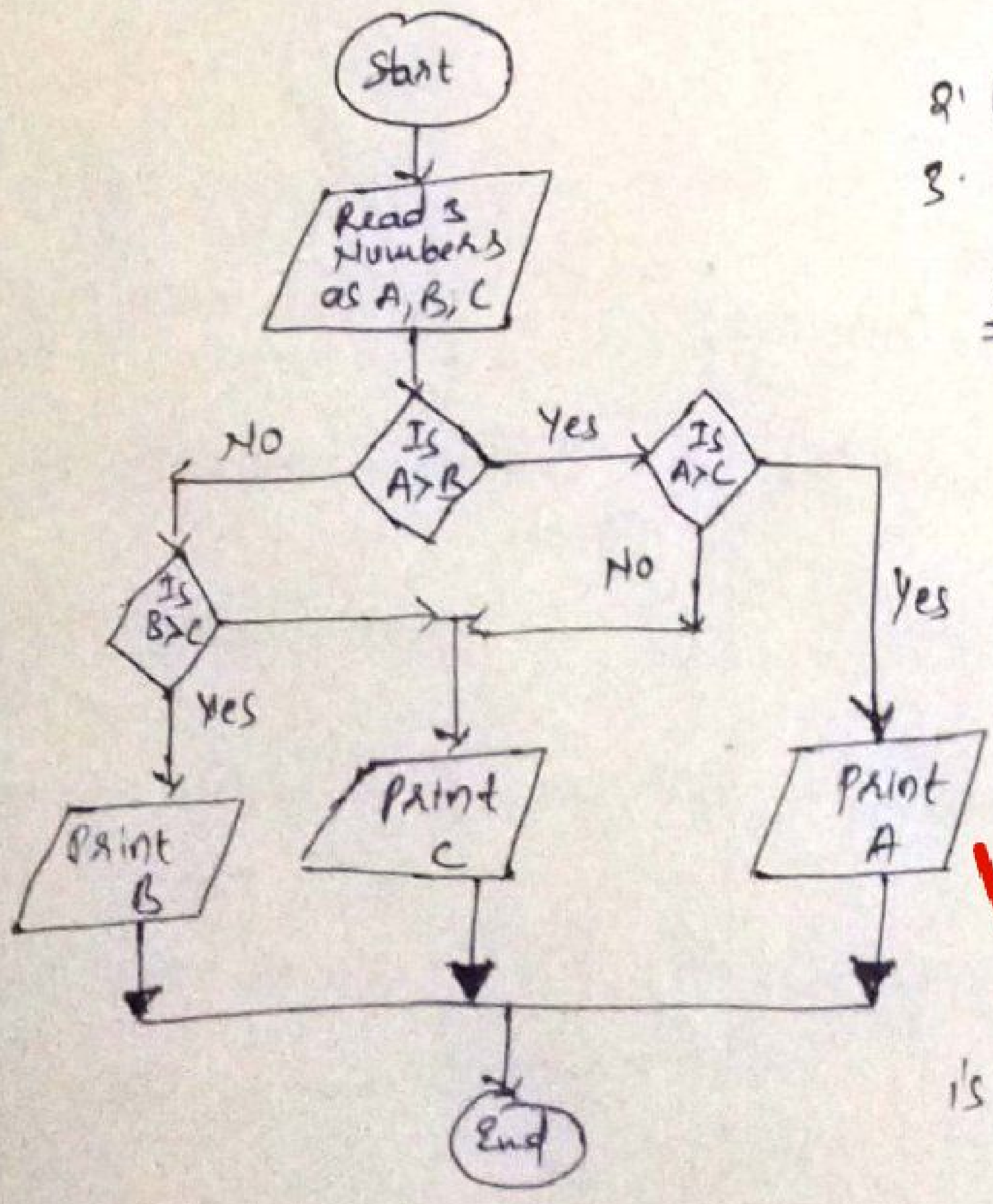
Vertical Programmed :-

For Vertical Programmed bits for 64 control signals = $\log_2 64 = 6$

So Control word size = 0 + 4 + 6 + 12 = 22 bits

Control Memory = 4 K words = $\frac{4 \times 22}{8} K = 11 KB$

(iii) Algorithm to find the largest among three different number



1. Start.
2. Read the 3 numbers as A, B & C
3. If A>B Check
   3.1 If A>C If yes print A.
   If No.
   then Check B>C
   If yes then print B
   If No. then print C
4. END

Hence the largest number is identified by the algorithm.

