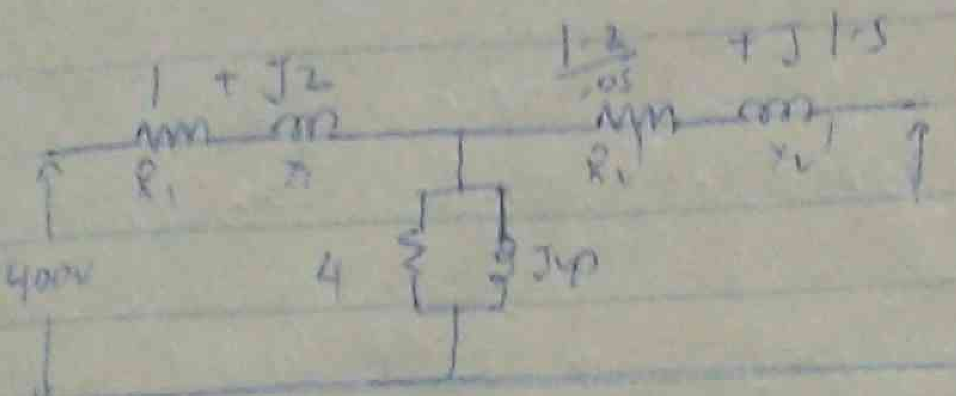


$Z_2' = \frac{1.2}{.05} + J1.5 = 24 + J1.5$

$Z_1 = \frac{(24 + J1.5)(4 + J40)}{24 + J1.5 + 4 + J40} = \frac{96 + J6 + J960 - 60}{28 + J41.5} = \frac{36 + J966}{28 + J41.5}$

$Z_T = 1 + J2 + \frac{36 + J966}{28 + J41.5} = \frac{28 + J56 + J41.5 - 83 + 36 + J966}{28 + J41.5}$

$= \frac{-29 + J1063.5}{28 + J41.5} = \frac{1063.5 \angle 180 - 88.435}{50 \angle 56} = 21.25 \angle 35.565$

$I_t = \frac{400 \angle 0}{\sqrt{3} \times 21.25 \angle 35.565} = 10.8 \angle -35.565$ amp I/P pf = .813 lagg

$I_2' = 10.85 \angle -35.565 \times \frac{4 + J40}{50 \angle 56} = 8.68 \angle 17.995$ amp

I/P power $= \sqrt{3} E I \cos\theta = \sqrt{3}\, 400 \times 10.8 \times .813 = \sqrt{3}\, 3580$ watts

O/P $= 3 I_2^2 R_2 \frac{(1-s)}{s} = \frac{3 \times 8.68^2 \times 1.2 \times .95}{.05}$

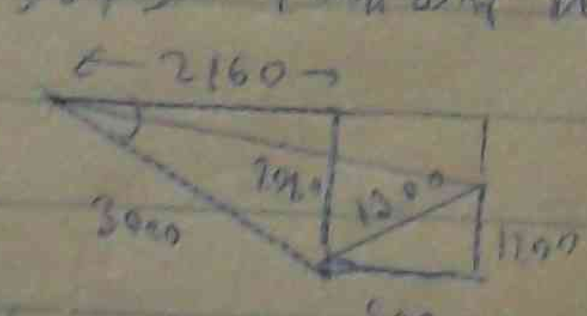
$= 3.6 \times 19 \times 227 = 4920$ watts

O/P $= 4920 - 250 = 4990$ watts

Effy $= \frac{4990}{\sqrt{3} \times 3580} = \frac{4990}{6150} = 80.3\%$

* Line voltage, [illegible] 3φ [illegible] $\sqrt{3}$ [illegible]
[illegible] = [illegible] = 3φ [illegible] 3φ [illegible]
[illegible]

③ Plant [illegible] load [illegible] .72 lagging [illegible] 3000 kw [illegible] plant pf [illegible] line shaft [illegible] 1200 kVA [illegible] Synchronous motor [illegible] motor [illegible] 600 HP load [illegible] effy 89.5 [illegible] plant overall kVA [illegible]



Motor I/p $= \frac{600 \times .746}{.895} = 500$ kw

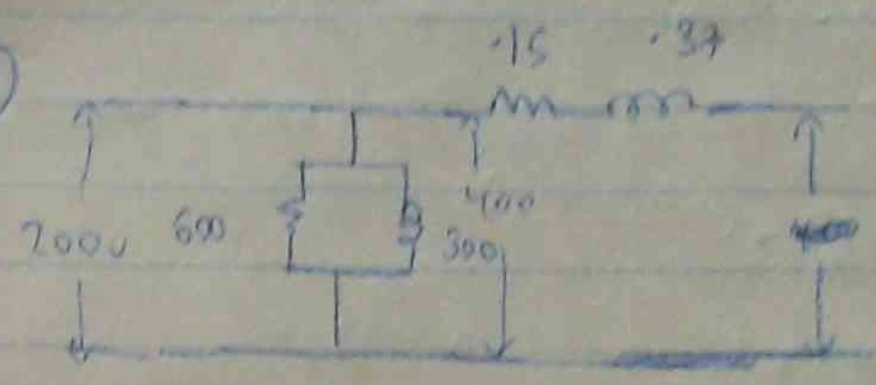
kVAR $= 3000 \times .72 = 2160$

kVAr $= \sqrt{3000^2 - 2160^2} = 2080$ kw T $= 2160 + 500 = 2660$ kVAr $= 2080 - 1200 = 880$

kVA $2660 - J880 = 2800 \angle -18.3$ kVA
pf $= .95$ lagg

1981 Chuck (Final Exam)

①



[illegible] 200/400 V 1φ 50Hz 4 kVA transformer [illegible] L-side [illegible] referred [illegible] H-side [illegible] 10 amp 0.8 pf lagging [illegible]
(a) L-side (b) H-side [illegible] terminal voltage (c) effy [illegible]

