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(To be filled by candidate)

Name of Candidate : Aditya Srivastava

Roll No. :

Registration Number : Date of Examination : 30/08/22

CSE 2022 : MAIN TEST SERIES

ELECTRICAL ENGINEERING

Test -5
Full Syllabus Test
Paper-I

Time Allowed.: Three Hours

Maximum Marks: 250

GENERAL INSTRUCTIONS

There are EIGHT questions divided in TWO SECTIONS. Candidate has to attempt FIVE questions in all. Question no. 1 and 5 are compulsory and out of remaining, THREE are to be attempted choosing at least ONE from each section.

This Question-cum Answer Booklet (QCAB) contains 74 pages. Immediately on receipt of the booklet, please check that this booklet does not have any misprint or torn or missing pages etc. If so, get it replaced by a fresh booklet.

Candidates must read the instructions on this page and the following pages carefully before attempting the paper.

Candidates should attempt the questions strictly in accordance with the instructions specified in the question paper and in the space prescribed under each question in the booklet. Any answer written outside the space allotted will not be given credit.

Question paper will be provided separately and can be taken by the candidates after conclusion of the exam.

SUBJECT/PAPER
ELECTRICAL ENGINEERING

Invigilator's Sign. : . . . .

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Name of Candidate : Aditya Srivastava

Test : Electrical engineering Test 5

Stream :

Centre :

Online ☑

Offline ☐

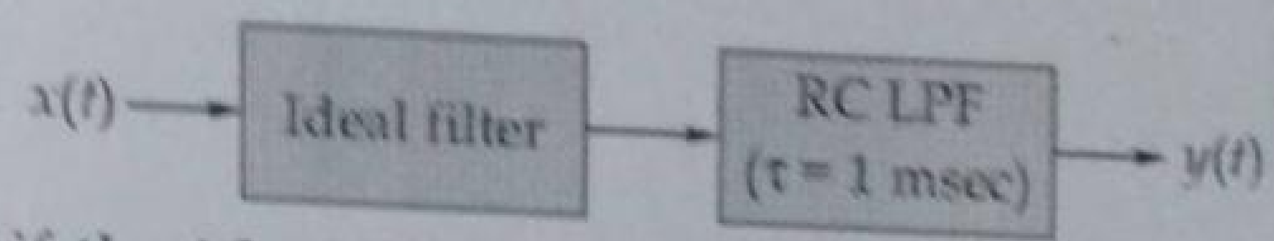
Q. No.	Page No.	Marks	Total	Signature	Q. No.	Page No.	Marks	Total	Signature
1	1				5	39			
2	11				6	49			
3	20				7	58			
4	30				8	67			
						GRAND TOTAL			

EVALUATION INDICATORS	Remarks			
	Excellent	Good	Average	Needs Improvement
1. Clarity of Concepts				
2. Relevance to question				
3. Illustration - Diagram/Graphs/ Flow chart/Formula				
4. Presentation				
5. Accuracy				

Observations:

Section A

(a) A periodic signal $x(t) = 2 + \sum_{n=1}^{\infty} \frac{6}{n} \sin^2\left(\frac{n\pi}{2}\right) \cos(1600\pi n t)$ is applied to the system shown.



Compute the output $y(t)$ if the ideal filter passes frequencies only between 200 Hz-2000 Hz. **10**

For the $x(t)$;

frequencies are $\frac{1600\pi n}{2\pi} = 800n$ Hz.

Now only remaining freq are:—

$$x'(t) = \cancel{2+} \frac{6}{1}\sin^2\left(\frac{\pi}{2}\right)\cos(1600\pi t) + \frac{6}{2}\sin^2(\pi) \times \cos(3200\pi t)$$

After Ideal filter only these 3 terms remain.

$$\text{or } x'(t) = 6\cos(1600\pi t)$$

For the LPF; cutoff freq $= \frac{1}{\tau} = 1000$ Hz

$$\Rightarrow \boxed{y'(t) = 6\cos(1600\pi t)}$$

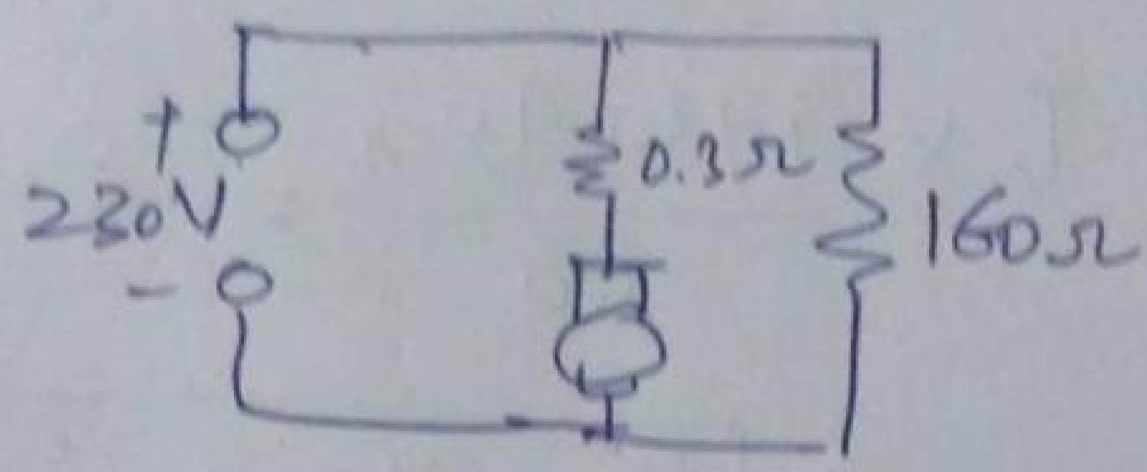
But $|H_{RC}(\omega)| = \frac{1}{1+(\omega RC)^2} = \frac{1}{1+(1600\pi\times 10^{-3})^2} = 0.195$

& $\angle H_{RC}(\omega) = -\tan^{-1}(\omega RC) = -\tan^{-1}\left(\frac{1600\pi}{1000}\right) = -78.75°$

$$\Rightarrow \boxed{y(t) = 1.17\cos(1600\pi t - 78.75°)}$$

A 230 V, dc shunt motor, takes an armature current of 3.33 Amp at rated voltage and at no-load speed of 1000 rpm. The resistances of the armature circuit and field circuit are respectively 0.3 Ω and 160 Ω. The line current at full load and rated voltage is 40 A. Calculate the speed and the developed torque at full load in case the armature reaction weakens the no-load flux by 4%.

10



For given case @ no load :-

$$I_a = 3.33 \Rightarrow E_a = 230 - 3.33 \times 0.3$$
$$= 229\,V$$

$$\& \quad \omega_m = \frac{1000 \times 2\pi}{60} = \frac{100\pi}{3}$$

$$\Rightarrow 229 = K_m \times \frac{100\pi}{3} \quad \text{—— (1)}$$

Also No load loss $= 229 \times 3.33$ W
$= 762.57$ W.

Now at full load :-

$$I_a = 40 - \frac{230}{160} = 38.5625\,A$$

$$\Rightarrow E_a = 230 - 38.5625 \times 0.3$$
$$\boxed{E_a = 218.43\,V}$$

~~$\Rightarrow \omega_m = \frac{218.43}{229} \times \frac{100\pi}{3} \Rightarrow$ Speed = 953.85 rpm~~

But by armature reaction :-

$$218.43 = 0.96\, K_m \times \omega_m$$

$$\Rightarrow \frac{218.43}{229} = \frac{0.96 \times (\omega_m)_{rpm}}{1000} \Rightarrow \boxed{\text{speed} = 993.59\,\text{rpm}}$$

Power developed $= E_a \times I_a$

$= 218.43 \times 38.5625$

$= 8.423\ kW$

Now $T \times \frac{993.59 \times 2\pi}{60} = 8.423 - 0.763$

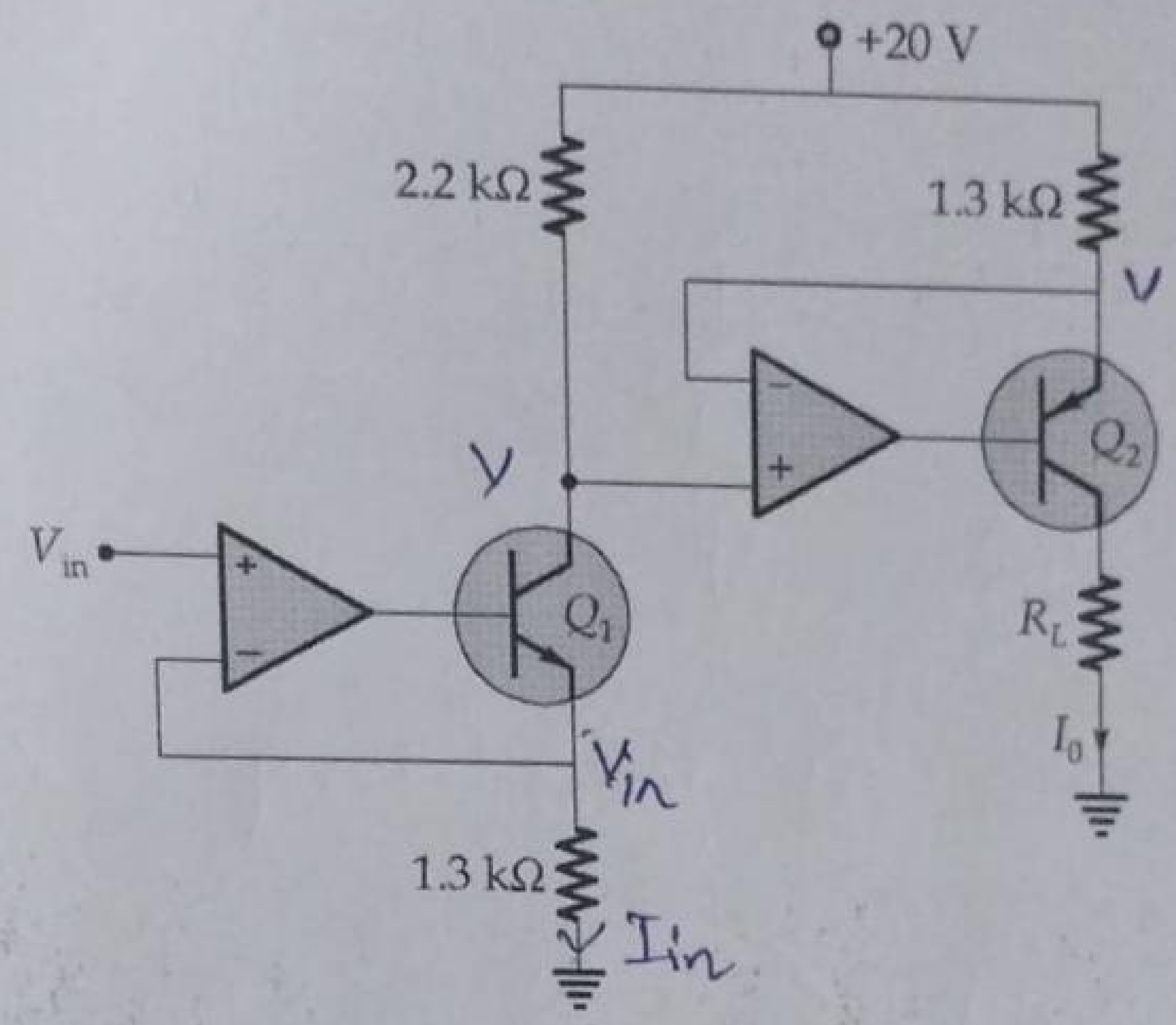
$\Rightarrow \boxed{T = 73.626\ Nm}$

Candidates must not write on this margin

In the op-amp circuit below, following specifications are given:

