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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-3 : Analog Circuits + Electromagnetics

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.
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Question No.	Marks Obtained
Section-A	
Q.1	29
Q.2	49
Q.3	/
Q.4	/
Section-B	
Q.5	37
Q.6	38
Q.7	/
Q.8	19
Total Marks Obtained	172

Signature of Evaluator: Ch. Rerft

Cross Checked by ....

• Good attempt

• Avoid Calculation mistakes

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Name : GAURAV SEHRAWAT

Roll No : E C 2 5 M 7 D L A 0 1 3

Test Centres				Student's Signature
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IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

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.

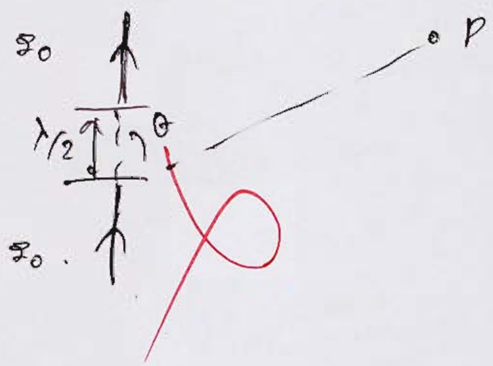
DO'S

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.

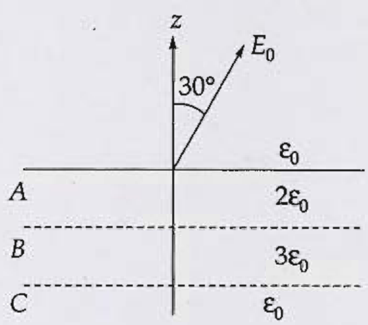
Section A : Analog Circuits + Electromagnetics

.1 (a) A two element array consists of collinear hertz dipoles. The element spacing is $\frac{\lambda}{2}$. Find the directivity of the array when the elements are excited in phase.

[16 marks]



1 (b) Two planar slabs of equal thickness but with different dielectric constants are shown in below figure. E_0 in air makes an angle of 30° with the z-axis. Calculate the angle that E makes with z-axis in each of the three regions A, B and C.



[12 marks]

Do not write in this margin

1 (c) A line of 300 Ω characteristic impedance is terminated in an admittance of $0.01 + j\,0.02$ ℧. Find:

(i) The reflection coefficient at the load-end.

(ii) Reflection coefficient at a distance of 0.2λ from the load-end.

(iii) Impedance at a distance of 0.2λ from the load-end.

[12 marks]

1 (c) Given: $Z_0 = 300\,\Omega$

$Y = 0.01 + j0.02$ ℧

(i) Reflection Coefficient at load end

admittance $= \dfrac{1}{\text{Impedance}}$

$$Z_L = \frac{1}{Y_L} = \frac{1}{0.01 + j0.02} = 20 - 40i$$

Reflection coefficient is defined as

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{20 - 40i - 300}{20 - 40i + 300}$$

$$\Gamma = \frac{-11}{13} - \frac{3}{13}i \Rightarrow \boxed{\Gamma = 0.877 \angle -2.875^{\circ}}$$

(ii) Reflection coefficient at 0.2λ from load end

$$r(d) = r_L e^{-2\gamma d}.$$

$$= |r_L| e^{j\theta r_L} e^{-2(\alpha + j\beta)d}.$$

$$= |r_L| e^{-2\alpha d} . e^{j\theta r_L} . e^{-2j\beta d}.$$

$$r(d) = |r_L| e^{-2\alpha d} e^{j(\theta r_L - 2j\beta d)} \quad - (1).$$

from (1), put $d = 0.2\lambda$.

Assumption: The line is lossless, $\therefore \alpha = 0$.

$$r(d)\Big|_{d=0.2\lambda} = |r_L| e^{j(\theta r_L - 2\beta d)}.$$

$$= 0.877 e^{j\left(-2.857 - 2\times\frac{2\pi}{\lambda}\times 0.2\lambda\right)}$$

$$= 0.877 e^{j(-2.857 - 2.44)}$$

$$\boxed{r(0.2\lambda) = 0.877 e^{-j146.857}}$$

$$r(0.2\lambda) = 0.877 \angle -146.85^\circ.$$

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(iii) Impedance from 0.2λ distance from load

$$Z(d) = Z_0 \frac{Z_L + jZ_0 \tan\beta d}{Z_0 + jZ_L \tan\beta d}$$

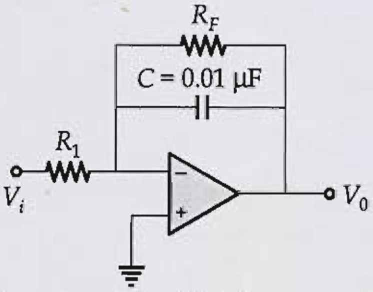
$$Z(d) = 300 \left[\frac{20 - 40i + i\,300 \tan(0.4\pi)}{300 + i(20 - 40i)\tan(0.4\pi)}\right]$$

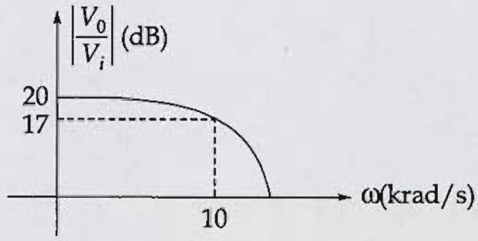
$$Z(d) = 300 \left[\frac{(20 - 40i) + 900i}{300 + (40 + 20i)\times 3}\right]$$

$$120 + 60i$$

$$\boxed{Z(d) = 100 + 600i.} \qquad \boxed{Z(d) = 608.22 \angle 1.405^\circ}$$

1 (d) Consider the circuit and the gain-frequency characteristics given below. Find the value of R_1 and R_F.





[8 marks]

1 (d) Given circuit : pratical Integrator.

$$\frac{V_o}{V_i} = -\frac{Z_2}{Z_1} = A_v$$

where, $Z_2 = R_F \| \frac{1}{CS}$

$$Z_2 = \frac{\frac{R_F}{CS}}{R_F + \frac{1}{CS}} = \frac{R_F}{R_F CS + 1}$$

$$Z_1 = R_1$$

$$|A_v| = \frac{Z_2}{Z_1} = \left|\frac{\frac{R_F}{R_F C j\omega + 1}}{R_1}\right|$$

$$|A_v| = \frac{R_F \times R_1}{\sqrt{1 + \omega^2 R_F^2 C^2}}$$

from diagram,

@ $\omega = 0$ rad / sec.

$|A_v| = 20$ dB.

$20 = 20 \log_{10} A_v$

$\therefore 10 = A_v$

$10 = R_F \times R_1$ — ①

@ ω_{3dB} $|A_v| = 17$ dB.

$17 = 20 \log_{10} A_v$

$10^{\frac{17}{20}} = A_v$

$|A_v| = 7.07$

$$\therefore 7.07 = \frac{R_F \times R_1}{\sqrt{1 + (10^4)^2 R_F^2 (10^{-8})^2}}$$

$$7.07 = \frac{R_F \times R_1}{\sqrt{1 + 10^8 \times 10^{-16} R_F^2}} \leftarrow ②$$

put ① in ②

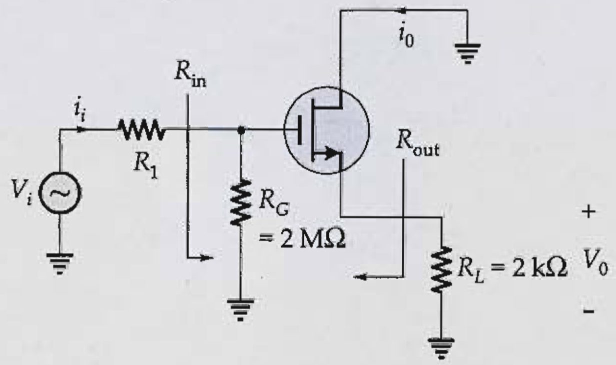
$$7.07 = \frac{10}{\sqrt{1 + 10^{-8} \times \frac{10^2}{R_1^2}}}$$

on solving

$$\therefore \boxed{R_1 = 1\,k\Omega \quad R_F = 10\,k\Omega}$$

Q.1 (e) In the following amplifier circuit, assume that $R_G = 2\ \text{M}\Omega$, $R_1 = 100\ \text{k}\Omega$, $R_L = 2\ \text{k}\Omega$, $g_m = 10$ mS, $\lambda = 0$ and $r_0 = \infty$.

Find A_v, R_{in}, R_{out} and $A_i = \dfrac{i_0}{i_i}$

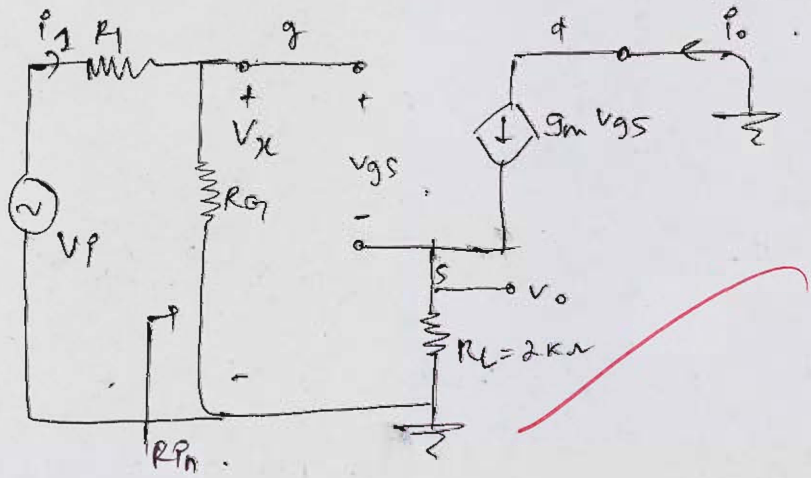


[12 marks]

Q1 (e)

Given: common drain amplifier.

considering small signal equivalent for MOSFET :-



voltage gain : $(A_v) = \dfrac{v_o}{v_i}$.

v_o can be written as.