$a = \frac{200}{400} = \frac{1}{2}$ $\frac{I_2}{I_1'} = \frac{1}{2}$ $\therefore I_2' = 20 \angle -36.8$ amp

$I_1 = I_2' + I_0 = 20(.8 - J.6) + \frac{200}{600} - J\frac{200}{300}$
$= 16 - J12 + .333 - J.667 = 16.333 - J12.667$

$I_1 = 20.65 \angle -37.8$ amp

$V_1 = V_2' + IZ$

$200 = V_2' + 20 \angle -36.8\,(.15 + J.37)$

$200 = V_2' + 20 \angle -36.8 \times .4 \angle 67.93$

$V_2' = 200 - 8 \angle 31.13 = 193.16$ V $V_2 = 386.32$ V

Effy $= \frac{4000 \times .8}{4000 \times .8 + \left(\frac{200}{600}\right)^2 \times 600 + 20^2 \times .15} = 96.37\%$

② Primary 6000 V 3φ 50 Hz Δ/λ connected Transformer [illegible] % resistance [illegible] % reactance [illegible] 1% [illegible] 5% [illegible] full load [illegible] pf 0.8 lagg [illegible] turn ratio [illegible] terminal voltage 415 V

$\%R = \frac{IR}{V} \times 100$

$V_1 = V_T + IZ$ $\frac{1V}{100} = IR$

$||^{ly}\ \frac{5V}{100} = IX$

$\therefore V_1 = 415 + \quad V_1 = \frac{415}{\sqrt{3}} + IR + JIX$

$V_1 = \frac{415}{\sqrt{3}} + \frac{V}{100} + J\frac{5V}{100}$

$\therefore \frac{99V}{100} - J\frac{5V}{100} = 415/\sqrt{3}$

$\frac{99V}{100} = \frac{415}{\sqrt{3}}$ $V = \frac{41500}{99 \times \sqrt{3}} = \frac{418}{\sqrt{3}}$ V

Turn ratio: $\frac{418}{\sqrt{3}} = 242$ V

Turn ratio $= \frac{6000}{242} = 24.8$

(3) Lap winding star connected [illegible] 8 poles 900 r.p.m 3φ alternator [illegible] 144 stator slots 6 turns / coil, coil span 1 to 16 slots [illegible] 1.8×10^6 lines flux / pole [illegible]
(1) V/ph (2) V between terminal [illegible]

$T_p = \frac{S T_c}{3} = \frac{144 \times 6}{3} = 288$ turns

$N = \frac{120f}{P}$

$S/p = 144/8 \quad \alpha = 180°$

$15 \quad \alpha = 180 \times \frac{15}{18} = 150°$

$k_p = \sin \beta/2 = \sin 75 = .965$

$N = \frac{120f}{P} \quad \therefore f = \frac{NP}{120} = \frac{900 \times 8}{120} = 60\,Hz$

$S/p \; 18 \quad 180°$ $\qquad n = 144/8/3 = 6$

$1 \quad \alpha = 10°$

$\therefore k_d = \frac{\sin n\alpha/2}{n \sin \alpha/2} = \frac{\sin \frac{6 \times 10}{2}}{6 \sin \frac{10}{2}} = \frac{.5}{6 \times .0873} = \frac{.5}{.523}$

$= .957$

$E_p = 4.44 f T_p \phi_m 10^{-8} \times k_p k_d$

$= 4.44 \times 60 \times 288 \times 1.8 \times 10^6 \times 10^{-8} \times .957 \times .965$

$= 266.5 \times 518 \times 10^{-2} \times .923 = 1275\,V$

$E_L = \sqrt{3} \times 1275 = 2210\,V$

(4) 400 50 KVA 3φ 50 Hz λ connected alternator [illegible] effective resistance / ph [illegible] field exit 5 amp [illegible] open circuit voltage 90 [illegible] (1) synchronous reactance [illegible] impedance (2) 0.8 pf lagging [illegible] full load regulation [illegible]

$Z_s =$

(5) 3φ slip ring induction motor [illegible] slip ring [illegible] open circuit voltage 60 V [illegible] rotor reactance / ph [illegible] stand still reactance / ph [illegible] rotor current / ph [illegible]
(1) rotor [illegible] slip ring [illegible] short [illegible]
(2) rotor [illegible] resistance / ph [illegible] reactance / ph [illegible]

[illegible] rheostat [illegible]

$E_{ph_1} = I_1 Z_1 \rightarrow R_2'/s + jx_2'$

$\frac{60}{1.731} = I_1 \left(\frac{.06}{.05} + j4\right)$

$\therefore I_1 = \frac{34.6}{1.2 + j4} = \frac{34.6}{4.17 \angle 73.7} = 8.27 \angle -73.7$ amp

$\frac{60}{1.731} = I_1 (.06 + 5 + j2 + 2)$

$I_1 = \frac{34.6}{5.06 + j4} = \frac{34.6}{6.93} = 5.28$ amp

(6) 6 poles 3φ 50 Hz induction motor [illegible] full load [illegible] usefull torque 120 lb-ft [illegible] frequency 90 c/min [illegible] (1) mechanical torque 10 lb-ft [illegible] friction [illegible] B.H.P [illegible]
(2) rotor copper losses
(3) stator input
(4) stator losses 780 watts [illegible] efficiency [illegible]

