1.(a) (i)

$x_a(t) = 3\cos 100\pi t$

$\omega_m = 100\pi \Rightarrow f_m = \frac{\omega_m}{2\pi} = 50\,Hz$

for avoiding aliasing effecting

Sampling rate $f_s \geq 2 f_m$

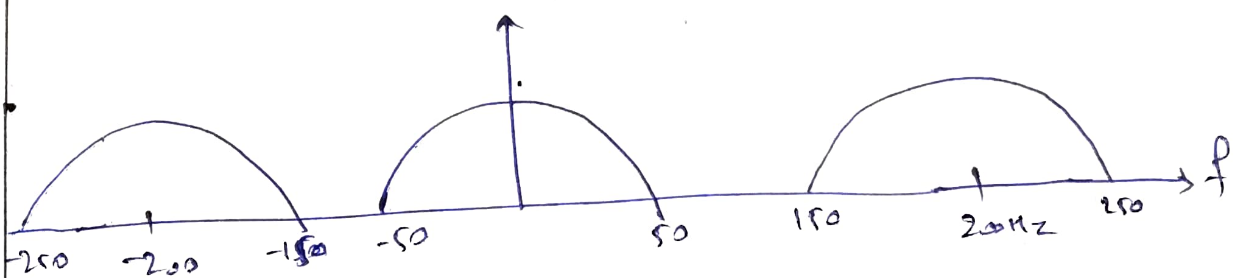
$\therefore f_{s\,min} = 2 f_m \Rightarrow \boxed{f_{s\,min} = 2 \times 50 = 100\,Hz}$

(ii) $F_s = 200\,Hz$

$x_a(t) = 3\cos 100\pi t$

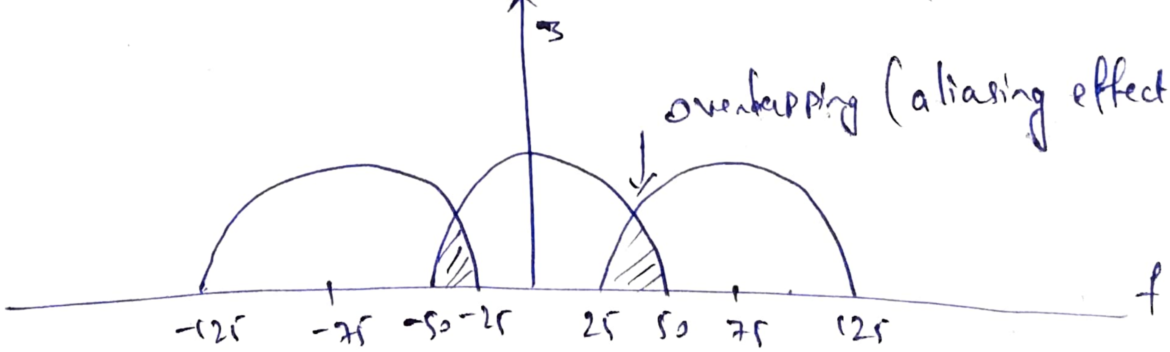
$x_a(nT) = 3\cos[100\pi nT] = 3\cos(\frac{n\pi}{2})$ } No aliasing effect

now sampling at $F_s = 200\,Hz$ as $F_s > F_{s\,min}$.



(iii) Now at $F_s = 75\,Hz$

$x_a(nT) = 3\cos(100 n\pi T) = 3\cos\left(\frac{4n\pi}{3}\right)$



as $F_s < F_{s\,min}$.

$x_a(nT) = 3\cos\left(2\pi - \frac{2\pi}{3}\right)n = \boxed{3\cos\frac{2\pi}{3}n}$

1. a(iv) To get the samples as in Part (iii), there should be again aliasing effect

therefore, $F = f\,F_s = f\,75$

$f = \frac{1}{3}$ in Part(iii)

$\Rightarrow \therefore F = \frac{75}{3} \Rightarrow \boxed{F = 25\,Hz}$

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1. (b) $x(n) = \{0, 1, 2, 3\}$

$X(K) = [W_N][x_n]$

$$\begin{bmatrix} X(0) \\ X(1) \\ X(2) \\ X(3) \end{bmatrix} = \begin{bmatrix} & & \\ & W_4 & \\ & & \end{bmatrix} \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ x(3) \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 2 \\ 3 \end{bmatrix} = \begin{bmatrix} 0+1+2+3 \\ 0-j-2+j3 \\ 0-1+2-3 \\ 0+j-2-j3 \end{bmatrix}$$

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$$\begin{bmatrix} X(0) \\ X(1) \\ X(2) \\ X(3) \end{bmatrix} = \begin{bmatrix} 6 \\ -2+j2 \\ -2 \\ -2-j2 \end{bmatrix}$$

$$\boxed{X(K) = [6, -2+j2, -2, -2-j2]}$$

1(c)

$$T = \frac{1}{2} I^2 \frac{dL}{d\theta} = K\theta$$

for $I = 1.5\,A$, $\theta = 90° = \pi/2$

$$\frac{1}{2} \times (1.5)^2 \times \frac{d}{d\theta}\left[200 + 40\theta + 4\theta^2 - \theta^3\right] \times 10^{-6} = K\theta$$

$$\frac{1}{2} \times 2.25 \times \left[40 + 8\theta - 3\theta^2\right] \times 10^{-6} = K\theta$$

$$\frac{1}{2} \times 2.25 \times \left[40 - 8 \times \frac{\pi}{2} - 3 \times \left(\frac{\pi}{2}\right)^2\right] \times 10^{-6} = K \times \frac{\pi}{2}$$

$$K = 14.346 \times 10^{-6}\ Nm/rad.$$

Now for $I = 1A$,

$$\frac{1}{2} \times 1^2 \times \frac{d}{d\theta}\left[200 + 40\theta - 4\theta^2 - \theta^3\right] \times 10^{-6} = 14.346 \times 10^{-6} \times \theta$$

$$\frac{1}{2} \times \left[40 - 8\theta - 3\theta^2\right] = 14.346\,\theta$$

$$\Rightarrow 3\theta^2 + [8 + 28.6924]\theta - 40 = 0$$

$\boxed{\theta = 1.007\ \text{radian}}$ [ignoring negative value]

$\boxed{\theta = 57.697°}$

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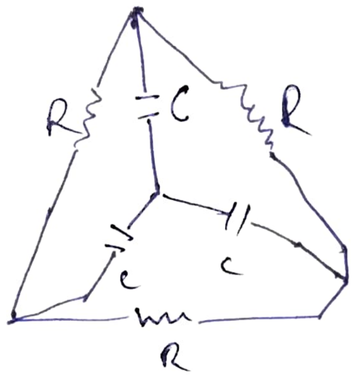
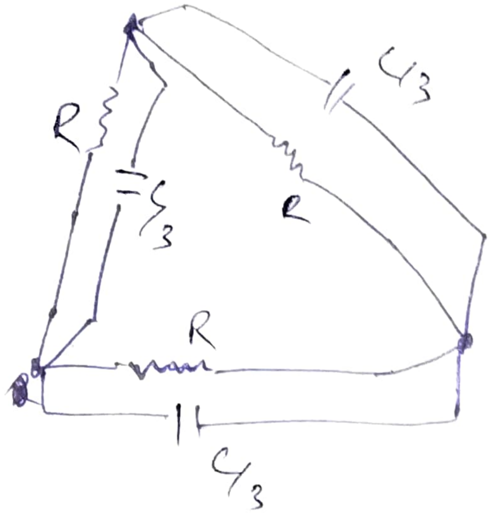
1(d)