$V_{in} = 6$ V, $V_{CE\,sat}$ of transistor $Q_2 = -0.2$ V

Determine output current I_0, maximum value of R_L that can be used in given circuit.



10

$V_{in} = 6\text{ V} \Rightarrow I_{in} = \dfrac{6\text{ V}}{1.3\text{ k}\Omega} = 4.615\text{ mA}$

$\Rightarrow V = 20 - 4.615 \times 2.2$

$= 9.847\text{ V}$

$\Rightarrow \cancel{V} \; I_{E_2} = \dfrac{20 - V}{1.3\text{ k}\Omega} = 7.81\text{ mA}$

For large β:— $I_{C_2} = 7.81\text{ mA}$

or $\boxed{I_0 = 7.81\text{ mA}}$

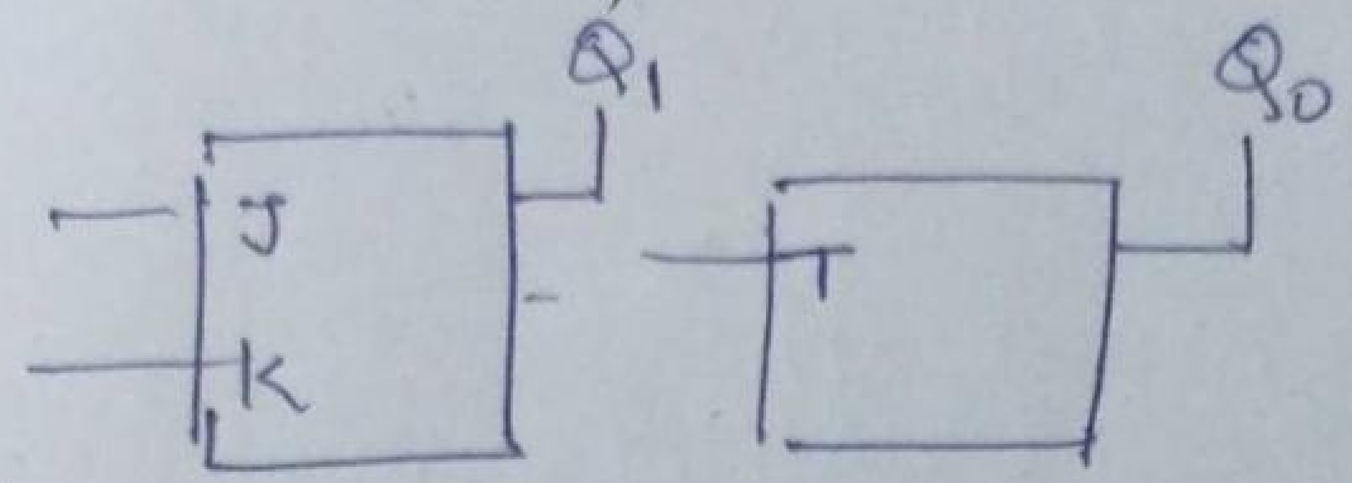
Now for max R_L:—

$R_L \times 7.81 \times 10^{-3} + 0.2 + 1.3 \times 7.81 = 20$

$\boxed{R_L = 1.235\text{ k}\Omega}$

Design a sequential circuit using J-K flip flop followed by T-flip flop to count a sequence $1 \to 3 \to 2 \to 0 \to 1$. (Use J-K FF for MSB)

10



Q_1^{n+1}	Q_0^{n+1}	Q_1^n	Q_0^n	J	K	T
0	1	0	0	0	X	1
1	1	0	1	1	X	1
0	0	1	0	X	1	1
1	0	1	1	X	0	0

Q_n	Q_{n+1}	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

$Q_1 \backslash Q_0$	0	1
0	0	1
1	X	X

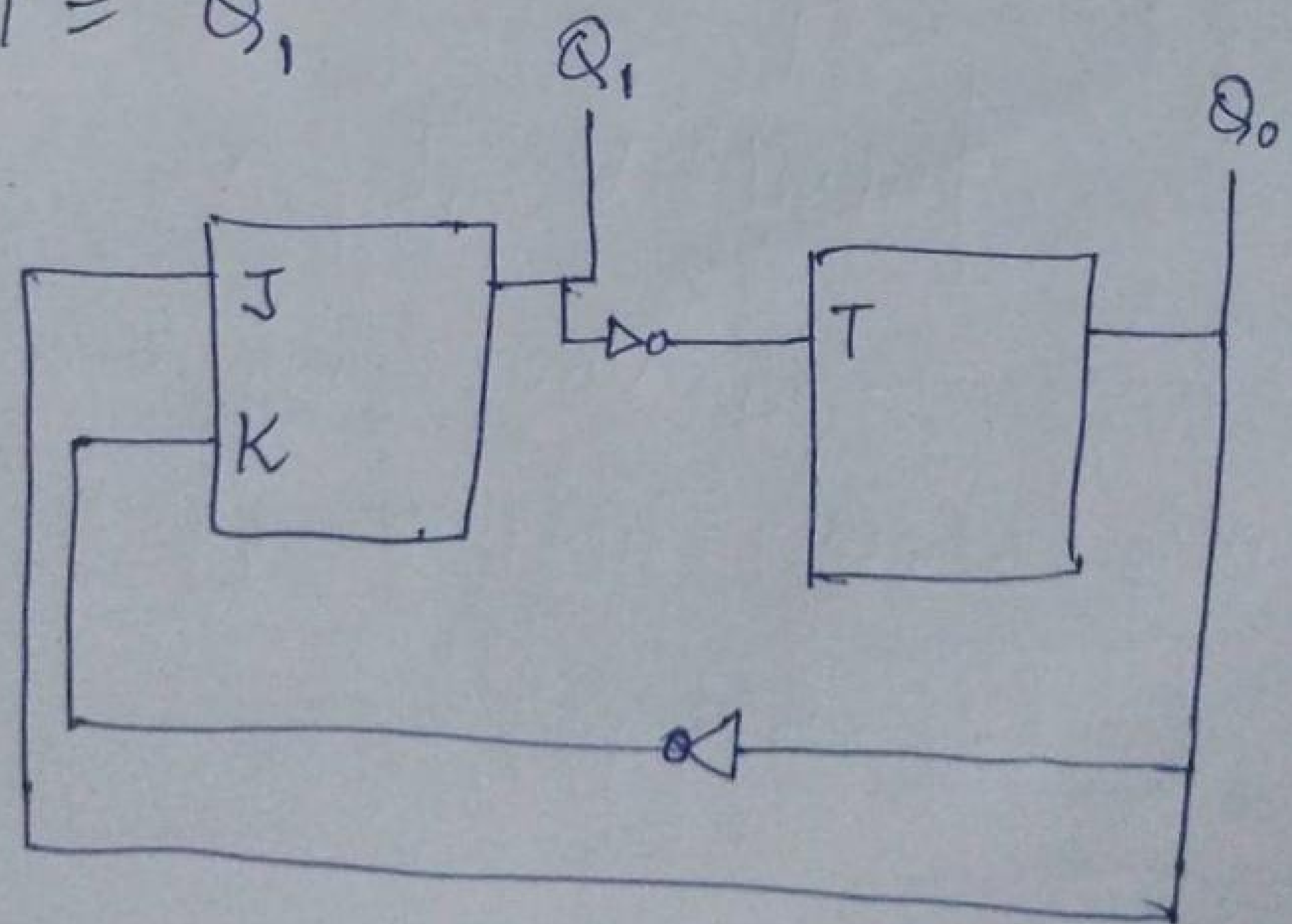
$J = Q_0$

$Q_1 \backslash Q_0$	0	1
0	X	X
1	1	0

$K = \overline{Q_0}$

$Q_1 \backslash Q_0$	0	1
0	1	1
1	0	0

$T = \overline{Q_1}$



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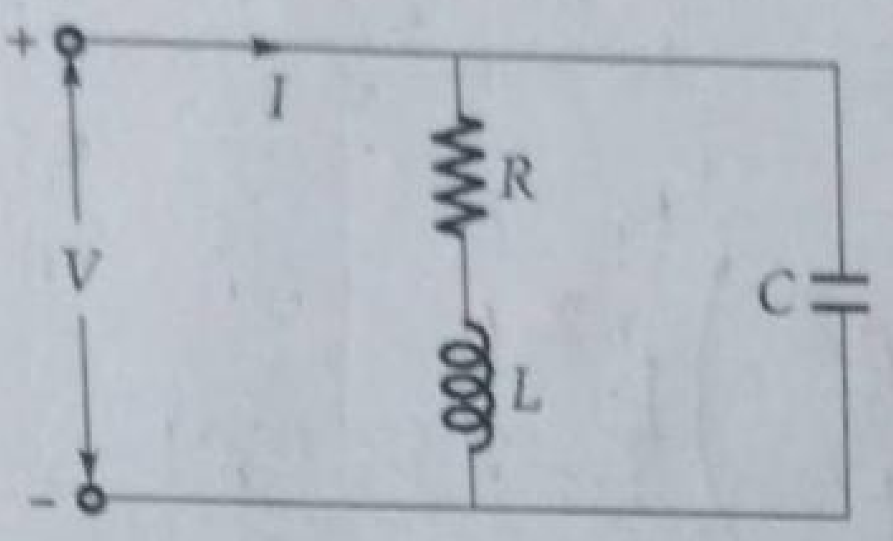
Determine the resonance frequency and dynamic impedance for given circuit in figure below, in terms of circuit parameters.