Do not write in this margin

Q.7 (c) **(i)** What are quantum dots and its advantages with respect to solar cell design?

(ii) Explain Josephson effect and illustrate some practical applications of it.

(iii) What is seebeck effect? The corresponding temperature of a thermocouple for 11.167 mV is 207° C, while the same thermocouple generates 11.223 mV for 208° C. Find the temperature corresponding to 11.191 mV generated by this thermocouple (accurate to two decimal places). (Assuming linear interpolation)

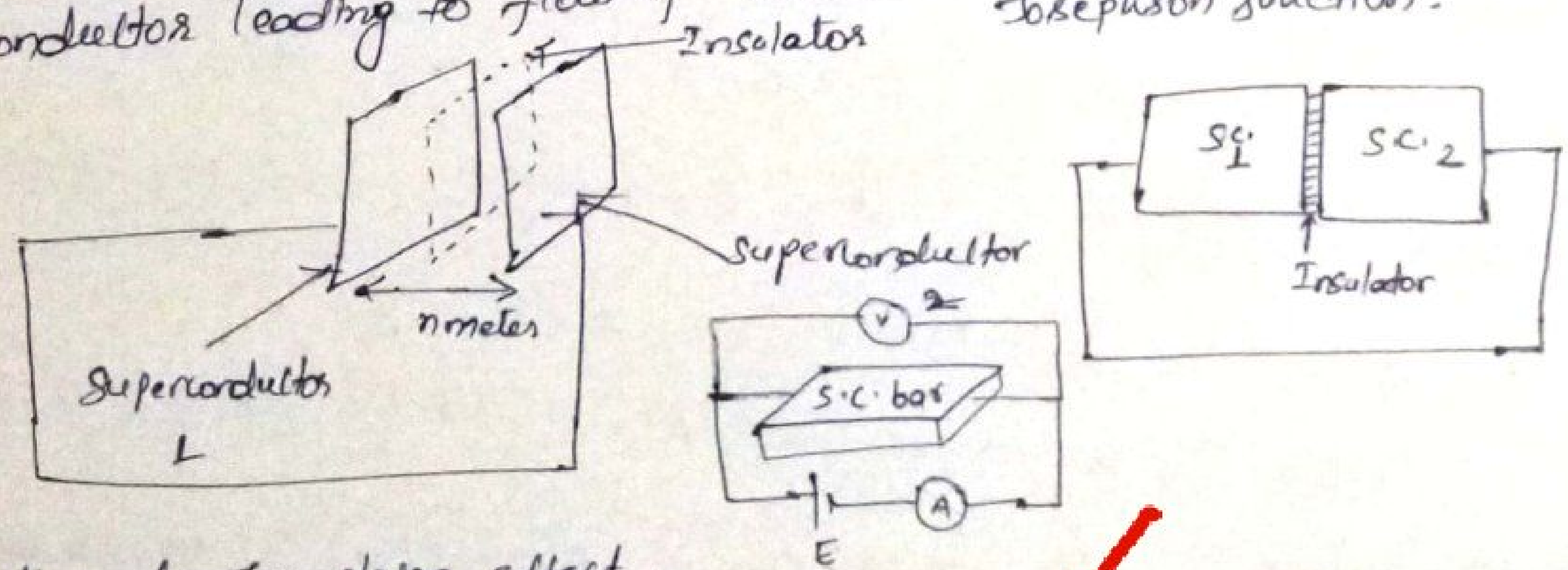
[6 + 8 + 6 marks]

Ans 7 (c) (i) Quantum dots :- Quantum dots are tiny semiconductors particles a few nanometre in size having optical and electronic properties that differ from larger particles due to quantum mechanics.

Advantages with respect to Solar cell design

- Quantum dots have a favorable power to weight ratio with high efficiency.
- Their power consumption is low.
- The mass and area savings as well as flexibility leads to miniaturization.
- Quantum dots have advantages of turnable bandgap which could be used in greater advantage in electrical / semiconductor field.

(ii) Josephson Effect :- When two super conductors are bring closer to each other of nanometer size and an insulator is used in between them then electron tunnels from one super conductor to another superconductor leading to flow of current and junction formed is Josephson junction.



Application of Josephson effect :-

① Practical application of dc Josephson effect has been realized in very sensitive galvanometer and magnetometer.