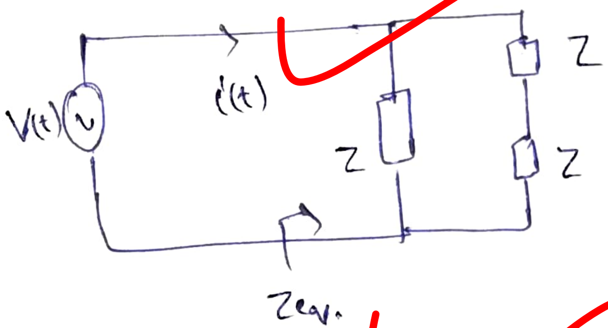


⇒



$$Z = \left[R \parallel \frac{1}{j\omega C/3}\right] = \left[1000 \parallel \frac{3}{j1000\times 10^{-6}}\right]$$

$$= (900 - j\,300)\,\Omega$$



$$Z_{eq.} = 2Z \parallel Z$$

$$= 2(900-300j) \parallel (900-j300)$$

$$= 600 - j200$$

$$i(t) = \frac{V(t)}{Z_{eq.}} = \frac{2\sin 1000t}{600-j200}$$

$$\boxed{i(t) = 3.162\sin[1000t + 18.435^\circ]\ \text{mA}}$$

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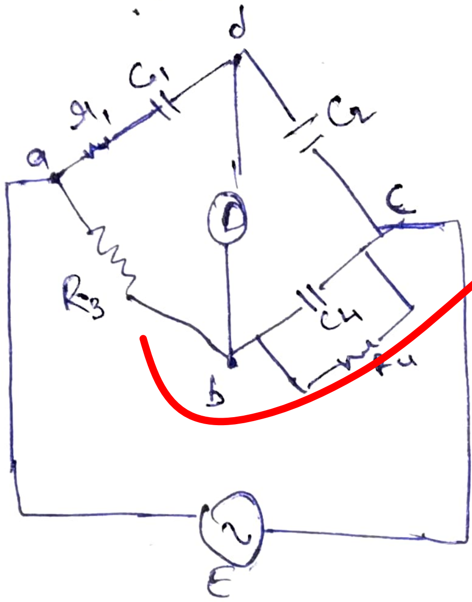
1.(e) Schering bridge.



To obtain balance

$$\left[r_1 + \frac{1}{j\omega C_1}\right] \times \left[\frac{R_4 \times \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}}\right] = \left[\frac{1}{j\omega C_2} \times R_3\right]$$

$$\left[r_1 + \frac{1}{j\omega C_1}\right] \frac{R_4}{C_4} = \frac{R_3}{C_2}\left(R_4 + \frac{1}{j\omega C_4}\right)$$

Comparing Real and imaginary parts.

$$r_1 \frac{R_4}{C_4} = \frac{R_3 R_4}{C_2}$$

$$\Rightarrow \boxed{r_1 = R_3 \frac{C_4}{C_2}}$$

$$\frac{R_4}{C_1 C_4} = \frac{R_3}{C_2 C_4}$$

$$\boxed{C_1 = \frac{R_4 C_2}{R_3}}$$

$$C_1 = \frac{1000}{\pi \times 260} \times 106 \text{ pF}$$

$$\boxed{C_1 = 129.77 \text{ pF}}$$

Dissipation factor $(\tan\delta) = \omega r_1 C_1 = 2\pi f \times \frac{R_3 C_4}{C_2} \times \frac{R_4 C_2}{R_3}$
D

$$= 2\pi f \times R_4 C_4$$

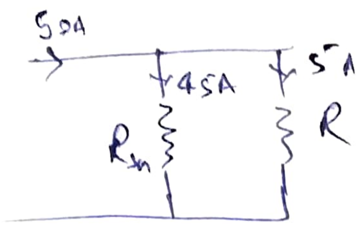
$$= 2 \times \pi \times 50 \times \frac{1000}{\pi} \times 0.5 \times 10^{-6}$$

$$\boxed{D = \tan\delta = 0.05}$$

$$C_1 = \frac{\varepsilon_0 \varepsilon_r A}{t} = \frac{8.854\times10^{-12} \times \varepsilon_r \times \pi \times 0.12^2}{4.5\times10^{-3} \times 4} = 129.77\times10^{-12}$$

$$\boxed{\varepsilon_r = 5.83}$$

3(a)(i) ON DC, Inductor behaves as short circuit so, L can be neglected on dc

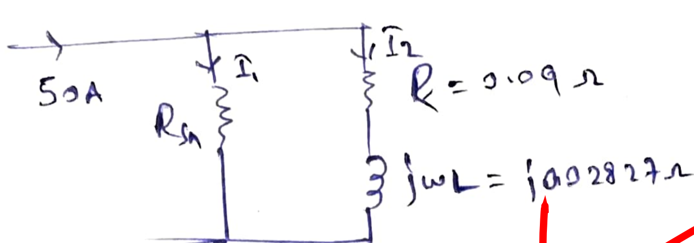


$\therefore \quad 45 \times R_{sh} = 5 \times R$

$$R_{sh} = \frac{5 \times 0.09}{45}$$

$\boxed{R_{sh} = 0.01\,\Omega}$ → shunt resistance to extend the range,

Now on AC, f = 50Hz



Using Current division Rule,

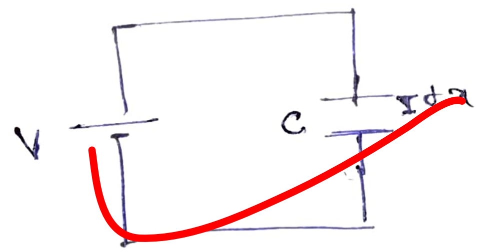
$$I_2 = 50 \times \frac{R_{sh}}{R_{sh} + R + j\omega L} = 50 \times \frac{0.01}{0.01 + 0.09 + j0.028274}$$

$$= 4.811 \angle -15.78$$

$$\%\ \text{error} = \frac{I_{measure} - I_{true}}{I_{true}} \times 100 = \frac{4.811 - 5}{5} \times 100$$

$$\boxed{\%\ \text{error} = -3.78\ \%}$$

(ii) Considering an Electrostatic instrument



in this Capacitor one plate can be move to change the capacitance, and for that some force will be applied ~~by~~

so, here capacitance is variable with respect to distance between plates 'x'.

