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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 :

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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	38
Q.2	
Q.3	52
Q.4	50
Section-B	
Q.5	33
Q.6	
Q.7	
Q.8	54
Total Marks Obtained	227

Signature of Evaluator: Sourabh kumar

Cross Checked by: ....

IMPORTANT INSTRUCTIONS

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2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
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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.
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6. Handover your QCAB personally to the invigilator before leaving the examination hall.

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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]

Given :- $\bar{J} = \frac{1}{r^3}(2\cos\theta\ \hat{a}_r + \sin\theta\ \hat{a}_\theta)$ A/m²

(i) For $r = 20$ cm

$0 < \theta < \pi/2$, $0 < \phi < 2\pi$

$ds = r^2 \sin\theta\, d\theta\, d\phi\ \hat{a}_r$

~~$= 4(0.2)^2 \cos\theta$~~

$\bar{J} \cdot \bar{ds} = \frac{1}{r^3} \cdot 2\cos\theta \times r^2 \sin\theta\, d\theta\, d\phi$

$= \frac{1}{r} \cdot 2\sin\theta\cos\theta\, d\theta\, d\phi$

$= \frac{\sin 2\theta}{r}\, d\theta\, d\phi$

Current,

$I = \iint J \cdot ds$

$= \int_{\theta=0}^{\pi/2}\int_{\phi=0}^{2\pi} \frac{\sin 2\theta}{0.2}\, d\theta\, d\phi$

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

$= \frac{5}{2}\{2\} \times 2\pi = 10\pi$

$\therefore \quad I = 10\pi \text{ A}$

$$\boxed{I = 31.416 \text{ A}}$$

(ii) for spherical shell, $r = 10$ cm

$0 < \theta < \pi \quad 0 < \phi < 2\pi$

$$I = \iint J \cdot dS$$

$$= \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} \frac{\sin 2\theta}{0.1} \, d\theta \, d\phi$$

$$= 10 \times \left[-\frac{\cos 2\theta}{2} \right]_0^{\pi} \times (\phi)_0^{2\pi}$$

$$= 5 \times (1 - 1) \times 2\pi$$

$$= 0$$

$\therefore$ current, $\boxed{I = 0}$

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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]

For $0 \le r \le R$

$$\rho_v = \frac{\rho_0 r}{R}$$

According to Gauss divergence theorem -

$$\oint \bar{D} \cdot \bar{ds} = Q_{enc} = \iiint \rho_v \, dv$$

$$\oint D_r \cdot ds = \iiint \frac{\rho_0 r}{R} \cdot r^2 \sin\theta \, dr \, d\theta \, d\phi$$

$$D_r (4\pi r^2) = \frac{\rho_0}{R} \times \frac{r^4}{4} \times 2 \times 2\pi$$

$$D_r = \frac{\rho_0 r^2}{4R}$$

Electric field

$$\bar{E} = \frac{\bar{D}}{\epsilon}$$

$$\boxed{\bar{E} = \frac{\rho_0 r^2}{4 \epsilon R} \hat{a}_r}$$

For $r > R$

$$\rho_v = 0$$

$$Q_{enc} = \iiint \rho_v \, dv$$

$$= \iiint \frac{\rho_0 r}{R} \cdot r^2 \sin\theta \, dr \, d\theta \, d\phi$$

$$Q_{encl} = \frac{\rho_0}{R} \cdot \frac{R^4}{4} \cdot 4\pi$$

$$= \frac{\rho_0 R^3}{4} \cdot 4\pi$$

$$\therefore \oint \bar{D} \cdot d\bar{s} = Q_{encl}$$

$$D_r (4\pi r^2) = \frac{\rho_0 R^3}{4} \cdot 4\pi$$

$$D_r = \frac{\rho_0 R^3}{4 r^2}$$

Electric field

$$\bar{E} = \frac{\bar{D}}{\epsilon_0}$$

$$= \frac{\rho_0 R^3}{4 \epsilon_0 r^2} \hat{a_r}$$

$$\therefore \bar{E} = \begin{cases} \frac{\rho_0 r^2}{4 \epsilon R} \hat{a_r} & 0 \le r \le R \\ \frac{\rho_0 R^3}{4 \epsilon_0 r^2} \hat{a_r} & r > R \end{cases}$$

Good approach

11

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]

l = 3000 km

BW = 1.544 Mbps

v = 0.16×10^6 km/sec

frame size = 64 B

∴ $l \times BW = 3000 \times 1.544 \times 10^6$

$= 4.632 \times 10^9$

and frame size × v

$= 0.16 \times 10^6 \times 64 \times 8$

$= 81.92 \times 10^6$

window size = $\frac{4.632 \times 10^9}{81.92 \times 10^6}$

window size = 5.654

(3)

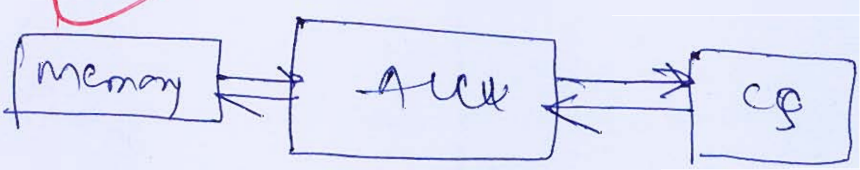
Q.1 (d) What does "computer architecture" term means in regards to computing system? Enumerate properties of reduced instruction set computer architecture.

[12 marks]

Computer Architecture

computer architecture means the basic architecture at which basic component of system i.e. memory, ALU, and control unit are connected together.

For example Van-neumann computer architecture



Reduced Instruction set Computer architecture (RISC)

- In this architecture, simple instruction are used
- Since it is simple instruction hence it require more number of instruction
- Number of resistor require is more
- It Consume more power
- It is slower.

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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]

(i) $\bar{A} = \rho z^2 \hat{\rho} + \rho \sin^2\phi \hat{\phi} + 2\rho z \sin^2\phi \hat{z}$

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

$$= \frac{1}{\rho} \begin{vmatrix} \hat{a}_\rho & \rho \hat{a}_\phi & \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ \rho z^2 & \rho^2 \sin^2\phi & 2\rho z \sin^2\phi \end{vmatrix}$$

$$= \frac{1}{\rho} \Big[(4\rho z \sin\phi \cos\phi - 0)\hat{a}_\rho - (2z\sin^2\phi - 2\rho z)\rho \hat{a}_\phi + (2\rho \sin^2\phi - 0)\hat{a}_z \Big]$$

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

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(ii) $\bar{B} = r\,\hat{a}_r + r\cos^2\phi\,\hat{a}_\phi$

$$\nabla\times\bar{B} = \frac{1}{r^2\sin\theta}\begin{vmatrix} \hat{a}_r & r\hat{a}_\theta & r\sin\theta\,\hat{a}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial\theta} & \frac{\partial}{\partial\phi} \\ A_r & rA_\theta & r\sin\theta\,A_\phi \end{vmatrix}$$

$$= \frac{1}{r^2\sin\theta}\begin{vmatrix} \hat{a}_r & r\hat{a}_\theta & r\sin\theta\,\hat{a}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial\theta} & \frac{\partial}{\partial\phi} \\ r & 0 & r\cos^2\phi \end{vmatrix}$$