10

$$Z_{eq} = (R+j\omega L) \,||\, \frac{1}{j\omega C}$$

$$= \frac{(R+j\omega L) \times \frac{1}{j\omega C}}{R+j\omega L + \frac{1}{j\omega C}}$$

$$= \frac{R+j\omega L}{1+j\omega C(R+j\omega L)} = \frac{R+j\omega L}{(1-\omega^2 LC)+j\omega RC}$$

$$= \frac{(R+j\omega L)\left[(1-\omega^2 LC)-j\omega RC\right]}{(1-\omega^2 LC)^2+(\omega RC)^2}$$

numerator $= \left[R(1-\omega^2 LC)+\omega^2 LRC\right]$
$+j\left[(1-\omega^2 LC)\omega L - \omega R^2 C\right]$

For resonance :-

$$(1-\omega^2 LC)\cancel{\omega} L = \cancel{\omega} R^2 C$$

$$1-\omega^2 LC = \frac{R^2 C}{L} \Rightarrow \omega^2 LC = 1 - \frac{R^2 C}{L}$$

or. $\boxed{\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$

or $\boxed{f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$

So; at resonance —

$$Z_0 = \frac{R^2 + \omega_0^2 L^2}{R}$$

$$= \frac{R^2 + \left(\frac{1}{LC} - \frac{R^2}{L^2}\right) L^2}{R}$$

$$= \cancel{R} + \frac{L}{RC} - \cancel{R}$$

or $\boxed{Z_0 = \frac{L}{RC}}$

Q.4 (a) Design a 3-bit gray code to excess-3 code converter using 2-input logic gates.

For given Condition :-

Input (Gray code) A	B	C	Output W	X	Y	Z
0	0	0	0	0	1	1
0	0	1	0	1	0	0
0	1	1	0	1	0	1
0	1	0	0	1	1	0
1	1	0	0	1	1	1
1	1	1	1	0	0	0
1	0	1	1	0	0	1
1	0	0	1	0	1	0

W

A \ BC	00	01	11	10
0	0	0	0	0
1	1	1	1	0

$= A\bar{B} + AC$

X

A \ BC	00	01	11	10
0	0	1	1	1
1	0	0	0	1

$= \bar{A}C + B\bar{C}$

Y

A \ BC	00	01	11	10
0	1	0	0	1
1	1	0	0	1

$= \bar{C}$

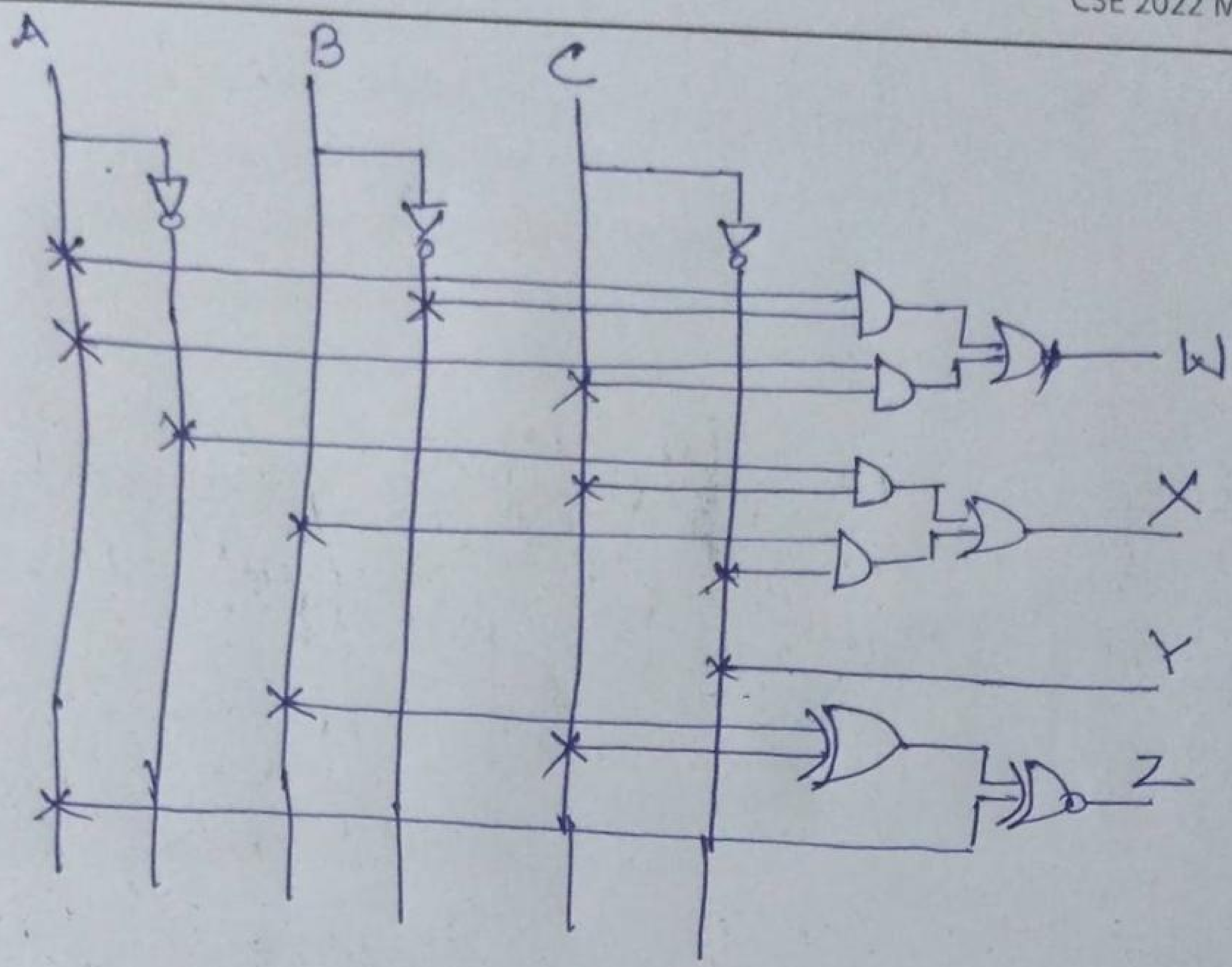
Z

A \ BC	00	01	11	10
0	1	0	1	0
1	0	1	0	1

$= \bar{A}\bar{B}\bar{C} + A\bar{B}C + \bar{A}BC + AB\bar{C}$

$= \bar{A}(B \odot C) + A(B \oplus C)$

$= \cancel{A \oplus (B \odot C)}\; A \odot (B \oplus C)$

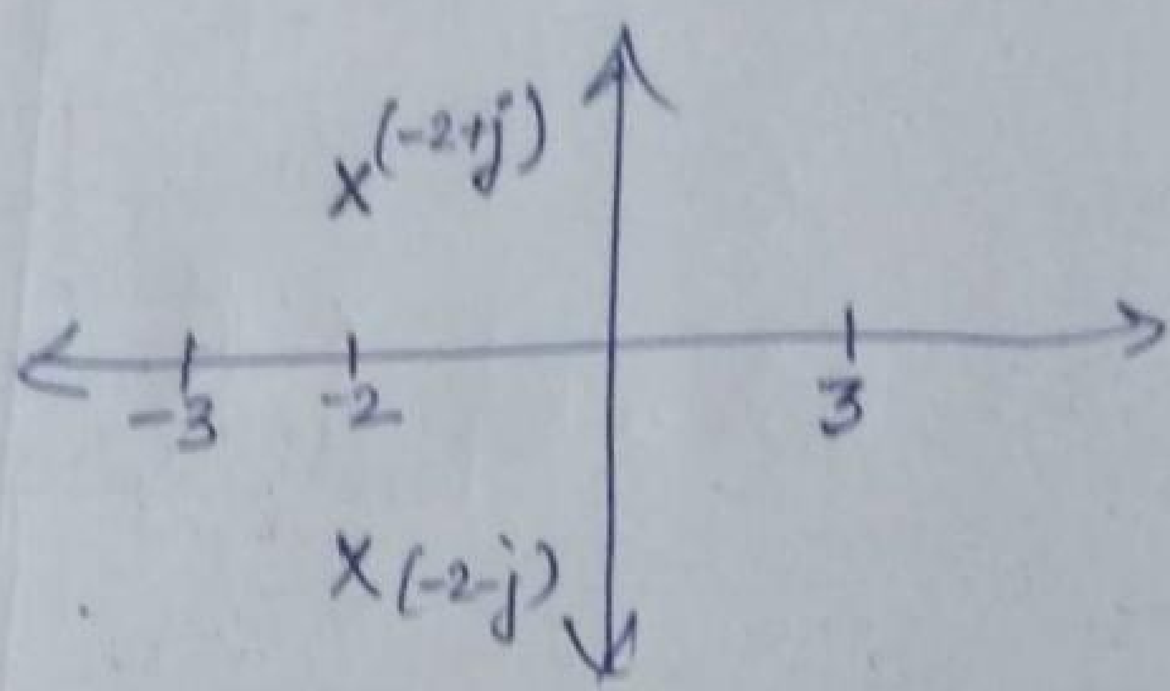

A
B
C
W
X
Y
Z

(i) We are given the following facts about a real signal $x(t)$ with Laplace transform $X(s)$.

1. $X(s)$ has exactly two poles.
2. $X(s)$ has no zeros in the finite s-plane.
3. $X(s)$ has a pole at $s = -2 + j$.
4. $e^{3t}\, x(t)$ is not absolutely integrable.
5. $X(0) = 8$.

Then find the $x(t)$?

12



Since signal is real

⇒ X(s) should have symmetrical pole placement

⇒ other pole $= -2-j$

Now $X(s) = \dfrac{k}{(s+2-j)(s+2+j)} = \dfrac{K}{s^2+4s+5}$

Now $X(0) = 8 \Rightarrow \dfrac{k}{5} = 8$ or $\boxed{K = 40}$

$$\Rightarrow \boxed{X(s) = \frac{40}{s^2+4s+5}}$$

Now $e^{3t} x(t)$ is not absolutely integrable

⇒ $\sigma = -3$ is outside the ROC

⇒ ROC is such that $\sigma > -3$ or $\boxed{\sigma > -2}$

⇒ we have poles to the ~~right~~ left of the ROC & system is ~~not~~ causal.