$f_s = s \times f$

$\frac{90}{60} = s \times 50 \qquad s = \frac{90}{3000} = .03$

$N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000$ r.p.m

$N_r = N_s(1-s) = 1000(1-.03) = 970$ r.p.m

$HP = \frac{2\pi N_r T}{33000} = \frac{2 \times 3.14 \times 970 \times 120}{33000} = 22.1\,HP$

$\frac{7.04}{N_s} \times \frac{3 I_2^2 R_2'}{s} = 130$

$\frac{3 I_2^2 R_2'}{s} = \frac{130 \times 1000}{7.04} = 18500$ watts

rotor copper loss $= 18500 \times .03 = 555$ watts

$\therefore$ stator Input $= 18500 + 780 = 19270$ watts

$= 19.27$ kw

$Eff_y = \frac{22.1}{\frac{19.27}{.746}} \times 100 = 86\%$

(7) [illegible]

(8) 3 Anode mercury arc rectifier [illegible] secondary ~~over lap~~ voltage/ph: [illegible] $\frac{1300}{\sqrt{2}}$ [illegible] full load over lap angle [illegible] arc drop 25v [illegible] output no load terminal voltage [illegible] full load output voltage [illegible]

$$E_s = \sqrt{2} V_s \frac{m}{\pi} \sin\frac{\pi}{m}$$
$$= \sqrt{2} \times \frac{1300}{\sqrt{2}} \times \frac{3}{3.14} \sin\frac{180}{3}$$
$$= 1075v$$

o/p - 1075 - 25 = 1050v (no load output terminal voltage

full load output terminal voltage $= 1075 \cos^2 \frac{\mu}{2} - 25$
$= 993 - 25 = 978v$

1981 Prome (Final Exam)

1(a) T.R [illegible] efficiency maximum [illegible]

(b) 20 kVA 2000/200 V 1φ Transformer [illegible] Iron losses 88.2 watts [illegible] primary winding [illegible] resistance 0.2Ω [illegible] secondary winding [illegible] resistance 0.002 [illegible] secondary winding [illegible] resistance [illegible] 0.006Ω [illegible] max. eff. [illegible] load % [illegible]

(a) T.R [illegible] constant losses [illegible] Iron loss [illegible] variable loss [illegible]

(b) $W_i = W_{cu}$ = $\frac{1}{m}$ x L x rated kVA x Pf

Full load current - $\frac{20,000}{2000}$ = 10 amp

Full load = $I^2 R = 10^2 \times (.2 + \frac{2}{(\frac{2000}{20})^2} \times .006)$ = 20 watts

$L^2 W_{cu} = W_i$

$L = \sqrt{\frac{88.2}{80}} = 1.05 = 105\%$

(2) 400v 50c/s [illegible] T.R [illegible] Low tension [illegible] no load [illegible] 350 watts [illegible] frequency [illegible] frequency [illegible] potential 25% [illegible] no load [illegible] 225 watts [illegible] 440 Volts [illegible] Hysteresis loss [illegible] eddy current loss [illegible] ([illegible])

~~400~~ $P_t = \eta_h' f B_m^{1.6} + \eta_e' f^2 B_m^2$

$E = 4.44 f N B_m A c f \times 10^{-8}$

$\therefore B_m = K \times \frac{V}{f}$

$\therefore P_t = \eta_h' V^{1.6} + \eta_e' V^2$

$\therefore \eta_h' \times 400^{1.6} + \eta_e' \times 400^2 = 350$

$14700 \eta_h' + 160000 \eta_e' = 350$

$\eta_h' + 11.08 \eta_e' = .0237$ ——— (1)

$\eta_h' 300^{1.6} + \eta_e' 300^2 = 225$

$9200 \eta_h' + \eta_e' 90000 = 225$

$\eta_h' + 9.67 \eta_e' = .0233$ ——— (2)

(1) - (2)

$1.41 \eta_e' = .0007$

$\eta_e' = \frac{.0004}{1.41}$

$\eta_h' + 11.08 \times \frac{.0004}{1.41} = .0242$

$\eta_h' + \frac{.0032}{1.41} = .0242$

$\eta_h' = .0242 - .008 = .0162$

$W_H = \eta_h' V^{1.6} = .0132 \times (240)^{1.6} = .0132 \times 6400 = 345$

$W_E = \eta_e' V^2 = \frac{.0011}{1.41} \times 57600$ = ~~[illegible] watts~~ = 44.8 watts

W_E =

(3)(a) Auto Transformer [illegible]

(b) [illegible] laminated [illegible] 230/200 v [illegible] insulation [illegible] 12.5% [illegible] max. flux density 11000 gauss [illegible] frequency 50c/s [illegible] turns [illegible] single layer [illegible] wire size [illegible]

[illegible]

(4) 3φ star connected alternator [illegible] no load line voltage [illegible] 6600v [illegible] frequency 50c/s [illegible] alternator [illegible] voltage wave [illegible] sine wave [illegible] full pitch [illegible] alternator [illegible] 8 conductor/slot [illegible] 6 slot/pole/ph [illegible] alternator [illegible] flux [illegible]