Let ~~charge~~ Energy stored by capacitor $= \frac{1}{2} C V^2$

As we know

$$F = \frac{dW}{dx}$$

$$F = \frac{d}{dx}\left(\frac{1}{2} C V^2\right)$$

$$\boxed{F = \frac{1}{2} V^2 \frac{dC}{dx}}$$ → expression of force developed by an electrostatic instrument.

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3.(b)

$$x(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + \sum_{n=1}^{\infty} b_n \sin n\omega_0 t \quad \text{--- (1)}$$

$$a_0 = \frac{1}{T_0} \int_{T_0} x(t) \cdot dt$$

Here, $T_0 = 2\pi$, $\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{2\pi} = 1$

$$a_0 = \frac{1}{2\pi} \int_0^{2\pi} x(t)\, dt = \frac{1}{2\pi} \int_0^{\pi} A \sin \omega_0 t \; dt$$

$$a_0 = \frac{A}{2\pi} \int_0^{\pi} \sin t \, dt = \frac{2A}{2\pi} = \frac{A}{\pi}$$

$$\boxed{a_0 = \frac{A}{\pi}}$$

$$a_n = \frac{2}{T_0} \int_{T_0} x(t) \cdot \cos n\omega_0 t \; dt$$

$$= \frac{2}{2\pi} \int_0^{2\pi} x(t) \cos nt \; dt = \frac{1}{\pi} \int_0^{\pi} A \sin t \cdot \cos nt \; dt$$

$$= \frac{A}{\pi} \int_0^{\pi} \sin t \cos nt \; dt$$

$$= \frac{A}{2\pi} \int_0^{\pi} [\sin(1+n)t + \sin(1-n)t] \, dt$$

$$= \frac{A}{2\pi} \left[-\frac{\cos(1+n)t}{(1+n)} - \frac{\cos(1-n)t}{(1-n)} \right]_0^{\pi}$$

$$= -\frac{A}{2\pi}\left[\frac{\cos(1+n)\pi}{(1+n)} + \frac{\cos(1-n)\pi}{1-n} - \frac{1}{1+n} - \frac{1}{1-n}\right]$$

$$= -\frac{A}{2\pi}\ \frac{(1-n)\times(-1)^{1+n} + (-1)^{1-n}(1+n) - 1+\cancel{n} - 1 - \cancel{n}}{1-n^2}$$

$$= -\frac{A}{2\pi}\left[\frac{(-1)^n\left[-1+n-1-n\right]-2}{1-n^2}\right]$$

$$= \frac{2A}{2\pi}\left[\frac{1+(-1)^n}{1-n^2}\right] = \frac{A}{\pi}\left(\frac{1+(-1)^n}{1-n^2}\right)$$

now for $n=1$, $\frac{0}{0}$ form occurs,

$$\therefore\ a_1 = \frac{2}{2\pi}\int_0^{2\pi} x(t)\cos\omega_0 t\ dt$$

$$= \frac{A}{\pi}\int_0^{\pi} \sin t\cdot\cos t\ dt = 0$$

<u>Now</u>

$$\boxed{a_n = \begin{cases} -\frac{2A}{\pi}\times\frac{1}{n^2-1} & n = \text{even} \\ 0 & n = \text{odd} \end{cases}}$$

<u>Now,</u>

$$b_n = \frac{2}{T_0}\int_{T_0} x(t)\ \sin n\omega_0 t\ dt = \frac{2}{2\pi}\int_0^{2\pi} x(t)\ \sin nt\ dt$$

$$= \frac{A}{\pi}\int_0^{\pi} \sin t\cdot\sin nt\ dt = \frac{A}{2\pi}\int_0^{\pi}\left(\cos(1-n)t - \cos(1+n)t\right)dt$$

$$= \frac{A}{2\pi}\left[\frac{\sin(1-n)t}{1-n} - \frac{\sin(1+n)t}{1+n}\right]_0^{\pi}$$

$$= \left[\frac{\sin(1-n)\pi}{1-n} - \frac{\sin(1+n)\pi}{1+n}\right] \times \frac{A}{2\pi}$$

$$= \frac{A}{2\pi}\left[\frac{\sin(\pi - n\pi)}{1-n} - \frac{\sin(\pi + n\pi)}{1+n}\right]$$

$$= \frac{A}{2\pi}\left[\frac{\sin\pi \cdot \cos n\pi - \cos\pi \cdot \sin n\pi}{1-n} - \frac{[\sin\pi \cdot \cos n\pi + \cos\pi \cdot \sin n\pi]}{1+n}\right]$$

$$= \cancel{\frac{A}{2\pi}} \frac{A}{2\pi}\left[\frac{\sin n\pi}{1-n} + \frac{\sin n\pi}{1+n}\right] = \frac{A}{\cancel{2}\pi}\left[\frac{\sin n\pi \times \cancel{2}}{1-n^2}\right]$$

At $n=1$, $\frac{0}{0}$ form

by L' hospitall rule,

$$b_1 = \frac{A}{\pi} \cdot \frac{\cos\pi \times \pi}{-2} = \frac{A}{2}$$

$$b_n = \begin{cases} \frac{A}{2} & , n=1 \\ 0 & 1<n<\infty \end{cases}$$

Using ①

~~$x(t) =$~~

$$\boxed{x(t) = \frac{A}{\pi} + \sum_{n=2,4,6..}^{\infty} -\frac{2A}{\pi} \times \frac{1}{n^2-1} \cos nt + \frac{A}{2}}$$

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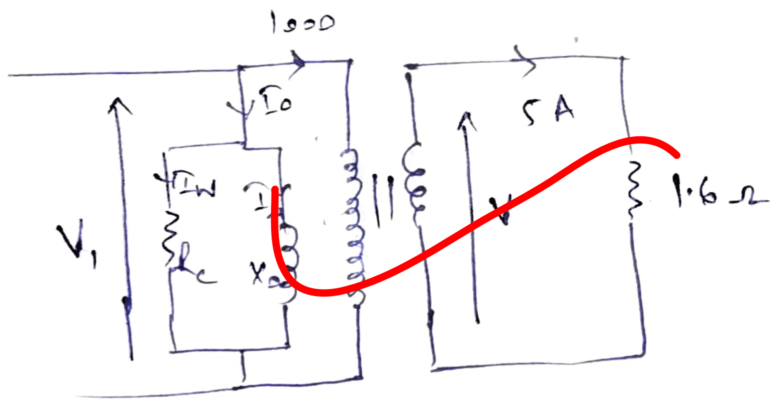
3(c)(ii)

$$R = n + \frac{I_0 \sin(\alpha+\delta)}{I_s} = n + \frac{I_w \cos\delta + I_\mu \sin\delta}{I_s} \quad (1)$$

$$K = n = \frac{1000}{5} = 200 \qquad I_s = 5A$$

$I_\mu = 0$, $\delta = 0^\circ$

No leakage reactance. Purely resistive burden.



