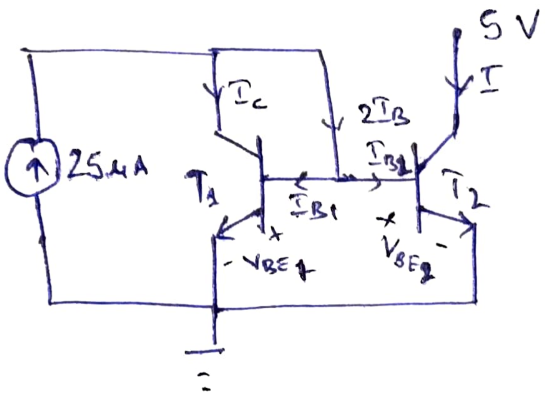
Name:

Roll no:

Test No.:

Subject: BEE + Analog Electronics
+ Electrical Materials.

1.(a)



Since both the transistors are Identical

$\therefore V_{BE1} = V_{BE2}$

& $I_{B1} = I_{B2}$

<u>for transistor T_1</u>

$I_C + 2I_B = 25\ \mu A$

as $I_C = \beta I_B = 25\, I_B$

$\cancel{I_B + 2 \times 25 I_B = 25\ \mu A}$

$\cancel{I_B = \frac{25}{51}\ \mu A}$

$\cancel{\therefore I = \beta I_B = 25 \times \frac{25}{51}\ \mu A}$

$25 I_B + 2 I_B = 25\ \mu A$

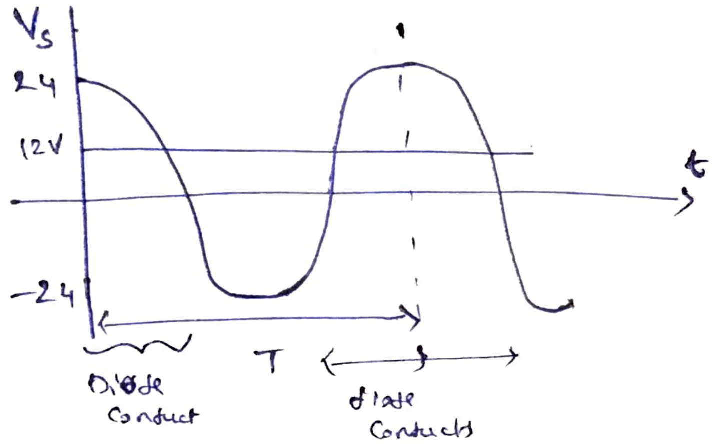
$I_B = \frac{25}{27}\ \mu A$

$\therefore$ Current $I = \beta I_B$

$= 25 \times \frac{25}{27}\ \mu A$

$\boxed{I = 23.148\ \mu A}$

1.(n)



Conduction

$\theta = \sin^{-1}\left(\frac{12}{24}\right) = \frac{\pi}{6}$

Conduction angle of diode = $\pi - 2\theta = \pi - \frac{2\pi}{6} = \frac{2\pi}{3}$

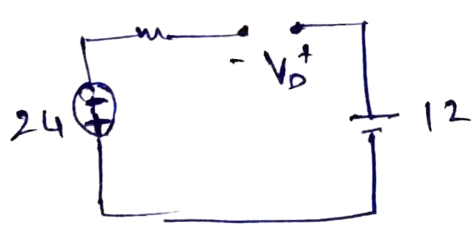
fraction of each cycle during which diode conducts

is $\frac{2\pi/3}{2\pi} = \frac{1}{3}$ of each cycle.

Peak value of diode current (I_{PK}) = $\frac{(V_s)_{max} - 12}{100} = \frac{24 - 12}{100}$

$\boxed{\hat{I}_{PK} = 0.12\ A}$

when Diode is off

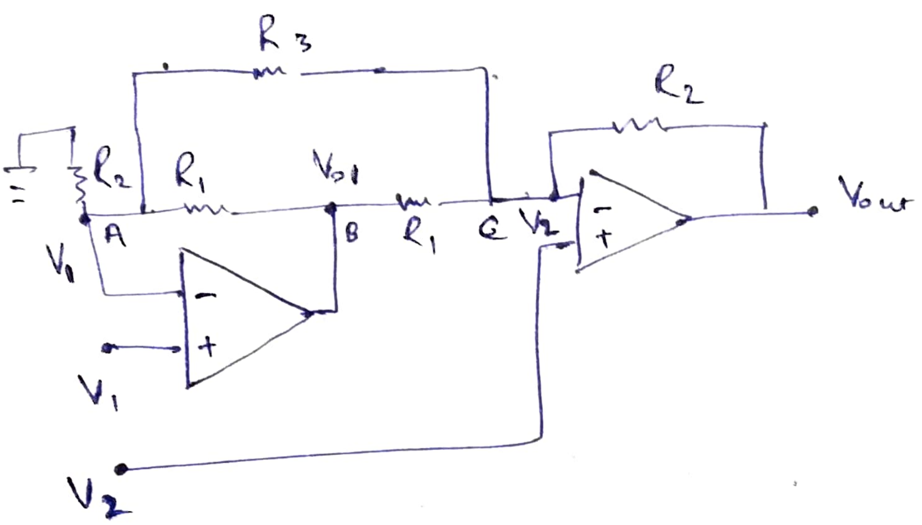


$V_D = 12 + (-V_s)_{max}$

$= 12 + 24 = 36\ V$

max. reverse bias voltage that appears across diode is $\boxed{V_D = 36\ V}$

1.(c)



By ~~vitaucta~~ Virtual ground Concept

$V_C = V_2 \quad , \quad V_A = V_1$

Now KCL at Node A

$$\frac{V_1}{R_2} + \frac{V_1 - V_2}{R_3} + \frac{V_1 - V_{o1}}{R_1} = 0 \qquad -①$$

Now KCL at Node C

$$\frac{V_2 - V_1}{R_3} + \frac{V_2 - V_{o1}}{R_1} + \frac{V_2 - V_{out}}{R_2} = 0 \qquad -②$$

Using ① in ②

$$\frac{V_1}{R_2} + \frac{V_1 - V_{o1}}{R_1} + \frac{V_2 - V_{o1}}{R_1} + \frac{V_2 - V_{out}}{R_2} = 0$$

$$\frac{V_1}{R_2} + \frac{V_1}{R_1} - \frac{2V_{o1}}{R_1} + \frac{V_2}{R_2} - \frac{V_{out}}{R_2} + \frac{V_2}{R_1} = 0$$

$$\frac{V_1}{R_2} + \frac{V_1}{R_1} - \frac{2V_1}{R_2} - \frac{2V_1}{R_3} + \frac{2V_2}{R_3} - \frac{2V_1}{R_1} + \frac{V_2}{R_2} - \frac{V_{out}}{R_2} + \frac{V_2}{R_1} = 0$$