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

$$= \frac{1}{r^2\sin\theta}\Big\{ -2r\sin\phi\cos\phi\,\hat{a}_r - \cos^2\phi\,r\,\hat{a}_\phi \Big]$$

$$\nabla\times\bar{B} = -\frac{2\cos\phi}{r}\,\hat{a}_r - \frac{\cos^2\phi}{r\sin\phi}\,\hat{a}_\phi$$

6

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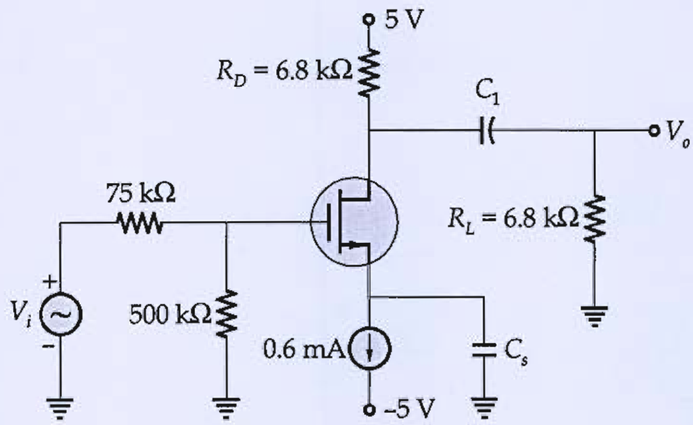
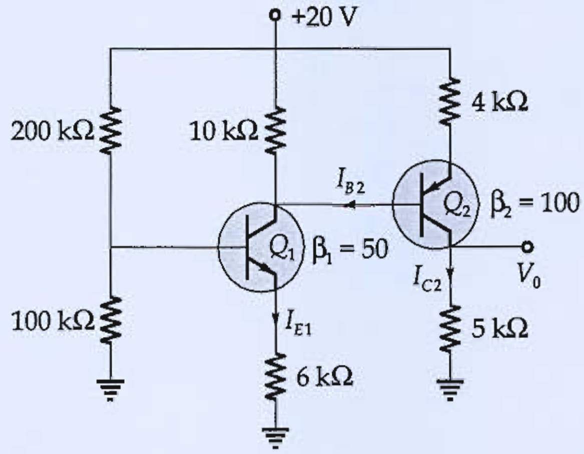
Q.2 (a) Determine the small signal voltage gain of the circuit shown in below figure having parameters $V_T = 0.8$ V, $k = \frac{\mu_n C_{ox} W}{2L} = 1.2$ mA/V^2, $\lambda = 0$. Also calculation gate-to-source voltage (V_{GSQ}).



[20 marks]

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



Determine:

(i) Base current of transistor, Q_2.

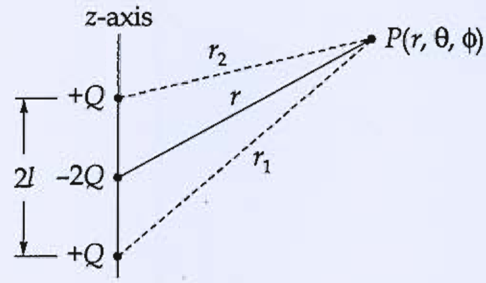
(ii) Collector current of transistor, Q_2.

(iii) Emitter current of transistor, Q_1.

(iv) Output voltage, V_0.

[20 marks]

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/m^2 on the conductor, determine $\vec{E}$ and $\vec{D}$ at $A(3, -2, 2)$ and $B(-4, 1, 5)$.

[8 marks]

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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/m^3) in both dielectrics.

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

[20 marks]

$z > 0$ medium 1 $\qquad \varepsilon_{r_1} = 4$

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

$\uparrow \hat{a}_n$

———————————— $z = 0$

$z < 0$ medium 2 $\qquad \varepsilon_{r_2} = 3$

$\hat{a}_n = \hat{a}_z$

$\bar{E}_{n_1} = 3\hat{a}_z$ kV/m

$\bar{E}_{t_1} = 5\hat{a}_x - 2\hat{a}_y$ kV/m

(i) Now, $\bar{E}_{t_2} = \bar{E}_{t_1}$

$\bar{E}_{t_2} = 5\hat{a}_x - 2\hat{a}_y$ kV/m — (1)

and, $\bar{D}_{n_2} = \bar{D}_{n_1}$

$\Rightarrow \varepsilon_{r_2} \cdot \varepsilon_0 \bar{E}_{n_2} = \varepsilon_{r_1} \cdot \varepsilon_0 \bar{E}_{n_1}$

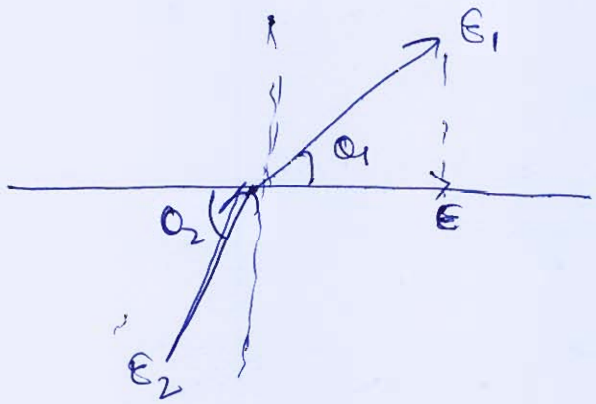
$\bar{E}_{n_2} = \frac{4}{3} \times 3\hat{a}_z$

$\bar{E}_{n_2} = 4\hat{a}_z$ kV/m

$$\therefore \bar{E}_2 = \bar{E}_{t_2} + \bar{E}_{n_2}$$

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

(ii)



$$|E_1| \cos\theta_1 = |E_{t_1}|$$

$$\sqrt{5^2 + 2^2 + (3)^2} \cdot \cos\theta_1 = \sqrt{5^2 + (2)^2}$$

$$\cos\theta_1 = \frac{\sqrt{5^2 + 2^2}}{\sqrt{5^2 + (2)^2 + (3)^2}}$$

$$\cos\theta_1 = \frac{\sqrt{29}}{\sqrt{38}}$$

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

and, $|E_2| \cos\theta_2 = |E_{t_2}|$

$$\sqrt{5^2 + (2)^2 + (4)^2} \cos\theta_2 = \sqrt{5^2 + (2)^2}$$

$$\cos\theta_2 = \frac{\sqrt{29}}{\sqrt{45}}$$

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

(iii) Energy density in medium ①

$$w_{E_1} = \frac{1}{2} \epsilon_1 E_1^2$$

$$= \frac{1}{2} \times 4 \times 8.85 \times 10^{-12} \times (\sqrt{38} \times 10^3)^2$$

$$\boxed{w_{E_1} = 6.726 \times 10^{-4} \ J/m^3}$$

Energy density in medium ②

$$w_{E_2} = \frac{1}{2} \epsilon_2 E_2^2$$

$$= \frac{1}{2} \times 3 \times 8.85 \times 10^{-12} (\sqrt{45} \times 10^3)^2$$

$$\boxed{w_{E_2} = 5.974 \times 10^{-4} \ J/m^3}$$

(iv) cube of side 2m centred at (3,4,-5)

as $z = -5$ it lies in medium ② a

volume of cube = $(2)^3$ = 8 m^3

Energy = $w_{E_2} \times$ volume of cube

$= 5.974 \times 10^{-4} \times 8$

$= 4.78 \times 10^{-3}$ J

$$\boxed{\text{Energy} = 4.78 \ mJ}$$

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Good Approach

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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]