$T_c = 8/2 = 4$

$S = 6 \times 3 \times 10 = 180$

$N = \frac{120f}{P}$

$\therefore P = \frac{120f}{N} = \frac{120 \times 50}{600} = 10$

$T_p = \frac{S T_c}{3} = \frac{180 \times 4}{3} = 240$ turns

$E_{ph} = 4.44 f T_p \phi_m 10^{-3} \times k_p k_d$

$k_p = \sin \frac{\beta}{2} = 1$

$\beta / p = \frac{180}{10}$ [illegible] $= 180°$

$1 \longrightarrow ? = \frac{120 \times 10}{120} = 10°$

$\therefore k_d = \frac{\sin m d/2}{m \sin d/2} = \frac{\sin \frac{10 \times 6}{2}}{6 \sin 10/2} = \frac{.5}{6 \times .0873} = \frac{.5}{.524} = .955$

$E_{ph} = 4.44 f T_p \phi_m \times 10^{-3} \times k_p k_d$

$\phi_m = \frac{6600/\sqrt{3} \times 10^{3}}{4.44 \times 50 \times 240 \times .955} = \frac{381000 \times 10^{6}}{222 \times 240 \times .955}$

$\phi_m = \frac{381000 \times 10^{6}}{53280 \times .955} = \frac{381000 \times 10^{6}}{49800} = 7.64$ m lines

(5) 400V 3φ 50Hz induction motor [illegible] 1440 r.p.m [illegible] stator input, stator losses [illegible] mechanical losses [illegible] 25kW 1000W 600W [illegible] (1) motor [illegible] (2) [illegible] rotor copper losses (3) efficiency [illegible]

$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ r.p.m

$s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500} = \frac{60}{1500} = .04$

rotor i/p $= 25 - 1 = 24$ kW

$\frac{3 I_2^2 R_2'}{s} = 24000$

$3 I_2^2 R_2' = .04 \times 24000 = 960$ watts

$\frac{3 I_2^2 R_2' (1-s)}{s} = 24000 \times .96 = 23040$ watts

o/p $= 23040 - 600 = 22440$ watts

O.H.P $= \frac{22440}{746} = 30$ HP

Effy $= \frac{22440}{25000} = 89.7$ %

(6) 3φ star connected slip ring motor [illegible] rotor resistance per phase [illegible] stand still reactance per phase = 6Ω [illegible] rotor e.m.f at stand still = 100V [illegible]

(a) [illegible] star connected [illegible] resist [illegible] reactance/ph [illegible] (b) slip ring [illegible] short [illegible] motor [illegible] (c) [illegible] slip [illegible] rotor current/ph [illegible]

(a) $\cdot f = \frac{R_2'}{Z \times s} \longrightarrow .6 = \frac{R_2'}{Z \times s}$ [illegible]

$\therefore Z = R_2' / .6$

$I = 40$ amp $\therefore Z = \frac{100}{\sqrt{3} \times 40} = 1.445\,\Omega$

$R = 1.445 \times .6 = .87\,\Omega$

[illegible] resist $= .867 - .4 = .467\,\Omega$

$X = \sqrt{Z^2 - R^2} = \sqrt{1.445^2 - .867^2} = 1.155\,\Omega$

[illegible] $X = 11.55 - 6 = 5.55\,\Omega$

(b) $\cdot f = \frac{R_2'}{Z \times s}$

$.8 = \frac{R_2'}{Z \times s} \quad \therefore Z = \frac{R_2'}{.8 s}$ ——(1)

$Z^2 = \left(\frac{R_2'}{.8 s}\right)^2 + x_2'^2$

$\left(\frac{R_2'}{.8 s}\right)^2 = R_2'^2/s^2 + x_2'^2$

slip [illegible] short [illegible]

$\left[\frac{.4}{.8 s}\right]^2 = \frac{.4^2}{s^2} + 36$

$\frac{.25}{s^2} = \frac{.16}{s^2} + 36$

$\frac{.09}{s^2} = 36$

$\therefore s = \sqrt{\frac{.09}{36}}$

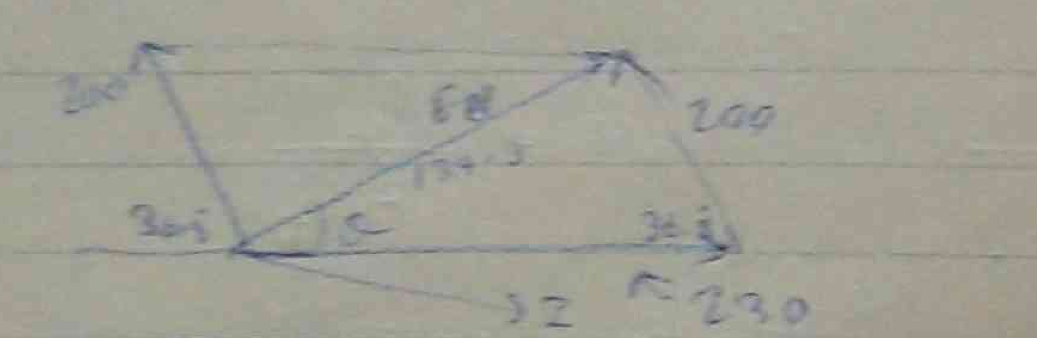
$= \sqrt{.3^2 \times \frac{1}{6^2}}$

$= \sqrt{.05^2} = .05$

$$I_2 = \frac{100}{\sqrt{3}\times[R_2'/s + jX_2']} = \frac{57.7}{[\frac{.4}{.05} + j6]} = \frac{57.7}{10}$$