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

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

1.(d)

$$H_c = H_0\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

For $H_c = 1.6 \times 10^5$ A/m $\quad T = 16$ K

$$1.6\times10^5 = H_0\left[1 - \left(\frac{16}{T_c}\right)^2\right] \quad -①$$

& $$4\times10^5 = H_0\left[1 - \left(\frac{14}{T_c}\right)^2\right] \quad -②$$

$$2.5 = \frac{\left[1 - \left(\frac{14}{T_c}\right)^2\right]}{\left[1 - \left[\frac{16}{T_c}\right]^2\right]} \Rightarrow 2.5 = \frac{T_c^2 - 14^2}{T_c^2 - 16^2}$$

$$2.5T_c^2 - 640 = T_c^2 - 14^2$$

$$T_c^2 = 296 \Rightarrow \boxed{T_c = 17.2046 \text{ K}}$$

Critical temperature.
(transition temperature)

Using ①

$$1.6\times10^5 = H_0\left[1 - \left(\frac{16}{17.204}\right)^2\right]$$

$$\boxed{H_0 = 1.184 \times 10^6 \text{ A/m}}$$ is critical field at 0K

At 4.2 K

$$H_c = 1.184\times10^6\left[1 - \left(\frac{4.2}{17.2046}\right)^2\right]$$

$$\boxed{H_c = 1.13 \times 10^6 \text{ A/m}}$$

1.(e)

$N = 10^{30}$ atoms/m^3 $\quad T = 300\,K$

$p_m = 1.8 \times 10^{-23}$ ~~Atm~~ Am^2

$\chi = \frac{M}{H} = \frac{N p_m^2 \mu_0}{KT}$ [By Curie law]

$= \frac{10^{30} \times (1.8 \times 10^{-23})^2 \times 4\pi \times 10^{-7}}{1.38 \times 10^{-23} \times 300}$

$\boxed{\chi = 0.0983}$ is susceptibility of Paramagnetic material

Now for dipole moment of bar

Volume = $l \times$ area of crossection

$= 0.12 \times 1 \times 10^{-4} = 1.2 \times 10^{-5}\,m^3$

Total numberof atoms $= 10^{30} \times 1.2 \times 10^{-5}$

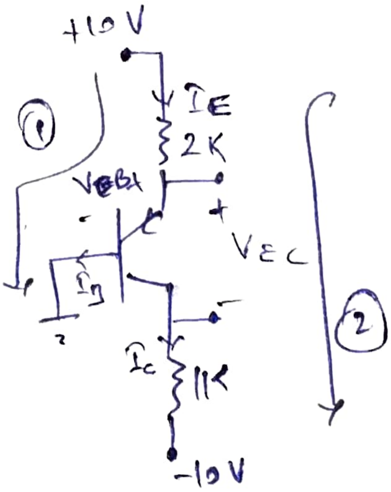
$= 1.2 \times 10^{25}$

Total dipole moment = $p_m \times$ no of atoms

$= 1.8 \times 10^{-23} \times 1.2 \times 10^{25}$

$= 216\ Am^2$

2.(a)(i)



Assuming the transistor in active region

$V_{EB} = 0.7$

KVL in loop 1

$10 = I_E \times 2K + 0.7$

$I_E = 4.65$ mA

$I_B = \dfrac{4.65}{1+\beta} = \dfrac{4.65}{101}$ mA

$I_E = I_E + I_B = \cancel{4.6\ldots\text{ mA}} = 4.604$ mA

KVL in loop 2

$10 = 2K I_E + V_{EC} + 1K\, I_c - 10$

$20 = 2K \times 4.65 + V_{EC} + 1K \times 4.604$

$V_{EC} = 6.096$ V

$V_{EC} > 0.2$ V

∴ Our assumption is correct transistor is in Active region.

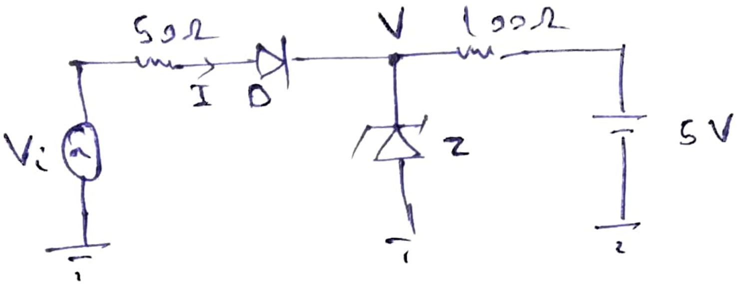
$$\boxed{\begin{array}{l} I_E = 4.65 \text{ mA} \\ I_B = 46.04\ \mu\text{A} \\ I_c = 4.604 \text{ mA} \end{array}}$$

$$\boxed{\begin{array}{l} V_B = 0\text{ V} \\ V_E = 0.7\text{ V} \end{array}}$$

$V_c = 4.604 \times 1K - 10$

$\boxed{V_c = -5.396\text{ V}}$

2a(ii)



Assuming D → ON , Z → OFF

$I = \frac{V_i - 5}{150}$, $V = 5 + 100 \times I$

So if $I > 0$, $V > 5V$ which will turn on the Zener diode and current through 100 Ω Resistor will become Zero.

as $V_Z = 5$

$I = \frac{V_Z - 5}{100} = \frac{5-5}{100} = 0\ A$

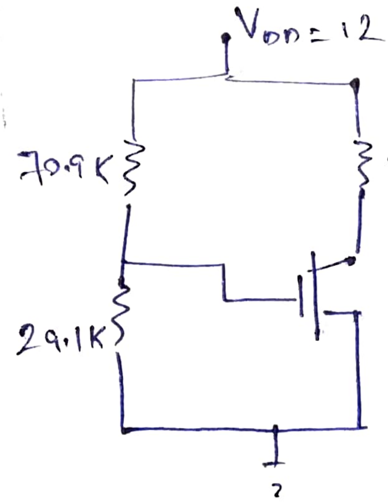
So, Power will be dissipiated in 100Ω resistor when Z → OFF and D → ON and ~~Vi is~~. $V_i < 5$

But when $V_i < 5$, this will make diode 'D' reverse bias so current will not flow

