• Try to avoid calculation mistake

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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-5 : Basic Electronics Engineering + Computer Fundamentals + Electromagnetic Field Theory

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	37
Q.2	43
Q.3	41
Q.4	
Section-B	
Q.5	42
Q.6	52
Q.7	
Q.8	
Total Marks Obtained	215

Signature of Evaluator: Sourabh kumar

Cross Checked by: ....

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IMPORTANT INSTRUCTIONS

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DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Basic Electronics Engineering + Computer Fundamentals + Electromagnetic Field Theory

Q.1 (a) If $\vec{J} = \frac{1}{r^3}(2\cos\theta\,\hat{a}_r + \sin\theta\,\hat{a}_\theta)\ \text{A/m}^2$, calculate the current passing through

(i) a hemispherical shell of radius 20 cm, $0 < \theta < \frac{\pi}{2}, 0 < \phi < 2\pi$.

(ii) a spherical shell of radius 10 cm.

[12 marks]

Sol^n:

(i) $\bar{J} = \frac{1}{r^3}\ 2\cos\theta\hat{a}_r + \sin\hat{a}_\theta\ \ \text{A/m}^2$

$I = \int_S \bar{J}\cdot d\bar{s}$

$= \int \left(\frac{1}{r^3}\ 2\cos\theta\cdot\hat{a}_r + \sin\theta\,\hat{a}_\theta\right)\cdot\left(r^2\sin\theta\, d\theta\, d\phi\,\hat{a}_r + r\sin\theta\, dr\, d\phi\,\hat{a}_\theta\right)$

$= \iint \frac{1}{r^3}\ 2\cos\theta\ r^2\sin\theta\, d\theta\, d\phi + \iint \frac{r\sin^2\theta}{r^3}\, dr\, d\theta$

$I = \iint \frac{\sin 2\theta}{r}\, d\theta\, d\phi + \int dr + 0 \quad (dr = 0$

$I = \frac{1}{r}\int_0^{\pi/2}\sin 2\theta\, d\theta \int_0^{2\pi} d\phi$

$= 5\left(\frac{-\cos 2\theta}{2}\right)_0^{\pi/2}\ 2\pi$

$= \frac{10\pi}{2}\left[--1+1\right]$

$\boxed{I = 10\pi\ \text{A}}$

(ii) A spherical shell of radius 10 cm

$I = \int_S \bar{J}\cdot d\bar{s}$

$= \iint \frac{1}{r^3}\left(2\cos\theta\,\hat{a}_r + \sin\theta\,\hat{a}_\theta\right)\ r^2\sin\theta\, d\theta\, d\phi\ \hat{a}_r$

Do not write in this margin

$$I = \iint \frac{2\cos\theta \quad r^2 \sin\theta \; d\theta \, d\phi}{r^3}$$

$$I = \frac{1}{r} \int_0^{\pi} \sin 2\theta \, d\theta \int_0^{2\pi} d\phi$$

$$I = 10 \left(-\frac{\cos 2\theta}{2} \right)_0^{\pi} 2\pi$$

$$= 5 \left(\cos 2\theta \right)_{\pi}^{0} 2\pi$$

$$\boxed{I = 0 \text{ A}}$$

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Good Approach

Q.1 (b) A charge distribution with spherical symmetry has density $\rho_v = \begin{cases} \frac{\rho_0 r}{R}, & 0 \le r \le R \\ 0, & r > R \end{cases}$.

Determine $\vec{E}$ everywhere.

[12 marks]

Ans:-

$P_v = \begin{cases} \frac{P_0 r}{R} & 0 \le r \le R \\ 0 & r > R \end{cases}$

$\nabla \cdot D = P_v$

~~$E = -\nabla V$~~

and

~~$\nabla \cdot (\epsilon_0 \bar{E}) = P_v$~~

~~$\nabla \cdot \bar{E} = \frac{P_v}{\epsilon_0}$~~

Ans:-

$P_v = \begin{cases} \frac{P_0 r}{R} & 0 \le r \le R \\ 0 & r > 0 \end{cases}$

Acc. to Gauss law

$\int \bar{D} \cdot d\bar{r} = \iiint P_v \, dV$

(i) $0 \le r \le R$

$\epsilon_0 E 4\pi r^2 = \iiint \frac{P_0 r}{R} r^2 \sin\theta \, dr \, d\theta \, d\phi$

$E = \frac{P_0}{\epsilon_0 4\pi r^2 R} \int_0^r r^3 \, dr \int_0^\pi \sin\theta \, d\theta \int_0^{2\pi} d\phi$

$E = \frac{P_0}{4\pi \epsilon_0 R r^2} \frac{r^4}{4} \times 2 \times 2\pi$

$\boxed{\bar{E} = \frac{P_0 r^2}{4 \epsilon_0 R}} \frac{V}{m}$

$$\bar{E} = \frac{\rho_0}{4\epsilon_0 R} r^2 \, \hat{a}_r \quad V/m$$

(ii) $r > R$

$$E = \frac{\rho_0}{4\pi\epsilon_0 R r^2} \int_0^R r^3 \, dr \int_0^{2\pi} d\phi \int_0^{\pi} \sin\theta \, d\theta$$

$$E = \frac{\rho_0}{4\pi\epsilon_0 R r^2} \frac{R^4}{4} 4\pi$$

$$E = \frac{\rho_0 R^3}{4\epsilon_0 r^2} \hat{a}_r \quad V/m$$

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Q.1 (c) Consider a network connecting two systems located 3000 kilometers apart. The bandwidth of the network is 1.544 Mbps. The propagation speed of the media is 0.16×10^6 km/sec. It is needed to design a Go-Back-N sliding window protocol for this network. The average frame size is 64 B. The network is to be used to its full capacity. Assume processing delays at nodes are negligible. Calculate the window size.

[12 marks]

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Q.1 (d) What does "computer architecture" term means in regards to computing system? Enumerate properties of reduced instruction set computer architecture.

[12 marks]

1^n:- Computer architecture refers to arrangement of different computer blocks such as CPU, Memory, IO, system bus in the computer.

→ It is of two type
(i) Von-neuman computer architechure
(ii) Harward computer architecture.

→ In van-neuman computer architecture main memory is common for both instruction and data (RAM).

→ In Harward-computer architecture instructions are stored in perpanent memory that is ROM and data are stored in temporary memory that is RAM.

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⇒ RISC (Reduced instruction set computer)
→ It has less number of instructions set.
→ It has more number of register set.
→ It has less addressing mode
→ It is used in Real time applications.
→ It is supercomputer.
→ ~~Pipelin~~ Pipeling and concurrency are possible in RISC.
→ CPI = 1
→ Instruction length is fixed

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Q.1 (e) Determine the curl of the following vector fields:

(i) $\vec{A} = \rho z^2 \hat{\rho} + \rho \sin^2 \phi \hat{\phi} + 2\rho z \sin^2 \phi \hat{z}$, in circular cylindrical coordinate system.

(ii) $\vec{B} = r\hat{r} + r\cos^2\theta\hat{\phi}$, in spherical coordinate system.