$= 5.77$ amp

(7) Single phase synchronous [illegible] motor [illegible] back e.m.f 200 V [illegible] supply voltage 230 V [illegible] lagging [illegible] Armature [illegible] synchronous [illegible] resistance [illegible] 5.5 [illegible] synchronous [illegible]



$$E_A = \sqrt{230^2 + 200^2 - 2\times 200\times 230\times .8}$$
$$= \sqrt{40000 + 52900 - 92000\times .8}$$
$$= \sqrt{92900 - 73600} = \sqrt{19400} = 139.3$$

$$200^2 = 139.3^2 + 230^2 - 2\times 139.3\times 230\cos\theta$$

$$\cos\theta = \frac{139.3^2 + 230^2 - 200^2}{2\times 139.3\times 230}$$

$$= \frac{19400 + 52900 - 40000}{64000} = \frac{32300}{64000} = .504$$

$\theta = \cos^{-1}.504 = 59.7°$

$\phi = \tan^{-1}5.5 = 79.7°$

$\therefore$ pf angle $= 79.7 - 59.7 = 20°$

$\therefore$ pf $= \cos 20 = .94$ lagging

(8) [illegible] 400 V [illegible] 3 anode mercury arc rectifier [illegible] bulb effy, over effy [illegible] arc drop 10 V, T.R [illegible] loss 350 W out put current 25 A [illegible] 235 watts [illegible] 50 watts [illegible]

$$20^2 \times R_e = 450$$
$$R_e = \frac{450}{400} = 1.125\,\Omega$$

power loss (cu) $= (25/\sqrt{3})^2 \times 1.125 = \frac{625\times 1.125}{3} = 235$ watts

arc loss $= \frac{25}{\cancel{3}} \times 10 = 250$ watts

W.T $= 350$, Smoothing loss $= 50$ watts

$$\text{overall effy} = \frac{25\times 400}{25\times 400 + 235 + 250 + 350 + 50}$$
$$= 91.75\%$$

$$\text{Bulb effy} = \frac{400}{400+10} = 97.5\%$$

Imsein AC [illegible]

(1) 4/page (8) $E_{ph} = 4\times 4.44 f N B_m A_{eff}\times 10^{-8}$ stk factor

$$220 = 4\times 4.44\times 50\times N_2\times 10000\times 20\times 10^{-8}\times .9$$

$$N_2 = \frac{220{,}0000}{888\times 18} = \frac{220{,}0000}{16000} = 137.5 \text{ turns}$$

$$a = \frac{3300}{220} = 15$$

$\frac{N_1}{N_2} = a \quad \therefore N_1 = 15\times 137.5 = 2062.5$ turns

(2) Example/page (13) $I_1 = I_N + I_2'$ $\qquad \frac{I_2}{I_2'} = \frac{440}{110} = 4$

$= 5\angle{-100'2} + 30\angle{-36.8}$ $\qquad \therefore I_2' = \frac{120\angle{-36.8}}{4} = 30\angle{-36.8}$ amp

$= 5[.2 - j.9798] + 30(.8 - j.6)$

$= 1 - j4.9 + 24 - j18$

$= 25 - j22.9 = 33.9\angle{-42.5}$ amp

$$\text{effy} = \frac{E_2 I_2 \cos\theta_2}{E_1 I_1\cos\theta} = \frac{440\times 30\times .8}{440\times 33.9\cos 42.5} = \frac{24}{33.9\times .737}\times 100 = 96\%$$

(3) 1/Exercise (3) Page (29) $R_e' = R_1 + a^2 R_2 = .224 + [\frac{400}{200}]^2\times .054$

$R_e' = .224 + 4\times .054 = .224 + .216 = .44\,\Omega$

$I_{FL_1} = \frac{10{,}000}{400} = 25$ amp $\quad$ Cu loss $= I_{FL_1}^2 R_e' = 625\times .44 = 275$ watts

% Resist $= \frac{IR}{V}\times 100 = \frac{25\times .44}{440}\times 100 = 2.5\%$

$X_e' = .5 + [\frac{400}{200}]^2\times .12$

$= .5 + 4\times .12 = .5 + .48 = .98\,\Omega$

% react $= \frac{25\times .98}{440}\times 100 = 5.57\%$

(4)

(3) / page 20 $\cos\theta_N = \frac{70}{200 \times .7} = .5$ $\sin\theta_N = .866$

$R_o = \frac{200}{.7 \times .5} = \frac{400}{.7} = 286\,\Omega$

$X_o = \frac{200}{.7 \times .866} = \frac{200}{.6075} = 330\,\Omega$

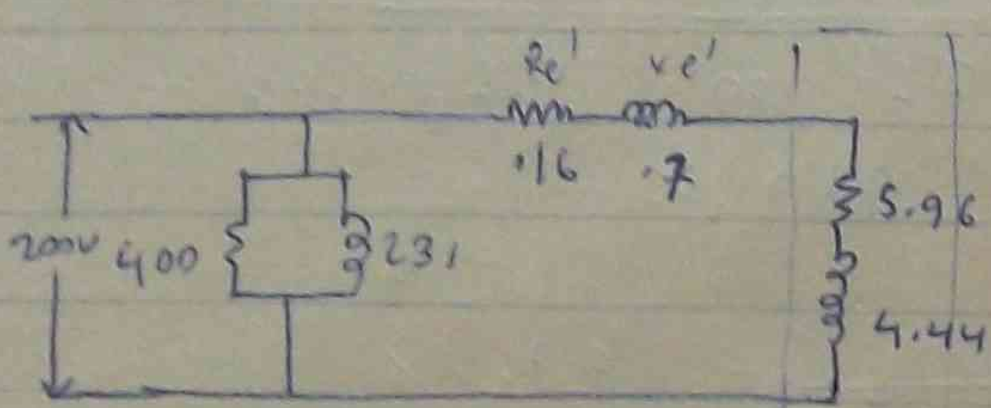
$I^2 R_e'' = 80 \therefore R_e'' = \frac{80}{100} = .8\,\Omega$ $\therefore R_e' = \left(\frac{200}{400}\right)^2 \times .8 = .2\,\Omega$