$$V = 1.6 \times 5 = 8\ V$$

$$V_1 = 8 \times \frac{5}{1000} = 0.04\ V$$

$$\frac{V_1^2}{R_c} = 1.5\ W \Rightarrow R_c = \frac{(0.04)^2}{1.5} = 1.0667\times10^{-3}\ W$$

$$I_w = \frac{V_1}{R_c} = \frac{0.04}{1.0667\times10^{-3}} = 37.5\ A$$

$$R = 200 + \frac{37.5 \times \cos 0}{5} = 207.5$$

$$\text{Ratio error } (\sigma) = \frac{K-R}{R} = \frac{200-207.5}{207.5} = -0.0361$$

$$\boxed{\begin{aligned}\sigma &= -0.0361 \\ &= -3.61\%\end{aligned}}$$

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$\left\{ \begin{matrix} N_1 = 1 \\ N_2 = 200 \end{matrix} \right\}$

Now by using emf equat

$e = \sqrt{2}\pi f N_{ph.} \phi$

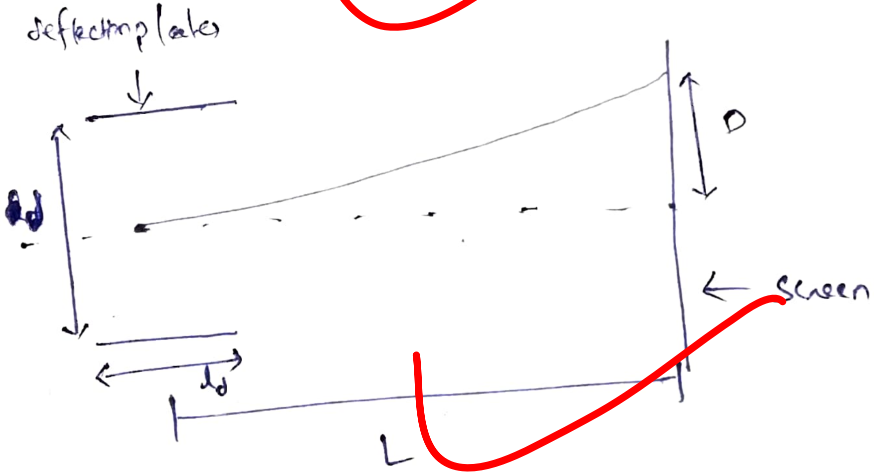
$8 = \sqrt{2} \times \pi \times 50 \times 200 \times \phi$

$\boxed{\phi = 1.8 \times 10^{-4}\ Wb}$ → flux in the core.

3. (ii)

$\boxed{D = \frac{L\, l_d\, V_y}{2 d V_A}}$ → expression for deflection on electron beam on screen in Electrostatic deflection arrangement

1



D → deflection on electron beam
L → distance from centre of plate to the screen
l_d → length of deflection plates
d → distance between deflection plates
V_y → Voltage at deflecting plates.
V_A → Anode Voltage

given, $V_A = 2000\,V$, $l_d = 2\times10^{-2}\,m$

$d = 5\times10^{-3}\,m$, $L = 30\times10^{-2}\,m$

$D = 3\times10^{-2}\,m$ $A = 100$

using (1)

$$3\times10^{-2} = \frac{30\times10^{-2}\times 2\times10^{-2}\times V_y}{2\times 5\times10^{-3}\times 2000}$$

$V_y = 100\,V$

$V_y = A\,V_{in}$ [A = gain]

$100 = 100 \times V_{in}$

$\boxed{V_{in} = 1\,V}$ → input voltage.

8

5(a)

number of atoms in a unit cell = 4 (∵ fcc Structure)

$r = 0.15 \times 10^{-9}$ m

$m = 65.5$ gm mol^{-1}

(i) atomic concentration = $\frac{\text{no. of atoms in unitcell}}{\text{Volume of unit cell}}$

In fcc,

$16r^2 = 2a^2 \Rightarrow a = 2\sqrt{2}r$ [a = edge length]

atomic concentration (n_{at}) = $\frac{4}{[2\sqrt{2} \times 0.15 \times 10^{-9}]^3}$

$\boxed{n_{at} = 5.238 \times 10^{28} \text{ m}^{-3}}$

(ii) Density (ρ) = $\frac{n\,m}{N_A \times V} = \frac{4 \times 65.5}{6.023 \times 10^{23} \times [2\sqrt{2} \times 0.15 \times 10^{-7}]^3}$

$\boxed{\rho = 5.696 \text{ gm cm}^{-3}}$

5(b) Glass Ceramic Combines the property of glass with benifits of ceramics.

Properties:

→ Glass Ceramics Can range from highly Crystalline to Containing a more substantial glassy phase. So it Can range from transparent to opaque.

→ In general they exhibit almost zero thermal expansion, and high toughness.

→ They are resistant to thermal shock and high impact resistance.

Applications

→ Household appliances including toster and clothes irons

→ Smartphone Screens

→ Infrared heating elements

→ In high temperature ~~mat~~ furnaces as an insulation material, due to their high thermal robustness.

→ Bio medical engineering

→ Optoelectronic applications

→ Dental applications.

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5(e) (i) Current gain $(A_I) = \frac{I_L}{I_{in}}$

$$I_L = \frac{V_L}{R_L} = \frac{9}{1k\Omega} = 9mA$$

$$A_I = \frac{9}{0.1} \Rightarrow \boxed{A_I = 90}$$

(ii) Power gain ⇒ $A_p = \frac{V_L \, I_L}{V_{in} \cdot I_{in}} = \frac{9}{1} \times \frac{9}{0.1}$

$$\boxed{A_P = 810}$$

5(c)

(iii) Power drawn from DC supplies.

$$P = [10 \times 9.5] \times 2 \quad mW$$

$$\boxed{P = 190 mW}$$

(iv) Power dissipated in amplifier

$$P_{out} = \frac{V_{out}^2}{R_L} = \frac{9 \times 9}{2 \times 1K\Omega} = \frac{81}{2} mW$$

$$P_{out} = 40.5 \text{ mW}$$

$$(P_{in})_{AC\,src} = \frac{1}{2} \times 1 \times 0.1 = 0.05 mW$$

$$\text{Power dissipated} = P - P_{out} + P_{in}$$

$$P_d = 190 - 40.5 + 0.05$$

$$\boxed{P_d = 149.55 \text{ mW}}$$

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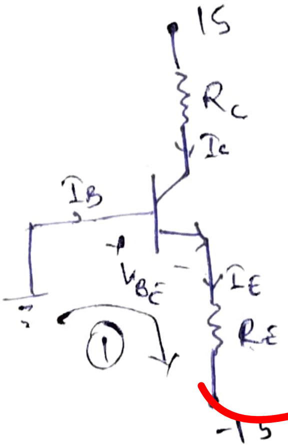
(v) $$\eta_{amplifier} = \frac{P_{out}}{P + P_{in}} = \frac{40.5}{190 + 0.05} = 0.2131$$

$$\boxed{\% \eta = 21.31\%}$$

5.(d)