[6 + 6 marks]

Soln:- Curl of vecture

$$\nabla \times \bar{A} = \frac{1}{h_1 h_2 h_3} \begin{bmatrix} h_1 \hat{a}_\rho & h_2 \hat{a}_\phi & h_3 \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial z} \\ h_1 A_\rho & h_2 A_\phi & h_3 A_z \end{bmatrix}$$

(i) $$\nabla \times \bar{A} = \frac{1}{\rho} \begin{bmatrix} \hat{a}_\rho & \rho \hat{a}_\phi & \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ \rho z^2 & \rho^2 \sin^2\phi & 2\rho z \sin^2\phi \end{bmatrix}$$

$$= \frac{1}{\rho}\Big[\hat{a}_\rho (2\rho z\, 2\sin\phi\cos\phi - 0) + \rho\hat{a}_\phi (2\rho z - 2z\sin^2\phi) \quad \hat{a}_z(2\rho\sin^2\phi - 0) \Big]$$

$$\boxed{\nabla \times \bar{A} = 2z\sin 2\phi\, \hat{a}_\rho + (2\rho z - 2z\sin^2\phi)\hat{a}_\phi + 2\sin^2\phi\, \hat{a}_z}$$

(ii) $$\nabla \times \bar{B} = \frac{1}{r^2\sin\theta} \begin{bmatrix} \hat{a}_r & r\hat{a}_\theta & r\sin\theta\, \hat{a}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ r & 0 & r^2\cos^2\theta\sin\theta \end{bmatrix}$$

$$= \frac{1}{r^2\sin\theta}\Big[\hat{a}_r \big(r^2(2\cos\theta\sin\theta\,(\sin\theta) + \cos^3\theta \big) \quad r\hat{a}_\theta (0 - 2r\cos^2\theta\sin\theta) \Big]$$

$$\nabla \times \bar{B} = \frac{1}{r^2 \sin\theta}\left[\left(-2\cos\theta \sin^2\theta + \cos^3\theta\right)\hat{a}_r - 2r^2\cos^2\theta \sin\theta\, \hat{a}_\theta\right]$$

$$\boxed{\nabla \times \bar{B} = \frac{1}{r^2 \sin\theta}\left(\cos^2\theta - 2\cos\theta \sin^2\theta\right)\hat{a}_r - 2\cos^2\theta\, \hat{a}_\theta}$$

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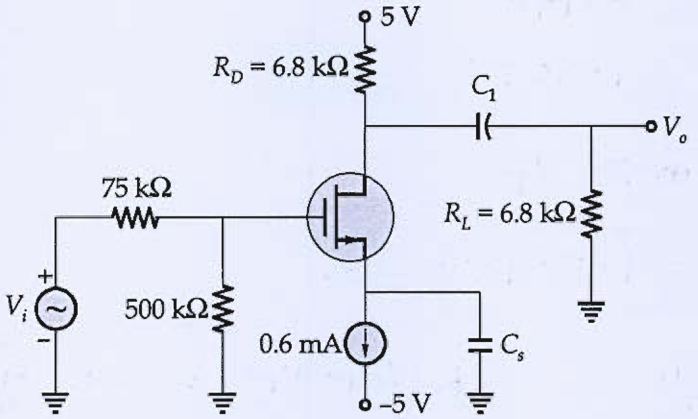
Q.2 (a) Determine the small signal voltage gain of the circuit shown in below figure having parameters $V_T = 0.8$ V, $k = \frac{\mu_n C_{ox} W}{2L} = 1.2$ mA/V^2, $\lambda = 0$. Also calculation gate-to-source voltage (V_{GSQ}).



[20 marks]

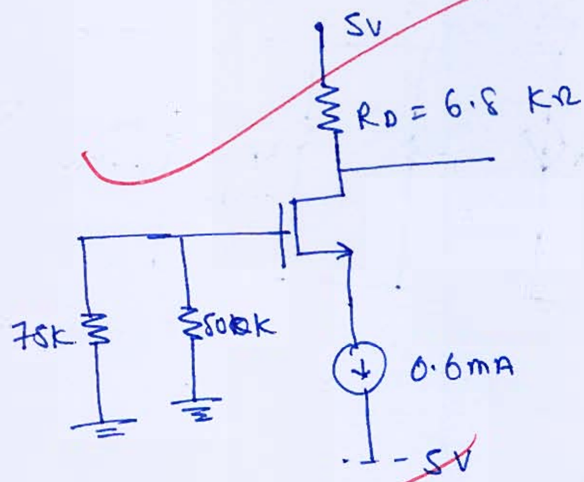
Ans:

$V_T = 0.8$ V

$k = \frac{\mu_n C_{ox} W}{2L} = 1.2$ mA/V^2

$\lambda = 0$

→ DC equivalent circuit



$I_D = 0.6$ mA

KVL:

$V_D = 5 - I_D R_D = 5 - 6.8 - 0.6$

$V_D = 0.92$ V

$I_D = k(V_{GSQ} - V_T)^2$

$0.6 = 1.2(V_{GSQ} - 0.8)^2$

$$0.5 = (V_{GSQ} - 0.8)^2$$

$$V_{GSQ} = 0.8 \pm \sqrt{0.5}$$

$$V_{GSQ} = 0.107V$$
$$1.507V$$

$V_{GSQ} > V_T$

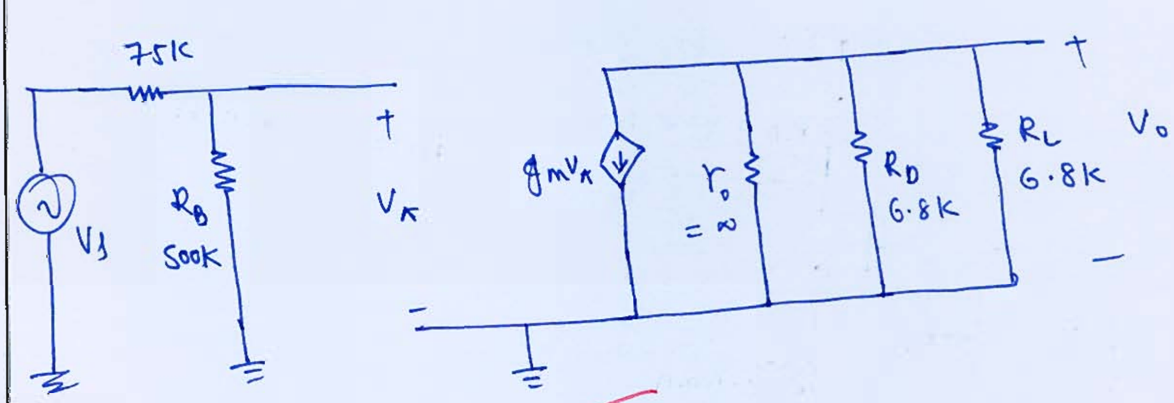
$$\boxed{V_{GSQ} = 1.507V}$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = 2K(V_{GS} - V_T) = 2K\sqrt{\frac{I_D}{K}}$$

$$g_m = \sqrt{2}\sqrt{2kI_D} = 2\sqrt{2 \times 1.2 \times 0.6}$$

$$\boxed{g_m = 1.697\ mA/V}$$

π-model for circuit



$$V_\pi = \frac{500}{500+75} V_s$$

$$\boxed{V_\pi = 0.8695 V_s}$$

$$V_o = -g_m V_\pi (R_D || R_L)$$

$$\frac{V_o}{V_\pi} = -g_m (R_D || R_L)$$

voltage gain

$A_v = \frac{V_o}{V_i} = -0.8695 \times 1.697 \times 3.4$

$A_v = \frac{V_o}{V_s} = -5.017$

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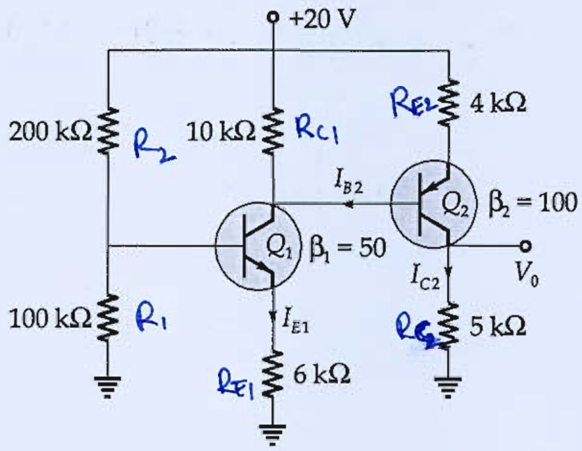
Good Approach

Q.2 (b) Consider the transistor configuration shown below.



Determine:

(i) Base current of transistor, Q_2.

(ii) Collector current of transistor, Q_2.

(iii) Emitter current of transistor, Q_1.

(iv) Output voltage, V_0.

