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ESE-2020
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER-I

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE_MAINS_2020_PAPER – I

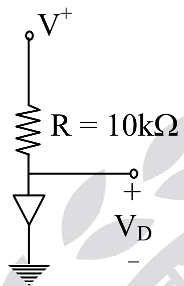
Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	Basic Electrical Engineering	40
02	Basic Electronics Engineering	60
03	Materials Science	84
04	Electronic Measurements & Instrumentation	60
05	Network Theory	128
06	Analog Electronics	56
07	Digital Electronics	52

SECTION - A

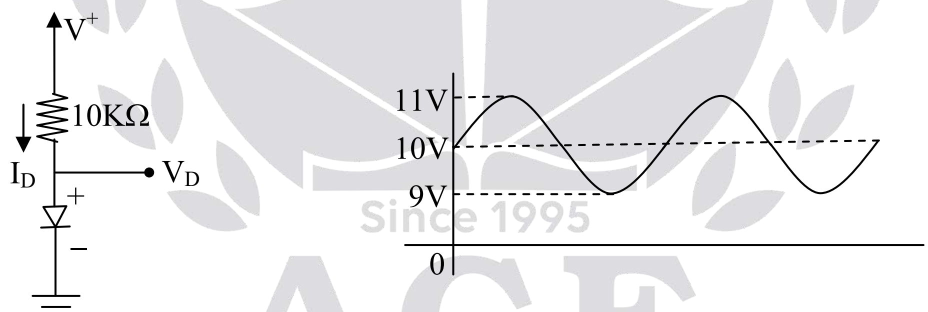
01.(a)(i) Consider the circuit shown below. The power supply V^+ has a dc value of 10V on which is superimposed a 60 Hz sinusoid of 1V peak amplitude, i.e. has a power supply ripple. Calculate both the dc voltage of the diode and the amplitude of the sine-wave signal appearing across it, assuming a 0.7 V drop across it at 1mA current.



(6 M)

Sol:

(i) Given power supply $V^+ = 10 + V_m \sin\omega t = 10 + 1\sin 2\pi(60)$



Diode obeys a relation $I_D = I_S e^{\frac{V_D}{V_t}}$ $[\eta = 1]$

$$V_D = V_t \ell n\left[\frac{I_D}{I_S}\right]$$

(or)

$$V_{D1} - V_{D2} = V_t \ell n\left[\frac{I_{D1}}{I_{D2}}\right]$$

Given $V_D = 0.7V$ when $I_D = 1mA$

$$V_{D1} - 0.7 = 26mV\ell n\left[\frac{I_{D1}}{1m}\right]$$

Let as consider $V^+ = 10V, 11V, 9V$

Case1 $V^+ = 10V \rightarrow I_{D1} \approx \frac{10-0.7}{10K} = 0.93\ mA$

$$V_{D1} = 0.7 + 26mV\ell n\left[\frac{0.93m}{1m}\right] = 0.698V$$

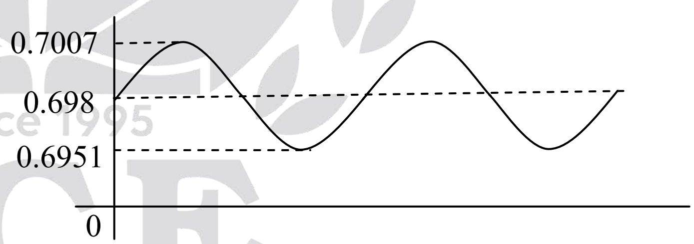
Case2 $V^+ = 11V \rightarrow I_{D1} \approx \frac{11-0.7}{10K} = 1.03m$

$$V_{D1} = 0.7 + 26mV\ell n\left[\frac{1.03m}{1m}\right] = 0.70076V$$

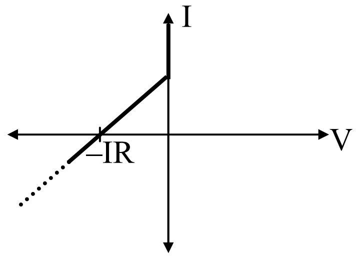
Case3: $V^+ = 9V \rightarrow I_{D_1} \approx \frac{9-0.7}{10K} = 0.83m$

$$V_{D1} = 0.7 + 26mV\ell n\left[\frac{0.83m}{1m}\right] = 0.6951V$$

V^+	V_D
10V	0.698V
11V	0.70076
9V	0.6951

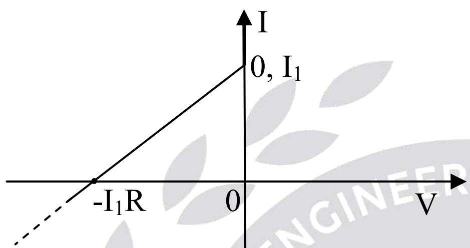


01.(a)(ii) For the V-I characteristics as shown below, draw the circuit model using an ideal diode.



(6 M)

Sol:



Equation of line $(0,I_1)$ $(-I_1R,0)$

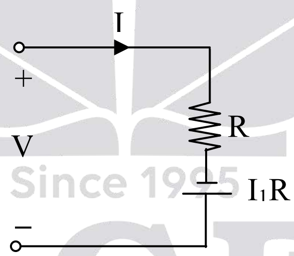
$$y-y_1=\frac{y_2-y_1}{x_2-x_1}(x-x_1)$$

$$I-0=\frac{I_1}{0-(-I_1R)}(V+I_1R)$$

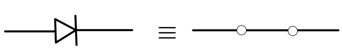
$$I=\frac{1}{R}(V+I_1R)$$

(or)

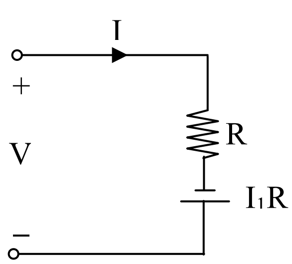
$$V=IR-I_1R$$



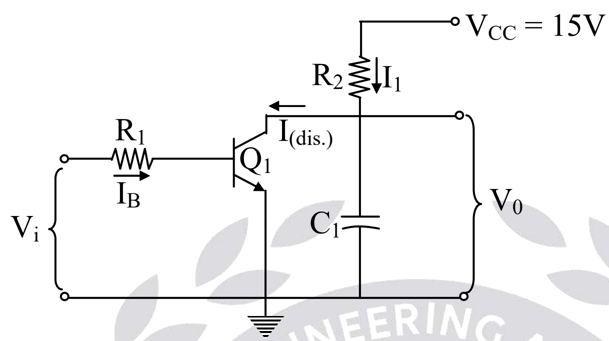
(a) For $I>I_1\rightarrow V=0$



(b) For $V<0\rightarrow V=IR-I_1R$

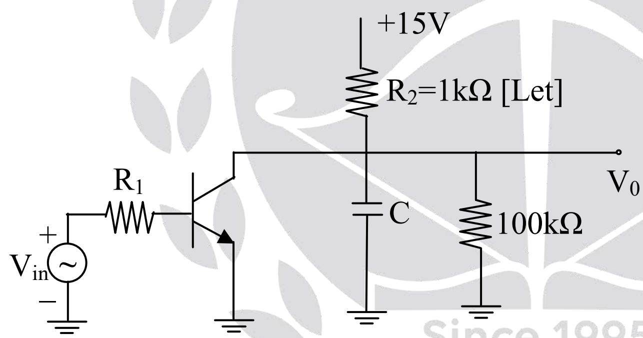


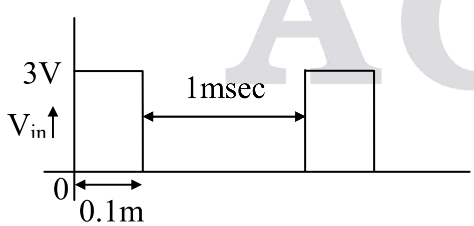
01. (b) The circuit shown below is to be used as ramp generator to produce a 1V ramp output when the input is 3V, 0.1ms pulse with a 1ms interval between pulses. The supply voltage is 15V and a load resistance of 100kΩ is connected at the output terminals. Assume Q_1 has $h_{FE(min)} = 50$. Determine values of R_1, R_2 and C_1.



(12 M)

Sol:



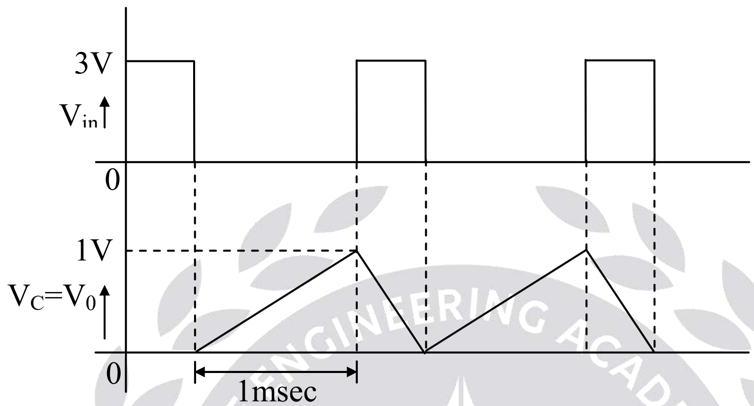


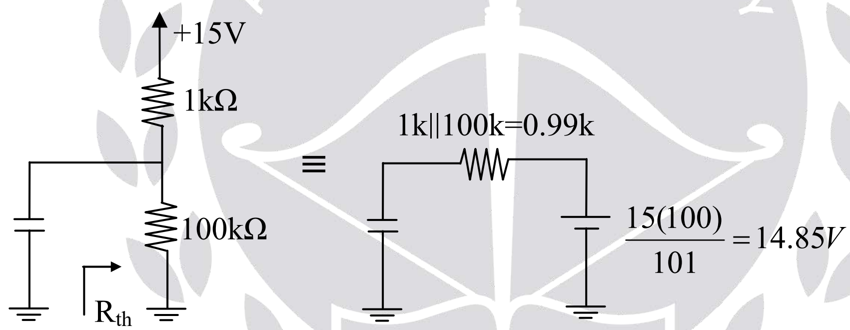
Operation (1) If $V_{in} = 3V$, the transistor is ON.

Capacitor discharges through the transistor

$V_0 = V_C = V_{CE(sat)} \approx 0V$

2. If $V_{in} = 0V$, the transistor is off. capacitor charges. The final value of capacitor is almost 15V. The wave form looks almost linear when it charges to 1V in 1msec duration (through the path is exponential)





$$V_C(t) = 14.85\left[1 - e^{-t/\tau}\right]$$

when $t = 1m\sec \rightarrow V_c(t) = 1V$

$$\therefore 1 = 14.85\left[1 - e^{-\frac{1m}{\tau}}\right] \rightarrow \tau = 14.34\ m\sec$$

$$\therefore \tau = 14.34 m\sec = R_{th}C$$

$14.34m = 0.99\ [C]$

for sat condition

$$|I_B| > \left|\frac{I_C}{\beta}\right|$$

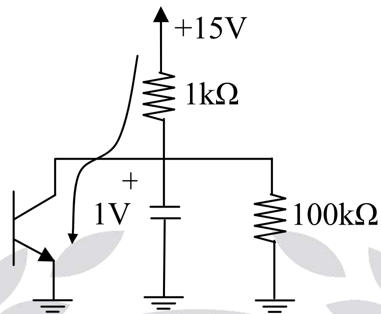
$$I_C \max = \frac{(15-1)/1k}{200}$$

$$I_B = \frac{3-0.7}{R_B}$$

$$I_B > I_{cmax}/\beta$$

$$\frac{3-0.7}{R_B} > \frac{14m}{200}$$

$$R_B < 32.857k\Omega$$



01. (c) A 40 μF capacitance is charged to store 0.2J of energy. An uncharged, 60 μF capacitance is then connected in parallel with the first one through perfectly conducting leads. What is the final energy of the system? (12 M)

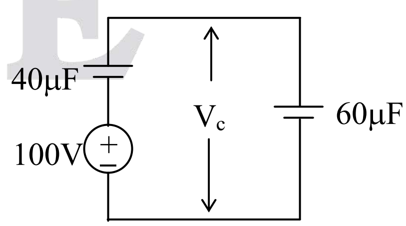
Sol: A 40μF charged to 0.2 J

$$Wc_1 = \frac{1}{2}c_1v_1^2 \Rightarrow 0.2 = \frac{1}{2}40\mu v_1^2$$

$$0.4 = 40\times10^{-6}\left(v_1^2\right)$$

$$10^4 = v_1^2 \Rightarrow v_1 = 100 \text{ volts}$$

It is connected in parallel with 60μF uncharged capacitor



Capacitor combination voltage v_C

$$V_C = \frac{V_1C_1 + V_2C_2}{C_1+C_2} = \frac{100\times40+60\times0}{(40+60)} = 40V$$

$$\text{Total energy} = W_{C_T} = \frac{1}{2}C_TV_C^2$$

$$W_{C_T} = \frac{1}{2}(40+60)\times10^{-6}\times(40)^2 = 0.08\text{J}$$

01. (d) Identify magnitude of the Burgers vector for a material having cubic crystal structure, if the density, atomic weight and lattice constant are 7870 kg/m^3, 55.85 g/mol and 2.86 $\overset{o}{A}$, respectively. (12 M)

Sol: Given data:

Cubic crystal structure

Density = 7870 kg/m^3

Atomic weight = A = 55.85 g/mol

Lattice constant = 2.86 $\overset{o}{A}$

Theoretical density = $\dfrac{n \times AW}{AN \times V_{VC}}$

$$7870 = \frac{n \times 55.85}{6.023 \times 10^{23} \times (2.86 \times 10^{-10})^3}$$

n ≃ 2

From the above, the crystal structure of metal in body centered cubic (BCC) structure

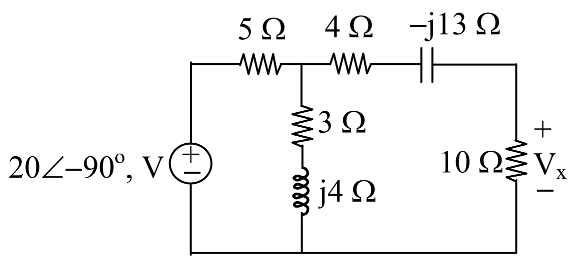
This slip direction in BCC structure is [111]

$$\text{Burgers vector } = \frac{a}{2}[111]$$

$$= \frac{a}{2}[1^2 + 1^2 + 1^2]^{1/2}$$

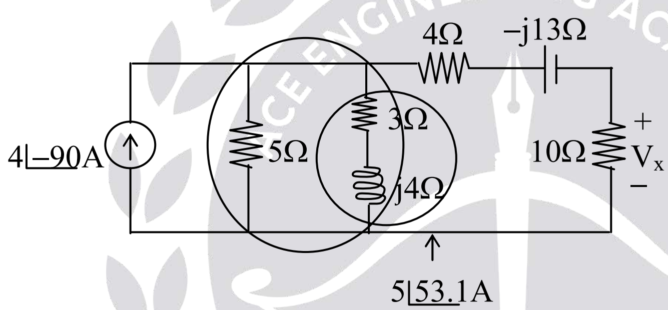
$$= \frac{a}{2} \times \sqrt{3} = \frac{2.86 \times \sqrt{3}}{2} = 3.502\ \overset{o}{A}$$

01. (e) Calculate V_x in the circuit shown in the figure using the method of source transformation.