So; $x(t) = \dfrac{10}{5} \times \dfrac{5}{(s+2)^2+1^2}$

$$\boxed{x(t) = 40 \sin(t)\, e^{-2t} u(t)}$$

Candid... must no... on this ...

(ii) Design a 3-phase FIR filter with impulse response $h(n) = [\alpha, \beta, \alpha]$ and the amplitude response blocks the frequency $f = \frac{1}{3}$ and passes the frequency $f = \frac{1}{8}$ with unity gain. What is the DC gain of filter?

8

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The joint PDF $p_{xy}(x, y)$ of two continuous RV's is given by,

$$p_{xy}(x, y) = xy e^{-(x^2+y^2)/2} u(x)u(y)$$

(i) Find $p_x(x)$, $p_y(y)$, $p_{xy}(x \mid y)$ and $p_{xy}(y \mid x)$.

(ii) Are x and y independent?

10

(i) $$P_x(x) = \int_{-\infty}^{\infty} P_{xy}(x,y) \cdot dy$$

$$= \int_{-\infty}^{\infty} xy\, e^{-\left(\frac{x^2+y^2}{2}\right)} u(x)\, u(y)\, dy$$

$$= x \cdot e^{-x^2/2} \int_0^{\infty} y \cdot e^{-y^2/2} dy$$

let $\frac{y^2}{2} = t$

$y\,dy = dt$

$$= x \cdot e^{-x^2/2} \underbrace{\int_0^{\infty} e^{-t} dt}_{\to 1} \Rightarrow \boxed{P_x(x) = x e^{-x^2/2} u(x)}$$

Similarly by symmetry :- $\boxed{P_Y(y) = y e^{-y^2/2} u(y)}$

Now $P_{xy}(x/y) = \dfrac{P_{xy}(x,y)}{P_y(y)} = \dfrac{xy e^{-(x^2+y^2/2)} u(x)\cancel{u(y)}}{y e^{-y^2/2} \cancel{u(y)}}$

$$\boxed{P_{xy}(x/y) = x e^{-x^2/2} u(x)}$$

Similarly by symmetry $\boxed{P_{xy}(y|x) = y e^{-y^2/2} u(y)}$

(ii) For independence $P_{xy}(x,y) = P_x(x) P_Y(y)$

Now $P_X(x) \cdot P_Y(y) = x \cdot e^{-x^2/2} \cdot y e^{-y^2/2} \cdot u(x)\, u(y)$

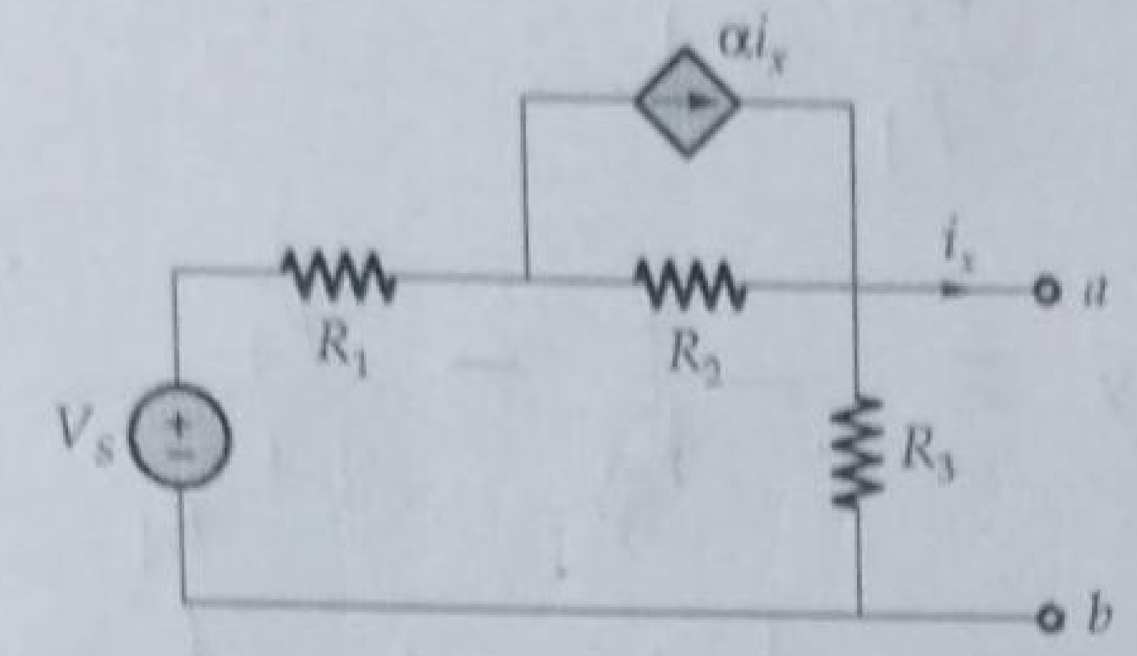
$= xy e^{-(x^2+y^2)/2} u(x)(u(y))$

$\Rightarrow P_X(x) P_Y(y) = P_{xy}(x,y)$

$\Rightarrow$ $\boxed{\text{Independent}}$

Section B

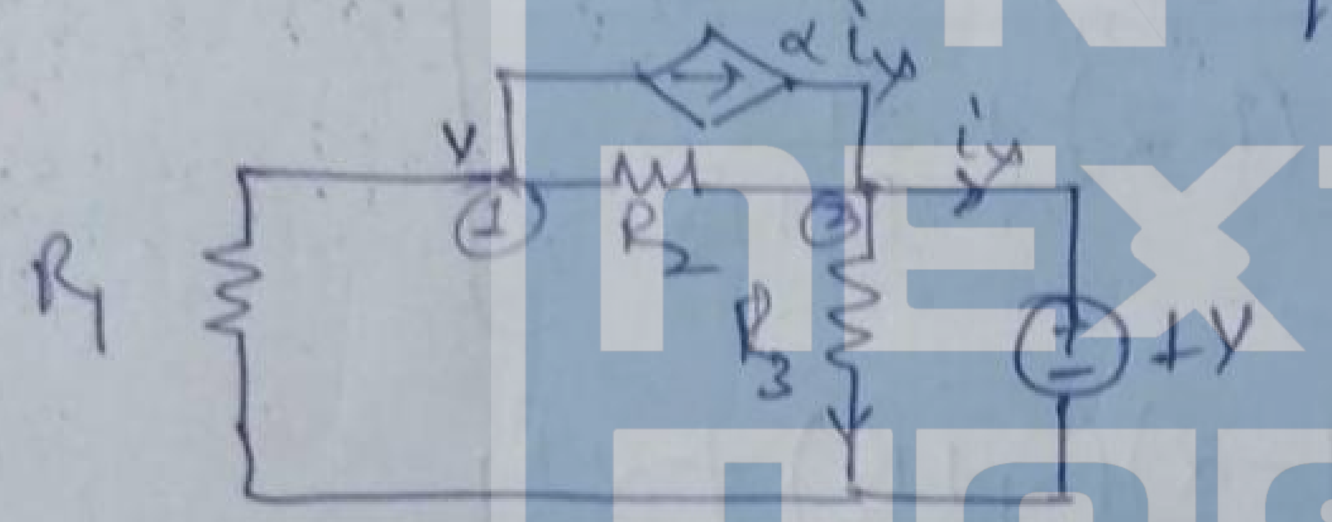
(a) Find the thevenin's equivalent network at $a - b$ for the circuit shown in figure below, 10



For open circuit :— $i_x = 0 \Rightarrow \alpha i_x = 0$

$$\Rightarrow \boxed{V_{oc} = V_s \times \frac{R_3}{R_1+R_2+R_3}}$$

For ~~short circuit~~ R_{eq} analysis :—



At node (1) :—

$$\frac{V}{R_1} + \frac{V-1}{R_2} + \alpha i_x = 0$$

At node (2) :—

$$i_x + \frac{1}{R_3} - \alpha i_x + \frac{1-V}{R_2} = 0$$

$$V\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{1}{R_2} - \alpha i_x \Rightarrow V = \frac{\frac{1}{R_2}-\alpha i_x}{\frac{1}{R_1}+\frac{1}{R_2}}$$

$$\Rightarrow i_x + \frac{1}{R_3} - \alpha i_x + \frac{1 - \frac{\frac{1}{R_2}-\alpha i_x}{\frac{1}{R_1}+\frac{1}{R_2}}}{R_2} = 0$$

$$(1-\alpha) i_x + \frac{1}{R_3} + \frac{\frac{1}{R_1}+\alpha i_x}{\frac{R_2}{R_1}+1} = 0$$

$$(1-\alpha)i_x + \frac{1}{R_3} + \frac{\frac{1}{R_1} + \alpha i_x}{\frac{R_2}{R_1}+1} = 0$$

$$\left[(1-\alpha) + \frac{\alpha}{1+\frac{R_2}{R_1}}\right] i_x = -\frac{1}{R_3} - \frac{\frac{1}{R_1}}{1+\frac{R_2}{R_1}}$$

$$\left[(1-\alpha) + \frac{R_1\alpha}{R_1+R_2}\right] i_x = -\left[\frac{1}{R_3} + \frac{1}{R_1+R_2}\right]$$