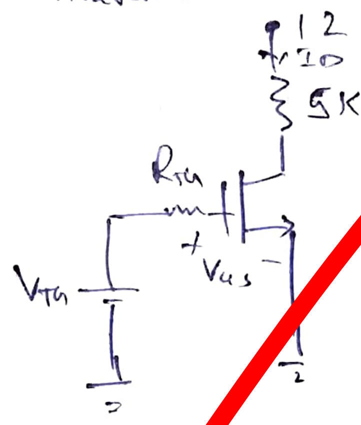
∴ $\boxed{\text{Power dissipiated in 100Ω resistor is Zero watts}}$

2(b) **Dc Analysis**

Opening all Capacitors [C_c]



$\Rightarrow$ using thevenin theorem



$$V_{TH} = \frac{12 \times 29.1\,K}{70.9K + 29.1\,K} = 3.492\,V$$

$$R_{TH} = 70.9K \parallel 29.1K = 20.6319\,K\Omega$$

As $I \approx 0$ $\therefore$ $\cancel{V_{TH}}$ $V_{GS} = V_{TH} = 3.492\,V$

$$I_D = K_n (V_{GS} - V_t)^2$$

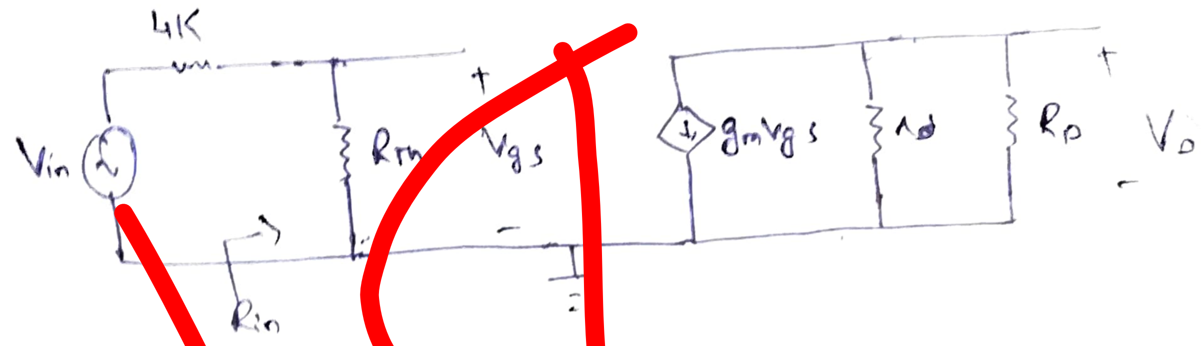
$$= 0.5 \times (3.492 - 1.5)^2 = 1.984\,mA$$

$$r_d = \frac{1}{\lambda \cdot I_D} = \frac{1}{0.01 \times 1.984} = 54.4\,K\Omega$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = 2K_n [V_{GS} - V_t] \times 1$$

$$= 2 \times 0.5 [3.492 - 1.5) = 1.992\,mS$$

AC equivalent circuit



$$V_{gs} = \frac{V_{in} \times R_{Th}}{R_{Th} + 4K} = \frac{V_{in} \times 20.6319\,K}{20.6319\,K + 4K}$$

$$V_{in} = 1.194\, V_{gs}$$

$$V_o = -g_m V_{gs} [r_d \,||\, R_D]$$

$$= -1.992\, [54.4 \,||\, 5]\, V_{gs} = -9.12\, V_{gs}$$

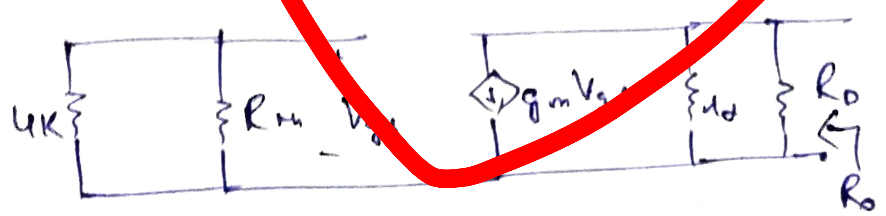
$$A_v = \frac{V_o}{V_{in}} = \frac{-9.12\, V_{gs}}{1.194\, V_{gs}}$$

$$\boxed{A_v = -7.64}$$

By seeing the circuit

$$\boxed{R_{in} = R_{Th} = 20.6319\, K\Omega}$$

For output resistance (R_o)

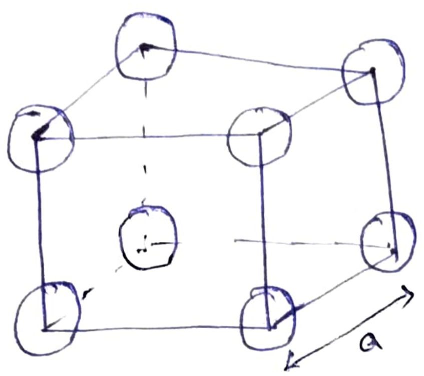


$V_{gs} = 0$ ∴ Current source gets open circuit

$$\therefore R_o = r_d \,||\, R_D = [54.4 \,||\, 5]\, K\Omega$$

$$\boxed{R_o = 4.58\, K\Omega}$$

2.(c) (i) Simple cube



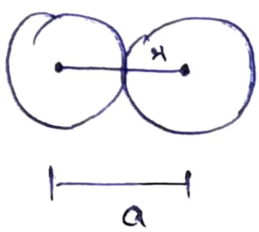
number of atoms

$= \frac{1}{8} \times 8 = 1$ atom

Let radius of each atom be 'r'

and edge length of lattice be 'a'

Here



$a = 2r \Rightarrow \boxed{r = \frac{a}{2}}$

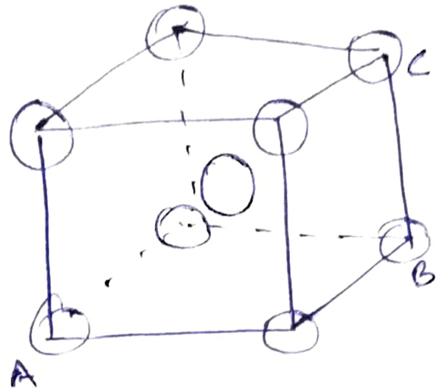
APF (atomic Packing factor) = $\frac{\text{Volume of atoms/cell}}{\text{Volume of cell}}$

$= \frac{\text{no. of atom} \times \text{volume of 1 atom}}{\text{Volume of cell}}$

$= \frac{1 \times \frac{4}{3}\pi r^3}{a^3} = \frac{\frac{4}{3}\pi \left(\frac{a}{2}\right)^3}{a^3}$