Given :- $r = 5\,mm$, $l = 20\,m$

$V = 0.1\,V$ $\quad \bar{H} = 10^5 \rho^2 \hat{a}_\phi$ A/m

(i) current density,

$$\bar{J} = \nabla \times \bar{H}$$

curl in cylindrical co-ordinates system :-

$$\nabla \times \bar{H} = \frac{1}{\rho} \begin{vmatrix} \hat{a}_\rho & \rho \hat{a}_\phi & \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\phi & A_z \end{vmatrix}$$

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

$$= \frac{1}{\rho} \left[\frac{\partial}{\partial \rho} (10^5 \rho^3)\, \hat{a}_z \right]$$

$$= \frac{1}{\rho} \times 10^5 \cdot 3\rho^2\, \hat{a}_z$$

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

$$\bar{J} = 3 \times 10^5 \rho\, \hat{a}_z \quad A/m^2$$

Now, Electric field $\bar{E} = \frac{V}{d}$

$$\bar{E} = \frac{0.1}{20} = 5 \times 10^{-3}\ V/m$$

~~Elo~~ Conductivity,

~~Re2~~ $J = \sigma E$

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

$= \frac{3\times10^5 \times (5\times10^{-3})}{5\times10^{-3}}$

~~$\sigma = 4\times10^{7}$ ℧/m~~

$\sigma = 3\times10^5$ ℧/m

(ii) $I = \int \bar{J}\cdot d\bar{s}$

$\bar{J} = 3\times10^5 \rho\, \hat{a}_z$ A/m²

$ds = \rho\, d\rho\, d\phi\, \hat{a}_z$

$I = \int_{\rho=0}^{5mm}\int_{\phi=0}^{2\pi} 3\times10^5 \cdot \rho \times \rho\, d\rho\, d\phi$

$= 3\times10^5 \times \left[\frac{\rho^3}{3}\right]_0^{5mm} \times (\phi)_0^{2\pi}$

$= 3\times10^5 \times \frac{(5\times10^{-3})^3}{3} \times 2\pi$

~~Sol~~ ~~Oelleeen~~

$I = 0.0785$ A

∴ Resistance,

$$R = \frac{V}{I}$$

$$= \frac{0.1}{0.0785}$$

$$\boxed{R = 1.273\ \Omega}$$

Hence, resistance, $R = 1.273\ \Omega$

(18)

Good Approach

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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) Program to check a character is a vowel or a consonant

```
# include <studio.h>
int main()
{
    char ch;
    printf("Enter an alphabet: ");
    scanf(" %c", &ch);
    if ((ch>='a' && ch<='z' ||
                 (ch>='A' && ch<='Z'))
    { char lower = (ch>='A' &&
                    ch<='Z') ? ch+32 :
                                 ch;
    if (lower = 'a' || lower == 'e' ||
           lower == 'i' || lower == 'o' ||
              lower == 'u')
    printf(" %c is vowel \n", ch);
    else
       printf(" %c is consonent \n", ch);
    }
    else
       printf(" Invalid input. Plese
              enter a valid input. \n");
    return 0;
}
```

Do not write in this margin

(ii) ① Do - while loop and while loop

Features	while loop	Do - while loop
Condition check	At the begining	At the end
Minimum execution	may not execute even once	Execute at least once
Syntax	while (condition) { - - - };	do { - - - } while (condition);

②

Iteration	Recursion
- Repeating a block using loops (for, while)	- function calling itself repeatedly
- used in loops	- used in functions
- controlled by loop conditions	- controlled by base condition
- less memory, uses a single loop	- more memory uses stack
- Generally faster and more efficient	- can be slower due to function call overhead
- Longer but more efficient	- shorter but sometimes harder to debug.

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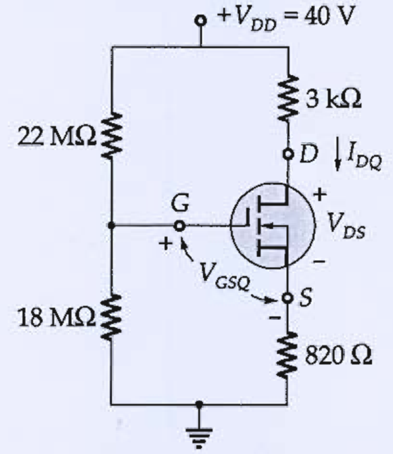
Q.4 (a) Determine I_{DQ}, $V_{GS\,Q}$ and V_{DS} for the circuit shown in figure,



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

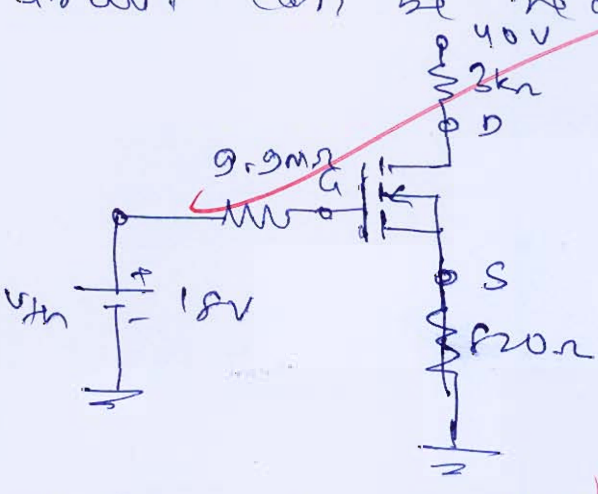
[20 marks]

For the given circuit −

$$V_{th} = 40 \times \frac{18\,M\Omega}{(22+18)\,M\Omega} = 18\,V$$

$$R_{th} = \frac{18 \times 22}{18 + 22} = 9.9\,M\Omega$$

circuit can be redrawn as −



It is n-channel MOSFET

as Gate current, $I_G = 0$

Gate voltage,

$\therefore V_G = 18V$

source voltage, $V_S = V$ (let)

$\therefore V_{GS} = 18 - V$ — ①

$(V_{GS})_{TH} = 5V$

$V_{GS} = 18 - V > (V_{GS})_{th} = 5V$

~~and everpee~~

let the ~~term~~ MOSFET in saturation region, then drain current –

$I_D = K(V_{GS} - V_{th})^2$

Given, $I_D = 3\,mA$ at $V_{GS(on)} = 10V$

put the value –

$3 = K(10 - 5)^2$

$$\boxed{K = 0.12\ mA/V^2}$$

Now, for $V_{GS} = 18 - V$

Drain current –

$I_D = 0.12(18 - v - 5)^2$

$I_D = 0.12(13 - V)^2$ — (I)

Also, $I_D = \frac{V_S - 0}{0.82} = \frac{V}{0.82}$ — (II)