(12 M)

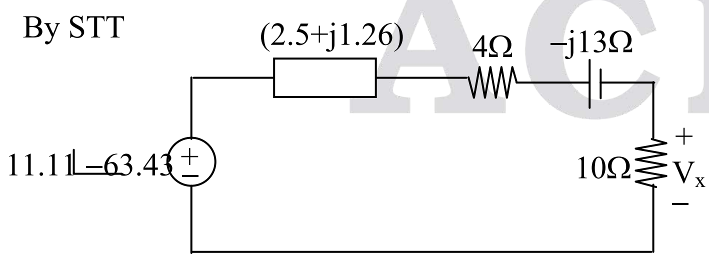
Sol: By STT (source transformation technique)



$$\frac{5(3+j4)}{(8+j4)}=\frac{5(5\angle 53.14)}{4\sqrt{5}\angle 26.56}=2.79\angle 26.5$$

$$= 2.79\angle 26.57=(2.5+j1.25)$$

By STT

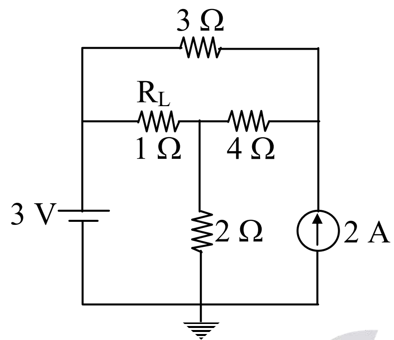


By VDR

$$V_x=\frac{(11.11\angle -63.43)(10)}{(2.5+j1.25)+(4-j13)+10}$$

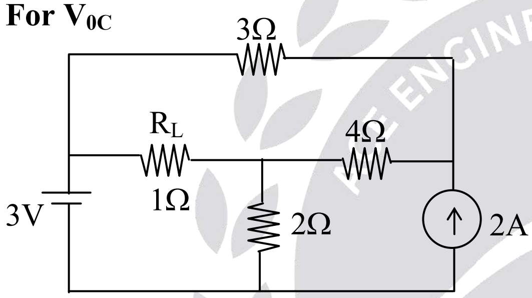
$$V_x=5.484\angle -27.97 \text{ volts}$$

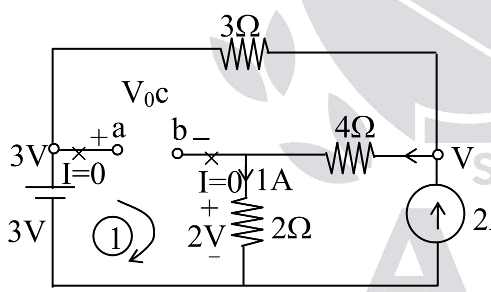
02. (a) Find the current through the load resistance 'R_L' using Thevenin's theorem and hence calculate the voltage across the current source for the circuit shown in figure. (20 M)



Sol: Current in R_L by using Thevenin equation

For V_{OC}





By KCL at V

$$\frac{V-3}{3}+\frac{V}{2+4}=2 \Rightarrow 2V-6+V=12$$

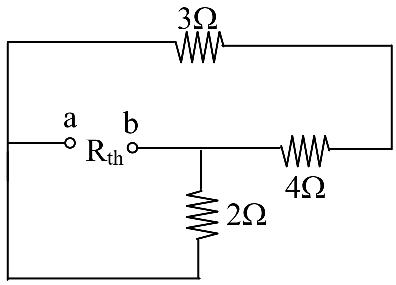
$3V = 18 \Rightarrow V = 6$ volts

By KVL for V_{OC}

$$-3+V_{OC}+2=0$$

$V_{oc}=V_{th}=1V$

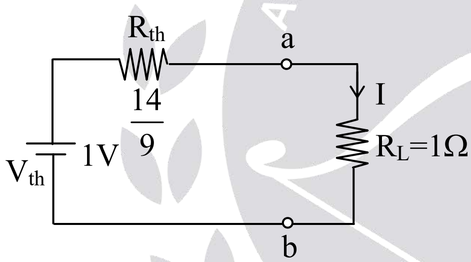
For R_{th} ($V \rightarrow S.C, I \rightarrow 0 - C$)



$R_{th} = (3 + 4) // 2$

$R_{th} = \frac{14}{9}\Omega$

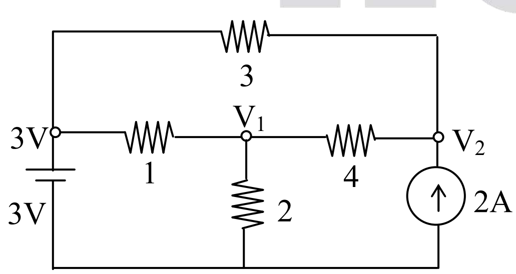
Thevenin's equivalent circuit across R_L



$$I = \frac{V_{th}}{R_{th} + R_L} = \frac{1}{\frac{14}{9} + 1} = \frac{9}{23} = 0.39 \text{ A}$$

$I = 0.4A$

The voltage across current source



By KCL at V_1

$$\frac{V_1 - 3}{1} + \frac{V_1}{2} + \frac{V_1 - V_2}{4} = 0$$

$4V_1 - 12 + 2V_1 + V_1 - V_2 = 0$

$7V_1 - V_2 = 12$ ---------- (1)

By KCL at V_2

$$\frac{V_2 - V_1}{4} + \frac{V_2 - 3}{3} = 2$$

$3V_2 - 3V_1 + 4V_2 - 12 = 24$

$7V_2 - 3V_1 = 36$

$$3V_1 = 7V_2 - 36 \Rightarrow V_1 = \left(\frac{7V_2 - 36}{3}\right)$$

From (1)

$7V_1 - V_2 = 12$

$$7\left[\frac{7V_2 - 36}{3}\right] - V_2 = 12$$

$$\frac{49}{3}V_2 - 7\times 12 - V_2 = 12$$

$$\frac{46}{3}V_2 = 8\times 12 \Rightarrow V_2 = \frac{8\times 12\times 3}{46}$$

$V_2 = 6.26$ Volts

02. (b) An abrupt Si p-n junction ($A = 10^{-4}$ cm^2) has the following properties at 300 K:

p-side	**n-side**
$N_a = 10^{17}$ cm^{-3}	$N_d = 10^{15}$ cm^{-3}
$\tau_n = 0.1$ μs	$\tau_n = 10$ μs
$\mu_p = 200$ cm^2/v-s	$\mu_n = 300$ cm^2/v-s
$\mu_n = 700$ cm^2/v-s	$\mu_p = 450$ cm^2/v-s

Taken $n_i = 1.5\times 10^{10}$ cm^{-3}

The junction is forward biased by 0.5V. Find

(i) forward current

(ii) current at a reverse bias of –0.5V. (20 M)

Sol: $I = qA\left[\frac{D_P}{L_P}P_n + \frac{D_n}{L_n}n_P\right][e^{\frac{qv}{KT}} - 1]$

$$I = I_o\left[e^{\frac{qv}{KT}} - 1\right]$$

$$P_n = \frac{n_i^2}{n_n} = \frac{(1.5\times10^{10})^2}{10^{15}} = 2.25\times10^5 cm^{-3}$$

$$n_P = \frac{n_i^2}{P_p} = \frac{(1.5\times10^{10})^2}{10^{17}} = 2.25\times10^3 cm^{-3}$$

For minority carriers

$$D_P = \frac{KT}{q}\mu_p = 0.0259\times450 = 11.66\frac{cm^2}{s} \text{ on the n side}$$

$$D_n = \frac{KT}{q}\mu_n = 0.0259\times700 = 18.13\frac{cm^2}{s} \text{ on the P side}$$

$$L_P = \sqrt{D_P\tau_P} = \sqrt{11.66\times10\times10^{-4}} = 1.08\times10^{-2} cm$$

$$L_n = \sqrt{D_n\tau_n} = \sqrt{18.13\times0.1\times10^{-6}} = 1.35\times10^{-3} cm$$

$$I_o = qA\left[\frac{D_P}{L_P}P_n + \frac{D_n}{L_n}n_P\right]$$

$$= 1.6\times10^{-19}\times0.0001\left[\frac{11.66}{0.0108}\times2.25\times10^5 + \frac{18.13}{0.00135}\times2.25\times10^3\right]$$

$I_o = 4.37 \times 10^{-15}$A

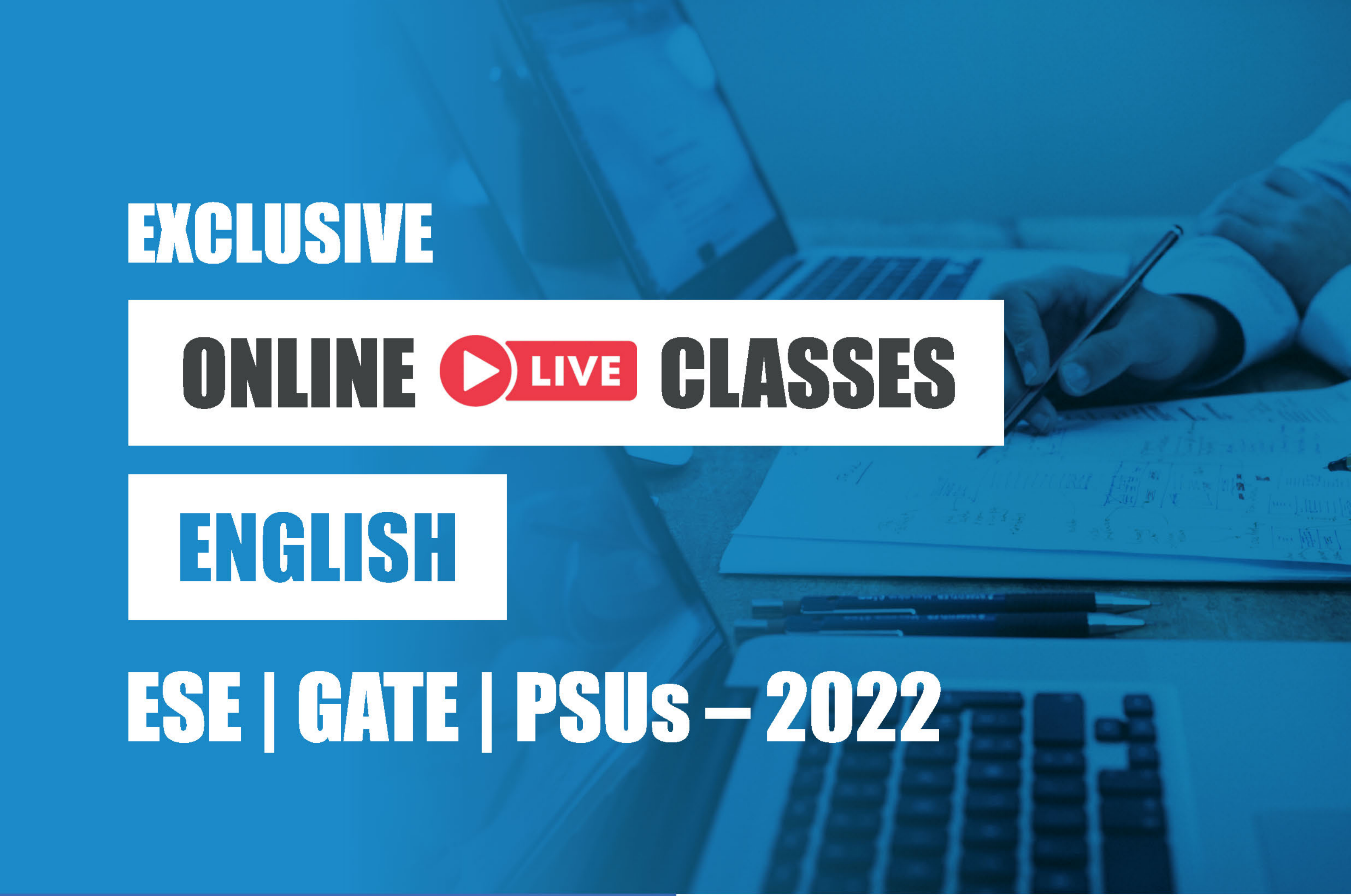
i) Forward current at a forward bias of O.S.V

$$I = I_o\left[e^{\frac{0.5}{0.0259}} - 1\right] \simeq 1.058 \times 10–6 \text{ A}$$

ii) Reverse current at a reverse bias of -O.S.V

$$I = I_o\left[e^{\frac{-0.5}{0.0259}} - 1\right] \simeq -Io$$

$= -4.37 \times 10^{-15}$A



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02. (c) An InGaAs pin photodiode has the following parameters at a wavelength of 1300 nm:

I_D = 4nA; η = 0.90; R_L = 1kΩ; P_{in} = 300 nW

Where P_{in} is incident optical power. The receiver bandwidth is 20 MHz.

Assume surface leakage current is negligible.

Determine

(i) mean-square shot noise current,

(ii) mean-square dark current and

(iii) mean-square thermal noise current.

Which noise is more severe and why? (20 M)

Sol: Primary photocurrent (I_p)

$$I_p = \frac{\eta q}{hf} P_{in} = \frac{\eta q \lambda}{hc} P_{in}$$

$$I_P = \frac{(0.9)\times(1.6\times10^{-19}\,C)\times(1.3\times10^{-6}\,m)}{(6.625\times10^{-34}\,J-s)\times(3\times10^{8}\,m/s)}\times 3\times10^{-7}\,W$$

I_P = 0.282 μA

i) Mean square shot noise current (i^2_{shot}):

$i^2_{shot} = 2qI_PB_e$

$= 2 \times (1.6 \times 10^{-19}\text{ C}) (0.282 \times 10^{-6}\text{A}) (20 \times 10^{6}\text{ Hz})$

$= 1.8 \times 10^{-18}\text{ A}^2$

or $[i^2_{shot}]^{1/2}$ = 1.34nA

ii) Mean-square dark current (i^2_{DB}):

$i^2_{DB} = 2qI_DB_e$

$= 2 \times (1.6 \times 10^{-19}\text{ C}) (4 \times 10^{-9}\text{A}) (20 \times 10^{6}\text{ Hz})$

$= 2.56 \times 10^{-20}\text{ A}^2$

or $[i^2_{DB}]^{1/2}$ = 0.16nA

iii) Mean square thermal noise current (i^2_T):

$$i_T^2 = \frac{4K_BT}{R_L}B_e$$

$$= \frac{4(1.38\times10^{-23} J/K)(293K)}{1K\Omega} B_e = 323\times10^{1-8} A^2$$

or $[i^2_T]^{1/2} = 18$ nA

Thus for this receiver the rms thermal noise current is about 14 times greater than the rms shot noise current and about 100 times greater than the rms dark current

03. (a) The entry point and exit point of X-rays on a power pattern taken from a cubic crystal material could not be distinguished. Assuming one of the points to be the exit point, the following S values were obtained:

S values: 311.95 mm, 319.10 mm and 335.05 mm.

The camera radius is 57.3 mm and Molybdenum K_α radiation of wavelength 0.7 $\overset{o}{A}$ was used.