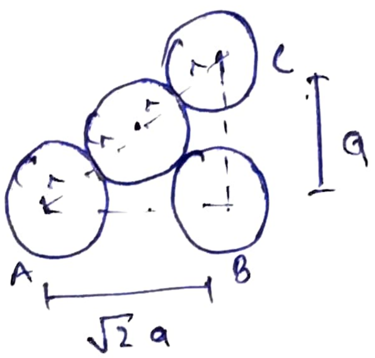
$$\boxed{\begin{aligned} APF &= 0.5236 \\ &= 52.36\% \end{aligned}}$$

(ii) Body Centred Cube



$$\text{no. of atoms} = \frac{1}{8} \times 8 + 1$$

$$n = 2 \text{ atoms}$$



Here

$$(4r)^2 = (\sqrt{2}a)^2 + a^2$$

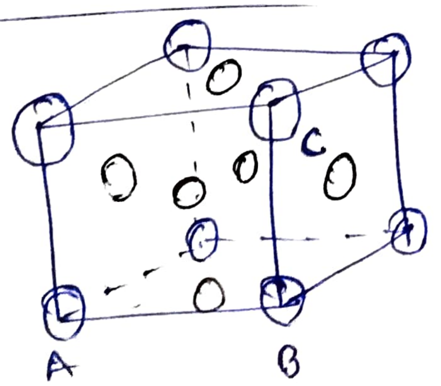
$$16r^2 = 3a^2$$

$$\boxed{r = \frac{\sqrt{3}}{4} a}$$

$$APF = \frac{2 \times \frac{4}{3}\pi r^3}{a^3} = \frac{2 \times \frac{4}{3}\pi \left(\frac{\sqrt{3}}{4}\right)^3 \times a^3}{a^3}$$

$$\boxed{\begin{aligned} APF &= 0.6801 \\ &= 68.01\% \end{aligned}}$$

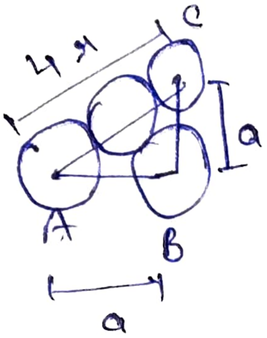
(iii) Face Centred Cube



number of atoms

$$= \frac{1}{8} \times 8 + \frac{1}{2} \times 6$$

$$n = 4 \text{ atoms}$$



Here

$(4r)^2 = a^2 + a^2$

$16r^2 = 2a^2$

$$\boxed{r = \frac{a}{2\sqrt{2}}}$$

$$APF = \frac{n \times \frac{4}{3}\pi r^3}{a^3} = \frac{4 \times \frac{4}{3}\pi \times \left(\frac{1}{2\sqrt{2}}\right)^3 \times a^3}{a^3}$$

$$\boxed{\begin{aligned} APF &= 0.7405 \\ &= 74.05\% \end{aligned}}$$

(iv) Diamond Cube.

For this $r = \frac{\sqrt{3}}{8} a$

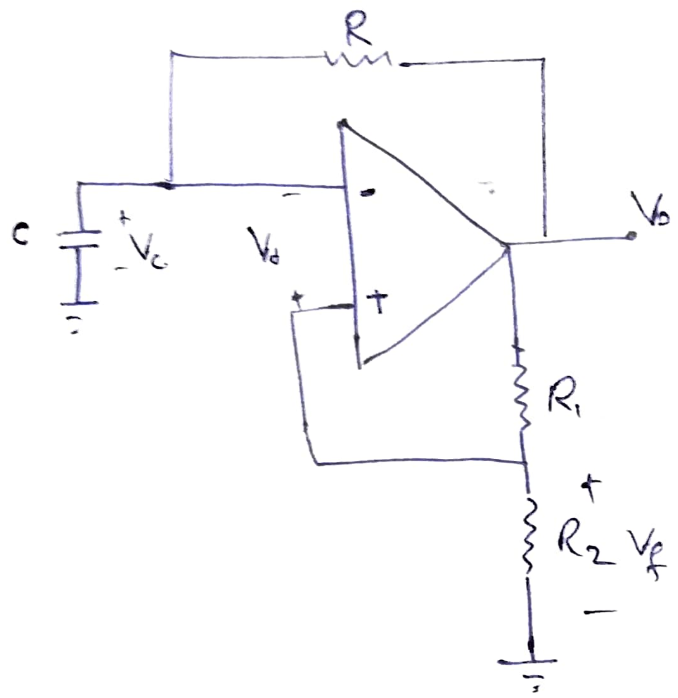
number of atoms $(n) = 8$

$$APF = \frac{n \times \frac{4}{3}\pi r^3}{a^3} = \frac{8 \times \frac{4}{3}\pi \times \left(\frac{\sqrt{3}}{8}\right)^3 \times a^3}{a^3}$$

$$\boxed{\begin{aligned} APF &= 0.34 \\ &= 34\% \end{aligned}}$$

3(a)

Astable Multivibrator



Assume $V_o = +V_{sat}$

$$V_f = V_o\left(\frac{R_2}{R_1+R_2}\right) = \beta V_o = \beta V_{sat} \quad \left[\beta = \frac{R_2}{R_1+R_2}\right]$$

and during this Capacitor starts charging through ~~Vc~~ R

$$V_d = V_f - V_c$$

When V_c reaches $+\beta V_{sat}$, V_d becomes negative

and then $V_o = -V_{sat}$

$$V_f = -V_{sat} \times \left(\frac{R_2}{R_1+R_2}\right) = -\beta V_{sat}$$

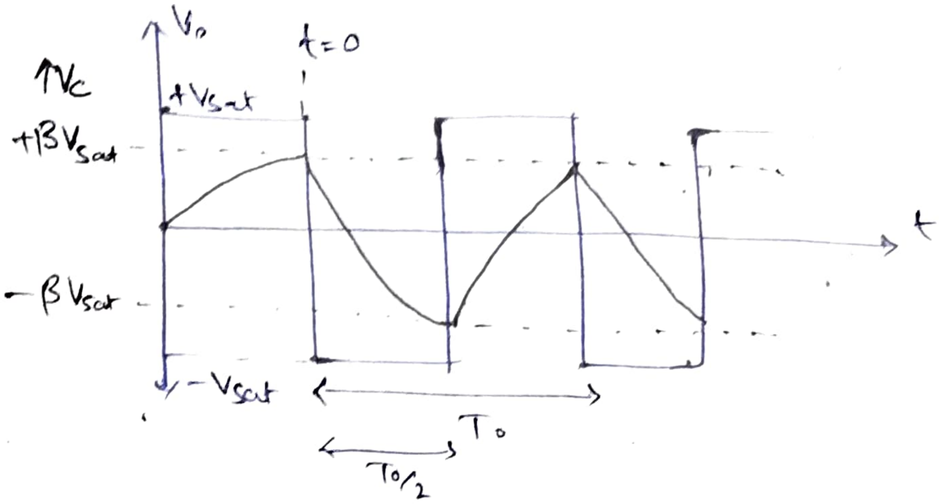
and Capacitor Starts discharging through R

$$V_d = V_f - V_c = \cancel{V_c + \beta V_{sat}}$$

When V_c becomes $-\beta V_{sat}$

V_d becomes ~~negative~~ Positive

and V_o becomes $V_o = +V_{sat}$
and the cycle repeats.