$Z_e'' = \frac{15}{10} = 1.5\,v$

$X_e'' = \sqrt{1.5^2 - .8^2} = \sqrt{2.25 - .64} = \sqrt{1.81} = 1.269\,\Omega$

$X_e' = \frac{1}{4} \times 1.269 = .317\,\Omega$

(4) 1/page 23



a = 10

$I_2' = \frac{V}{Z_e' + Z_{load}} = \frac{200}{.16 + J.7 + 5.96 + J4.44} = \frac{200}{6.12 + J5.14}$

$= \frac{200}{8\angle 40^\circ} = 25\angle -40^\circ$ amp

$I_2' = 25(\cos 40 - J\sin 40) = 25(.765 - J.643) = 19.1 - J16.05$ amp

$I_N = \frac{200}{400} - J\frac{200}{231} = .5 - J.865$ amp

$I_1 = I_N + I_2' = 19.1 - J16.05 + .5 - J.865 = 19.6 - J16.935$

$= 25.9\angle -40.8^\circ$ amp

$V_1 = V_2' + I Z_e'$

$200 = V_2' + 25\angle -40\,(.16 + J.7)$

$200 = V_2' + 25\angle -40 \; .718\angle 77.12$

$V_2' = 200 - [17.95\angle 37.12] = 200 - [17.95(.798 + J.603)]$

$V_2' = 200 - 14.35 - J10.83 = 185.65 - J10.83 = 185.65$

$V_2 = 1856\,V$

or) $V_2' = (5.96 + J4.44)(25.9\angle -40.8)$ ...

Input: $EI\cos\theta = 200 \times 25.9 \times \cos 40.8 = 5200 \times .757 = 3940$ watts

$W_I = I_{N}^2 R_o = (.5)^2 \times 400 = .25 \times 400 = 100$ watts

$W_C = I_{fl}^2 R_e' = 25^2 \times .16 = 625 \times .16 = 100$ watts

effy = $\frac{I/P - \text{losses}}{I/P}$, effy $= \frac{3940 - [200]}{3940 + \cancel{100+100}} \times 100 = 94.5\%$

effy → $\frac{O/P}{I/P} = \frac{25^2 \times 5.96}{3940} = 94.5\%$

(5)

(3) / page (23) $R_e' = R_1 + a^2 R_2 = .21 + \left[\frac{6600}{250}\right]^2 \times 2.72 \times 10^{-4}$

$R_e' = .21 + 697 \times 2.72 \times 10^{-4} = .3995\,\Omega$

$X_e' = X_1 + a^2 X_2 = 1 + 697 \times 1.3 \times 10^{-3} = 1.907\,\Omega$

$I_1 = \frac{V}{R_e' + JX_e'} = \frac{400}{(.3995 + J1.907)} = \frac{400}{1.95\angle 78.18} = 204.5\angle -78.18$ amp

Pf = $\cos 78.18$ = .205 lags.

$I/P = VI\cos\theta = 400 \times 204.5 \times .205 = 81700 \times .205 = 16750$ watts

(6)

6/page 24 $W_I = 50$ watts $R_e'' = \frac{40}{100} = .4\,\Omega$

$I_{fl} = \frac{4000}{400} = 10$ amp $W_C = 10^2 \times .4 = 40$ watts

1/2 load pf .9 = $\frac{1}{2} \times 4000 \times .9 = 1800$ watts

effy = $\frac{1800}{1800 + 40 + 50} = 95.3\%$

III, full load unity pf pf .9
1/2 " " " } ...

(7) 2/page 27 $W_H = \eta h' f B_m^{1.6}$ $W_E = \eta e' f^2 B_m^2$

at 60 HZ → $\frac{W_H}{W_E} = \frac{1}{3}$

$\frac{\eta h' \times 60}{\eta e' \times 3600} = \frac{1}{3}$ $\therefore \frac{\eta h'}{\eta e'} = \frac{3600}{180} = 20$ — (1)

at 50 HZ → $\frac{W_H}{W_E} = \frac{\eta h' f_1}{\eta e' f_1^2} = 20 \times \frac{50}{2500}$ $\frac{100}{250} = \frac{1}{2.5}$

1 : 2.5

(8) 5/page 27 $W_I + L^2 W_{CFL} = \frac{1 - \eta}{\eta} \times L \times$ rated KVA × Pf

$2(3/4)^2 \times W_{CFL} = \frac{1 - .98}{.98} \times \frac{3}{4} \times 200 \times .8$

$2 \times \frac{9}{16} W_{CFL} = \frac{1}{49} \times \frac{600 \times .8}{4}$

$W_{CFL} = \frac{120 \times 16}{49 \times 18} = \frac{320}{147} = 2.133$ kilo watts