Equating (I) & (II) we get –

$0.12(13 - V)^2 = \frac{V}{0.82}$

$\Rightarrow 0.0984(13 - V)^2 = V$

$\Rightarrow 0.0984(169 + V^2 - 26V) = V$

$0.0984 V^2 - 3.5584 + 16.62 = 0$

solving the above eq^n we get -

$V = 30.64, 5.514$

↑ this value is discarded as $18 - V > 5$, $V < 23$

$\therefore V = 5.514 V$

from eq- (11) -

Drain current $I_D = \frac{5.514}{0.82}$

$I_{DQ} = 6.724 mA$

and gate-source voltage

$V_{GSQ} = 18 - V$
$= 18 - 5.514$

$V_{GSQ} = 12.486 V$

18

Good Approach

$\therefore$ Drain voltage

$V_D = 40 - 3 \times 6.724$

$V_D = 19.828 V$

$V_{DSQ} = 19.828 - 5.514 = 14.314$

$V_{DS} = 14.314 V$

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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]

```
# include <studio.h>
int main ()
{
    int a[100], n, i, j, temp;
    printf(" Enter number of elements : ");
    scanf(" %d", &n);
    printf(" Enter %d elements : \n", n);
    for (i=0; i<n ; i++)
        scanf(" %d", &a[i]);
    for (i=0 ; i<n-1 ; i++)
    {
        for (j=0 ; j<n-i-1 ; j++)
        {
            if (a[j] > a[j+1])
            temp = a[j]
            a[j] = a[j+1];
            a[j+1] = temp;
        }
    }
    print f(" sorted array in ascending order : \n");
    for (i=0 ; i<n ; i++)
        printf(" %d ", a[i]);
    return 0;
}
```

8

Do not write in this margin

(11) Translator software

- General term for any program that translates code from one language to another
- convert high-level or assembly language into machine language (binary)
- Includes – Assembler,
  – compiler,
  – Interpreter

Assembler

- translates Assembly language (low-level) into machine code
- one to one conversion (each assembly instruction → one machine instruction)

Compiler

- Translates entire high-level program (e.g C, C++) into machine code at once

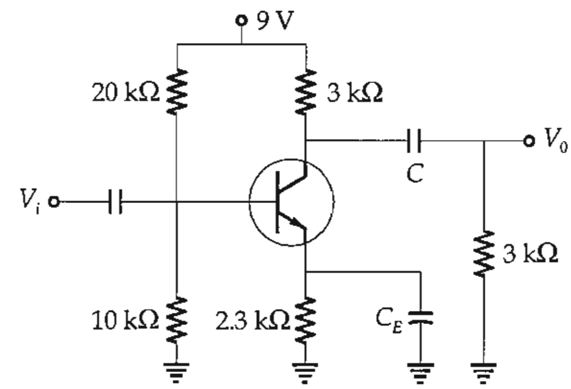
Interpreter

- Translates high-level code line by line into machine code and execute it immediately.

Compiler	Interpreter
- Translates entire high-level program into machine code at once	- Translates high-level code line by line into machine code and execute it immediately
- Faster than Interpreter because it execute entire code at once	- Slower than a compiler because it reads and runs one line at a time
- Error are shown after full compilation	- stops at first error
- e.g. GCC (for C, C++) javac (for java)	- e.g. Phython interpreter, Javascript engine

9

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:

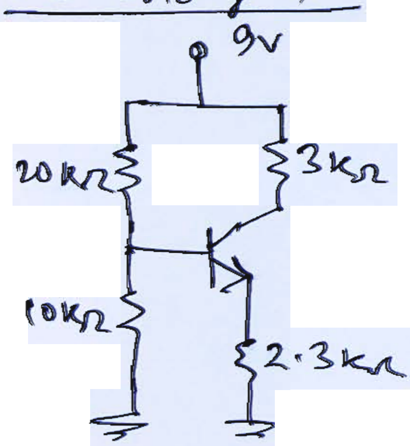
1. The value of DC current I_E.
2. The mid band voltage gain of the amplifier.

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

[12 + 8 marks]

(i) DC analysis

(1)

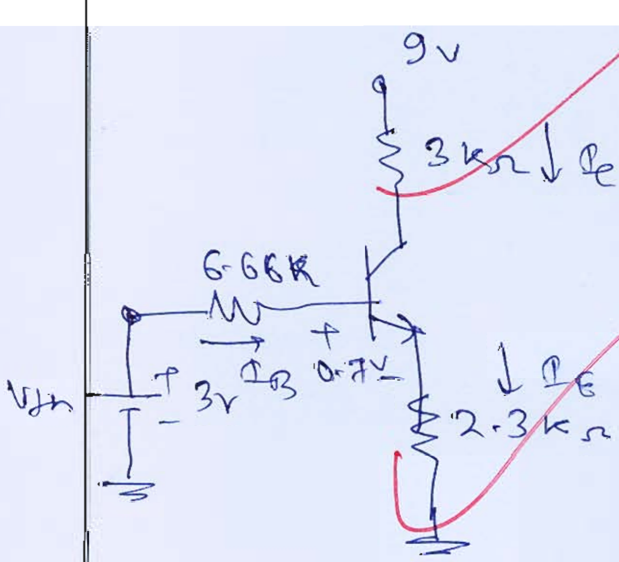


$V_{th} = 9 \times \frac{10}{10+20}$

$V_{th} = 3V$

$R_{th} = \frac{20 \times 10}{20+10}$

$R_{th} = 6.66 k\Omega$



KVL —

$3 - 6.66 I_B - 0.7 - (\beta+1) I_B \times 2.3 = 0$

let $\boxed{\beta = 100}$ (as it is not given in question)