For $\underline{t>0}$

$$V_c = -V_{sat} + \left[\beta V_{sat} + V_{sat}\right] e^{-t/\tau} \qquad [\tau = RC]$$

At $t = T_o/2$

$$V_c = -\beta V_{sat}$$

$$-\beta V_{sat} = -V_{sat} + \left[\beta V_{sat} + V_{sat}\right] e^{-\frac{T_o}{2\tau}}$$

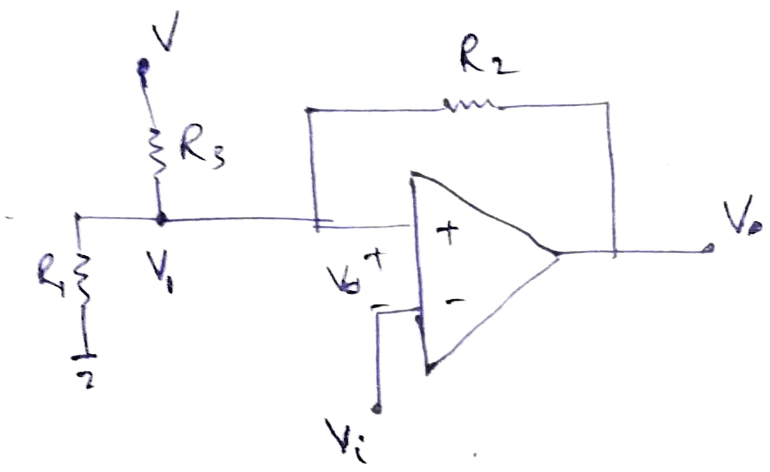
$$1-\beta = (1+\beta)\, e^{-T_o/2\tau}$$

Taking natural log on both sides

$$\ln\left(\frac{1-\beta}{1+\beta}\right) = -\left[\frac{T_o}{2\tau}\right] \Rightarrow T_o = 2\tau \ln\left(\frac{1+\beta}{1-\beta}\right)$$

$$\boxed{T_o = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)}$$

3.(b)



Applying KCL at V_1

$$\frac{V_1-V}{R_3}+\frac{V_1}{R_1}+\frac{V_1-V_o}{R_2}=0$$

$$V_1\left[\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right]=\frac{V_o}{R_2}+\frac{V}{R_3}$$

$$V_1=\frac{V_oR_3+VR_2}{R_2R_3}\times\frac{[R_1R_2R_3]}{R_2R_3+R_1R_2+R_1R_3}$$

$$V_1=\frac{V_oR_1R_3+VR_1R_2}{R_1R_2+R_2R_3+R_1R_3}$$

Now, Assume $V_o = V^+$

Now,

$$V_d = V_1 - V_i$$

When $V_i < V_1$ $\quad V_d = +V_e$

& V_o stays at V^+

When $V_i > V_1$ $\Rightarrow$ V_d becomes negative

$$V_o = V^-$$

$$\therefore \boxed{V_{TH}=\frac{V^+R_1R_3+VR_1R_2}{R_1R_2+R_2R_3+R_3R_1}}$$

3(b) Assuming $V_o = V^-$

$$V_1 = \frac{V^- R_1 R_3 + V R_1 R_2}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

$$V_d = V_1 - V_i$$

when $V_i < V_1 \Rightarrow V_o \Rightarrow$ negative

$$V_o = V^-$$

Now when $V_i > V_1 \Rightarrow V_d \Rightarrow$ Positive

$$V_o = V^+$$

$$V_{TL} = V_1$$

$$\Rightarrow \boxed{V_{TL} = \frac{V^- R_1 R_3 + V R_1 R_2}{R_1 R_2 + R_2 R_3 + R_3 R_1}}$$

(ii) $V_{TL} = 4.9\,V$, $V_{TH} = 5.1\,V$

$$V_{TH} = \frac{13 \times 10K\, R_3 + 15 \times 10K\, R_2}{10K\, R_2 + R_2 R_3 + 10K\, R_3} = 5.1$$

$$130 R_3 + 150 R_2 - 51 R_2 - 51 R_3 = 5.1 R_2 R_3$$

$$99 R_2 + 79 R_3 = 5.1 R_2 R_3 \quad \text{— (1)}$$

$$V_{TL} = \frac{-13 \times 10K\, R_3 + 15 \times 10K\, R_2}{10K\, R_2 + R_2 R_3 + 10K\, R_3} = 4.9$$

$$101 R_2 - 179 R_3 = 4.9 R_2 R_3 \quad \text{— (2)}$$

Solving (1) & (2)

$$\boxed{R_3 = \frac{257}{13} K\Omega = 19.77 K\Omega}$$

$$\boxed{R_2 = \frac{2570}{3} K\Omega \quad R_2 = 856.67 K\Omega}$$

3.(c) Crystal Imperfections

→ A crystal is formed ~~a~~ when a unit cell is repeated such that every unit cell is surrounded by unit cells which same as that of other unit cell and atoms are present on its lattice sites. But some times the position of atoms are dislocated from their natural or normal position which creates imperfection in crystal and this is known as crystal imperfections.

These are classified on the basis of dimensions

(i) Point defect [0-D]

(ii) Line defect [1-D]

(iii) Surface defect [2-D]

(iv) Volumetric defect [3-D]

Point defect is due to the two types of missing of an atom from its lattice site.