② Squid (Super-conducting quantum interference device) is used for measuring small magnetic field strength.

③ It has extensive used in geological surveying.

- AC Josephson effect has been used in precision determination of value of h/e.
- Application in computer field promise higher density lower power component.
- RF frequency oscillation obtained between junction when a dc voltage is applied across the super conductor.

Ans 7 (c) (iii) Seeback effect:- It is a phenomena in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between two substances.

- This can be applied to thermal to electrical energy conversion.

Given. $\Delta T_1 = 207^\circ C$, $V_1 = 11.167\,mV$, $T_2 = 208^\circ C$, $V_2 = 11.223\,mV$

let voltage and temperature are dependent so

$V = AT + B$ where A and B are constant.

So $V_1 = 11.167 \times 10^{-3} = A \times 207 + B$ ——— (1)

also $V_2 = 11.223 \times 10^{-3} = A \times 208 + B$ ——— (2)

from eq (1) & (2) $A = 5.6 \times 10^{-5}\,V/^\circ C$ and $B = -4.25 \times 10^{-4}\,V$

So, Given $V_3 = 11.191\,mV = A \times T_3 + B$

where T_3 is temperature at which V_3 voltage is developed

Putting values, $V_3 = 11.191 \times 10^{-3} = 5.6 \times 10^{-5} \times T_3 - 4.25 \times 10^{-4}$

$$\boxed{T_3 = 207.429^\circ C}$$

Hence temperature required is approximately $\boxed{T_3 = 207.43^\circ C}$

15

Q.8 (a) **(i)** Define locality of reference with respect to memory.

(ii) What is virtual memory? Explain with an example the purpose of paging technique.

(iii) A computer has a cache, main memory and a disk used for virtual memory. An access to the cache takes 10 ns. An access to main memory takes 100 ns. An access to the disk takes 10000 ns. Suppose the cache hit ratio is 0.9 and the main memory hit ratio is 0.8. Determine the effective access time required to access a referenced word on the system when simultaneous access and hierarchial access memory organization are used.

[4 + 6 + 10 marks]

Q.8 (b) The differential amplifier uses transistors with $\beta = 100$ and $V_A = 100$ V. Evaluate:

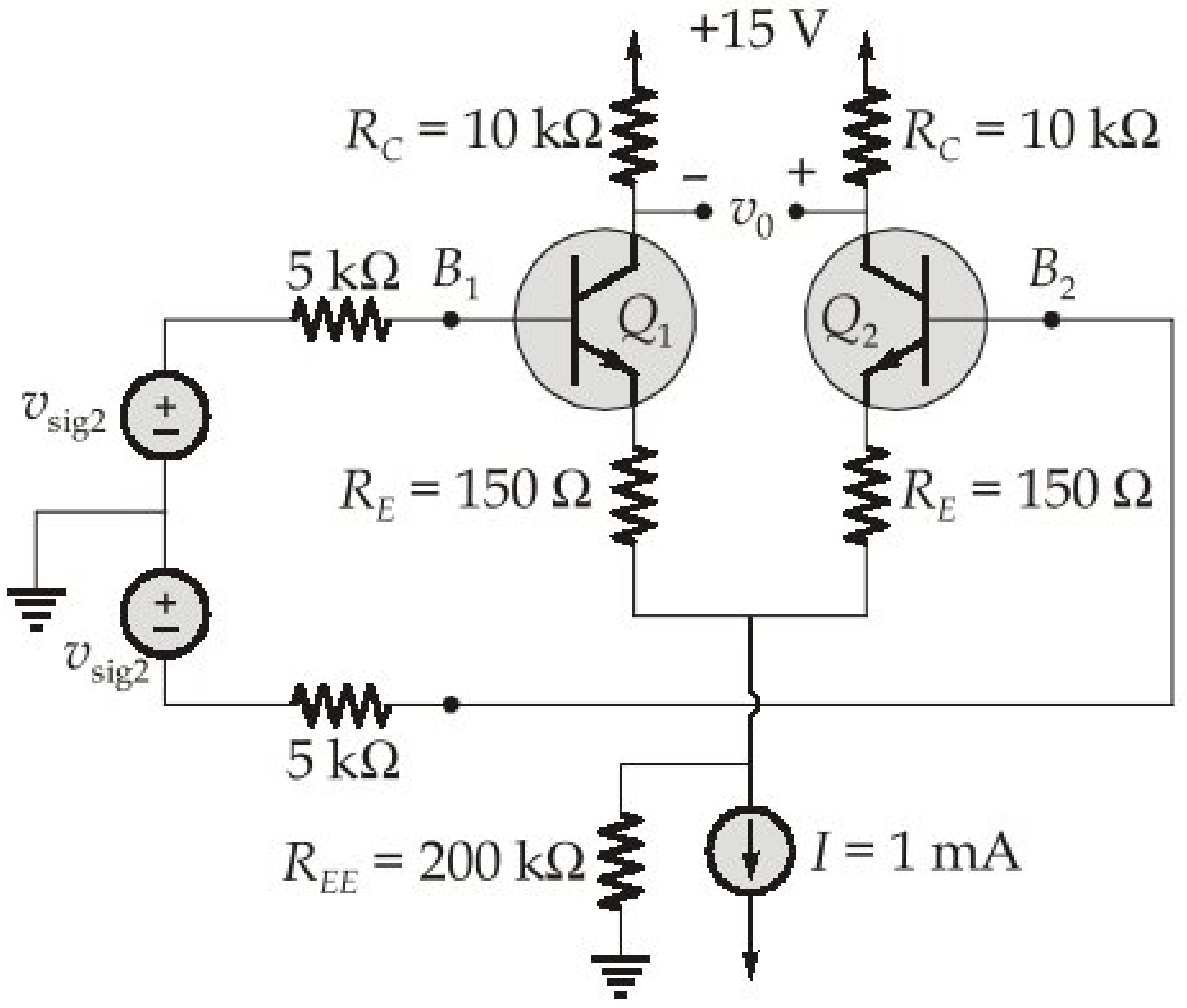
(i) The input differential resistance R_{id} and input common mode resistance R_{ic}.