$$I_B = \frac{2.3}{6.66 + 101 \times 2.3}$$

$$I_B = 9.625\ \mu A$$

$\therefore \quad I_E = (\beta+1) I_B$

$$= 101 \times 9.625 \times 10^{-6}$$

$$\boxed{I_E = 0.972\ mA}$$

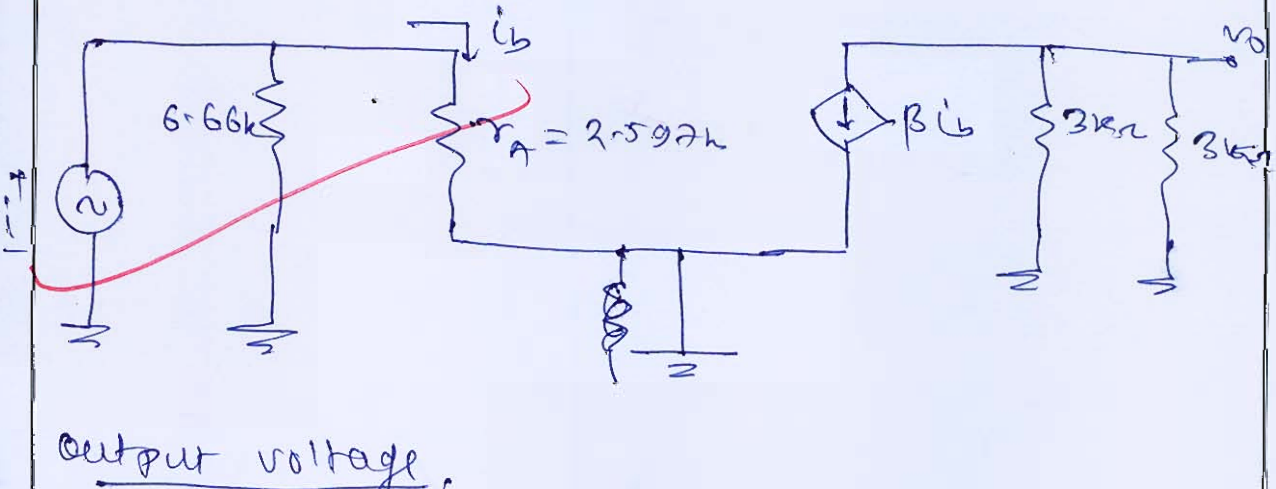
(2) AC analysis

$$r_e = \frac{V_T}{I_E} = \frac{25\ mV}{0.972\ mA} = 25.716\ \Omega$$

$$r_\pi = (\beta+1) r_e = 101 \times 25.716$$

$$r_\pi = 2.597\ k\Omega$$

r_π - model



Output voltage,

$$V_o = -\beta i_b (3k \parallel 3k)$$

$$= -\beta i_b (1.5k)$$

and input voltage

$v_{in} = i_b \times r_\pi$

∴ midband voltage gain –

$A_v = \frac{v_0}{v_{in}}$

$= \frac{-\beta i_b (1.5k)}{i_b \times r_\pi}$

$= \frac{-\beta (1.5k)}{r_\pi}$

$= -\frac{100 \times 1.5k}{2.597k}$

$A_v = -57.76$

-60

Hence, midband voltage gain –

$A_v = -57.76$

10

(11) Direct Memory access

Direct memory access (DMA) is a technique used in computer system to transfer data directly between memory and peripheral devices (like hard drives, ~~source~~ sound cards, network cards) without involving CPU.

Different types of DMA transfer mode

(1) Burst mode - DMA transfer all data in one go, blocking CPU temporarily

(2) Cycle stealing - DMA transfer one byte at a time, giving CPU access between bytes.

(3) Transparent mode - DMA transfers only when CPU is idle.

5

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/m², find $\vec{H}_1$ and $\vec{B}_1$.

[12 marks]

$z > 0$ medium ② $\quad \mu_{r_2} = 4 \quad \bar{B}_2 = 5\hat{a}_x + 8\hat{a}_z$ mWb/m²

$\hat{a}_n = \hat{a}_z$

$z = 0$

$z < 0$ medium ① $\quad \mu_{r_1} = 6$

$$\bar{K} = \frac{1}{\mu_0}\hat{a}_y \text{ mA/m}$$

$$\bar{B}_2 = 5\hat{a}_x + 8\hat{a}_z \text{ mWb/m}^2$$

$$\bar{B}_{2n} = 8\hat{a}_z \text{ mWb/m}^2$$

$$\bar{B}_{2t} = 5\hat{a}_x \text{ mWb/m}^2$$

∴ Across the interface -

$$\bar{B}_{2n} = \bar{B}_{1n}$$

$$\bar{B}_{1n} = 8\hat{a}_z \text{ mWb/m}^2$$

$$\bar{B}_{2t} = 5\hat{a}_x \text{ mWb/m}^2$$

$$\mu_{r_2}\bar{H}_{2t} = 5\hat{a}_x$$

$$\bar{H}_{2t} = \frac{1}{4\mu_0} 5\hat{a}_x \text{ mA/m}$$

$$\bar{H}_{1t} - \bar{H}_{2t} = \bar{K} \times \hat{a}_n$$

$$= \frac{1}{\mu_0} \hat{a}_y \times \hat{a}_z$$

$$= \frac{1}{\mu_0} \hat{a}_x$$

$$\bar{H}_{1t} = \frac{1}{4\mu_0} 5\hat{a}_x + \frac{1}{\mu_0} \hat{a}_x$$

$$\bar{H}_{1t} = \frac{2.25}{\mu_0} \hat{a}_x$$

$$\bar{B}_{1t} = 6\mu_0 \times \frac{2.25}{\mu_0} \hat{a}_x$$

$$\bar{B}_{1t} = 13.5 \hat{a}_x \text{ mWb/m}^2$$

$$\therefore \bar{B}_1 = \bar{B}_{1n} + \bar{B}_{1t}$$

$$\boxed{\bar{B}_1 = 13.5 \hat{a}_x + 8 \hat{a}_z \text{ mWb/m}^2}$$

$$\text{and } \bar{H}_1 = \frac{\bar{B}_1}{6\mu_0}$$

$$= \frac{1}{6\mu_0}\left[13.5 \hat{a}_x + 8 \hat{a}_z\right] \text{ mA/m}$$

$$\boxed{\bar{H}_1 = \frac{1}{\mu_0}\left[2.25 \hat{a}_x + 1.33 \hat{a}_z\right] \text{ mA/m}}$$

5

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Q.5 (b) In spherical coordinates, electric field intensity is given by $\vec{E} = \dfrac{2r}{(r^2+a^2)^2}\hat{a}_r$ 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]

Given :- $\bar{E} = \dfrac{2r}{(r^2+a^2)^2}\hat{a}_r$ V/m

$$\bar{E} = -\nabla V = -\frac{dV}{dr}$$

$$dV = -\frac{2r}{(r^2+a^2)^2}dr$$

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

$r^2+a^2 = t$

$2r\,dr = dt$

$$= \int -\frac{dt}{t^2}$$

$$= \frac{1}{t} + C$$

$$V = \frac{1}{(r^2+a^2)} + C$$

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

$$0 = \frac{1}{\infty} + C$$

$$C = 0$$

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

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

$$0 = \frac{1}{a^2} + C$$

$$C = -\frac{1}{a^2}$$

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

$$= \frac{a^2 - r^2 - a^2}{a^2(r^2+a^2)}$$

$$V = \frac{-r^2}{a^2(r^2+a^2)}$$

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

$$100 = \frac{1}{a^2+a^2} + C$$

$$C = 100 - \frac{1}{2a^2}$$

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

$$= \frac{2a^2 - (r^2+a^2)}{2a^2(r^2+a^2)} + 100$$

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

11

Good Approach

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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]

Two level memory hierarchy

L_1 (cache), $t_c = 5$ ns

L_2 (main memory), $t_m = 100$ ns

$h = 0.8$

For writing

$L_1 - t_{L_1} = 20$ ns

$L_2 - t_{L_2} = 200$ ns

4

For Read instruction -

$t_{avg_1} = 0.8 \times 5 + 0.2 (5 + 100)$

$= 25$ ns

24ns

For writing instruction

$t_{avg_2} = 0.8 \times 20 + 0.2 (20 + 100)$

$= 40$ ns.

For 60% instruction are read only

average memory access time

$t_{avg} = 0.6 \times t_{avg_1} + 0.4\ t_{avg_2}$

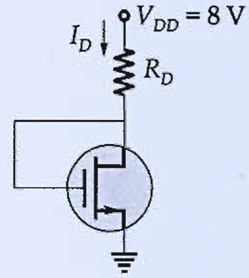
$= 0.6 \times 25 + 0.4 \times 40$

$t_{avg} = 31\,ns$

$\therefore$ Average memory access time

$t_{avg} = 31\,ns$

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.