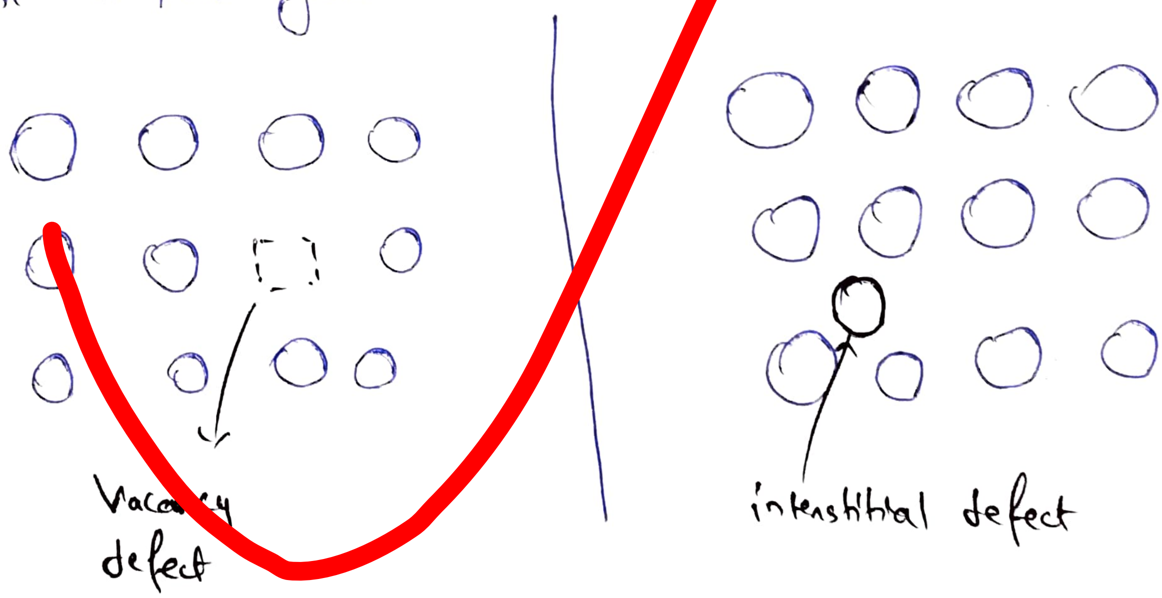
(a) when ~~—~~ the atom is not present in crystal creating a void or vaccancy is known as Vacancy defect.

(b) when the atom is present in crystal but not at its original position. This is known as interstitial defect.

→ if these two defect occur in ionic crystal i.e, both cation and anion are not present in crystal then it is known as Schottky defect.

→ If cation is present ~~but~~ in between small spacing instead of its original position then it is known as Frenkel defect.

→ These defects general occur alkali halides.



Line defect

→ Edge dislocation & Screw dislocation

→ When extra half plane of atoms inserted into the crystal lattice. This will increase the plasticity in material. This is known as Edge dislocation.

When one Part of Crystal is shifted relative to other Part is known as ~~Crystal~~ Screw dislocation.

Surface defects may rise at boundary ~~of~~ ~~between~~ two grains i.e, small Crystals in large crystal. This may cause the rows ~~into~~ of atoms may run in slightly different directions.

Volumetric defect:

These are 3D defect occur such as pores, cracks. This may occur due to cluster of vaccancies created in Crystal, or cluster of impurities Present inside the Crystal.

5(a)

$m = 8$ $N_r = 6$

(i) Step size $(\alpha) = \frac{360^\circ}{m \times N_r} = \frac{360^\circ}{6 \times 8}$

$$\boxed{\alpha = 7.5^\circ}$$

(ii) In one revolution $\Rightarrow$ $\theta = 360^\circ$

number of step $= \frac{360^\circ}{\alpha} = \frac{360^\circ}{7.5^\circ}$

$$\boxed{\text{Step/revolution} = 48}$$

(iii) As $f = 120\,Hz$

~~In rotation completes~~

Steps/second $= \frac{f}{\text{Step/revolution}} = \frac{120}{48} = 2.5$

Speed $= 2.5 \times 60 = 150$ rpm

$$\boxed{N = 150\,rpm}$$

5.(b)

(i)

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{2} = 3000 \text{ rpm}$$

$$N = 2950 \text{ rpm}$$

$$S = \frac{N_s - N}{N_s} = \frac{3000 - 2950}{3000}$$

$$\boxed{\begin{aligned} S &= 0.0167 \text{ pu} \\ &= 1.67\% \end{aligned}}$$

(ii)

$$P_{out} = (1-S) \cdot P_g = 15 \text{ kW}$$

$$P_g = \frac{15 \times 10^3}{1 - 0.0167} = 15.254 \text{ kW}$$

$$\text{Torque } (T) = \frac{P_g}{\omega_s} = \frac{15.254 \times 10^3 \times 60}{2\pi \times 3000}$$

$$\boxed{T = 48.555 \text{ Nm}}$$

(iii)

Now when Torque is doubled.

$$T = 48.555 \times 2 = 97.11 \text{ Nm}$$

$$\cancel{97.11 = \frac{15.254 \times 10^3 \times 60}{\omega}} \qquad \left[T = \frac{P_g}{\omega}\right]$$

~~Assuming Constant load the speed becomes~~

$$\cancel{T \propto \frac{P_g}{\omega}}$$

~~So, doubling the torque, Speed becomes half~~

$$\cancel{\therefore N = \frac{2950}{2} \Rightarrow N = 1475}$$

5(b)(iii)

$T = 97.11$

$T \propto \frac{s V^2}{R_2 f}$

So for doubling the torque,

Slip double, $\therefore S = 2 \times \frac{1}{60} = \frac{1}{30} = 0.033$

Speed $= N = N_s(1-s) = 3000 \times \left(1 - \frac{1}{30}\right)$

$\boxed{N = 2900 \text{ rpm}}$

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(iv)

$P_{out} = P_g\,[1 - s]$

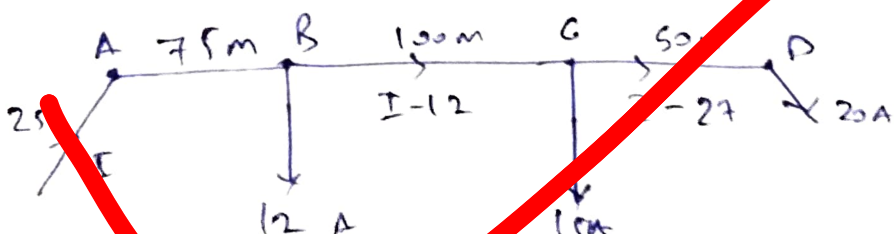
$= 15.254 \times 10^3 \left[1 - \frac{1}{30}\right]$

$\boxed{P_{out} = 14.74 \text{ KW}}$

5.(c)

$r = \frac{\rho l}{A} = \frac{1.78 \times 10^{-6} \times 10^{-2} \times 1}{0.27 \times 10^{-4}}$