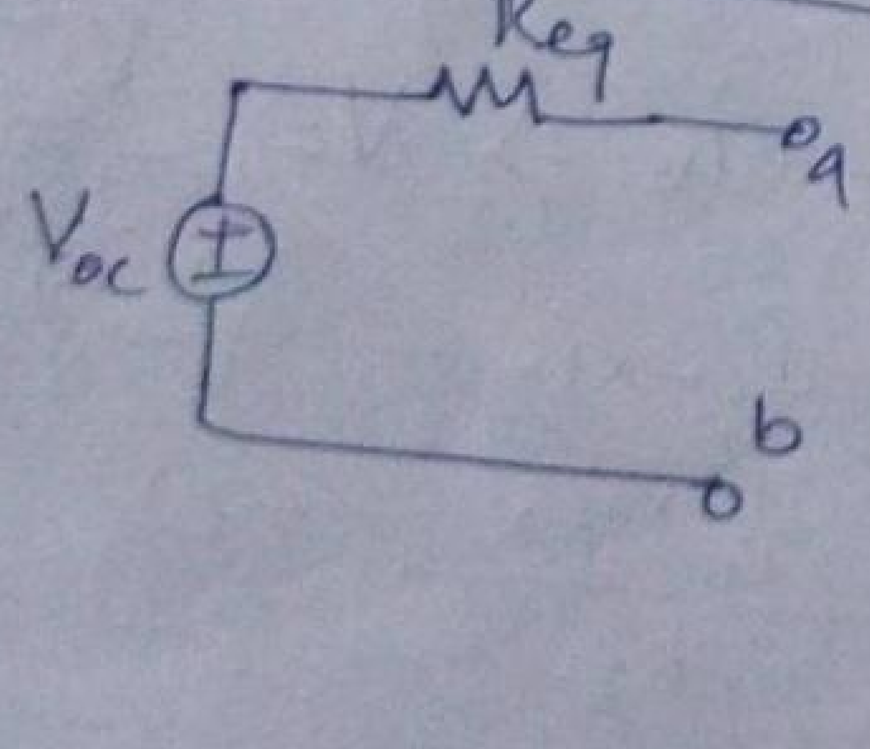
$$\Rightarrow i_x = -\frac{\left[\frac{1}{R_3} + \frac{1}{R_1+R_2}\right]}{(1-\alpha) + \frac{R_1\alpha}{R_1+R_2}}$$

Now $$R_{eq} = \left[\frac{\frac{1}{R_3} + \frac{1}{R_1+R_2}}{(1-\alpha) + \frac{R_1\alpha}{R_1+R_2}}\right]^{-1}$$

$$= \frac{(1-\alpha)(R_1+R_2) + \alpha R_1}{1 + \frac{R_1+R_2}{R_3}}$$

$$= \frac{R_1 + R_2 - \cancel{\alpha R_1} - \alpha R_2 + \cancel{\alpha R_1}}{1 + \frac{R_1+R_2}{R_3}}$$

$$\boxed{R_{eq} = \frac{(R_1+R_2-\alpha R_2)R_3}{R_1+R_2+R_3}}$$



The full load voltage drops in a single phase transformer are 2% and 4% due resistance and leakage reactance respectively. The full load ohmic loss is equal to the iron loss.

Determine:

(i) the efficiency on full load at unity power factor.

(ii) the full-load power factor at which voltage drop is maximum and

(iii) the load pf at which voltage drop is zero.

10

$P_{cu} = P_i$ & $I \times R = 2\%$

& $I \times X = 4\%$

$\Rightarrow \boxed{X = 2R}$

(i) For full load and unity pf :-

$$\eta = \frac{S \times 1}{S \times 1 + I^2R + P_i} = \frac{S \times 1}{S + 2 \times I^2R}$$

Now $I \times R = 0.02V$ or $I^2R = 0.02S$

&

$$\Rightarrow \eta = \frac{S}{S + 2 \times 0.02S} = \boxed{96.15\%}$$

(ii) For max voltage drop :-

$$Z_{Load} = |Z|\frac{(1+2j)}{\sqrt{1+4}} = \frac{|Z|}{5} \times (1+2j)$$

$\Rightarrow$ power factor $= \cos[\tan^{-1}(2)] = \boxed{0.447 \text{ lag}}$

(iii)

In a dielectric ($\sigma = 10^{-4}$ S/m, $\mu_r = 1$, $\epsilon_r = 4.5$), the conduction current density is given as $J_c = 0.4 \cos(2\pi \times 10^8 t)$ A/m^2. Determine the displacement current density.

10

$$\sigma E = 0.4 \cos(2\pi \times 10^8 t)$$

$$\Rightarrow E = 4\times10^3 \cos(2\pi\times10^8 t) \text{ V/m}$$

$$\Rightarrow \eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$$

But $\omega\epsilon = 2\pi\times10^8 \times 8.854\times10^{-12} \times 4.5$

$= 0.025$

$\omega\mu = 2\pi\times10^8 \times 4\pi\times10^{-7}$

$=$

$$= \sqrt{\frac{789.57j}{10^{-4} + j\,0.025}}$$

$$= \sqrt{31582.48\angle 0.23^\circ}$$

$$\eta = 177.7\angle 0.11^\circ\ \Omega$$

$$\Rightarrow H = 22.508 \cos(2\pi\times10^8 t - 0.11^\circ)$$

Now $J_d = \frac{\partial D}{\partial t} = \epsilon \times \frac{\partial E}{\partial t}$

$$= -4.5\times8.854\times10^{-12} \times 4000 \times 2\pi\times10^8 \times \sin(2\pi\times10^8 t)$$

$$\boxed{J_d = -100.14 \sin(2\pi\times10^8 t) \text{ A/m}^2}$$

A 80 kW, 440 V, 800 rpm dc motor is operating at 600 rpm and developing 75% rated torque is controlled by 3-ϕ , six-pulse thyristor converter. If the back emf at rated speed is 410 V, determine the triggering angle of the converter. The input to the converter is 3-ϕ, 415 V, 50 Hz a.c. supply. Assume flux as constant.

10

For the fully controlled convertor —

$$V_t = \frac{3V_{ml}}{\pi}\cos\alpha \qquad \text{where } V_{ml} = 415\sqrt{2}\,V$$

For full load condition :—

$$\tau \times \frac{800 \times 2\pi}{60} = 80 \times 10^3$$

But given condition has.

$$0.75\,\tau \times \frac{600 \times 2\pi}{60} = P_L.$$

$$\Rightarrow \frac{800}{600} \times \frac{1}{0.75} = \frac{80\,kW}{P_L} \Rightarrow \boxed{P_L = 45\,kW}$$

Now We know $410 = k \times 800\,rpm$

$$\Rightarrow E_a = \cancel{800}\ \frac{600}{800} \times 410$$

$$\boxed{E_a = 307.5\,V}$$

Now power output is 45 kW ⇒

$$\frac{45}{3} \times 10^3 = 307.5 \times I_a \Rightarrow \boxed{I_a = 48.78\,A}$$

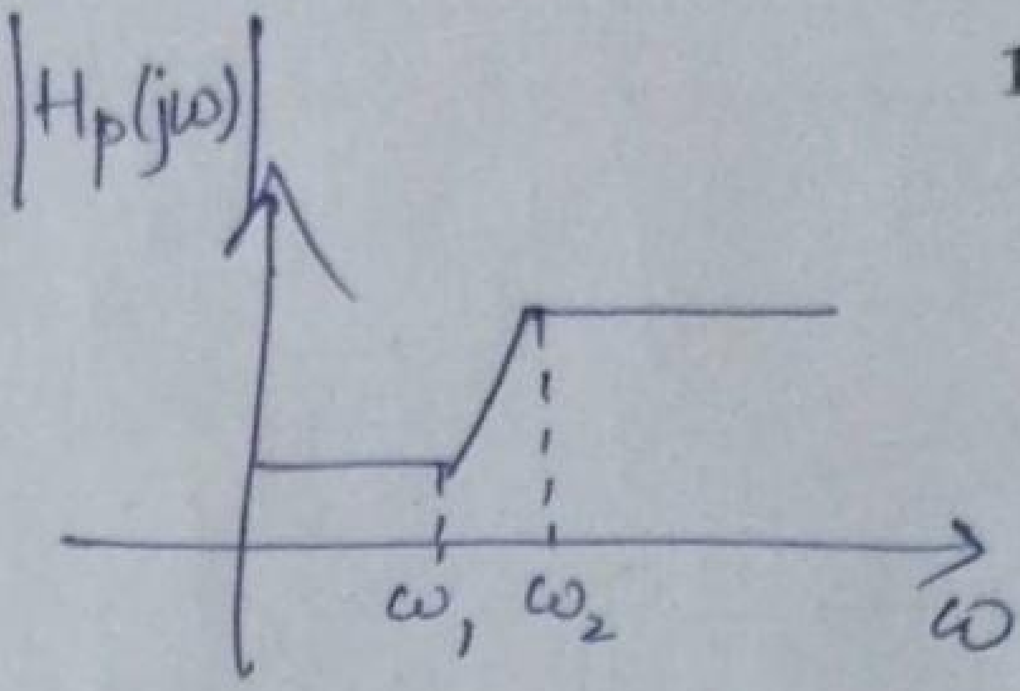
Now $410 = 440 - \frac{80 \times 10^3}{440} \times R_a \Rightarrow R_a = 0.165\,\Omega$

Now $V_t = 307.5 + 48.78 \times 0.165$

$= 315.55\ V$

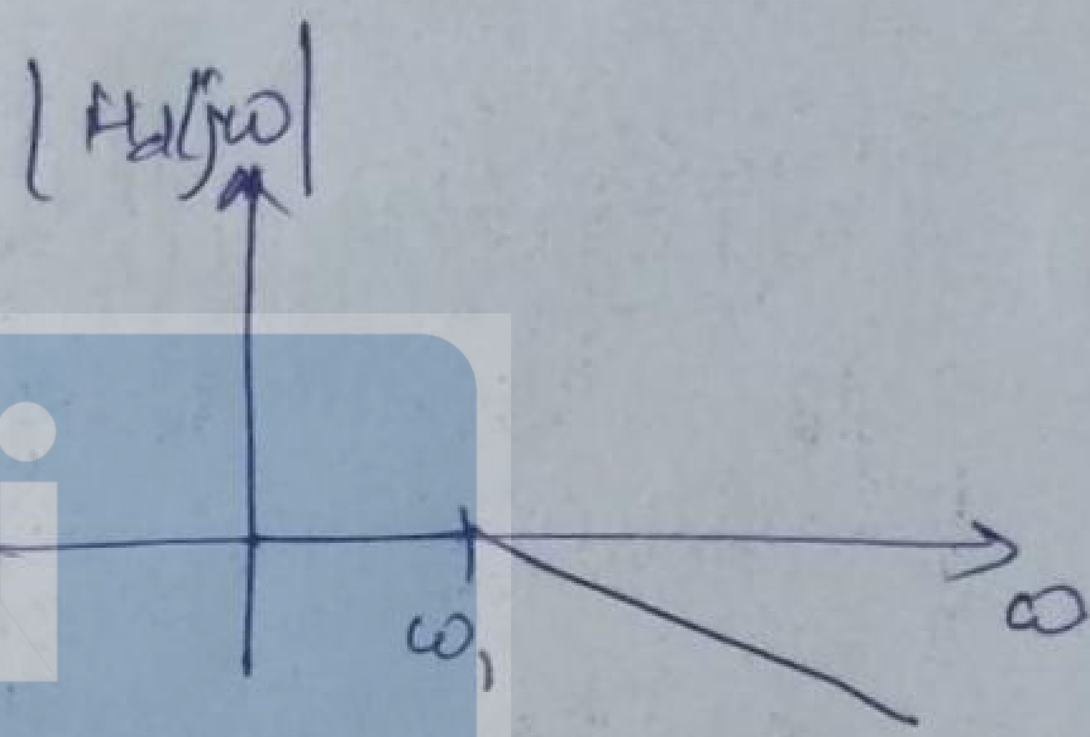
$$\Rightarrow \frac{3 \times 415\sqrt{2}}{\pi} \times \cos\alpha = 315.55 \Rightarrow \boxed{\alpha = 55.73^\circ}$$

Explain how pre-emphasis in transmitter and de-emphasis in receiver improves the noise performance of the FM system? 10



Preemphasis

This boosts the ~~sto~~ selected mid range frequencies of the transmitted wave.