[20 marks]

Sol^n:- Assuming both transistor in active region

$V_{th} = \frac{R_1}{R_1+R_2} \times 20$

$V_{th} = 6.67V$

$R_B = R_1 || R_2 = 66.67 k\Omega$

KVL :

$V_{th} - R_B I_{b1} - 0.7 - R_{E1} I_{E1} = 0$

$6.67 - 66.67 I_{b1} - 0.7 - 6 \times 51 I_{b1} = 0$

$I_{b1} = \frac{6.67 - 0.7}{66.67 + 6 \times 51}$

$I_{b1} = 0.016019 \text{ mA}$

$I_{E1} = 0.8 \text{ mA}$

$I_{E1} = 0.81699 \text{ mA}$

For Q_2,

KVL :

$20 = R_{E2} I_{E2} + 0.7 + V_{C1}$ — (1)

$V_{C1} = 20 - R_{C1}(I_{C1} - I_{B2})$

$20 = R_{E2} I_{E2} + 0.7 + 20 - R_{C1}(I_{C1} - I_{B2})$

~~$0 = 4 \times 101 I_{b2}$~~

$0 = 4 \times 101 I_{b2} + 0.7 - 10 \times (0.8 - I_{b2})$

$-0.7 = (404 + 10) I_{b2} - 8$

$\frac{8 - 0.7}{404 + 10} = I_{b2}$

$I_{b2} = 0.01763 \text{ mA}$

$I_{C2} = 1.7632 \text{ mA}$

$I_{E2} = 1.7809 \text{ mA}$

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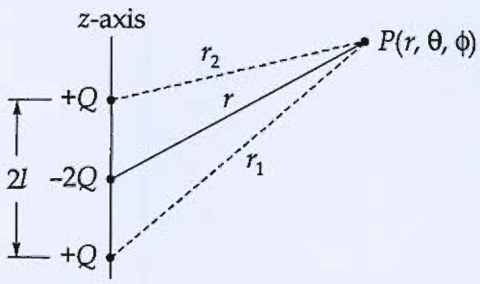
$V_o = R_{C2} I_{C2}$

$V_o = 5 \times I_{C2}$

$V_o = 8.816 \text{ V}$

Good Approach

Q.2 (c) (i) Figure below shows a linear quadrupole arrangement, with charges $+Q$, $-2Q$ and $+Q$ disposed as indicated. Show that the potential due to this quadrupole at a large distance 'r' in comparison with the spacing '$2l$' is $V = \frac{Ql^2}{4\pi\varepsilon_0 r^3}(3\cos^2\theta - 1)$.

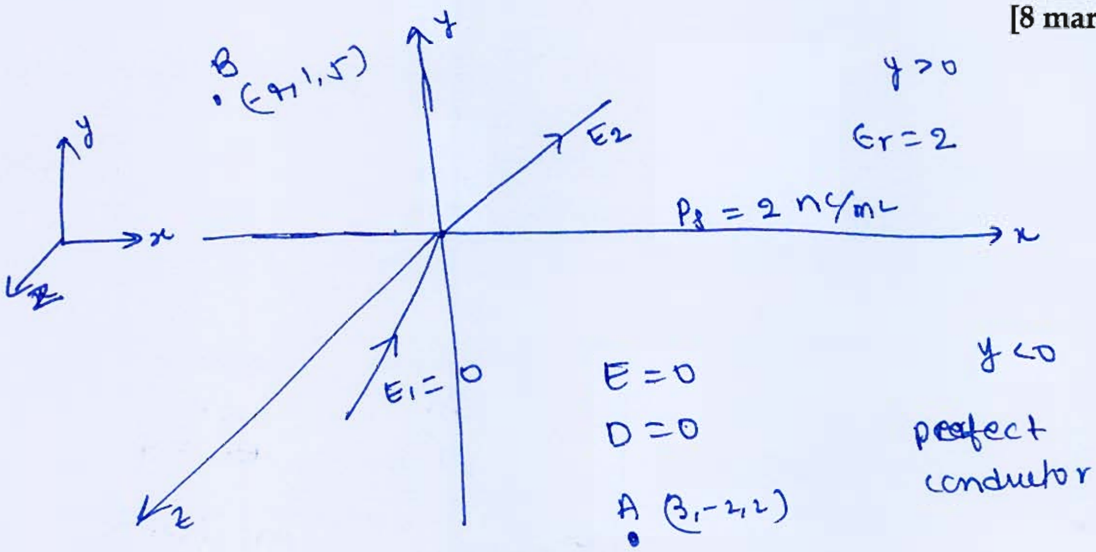


[12 marks]

Q.2 (c) (ii) Region $y \leq 0$ consists of a perfect conductor while $y \geq 0$ is a dielectric medium ($\varepsilon_r = 2$). If there is a surface charge of 2 nC/m² on the conductor, determine $\vec{E}$ and $\vec{D}$ at $A(3, -2, 2)$ and $B(-4, 1, 5)$.

[8 marks]

Sol.:-



Tangential component

$E_{1t} = E_{2t} = 0$

$D_{1t} = D_{2t} = 0$

Normal component

$D_{2n} - D_{1n} = \rho_s$

$D_{2n} = 2 \times 10^{-9} \hat{a}_y \; C/m^2$

$E_{2n} = \dfrac{2 \times 10^{-9}}{\varepsilon_0 \varepsilon_r} \hat{a}_y \; V/m$

$D_2 = 2 \times 10^{-9} \hat{a}_y$

$E_2 = 112.99 \hat{a}_y \; V/m$

At point A $(3, -2, 2)$, $\bar{E}_1 = 0$, $\bar{D}_1 = 0$

At point B $(-4, 1, 5)$, $\bar{E}_2 = 112.99 \hat{a}_y \; V/m$

$\bar{D}_2 = 2 \times 10^{-9} \hat{a}_y \; nC/m^2$

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Good Approach

Q.3 (a) Two extensive homogeneous isotropic dielectric meet on plane $z = 0$. For $z > 0$, $\varepsilon_{r1} = 4$ and for $z < 0$, $\varepsilon_{r2} = 3$. A uniform electric field $\vec{E}_1 = 5\hat{a}_x - 2\hat{a}_y + 3\hat{a}_z$ kV/m exists for $z \geq 0$.

Find:

(i) $\vec{E}_2$ for $z \leq 0$.

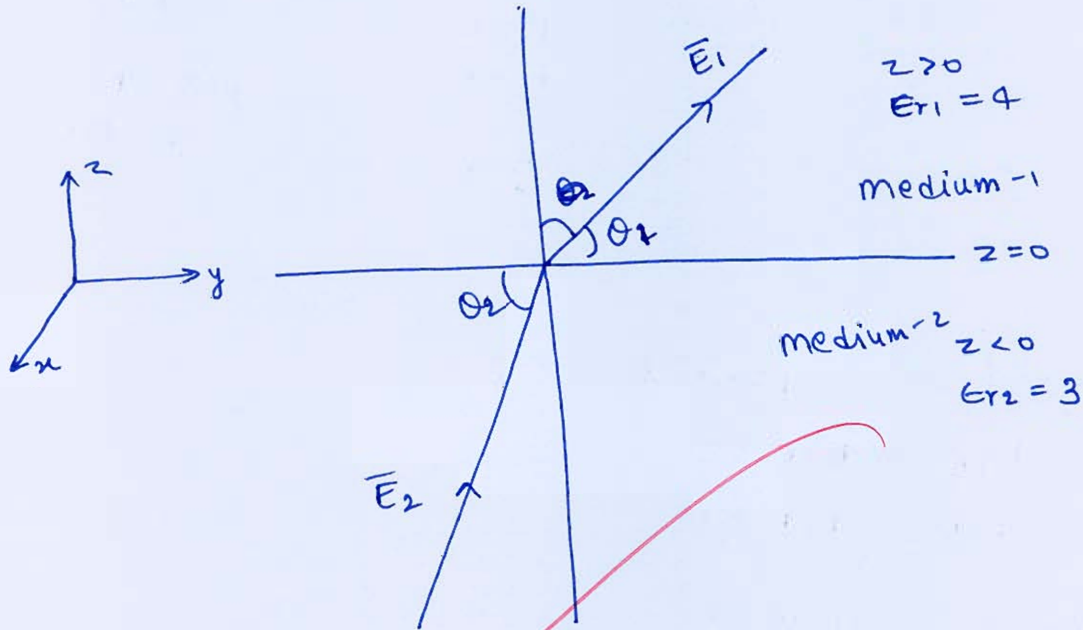
(ii) The angles $\vec{E}_1$ and $\vec{E}_2$ make with the interface.