$r' = 6.5926 \times 10^{-4}\ \Omega/m$



$I - 27 = 20\text{ A} \Rightarrow \underline{I = 47\text{ A}}$

(i) Current in Section AB $\Rightarrow$ 47 A

Current in Section BC $\Rightarrow$ 47−12 = 35 A

Current in Section CD $\Rightarrow$ 20 A

(ii) Two Core resistance = $2r' = 2 \times 6.5926 \times 10^{-4}$

$= 1.318 \; m\Omega/m$

(iii) $V_B = V_A - I \times (2r') \times 75$

$= 250 - 47 \times 1.318 \times 10^{-3} \times 75$

$\boxed{V_B = 245.354 \; V}$

$V_C = V_B - 35 \times (2r') \times 100$

$= 245.354 - 35 \times 1.318 \times 10^{-3} \times 100$

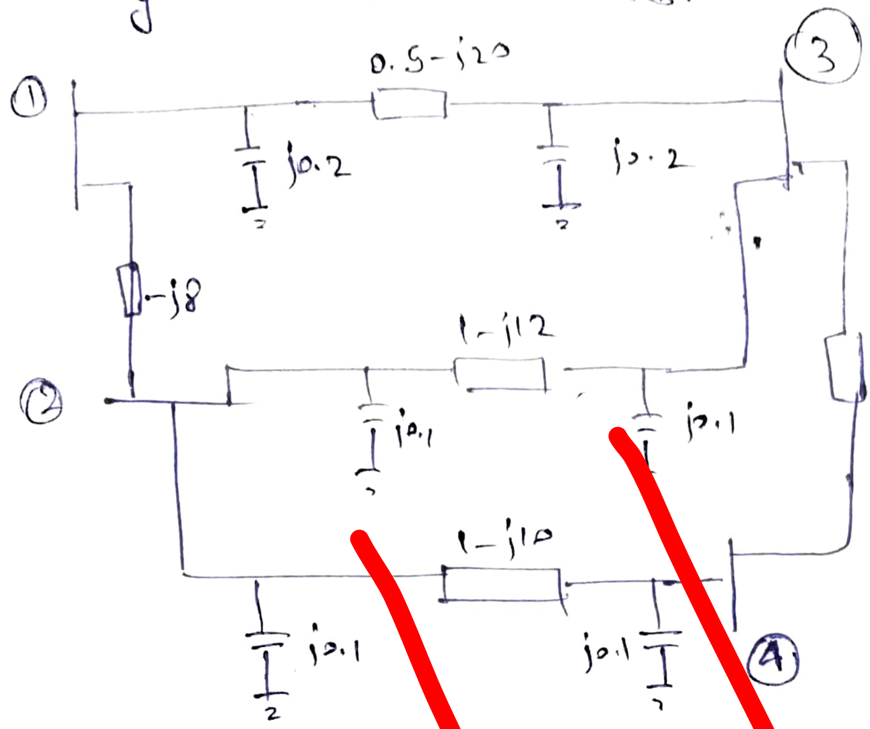
$\boxed{V_C = 240.74 \; V}$

$V_D = V_C - 20 \times (2r') \times 50$

$= 240.74 - 20 \times 1.318 \times 10^{-3} \times 50$

$\boxed{V_D = 239.423 \; V}$

5(d) Deactivating all active sources.



Total admittance at bus ①

$Y_{11} = -j8 + j0.2 + 0.5 - j20 = 0.5 - j27.8$

at bus ②

$Y_{22} = -j8 + j0.1 + j0.1 + 1 - j12 + 1 - j10 = 2 - j29.8$

at bus ③

$Y_{33} = 0.5 - j20 + j0.2 + j0.1 + 1 - j12 - j8 = 1.5 - j39.7$

at bus ④

$Y_{44} = 1 - j10 + j0.1 - j8 = 1 - j17.9$

$$[Y]_{Bus} = \begin{bmatrix} 0.5-j27.8 & j8 & -0.5+j20 & 0 \\ j8 & 2-j29.8 & -1+j12 & -1+j10 \\ -0.5+j20 & -1+j12 & 1.5-j39.7 & j8 \\ 0 & -1+j10 & j8 & 1.5-j39.7 \end{bmatrix}$$

→ Bus admittance matrix

5(e)

Overhead System	Underground System
→ This System is suitable for every condition, i.e., for short transmission or long transmission but prefered for long transmission	→ only Prefered for short transmission, due to high cost increment as length of underground Cable increases.
→ less Problem of leakage Current	→ More leakage Current when length increases
→ Insulation Cost is lesser in this System as overhead line does not have insulation	→ High insulation Cost as it has to stay underground and may be affected in underground condition & may leakage happens making Undesirable Condition
→ makes the System look Complex and untidy	→ make the System look beautiful as all the wiring is Under ground
→ Overhead line Produces hissing noise	→ Underground line are Silent.
→ This is less Safe as fault may occur more frequently as it is in Contact with Surroundings.	→ This is more Safe in terms of fault

Overhead line	Underground line
→ Require space to erect the poles for transmission line and Right of way is also considered	→ ~~[illegible]~~ As it is underground so there is less problem of space requirement
→ Fault detection is easier in this system	→ Fault detection is ~~complex~~ difficult in underground system as it is not visible directly.
→ Prefered for High Voltage transmission	→ Cannot be used for High Voltage transmission
→ efficiency of this System is higher (generally)	→ lower efficiency of the lines.

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8.(a) For Economic load Power dispatch the increment fuel cost of all plants must be equal.

$$\therefore \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4$$

$$0.012 P_{g_1} + 9 = 0.0096 P_{g_2} + 6 = 0.008 P_{g_3} + 8$$
$$= 0.0068 P_{g_4} + 10 \quad -(1)$$