Determine the structure and the lattice parameter of the material. (20 M)

Sol: Given Data:

X-Ray distraction method

S values

$S_1 = 311.95$ mm

$S_2 = 319.10$ mm

$S_3 = 335.05$ mm

The camera radius = 57.3 mm

Wave length $\lambda = 0.7\ \overset{o}{A}$

From the Brag's law,

The Brag's angle of each characteristic line on the film follows the ratio, $\frac{S_i}{S_n} = \frac{\theta_i}{\theta_n}$

S_i = distance from the exit to the line of interest = 57.3 mm

S_n = distance from the exit to the entrance ($\theta_n = 90^o$)

$$S_n = \frac{2\pi R}{4} = \frac{2\pi\times57.3}{4} = 89.961$$

$$\theta_1 = \frac{89.961}{311.95}\times90 = 25.95$$

$$\theta_2 = \frac{89.961}{319.10} \times 90 = 25.37$$

$$\theta_3 = \frac{89.961}{335.05} \times 90 = 24.165$$

$$Q^2 = h^2 + k^2 + l^2$$

$$\lambda = \frac{2a \sin\theta}{\sqrt{h^2 + k^2 + \ell^2}}$$

$$\lambda^2 = \frac{4a^2 \sin^2\theta}{Q^2}$$

Example of Trial calculations on assumption of FCC

Q_i	$\sin\theta_i$	$\frac{4\sin^2\theta}{\lambda^2}(1)$	Q^2	$h^2 + k^2 + l^2$	hk$l$	a
25.95	0.437	1.5589	1.142	$\simeq 3(1.142)$	111	1.48
25.37	0.428	1.495	1.09	3(1.09)	111	1.48
4.16	0.409	1.365	1	3(1.00)	111	1.48

$$a = \frac{\lambda\sqrt{h^2 + k^2 + \ell^2}}{2\sin\theta} = 1.48\,\mathring{A}$$

Lattice parameter is 1.48 Å

Structure is FCC

03. (b) (i) Obtain the exact equivalent circuit (per phase) of three-phase induction motor.

(ii) A 6-pole, 3-phase, 50 Hz induction motor takes 50 kW power at 940 rpm. The stator copper loss is 1.4kW, stator core loss is 1.6 kW, and rotor mechanical losses are 1kW. Find the motor efficiency. (20 M)

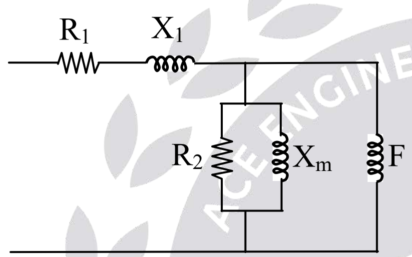
Sol: (i) Equivalent circuit Analysis:

Equivalent circuit

A 3-phase wound rotor induction is very similar in construction to a 3-phase transformer. Thus, the motor has 3 identical primary windings and 3 identical secondary windings-one set for each phase. On account of the perfect symmetry, we can consider a single primary winding and single secondary winding in analysing the behaviour of the motor.

When the motor is at standstill, it acts exactly like a conventional transformer, and so its equivalent circuit is the same as that of a transformer.

Equivalent Circuit of Stator:



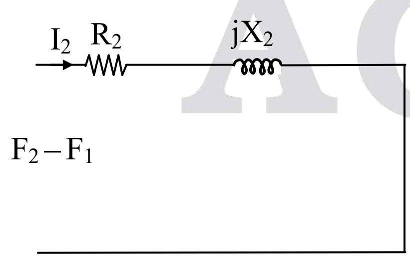
R_1 : Resistance of the stator winding/ph

X_1 : Leakage reactance of the stator/ph

R_n : Iron loss component

X_m: Magnetizing component E_C induced emf stator winding N_w: Effective turns stator

Equivalent circuit of rotor



R_2: Rotor resistance/ph

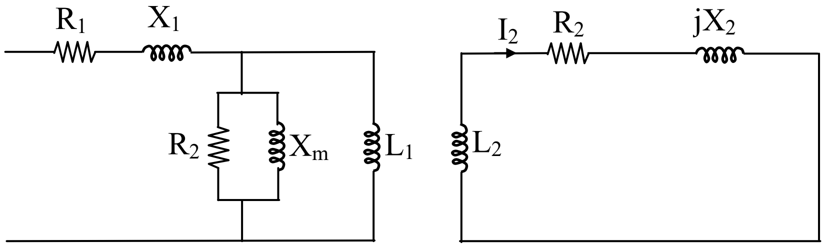
X_2: Leakage reactance of the rotor/ph

F_2: EMF induced in the rotor/ph

I_2: Rotor current/ph

F_2: $8F_{20}$; $X_2 = 5X_{20}$

Exact equivalent circuit of the induction motor

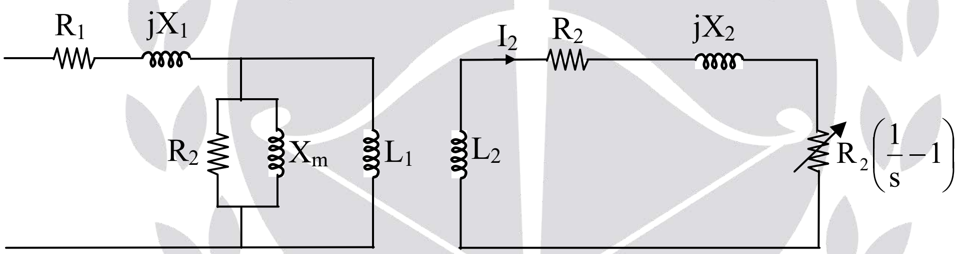


The secondary side loop is excited by a voltage SF_2. Which is also at a frequency sf1. This is the reason why the rotor

$$I_2 = \frac{SF_{22}}{\sqrt{R_2^2 + (SX_{22})^2}}$$

This expression can be modified as follows (diving numerator and denominator by S)

$$\frac{V_1 - V_2}{V_1} \times 100 = 22.86\%$$



Now the resistance $\frac{R_2}{s}$ can be written as R_2, $R_2\left(\frac{1}{s}-1\right)$. It consists of two points

(i) The first part R_2 is the rotor resistance itself and represents the rotor copper loss

(ii) The second part is $R_2\left(\frac{1}{s}-1\right)$.

$R_2\left(\frac{1}{s}-1\right)$ is known as the load resistance R_1 and is the electrical equivalent at the mechanical load placed on the motor shaft. In other words. The mechanical load on an induction motor can be represented by a non-inductive resistance of the value.

$$R_2\left(\frac{1}{s}-1\right)$$

Equivalent circuit of the induction motor referred to stator side

As in the case of transformer, in this case also, the secondary values may be transferred to the primary values may be transferred to the primary and vice versa. As before, it should be remembered that when shifting impedance on resistance from secondary to primary, it should be divided by K2 whereas current should be multiplied by K. The equivalent circuit at an induction motor all values have been referred to stator side is shown in the following figure.

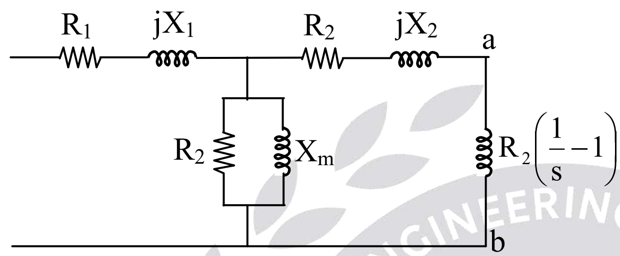


Fig: Equivalent circuit of induction motor referred to stator side with load impedance

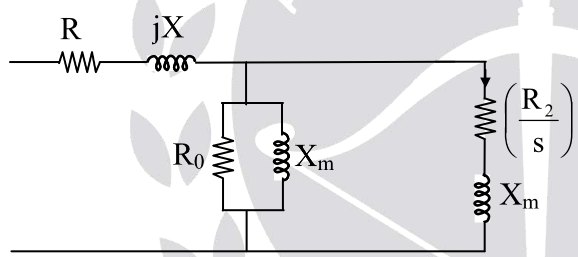


Fig: Equivalent circuit of induction motor referred to stator side with load impedance

This is then the per-phase equivalent circuit of the induction machine, also called as exact equivalent circuit, note that the voltage coming across the magnetizing branch is the applied stator voltage, reduced by the stator impedance drop. Generally the stator impedance drop is any a small fraction of the applied voltage.

From the equivalent circuit, one can see that the dissipation in R. represents the stator loss, and dissipation in R_o, represents the iron loss. Therefore the power absorption indicated by the inner part at the circuit must represent all other means at power consumption the actual mechanical output, friction and windage loss components and the rotor copper loss components. Since the dissipation in R'_2 is rotor copper loss. The power dissipation in $R'_2\,(1 - s)/s$ is the sum total of the remaining in standard terminology, dissipation in $I_2^2\,\frac{R'_2}{s}$ is called the air gap power

(ii) Given data:

P = 6; f = 50 Hz, I/P = 50 kW

N_r = 940 rpm

Stator Copper loss = 1.4 kW

Stator Iron loss = 1.6 kW

rotor mechanical loss = 1 kW

η = ?

$$N_s = \frac{120 \times f}{P} = \frac{120 \times 50}{6} = 1000\,\text{rpm}$$

$$S = \frac{N_s - N_r}{N_s} = \frac{1000 - 940}{1000} = 0.06$$

⇒ Stator O/P = Rotor I/P = Motor I/P – stator losses

= 50 kW – (1.4 + 1.6) kW

= 47 kW

⇒ Rotor copper loss = 5× Rotor I/P

= 0.006 × 47kW

= 2.82 kW

⇒ Gross Rotor O/P = Rotor I/P – Rotor loss

= 47kW – 2.82 kW

= 44.18 kW

⇒ Net Rotor O/P = 44.18 kW – Rotor mechanical loss

= 44.18 kW – 1 kW

= 43.18 kW

$$\therefore \text{ Efficiency, } \eta = \frac{O/P}{I/P} = \frac{43.18}{50} \times 100 \;\; = 86.36\%$$

03. (c) An industrial consumer is operating a 50 kW induction motor at a lagging p.f. of 0.8. The source voltage is 230V rms. In order to obtain lower electrical rates, the customer wishes to raise the p.f. to 0.95 lagging. Specify a suitable solution. (20 M)

Sol: $P_{I/P} = 50$ kW

$\cos\phi_1 = 0.8$ lag $\Rightarrow$ $\tan\phi_1 = 0.75$

$V_s = 230$ V

$\cos\phi_2 = 0.9$ lag $\Rightarrow$ $\tan\phi_2 = 0.48$

In order to improve the power factor capacitor bank must be connected across the machine.

The VAR supplied by the capacitor bank is

$= P[\tan\phi_1 - \tan\phi_2]$

$= 50\times10^3[0.75 - 0.48]$

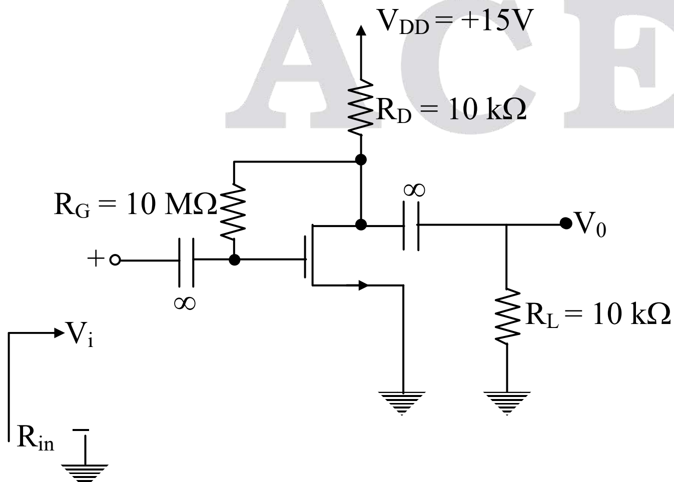
$= 13.5$ KVAR

Reactive power, $Q = 13.7 \text{ kVAR} = \dfrac{V^2}{X_C}$

$$X_C = \frac{V^2}{Q} = \frac{230\times230}{137\times10^3} = 3.86\Omega$$

The capacitor of reactance 3.86 Ω is to be connected to increase the p.f from 0.8 to 0.95.

04. (a) Figure below shows a discrete MOSFET amplifier utilizing a drain-to-gate resistance R_G. The input signal V_i is coupled to the gate via a large capacitor, and the output signal at the drain is coupled to load resistance R_L via another large capacitor. Analyze this amplifier circuit to determine its small signal voltage gain, its input resistance, and the largest allowable input signal. Assume $V_t = 1.5$ V, K'_n (W/L) (process transconductance parameter) $= 0.25$ mA/V^2, and $V_A = 50$V, where V_A is the intercept on the V_{DS} axis of the $i_D - V_{DS}$ characteristics when extrapolated. Assume that coupling capacitors are sufficiently large so as to act as short circuit at the frequencies of interest.



The effect of channel length modulation on the dc operating point can be neglected (20 M)

Sol:

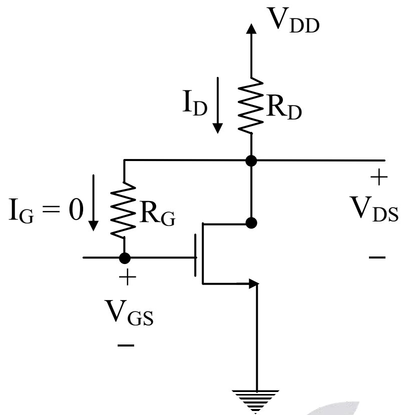


Fig (a): circuit for determining the DC operating point

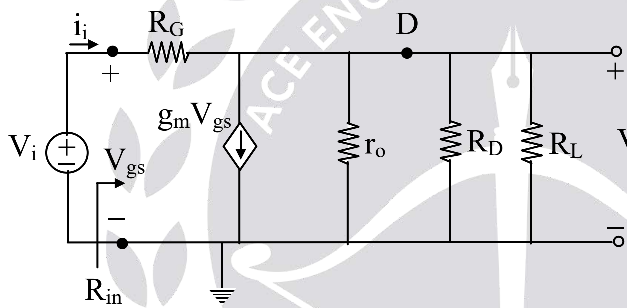


Fig (b)