$v_o = g_m v_{gs} R_L$ — (4)

By KVL, $-v_x + V_{gs} + V_o = 0$.

$V_x = v_{gs} + V_o$ — (1)

By voltage division,

$V_x = v_i \times \dfrac{R_G}{R_1 + R_G}$ — (2)

from (1) & (2), $\dfrac{v_i R_G}{R_1 + R_G} = v_{gs} + v_o$.

$\therefore v_{gs} = \dfrac{v_i R_G}{R_1 + R_G} - v_o$ — (3)

Put (3) in (4).

$V_o = g_m R_L v_{gs}$

$V_o = g_m R_L \left[\dfrac{v_i R_G}{R_1 + R_G} - V_o\right]$

$V_o = \dfrac{g_m R_L v_i R_G}{R_1 + R_G} - V_o g_m R_L$

$v_o(1+g_m R_L) = v_i \dfrac{g_m R_L R_G}{R_1+R_G}$.

$$\frac{v_o}{v_i} = \frac{\dfrac{g_m R_L R_G}{R_1+R_G}}{1+g_m R_L}$$

substituting all values,

$$\frac{v_o}{v_i} = \frac{\dfrac{10\times10^{-3}\times 2\times10^{3}\times 2\times10^{6}}{100\times10^{3}+2\times10^{6}}}{1+10\times10^{-3}\times 2\times10^{3}}$$

$$\boxed{|A_v| = 0.907 \simeq 1}$$

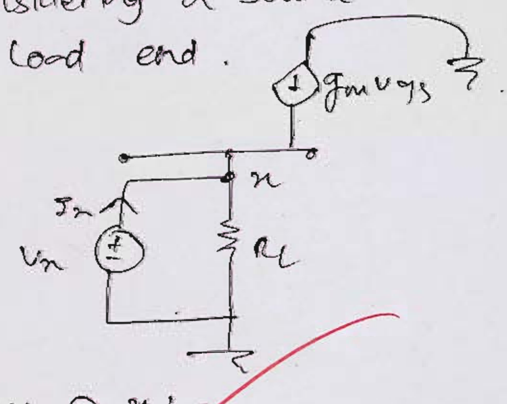
Input Resistance (Ri) :

$R_i = R_G$ only

$$\boxed{R_i = 2M\Omega}$$

output Resistance (Rout)

considering a source v_x @ Load end.



KCL @ x :-

$g_m v_{gs} + I_x = \dfrac{V_x}{R_L}$

and since all sources are deactivated,

By KVL, $v_{gs} + V_x = 0$

$V_x = -V_{gs}$.

$I_x = \dfrac{V_x}{R_L} + g_m V_x$.

$I_x = v_x\left(\dfrac{1}{R_L} + g_m\right)$

$R_x = \dfrac{V_x}{I_x} = \dfrac{1}{\dfrac{1}{R_L} + g_m}$.

$$\therefore \boxed{R_{out} = \tfrac{1}{g_m} \,||\, R_L}$$

current gain (Ai) :

$A_i = \dfrac{i_o}{i_i}$.

$i_o = g_m v_{gs}$.

$i_i = \dfrac{v_i - v_x}{R_1}$.

$V_x = v_{gs} + i_o \times 2$.

11

Q.2 (a) In a certain region for which $\sigma = 0$, $\mu = 2\,\mu_0$ and $\varepsilon = 10\varepsilon_0$, the displacement current density is, $\vec{J_d} = 60\sin(10^9 t - \beta z)\hat{a}_x \text{ mA/m}^2$.

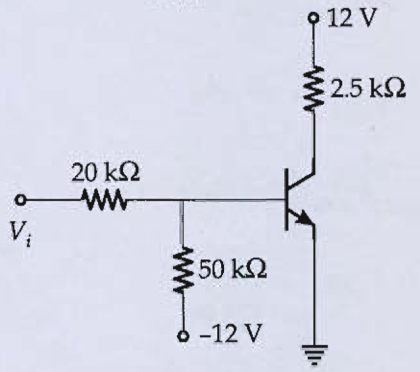
(i) Find $\vec{D}$ and $\vec{H}$.

(ii) Determine β.

[20 marks]

Do not write in this margin

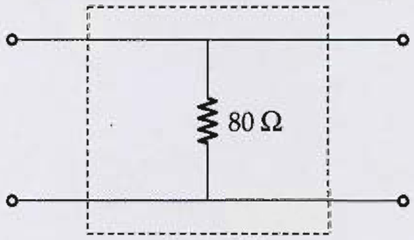
Q.2 (b) **(i)** A silicon transistor with $\beta = h_{fE} = 100$ is used in the circuit shown below. Find the maximum input supply voltage 'V_i' for which transistor remains in saturation region. Assume $V_{CE\,sat} = 0.2$ V and $V_{BE\,sat} = 0.8$ V.



(ii) For input voltage of 2 volt, it is noted that the above circuit is in cut-off region upto 100°C. Calculate the reverse saturation current (I_{CO}) of the circuit at room temperature. (Assume room temperature as 37°C)

[12 + 8 marks]

2 (c) (i) Determine the s-parameters for the given two-port network:



(ii) A uniform loss-less transmission line with a characteristic impedance $Z_o = 100\ \Omega$ has a length of 0.65λ. The line is driven by a time-harmonic source with a 2 V Thevenin voltage and a 50 Ω internal impedance. The line is terminated by a load $Z_L = (25 - j25)\Omega$.

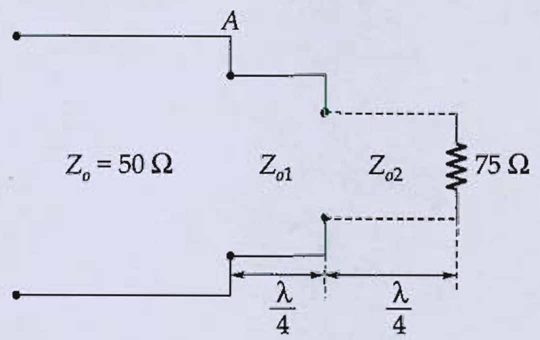
1. Determine the input impedance of the line.
2. Determine amplitude of the forward wave, V_o^+.

[10 + 10 marks]

Do not write in this margin

Q.3 (a) (i) In a one-dimensional device, the charge density is given by $\rho_v = \frac{\rho_o x}{a}$.
If electric field, $E = 0$ at $x = 0$ and potential $V = 0$ at $x = a$, find V and E.

(ii) Two $\frac{\lambda}{4}$ transformers in tandem are to connect a 50 Ω line to a 75 Ω load as shown in below figure.



Determine the characteristic impedance Z_{o1} if $Z_{o2} = 30\ \Omega$ and there is no reflected wave to the left of A.

[12 + 8 marks]

Q3 (a) (i) Given : charge density $\rho_v = \frac{\rho_o x}{a}$.

from poisson's relation, $\frac{dE(x)}{dx} = \frac{\rho_v}{\epsilon_0}$ — ①.

where E : Electric field.
ρ_v : charge density
ϵ : permittivity

$\therefore$ $E(x) = \int \frac{\rho_v}{\epsilon_0} \cdot dx$.

$E = \frac{\rho_o}{\epsilon_0 a} \int x \cdot dx$

$E = \frac{\rho_o}{\epsilon_0 a} \times \frac{x^2}{2} + C$ — ②.

@ $x = 0$.
$E = 0$.
$\therefore C = 0$.

$\therefore$ $\boxed{E = \frac{\rho_o}{\epsilon_0 a} \frac{x^2}{2}}$ — ③

$E = \frac{dv}{dx}$.

$V(x) = \int E \cdot dx$.

where v : potential.

$\therefore$ $V(x) = \frac{\rho_o}{\epsilon_0 a} \times \frac{x^3}{6} + C$

@ $x = 0$
$V = 0$.
$\therefore C = 0$

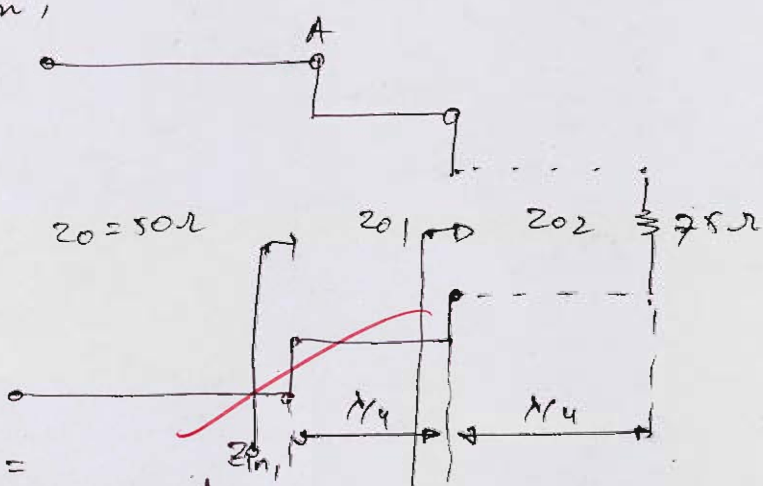
$\therefore$ $\boxed{V(x) = \frac{\rho_o}{\epsilon_0 a} \frac{x^3}{6}}$