$I_{C_1} = 1\,mA \Rightarrow V_{BE_1} = 0.7\,V$

$I_{C_2} = 2\,mA \Rightarrow V_{BE2} = ?$

$I_C = I_0\, e^{V_{BE}/V_T}$ — (1)

$\Rightarrow$ Using the (1) equation

$$\frac{I_{C_2}}{I_{C_1}} = \frac{e^{V_{BE2}/V_T}}{e^{V_{BE1}/V_T}} = e^{\frac{V_{B2}-V_{BE1}}{V_T}}$$

$$\Rightarrow \frac{2}{1} = e^{\frac{V_{BE2}-0.7}{25mV}} \Rightarrow \boxed{V_{BE2} = 0.7173\,V}$$

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Now applying KVL in loop (1)

$0 = V_{BE} + I_E R_E - 15$

$\left[I_E = \frac{1+\beta}{\beta} I_C \right]$

$0 = 0.7173 + 2 \times \left(\frac{1+100}{100}\right) R_E - 15$

$\Rightarrow \boxed{R_E = 7.07\,K\Omega}$

Now, $I_C = \frac{15 - V_C}{R_C} \Rightarrow 2\,mA = \frac{15-5}{R_C}$

$\boxed{R_C = 5\,K\Omega}$

5.(e)

$$S_{in} = S_1 + S_2 + S_3$$

$$S_1 = \frac{100}{0.78} \angle \cos^{-1} 0.78 = 128.205 \angle 38.74 \text{ KVA}$$

$$S_2 = \frac{200}{0.8} \angle \cos^{-1} 0.8 = 250 \angle 36.87 \text{ KVA}$$

$$S_3 = \frac{150}{0.9} \angle -\cos^{-1} 0.9 = 166.667 \angle -25.842 \text{ KVA}$$

$$S_{in} = 128.205 \angle 38.74 + 250 \angle 36.87 + 166.667 \angle -25.842$$

$$= 476.792 \angle 19.3 \text{ KVA}$$

$$S_{in} = \sqrt{3} V_L I_L^*$$ [Assuming the System is 3 phase]

$$\sqrt{3} \times 480 \, I_L^* = 476.792 \angle 19.3 \text{ KVA}$$

$$\boxed{I_L = 573.492 \angle -19.3 \text{ A}}$$ ← Transmission line Current

$$\boxed{\text{System Power factor} = \cos(19.3) = 0.9438 \text{ lagging}}$$

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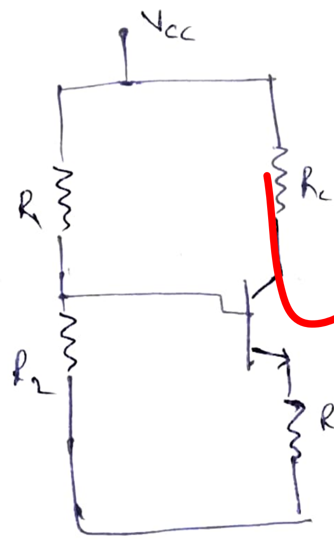
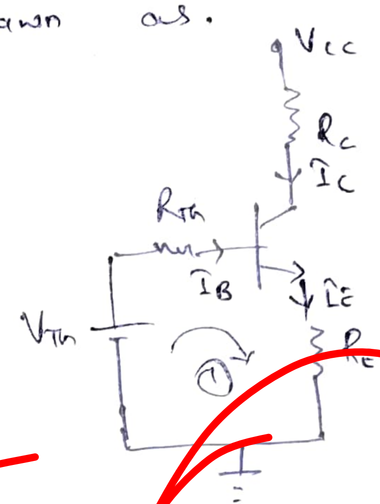
7(a) <u>DC Analysis</u>

(i) all AC supplies will be shorted and, all capacitors will be open circuited.



By using thevenin theorem, circuit can be drawn as.



$$V_{Th} = \frac{V_{CC} \times R_2}{R_1 + R_2} = \frac{10 \times 15}{27+15} = 3.5714\ V$$

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} = \frac{27 \times 15}{27+15} = 9.643\ K\Omega$$

<u>KVL in loop (1)</u>

$$V_{Th} = I_B R_{Th} + V_{BE} + I_E R_E$$

$$3.5714 = I_B \times 9.643 + 0.7 + (1+100)\, 1.2\, I_B \qquad [I_E = (1+\beta) I_B]$$

$$I_B = 21.945\ \mu A$$

$$I_C = \beta I_B = 100 \times 21.945 = 2.1945\ mA$$

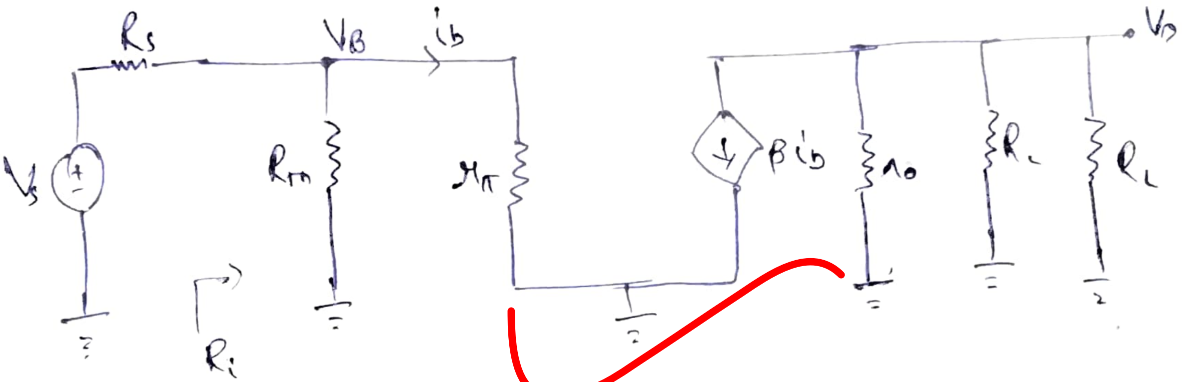
$$\boxed{I_E = 2.2165\ mA}$$

(ii) $$g_m = \frac{I_C}{V_T} = \frac{2.1945}{25} = 0.08778\ S$$

$$r_\pi = \beta / g_m = \frac{100}{0.08778} = 1.14\ K\Omega$$

$$r_o = \frac{V_A}{I_C} = \frac{100}{2.1945m} = \underline{45.57\ K\Omega}$$

AC equivalent circuit → (π-model)



from the circuit

$$R_i = R_{th} \parallel r_\pi = [9.643^{-1} + 1.14^{-1}]^{-1}\ K\Omega$$

$$\boxed{R_i = 1.019\ K\Omega}$$

Now for voltage gain (V_o/V_B)

$$V_B = r_\pi i_b = 1.14\, i_b \times 10^3$$

$$V_o = -\beta i_b \times [r_o \parallel R_c \parallel R_L]$$

$$= -100\, i_b\, [45.57 \parallel 2.2 \parallel 2.5] \times 10^3$$

$$V_o = -114.09\, i_b \times 10^3$$

$$A_v = \frac{V_o}{V_B} = \frac{-114.09\, i_b \times 10^3}{1.14\, i_b \times 10^3} \Rightarrow \boxed{A_v = 100.08}$$

$$\boxed{A_v \simeq 100}$$

4

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7 (b)
(i)