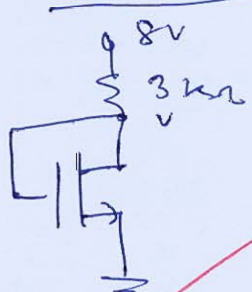


[12 marks]

Given :- $V_T = 1V$ $R_{D_1} = 3k\Omega$

$I_D = 2mA$

when $R_{D_1} = 3k\Omega$



$V_{GS} = V > V_{th} = 1V$

$V_{DS} = V > V - 1$

Hence it is saturation region

For MOSFET in saturation —

$$I_D = K(V_{GS} - V_{th})^2$$

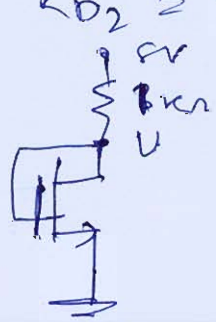
For $I_D = 2mA$

$V_{GS} = V = 8 - 3 \times 2 = 2V$

$$2mA = K(2-1)^2$$

$$K = 2 mA/V^2$$

when $R_{D_2} = 1k\Omega$



MOSFET saturation

$$I_D = K(V_{GS} - V_T)^2$$

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

also, $I_D = \frac{8-V}{1}$

$\therefore\ 2(V-1)^2 = \frac{8-V}{1}$

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

$\Rightarrow 2(V^2+1-2V) = 8-V$

$2V^2 - 3V - 6 = 0$

$V = 2.64V, -1.137V$

this value is discarded as $V > 1V$

$\therefore$ $\boxed{V = 2.64V}$

Hence, drain current –

$I_D = \frac{8-V}{3} = \frac{8-2}{3} = 2mA$

$\boxed{I_D = 2mA}$

5

Drain current I_D

$I_D = \frac{8-2.64}{1}$

$\boxed{I_D = 5.36mA}$

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

[12 marks]

Functions of operating system –

① Process Management

- manage process in the system (running, waiting, ready)
- Handles multitasking and process scheduling
- Allocate CPU time to various process

② Memory management

- manage physical and virtual memory
- Allocates and deallocates memory space as needed

③ File system management

- organize and manage data storage using files and directories
- Provides access, permission and storage services
- support file like read, write, delete copy etc

④ Device Management

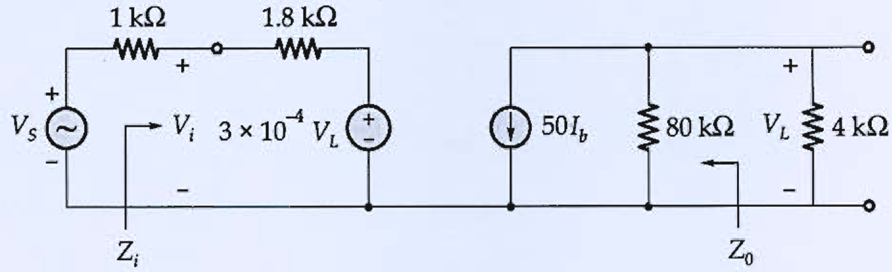
- manage Input/output devices (Keyboard, mouse, printer)
- uses device drivers to communicate with hardware

(5) User interface

- Provide a way for users to interact with ~~the~~ system

8

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]

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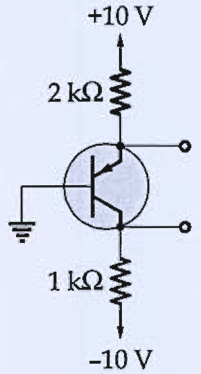
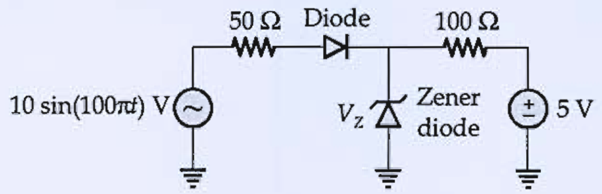
Q.6 (b) (i) Determine the voltages at all nodes and currents through all branches. (Assume $\beta = 100$).



(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]

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]

Q.7 (a) (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]

Do not write in this margin

Q.7 (a) (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]

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Q.7 (b) 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 $y = 3x^2 + z$, $z = x + 4$.

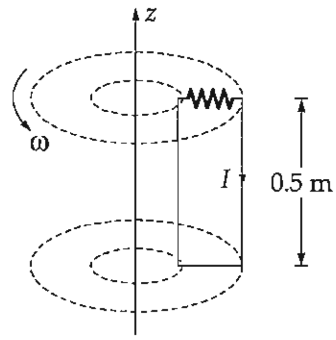
(ii) The straight line from B to A.

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

[20 marks]

Do not write in this margin

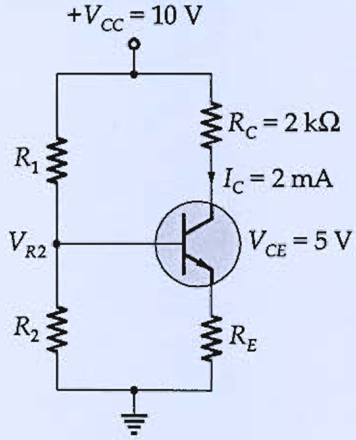
Q.7 (c) (i) A rectangular conducting loop with resistance of 0.2 Ω rotates at 500 rpm, as shown in figure below. The vertical conductor at $r_1 = 0.03$ m is in the field $\vec{B}_1 = 0.25\hat{a}_r T$ and other conductor is at $r_2 = 0.05$ m and is in the field $\vec{B}_2 = 0.8\hat{a}_r T$. Find the current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

Q.8 (a) A silicon n-p-n transistor operated with self bias gives $V_{CEQ} = 5$ V, $I_{CQ} = 2$ mA for $V_{CC} = 10$ 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.

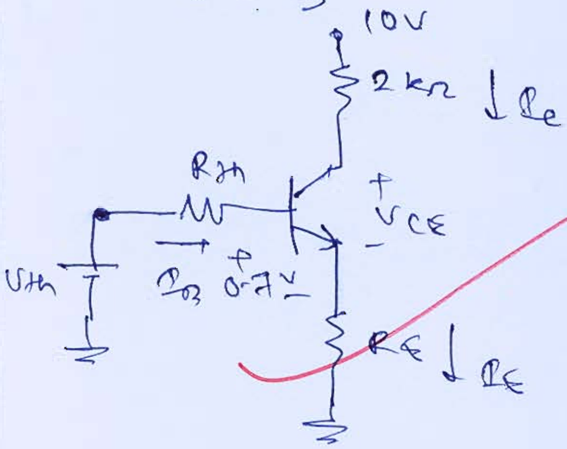


[20 marks]

Given :- $V_{CEQ} = 5V$ $\quad I_{CQ} = 2mA$

$V_{CC} = 10V \quad R_C = 2k\Omega, \quad \beta = 50, \quad V_{BE} = 0.7V$

$S = 5$



$I_C = 2mA$

$\beta = 50$

$I_B = \frac{I_C}{\beta} = \frac{2}{50} = 0.04mA$

$I_E = I_C + I_B$
$= 2.04 mA$

KVL –

$10 - 2\times 2 - 5 - R_E \times 2.04 = 0$

$R_E = 0.490 k$

$\boxed{R_E = 490\,\Omega}$

Now, for voltage - divider biasing stability

$$S = \frac{(\beta+1)(R_{th}+R_E)}{R_{th}+(\beta+1)R_E}$$

$$\Rightarrow \frac{51(R_{th} + 490)}{R_{th} + 51 \times 490} = 5$$

$$\Rightarrow 51 R_{th} + 51 \times 490 = 5 R_{th} + 5 \times 51 \times 490$$

$$R_{th} = 2173\ \Omega$$

KVL in ~~input~~ B-E junction

$$V_{th} - I_B \times R_{th} - 0.7 - I_E R_E = 0$$

$$V_{th} - 0.04 \times 10^{-3} \times 2173 - 0.7 - 2.04 \times 10^{-3} \times 490 = 0$$