(iii) The energy densities (in J/m³) in both dielectrics.

(iv) The energy within a cube of side 2 m centered at (3, 4, –5).

[20 marks]

Soln:-



(i) $\bar{E}_1 = 5\hat{a}_x - 2\hat{a}_y + 3\hat{a}_z$ kV/m

$\bar{D}_1 = \epsilon_{r1}\epsilon_0 E_1$

$\bar{D}_1 = (20\hat{a}_x - 8\hat{a}_y + 12\hat{a}_z)\epsilon_0$ kC/m²

Given surface is charge free, $\rho_s = 0$

$D_{1n} = D_{2n} = 12\epsilon_0 \hat{a}_z$ kC/m²

Tangential component:

$E_{1t} = E_{2t}$

$E_{2t} = 5\hat{a}_x - 2\hat{a}_y$ kV/m

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$$E_{2n} = \frac{D_{2n}}{\epsilon_{r2}\epsilon_0} = \frac{12\epsilon_0}{3\times\epsilon_0} = 4\,\hat{a}_z \text{ kV/m}$$

$$\boxed{\bar{E}_2 = 5\hat{a}_x - 2\hat{a}_y + 4\hat{a}_z \text{ kV/m}}$$

$$\bar{D}_2 = (15\hat{a}_x - 6\hat{a}_y + 12\hat{a}_z)\epsilon_0 \text{ kC/m}^2$$

(ii)
$$\tan\theta_1 = \frac{|E_{1n}|}{|E_{1t}|} = \frac{3}{\sqrt{5^2+2^2}}$$

$$\tan\theta_1 = \frac{3}{\sqrt{29}}$$

$$\boxed{\theta_1 = 29.12^\circ}$$

$$\tan\theta_2 = \frac{|E_{2n}|}{|E_{2t}|} = \frac{4}{\sqrt{5^2+2^2}} = \frac{4}{\sqrt{29}}$$

$$\boxed{\theta_2 = 36.6^\circ}$$

(iii) Energy densities, $z > 0$

$$U_1 = \frac{1}{2}|\bar{D}_1|\,|\bar{E}_1|$$

$$= \frac{1}{2}\sqrt{20^2+8^2+12^2}\,\epsilon_0 \times 10^3 \times \sqrt{5^2+2^2+3^2} \times 10^3$$

$$\boxed{U_1 = 6.726\times10^{-4} \text{ J/m}^3}$$ energy density

Energy densities, $z < 0$

$$U_2 = \frac{1}{2}|\bar{D}_2|\,|E_2|$$

$$= \frac{1}{2}\sqrt{15^2+6^2+12^2} \times \epsilon_0 \times 10^6 \times \sqrt{5^2+2^2+4^2}$$

Do not write in this margin

$$U_2 = 5.973 \times 10^{-4} \ J/m^3$$

(iv) Energy inside cube of side 2 m centered at (3, 4, -5) which lies completly below $z < 0$

$W_2 = U_2 \times V_2$

$= 5.973 \times 10^{-4} \times 2^3$

$$W_2 = 4.779 \times 10^{-3} \ J$$

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Good Approach

Q.3 (b) A solid conductor of circular cross-section with a radius of 5 mm has a conductivity that varies with radius, the conductor is 20 m long and there is a potential difference of 0.1 V dc between its two ends. Within the conductor $\vec{H} = 10^5 \rho^2 \hat{a}_\phi$ A/m.

(i) Find conductivity σ.

(ii) Determine the resistance between the two ends.

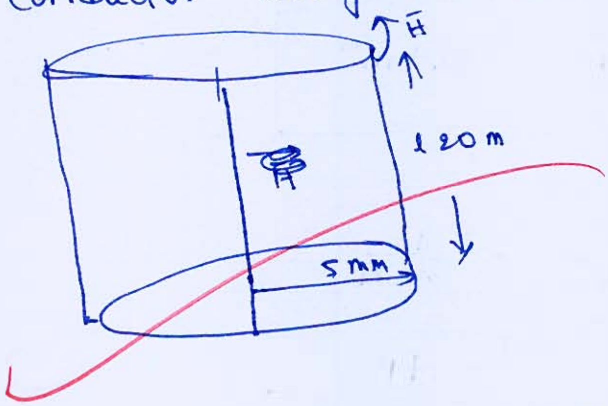
[20 marks]

Sol:- within conductor

$\bar{H} = 10^5 \rho^2 \hat{a}_\phi$ A/m

Radius of conductor, $r = 5 \times 10^{-3}$ m

Conductor length, $l = 20$ m



(i) As we know, $\nabla \times \bar{H} = \bar{J}$

$$\nabla \times \bar{H} = \frac{1}{\rho} \begin{vmatrix} \hat{a}_\rho & \hat{a}_\phi & \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ 0 & 10^5 \rho^3 & 0 \end{vmatrix}$$

$$= \frac{1}{\rho}\left[\hat{a}_z \left(3 \times 10^5 \rho^2 - 0 \right) \right]$$

$$\nabla \times \bar{H} = 3 \times 10^5 \rho \, \hat{a}_z = \bar{J}$$

$$\bar{J} = 3 \times 10^5 \rho \, \hat{a}_z$$

and $\bar{J} = \sigma \bar{E}$

$$\bar{E} = \frac{V}{l} = \frac{0.1}{20} = 5\times10^{-3}\,\hat{a}_z\ V/m$$

$$\bar{J} = \sigma \bar{E}$$

$$\sigma = \frac{\bar{J}}{\bar{E}} = \frac{3\times10^{5}\,\rho\,\hat{a}_z}{5\times10^{-3}\,\hat{a}_z}$$

$$\sigma = 0.6\times10^{8}\rho$$

$$\boxed{\sigma = 6\times10^{7}\,\rho \quad \Omega^{-1}m^{-1}}$$

(ii) Resistance $= \frac{l}{\sigma A}$

$$dR = \frac{1}{6\times10^{7}\rho}\,\frac{d\rho}{2\pi\rho l}$$

$$dR = \left(\frac{1}{6\times10^{7}\times l\times2\pi}\right)\frac{d\rho}{\rho^2}$$

$$R = \frac{1}{12\pi\times10^{7}\times20}\int_{r}^{0}\frac{d\rho}{\rho^2}$$

$$= \frac{1}{240\pi\times10^{7}}\left(\frac{-1}{\rho}\right)_{r}^{0}$$

$$R = \frac{1}{240\pi\times10^{7}}\left[\frac{1}{5\times10^{-3}} - \frac{1}{0}\right]\Omega$$

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Q.3 (c) (i) Write a 'C' program to check whether a character is a vowel or a consonant.

(ii) Differentiate between the following in C programming:

1. Do-while loop and while loop.
2. Iteration and recursion.

[20 marks]

(i)

```
# include . conio.h
# include . stdio.h
void main
{
 char c ;
 printf (" entre the charactor to check 'Vowel or
                 consonent\n" );

 scanf (" %c " &c);

 if ((c == 'A')||(c == 'E')||((c=='I')||(c=='O')
   ||(c=='U')||(c == 'a')||(c=='e')||(c=='i')
   ||(c=='o')||(c == 'u'))
 {
   printf (" charcter is vowel");
 }
 else
   printf (" charalter is consonent");
}
```

(ii)

①

Do - while loop	while loop
a) Check the ~~loop~~ condition at end of execution of loop	a) check loop condition at begining of loop
b) Executed at least once if its ~~not~~ loop condition is not True	b) It will execute loop only if loop condition is True

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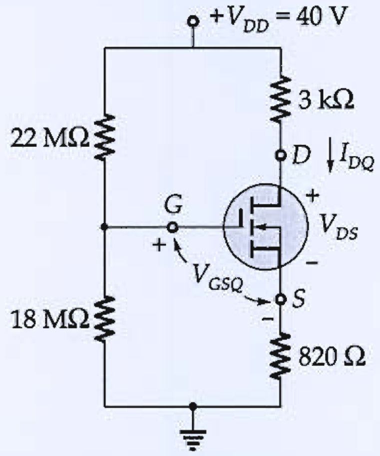
②

~~iteration~~	recursion

Q.4 (a) Determine I_{DQ}, $V_{GS\,Q}$ and V_{DS} for the circuit shown in figure,



$V_{GS\,(Th)} = 5$ V, $I_D(\text{on}) = 3$ mA at $V_{GS}(\text{on}) = 10$ V.