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

$$\omega_s = \frac{2\pi N_s}{60} = \frac{2\pi \times 1000}{60}$$

$$\boxed{\omega_s = 104.72 \text{ rad s}^{-1}}$$

(ii)

$$|E_f| = 480 \text{ V}$$

$$E_f = V + jI_a X_s \quad \text{— (1)}$$

$$\frac{480}{\sqrt{3}} \angle \delta = V \angle 0 + j1 \times 60 \angle \cos^{-1} 0.8$$ (leading power factor)

Equating the magnitudes.

$$\left(\frac{480}{\sqrt{3}}\right)^2 = (V - 36)^2 + (48)^2$$

$$V - 36 = 272.94$$

$$V = 308.94 \text{ V}$$ (phase value)

$$V_L = \sqrt{3} \times 308.94$$

Terminal voltage at leading Power factor of 0.8

$$\boxed{V_L = 535. \text{ Volts.}}$$

Now at rated current 0.8 p.f lag.
using (1)

$$\frac{480}{\sqrt{3}} \angle \delta = V \angle 0^\circ + j1 \times 60 \angle -\cos^{-1} 0.8$$

Equating magnitudes

$$\left(\frac{480}{\sqrt{3}}\right)^2 = (V+36)^2 + (48)^2$$

$V = 236.94$ Volts (phase)

$V_L = \sqrt{3} \times 236.94$

$\boxed{V_L = 410.4 \text{ Volts.}}$ → Terminal voltage.

(iii) $P_{out} = \sqrt{3} \times V_L I_L \times \cos\phi$

$= \sqrt{3} \times 410.4 \times 60 \times 0.8 = 34120$ ~~Watt~~

~~Rin~~ $\eta = \frac{P_{out}}{P_{out} + \text{Losses.}} \times 100$

$\eta = \frac{34120}{34.12 + 1.5 + 1} \times 100$

$\boxed{\eta = 93.17\ \%}$

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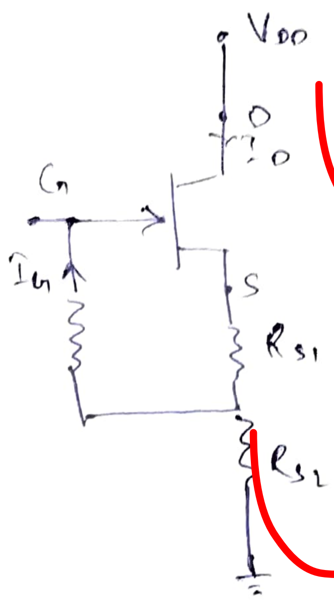
(iv) Voltage Regulation at 0.8 p.f leading

$\% VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100 = \frac{480 - 535.1}{535.1} \times 100$

$\boxed{\% VR = -10.29\ \%}$

7(c)(i) Dc Analysis



$I_G \approx 0\ A$

$V_S = I_D(R_{S1} + R_{S2})$

$V_G = I_D R_{S2}$ — ①

As,

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ — ②

$I_D = 12\left(1 - \left(\frac{-2}{-5}\right)\right)^2 = 4.32\ mA$

From the circuit

$V_{DD} = V_{DS} + V_S$

$15 = 10 + V_S \Rightarrow \boxed{V_S = 5\ V}$

$V_{GS} = -2 \Rightarrow V_G - V_S = -2$

$V_G - 5 = -2 \Rightarrow V_G = 3$ Volts.

using ①

$3 = 4.32 \times R_{S2} \Rightarrow \boxed{R_{S2} = 0.6944\ K\Omega}$

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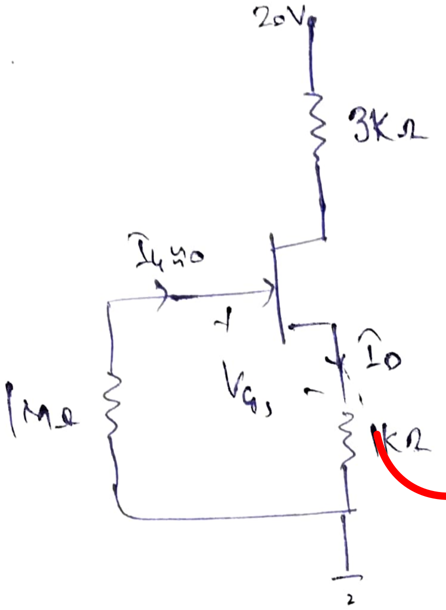
also, $V_S = I_D(R_{S1} + R_{S2})$

$5 = 4.32(R_{S1} + 0.6944)$

$\boxed{R_{S1} = 0.463\ K\Omega}$

7(c)(ii)



$\therefore V_G = 0$

$V_S = I_D \times 1K = I_D$

[Assuming I_D in mA]

$V_{GS} = -I_D$

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

$I_D = 10\left[1 - \frac{+I_D}{+4}\right]^2$

$I_D = 10\left(1 + \frac{I_D^2}{16} - \frac{I_D}{2}\right)$

$\frac{10}{16} I_D^2 - 6 I_D + 10 = 0$

Solving above equation.

$I_D = 7.453 \text{ mA}$ $\quad$ $I_D = 2.146 \text{ mA}$

$\Downarrow$ $\quad$ $\Downarrow$

$V_{GS} = -7.453 \text{ V}$ $\quad$ $V_{GS} = -2.146 \text{ V}$

As, I_D to flow, $V_{GS} > V_P$

So, $\boxed{I_{DQ} = 2.146 \text{ mA}}$

$\boxed{V_{GSQ} = -2.146 \text{ V}}$

from the circuit,

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$$20 = 3 I_D + V_{DS} + I_D$$

$$20 = 3 \times 2.146 + V_{DS} + 2.146$$

$$\boxed{V_{DS} = 11.416 \text{ V}}$$

8(a) (i)