4

3 (a) (ii) Given $Z_{02} = 30\Omega$.

for $\frac{\lambda}{4}$ line, $Z_{in}(d) = \frac{Z_0^2}{Z_L}$.

from diagram,



load of 1st line = input impedance seen by 2nd $\lambda/4$ line: Z_{in_2}.

$$Z_{in_2} = \frac{Z_{02}^2}{Z_L}.$$

$$Z_{in_2} = \frac{(30)^2}{75} = 12\,\Omega.$$

$$Z_{in_1} = \frac{(Z_{01})^2}{Z_L} = \frac{(Z_{01})^2}{12}.$$

since there is no reflected wave from A, $\therefore Z_{in_1} = Z_0 = 50$.

$$\therefore 50 = \frac{(Z_{01})^2}{12}$$

$$\sqrt{50 \times 12} = Z_{01}$$

$$\boxed{Z_{01} = 24.49\,\Omega}$$

Assumption: ① line is lossless

$$Z_{in}(d) = Z_0\left[\frac{Z_L + jZ_0\tan\beta d}{Z_0 + jZ_L\tan\beta d}\right]$$

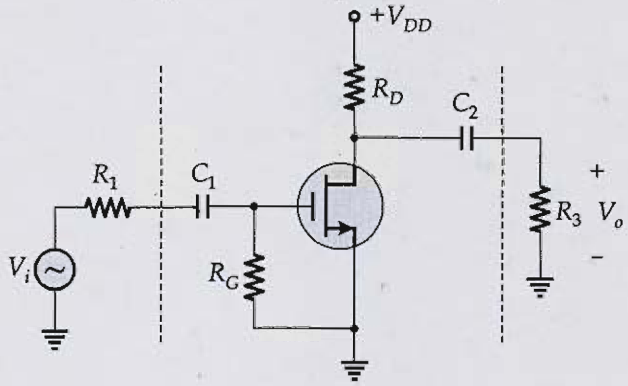
@ $d = \lambda/4$.

$$Z_{in}(d) = \frac{(Z_0)^2}{Z_L} \quad \text{— ①}$$

Using the results obtained from ① in the respective analysis.

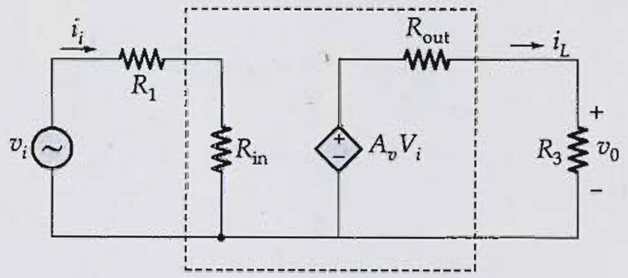
8

Q.3 (b) In the following amplifier circuit, assume that $V_{DD} = 15$ V, $\mu_N C_{ox}\frac{W}{L} = 225\,\mu A/V^2$, $V_{TN} = -3$ V, $R_G = 2.2$ MΩ, $R_D = 7.5$ kΩ, $R_1 = 10$ kΩ, $R_3 = 220$ kΩ, $\lambda = 0.015\ V^{-1}$.



(i) Draw the dc equivalent circuit and find the Q-point for the amplifier.

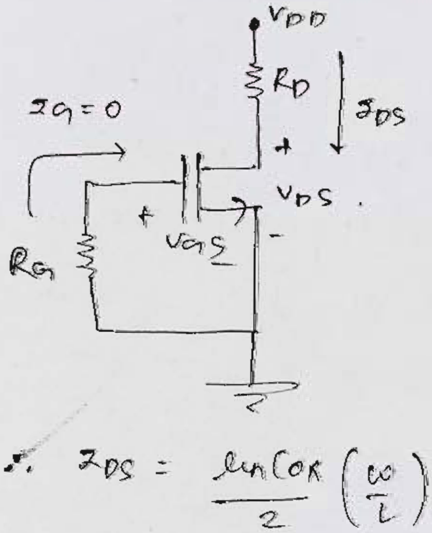
(ii) Draw the ac equivalent circuit of the amplifier. Assume all capacitors have infinite value. Obtain the values of R_{in}, R_{out} and A_v for the small-signal equivalent circuit of the amplifier as shown below:



[20 marks]

Q3 (b) DC equivalent circuit : • capacitors open circuit

• AC Sources Deactivated.



$V_{GS} = V_G - V_S$

$V_{GS} = 0$ V.

• $V_{DS} \geq V_{GS} - V_T$. for saturation to occur.

• Assuming, in Saturation,

∴ $I_{DS} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2$

$I_{DS} = \frac{225\times10^{-6}}{2}(3)^2$

$\boxed{I_{DS} = 1.012\ mA}$

$V_{DS} = V_{DD} - I_{DS}R_D$

$= 15 - 1.012 \times 7.5$

$\boxed{V_{DS} = 7.406\ V}$

veryfying, $V_{DS} \geq V_{GS} - V_T$

$7.406 \geq 0 - (-3)$ $= 3V$ ✓ $\therefore$ MOSFET in Saturation & analysis is correct.

$$\boxed{Q(V_{DS}, I_{DS}) = Q(7.406, 1.012)}$$

Q3 (b) (ii) Given : $\lambda = 0.015$

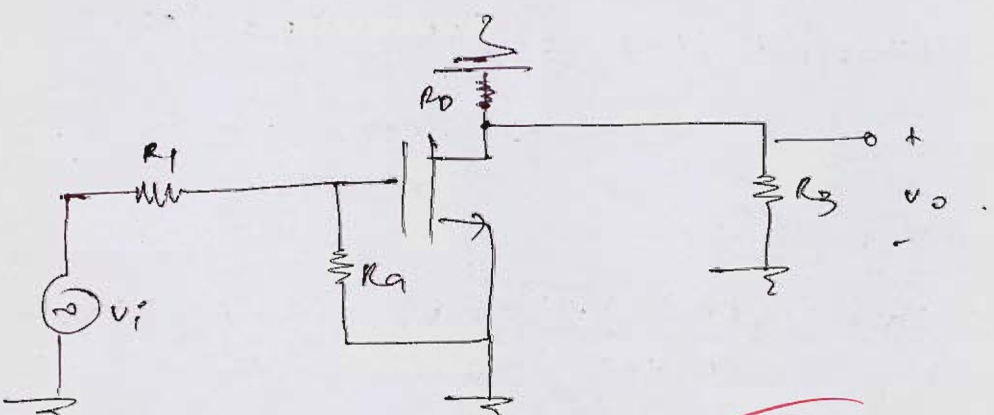
$$r_{ds} = \frac{1}{\lambda I_{DS}} = \frac{1}{0.015 \times 1.012} = 65.87\,k\Omega$$

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$g_m = 225 \times 10^{-6} (3) = 0.675\,m℧$$

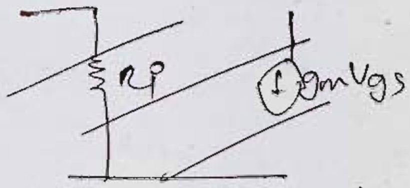
AC equivalent of the circuit :

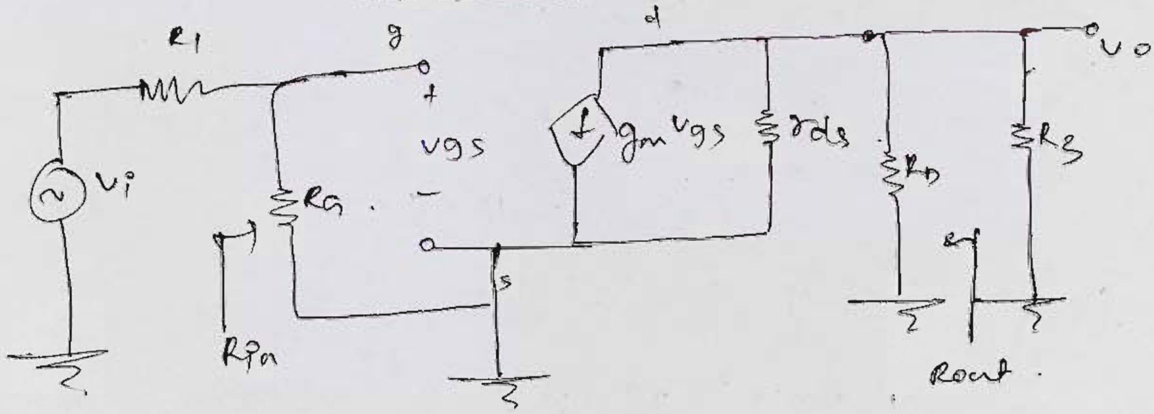
consider large capacitors to be short circuited and voltage source (DC) are made ground.



medium frequency model.

for small signal analysis, the equivalent model would be,





voltage gain (Av)

$$A_v = \frac{g_m v_{gs} R_L''}{v_i} = \frac{V_o}{V_i}$$

$V_o = -g_m v_{gs} R_L''$ —(1)

$R_L'' = (r_{ds} \| R_D \| R_3) = (65.87 \| 9.5 \| 220)$

$= 6.533\,k\Omega$

By voltage division,

$v_{gs} = \frac{v_i \times R_G}{R_1 + R_G}$ —(2), $v_i = \left(\frac{R_1 + R_G}{R_G}\right) v_{gs}$.