$W_I = (3/4)^2 W_{CFL}$

$= \frac{9}{16} \times 2.133 = 1.195$ kilo watts

effy = $\frac{1/2 \times 200 \times .8}{1/2 \times 200 \times .8 + 1.195 + 2.133} \times 100 = \frac{80}{83.3} \times 100 = 96.2\%$

(9) 4/page 27 full load effy = $\frac{1 \times 100 \times .8}{1 \times 100 \times .8 + 2.5 + 1.6} \times 100 = 95\%$

$L^2 \times W_{CFL} = W_I \rightarrow L^2 \times 2500 = 1600 \therefore L = \sqrt{\frac{1600}{2500}} = \frac{40}{50} = .8$

$\therefore$ KVA = $.8 \times 100 = 80$ KVA

$\eta_{max} = \frac{80 \times .8}{80 \times .8 + 1.6 + 1.6} \times 100 = \frac{64}{67.2} \times 100 = 95.25\%$

(10) 7/page 27 $W_I + L^2 W_{CFL} = \frac{1-\eta}{\eta} \times L \times \text{rated kVA} \times pf$

$2(3/4)^2 \times W_{CFL} = \frac{1-.97}{.97} \times 3/4 \times 500 \times 1$

$2 \times \frac{9}{16} W_{CFL} = \frac{3}{97} \times 375$

$W_{CFL} = \frac{3 \times 375 \times 16}{97 \times 18} = \frac{18000}{1745} = 10.3$ kilowatts

$W_{CFL} = 10300$ watts

$I_{FL_1}^2 R_e' = 10300$ watts

$\left[\frac{500}{3.3}\right]^2 R_e' = 10300 \quad \therefore R_e' = \frac{10.89 \times 10300}{2500,00} = \frac{112\cancel{000}}{250\cancel{000}} = .45\Omega$

$a = \frac{3300}{500} = 6.63$

$a^2 = 43.6 \qquad R_e'' = \frac{.45}{43.6} = .0103\Omega$

$\% Z = \frac{I_{FL_1} \times Z_1}{V_1} \times 100$

$10 = \frac{151.5 \times Z_1}{3300} \times 100 \qquad Z_e' = \frac{330}{151.5} = 2.18\Omega$

$X_e' = \sqrt{2.18^2 - .45^2} = \sqrt{4.75 - .2025} = 2.13\Omega$

$X_e'' = \frac{2.13}{43.6} = .0489\Omega$

[illegible] 4 hrs full load 2 ohr noload [illegible]

(11) 3/page (28) all day output $= 1 \times 1 \times 2 + 3/4 \times 1 \times 3 + .9 + \frac{1}{2} \times 1 \times 3 \times .75$

$+ 8 \times 1/4 \times .6 \times 1$

$= 2 + \frac{8.1}{4} + 1.125 + 1.2 = 6.35$ kwh

all day Iron loss $= \frac{160}{1000} \times 24 = 3.84$ kwh

all day copper loss $= 1 \times 125 \times 2 + (3/4)^2 \times 125 \times 3 + (1/2)^2 \times 125 \times 3$

$+ (1/4)^2 \times 125 \times 8 +$

$= 250 + \frac{9}{16} \times 375 + \frac{1}{4} \times 375 + \frac{1}{16} \times 1000$

$= 250 + 211 + 93.75 + 62.5$

$= 617.25$ wh $= .6172$ kwh

effy $= \frac{6.35}{6.35 + .617 + 3.84} \times 100$

(11) 3/page (28) all day o/p $= 1 \times 1 \times 2 + 3/4 \times 1 \times 3 \times .9$

$+ 1/2 \times 1 \times 3 \times .75 + 1/4 \times 1 \times 8 \times .6$

$= 2 + \frac{8.1}{4} + 1.5 \times .75 + 1.2$

$= 2 + 2.025 + 1.125 + 1.2$

$= 6.35$ kwh

all day Iron loss $= \frac{125}{1000} \times 24 = .125 \times 24 = 3$ kwh

all day copper loss $= 1^2 \times 160 \times 2 + (3/4)^2 \times 160 \times 3 + (1/2)^2 \times 160 \times 3$

$+ (1/4)^2 \times 160 \times 8$

$= 320 + \frac{9}{16} \times 480 + \frac{1}{4} \times 480 + \frac{1}{16} \times 160 \times 8$

$= 320 + 270 + 120 + 80 = .79$ kwh

effy $= \frac{6.35}{6.35 + .79 + 3} \times 100 = 63\%$

(12) Example / page (29) at full load

$W_I + W_{CFL} = \frac{1-.98}{.98} \times 1 \times 200 \times 1$

$W_I + W_{CFL} = 4.08$ kilowatts — (1)

$W_I + \frac{1}{4} W_{CFL} = \frac{1-.98}{.98} \times \frac{1}{2} \times 200 \times 1$

$W_I + .25 W_{CFL} = \frac{100}{49} = 2.04$ — (2)

(1) − (2) $\Rightarrow$ $.75 W_{CFL} = 2.04 \quad \therefore W_{CFL} = 2.72$ kilowatts

$W_I = 4.08 - 2.72 = 1.36$ kilowatts

$I_{h+e}^2 R_0 = 1360$ watts

$\frac{V^2}{R_0} = 1360 \qquad R_0$ at L.V $= \frac{384^2}{1360} = \frac{147500}{1360} = 108\Omega$