Also, $P_{g_1} + P_{g_2} + P_{g_3} + P_{g_4} = 800 \text{ MW} \quad -(2)$

Using (1)

$$0.012 P_{g_1} + 9 - 0.0096 P_{g_2} - 6 = 0$$

$$\Rightarrow P_{g_2} = \frac{1}{0.0096}\left[0.012 P_{g_1} + 3\right] \quad -(3)$$

$$P_{g_3} = \frac{1}{0.008}\left[0.012 P_{g_1} + 1\right] \quad -(4)$$

$$P_{g_4} = \frac{1}{0.0068}\left[0.012 P_{g_1} - 1\right] \quad -(5)$$

Using (3) (4) & (5) in (2)

$$P_{g_1}\left[1 + \frac{0.012}{0.0096} + \frac{0.012}{0.008} + \frac{0.012}{0.0068}\right] + \frac{3}{0.0096} + \frac{1}{0.008} - \frac{1}{0.0068} = 800$$

$$5.5147 P_{g_1} = 509.56$$

$$\boxed{P_{g_1} = 92.4 \text{ MW}}$$

$$P_{g2} = \frac{1}{0.0096}\left[0.012 \times 92.4 + 3\right] = 428 \text{ MW}$$

$$P_{g2} = 428 \text{ MW}$$

$$P_{g3} = \frac{1}{0.008}\left[0.012 \times 92.4 + 1\right] = 263.6 \text{ MW}$$

$$P_{g4} = \frac{1}{0.0068}\left[0.012 \times 92.4 - 1\right] = 16 \text{ MW}$$

$\boxed{P_{g2} = 428 \text{ MW}}$ $\boxed{P_{g3} = 263.6 \text{ MW}}$

$\boxed{P_{g4} = 16 \text{ MW}}$

$$\lambda = 0.012 \times P_{g1} + 9 = 0.012 \times 92.4 + 9$$

$\boxed{\lambda = 10.1088 \text{ dollar/MWh}}$

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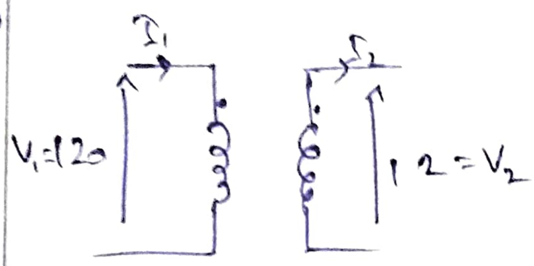
8.(b)

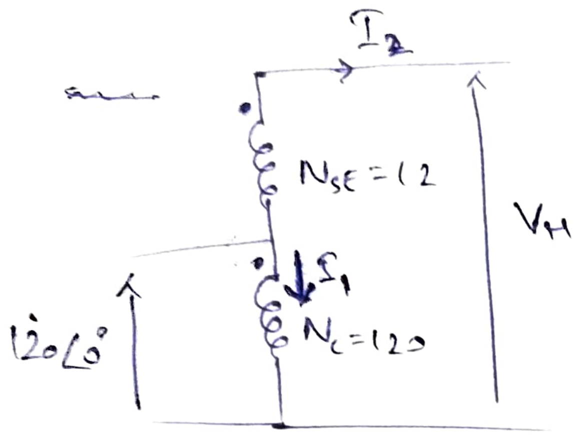


$I_1 = \frac{S}{V_1} = \frac{100}{120}$ A

$I_2 = \frac{S}{V_2} = \frac{100}{12}$ A

$\Downarrow$

(i)



$V_H = 120 + 12$

$\boxed{V_H = 132 \angle 0^\circ}$ ✓

$\downarrow$

Secondary voltage of transformer.

(ii) maximum VA rating in the mode

$S_{auto} = V_H \, I_2$

$= 132 \times \frac{100}{12} = 1100$ VA

$\boxed{S_{auto} = 1100 \text{ VA}}$

(iii)

$S_{2wdg} = 100$ VA

$S_{auto} = 1100$ VA

$\therefore$ advantage in VA $= S_{auto} - S_{2wdg}$
($S_{conductive}$)

$$\boxed{\begin{aligned} S_{conductive} &= 1100 - 100 \\ &= 1000 \text{ VA} \end{aligned}$$

8(c)

$P_{in} = \sqrt{3} \times V_L \times I_L \times \cos\phi$

$= \sqrt{3} \times 480 \times 60 \times 0.85 = 42400.6$ watts.

$= 42.4$ KW

Statorlosses = Coreloss + Stator Culoss

$= 1800 + 2000 = 3800$ W $= 3.8$ KW

(i) $P_{AG} = P_{in} -$ Stator loss $= 42.4 - 3.8$

$\boxed{P_{AG} = 38.6 \text{ KW}}$

(ii) P_{conv} $P_{AG} -$ Rotor Culoss $= 38.6 - 0.7$

$\boxed{P_{conv} = 37.9 \text{ KW}}$

(iii) $P_{out} = P_{conv} -$ ~~fw~~ friction and windage loss

$= 37.9 - 0.6$

$\boxed{P_{out} = 37.3 \text{ KW}}$

(iv) $\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{37.3}{42.4} \times 100$

$\boxed{\eta = 87.97 \%}$

8.(d)

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

$$S_m = \frac{N_s - N}{N_s} = \frac{1000 - 875}{1000} = 0.125 \text{ pu}$$

Slip at maximum torque,

(i)

$$\frac{T}{T_{max}} = \frac{2 S S_m}{S_m^2 + S^2}$$

$$\frac{T}{10} = \frac{2 \times 0.05 \times 0.125}{(0.05)^2 + (0.125)^2} = \frac{20}{29}$$

$$\text{Torque } (T) = \frac{20}{29} \times 10$$

$$\boxed{T = 6.896 \text{ Nm}}$$

(ii)

$$\frac{T_{st.}}{T_{max}} = \frac{2 S_m}{S_m^2 + 1}$$

When external resistance is added S_m is changed.

given $T_{st.} = 60\% \ T_{max} = 0.6 T_{max}$.

$$\frac{0.6 T_{max.}}{T_{max}} = \frac{2 S_m}{S_m^2 + 1} \Rightarrow 0.6 S_m^2 - 2 S_m + 0.6 = 0$$

$\underbrace{S_m = 3}_{\times \text{ neglected}}$ $\quad\quad$ $S_m = \frac{1}{3}$ ✓

$S_{m_1} = 0.125$ $\qquad$ $S_{m_2} = \frac{1}{3}$

$$S_{m_1} = \frac{R_2'}{X_2'} \Rightarrow X_2' = \frac{0.25}{0.125} = 2\,\Omega$$

$$S_{m_2} = \frac{[R_2' + R_{ext}]}{X_2'} \Rightarrow \frac{1}{3} = \frac{0.25 + R_{ext}}{2}$$

$$\boxed{R_{ext.} = 0.4167\,\Omega}$$

if we choose

$S_{m_2} = 3$

then

$$3 = \frac{[R_2' + R_{ext.}]}{2} \Rightarrow R_{ext} = 6 - 0.25$$

$$\boxed{R_{ext.} = 5.75\,\Omega}$$

as Here $S_{m_2} = 3$ which is ~~in the~~ the ~~fa~~ plugging region, not desirable to get maximum torque at this slip

So,

$R_{ext.} = 0.4167\,\Omega$ is selected to get 60% of max. torque at starting