$\therefore A_v = \frac{V_o}{V_i} \Rightarrow$ from (1),

$V_o = -g_m v_{gs} R_L''$

Put (2) in (1),

$$A_v = \frac{V_o}{V_i} = -g_m \frac{R_G}{R_1 + R_G} R_L''$$

$$A_v = -g_m \times \frac{2.2\times10^6}{10\times10^3 + 2.2\times10^6} \times 6.533\times10^3$$

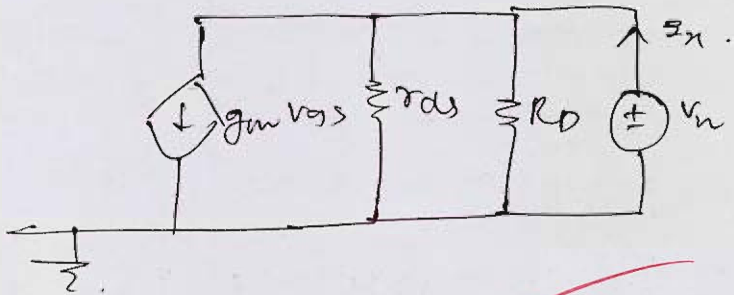
$$\boxed{A_v = -4.272\ V/V}$$

Input Resistance (Ri)

$$R_i = R_G = 2.2 \times 10^6$$

$$\boxed{R_i = 2.2\,M\Omega}$$

output Resistance (Ro)



By KCL :- $I_x = \frac{V_x}{r_{ds}} + \frac{V_x}{R_D} + g_m V_{gs}$.

∵ v_i is deactivated

∴ $V_{gs} = 0$.

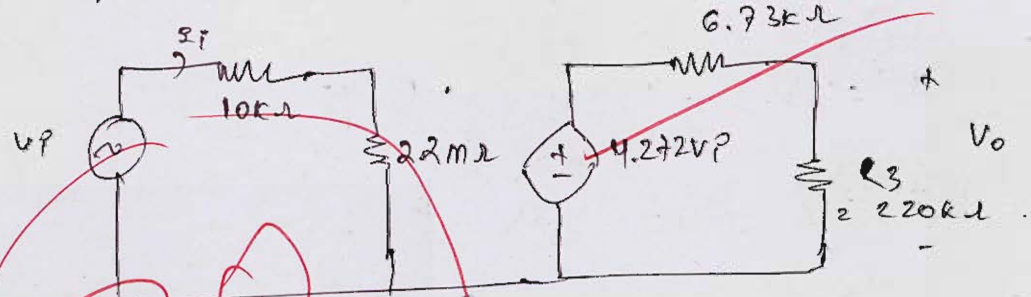
$$I_x = V_x\left(\frac{1}{r_{ds}} + \frac{1}{R_D}\right)$$

$$R_{out} = \frac{V_x}{I_x} = \frac{1}{\frac{1}{r_{ds}} + \frac{1}{R_D}}$$

$$R_{out} = r_{ds} \| R_D$$

$$\boxed{R_{out} = 6.73\,k\Omega}$$

∴ Equivalent model:-



Find model of the given amplifier

Q.3 (c) (i) Consider a plane wave with an electric field intensity $\bar{E} = -E_0 \cos(\omega t - \beta z)\hat{y}$ V/m where $E_0 = 1200$ V/m and $f = 400$ MHz propagating is in free space. Assume lossless propagation.

1. What is the direction of propagation of wave?
2. Calculate the instantaneous and time averaged power densities in the wave.
3. Calculate the total instantaneous and time averaged power transmitted by the wave.
4. Suppose a receiving dish antenna is 2 m in diameter. How much power is received by the receiving antenna if the surface of dish is perpendicular to the direction of propagation of the wave?

(ii) Obtain a wave equation of the electric scalar potential V for a time varying field.

[15 + 5 marks]

Q3 (c) (i) Given: $\vec{E} = -E_0 \cos(\omega t - \beta z)\,\hat{a_y}$ V/m.

- $E_0 = 1200$ V/m
- $f = 400$ MHz
- free space.
- lossless propagation.

1.) Standard equation for electric field is.

$$E(z,t) = E_0 e^{-\alpha z} \cos(\omega t - \beta z)\,\hat{a_y}$$

on comparison, the direction of propagation of wave is in $+z$ direction.

2) Instantaneous and time avgeraged power densities.

$$\vec{E}(t) = -1200 \cos(\omega t - \beta z)\,\hat{a_y}$$

for $\vec{H}(t)$: $\vec{H}(t) = \dfrac{\hat{a_k} \times \vec{E}}{\eta_0}$

$$\vec{H}(t) = \frac{\hat{a_z} \times (-1200 \cos(\omega t - \beta z)\,\hat{a_y})}{120\pi}$$

$$\vec{H}(t) = \frac{-1200 \cos(\omega t - \beta z)\,(\hat{a_z} \times \hat{a_y})}{120\pi}$$

$$= \frac{1200 \cos(\omega t - \beta z)\,\hat{a_x}}{120\pi} = 3.186 \cos(\omega t - \beta z)\,\hat{a_x} \text{ A/m}.$$

P(t) (Instantaneous) : $P(t) = \vec{E}(t) \cdot \vec{H}(t)$.

$$= -1200 \cos(\omega t - \beta z)\,\hat{a_y} \times 3.186 \cos(\omega t - \beta z)\,\hat{a_x}$$

$$P(t) = 3.819 \cos^2(\omega t - \beta z)\,\hat{a_z} \text{ kW/m}^2.$$

$$\vec{E_s} = -1200\, e^{-j\beta z}\,\hat{a_y}$$

$$\vec{H_s} = 3.186\, e^{-j\beta z}\,\hat{a_x}.$$

(Average power density) : $P_{avg} = \frac{1}{2}\{\text{Real}\{\vec{E_s} \times \vec{H_s}^*\}\}$.

$$\vec{P}_{avg} = \frac{1}{2} \text{Real}\{-1200\, e^{-j\beta z}\,\hat{a_y} \times 3.186\, e^{j\beta z}\,\hat{a_x}\}$$

$$= \frac{1}{2}\{3.819\,\hat{a_z}\}$$

$$\boxed{\vec{P}_{avg} = 1.909\,\hat{a_z} \text{ W/m}^2}$$

3. $P_{transmitted} = P_{rad} = \iint P_{avg} \cdot d\vec{s}$.

$$P_{rad} = \iint 3.819 \cos^2(\omega t - \beta z) \cdot \sin\theta \, d\theta \, d\phi.$$

$$P_{rad} = \iint 1.909\,\hat{a_z} \cdot \sin\theta \, d\theta \, d\phi \cdot \hat{a_z}$$

$$= 1.909\,\hat{a_z} \times 2 \times 2\pi \cdot \hat{a_r}$$

$$\boxed{P_{rad} = 24\,\hat{a_z} \text{ watts}}$$

$$P_{received} = P_t \times A_e = \frac{P_{rad}}{4\pi r^2} \times \frac{\lambda^2}{4\pi} G_{dr}(\theta, \phi).$$

Q.4 (a) (i) Design a voltage divider bias network using a depletion type MOSFET with I_{DSS} = 10 mA and V_p = –4 V to have a Q-point at I_{DQ} = 2.5 mA using a supply of 24 V. In addition, set gate voltage, V_G = 4 V and use R_D = 2.5 R_s with R_1 = 22 MΩ. (All the notations used are standard one)

(ii) Design a voltage regulator using zener diode that will maintain an output voltage of 20 V across 1 kΩ load with an input that will vary between 30 and 50 V. Specify the proper value of limiting resistor R_s and the maximum zener diode current I_{zm}.

[10 + 10 marks]

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Q.4 (b) (i) A 2 cm × 1 cm waveguide is made of copper ($\sigma_c = 5.8 \times 10^7$ S/m) and filled with a dielectric material for which $\varepsilon = 2.6\varepsilon_0$, $\mu = \mu_0$, $\sigma_d = 10^{-4}$ S/m. If the guide operates at 12 GHz, evaluate attenuation constant due to dielectric losses (α_d) for TE_{10} mode.

(ii) A lossless 60 Ω line is terminated by a load of $60 + j60$ Ω. If $Z_{in} = 120 - j60$ Ω, how far (in terms of wavelength) is the load from the generator?

[10 + 10 marks]

Q.4 (c) (i) Design a monostable multivibrator using 555 IC which generate a pulse of 1 μs width when trigger input is applied. Use a capacitor of 325 pF. Explain the circuit operation with waveforms.

(ii) A full-wave rectifier uses a transformer with secondary voltage of 50 V_{rms} and diode having internal resistance of 20 Ω. A 6 H inductor of DC resistance 30 Ω is connected in series with load resistance of 650 Ω. If line frequency is 60 Hz and DC resistance of secondary winding is 45 Ω, calculate:

1. Ripple factor.
2. DC output voltage and AC output voltage.
3. Regulation factor.

[15 + 5 marks]

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Section B : Analog Circuits + Electromagnetics

Q.5 (a) An electric field strength of 10 μV/m is to be measured at an observation point $\theta = \frac{\pi}{2}$, 500 km from a $\frac{\lambda}{4}$ monopole operating in air at 50 MHz.

(i) What is the length of the dipole?

(ii) Calculate the current that must be fed to the antenna.

(iii) Find the power radiated by the antenna.

(iv) If a transmission line with $Z_0 = 75\ \Omega$ is connected to the antenna, determine the standing wave ratio.

[12 marks]

Q5) (a) Given: $|E| = 10\ \mu V/m$ $\quad$ $\lambda/4$ monopole

$\theta = \pi/2$ $\quad$ $f = 50\ MHz$.

$r = 500\ km$.

(i) length of dipole: $l = \frac{\lambda}{2} = \frac{c}{2f} = \frac{3\times10^8}{2\times50\times10^6}$.

$\therefore \boxed{l = 3m}$

(ii) Current to antenna

$H_{\phi s} = \frac{jI_0}{2\pi r} F(\theta).e^{-j\beta r}\hat{a_\phi}$.