Generator 1

250 KW

$$I_{FL} = \frac{250 \times 10^3}{400} = 625 \text{ A}$$

Drop in voltage at full load

$= 0.03 \times 400$

$= 12\text{V}$

Generator 2

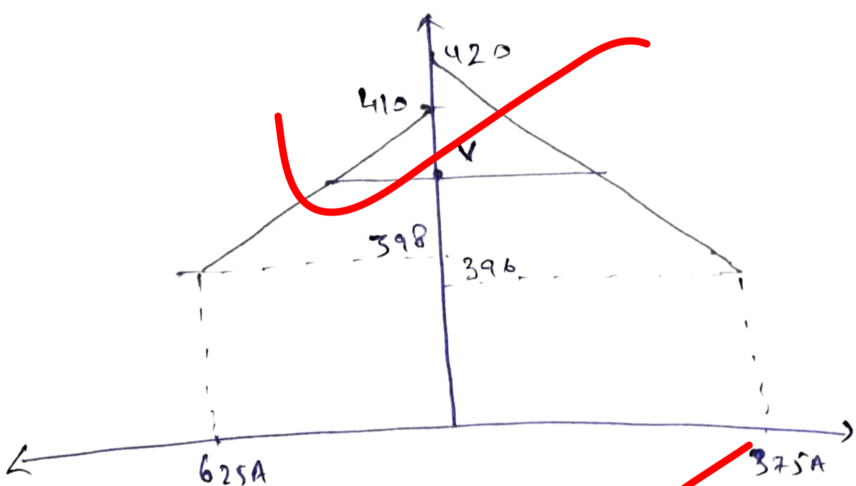
150 KW

$$I_{FL} = \frac{150 \times 10^3}{400} = 375 \text{ A}$$

Drop in voltage at full load

$= 0.06 \times 400$

$= 24 \text{ V}$



$\Rightarrow \quad I_1 + I_2 = 1000 \text{ A}$

using slopes,

$$\frac{410 - 398}{625} = \frac{410 - V}{I_1} \Rightarrow 12 I_1 = 256250 - 625 V$$

$$625V + 12 V_1 = 256250 \quad \text{— (1)}$$

$$\frac{420-396}{375} = \frac{420-V}{1000-I_1} \Rightarrow \frac{8}{125} = \frac{420-V}{1000-I_1}$$

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$$8000 - 8I_1 = 52500 - 125V$$

$$125V + 8I_1 = 44500 \quad -②$$

Solving ① & ②

$\boxed{V = 397.54 \text{ Volts.}}$ → bus voltage.

$\boxed{I_1 = 649.04 \text{ A}}$

$\boxed{I_2 = 350.96 \text{ A}}$

(ii) ~~Assuming~~ Let x% drop for Generator 2 (150 kW)

and No load voltage 'V''

for proportion load sharing.

$$\frac{0.03V}{250} = \frac{V-V'}{I_1} \quad -①$$

↑ for Generator 1

$$\frac{xV}{150} = \frac{V-V'}{\frac{3}{5}I_1} \quad -②$$

from ① & ②

$$\frac{0.03V}{250} = \frac{xV}{150} \times \frac{3}{5}$$

$$\Rightarrow \boxed{x = 0.03} \Rightarrow \underline{3\%}$$

∴ for Proportional load sharing

there % drops ~~will~~ should be same.

for load Current of 1000 A

$I_2 = 375\,A$

$V_{NL} = V_t + x\,V_t$

$= 400 + 0.03 \times 400$

$\boxed{V_{NL} = 412\,V}$

8(b) $P = \frac{V E_f}{X_s} \cdot \sin\delta + \frac{1}{2} V^2 \left[\frac{1}{X_q} - \frac{1}{X_d} \right] \sin 2\delta$

When $E_f = 0$, $P_{max} = 540\,KW$

$540 \times 10^3 = \frac{1}{2} V^2 \left[\frac{1}{15.4} - \frac{1}{85.4} \right] \sin 90^\circ$

$V = 6499.637$ Volts.

$V \approx 6.5\,KV$

Now when Excited with nominal field.

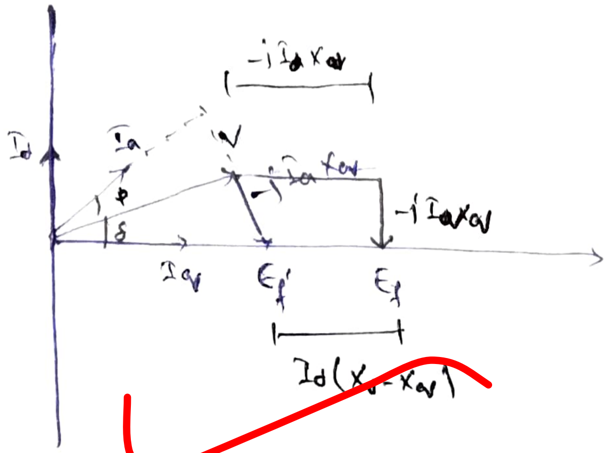
$P = \omega T = \frac{2\pi \times 1000}{60} \times 3.5 \times 10^3$

$P = 366.52\,KW$

$P = \sqrt{3} \times V \times I_a \times \cos\phi$

$366.52 \times 10^3 = \sqrt{3} \times 6.5 \times I_a \times 0.8$

$I_a = 40.69 \angle \cos^{-1} 0.8\ A$



$\psi = \phi + \delta$

$$E_f' = V - jI_a X_q$$

$$= \frac{6.5}{\sqrt{3}} \angle 0^\circ \times 10^3 - j15.4 \times 40.69 \angle \cos^{-1} 0.8$$

$$E_f' = 4.159 \angle -6.922 \text{ KV}$$

$$\boxed{\text{Power angle } \delta = 6.922}$$

$$I_d = I_a \sin\psi = 40.69 \sin(6.922 + 36.87)$$

$$= 28.159 \text{ A}$$

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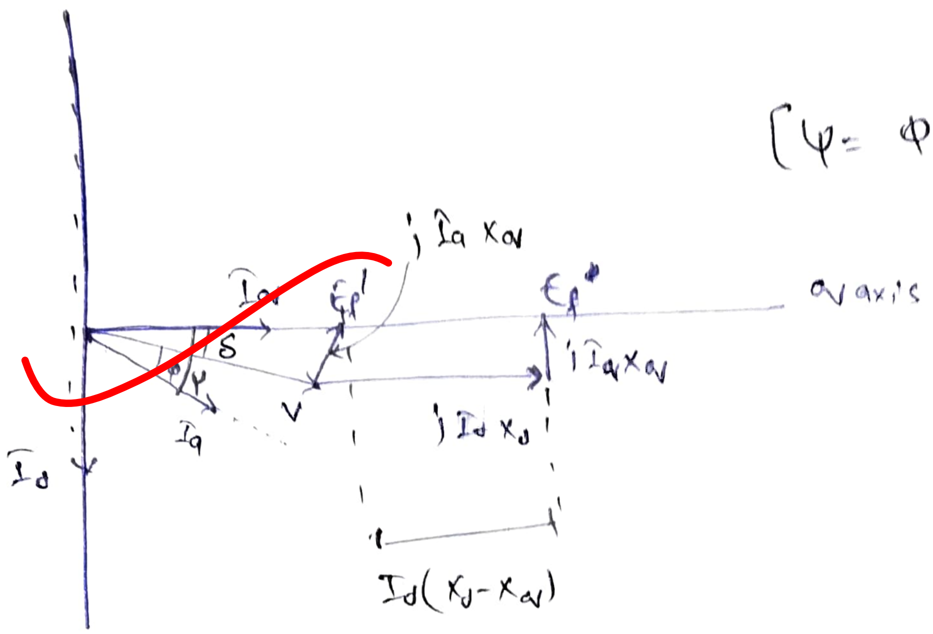
$$|E_f| = 4.159 + I_d(X_d - X_q)$$

$$= 4.159 + 28.159(25.4 - 15.4) \times 10^{-3}$$

$$= 4.44 \text{ KV}$$

$$\boxed{E_{f\,L\text{-}L} = \sqrt{3} \times 4.44 = 7.69 \text{ KV}}$$

(ii) Taking a Synchonous machine working at lagging pf
(Alternator)



from phasor diagram.