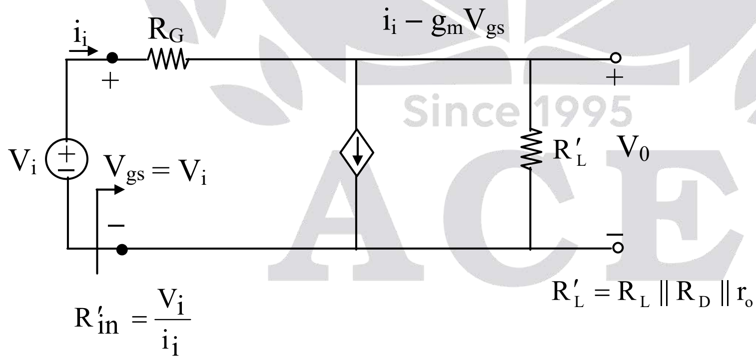


Fig (c) simplified Amplifier Small-signal equivalent circuit

$V_{GS} = V_{DS} = V_{DD} - I_D R_D$

with $V_{DS} = V_{GS}$, the NMOS transistor will be operating in saturation. Thus

$$I_D = \frac{1}{2} K_n [V_{GS} - V_T]^2$$

$$I_D = \frac{1}{2} \times 0.25 \times 10^{-3} (V_{DD} - I_D R_D - V_T)^2$$

$8I_D = [15 - 10\, I_D - 1.5]^2$

$8I_D = (13.5 - 10\, I_D)^2$

$\Rightarrow I_D = 1.06$ mA

which corresponds to: $V_{GS} = V_{DS} = 15 - 1.06$ mA × 10 k

$= 4.4$ V

and $V_{OV} = V_{GS} - V_T = 4.4 - 1.5 = 2.9$ V

$g_m = K_n[V_{GS} - V_T] = K_n^1 \frac{W}{L}.V_{ov} = 0.25 \times 2.9 = 0.725\text{mA/V}$

$$r_o = \frac{V_A}{I_D} = \frac{50}{1.06} = 47K\Omega$$

$R^1_L = R_L \,||R_D||\, r_o = 10 \,||\, 10 \,||\, 47 = 4.52$ K

$V_o = (i_i = g_m V_{gs})R^1_L$ ………….. (1)

$$i_i = \frac{V_{gs} - V_o}{R_G} \text{ ……………(2)}$$

Substituting equation (2) in (1)

$$A_v = \frac{V_o}{V_i} = \frac{V_o}{V_{gs}} = -g_m R_L^1 \left[\frac{1 - \frac{1}{g_m R_G}}{1 + \frac{R_L^1}{R_G}} \right]$$

since R_G is very large $g_m R_G >> 1$ & $\frac{R_L^1}{R_G} << 1$

Voltage gain (Av): AV ≃ gm R1L

$A_v = -0.725$ mA/V × 4.52 k = –3.3

Input resistance (R_{in}): $R_{in} = \frac{R_G}{1 - A_v} = \frac{R_G}{1 + g_m R_L^1} = \frac{10M\Omega}{1 + 3.3} = 2.33M\Omega$

Largest allowable input signal $(\hat{V}_i)$:

The largest allowable i/p signal $(\hat{V}_i)$ is considered by the need to keep the transistor in saturation at all times, that is

$V_{DS} \geq V_{GS} - V_t$

Enforcing this condition with equality at the point V_{GS} is maximum and V_{DS} is minimum, we write

$$V_{DS_{min}} = V_{GS_{max}} - V_t$$

$$V_{DS} - |A_V|\hat{V}_i = V_{GS} + \hat{V}_i - V_t$$

since $V_{DS} = V_{GS}$, we obtain

$$\hat{V}_i = \frac{V_t}{|A_v|+1}$$

$$\hat{V}_i = \frac{1.5}{3.3+1} = 0.35V$$

04.(b)(i) Define nanomaterials and classify nanomaterials on the basis of number of dimensions. What are the different approaches for the preparation of nanomaterials? Discuss any one method of preparation of nanomaterials from each approach. (10 M)

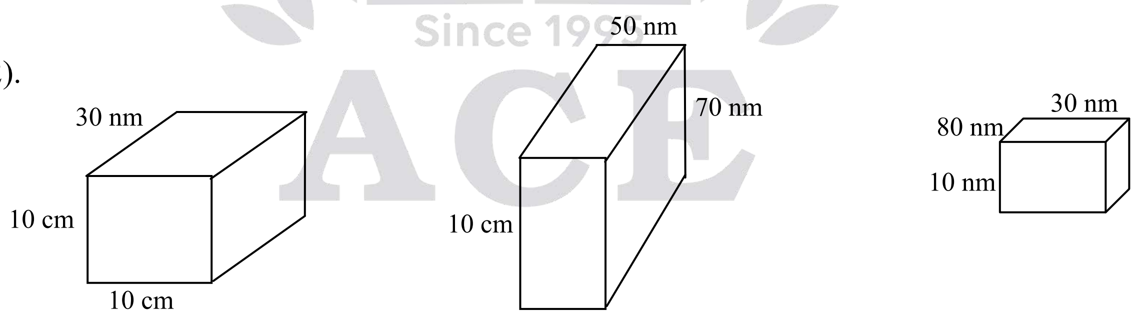
(ii) Explain how dislocation density increases on cold working. (10 M)

Sol:

(i) * At least one dimension of material is in nano-scale that is varying from 1 nm - 100 nm.

Ex: (1). $\left.\begin{array}{l}\text{DNA \& virus} = 40\text{nm}\\ \text{Transistor} = 30\text{nm}\end{array}\right\}$ Nano material

(2).

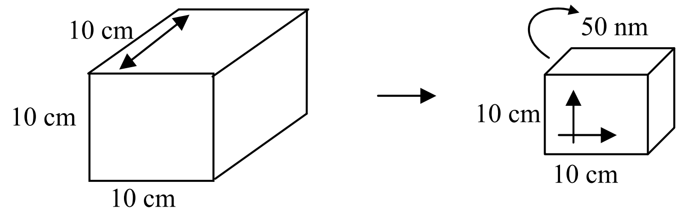


Types of Nano Materials:

1. Quantum Well: (One dimensional nanomaterial) (Two dimensional bulk material)

Reduction of size of bulk material upto the nano range in only one dimension and other two dimensions are in normal range (or) bulk form and hence this material is known as one dimensional nanomaterial.

* In Quantum well electron flow takes place in two dimension & in nano direction electron flow is restricted.

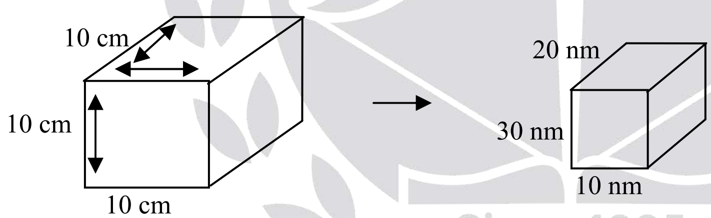


* **Graphene:**

Graphene is a carbon made nanomaterial and graphene is a single layer of graphite.

* In graphene every carbon atom is covalently bonded with three carbon atoms and forms "two single covalent bonds & double covalent bonds". It is also called SP^2 hybridization. To break the double covalent bond requires more energy and hence it is the hardest, strongest, thinnest nanomaterial.

2. Quantum Dot: (Three dimensional nanomaterial) (Zero dimensional material)



Ex: 1. Fullerence

2. Dendrimers

3. Quantum dot

* Reduction of size of bulk material upto the nanorange in all directions.
* Electron flow is completely restricted in all directions.

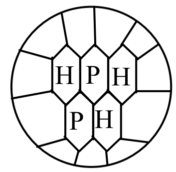
* **Fullerenes:**

Fullerenes are produced by folding single layer of graphite (or) graphene into spherical form.

* In Fullerenes both hexagon & pentagons present in the shape of soccer ball. In C_{60} fullerence, 12 pentagons & 20 Hexagons are present.

Applications:

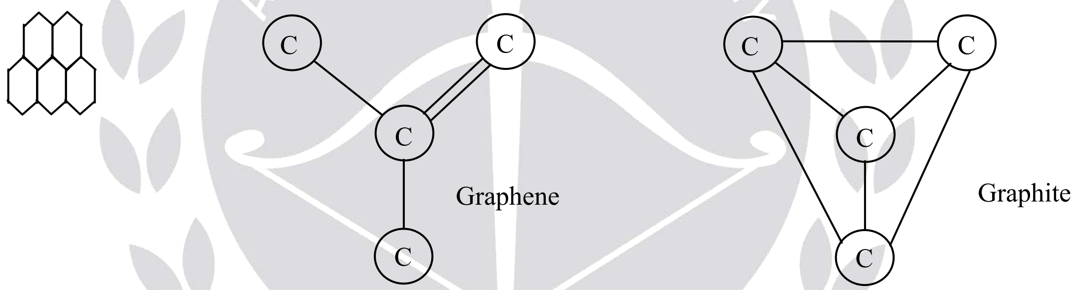
1. Drug delivery
2. Gene therapy



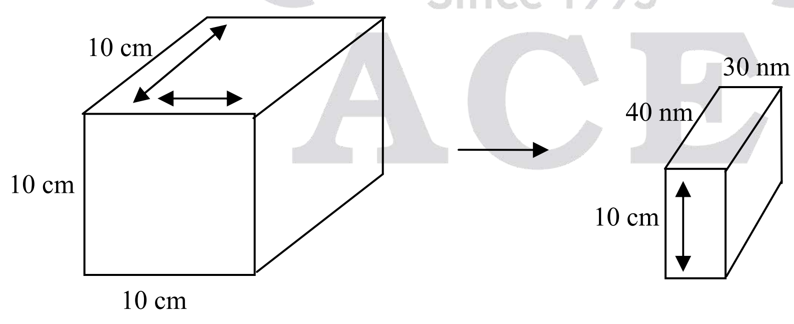
Quantum Dot:

* It is a smallest size zero dimensional material and the size of quantum dot is less than (< 10 nm)
* In quantum dot, the surface atoms are having high energy levels with low wave length and inner core atoms are having low energy and high wave length.

* By changing wavelength of the atom conduction of electron takes place and hence, these materials are used in electronic industry as semi conductors.
* The structure of graphene is honey comb structure.
* The graphene is the highest electrical conductively material with -ve temperature coefficient of resistivity.



3. Quantum Wire: (Two dimensional nanomaterial) (One dimensional material)



* Reduction of size of bulk material upto nano range in two dimensions and in third dimension the size is in normal range.
* In Quantum wire electron flow takes place in only one direction

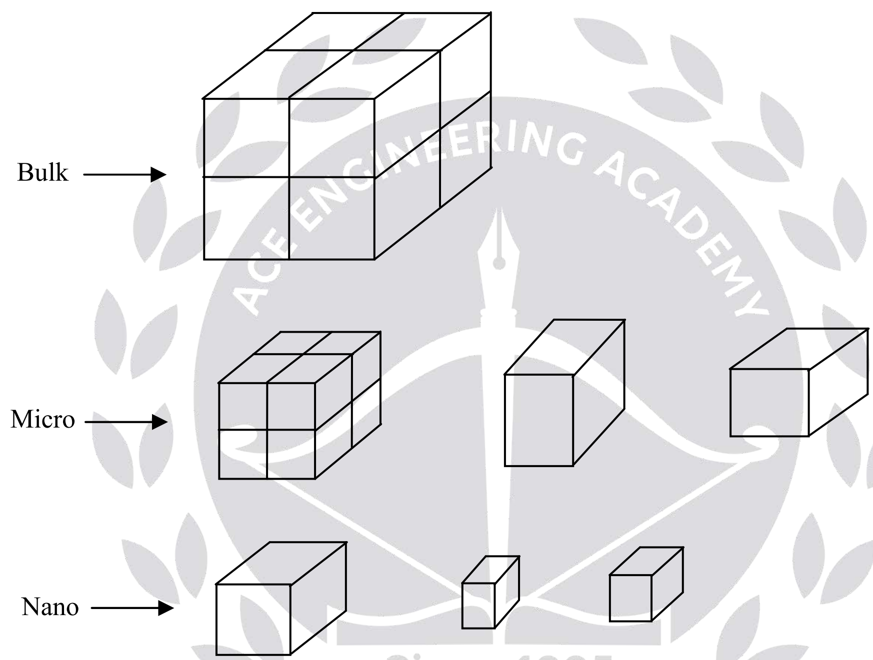
Ex: Carbon Nano Tube, Nano wire, Nano rod, Whiskers.

a) Carbon NanoTube:

* Carbon Nano Tubes are produced by folding single layer of graphite (or) graphene into a cylindrical form and capped with hemispherical fullerene on both sides of material.
* The electrical conductivity of Nano material also depends on shape.
* The electrical conductivity of single wall nanotube different form the multi wall carbon nanotube.

1. Top-Down Approach Method:

Principle: Cutting/Slicing of material



Ex: Ball Milling Method

Advantages:

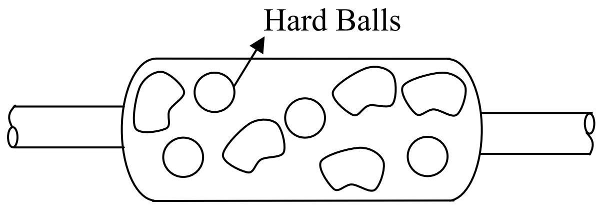
1. Easy to produce
2. No skilled & low cost

Disadvantages:

1. No uniform size
2. Impurities
3. Crystalline defects generated

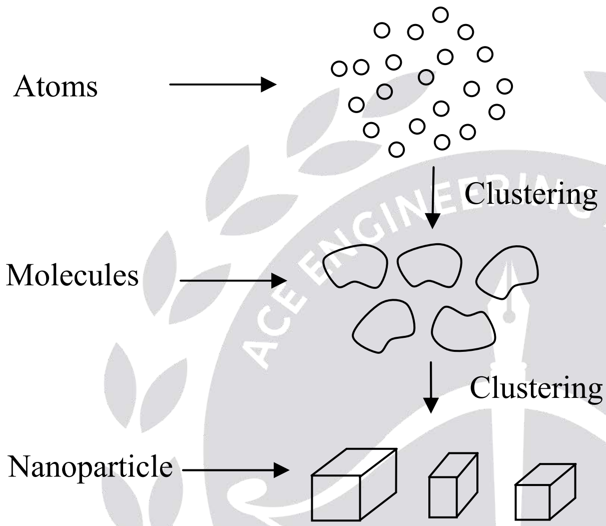
Methods:

1. Ball Milling
2. Lithography method → Photo lithography
   → Electron lithography
3. Laser Ablation method
4. Plasma Arcing

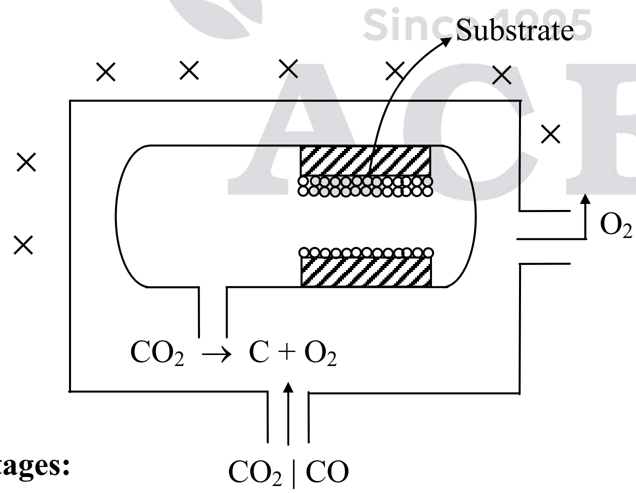


2. Bottom up approach Method:

Principle: Clustering of atoms and molecules



Ex: Chemical vapour deposition method:



Advantages:

1. Uniform size
2. Purity
3. No defects

Disadvantages:

1. More cost
2. Skilled

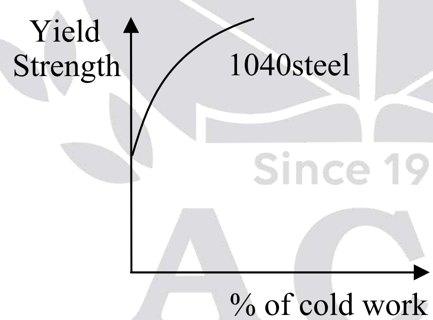
Methods:

1. Chemical vapour deposition method
2. Physical vapour deposition method
3. Sol gel Technique
4. Molecular self assembly method

(ii) Cold working is one of the strengthening mechanisms of applying mechanical force and deformed permanently below re-crystallization temperature.

$$\text{Dislocation Density} = \frac{\text{Total dislocation length}}{\text{Volume}}$$

In cold working process, number of point defects, line defects are increased by applying stresses on the material. So dislocation density increased in cold working and there dislocations arrest the dislocation motion so strength and hardness of material increased.