$E_{\theta s} = \frac{\eta jI_0}{2\pi r} F(\theta).e^{-j\beta r}\hat{a_\theta}$.

$|E_{\theta s}| = \frac{\eta I_0}{2\pi r} F(\theta)$ ... ①.

$P_{avg} = \frac{1}{2}\frac{|E_{\theta s}|^2}{\eta}$

~~$P_{rad} = P$~~

$P_{avg} = \frac{P_{rad}}{4\pi r^2}$.

from ①.

$10\times10^{-6} = \frac{120\pi\times I_0}{2\pi\times500\times10^3}\times F(\theta)$

$F(\theta) = \frac{\cos\left(\frac{\beta l}{2}\cos\theta\right) - \cos\frac{\beta l}{2}}{\sin\theta}$.

$\therefore l = \lambda/4$.

$F(\theta) = \frac{\cos\left(\frac{2\pi}{\lambda}\times\frac{1}{2}\times\frac{\lambda}{4}\times0\right) - \cos(\pi/4)}{1}$.

$F(\theta) = 1 - \frac{1}{\sqrt2} = \frac{\sqrt2 - 1}{\sqrt2}$

$= 0.29$.

$\therefore \boxed{I_0 = 0.287\ A}$

(iii) $P_{rad} = \frac{I_0^2}{2} \times R_{rad}$.

for $\lambda/4$ monopole

$R_{rad} = \frac{73}{2}\sqrt{\frac{\mu_r}{\epsilon_r}}$.

$P_{rad} = \frac{(0.287)^2}{2} \times \frac{73}{2}$

$\boxed{P_{rad} = 1.506 \text{ watts}}$

(iv) for SWR →

$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$.

where $Z_L = \frac{73 + j42.5}{2}$.

$\Gamma = \frac{\frac{73+j42.5}{2} - 75}{\frac{73+j42.5}{2} + 75}$,

$\boxed{\Gamma = 0.387 \angle 2.44°}$

$SWR = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+0.387}{1-0.387}$

$\boxed{SWR = 2.26}$

5 (b) In a conducting medium, the magnetic field is given as

$\vec{H} = y^2 z\hat{a}_x + 2(x+1)yz\hat{a}_y - (x+1)z^2\hat{a}_z$ A/m.

Determine the conduction current density at point (2, 0, –1). Also find the current enclosed by the square loop $y = 1, 0 \le x \le 1, 0 \le z \le 1$.

[12 marks]

5(b) From maxwell's relation,

$\nabla \times \vec{H} = J + \frac{\partial \vec{D}}{\partial t}$.

for conduction current density

$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} = \vec{J_c}$.

Given $\vec{H} = y^2 z\, \hat{a_x} + (2x+1)yz\,\hat{a_y} - (x+1)z^2\,\hat{a_z}$.

statement: for curl $\nabla \times \vec{H}$

$$\nabla \times \vec{H} = \begin{vmatrix} \hat{a_x} & \hat{a_y} & \hat{a_z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ y^2 z & 2(x+1)yz & -(x+1)z^2 \end{vmatrix}$$

$\nabla \times \vec{H} = [0 - 2(x+1)y]\,\hat{a_x} - [-z^2 - y^2]\,\hat{a_y} +$

$[2yz - \cancel{2yz}]\,\hat{a_z}$

$\therefore \nabla \times \vec{H} = -2(x+1)y\,\hat{a_x} + (y^2+z^2)\,\hat{a_y}$.

@ point $(2, 0, -1)$

$\nabla \times \vec{H} = -2(3)\,0\,\hat{a_x} + 1\,\hat{a_y}$.

$\boxed{\nabla \times \vec{H} = \hat{a_y}}$

$\boxed{|J_c| = 1\ A/m^2}$

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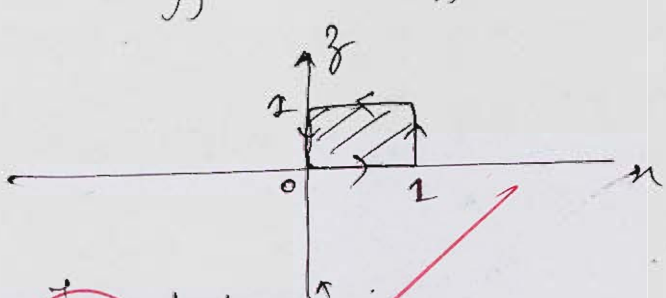
<u>current enclosed:</u>

$J = \frac{I}{A}$

$\iint \mathcal{J}.d\vec{s} = \iint J.ds \times A$.



$\vec{ds} = dx\,dz\,\hat{a_y}$.

2

$\therefore = \iint (y^2+z^2).dx\,dz \times$ Area.

$= \left[\iint y^2\,dx\,dz + \iint z^2\,dx\,dz\right] \times$ Area

$= \left[y^2[x][z] + \int 2z\Big|_0^1 .dx\right] \times$ Area

$= [1 \times 1 \times 1 + 2 \times 1 \times 1] \times$ Area

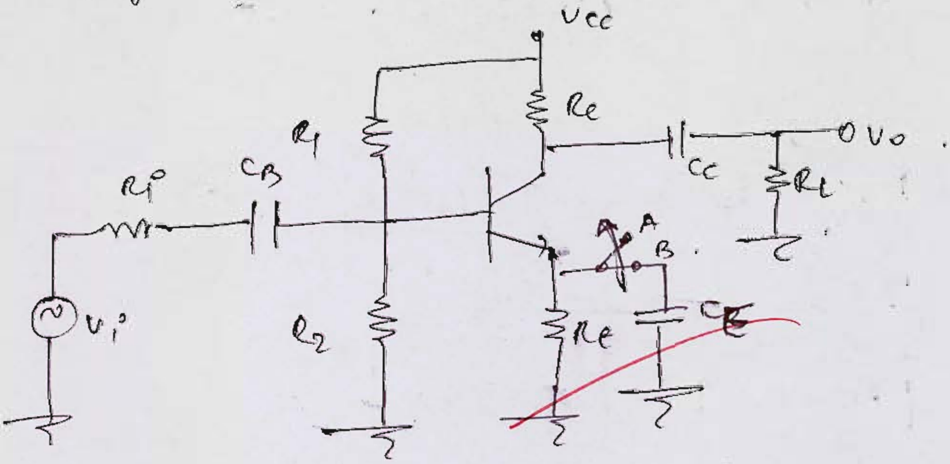
$= 3 \times \cancel{\text{Area}}^{\,1}$

$\boxed{I = 3\ A}$

Q.5 (c) Prove that Bypass capacitor in common emitter amplifier is used to enhance the voltage gain of the amplifier.

[12 marks]

Q5(c) consider common emitter amplifier configration.



C_B: Block capacitor C_E: Bypass capacitor.

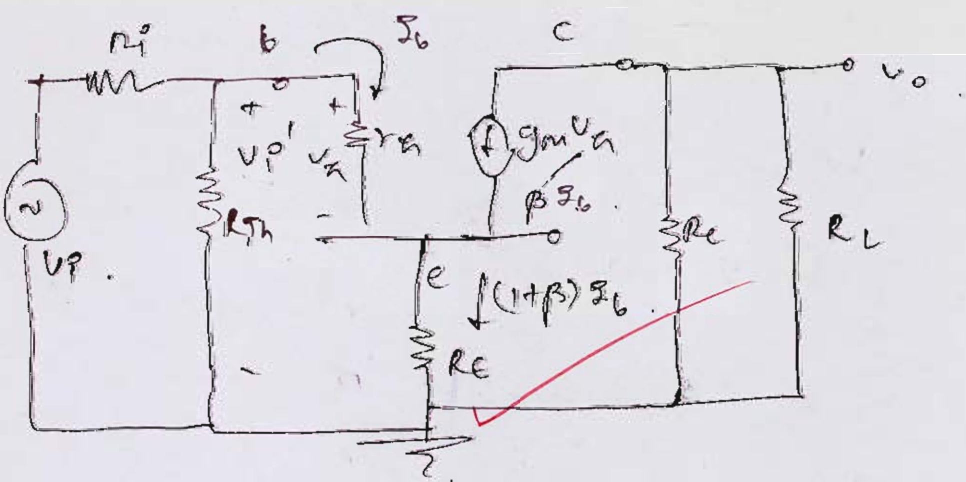
C_C: coupling capacitor

(#) case - (1) :

effect of bypass is ~~con~~ not considered.

∴ Emitter Resistance will have it's effect on the analysis.

small signal model:- (π) model :-



* model without bypass capacitor

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$v_o = -g_m v_\pi R_L'$ where, $(R_L' = R_c || R_L)$

(v_i') By KVL :-

$-v_i' + v_\pi + (1+\beta) i_b R_E = 0$.