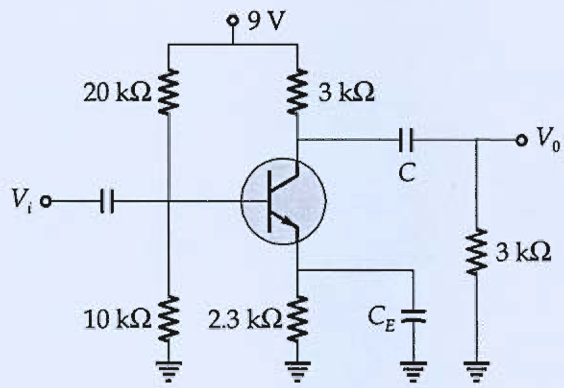
[20 marks]

Q.4 (b) (i) Write a program in C language to sort the array of numbers in ascending order using bubble sort.

(ii) Explain briefly the terms: Translator software, assembler, compiler and interpreter. Differentiate between a compiler and an interpreter.

[10 + 10 marks]

Q.4 (c) (i) In the following transistor circuit, $V_{BE} = 0.7$ V, $V_T = 25$ mV and the capacitance are very large.



Find:

1. The value of DC current I_E.
2. The mid band voltage gain of the amplifier.

(ii) What is meant by Direct Memory Access (DMA)? Explain briefly different types of DMA transfer modes.

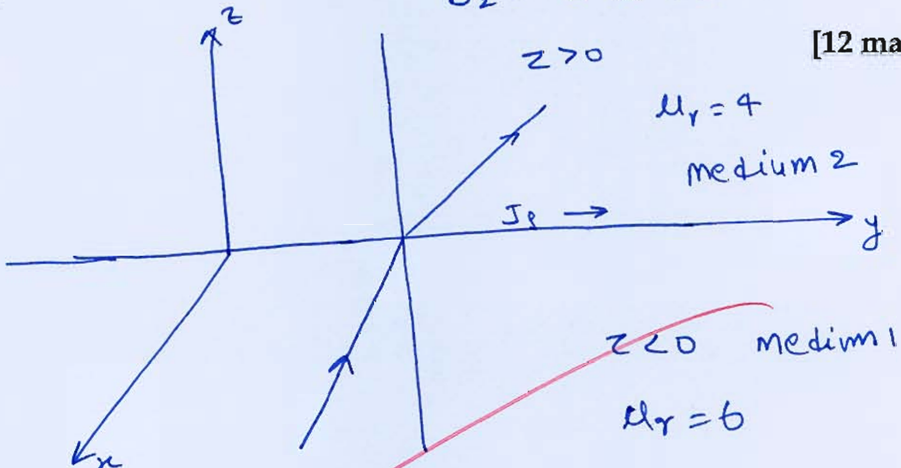
[12 + 8 marks]

Section B : Basic Electronics Engineering + Computer Fundamentals + Electromagnetic Field Theory

Q.5 (a) The xy-plane serves as the interface between two different mediums. Medium-1 ($z < 0$) is filled with a material whose $\mu_r = 6$ and medium-2 ($z > 0$) is filled with a material whose $\mu_r = 4$. If the interface carries current $\left(\frac{1}{\mu_0}\right)\hat{a}_y$ mA/m and $\vec{B}_2 = 5\hat{a}_x + 8\hat{a}_z$ mWb/m^2, find $\vec{H}_1$ and $\vec{B}_1$.

[12 marks]

$\bar{B}_2 = 5\hat{a}_x + 8\hat{a}_z$



for Normal component

$B_{1n} = B_{2n}$

$B_{1n} = 8\hat{a}_z$

$H_{1n} = \frac{B_{1n}}{6\mu_0} = \frac{4}{3\mu_0}\hat{a}_z = H_{1z}$

for tangential component

$(\bar{H}_2 - \bar{H}_1) \times a_{n21} = \bar{J}_s$ —— (1)

~~$H_2 \hat{a}_x + H_2 \hat{a}_y + H_2$~~

$H_2 = \frac{B_2}{\mu_{r2}} = \frac{5\hat{a}_x + 8\hat{a}_z}{4\mu_0}$

$H_2 = \frac{5}{4\mu_0}\hat{a}_x + \frac{2}{\mu_0}\hat{a}_z$

Do not write in this margin

$$\left(\frac{5}{4\mu_0}\hat{a}_x + \frac{2}{\mu_0}\hat{a}_z - H_{1x}\hat{a}_x - H_{1y}\hat{a}_y - H_{1z}\hat{a}_z\right) \times (-\hat{a}_z) = \frac{1}{\mu_0}\hat{a}_y$$

$$\left(\frac{5}{4\mu_0} - H_{1x}\right)\hat{a}_y - H_{1y}(-\hat{a}_x) = \frac{1}{\mu_0}\hat{a}_y$$

$$\frac{5}{4\mu_0} - H_{1x} = \frac{1}{\mu_0}$$

$$H_{1x} = \left(\frac{5}{4}+1\right)\frac{1}{\mu_0} = \frac{9}{4\mu_0}$$

$$H_{1y} = 0$$

$$H_{1z} = \frac{4}{3\mu_0}\hat{a}_z$$

8

$$\bar{H}_1 = \frac{9}{4\mu_0}\hat{a}_x + \frac{4}{3\mu_0}\hat{a}_z$$

$$\bar{B}_1 = 6\mu_0[\bar{H}_1]$$

$$\bar{B}_1 = \frac{27}{2}\hat{a}_x + 8\hat{a}_z$$

$$H_1 = \frac{9}{4\mu_0}\hat{a}_x + \frac{4}{3\mu_0}\hat{a}_z$$

Q.5 (b) In spherical coordinates, electric field intensity is given by $\vec{E} = \frac{2r}{(r^2 + a^2)^2}\hat{a}_r$ V/m. Find the potential at any point, using the reference

(i) $V = 0$ at infinity.

(ii) $V = 0$ at $r = 0$.

(iii) $V = 100$ at $r = a$.

[12 marks]

Soln:-

$$\bar{E} = \frac{2r}{(r^2+a^2)^2}\hat{a}_r \quad V/m$$

$$V = -\int \bar{E}\cdot d\bar{r}$$

(i) $V = 0$ at $r = \infty$

$$V - 0 = -\int_{\infty}^{r} \frac{2r}{(r^2+a^2)^2}\,dr$$

$$= -\int_{+\infty}^{r} \frac{2r}{(r^2+a^2)^2}\,dr$$

$$V = -\left(\frac{-1}{r^2+a^2}\right)_{+\infty}^{r}$$

$$\boxed{V = \frac{1}{r^2+a^2}}\ V$$

(ii) $V = 0$ at $r = 0$

$$V - 0 = -\int_{0}^{r} \frac{2r}{(r^2+a^2)^2}\,dr$$

$$V = \left(\frac{1}{r^2+a^2}\right)_{0}^{r} = \frac{1}{r^2+a^2} - \frac{1}{a^2}$$

$$\boxed{V = \frac{1}{r^2+a^2} - \frac{1}{a^2}}\ V$$

Do not write in this margin

$V = 100$ at $r = a$

$$V - 100 = -\int_a^r \frac{2r}{(r^2+a^2)^2}\, dr$$

$$V - 100 = \left(\frac{1}{r^2+a^2}\right)_a^r = \frac{1}{r^2+a^2} - \frac{1}{2a^2}$$

$$V = \frac{1}{r^2+a^2} - \frac{1}{2a^2} + 100$$

V ✓

11

Good Approach

Q.5 (c) Consider a two level memory hierarchy, L_1 (cache) has an accessing time of 5 ns and main memory has an accessing time of 100 ns. Writing or updating contents takes 20 ns and 200 ns for L_1 and main memory respectively. Assume L_1 gives misses 20% of the time with 60% of the instructions are read only instructions. What is the average access time for system (in ns) if it uses WRITE-THROUGH technique?