04.(c)(i) The Burgers vector of a mixed dislocation line is $\frac{1}{2}$ [1 1 0]. The dislocation line lies along the [1 1 2] direction. Find the slip plane on which this dislocation lies. (10 M)

(ii) Explain, why end centered tetragonal geometry does not exist. (10 M)

Sol: (i) The Burger's vector of a mixed dislocation line is $\frac{1}{2}[1\ 1\ 0]$

Crystallographic direction = [1 1 2]

Consider the slip plane tube to be: (h k *l*)

From Wies zone law:

$\vec{b} \rightarrow h + k = 0$ [on [110]] $\rightarrow$ (1)

$\bar{t} \rightarrow h + k + 2\ell = 0$ [on [112]]$\rightarrow$ (2)

from equation (1)

h = –k

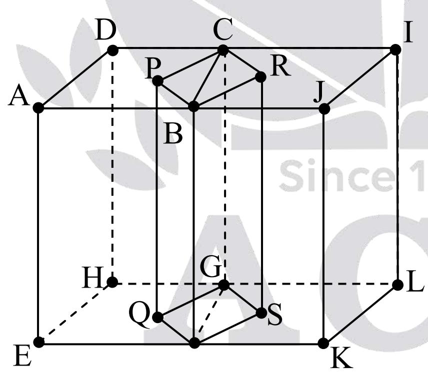
–k + k + 2*l* = 0

l = 0

Slip plane = (1 T 0)

(ii) To prove that a Base Centered Tetragonal lattice does not exist:

ABCDEFGH and BJICFKLG are two Base centered tetragonal unit cells joined together (see figure below).



In addition to the corner lattice points, top and bottom bases of the two unit cells have lattice points at their center (P, Q, R and S). Consider the unit cell formed by joining the points B, P, C, R in the top and Q, G, S, F in the bottom face. The side BP, PC, CR and RB are all equal and form the sides of a square. Similarly the sides QG, GS, SF & FQ form the sides of a square. The side surfaces of this cell are identical rectangle.

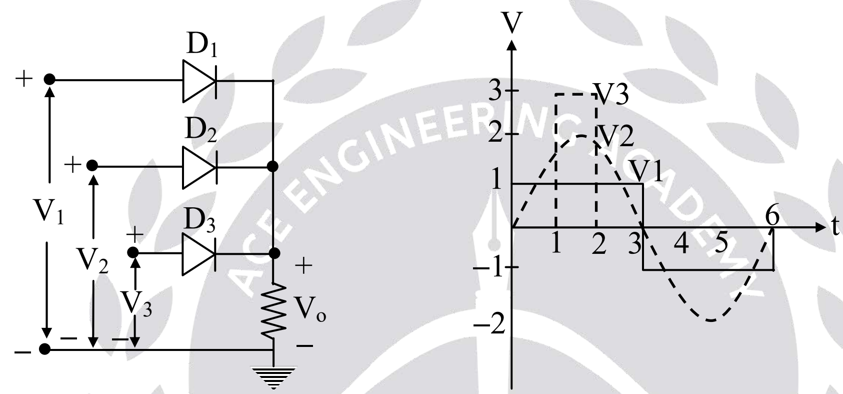
Hence it is a simple tetragonal lattice.

Hence a base centered tetragonal does not exist.

SECTION - B

05.(a)(i) Sketch the circuit of a one-shot using a 555 timer to provide one time period of 20 μs. If R_A = 7.5 kΩ, what value of C is needed? Also sketch the input and output waveforms, when triggered by a 10 kHz clock for R_A = 5.1kΩ and C = 5nF. (6 M)

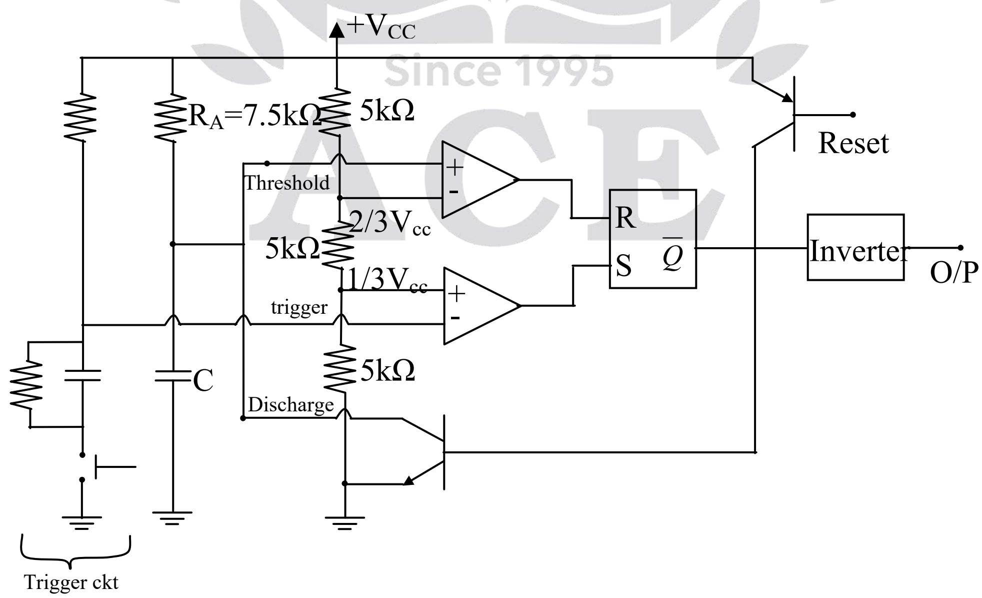
(ii) The logic OR gate can be used to fabricate composite waveforms. Sketch the output V_o of the gate of figure (a) shown below if the three signals as shown below in (b) are impressed on the input terminals. Assume the diodes are ideal. (6 M)



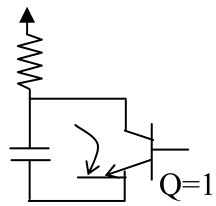
(a) (b)

Sol:

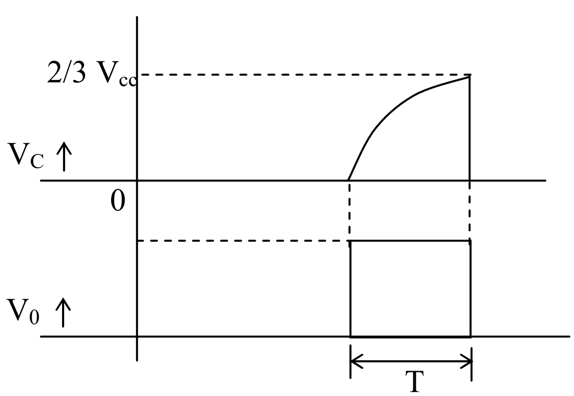
(i)



Let us assume, capacitor charges from V_{CC} towards 2/3 V_{CC}



		R	S	$\overline{Q}$	O/P	
Before trigger	$V_C > 2/3\ V_{CC}$	1	0	1	0	Transistor ON Capacitor discharge
	$V_C = 0$	0	0	0	0	(Previous state)
Let us give trigger for a short duration						
After	$V_C = 0$	0	1	0	1	Transistor OFF Capacitor discharge
	$V_C > 1/3\ V_{CC}$	0	0	0	0	(Previous state)
	$V_C > 2/3\ V_{CC}$	1	0	1	0	Transistor ON Capacitor discharge
	$V_C = 0$	0	0	1	0	



$V_C(t) = V_{CC}\left[1 - e^{-t/RC}\right]$

At $t = T$ $V_C(t) = 2/3\ V_{CC}$

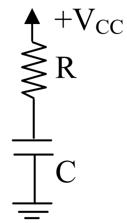
$2/3\ V_{CC} = V_{CC}\left[1 - e^{-T/RC}\right]$

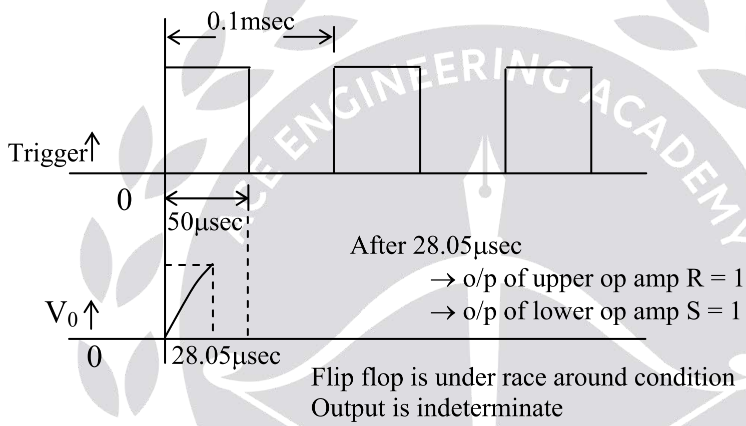
$T = 1.1RC = 20\mu Sec$

$1.1 \times 7.5k \times C = 20\mu$

$C = 2.42 \times 10F$

$\quad = 2.42$ nF

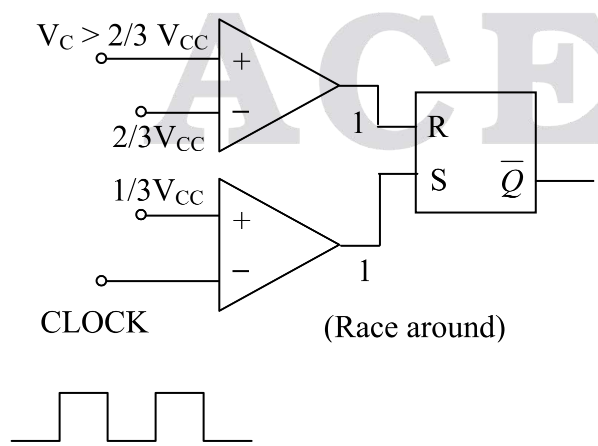




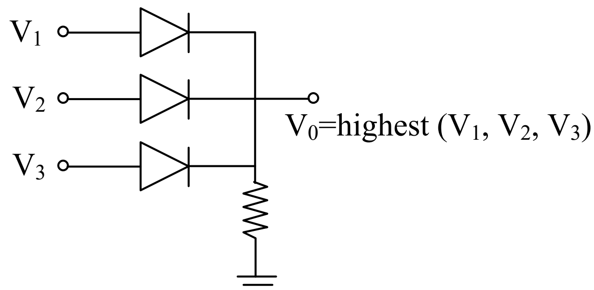
$R_A = 5.1K$

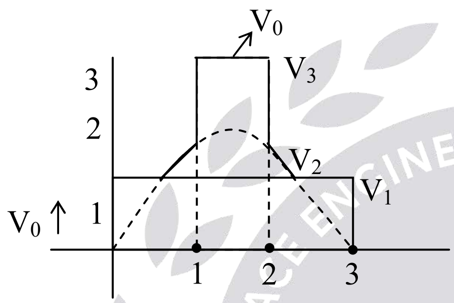
$C = 5nF$

$T = 1.1RC = 28.05\mu$ Sec



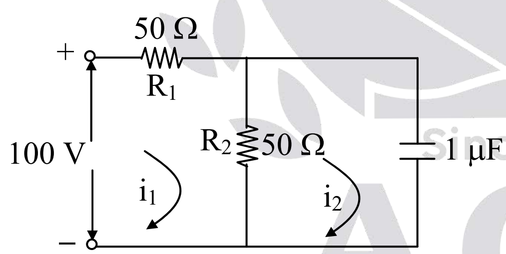
(ii)



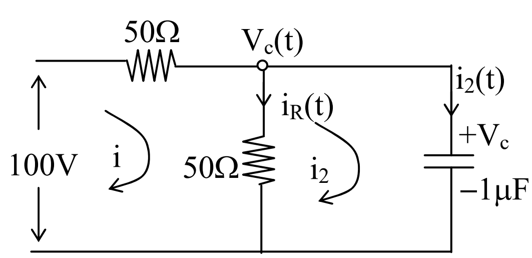


05. (b) A dc voltage of 100 v is suddenly applied in the network shown in the figure. Find the transient currents in both the loops and obtain the transient voltage across the capacitor.

(12 M)

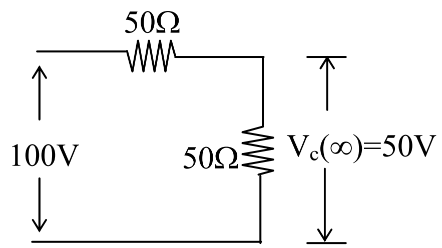


Sol:



For first order R – C network the voltage across capacitor $V_c(t) = V_c(\infty) + \left(V_c(0) - V_c(\infty)\right)e^{-t/RC}$

$V_c(0) = 0 \quad V_c(\infty) = ?$ At t = ∞, open circuit



Time constant $\tau = R_{eq}C = (50//50).1\mu F$

$= 25\mu Sec$

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

$= 50 + (0-50)e^{-t/25\mu}$

$V_c(t) = 50(1 - e^{-t/25\mu}) Volts\, t \geq 0$

For $i_2(t) = \frac{cdV_c(t)}{dt}$

$= 1\mu F\left[50\left(0 - e^{-t/25\mu}\left(\frac{-1}{25\mu}\right)\right)\right]$

$i_2(t) = 2e^{-t/25\mu}$ amps $t \geq 0$

$i_R(t) = \frac{V_c}{R} = (i_1 - i_2)$

$\frac{50(1-e^{-t/25\mu})}{50} = (i_1 - i_2)$

$i_1 = 1 - e^{-t/25\mu} + 2e^{-t/25\mu}$

$i_1(t) = (1 + e^{-t/25\mu})$ amps $t \geq 0$

Voltage across capacitor

$V_C(t) = 50(1 - e^{-4\times10^4 t})$ volts

Transient loop currents

$i_1(t) = (1 + e^{-4\times10^4 t})$ amps $t \geq 0$

$i_2(t) = (2e^{-4\times10^4 t})$ amps $t \geq 0$

05. (c) Predict and draw the crystal structure of MgO and compute its theoretical density. (Give Ionic radius of Mg^{++} ion, $r_{Mg^{++}}$ = 0.72 Å and ionic radius of O^{--} ion, $r_{O^{--}}$ = 1.40 Å; atomic masses of 'Mg' and 'O' are 24.31 g/mol and 16.00 g/mol, respectively, Avogadro's Number = 6.023×10^{23} g/mol) (12 M)

Sol: Given data:

$rMg^{++} = 0.72\,\text{Å}$

$r_o{--} = 1.40\,\text{Å}$

Atomic masses of ions

Amg = 24,31 g/mol

A_o = 16 g/mol

Avogadro's number (AN) = 6.023×10^{23} g/mol

$$\text{Theoretical Density} = \frac{n_{mg}\times A_{mg} + n_o \times A_o}{V_{vc}\times AN}$$

Mgo is a rocksalt structure with effective number of cations and anions = 4

$n_{Mg} = 4$, $n_o = 4$

Relationship between lattice parameters and ionic radius

$2(r_{Mg} + r_o) = a$

$a = 2\,(0.72 + 1.4) = 4.24\,\text{Å} = 4.25 \times 10^{-10}$ m

Volume of unit cell = $V_{UC} = a^3 = 76.22 \times 10^{-30}\ m^3$

$$\text{Theoretical Density} = \frac{4\times 24.31 + 4\times 16}{76.22\times10^{-30}\times 6.023\times10^{23}}$$

$= 0.3512 \times 10^7\ g/m^3$

$= 0.3512 \times 10^4\ kg/m^3$

$= 3512\ kg/m^3$

05. (d) A digital ramp A/D converter has the following values:

Clock frequency, f_c = 1MHz

Threshold voltage, V_T = 100 μV

D/A-$V_{ref.}$ = 10.24 V and number of input bits = 10

Determine:

(i) Digital/equivalent representation for V_{in} = 4.872 V

(ii) Resolution of the A/D converters and

(iii) Conversion time required by this digital ramp A/D converter. (12 M)

Sol: A digital ramp ADC has the following values

Clock frequency = 1MHz

Threshold voltage = 100 μV.