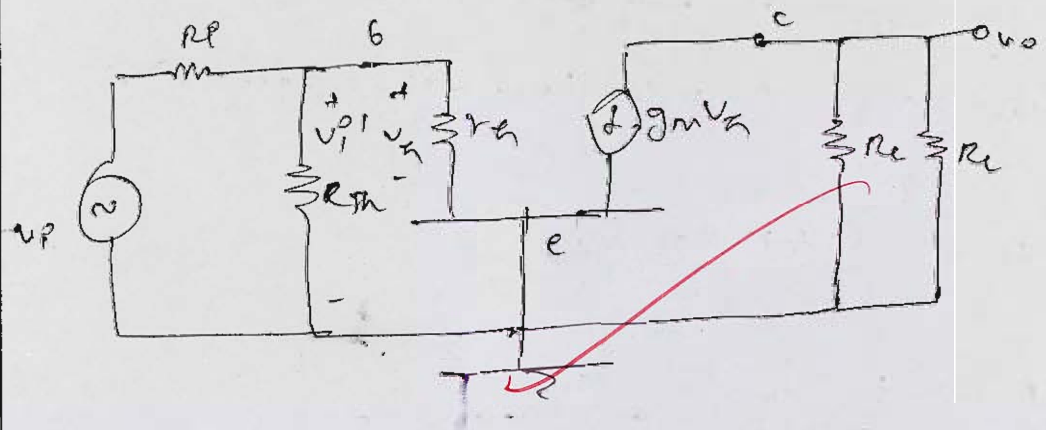
on solving

$$\boxed{A'_{v_i} = \frac{v_o}{v_i} = \frac{-g_m R_L'}{1+g_m R_E}} \quad -①$$

$\boxed{\text{if } R_E \uparrow, \; A_v \downarrow \text{ses}}$

<u>(case : 2)</u> : Considering CE configration with bypass capacitor.

∴ (π) model would be :-



$v_o = -g_m v_\pi R_L'$

& $v_\pi = v_i'$

$$A'_{v_i} = \frac{-g_m v_\pi R_L'}{v_\pi}$$

$$\boxed{A'_{v_i} = -g_m R_L'} \quad -②$$

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on comparison between ① & ②,
it is clearly visible that the gain i.e voltage ~~gain~~ is enhanced by the use of Bypass capacitor.

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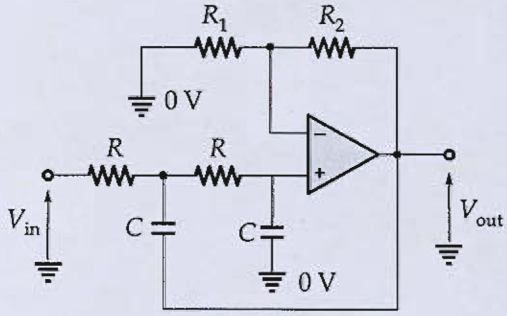
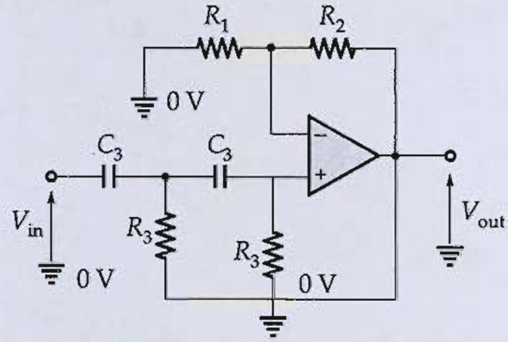
Q.5 (d) An application requires the use of a band pass filter having a roll-off rate of 40 dB/decade and cut-off frequencies $f_1 = 2$ kHz and $f_2 = 4$ kHz. Using the Sallen and Key sections, a band pass filter is designed to get maximally flat Butterworth frequency response. The low pass and high pass sections are shown in figure below.



(a) 2nd order low pass section



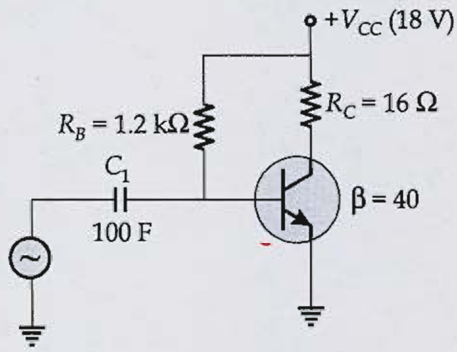
(b) 2nd order high pass section

(Assume $R_1 = 1\ \text{k}\Omega$, $C = 10^{-8}$ F and $C_3 = 10^{-7}$ F.)

Determine the numerical value of R_2, R_3 and R.

[12 marks]

Q.5 (e) Consider the circuit shown below:



Determine:

(i) Quiescent point

(ii) DC input power

(iii) Output Power

(iv) Power Efficiency

(Assume base current due to ac source, I_B = 5 mA rms)

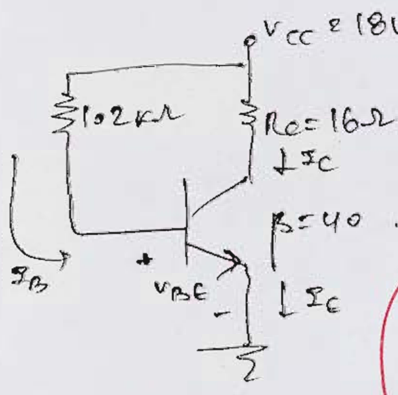
[12 marks]

Q5) (e) For Quiescent point Q(I_C, V_{CE}).

(i)

consider DC analysis, capacitor open circuit.

circuit becomes,



Fixed bias configuration

~~By KVL, $-18 + 1.2 I_B + V_{BE} = 0$~~

$I_B = \frac{18 - 0.7}{1.2}$

$\boxed{I_B = 14.41 \text{ mA}}$

$I_C = 14.41 \times 40$

$\boxed{\cancel{I_C = 0.57 \text{ A}}}$

$V_{CE} = V_{CC} - I_C R_C$

$\boxed{V_{CE} = 8.88 \text{ V}}$

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Assumption: since BJT is in fixed bias configuration, assuming it to be in active region.

∴ $\boxed{Q(8.88, 0.57)}$

(iii) $P_{out} = V_C \times I_C$

= 5 watts (output power)

(ii) Input power

~~P_{in} = 10.26 watts~~

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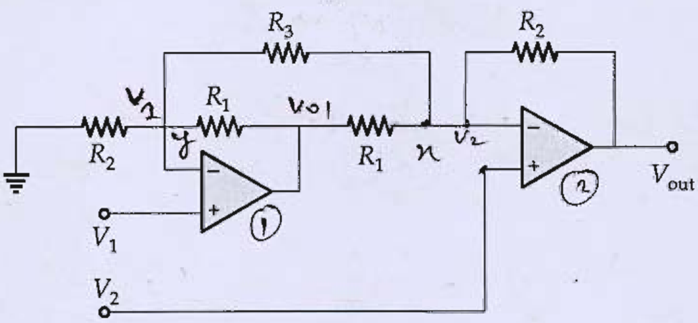
Power efficiency $= \dfrac{P_{out}}{P_{in}}$

$= \dfrac{5}{10.26}$

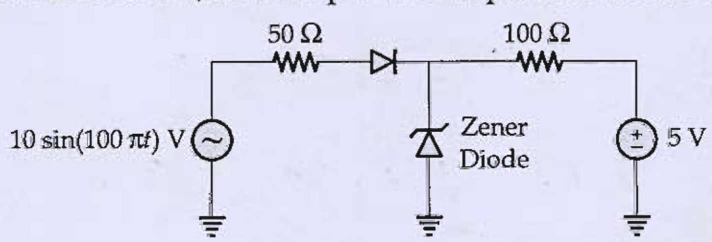
$$\boxed{\eta = 48.73\%}$$

.6 (a) (i) Consider the circuit shown in figure below:



Assuming the two op-amps to be ideal, calculate the value of $\dfrac{V_{out}}{V_2 - V_1}$.

(ii) If the diodes in the circuit shown below 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]

(a) (i) Due to virtual short :-

for op-amp ①,

$V_1^+ = V_1$

$V_1^- = V_1$ (virtual short) .

$V_2^+ = V_2$.

$V_2^- = V_2^+ = V_2$. (virtual short)

By KCL @ 'x' :-

$$\frac{V_2 - V_1}{R_3} + \frac{V_2 - V_{o1}}{R_1} + \frac{V_2 - V_{out}}{R_2} = 0 \quad - (1)$$

By KCL at 'y' :-

$$\frac{V_1}{R_2} + \frac{V_1 - V_{o1}}{R_1} + \frac{V_1 - V_2}{R_3} = 0 \quad - (2)$$

from (2),

$$V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_2}{R_3} = \frac{V_{o1}}{R_1}$$

$$\therefore V_{o1} = V_1 R_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{R_1}{R_3}V_2 \quad - (3)$$

put (3) in (1) & simplyfying (1),

$$V_2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_1}{R_3} - \frac{V_{out}}{R_2} = \frac{V_{o1}}{R_1}$$

$$V_2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_1}{R_3} - \frac{V_{out}}{R_2} = V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_2}{R_3}.$$

$$V_2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{2}{R_3}\right) - V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{2}{R_3}\right) = \frac{V_{out}}{R_2}.$$

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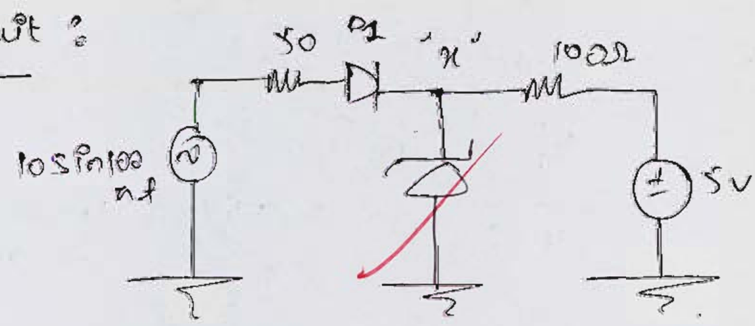
$$\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{2}{R_3}\right)(V_2 - V_1) = \frac{V_{out}}{R_2}.$$

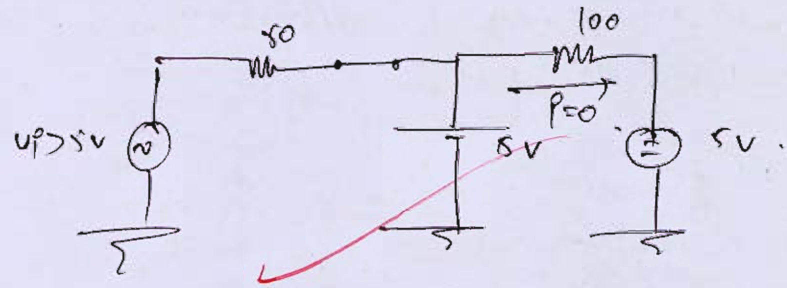
$$\boxed{R_2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{2}{R_3}\right) = \frac{V_{out}}{V_2 - V_1}}$$

Q6 (a) (ii) Given circuit :



if $v_i > 5V$ ~~voltage~~. Diode "D_1" will conduct, and at the same time, zener will be in breakdown.