(ii) The overall differential voltage gain v_0/v_{sig} (ignore r_0).

(iii) The worst case common-mode gain if the two collector resistances are accurate to within ±1%.

(iv) The CMRR in dB.

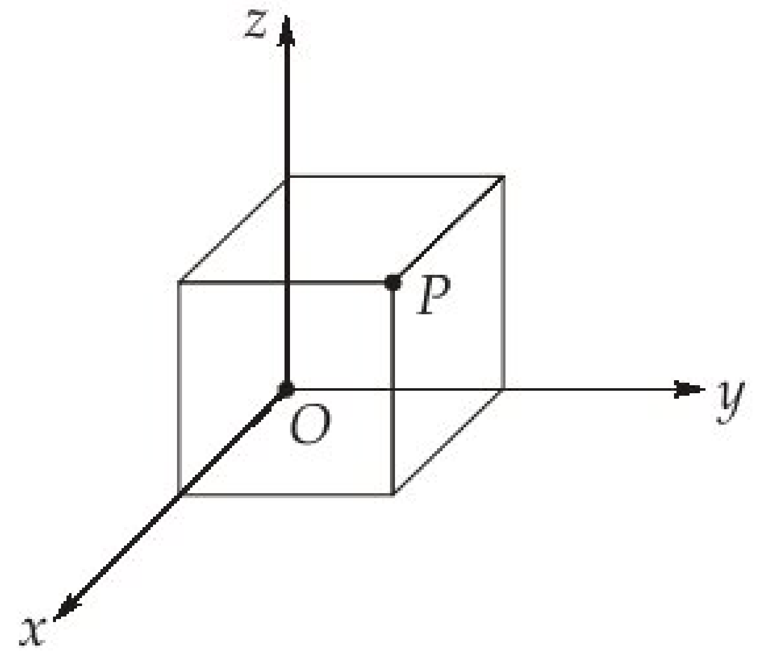
(Take $V_T = 25$ mV)



[8 + 6 + 4 + 2 marks]

Q.8 (c) **(i)** Show $u(x, y) = x^3 - 3xy^2 + 3x^2 - 3y^2$ is harmonic and find a harmonic conjugate.

(ii) A rectangular box is placed in the first octant as shown, with one corner at origin and the three adjacent faces in the coordinate planes. The opposite point $P : (x, y, z)$ is constrained to lie on the paraboloid $x^2 + y^2 + z = 1$. Find P which gives the greatest volume.



[8 + 12 marks]

❍❍❍❍

Space for Rough Work

Space for Rough Work

Space for Rough Work