[12 marks]

Soln:-

AT of L_1 = 5 ns

AT of MM = 100ns

Writing time of L1 = 20 ns

" " of MM = 200 ns

HT of L1 = 80% = 0.8

Read only instructions = 60%

write instructions = 40%

Using write-through protocol

Avage read time = $0.6[0.8 \times 5 + 0.2 \times 1 \times 100]$

Avarage read time = 14.4 ns

Avarage write time = $0.4[1 \times 20 + 1 \times 200\text{ns}]$

Average write time = 88 ns

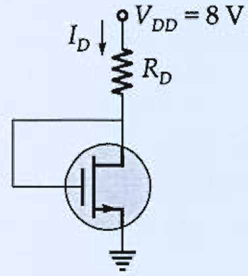
Average access time = Avg. Read time + Avg WT

Avg AT = 14.4 + 88

Avg. AT = 102.5 ns

5

Q.5 (d) In the circuit shown, V_T is 1 V. When R_D is 3 kΩ then I_D is 2 mA and when R_D decreased by 1 kΩ then find the value of I_D.



[12 marks]

Sol^n:-

$V_T = 1$ V

$R_D = 3$ kΩ

$I_D = 2$ mA

As we know, $V_G = V_D$, given MOSFET is in saturation region

~~$I_D = k_n$~~

$$I_D = \frac{k_n}{2}(V_{GS} - V_T)^2$$

$$I_D = \frac{k_n}{2}(V_{DD} - R_D I_D - V_T)^2$$

$$2 = \frac{k_n}{2}(8 - 2 \times 3 - 1)^2$$

$$= \frac{k_n}{2} \times 1$$

$$\boxed{k_n = 4}$$

Now, $R_D = 2$ kΩ

$$I_D = \frac{k_n}{2}(V_{GS} - V_T)^2 = \frac{4}{2}(V_{DD} - I_D R_D - V_T)^2$$

$$I_D = 2(8 - 2I_D - 1)^2$$

$$I_D = 2(7 - 2I_D)^2 = 2\left[49 + 4I_D^2 - 28 I_D\right]$$

Do not write in this margin

$I_D = 8 I_D^2 - 56 I_D + 98$

$8 I_D^2 - 57 I_D + 98 = 0$

$I_D = 4.226 \text{ mA}$ ×

$= 2.898 \text{ mA}$ ✓

$\boxed{I_D = 2.898 \text{ mA}}$

9

Q.5 (e) What are the basic functions of an operating system?

[12 marks]

Sol:- → Operating System :-
It is a software interface between hardware components and user application program.

→ functions of operating system :-

→ It acts as interface between hardware and application program

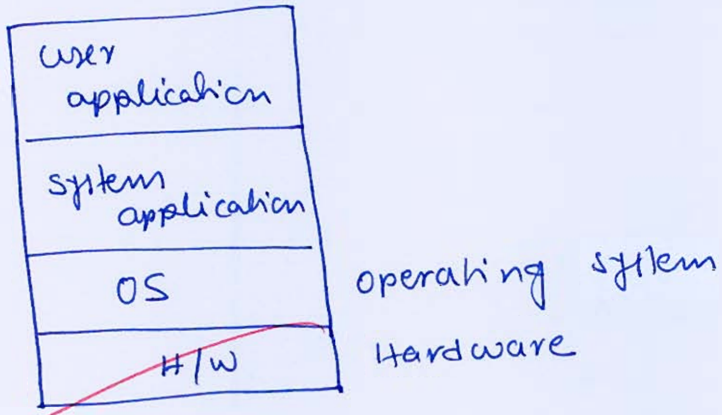
→ It acts as resource allocation such as CPU time, memory space, IO space etc.

→ It is responsible to manage virtual memory using secondary memory space.

→ In the case of page fault, OS is responsible to copy data from secondary memory to primary memory based on predefined replacement policy.

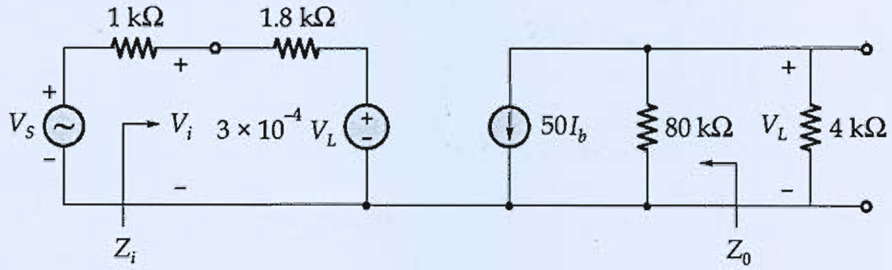
→ It is responsible to manage stack memory, data, temporary data in main memory.

→ It is responsible for process creation and allot CPU space based on predefined priority.


user application
system application
OS
H/W
operating system
Hardware

9

Q.6 (a) The small signal *h*-parameter ac equivalent circuit of a certain transistor connected in CE configuration is as shown in figure below.



Calculate:

(i) Current gain.

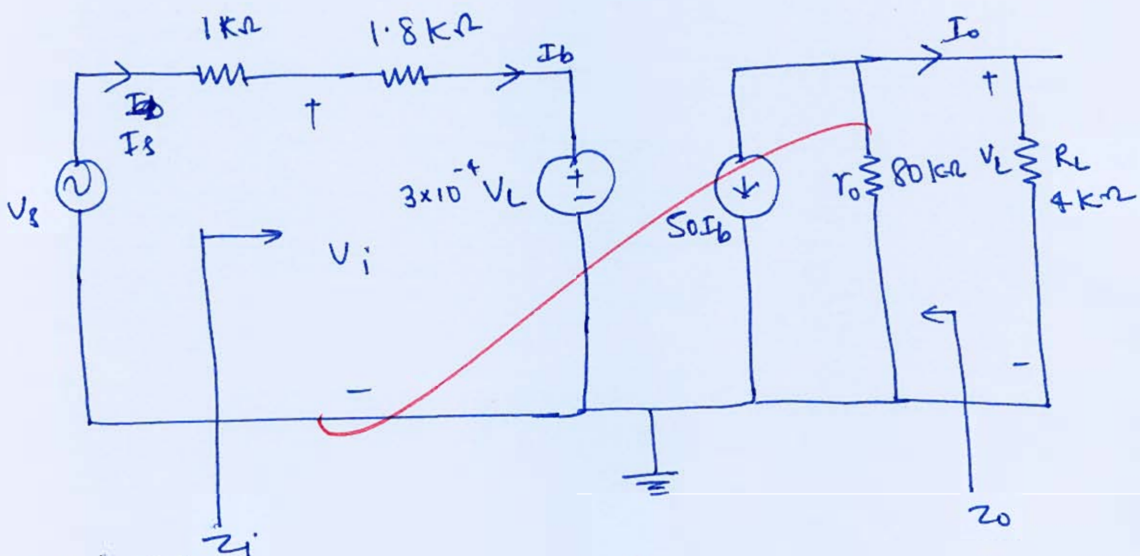
(ii) Voltage gain $\frac{V_L}{V_S}$.

(iii) Input impedance Z_{in}.

(iv) Output impedance Z_{out}.