∴ circuit



∴ for $v_i > 5V$.

$i = 0$.

$P = i^2 \times R$

$\boxed{P = 0}$

for $v_i < 5V$: Diode does not conduct. and zener never goes into breakdown. ~~i.e.~~ as for breakdown to occur, $V_Z > 5V$. [V_Z: voltage across zener diode].

∴ $V_Z < 5V$
& zener in Reverse bias.
it acts as open circuit.

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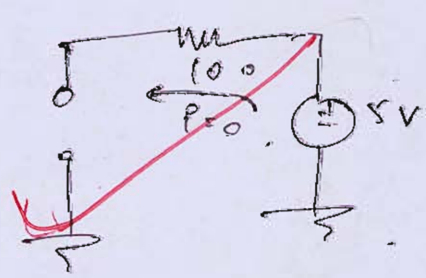
∴ Circuit



∴ $i = 0$.

$P = i^2 \times R$

$\boxed{P = 0}$

Hence in both cases power dissipated is "0" watts.

Q.6 (b) **(i)** An air-filled rectangular waveguide of dimensions $a = 2$ cm, $b = 4$ cm transports energy in the dominant mode at a rate of 2 mW. If the frequency of operation is 10 GHz, determine the peak value H_0 of the magnetic field in the waveguide.

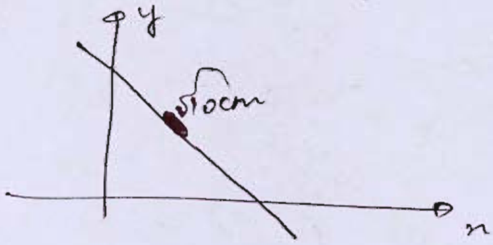
(ii) In free space, $\vec{H} = 0.2\cos(\omega t - \beta x)\hat{a}_z$ A/m. Find the total power passing through a square plate of side 10 cm on plane $x + y = 1$.

[12 + 8 marks]

Q6 (b) (i) Given: $a = 2cm$
$b = 4cm$.
Energy = 2mW.
$f = 10GHz$.

(ii) Given: $\vec{H} = 0.2\cos(\omega t - \beta x)\, a_y$ A/m.

plane:



$$\vec{P}_{avg} = \frac{1}{2}|H_0|^2 \eta_0 \,\hat{a_x}$$

$$= \frac{1}{2}\times(0.2)^2\times 120\pi. \quad \therefore (\text{free space } \eta_0 = 120\pi)$$

$$\boxed{\vec{P}_{avg} = 7.53\,\hat{a_x}}$$

$$P_{Total} = \iint \vec{P}_{avg}\cdot d\vec{s}.$$

where, $d\vec{s} = |ds|\cdot\hat{ds}$

$$|ds| = 10\times 10 = 100\,cm^2$$
$$= 100\times 10^{-4}\,m.$$
$$|ds| = 10^{-2}\,m.$$

$\hat{ds} \Rightarrow$ plane : $x+y=1$.

$$\hat{ds} = \frac{\hat{a_x}+\hat{a_y}}{\sqrt{2}}.$$

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$$\therefore P_{Total} = \iint 7.53\,\hat{a_x}\cdot \cancel{10^{-2}}\times\left(\frac{\hat{a_x}+\hat{a_y}}{\sqrt{2}}\right)$$

$$= 7.53\cdot\frac{1}{\sqrt{2}}[10^{-2}].$$

$$\boxed{P_{Total} = 53.31\ mW}$$

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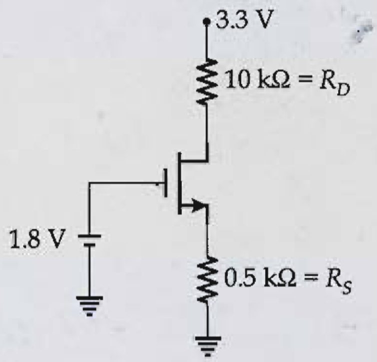
Q.6 (c) **(i)** The transistor shown in the figure below has $V_T = 1\text{ V}$, and $\mu_n C_{ox}\left(\frac{W}{L}\right) = 2\text{ mA/V}^2$.

Determine the drain voltage.

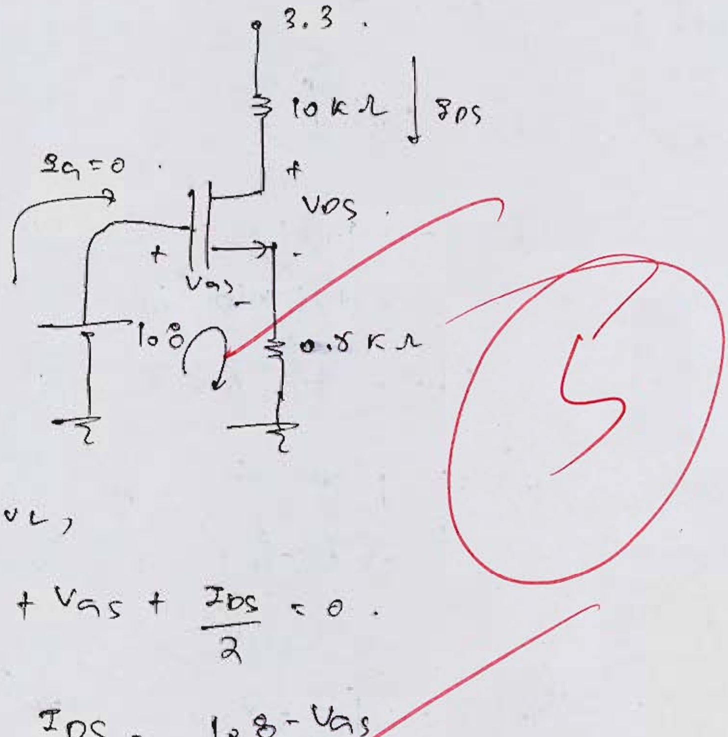


(ii) Define transconductance, dynamic drain resistance and amplification factor of JFET.

[14 + 6 marks]

Q6 (c) (i) Given: $V_T = 1\text{V}$

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



By KVL,

$$-1.8 + V_{GS} + \frac{I_{DS}}{2} = 0.$$

$$\frac{I_{DS}}{2} = 1.8 - V_{GS}$$

$$I_{DS} = 3.6 - 2V_{GS} \quad -(1)$$

Assumption: MOSFET in Saturation region,

$$I_{DS} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2 \quad -(2)$$

Substitute (1) in (2).

$3.6 - 2V_{GS} = \frac{\cancel{2}}{\cancel{2}} (V_{GS} - V_T)^2$.

$3.6 - \cancel{2V_{GS}} = V_{GS}^2 + 1 \cancel{- 2V_{GS}}$.

$V_{GS}^2 = 3.6 - 1 = 2.6$

$V_{GS} = \sqrt{2.6} = \pm 1.612\ V$.

$= +1.61\ V \checkmark, -1.61\ V \times$

$[\because V_{GS} > V_T.]$

$\therefore \boxed{V_{GS} = 1.61\ V} \leftarrow (3)$

Put (3) in (1),

$\boxed{I_{DS} = 0.38\ mA}$

calculation of V_{DS}:-

By KVL, $-3.3 + (10 + 0.5) I_{DS} + V_{DS} = 0$.

$V_{DS} = 3.3 - 10.5 \times I_{DS}$

$\boxed{V_{DS} = -0.66\ V}$

$\longrightarrow V_{DS} < V_{GS} - V_T$.

$\therefore$ MOSFET is in linear region, not in saturation.

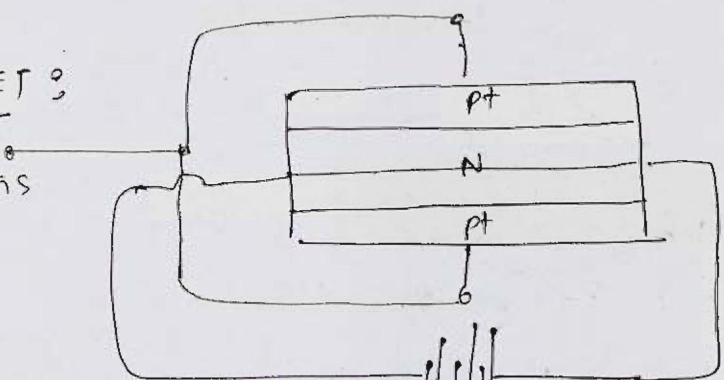
$I_{DS} = \mu_n C_{ox} \left(\frac{W}{L}\right) \left[(V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2}\right]$ → linear region.

$V_{DS} = V_{DSAT} = V_{GS} - V_T . \Big|$ onset of saturation.