De emphasis

This attenuates all freq above a threshold by the graph shown.

(*) Both are used in tandem such that they have the same slope

eqn 1 $\Rightarrow |H_p(j\omega)| = \dfrac{1}{|H_d(j\omega)|}$ over the signal freq range.

This makes the signal undergo pre-emphasis and boosts those signal freq before transmission. Now at the ~~s~~ receiver all the freq. above ω_1 are attenuated $\Rightarrow$ the signal spectrum ~~sto~~ returns to original due to eqn 1.

However the noise was not boosted by pre-emphasis but gets attenuated by deemphasis $\Rightarrow$ improves SNR overall & hence noise performance

A 500 KVA, 3-ϕ, 6.6 kV, star-connected synchronous motor has synchronous reactance of 20 Ω per phase.

(i) For a load angle of 10°, the motor takes rated current. Find the excitation emfs both at lagging and leading pfs.

(ii) Find the mechanical power developed and pf in part (i).

(iii) Find the minimum excitation voltage for delivering 200 kW at rated voltage without falling out of step.

20

(i) $\delta = 10^\circ$ & $I_{ph} = \dfrac{500 \times 10^3}{\sqrt{3} \times 6.6 \times 10^3} = 43.74\text{A}$.

Now for lagging pf :—

$I = 43.74\angle{-10^\circ}$ A.

$\Rightarrow E_m = \dfrac{6.6}{\sqrt{3}} \times 10^3 - 43.74\angle{-10^\circ} \times j20$

$\boxed{E_m = 3.759\angle{-13.25^\circ}\text{ kV}}$

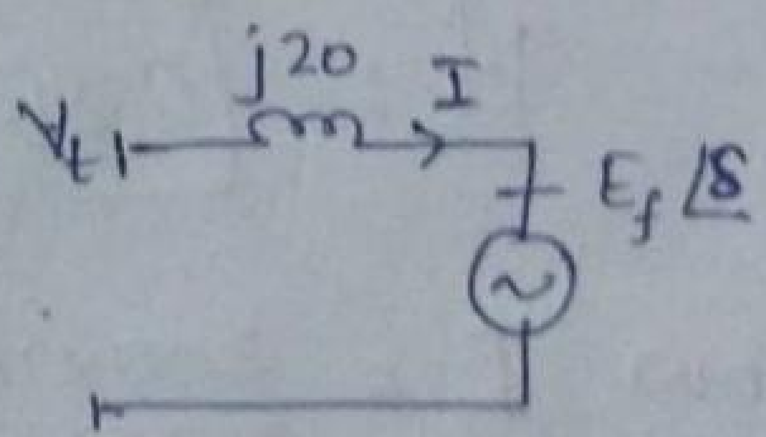
For leading pf :—

$I = 43.74\angle{10^\circ}$ A

$\Rightarrow E_m = \dfrac{6.6}{\sqrt{3}} \times 10^3 - 43.74\angle{10^\circ} \times j20$

$\boxed{E_m = 4.055\angle{-12.27^\circ}\text{ kV}}$

(i) $I = \dfrac{V_t - E_f\angle\delta}{j20}$



$|I| = \left| \dfrac{\frac{6.6 \times 10^3}{\sqrt{3}} - E_f\angle\delta}{j20} \right|$

Now $|I| = \dfrac{500 \times 10^3}{\sqrt{3} \times 6.6 \times 10^3} = 43.74$ A

Now $(3810.5 - E_f\cos\delta)^2 + (E_f\sin\delta)^2 = (43.74 \times 20)^2$

$1.452\times10^7 + E_f^2\times0.97 - 7505\,E_f + 0.03E_f^2 = 7.653\times10^5$

$\Rightarrow E_f^2 - 7505E_f + 1.3755\times10^7 = 0$

$\Rightarrow E_f = 3181.3V$ or $4323.7V$

so; $E_f = 3181.3\,V$ for leading pf
or 5510V line to line
& $E_f = 4323.7V$ for lagging pf
or 7489V line to line

(ii) $I = \dfrac{3810.5 - 3181.3\angle{-10}}{j20} = 43.72\angle{-129^\circ}$

Now power $= 3\times 3810.5\times43.72\times\cos57^\circ$
$= \boxed{314.525\,kW}$

& pf $= \boxed{0.629\ lag}$

For second case

$I = \dfrac{3810.5 - 4323.7}{j20} = 43.7\angle{30.5^\circ}$

$\Rightarrow$ power $= 3\times3810.5\times43.7\times\cos31$
$= \boxed{429.1\,kW}$
pf $= \boxed{0.857\ lead}$

(iii) Now $I = \dfrac{200\times10^3}{\sqrt3\times6.6\times10^3} = 17.5\,A$

Now excitation to be min $\Rightarrow \delta = 90^\circ$

$\Rightarrow \dfrac{3\times3810.5\times E_f}{20} = 20\times10^3\times10$

$\boxed{E_f = 350V}$

or $\underline{606.22}$ line to line

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Q.6 (b) (i) A 50 m long lossless transmission line with $Z_0 = 60\ \Omega$ operating at 3 MHz is terminated with a load $Z_L = 80 + j60\ \Omega$. If $u = 0.5c$ on the line, find :

1. The reflection coefficient Γ
2. The standing wave ratio S
3. The input impedance

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1) $\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{80+j60-60}{80+j60+60}$

$$\boxed{\Gamma = 0.415\angle 48.37^\circ}$$

2) $S = \frac{1+|\Gamma|}{1-|\Gamma|} = \boxed{2.42}$

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

Here $\frac{\omega}{\beta} = 0.5c \Rightarrow \beta = \frac{2\pi \times 3\times10^6}{0.5\times3\times10^8} = \frac{\pi}{25}$

Now $l = 50\,m \Rightarrow \beta l = 2\pi$

$\Rightarrow Z_{in} = Z_0 \times \frac{Z_L}{Z_0} = Z_L \Rightarrow \boxed{Z_{in} = 80+j60\ \Omega}$

6 (b) (ii) A distortionless line has $Z_0 = 50\ \Omega$, $\alpha = 15$ mNP/m, $V_p = 0.5\ c$, where c is the speed of light in a vacuum. Find R, L, G, C and λ at 110 MHz. (Where V_p is phase velocity)

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For distortionless line

$\alpha = \sqrt{RG}$; $\beta = \omega\sqrt{LC}$

& $\boxed{Z_0 = \sqrt{\frac{L}{C}}}$ —— (I)

Here $\beta = \frac{\omega}{0.5c} \Rightarrow \boxed{\frac{1}{\sqrt{LC}} = 0.5c}$ —— (II)

Now $\cancel{Z_0\beta = \frac{1}{C} = 50 \times}$

Now $50 \times 0.5 \times 3 \times 10^8 = \frac{1}{C} \Rightarrow \boxed{C = 133.33\text{pF/m}}$

$\Rightarrow L = (50)^2 \times 1.33 \times 10^{-10}$ H/m

$\boxed{L = 0.333\ \mu\text{H/m}}$

Now $\frac{R}{G} = \frac{L}{C} \Rightarrow \boxed{\frac{R}{G} = 2500}$ —— (III)

& $RG = \alpha^2 \Rightarrow \boxed{RG = 2.25 \times 10^{-4}}$ —— (IV)

$\Rightarrow R^2 = 0.5625$ or $\boxed{R = 0.75\ \Omega/m}$

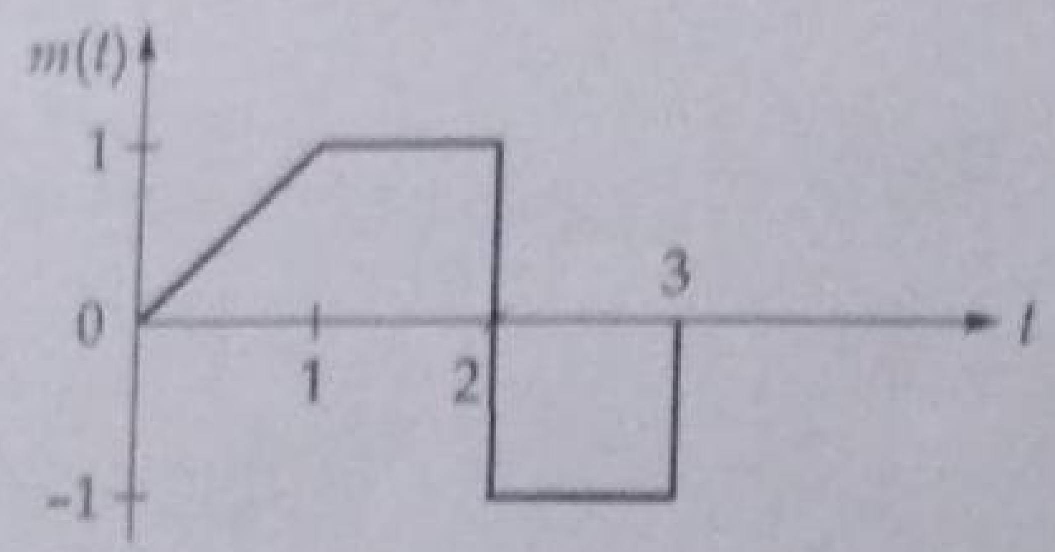
$\Rightarrow G = \frac{0.75}{2500} = 3 \times 10^{-4}$ ℧/m

or $\boxed{G = 0.3\text{ m℧/m}}$

Now $\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\omega} \times 0.5 \times 3 \times 10^8$

or $\lambda = \frac{\cancel{\pi} \times 3 \times 10^8}{2\cancel{\pi} \times 110 \times 10^6} \Rightarrow \boxed{1.364\text{m} = \lambda}$

Q.6 (c) The modulating signal $m(t)$ is shown below,



This signal is once used to frequency modulation of the carrier and once for phase modulation of the same carrier. Find the relation between K_p and K_f such that the maximum phase deviation in both the cases remains the same.