[20 marks]

Sol^n:- small signal-h parameter ac equivalent circuit



(i) current gain

$$I_o = -50 I_b \times \frac{80}{4+80}$$

$$= -50 \times \frac{80}{84}$$

$$\frac{I_o}{I_b} = \frac{I_o}{I_s} = \boxed{A_i = -47.62}$$

voltage gain

$V_s = 10^3(1\ I_b + 1.8\ I_b) + 3\times10^{-4}\ V_L$ — ①

$V_L = -50\ I_b\ (80 \| 4k\Omega)$

$V_L = -190.476\ I_b \times 10^3$ — ②

~~$V_s = 2.8\times10^3 + 3\times10^{-4}$~~

~~$V_s = 2.8\times190.476 + 3\times10^{-4}$~~

$V_s = \frac{-2.8}{190.476} V_L + 3\times10^{-4}\ V_L$

$V_s = -14.7\times10^{-3} + 0.3\times10^{-3}\ V_L$

$$\boxed{\frac{V_L}{V_s} = A_v = -69.44}$$

(iii) Input impedence :

$Z_i = \frac{V_i}{I_b} = \frac{1.8\times10^3\ I_b + 3\times10^{-4}\ V_L}{I_b}$

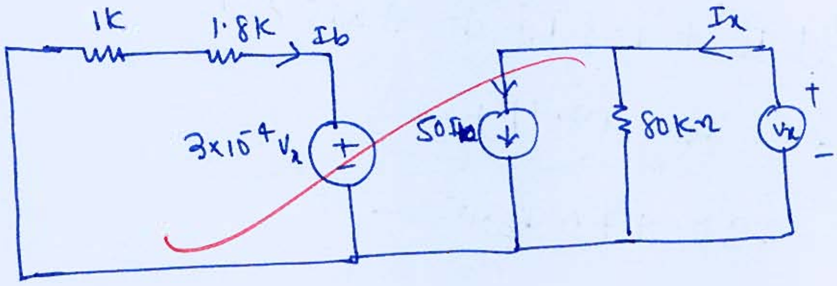
from eqn ②

$Z_i = \frac{1.8\times10^3\ I_b + 3\times10^{-4}\times(-190.476\times10^3)\ I_b}{I_b}$

$Z_i = 1.8\times10^3 + -57.14$

$$\boxed{Z_i = 1742.85\ \Omega}$$

(iv) Output impedence , $V_s = 0$



$$I_x = 50 I_b + \frac{V_x}{80\times10^3} \quad — ③$$

$$-2.8 I_b - 3\times10^{-4} V_x = 0 \quad — ④$$

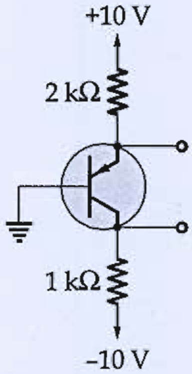
$$I_x = 50\left(\frac{-3\times10^{-4} V_x}{2.8\times10^3}\right) + \frac{V_x}{80\times10^3}$$

$$I_x = \frac{1}{140\times10^3} V_x$$

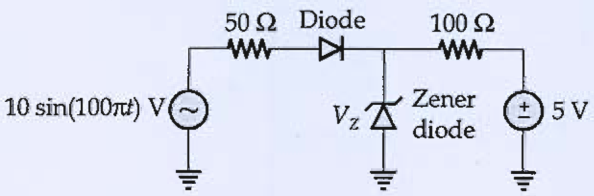
$$\boxed{\frac{V_x}{I_x} = Z_{out} = 140\,k\Omega}$$

18

(i) Determine the voltages at all nodes and currents through all branches. (Assume $\beta = 100$).

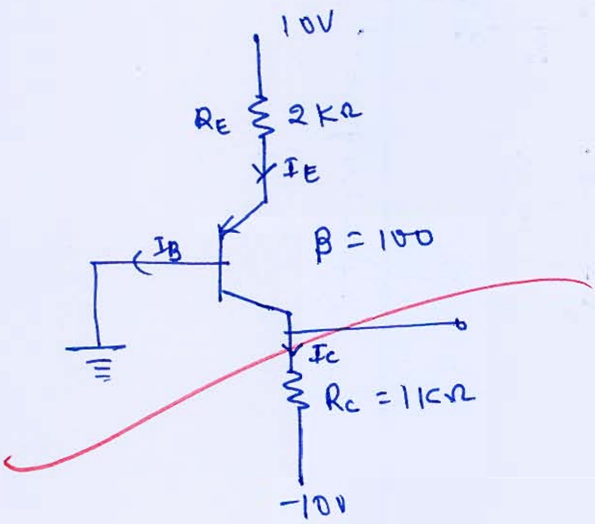


(ii) If the diodes in the circuit shown are ideal and the breakdown voltage V_z of the zener diode is 5 V, find the power dissipated in the 100 Ω resistor.



[10 + 10 marks]

Q1: (i)



KVL:

$10 - 0.7 = 2 I_E$

$I_E = 4.65 \text{ mA}$

Assuming in Active region

$I_c = \frac{\beta}{\beta+1} \times I_E$

$I_c = 4.604 \text{ mA}$, $I_B = 0.046 \text{ mA}$

$V_o = R_C I_C = 1 \times 4.604 - 10$

$V_o = -5.396\ V$

~~$V_{EC} = V$~~

$V_{E} = 10 - R_E I_E = 0.7$

$V_E = 0.7V$, $V_G = 0V$

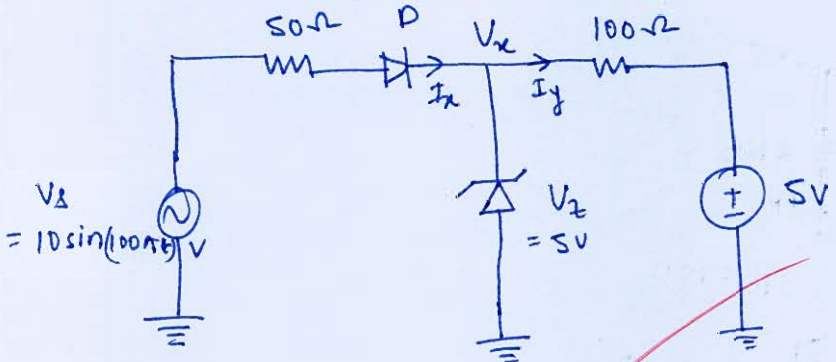
$V_{EC} = V_E - V_C$

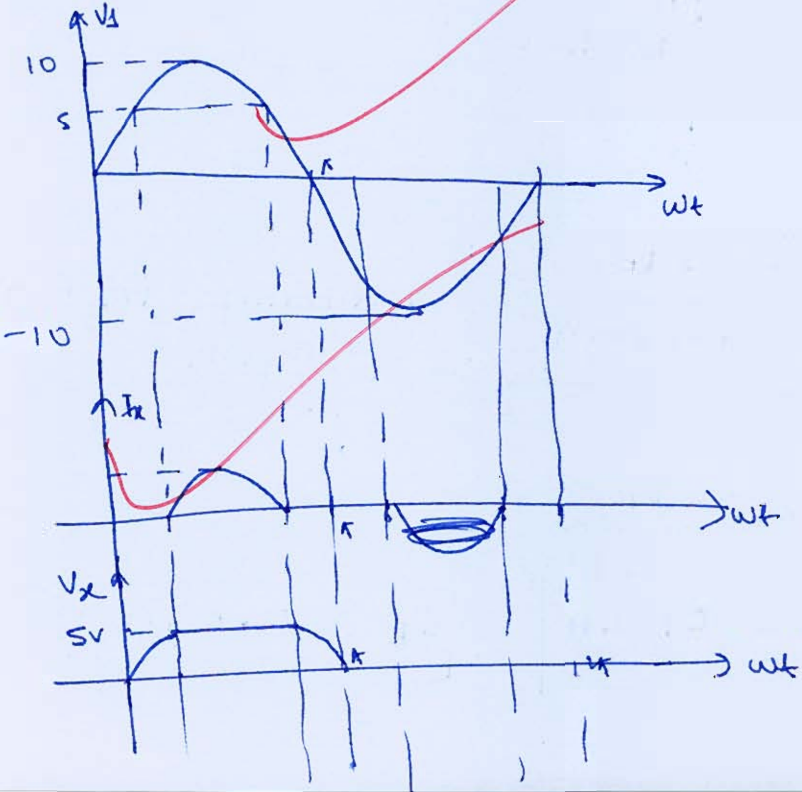
$V_{EC} = 0.7 - -5.396$

$V_{EC} = 6.096\ V$

6

(ii)





$I_y = 0$ will be zero in all case

So, power dissipation through

100Ω resistor = $\boxed{0W}$

8

Q.6 (c) **(i)** Explain the IEEE standard 754 floating point numbers representation.