DAC_{ref} = 10.24 V, number of input bits = 10.

(i) Digital equivalent representation for V_{in} = 4.872 V

$$\text{Stepsize} = \frac{V_R}{2^N} = \frac{10.24}{2^{10}} = 0.01\text{V} = 10\text{mV}$$

Given threshold value V_T = 100 μV = 0.1 mV = 0.0001 V

i.e., DAC output 'V_d' has to reach 4.872V + 0.1 mV before the comparator switch to 0.

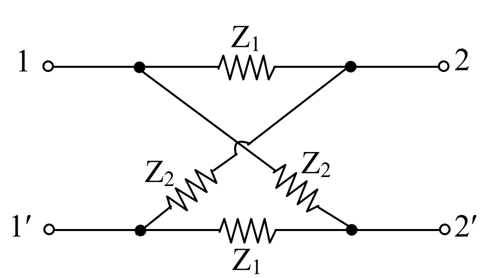
$$\text{Digital output } \frac{4.872\text{V} + 0.0001\text{V}}{10\text{mV}} = \frac{4.8721\text{V}}{10\,\text{mV}} = 487.21 = 488$$

i.e., Digital output = 488_{10} = $1E\,8_{16}$ = 0111101000.

(ii) ADC resolution = 10mV + V_T = 10.1 mV

(iii) Conversion time = 488 × 1T = 488 × 1μs = 488μs

05. (e) For the lattice two port network of the figure shown, find the image impedance and the image transfer constant. (12 M)



Sol: The given network is symmetrical and reciprocal network.

The z – parameter of the lattice network can be determined directly

$$z_{11} = z_{22} = \frac{z_1 + z_2}{2}\Omega$$

$$z_{12} = z_{21} = \frac{z_2 - z_1}{2}\Omega$$

The two part lattice network image impedances interms of ABCD parameters.

$$z_{i1} = \sqrt{\frac{AB}{CD}},\ z_{i2} = \sqrt{\frac{BD}{AC}}$$

And the image transfer constant

$$\theta = \text{Tan}^{-1}\left[\sqrt{\frac{BC}{AD}}\right]$$

The ABCD parameters interms of z – parameter

$$A = \frac{z_{11}}{z_{21}} = D \text{ is} \rightarrow \text{Symmetry}$$

$$B = \frac{\Delta z}{z_{21}},\ C = \frac{1}{z_{21}}$$

$$A = \left(\frac{z_2 + z_1}{z_2 - z_1}\right) = D \ \ and \ \ C = \frac{2}{(z_2 - z_1)} mho$$

$$B = \frac{\left(\frac{z_2 + z_1}{2}\right)^2 - \left(\frac{z_2 - z_1}{2}\right)^2}{\left(\frac{z_2 - z_1}{2}\right)} = \frac{2z_1z_2}{(z_2 - z_1)}\Omega$$

Image impedance

$$z_{i1} = \sqrt{\frac{AB}{CD}}$$

$$z_{i1} = \sqrt{\frac{\frac{2z_1z_2(z_2 - z_1)}{2}}{(z_2 - z_1)}} = \sqrt{z_1z_2} = z_{i2}$$

$$z_{i1} = z_{i2} = \sqrt{z_1z_2}\Omega$$

Image transfer constant $\theta = \text{Tan}^{-1}\sqrt{\dfrac{BC}{AD}}$

$$\theta = \text{Tan}^{-1}\sqrt{\dfrac{\dfrac{2z_1z_2}{(z_2-z_1)}\dfrac{2}{(z_2-z_1)}}{\left(\dfrac{z_2+z_1}{z_2-z_1}\right)^2}}$$

$$\theta = \text{Tan}^{-1}\left[\dfrac{2\sqrt{z_1z_2}}{(z_2+z_1)}\right]$$

06. (a) A first-order thermometer was dipped in a temperature-controlled water bath maintained at 100°C and the following time-temperature readings were obtained:

Time (s)	**0**	**4**	**8**	**12**	**16**	**20**
Temperature (°C)	**15**	**50**	**70**	**85**	**90**	**95**

Estimate the time constant of the thermometer. Determine the steady state error when the thermometer is required to measure the temperature of a liquid which is being heated at a constant rate of 0.1°C/s. (20 M)

Sol: A time constant is equal to time taken to reach 0.632 of the difference between old & new value.

So temperature corresponding to the time constant is

T = 0.632 (100 – 15) + 15°C = 53.72°C + 15°C = 68.72°C

From given chart time corresponding to temperature 68.72°C (≈ 70°C) is 8 sec.

So time constant τ = 8 sec

The steady state error (e_{ss}) when the thermometer is required to measure the temperature of a liquid which is being heated at a constant rate 0.1°C/sec is

$e_{ss} = A\tau$

Here A = 0.1 °C/sec

τ = 8 sec

$e_{ss} = 0.1 \times 8 = 0.8$ °C

06. (b) A quartz Piezoelectric Transducer (PZT) has the following specifications: Area = 1cm^2; Thickness = 2mm; Young's modulus = 9×10^{10} Pa; Charge sensitivity = 2 pC/N; Relative permittivity = 5 and Resistivity = 10^{12} Ω-cm. A 10pF capacitor and a 100 MΩ resistor are connected in parallel across the electrodes of the PZT. If a force F = 0.02 sin (10^{3}t) N is applied, determine

(i) the peak-to-peak voltage generated across the electrodes and

(ii) the maximum change in crystal thickness. (20 M)

Sol:(i). The rms value of voltage under open circuit is

$$e_o = \frac{F}{A} \times \frac{dt}{\varepsilon_o \varepsilon_r}$$

The maximum value of voltage

$$e_{o\,max} = \sqrt{2}\frac{dt}{\varepsilon_o\varepsilon_r} \times \frac{F}{A} = \frac{dt}{\varepsilon_o\varepsilon_r} \times \frac{F_{max}}{A} \quad (F_{max} = \sqrt{2}\ F)$$

Peak to peak value of voltage under open circuit:

$$e_{o(pp)} = 2e_{o\,max} = 2 \times \frac{dt}{\varepsilon_o\varepsilon_r} \times \frac{F_{max}}{A}$$

$$= \frac{2\times 2\times 10^{-12} \times 2\times 10^{-3}}{8.85\times 10^{-12} \times 5} \times \frac{0.02}{10^{-4}} = 0.0036\times 10$$

$$= 36\,mV$$

The leakage resistance of crystal

$$R_P = \frac{\rho t}{A} = \frac{10^{12}\times 10^{-2} \times 2\times 10^{-3}}{10^{-4}} = 2\times 10^{11}\ \Omega$$

Load resistance R_L = 100 MΩ

Conclusion is $R_p >> R_L$ so that we can neglect R_P

$$C_P = \frac{\varepsilon_o\varepsilon_r A}{t}$$

$$= \frac{8.85\times 10^{-12} \times 5\times 10^{-4}}{2\times 10^{-3}}$$

$$= 22.125\times 10^{-13}$$

$$C_P = 2.21\times 10^{-12}\ F$$

The peak to peak output voltage under load conditions is

$$C_P = \frac{2dF_{max}t}{\varepsilon_o \varepsilon_r A}\left[\frac{\omega C_P R_L}{\sqrt{1+\omega^2 (C_P + C_L)^2 R_L^2}}\right]$$

$$e_{OPP} = \frac{2\times 2\times 10^{-12}\times 0.02\times 2\times 10^{-3}}{8.85\times 10^{-12}\times 5\times 10^{-4}}\times\left[\frac{1000\times 2.21\times 10^{-12}\times 100\times 10^{6}}{\sqrt{1+\left[1000\times (2.21+10)\times 10^{-12}\times 100\times 10^{6}\right]^2}}\right]$$

$$= 36.15\times 10^{-3}\times 0.634\times 2.21\times 10^{-1}$$

$$= 50.65\times 10^{-4}$$

$$e_{OPP} = 5.065\,\text{mV}$$

(ii) The maximum value of change in thickness is

$$\Delta t = \frac{F_{max}t}{YA} = \frac{0.02\times 2\times 10^{-3}}{9\times 10^{10}\times 10^{-4}} = 0.0044\times 10^{-9}$$

$$(\Delta t)_{PP} = 4.4\times 10^{-12}\ \text{m}$$

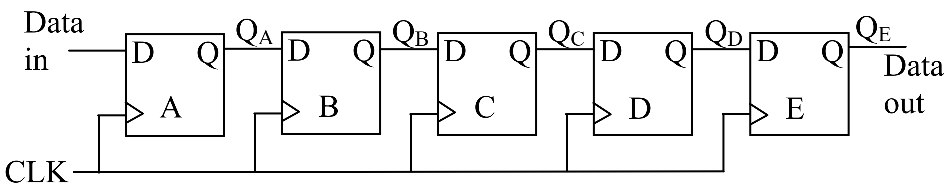
06.(c)(i) Generate the logic function given in the table below using IC74151 8-to-1 MUX.

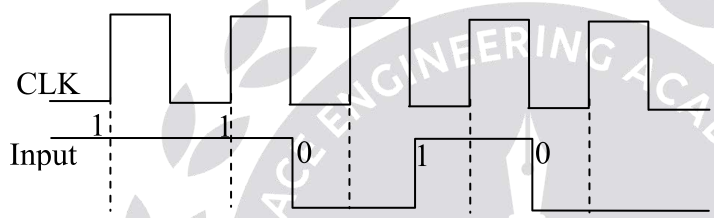
(10M)

Inputs			Output
C	**B**	**A**	**Y**
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

(ii) Show the states of the five-bit register shown below using waveforms, for the specified data input and clock signal. Assume the registers to be initially cleared (all 0s). How long will it take to shift an 8-bit number into a shift register if the clock is set to 10 MHz?

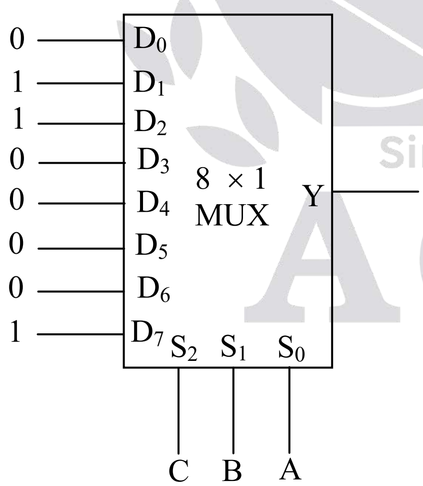
(10 M)

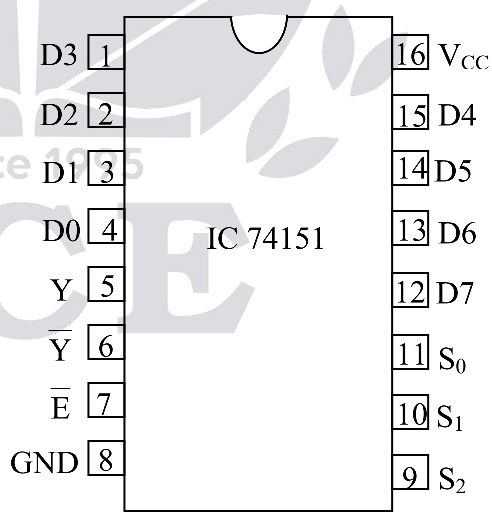




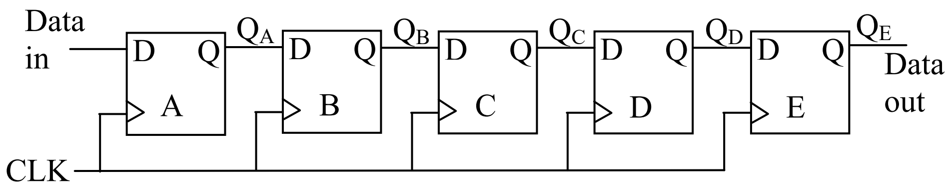
Sol:

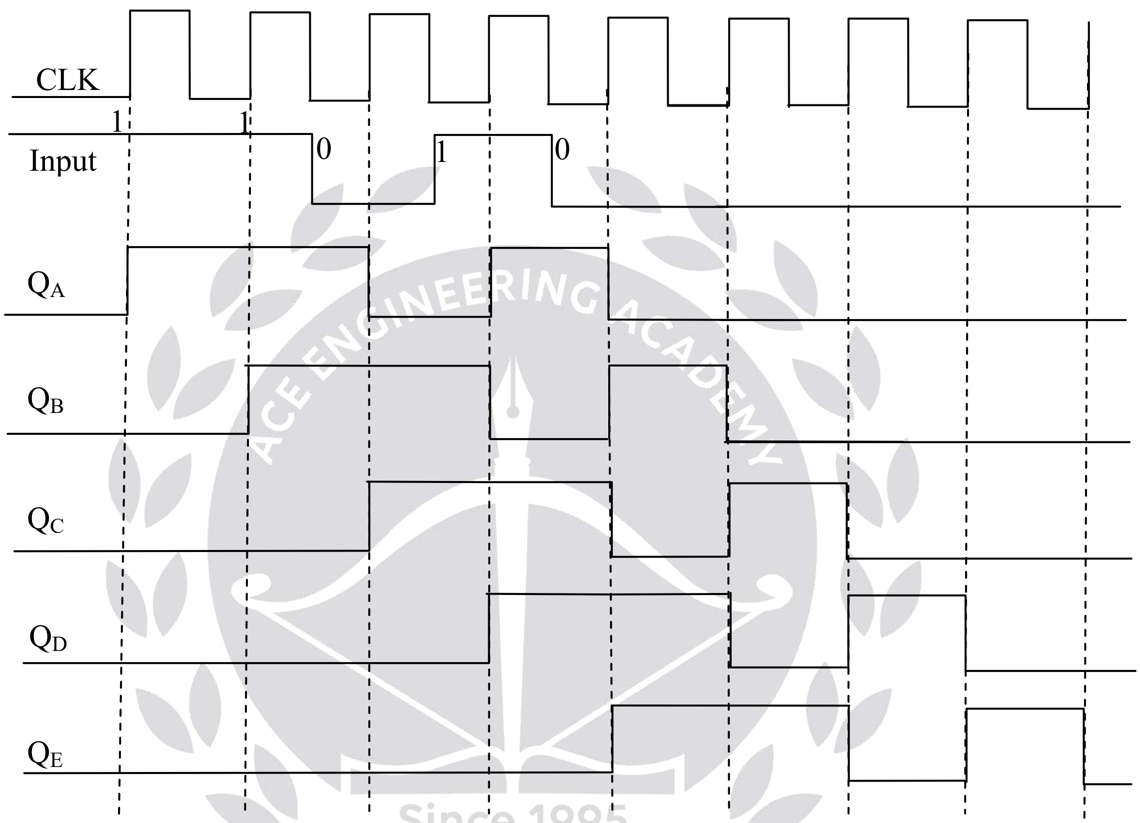
(i)





(ii)



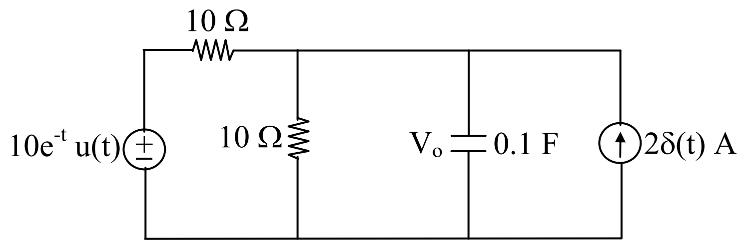


f = 10 MHz

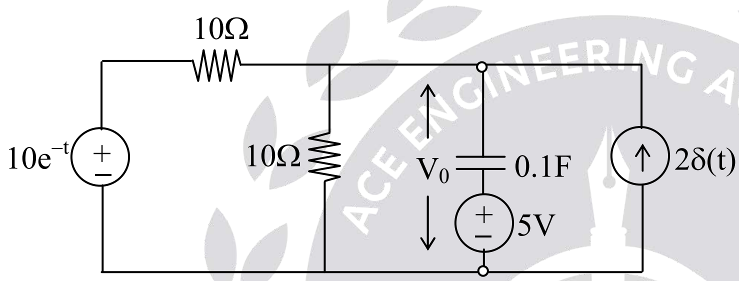
$$T = \frac{1}{10\,\text{MHz}} = 0.1\mu s$$

The number of clock cycles to read 8-bit data 8T and the time is = 8 × 0.1 μs = 0.8 μs.