$$I_q X_q = V \sin\delta$$

$$E_f = V\cos\delta + I_d X_d$$

$$I_d = I_a \sin\psi , \quad I_q = I_a \cos\psi$$

$$I_d = I_a \sin[\phi + \delta]$$
$$= I_a \sin\phi . \cos\delta + I_a \cos\phi . \sin\delta$$

$$I_q = I_a \cos\phi . \cos\delta - I_a \sin\phi . \sin\delta$$

Now, $P = V I_a \cos\phi = V I_a \cos(\psi - \delta)$

$$P = V I_a [\cos\psi . \cos\delta + \sin\psi . \sin\delta]$$

$$P = V I_q \cos\delta + V I_d \sin\delta$$

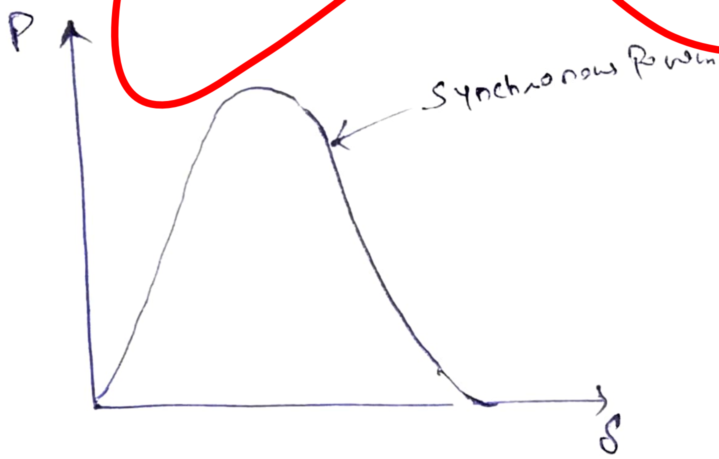
$$P = \frac{V\cos\delta}{X_q} I_q X_q + \frac{V I_d \sin\delta}{X_d} X_d$$

$$P = \frac{V\cos\delta}{X_q} V\sin\delta + \frac{V\sin\delta}{X_d}(E_f - V\cos\delta)$$ (from phasor diagram)

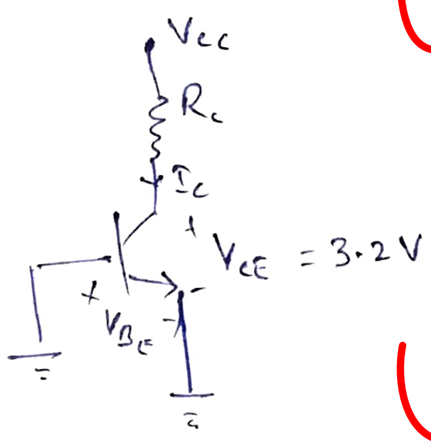
$$P = \frac{V^2}{2X_q}\sin 2\delta + \frac{E_f V}{X_d}\sin\delta - \frac{V^2}{2X_d}\cancel{\cos\delta}\sin 2\delta$$

$$\boxed{P = \frac{E_f V}{X_d}\sin\delta + \frac{V^2}{2}\left[\frac{1}{X_q} - \frac{1}{X_d}\right]\sin 2\delta}$$

Power angle Characteristics



8(c) (i) As $I_c = I_s e^{V_{BE}/V_T}$ —— (1)



$$I_c = \frac{V_{cc} - V_{CE}}{R_c}$$

$$= \frac{10 - 3.2}{6.8} = 1\,mA$$

$$\boxed{I_c = 1\,mA}$$

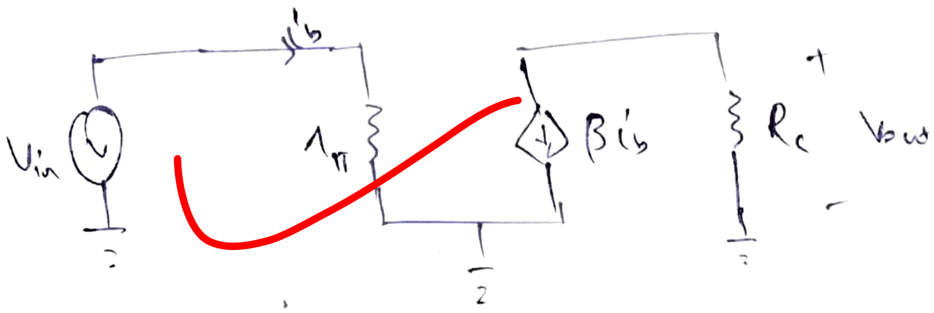
using (1)

$$1 \times 10^{-3} = 10^{-15} \cdot e^{V_{BE}/25mV}$$

$$\boxed{V_{BE} = 690.77\,mV \cong 0.69\,V}$$

(ii) $g_m = \frac{I_C}{V_T} = \frac{1}{25}$ S

$r_\pi = \beta / g_m$



$V_{out} = -\beta i_b R_C$

$V_{in} = r_\pi i_b$

$$A_V = \frac{V_{out}}{V_{in}} = \frac{-\beta R_C i_b}{r_\pi i_b} = \frac{-\beta R_C g_m}{\beta} = -g_m R_C$$

$$= -\frac{1}{25} \times 6.8 \times 10^3$$

$$\boxed{A_V = -272}$$

$[V_{out\,peak}] = \cancel{272 \times}\ A_V \times V_{in} = 272 \times 5 \times 10^{-3}$

$$\boxed{V_{out\,peak} = 1.36 \text{ volts.}}$$

(iii) $V_{CE} = 0.3$,

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{10 - 0.3}{6.8} = 1.426 \text{ mA}$$

b) Using (1)

$$1.426 \times 10^{-3} = 10^{-15} \times e^{V_{BE}/25mV}$$

$$V_{BE} = 699.64 \text{ mV}$$

$$\Delta V_{BE} = 699.64 - 690.77$$

$$\boxed{\Delta V_{BE} = 8.877 \text{ mV}}$$

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