(ii) Determine the size of subfields (in bits) in the address for direct mapping and associative mapping cache scheme:
Size of main memory = 256 MB
Size of cache memory = 1 MB
The address space of this processor is 256 MB. The block size is 128 bytes.

[10 + 10 marks]

Soln:- IEEE-754 floating point number resprentation

→ when any number is too large or too small (fraction) then for represen ting these numbers we use floating point number.

→ According to IEE-754, there are type of representation of floating points number.

(i) 32- bit representation

S	BE	M
1-bit +ve -ve	Bias exponent 8-bit	Mantissa 23-bit

So, any number N is representad in 32-bit floating point representation as

$$N = S \cdot 1.M \cdot 2^{AE}$$

Where, $BE = Bais + AE$

$AE = BE - Bias$

and $Bias = 2^{8-1} - 1 = +127$

64-bit floating point representation

s	BE	M
1-bit	11-bit	~~48 bit~~ 52-bit
+ve -ve		

$N = S * 1.M * 2^{AE}$

$AE = BE - Bias$

~~$Bias = 2^{48-1} - 1 = 2^{47} - 1$~~

$Bias = 2^{52-1} - 1 = 2^{51} - 1$

Size of main memory (MM) = 256×2^{20} B

" " cache memory (CM) = 1×2^{20} B

Block size = 128 B

Number of blocks in MM = $\frac{256 \times 10^{20}}{128}$

$= 2^{21}$

Number of line in CM = $\frac{1 \times 2^{20}}{128}$

$= 2^{13}$

Address space of processor = 256×2^{20}

$= 2^{28}$

= 28-bits

18

Good Approach

(a) using Direct mapping

Tag	Line offset	word offset
Tag	LO	WO
← 8-bits →	$\log_2 2^{13}$ ← 13-bits →	$\log_2 128$ ← 7-bits →

(b) using Associative mapping

	Word offset
Tag space	WO
$\log_2 2^{21}$ ← 21- bits →	$\log_2 128$ ← 7-bits →

(i) A processor has 16 integer registers (R0, R1, ..., R15) and 64 floating point registers (F0, F1, ..., F63). It uses a 2-byte instruction format. There are four categories of instructions: Type-1, Type-2, Type-3 and Type-4. Type-1 category consists of four instructions, each with 3 integer register operands (3Rs). Type-2 category consists of eight instructions, each with 2 floating point register operands (2Fs). Type-3 category consists of fourteen instructions, each with one integer register operand and one floating point register operand (1R+1F). Type-4 category consists of N instructions, each with a floating point register operand (IF). Find the maximum value of N.

[12 marks]

(ii) The memory access time is 1 nanosecond for a read operation with a hit in cache, 5 nanoseconds for a read operation with a miss in cache, 2 nanoseconds for a write operation with a hit in cache and 10 nanoseconds for a write operation with a miss in cache. Execution of a sequence of instructions involves 100 instruction fetch operations, 60 memory operand read operations and 40 memory operand write operations. The cache hit-ratio is 0.9. Find the average memory access time (in nanoseconds) in executing the sequence of instructions.

[8 marks]

An electrostatic field is given by,

$$\bar{E} = -8xy\,\hat{a}_x - 4x^2\hat{a}_y + \hat{a}_z \text{ V/m}$$

The charge of 6 C is to be moved from $B(1, 8, 5)$ to $A(2, 18, 6)$. Find the work done in each of the following cases:

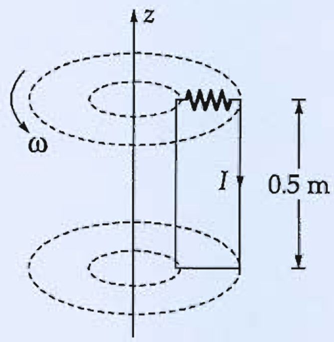
(i) The path selected is $y = 3x^2 + z$, $z = x + 4$.

(ii) The straight line from B to A.

Show that work done remains same and is independent of the path selected.

[20 marks]

Q.7 (c) **(i)** A rectangular conducting loop with resistance of 0.2 Ω rotates at 500 rpm, as shown in figure below. The vertical conductor at $r_1 = 0.03$ m is in the field $\vec{B}_1 = 0.25\hat{a}_r T$ and other conductor is at $r_2 = 0.05$ m and is in the field $\vec{B}_2 = 0.8\hat{a}_r T$. Find the current flowing in the loop.



(ii) A wire of non-magnetic material with radius R and length l carries a current I, which is uniformly distributed over its cross-section. What is the magnetic energy inside the wire?

[14 + 6 marks]

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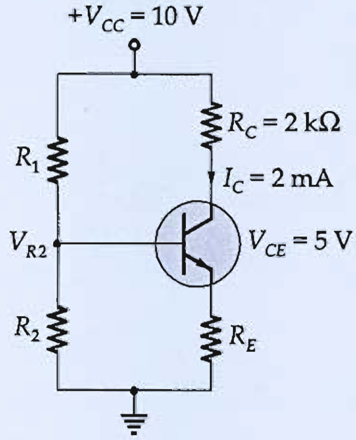
Q.8 (a) A silicon n-p-n transistor operated with self bias gives V_{CEQ} = 5 V, I_{CQ} = 2 mA fo V_{CC} = 10 V and R_C = 2 K. If β for the transistor is 50, V_{BE} = 0.7 V and stability factor "S is 5 calculate, the values of biasing resistors R_1, R_2 and R_E.



[20 marks]

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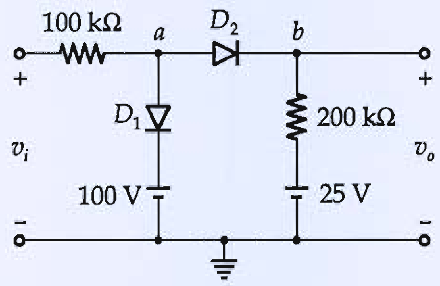
Determine and sketch the voltage transfer characteristic of the circuit shown in the figure below.



(Assume that the diodes are ideal)

[20 marks]

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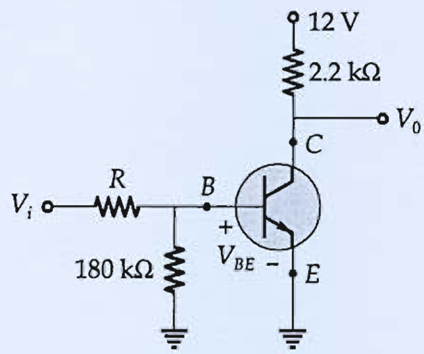
Q.8 (c) In the circuit shown below, a silicon transistor with specifications:
$\beta \geq 30$ and $I_{CBO} = 100$ nA.



Determine :

(i) The value of V_0 for $V_i = 12$ V and $R = 20$ kΩ and show that transistor is in saturation.

(ii) The minimum value of R for the transistor to remain in the active region for $V_i = 12$ V.

(iii) The value of V_0 for $V_i = 1$ V and $R = 15$ kΩ, also find the region of operation.

[20 marks]

0000

Space for Rough Work

Space for Rough Work

Space for Rough Work

$$\frac{A/m^2}{V/m}$$

$$\frac{A}{Vm}$$

$\Omega = \frac{m}{\sigma} \quad \frac{m}{m^2 m}$

$\sigma = \Omega^{-1} m^{-1}$