$$V_{th} = 1.786\ V$$

$$\Rightarrow 10 \times \left(\frac{R_2}{R_1 + R_2}\right) = 1.786$$

$$\frac{R_2}{R_1 + R_2} = 0.1786$$

Now, $R_{th} = \frac{R_1 R_2}{R_1 + R_2} = 2173$

$$R_1 \times (0.1786) = 2173$$

$$\boxed{R_1 = 12.16\ k\Omega}$$

$$\therefore \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_{th}}$$

$$\Rightarrow \frac{1}{R_2} = \frac{1}{2173} - \frac{1}{12.16 \times 10^3}$$

$$\boxed{R_2 = 2.645\ k\Omega}$$

Hence,

$R_E = 490\ \Omega$

$R_1 = 12.16\ k\Omega$

$R_2 = 2.645\ k\Omega$

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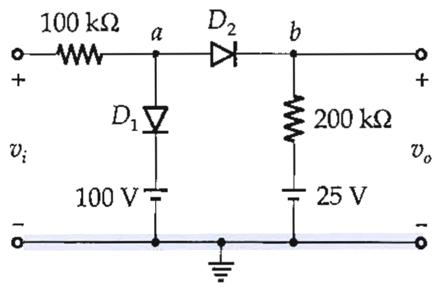
Good Approach

8 (b) Determine and sketch the voltage transfer characteristic of the circuit shown in the figure below.



(Assume that the diodes are ideal)

[20 marks]