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Max phase deviation for phase modulation

$$= K_p |m(t)|_{max}$$

$$\boxed{\phi_{dev} = K_p \times 1} \text{ --- (I)}$$

For freq. modulation; max phase deviation:-

$$= 2\pi K_f \left[\int_0^t m(t)\right]_{max}$$

This takes max value at $t=2$ by graph

$$\Rightarrow \left[\int_0^t m(t)\,dt\right]_{max} = \frac{1}{2}\times 1\times 1 + 1\times 1$$

$$= \frac{3}{2}$$

$$\Rightarrow \phi_{dev} = 2\pi k_f \times \frac{3}{2} = 3\pi K_f \text{ --- (II)}$$

Now $\boxed{K_p = 3\pi K_f}$

for same max phase deviation.

Q.7 (a) For the buck converter of figure below,

V_S = 24 V, L = 200 μH, R = 20 Ω

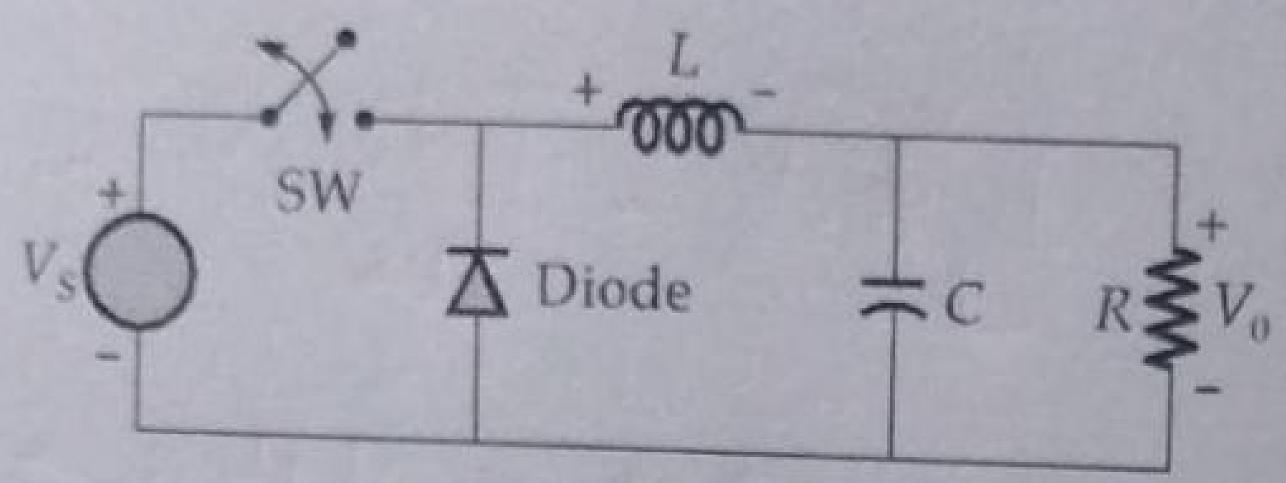
C = 1000 μF, switch frequency, f = 10 kHz,

D = 0.4

(i) Check whether the inductor current is continuous or discontinuous.

(ii) Determine the output voltage V_0.

Derive all required expression for inductor current and output voltage.



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For T_{on} :—

$$V_s - V_o = L \frac{\Delta I}{T_{on}}$$

$$\Rightarrow \Delta I = \frac{(V_s - V_o)\, T_{on}}{L} \quad \text{—— (I)}$$

For T_{off} :—

$$+V_o = L \frac{+\Delta I}{T_{off}}$$

$$\Rightarrow \Delta I = \frac{V_o T_{off}}{L} \quad \text{—— (II)}$$

But for no change in energy stored in L during cycle ⇒

$$\frac{(V_s - V_o)\, T_{on}}{L} = \frac{V_o T_{off}}{L}$$

$$\Rightarrow \boxed{V_o = D V_s}$$

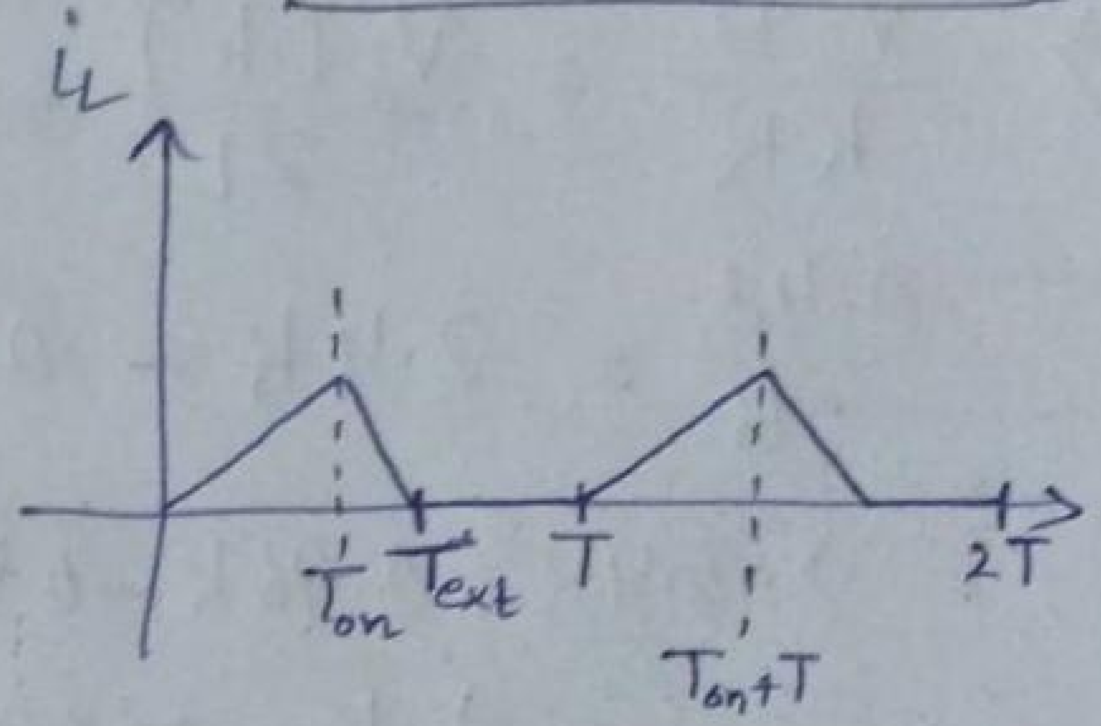
Now $$\Delta I = \frac{D V_s \times (1-D)\, T}{L}$$

$$= \frac{0.4 \times 24 \times 0.6 \times 10^{-4}}{200 \times 10^{-6}}$$

$$\Rightarrow \boxed{\Delta I = 2.88\,A}$$

Now $I_o = \frac{V_o}{R} = \frac{DV_s}{R} = \frac{0.4 \times 24}{20} = 0.48A$

since $I_o < \frac{\Delta I}{2} \Rightarrow$ **discontinuous current**



(ii) During T_{on}:-

$$\frac{(V_s - V_o)}{L} \times T_{on} = \Delta I$$

Now During T_{off}:-

$$\frac{V_o (T_{ext} - T_{on})}{L} = \Delta I$$

$$\Rightarrow \frac{V_s - V_o}{\cancel{L}} \times T_{on} = \frac{V_o}{\cancel{L}} (T_{ext} - T_{on})$$

$$V_s T_{on} = \cancel{V_o T_{on}} + V_o T_{ext} - \cancel{V_o T_{on}}$$

$$\Rightarrow \boxed{V_s T_{on} = V_o T_{ext}} \text{ —— (iii)}$$

also $I_{avg} = \frac{I_{max}}{2} \times \frac{T_{ext}}{T}$

where $I_{max} = \frac{V_s - V_o}{L} \times T_{on}$

& $I_{avg} = \frac{V_o}{R}$

$$\Rightarrow \frac{V_o}{R} = \frac{V_s - V_o}{L} \times \frac{T_{on}}{2} \times \frac{T_{ext}}{T} \quad \to D$$

$$\frac{V_o}{R} = \frac{V_s D}{2L} T_{ext} - \frac{V_o D T_{ext}}{2L}$$

Put $V_o = \frac{V_s T_{on}}{T_{ext}}$

$\Rightarrow$

$$\frac{V_o}{R} = \frac{V_s D}{2L} T_{ext} - \frac{V_o D T_{ext}}{2L} \quad \text{where } V_o = \frac{V_s T_{on}}{T_{ext}}$$

$$\Rightarrow \frac{V_s T_{on}}{R T_{ext}} = \frac{V_s D}{2L} T_{ext} - \frac{V_s D T_{on}}{2L}$$