~~V_{DSAT}~~

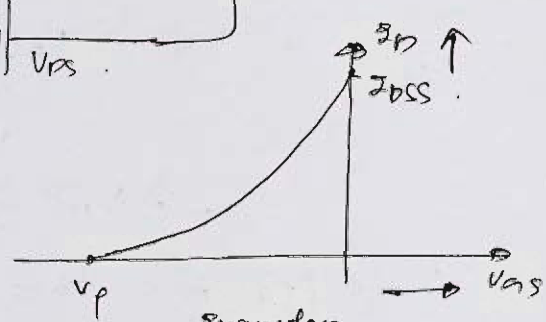
~~V_{DS}~~

(ii) For JFET :



Consider (N) channel JFET →

$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$



Transfer characteristics

Transconductance:

$\frac{\partial I_D}{\partial V_{GS}} = g_m = -\frac{2 I_{DSS}}{V_P}\left[1 - \frac{V_{GS}}{V_P}\right]$

$$\boxed{g_m = \frac{2 I_{DSS}}{|V_P|}\left[1 - \frac{V_{GS}}{V_P}\right]}$$

Ratio of output current to input voltage is transconductance.

Dynamic drain resistance:

$r_{ds} = \frac{V_A + V_{DS}}{I_{DS}}$

It is reciprocal of slope of output characteristics.

amplification factor (μ)

It is product of g_m & r_{ds}.

$\mu = g_m \times$

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.7 (a) (i) A section of a rectangular waveguide of cross-section 2 cm × 1.5 cm operating in the dominant mode is to be used as a delay line in a radar at 10 GHz. What should be the length of the section to realize a delay of 50 nsec?

(ii) Draw the voltage standing wave patterns for the following types of load impedances of the transmission line :

1. Complex Inductive load ($R + jX$)
2. Complex Capacitive load ($R - jX$)
3. Pure resistive load (R)
4. Pure Inductive load ($+jX$)
5. Pure Capacitive load ($-jX$)

[10 + 10 marks]

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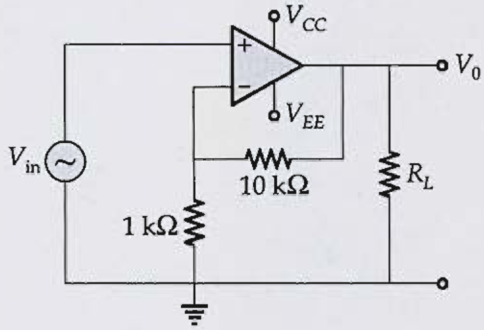
Q.7 (b) **(i)** The 741-IC Op-Amp having the following parameters is connected as shown in the figure.



Open loop voltage gain A = 20000, R_i = 2 MΩ, R_0 = 75 Ω, f_0 = 5 Hz, supply voltage = ±15 V and output voltage swing = ±13 V.

Find A_f, R_{if} and R_{0f} of the op-amp with feedback.

(ii) Draw the circuit diagram of voltage to current converter with floating load using op-amp. Derive the necessary equations that describes its operation.

[15 + 5 marks]

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Q.7 (c) A uniform plane wave is normally incident on an infinitely thick dielectric slab, having dielectric constant 10 and loss tangent 10^{-2} at $\omega = 10^{10}$ rad/sec. If the power density of the incident wave is 100 W/m^2, find the power density of the wave in the dielectric at a distance of 10 m from the surface.

[20 marks]

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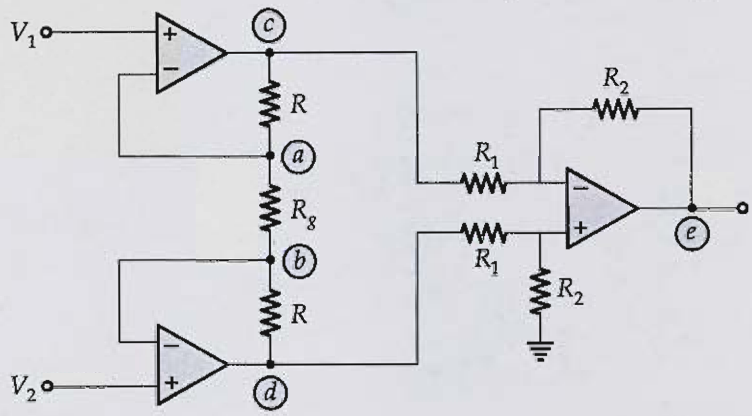
Q.8 (a) The circuit given below is made by three ideal operational amplifiers (op-amp):



(i) Specify the type of circuit. Comment upon its CMRR in comparison to op-amp.

(ii) Find the expressions for voltages at points ⓐ, ⓑ, ⓒ, ⓓ and ⓔ.

(iii) If $V_1 = 5$ V and $V_2 = 5.05$ V and V_e (voltage at point ⓔ) is 5 V, find the ratio R/R_g and R_2/R_1, when overall gain is divided in the ratio of 10 : 1 between first and second stage of the circuit.

[20 marks]

Q8

(a) (i) from the circuit

$V_a = V_1$
$V_b = V_2$ { by virtual short circuit }.

$V_c = V_{o1}$
$V_d = V_{o2}$. { outputs of opamp 1 & 2 }.

By the end of 2^{nd} op-amp.

$V_{o3} = V_e$ { output of op-amp 3 }.

4

$$V^+ = \frac{V_d \times R_2}{R_1 + R_2}$$

$$V^- = \frac{\cancel{V_c \times R_2} + V_e \times R_1}{R_1 + R_2}.$$

$V^+ = V^-$.

$$\frac{V_d R_2}{R_1 + R_2} = \frac{V_c R_2}{R_1 + R_2} + \frac{V_e R_1}{R_1 + R_2}$$

$$(V_d - V_c)\frac{R_2}{R_1+R_2} = V_e \frac{R_1}{R_1+R_2}$$

$$\boxed{\frac{V_e}{V_d - V_c} = \frac{R_2}{R_1}}$$

The abone circuit is a difference amplifier, when operated differences the input with gain $\frac{R_2}{R_1}$.

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8 (b) (i) The radiation resistance of an antenna is 280 Ω and the efficiency factor is 0.8. Calculate the loss resistance R_{loss} if the magnitude of the current is I_0 = 5 A. Also, calculate the power radiated and the ohmic loss.

(ii) An antenna in air radiates a total power of 100 kW so that a maximum radiated electric field strength of 12 mV/m is measured 20 km from the antenna.

Find: 1. its directivity in decibels,

2. its maximum power gain if η_r = 98%.

[12 + 8 marks]

(b) (i) $R_{rad} = 280\Omega$

$\eta = 0.8$.

$I_0 = 5A$.

$$\eta = \frac{R_{rad}}{R_l + R_{rad}}$$

$$0.8 = \frac{280}{R_l + 280}.$$

$$0.8 R_l = 56$$

$$\boxed{R_{loss} = 70\,\Omega}$$

$$P_{rad} = \frac{I_0^2}{2} R_{rad}.$$

$$= \frac{(5)^2}{2} \times 280 = \boxed{3.5\,kW}$$

11

$P_{radiated} = \eta \times P_{rad} = 2.8\,kW$.

$\therefore$ ohmic losses $= 0.7\,kW$

$= 700$ watts.

(b) (ii) $P_{rad} = 100\,kW$.

$|E| = 12\,mV/m$

$r = 20\,km$.

$$G_D(\theta, \phi) = \frac{U(\theta, \phi)}{U_{avg}} = \frac{r^2 P_{avg}}{P_{rad}} \times 4\pi \quad -(1)$$

$$D = \text{directivity} = \frac{U_{max}}{U_{avg}} \quad -(2)$$

from (1), $P_{avg} = \frac{1}{2} \frac{|E|^2}{\eta_0}$

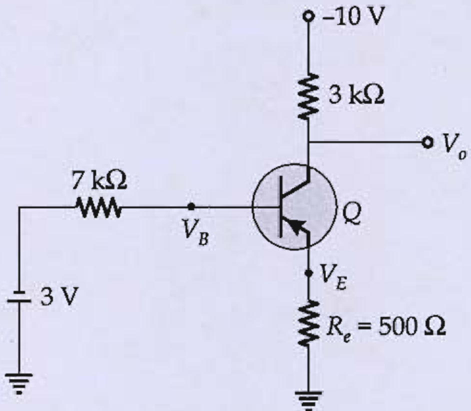
4

$$G_D(\theta, \phi) = \frac{1}{2} \times \frac{(12 \times 10^{-3})^2}{120\pi} \times \frac{(20 \times 10^3)^2}{100 \times 10^3} \times 4\pi$$

$$G_D(\theta, \phi) = 9.6 \times 10^{-3}$$

$$\boxed{D = 9.6 \times 10^{-3}}$$

8 (c) (i) For the circuit shown in the figure, assume $\beta = h_{FE} = 100$.



1. Determine if the silicon transistor is in cut-off, saturation or in active region.
2. Find V_0, V_B, V_E.

Assume $V_{CE\,sat} = -0.2$ V and $V_{BE\,sat} = -0.8$ V.

(ii) With reference to a BJT, show that $\frac{\partial P_c}{\partial T_j} < \frac{1}{\theta_{JA}}$ must be satisfied in order to prevent thermal runaway. Here, P_C is the heat generated at the collector junction, T_j is the junction temperature and θ_{JA} is the thermal resistance between the junction and the air.

[12 + 8 marks]

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OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

$$\frac{10\times10^{-6}\times2\pi\times500\times10^{3}}{120\pi\times0.29}=90.$$

Space for Rough Work

$\frac{2\pi}{\cancel{\lambda}} \times 0.2\cancel{\lambda}$

0.4π

$\sqrt{1+\frac{10^{-6}}{R_1^2}} = \frac{10}{7.07}$.

$1+\frac{10^{-6}}{R_1^2} = 2$.

$10^{-6} = R_1^2$.

$R_1 =$

Space for Rough Work