Diode D_1

D_1 is forward biased if

$V_a > 100$ V — D_1 FB

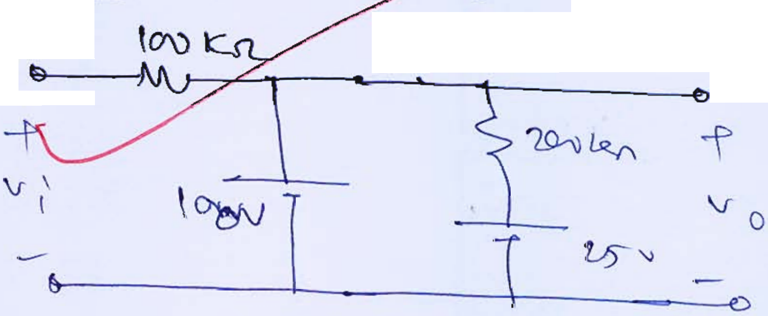
if $V_a < 100$ V — D_1 RB

Diode 2

$V_a > V_b$ — D_2 — FB

$V_a < V_b$ — D_2 — RB

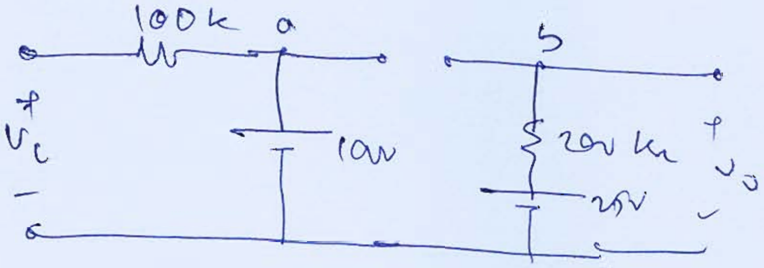
Case 1 D_1 and D_2 — FB



$V_o = 100$ V

for $V_i > 100$ V

Case II D_1 - FB D_2 - RB

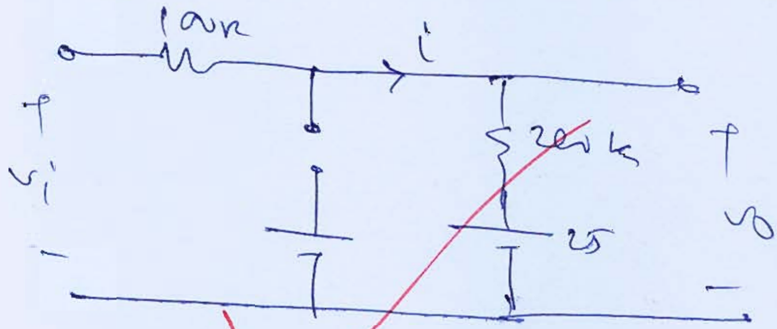


it is not possible because when

D_1 - FB $V_a = 10V > V_b$

D_2 is also FB

Case III D_1 - RB D_2 - FB



$i = \frac{v_i - 25}{300k}$

$v_0 = 200k \times \left(\frac{v_i - 25}{300k}\right) + 25$

$= \frac{2}{3}(v_i - 25) + 25$

$v_0 = \frac{2}{3}v_i - \frac{50}{3} + 25$

$v_0 = \frac{2}{3}v_i + \frac{25}{3}$

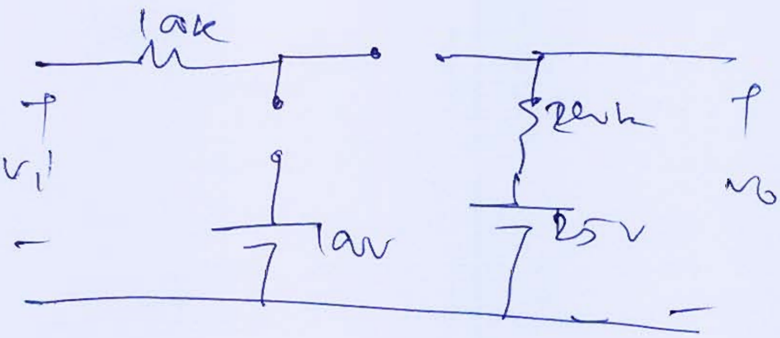
$v_0 = \frac{2}{3}(v_i + 25)$

Do not write in this margin

~~Case $v_i > 25$ V~~

$25V < v_i < 100V$

Case IV — D_1 & D_2 R.B



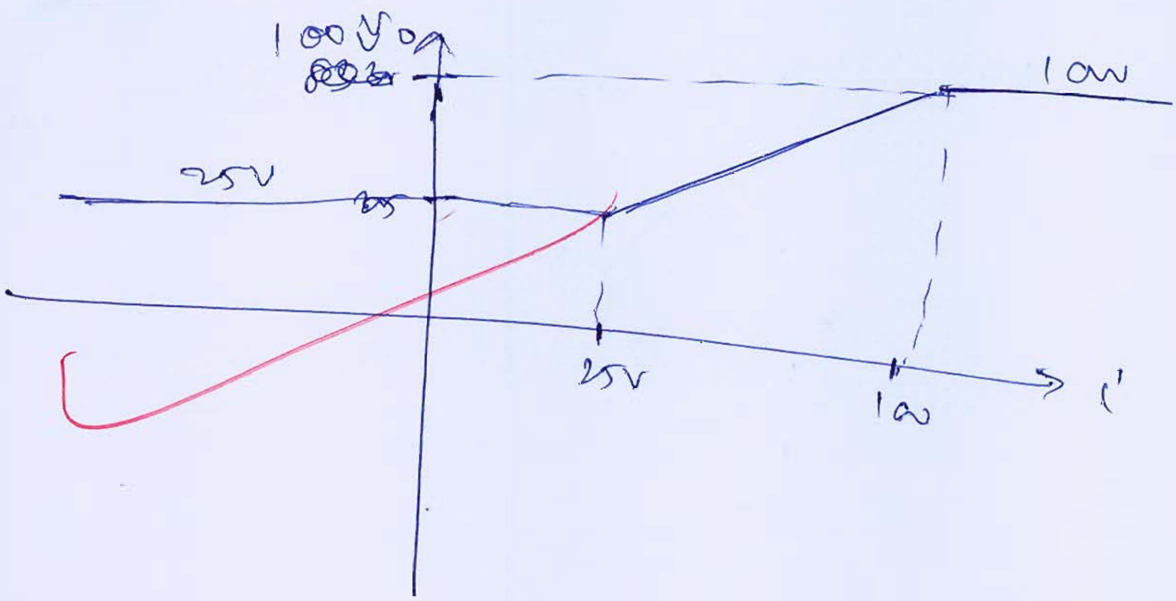
18

$V_o = 25 \qquad v_i < 0$

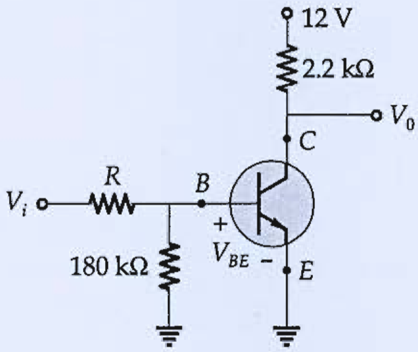
Good Approach

$$V_o = \begin{cases} 25\text{ V} & v_i < 0 \\ \frac{2}{3}(v_i + 25) & 25\text{V} \le v_i \le 100\text{V} \\ 100\text{ V} & v_i > 100 \end{cases}$$

~~$\frac{2}{3}(v_i + 25)$ $v_i \le 25$V~~



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.

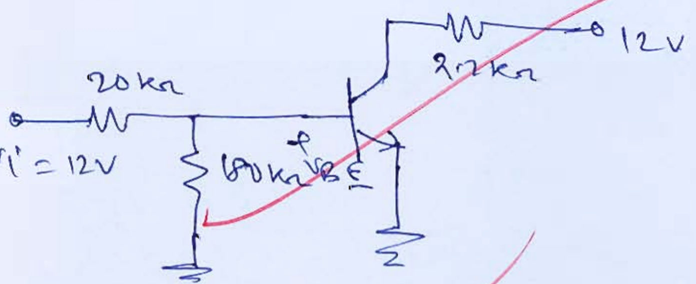
(ii) The minimum value of R for the transistor to remain in the active region for $V_i = 12$ V.

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

[20 marks]

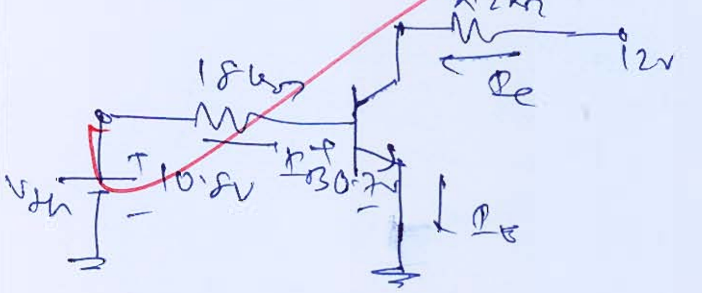
Given :- $\beta \geq 30$ $I_{CBO} = 100nA$

(i) $V_i = 12V$ $R = 20k\Omega$



$V_{th} = 12 \times \left(\frac{180}{180+20}\right) = 10.8V$

$R_{th} = \frac{20 \times 180}{20+180} = 18k\Omega$



let transistor is in Active region

KVL :-

$10.8 - 18 \times I_B - 0.7 = 0$

$I_B = 0.561 \text{ mA}$

$\beta_{min} = 30$

$I_C = \beta I_B = 0.561 \times 30$

$I_e = 16.833 \text{ mA}$

KVL

$12 - 2.2 \times 16.833 - V_{CE} = 0$

$V_{CE} = -25.03 < 0.2 V$

∴ our assumption is wrong

for the given condition transistor is in saturation region

) for transistor remain in active region

$V_{CE} > 0.2 V$

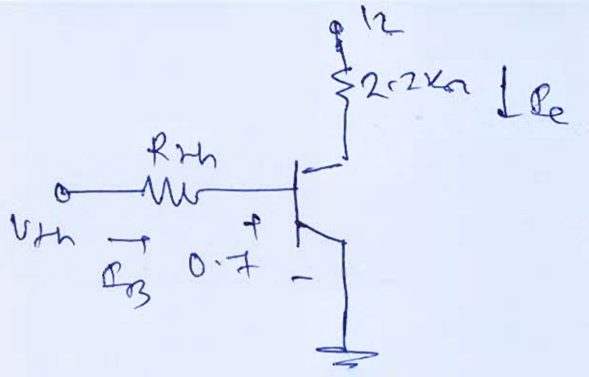
let $V_{CE} = 0.2 V$

$I_C = \frac{12 - 0.2}{2.2k} = 5.363 \text{ mA}$

$I_e = \beta I_B + (\beta + 1) I_{CBO}$

$5.363 = 30 \times I_B + 31 \times 100 \times 10^{-6}$

$I_B = 0.178 \text{ mA}$



$V_{th} = 12 \times \left(\frac{180}{180+R}\right)$

$R_{th} = \frac{180R}{180+R}$

$V_{th} - R_{th} \cdot I_B - 0.7 = 0$

$\frac{12 \times 180}{180+R} - \frac{180R}{180+R} \times 0.178 - 0.7 = 0$

$12 \times 180 - 180R \times 0.178 - 0.7(180+R) = 0$

$2034 - 32.74R = 0$

$\boxed{R = 62.125\ k\Omega}$

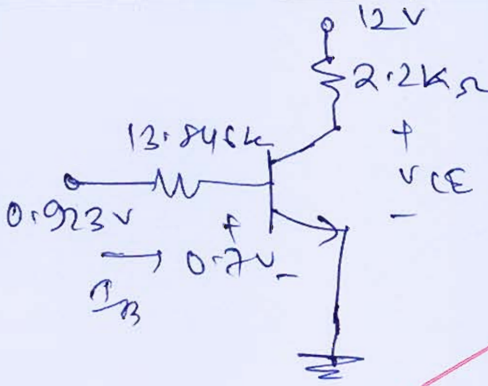
∴ minimum value of resistor for $v_i = 12$ in active region

$\boxed{R = 62.125\ k\Omega}$

(iii) $v_i = 1 \quad R = 15\ k\Omega$

$V_{th} = 1 \times \left(\frac{180}{180+15}\right) = 0.923V$

$R_{th} = \frac{180 \times 15}{195} = 13.846\ k\Omega$



let transistor is in active region −

KVL −

$0.923 - 13.846\, I_B - 0.7 = 0$

$I_B = 0.0161 mA$

for $\beta = 30$ $\quad I_C = 0.483 mA$

KVL −

$12 - 2.2 \times 0.483 - V_{CE} = 0$

$V_{CE} = 10.937 V > 0.2 V$

Hence, for $v_i = 1V$ and $R = 15 k\Omega$ transistor is in active region

and $\boxed{V_0 = V_{CE} = 10.937 V}$

18

Good Approach

Space for Rough Work

Space for Rough Work

Space for Rough Work