$\Rightarrow$ Let $T_{ext} = kT$

$$\Rightarrow \frac{V_s D}{kR} = \frac{V_s D k T}{2L} - \frac{V_s D^2 T}{2L}$$

$$\frac{0.48}{k} = 2.4k - 0.96$$

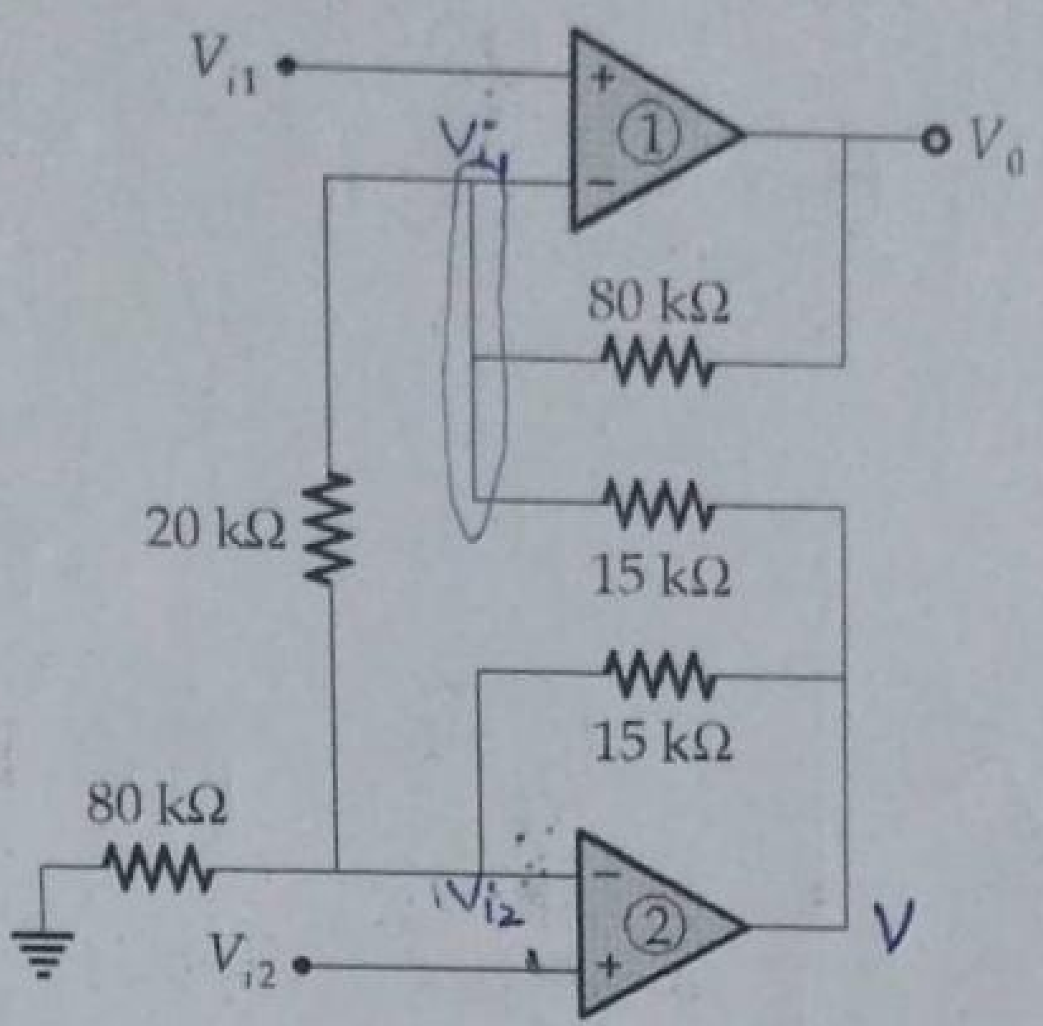
$$\Rightarrow 2.4k^2 - 0.96k - 0.48 = 0$$

$$\Rightarrow k = 0.69, \cancel{-0.29} \text{ reject.}$$

$$\Rightarrow T_{ext} = 0.69 \times 10^{-4}\,s$$

or $$V_o = \frac{24 \times 0.4 \times \cancel{10^{-4}}}{0.69 \times \cancel{10^{-4}}} = \boxed{13.913\,V}$$

(b) (i) Determine the value of overall differential voltage gain $\left(\frac{V_0}{V_{i1}-V_{i2}}\right)$ of the following op-amp circuit. (Both op-amps are ideal).



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$$\frac{V_{i_1}-V_o}{80k\Omega} + \frac{V_{i_1}-V}{15k\Omega} + \frac{V_{i_1}-V_{i_2}}{20k\Omega} = 0$$

Also $$\frac{V_{i_2}-V}{15k\Omega} + \frac{V_{i_2}-V_{i_1}}{20k\Omega} + \frac{V_{i_2}}{80k\Omega} = 0$$

But $$\frac{V}{15k\Omega} = \frac{V_{i_1}-V_o}{80k\Omega} + \frac{V_{i_1}}{15k\Omega} + \frac{V_{i_1}-V_{i_2}}{20k\Omega} \quad \text{—— (1)}$$

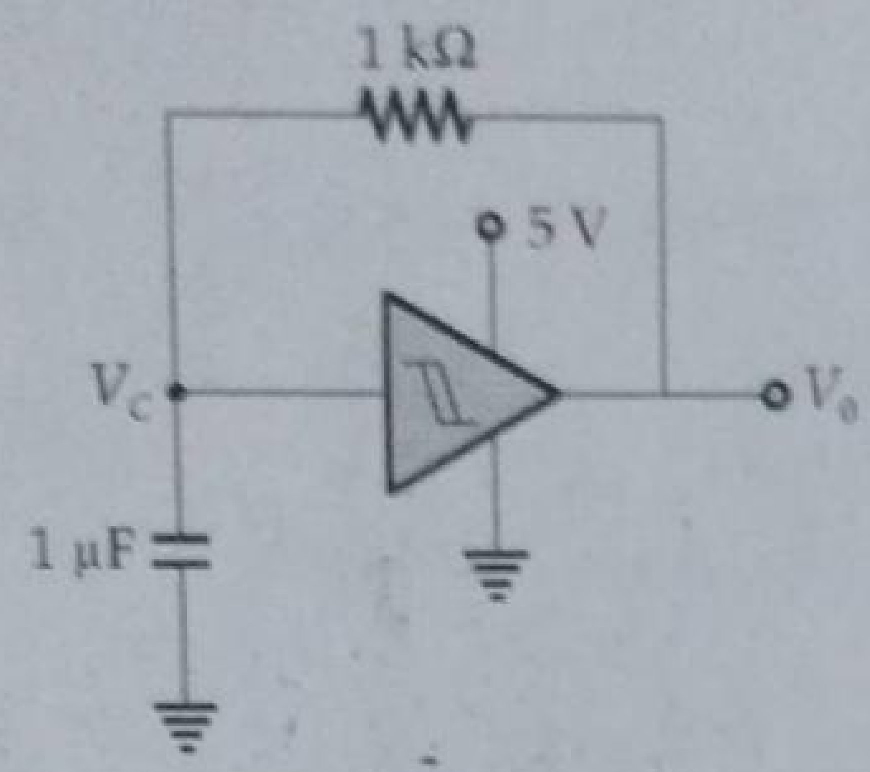
$$\Rightarrow \frac{V_{i_2}}{15k\Omega} + \cancel{\frac{V_{i_2}-V_{i_1}}{20k\Omega}} + \frac{V_{i_2}}{80k\Omega} = \frac{V_{i_1}-V_o}{80k\Omega} + \frac{V_{i_1}}{15k\Omega} + \cancel{\frac{V_{i_1}-V_{i_2}}{20k\Omega}}$$

$$\frac{V_o}{80k\Omega} = \frac{V_{i_1}-V_{i_2}}{80k\Omega} + \frac{V_{i_1}-V_{i_2}}{15k\Omega} + \cancel{\frac{2(V_{i_1}-V_{i_2})}{20k\Omega}} \to 0$$

$$\Rightarrow \frac{V_o}{V_{i_1}-V_{i_2}} = \frac{80k\Omega}{80k\Omega} + \frac{80k\Omega}{15k\Omega} + \cancel{\frac{2\times 80k\Omega}{20k\Omega}}$$

$$\boxed{\frac{V_o}{V_{i_1}-V_{i_2}} = \cancel{\frac{45}{3}}\ 19/3}$$

(ii) A hysteresis type TTL inverter is used to realize an oscillator in the circuit shown in the figure. It has input thresholds of 1.8 V and 3.4 V. The input capacitance and output resistance of the TTL inverter are negligible. Determine the frequency of the oscillator.



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Charging eqn :—

$$V(t) = V(\infty) + [V(0) - V(\infty)]e^{-t/RC}$$

$$3.4 = 5 + [1.8 - 5]e^{-t/RC}$$

$$2 = e^{t/RC} \Rightarrow t_1 = RC \ln 2$$
$$= 0.693\text{ms}.$$

For discharging :—

$$1.8 = 0 + [3.4 - 0]e^{-t/RC}$$

$$\Rightarrow e^{t/RC} = \frac{34}{18}$$

$$\Rightarrow t_2 = RC\ln\left(\frac{17}{9}\right) = 0.636\text{ms}.$$

$\Rightarrow$ Total time period = 1.329 ms.

$$\Rightarrow \boxed{\text{freq} = 752.37\text{Hz}}$$

In a certain region with $\sigma = 0$, $\mu = \mu_0$ and $\epsilon = 6.25\,\epsilon_0$. The magnetic field of an EM wave is $\vec{H} = 0.6\cos\beta x \cos 10^8 t\,\hat{a}_z$ A/m. Find the phase constant β and the corresponding $\vec{E}$ (electric field) using Maxwell's equations. 10

For the given region:–

$$\eta = \sqrt{\frac{\mu}{\epsilon}} = \frac{120\pi}{\sqrt{6.25}} = 48\pi\ \Omega$$

$$\Rightarrow |E| = 0.6 \times 48\pi = 90.478\ \text{V/m}.$$

Now we know that

$$\nabla \times \vec{H} = \epsilon \frac{\partial \vec{E}}{\partial t}$$

Now
$$\nabla \times \vec{H} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 0 & 0 & H_z \end{vmatrix} = -\hat{a}_y\left[\frac{\partial}{\partial x} H_z\right]$$

$$= +0.6\beta \sin\beta x \cos(10^8 t)\,\hat{a}_y.$$

Now
$$\frac{\omega}{\beta} = \frac{1}{\sqrt{\mu\epsilon}} \Rightarrow \frac{10^8}{\beta} = \frac{3\times 10^8}{\sqrt{6.25}}$$

$$\Rightarrow \boxed{\beta = 9\times 10^{-7}\ \text{rad/m}}$$

Now
$$\epsilon \frac{\partial \vec{E}}{\partial t} = 5.4\times 10^{-7} \sin\beta x \cos(10^8 t)\,\hat{a}_y$$

$$\frac{\partial \vec{E}}{\partial t} = 9758.3 \sin\beta x \cos 10^8 t\,\hat{a}_y$$

$$\Rightarrow \vec{E} = \frac{9758.3}{10^8} \sin\beta x \sin 10^8 t\,\hat{a}_y$$

or
$$\boxed{\vec{E} = 90.355 \sin\beta x \sin 10^8 t\,\hat{a}_y\ \text{V/m}}$$

where $\beta = 9\times 10^{-7}$ rad/m