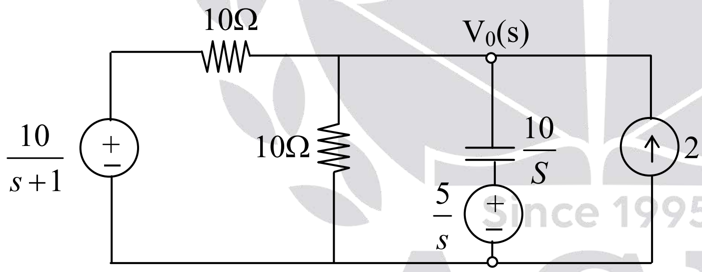
07. (a) Find $V_o(t)$ in the circuit shown in the figure. Assume $V_o(0)$ = 5V. **(20 M)**



Sol: For t > 0, $10e^{-t}u(t) = 10e^{-t}$



t – domain



S – domain

By KCL at $V_0(s)$

$$\frac{V_0(s)-\frac{10}{s+1}}{10}+\frac{V_0(s)}{10}+\frac{V_0(s)-\frac{5}{s}}{\frac{10}{s}}=2$$

$$V_0(s)\left[\frac{1}{10}+\frac{1}{10}+\frac{s}{10}\right]=\frac{1}{s+1}+\frac{1}{2}+2$$

$$V_0(s)\left[\frac{s+2}{10}\right]=\frac{1}{s+1}+\frac{5}{2}$$

$$V_0(s)\left[\frac{s+2}{10}\right]=\frac{2+5(s+1)}{(s+1)2}$$

$$V_0(s)\left[\frac{s+2}{10}\right]=\frac{5s+7}{2(s+1)}$$

$$V_0(s)=\frac{25s+35}{(s+1)(s+2)}=\frac{25s+25+10}{(s+1)(s+2)}$$

$$V_0(s)=\frac{25}{(s+2)}+\frac{10}{(s+1)(s+2)}$$

$$V_O(s)=\frac{25}{s+2}+\frac{10}{s+1}-\frac{10}{s+2}=\frac{15}{s+2}+\frac{10}{s+1}$$

By I.L.T

$$V_0(t)=\left(15e^{-2t}+10e^{-t}\right)Volts\ t\geq 0$$

07.(b)(i) In a cathode-ray tube, the electron beam is displaced vertically by a magnetic field of flux density 2×10^{-4} Wb/m^2. The length of the magnetic field along the tube axis is same as that of electrostatic deflection plates. The final anode voltage is 1kV. Determine the voltage which should be applied to the y-deflection plates 10mm apart to return the spot back to the centre of the screen. Take

Mass of electron = 9.107×10^{-31} kg and

Charge on electron = 1.6×10^{-19} C. (10 M)

(ii) A moving coil milli-ammeter having a resistance of 20 Ω gives full scale deflection when a current of 10 mA is passed through it. Describe how this instrument can be used for measurement of current up to 1 A and voltage up to 5V. (10 M)

Sol:

(i) The magnetostatic deflection,

$$D=\frac{lBL}{\sqrt{V_a}}\sqrt{\frac{q}{2m}} \qquad \text{- - - - - (1)}$$

The electrostatic deflection,

$$D = \frac{lLV_d}{2dV_a} \qquad \text{- - - - - (2)}$$

For returning the beam back to the centre, the electrostatic deflection & the magnetostatic deflection must be equal from (1) & (2)

$$\frac{lBL}{\sqrt{V_a}}\sqrt{\frac{q}{2m}} = \frac{lLV_d}{2dV_a}$$

$$V_d = dB \times \sqrt{\frac{2V_a q}{m}}$$

Here $d = 10\,\text{mm}$

$B = 2 \times 10^{-4}\ \text{Wb/m}^2$

$V_a = 1\,\text{kV}$

$q = 1.6 \times 10^{-19}\ \text{C}$

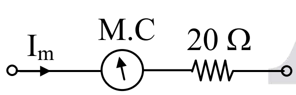
$m = 9.107 \times 10^{-31}\ \text{kg}$

$$V_d = 10 \times 10^{-3} \times 2 \times 10^{-4} \times \sqrt{\frac{2 \times 1000 \times 1.6 \times 10^{-19}}{9.107 \times 10^{-31}}}$$

$$= 2 \times 10^{-6}\sqrt{351.4 \times 10^{12}}$$

$V_d = 37.49\,\text{V}$

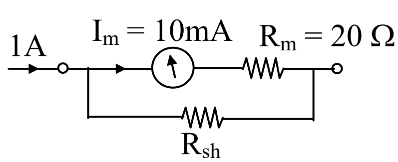
(ii)



$I_m = 10\text{mA};\ R_m = 20\ \Omega$

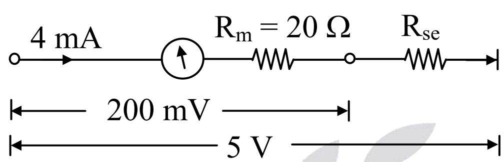
$V_m = I_m R_m = 200\ \text{mV}$

(1) By using this basic instrument, we can measure current 1 A by connecting shunt resistance



$$R_{sh} = \frac{R_m}{\left(\frac{I}{I_m} - 1\right)} = \frac{20}{\left(\frac{1}{10\,mA} - 1\right)} = \frac{20}{99} = 0.2\,\Omega$$

(2)We can measure voltage 5V, by connecting a series resistance.



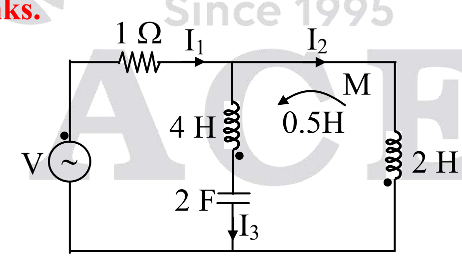
$$R_{se} = R_m\left(\frac{V}{V_m} - 1\right) = 20\left(\frac{5}{200\,mV} - 1\right) = 480\,\Omega$$

07.(c)(i) Draw the oriented graph of a network with fundamental cutset matrix as shown below:

(10 M)

Twigs				Links		
1	**2**	**3**	**4**	**5**	**6**	**7**
1	**0**	**0**	**0**	**–1**	**0**	**0**
0	**1**	**0**	**0**	**1**	**0**	**1**
0	**0**	**1**	**0**	**0**	**1**	**1**
0	**0**	**0**	**1**	**0**	**1**	**0**

(ii) For the network shown in the figure, draw the oriented graph, obtain the cutset matrix and find the number of links. **(10 M)**



Sol:

(i) The fundamental cutset matrix

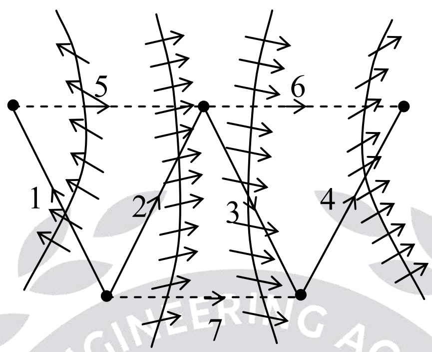
Twigs *Links*

$$[C] = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 1 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}_{(n-1)\times b}$$

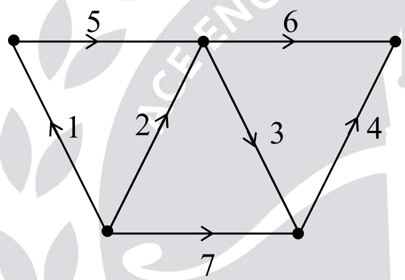
$$[C]=\left[[V_l]_t\,[C]_l\right]_{(n-1)\times b}$$

(n – 1) = 4 ⇒ n = 5 = number of nodes in the graph

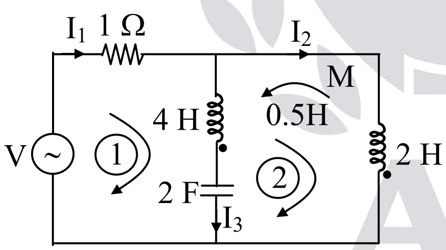
The tree for the given cut set



The oriented graphs



(ii)

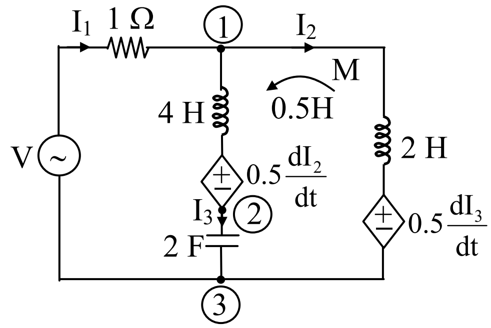


By KVL for (1)

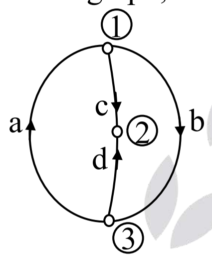
$$V = 1I_1 + 4\frac{dI_3}{dt} + 0.5\frac{dI_2}{dt} + \frac{1}{2}\int I_3 dt \qquad ---- (1)$$

$$2\frac{dI_2}{dt} + 0.5\frac{dI_3}{dt} = \frac{1}{2}\int I_3 dt + 4\frac{dI_3}{dt} + 0.5\frac{dI_2}{dt} \qquad ---- (2)$$

The circuit can be drawn without dots



The oriented graph, of the given coupled circuit

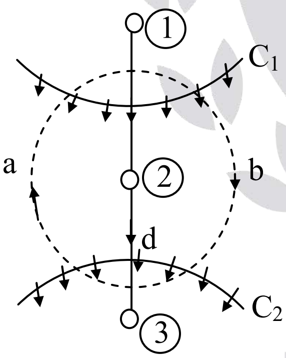


Cut-set matrix (Q):

For cut-set matrix select any one of the tree form the obtained oriented graph

Number of twigs = N – 1 = 2

Number of links = 2



Cut-set matrix (Q):

Braches **Links** **Twigs**

Cut-set

[Q] =

Cut-set \ Branches	a	b	c	d
C_1	-1	+1	+1	0
C_2	-1	+1	0	+1

(n-1)×b
2×4

$[Q] = [[C_l]\ [V_t]]_{2\times4}$

08.(a)(i) For the network in the figure shown below, determine

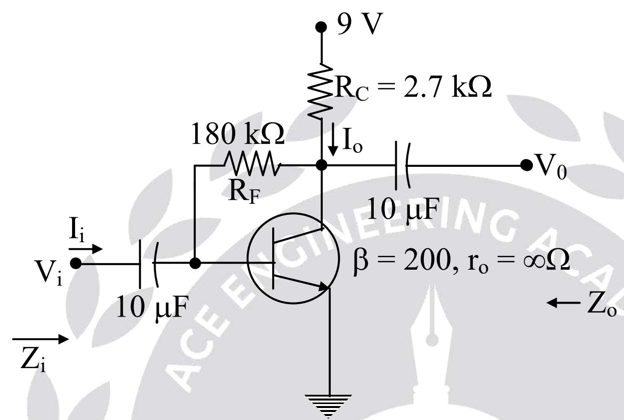
I. r_e

II. Z_i

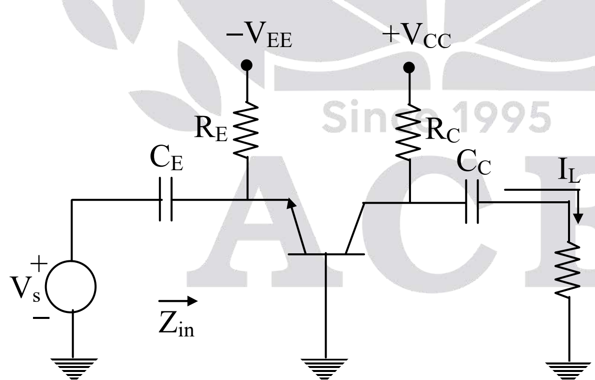
III. Z_o

IV A_V

Repeat parts II, III and IV with r_o = 20kΩ and compare results. (10 M)

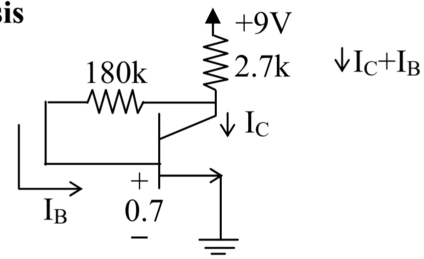


(ii) Draw the equivalent circuit (hybrid-π high frequency model) of the CB amplifier shown below. Find an expression for the high-frequency voltage-gain ratio. Also describe the high-frequency behaviour of this amplifier. (10 M)



Sol:

(i) DC Analysis



KVL

$$9 = (I_C + I_B)2.7k + I_B(180k) + 0.7$$

$$I_C = \frac{9-0.7}{2.7K + \frac{182.7k}{\beta}} = \frac{9-0.7}{2.7k + \frac{182.7k}{200}}$$

$$= 2.29694\ \text{mA}$$

$$1.\ r_e = \frac{\alpha}{g_m}$$

where $g_m = \frac{I_C}{V_t}$

$$= \frac{2.2969m}{26m}$$

$$= 0.08834\ (A/V)$$

$$= \frac{\left(\frac{\beta}{\beta+1}\right)}{g_m}$$

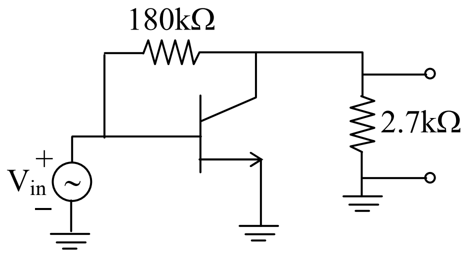
$$= \frac{[200/201]}{0.08834}$$

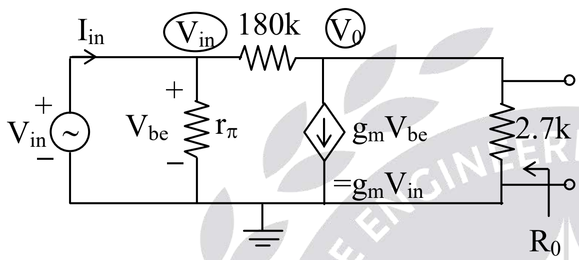
$$= 11.263\Omega$$

$$r_\pi = \frac{\beta}{g_m} = \frac{200}{0.08834}$$

$$= 2.2638k$$

AC Analysis





KCL $\quad \dfrac{V_0 - V_{in}}{180K} + g_m\, V_{in} + \dfrac{V_0}{2.7K} = 0$

$$V_0\left[\frac{1}{180K}+\frac{1}{2.7K}\right] = V_{in}\left[\frac{1}{180K} - g_m\right]$$

2. $A_V = \dfrac{V_0}{V_m} = \left[\dfrac{\dfrac{1}{180K} - g_m}{\dfrac{1}{180K}+\dfrac{1}{2.7K}}\right]$

-234.988

$= -235\,(V/V)$

3. $Ri = \dfrac{V_{in}}{I_{in}}$

$$I_{in} = \frac{V_{in}}{r_\pi} + \frac{V_{in} - V_0}{180k}$$

$$I_{in} = V_{in}\left[\frac{1}{r_\pi} + \frac{1}{180K} - \frac{A_v}{180K}\right]$$

$$\frac{V_{in}}{I_{in}} = \frac{1}{\dfrac{1}{r_\pi} + \dfrac{1}{180k} + \dfrac{235}{180k}}$$

$$= \frac{1}{\frac{1}{2.2638K} + \frac{1}{180K} + \frac{235}{180K}}$$

$$= 0.57k\Omega = 570\Omega$$

(or)

$$R_{in} = r_\pi \left[\frac{180K}{10Av}\right] = 2.2638k \,||\, \frac{180k}{236}$$

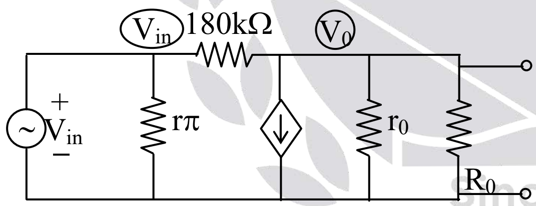
$$= 0.57k\Omega$$

Output resistance

$$R_0 \Big|_{V_{in}=0} = R_0 \Big|_{V_{be}=0} = R_0 \Big|_{g_m v_{be}=0}$$

$$= 2.7k\Omega$$

With $r_0 = 20k\Omega$



2. $$A_V = \frac{V_0}{V_m} = \frac{\frac{1}{180k} - gm}{\frac{1}{180k} + \frac{1}{2.7k} + \frac{1}{20k}}$$

$$= (2.347k)[-0.08833]$$

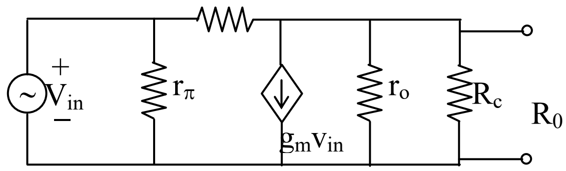
$$= -207.33$$

3. $$R_{in} = r\pi \left\| \frac{180K}{1 + A_V} = 2.2638K \right\| \frac{180K}{1 + 207.3}$$

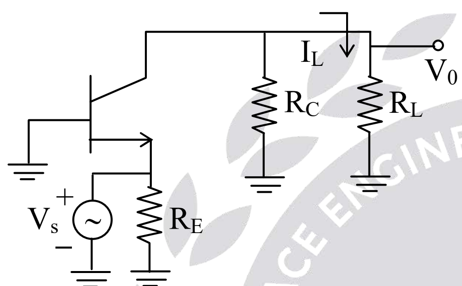
$$= 2.2638k \,||\, 0.864k$$

$$= 625.33\Omega$$

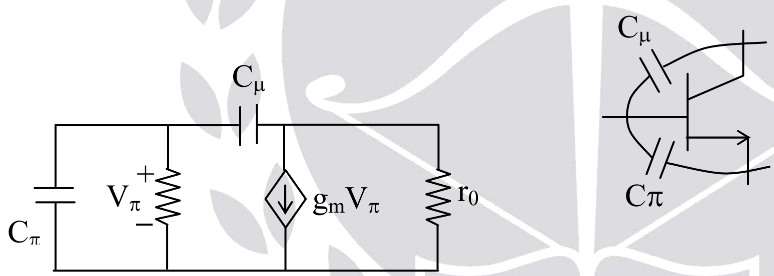
3. $R_0 = r_0 \| R_C = 20k \| 2.7k = 2.37k\Omega$

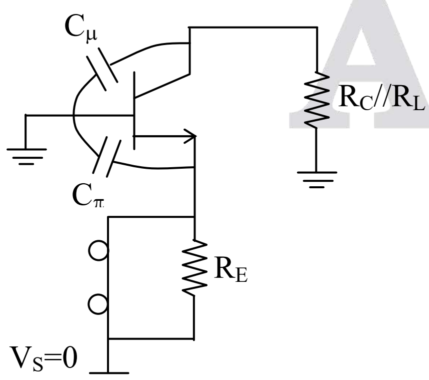


(ii) AC equivalent



HF model of BJT

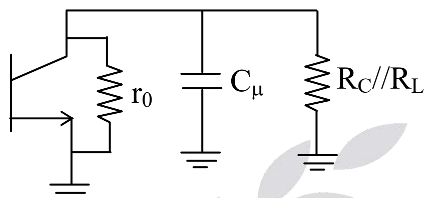




Input pole $\left(\omega_{p1}\right)=\frac{1}{T_2}=\frac{1}{C\pi\left[Req\right]}$

$=\frac{1}{(\pi(0)}=\propto$

Out put pole $\left(\omega_{p2}\right)=\frac{1}{T_2}=\frac{1}{C\mu\left[RC \parallel R_L\right]r_o}$

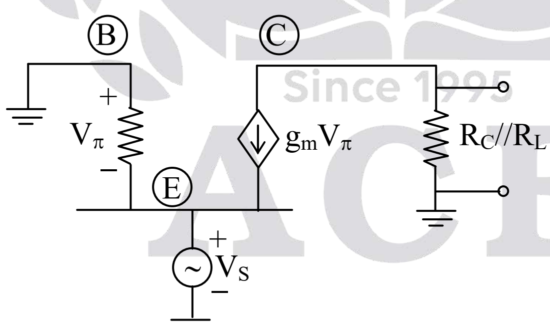


Bandwidth $\left(\omega_{3db}\right)=\frac{1}{\frac{1}{\omega_{p1}}+\frac{1}{\omega_{p2}}}$

$=\frac{1}{\frac{1}{\omega_{p1}}}$

$\omega_{3db}=\omega_{p1}$

Neglect early effect $r_0=\infty$



KVL

$V_\pi+V_S=0 \rightarrow V_S=V_\pi$

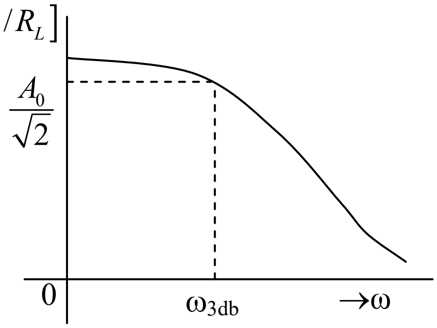
$V_0=-g_m V_\pi\left[R_C \parallel R_L\right]$

$=-g_m(-V_S)\left[R_C \parallel R_L\right]$

$\frac{V_0}{V_S}=g_m\left[R_C \parallel R_L\right]$

Frequency response

$A_0 = gm\left[R_C // R_L\right]$



08. (b) Find (z) and (g) of a two-port network if [T] = $\begin{bmatrix} 10 & 1.5\Omega \\ 2s & 4 \end{bmatrix}$ (20 M)

Sol: Two - port network ABCD parameters

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = [T] = \begin{bmatrix} 10 & 1.5\Omega \\ 25 & 4 \end{bmatrix} \text{(given)}$$

For ABCD parameters

$$\left.\begin{aligned} V_1 &= 10V_2 - 1.5I_2 \\ I_1 &= 2V_2 - 4I_2 \end{aligned}\right\} \ldots\ldots\ldots (1)$$

For Z – parameters $V_1 = z_{11}I_1 + z_{12}I_2$

$V_2 = z_{21}I_1 + z_{22}I_2$

From (1)

$I_1 = 2V_2 - 4I_2$

$$V_2 = \frac{(I_1 + 4I_2)}{2} = 0.5I_1 + 2I_2$$

$$V_1 = 10(0.5I_1 + 2I_2) - 1.5I_2$$

$$V_1 = 5I_1 + 18.5I_2$$

$$V_2 = 0.5I_1 + 2I_2$$

Z – parameter matrix

$$\begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} = \begin{bmatrix} 5 & 18.5 \\ 0.5 & 2 \end{bmatrix}$$

In g – parameters

$$I_1 = g_{11}V_1 + g_{12}I_2$$

$$V_2 = g_{21}V_1 + g_{22}I_2$$

From (1)

$$I_1 = 2V_2 - 4I_2$$

$$I_1 = 2\left[\frac{\overbrace{V_1 + 1.5I_2}^{V_2}}{10}\right] - 4I_2$$

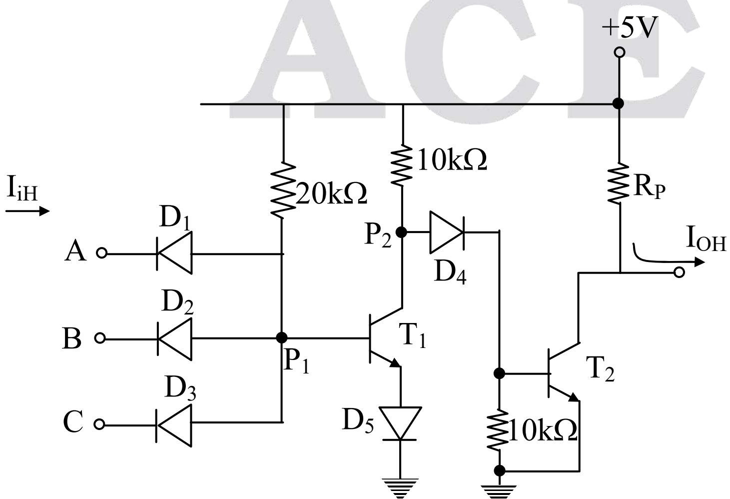
$$I_1 = 0.2V_1 - 3.7I_2$$

$$V_2 = 0.1V_1 + 0.15\, I_2$$

g – parameters

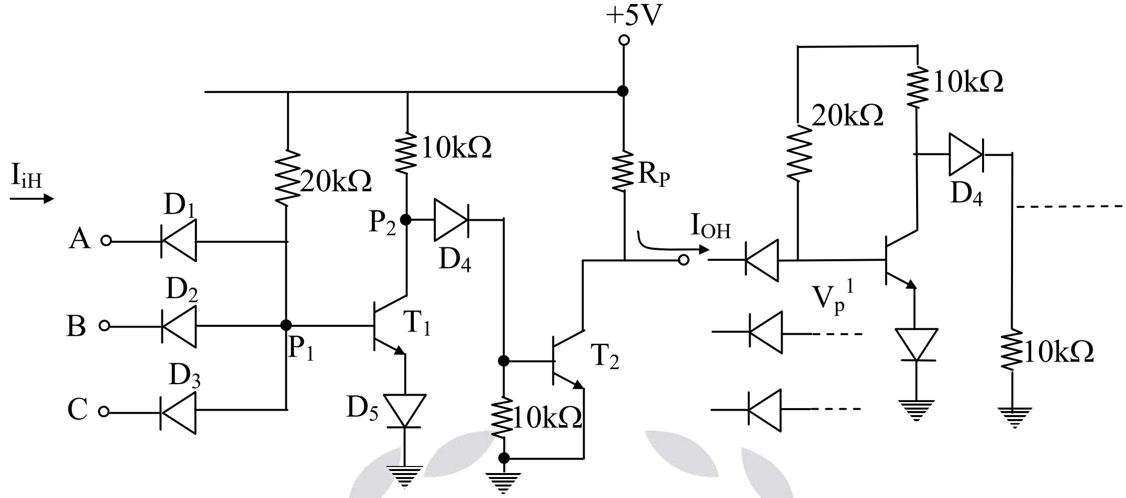
$$\begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} = \begin{bmatrix} 0.2 & -3.7 \\ 0.1 & 0.15 \end{bmatrix}$$

08. (c) For the circuit shown below, identify the logic function performed by it. Also determine the high level fan-out, if R_P (pull-up resistor) = 10 kΩ. Compute the maximum value of R_P for a fan-out of 5. Assume that input diode has a leakage current of 100 μA.
Given: V_T = 0.7 V, V_D (forward voltage drop) = 0.8 V, $V_{BE(cut\text{-}in)}$ = 0.5 V, $V_{CE(sat)}$ = 0.2 V. Transistor leakage current is negligible. (20 M)



Sol:

(i)



Given $R_p = 10k\Omega$

$$\text{Fan out} = \frac{I_{OH}}{I_{IH}}$$

Let A = B = C = 1 ⇒ $V_o = 1$ and $V'_P = 0.7 + 0.8 = 1.5V$

Thus, $I_{OH} = \frac{V_{CC} - V'_{P1}}{R_P} = \frac{5-1.5}{10k} = 3.5\times10^{-4} = 350\,\mu A$

and $I_{IH} = 100\,\mu A$

So Fanout = $I_{OH} = \frac{I_{OH}}{I_{IH}} = \frac{350}{100} = 3.5$

i.e., Fanout = 3

(ii) Find R_p if Fanout is 5

$$\text{Fanout} = \frac{I_{OH}}{I_{IH}} \Rightarrow 5 = \frac{I_{OH}}{100\times10^{-6}} \Rightarrow I_{OH} = 500\times10^{-6}$$

$$\frac{5-(0.8+0.5)}{R_P} = 500$$

$$R_P = \frac{5-1.3}{500\times10^{-6}} = 7.4k\Omega$$

$R_P = 7.4k\Omega$

(iii) It is an AND gate

If any one input is 0 → then $V_o = 0$

If all inputs are 1 → then $V_o = 1$