$E\, I_N \cos\theta_N = W_I$

$I_N = \frac{1360}{384 \times .2} = \frac{1360}{76.8} = 17.7$ amp

$\sin\theta_N = \sqrt{1 - .2^2}$

$= \sqrt{1 - .04} = \sqrt{.96} = .9798$

$X_0 = \frac{V}{I_N \sin\theta_N} = \frac{384}{17.7 \times .9798} = \frac{384}{17.3} = 22.1\Omega$

$I_{FL_2}^2 R_e'' = 2720$ watts $\quad \therefore R_e'' = \frac{2720}{\left[\frac{200 \times 10^3}{384}\right]^2} = \frac{2720 \times 384 \times 384}{200 \times 200 \times 10^6}$

$R_e'' = \frac{2720 \times 147500}{40000 \times 10^6} = \frac{402\cancel{000000}}{40000 \times 10\cancel{00000}} = .01005$

$\% R = \frac{I_{FL_2} \times R_2}{V_2} \times 100 = \frac{\left[\frac{200 \times 10^3}{384}\right] \times .01005}{384} \times 100$

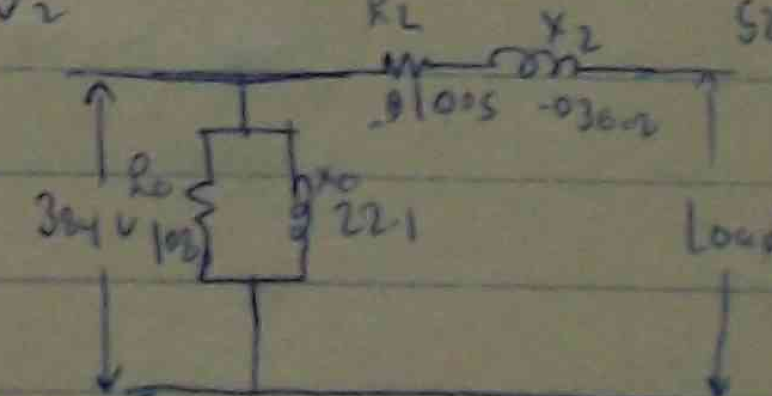
$\% R = \frac{522 \times 1.005}{384} = 1.355\%$

% Reg $= L\,(\% R \cos\theta + \% X \sin\theta)$

$4 = 1\,(1.355 \times .8 + \% X \times .6]$

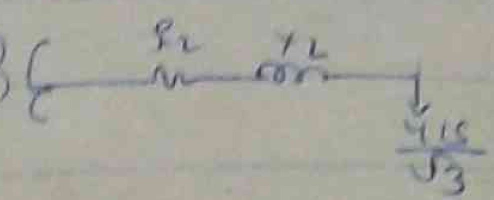
$\% X = \frac{4 - 1.085}{.6} = \frac{2.915}{.6} = 4.87\%$

$\% X = \frac{I_{FL_2} X_2}{V_2} \times 100 \qquad X_2 = \frac{4.87 \times 384}{522 \times 100} = \frac{1870}{52200} = .036$



(13) S/page (3)

$\% \text{Resistance} = \dfrac{I_2 R_2}{V_2} \times 100$



$\therefore \; I_2 R_2 = \dfrac{1 \times V_2}{100}$

$\% \text{reactance} = \dfrac{I_2 X_2}{V_2} \times 100$

$\therefore \; I_2 X_2 = \dfrac{5 V_2}{100}$

$V_2 = I_2 (R_2 + J X_2) + \dfrac{415}{\sqrt{3}}$

$V_2 = I_2 R_2 + J I_2 X_2 + \dfrac{415}{\sqrt{3}}$

$V_2 = \dfrac{V_2}{100} + J \dfrac{5 V_2}{100} + 239$

$\therefore \; \dfrac{99 V_2}{100} - J \dfrac{5 V_2}{100} = 239$

$\therefore \; \dfrac{99 V_2}{100} = 239$

$V_2 = \dfrac{23900}{99} = 242 V$

Pri. voltage $= 6600 V$

turn ratio $= \dfrac{6000}{242} = 24.8$

(14) A 8r kVA 750 Base of 2: $\% R_1 + J\% X_1 = \%\cancel{3} + J\%8$

B 8r kVA of Base of 500 $= \cancel{500}\ \dfrac{750}{500} [2 + J4]$

$= 1.5 [2 + J4] = 3 + J6$ $\qquad$ $27 = 6 + J11$ $\quad \angle 61.35$

A 8r kVA $=$ rated kVA $\times \dfrac{Z_B}{Z_T} = 1000 \angle -36.8 \times \dfrac{3 + J6}{8 + J9}$

$\therefore \; kVA_A = 1000 \angle -36.8 \; \dfrac{6.72 \angle 63.45}{12.55 \angle 61.4}$

$= \dfrac{6720 \angle 26.65}{12.85 \angle 61.4} = \cancel{538 \angle} = 535 \angle -34.75$ kVA

$kVA_{\cancel{A}} = 1000 \angle -36.8 \; \dfrac{3 + J6}{12.55 \angle 61.4} = \dfrac{1000 \angle \cancel{-36} 26.7 \angle 63.4}{12.55 \angle 61.4}$ kVA

~~kVA B~~ $\qquad kVA_B = 1000 \angle -36.8 \times \dfrac{3 + J5}{12.55 \angle 61.4}$

$= \dfrac{1000 \angle -36.8 \;\; 5.83 \angle 59}{12.55 \angle 61.4} = 465 \angle -39.2$ kVA

(15) $\dfrac{6600}{\sqrt{3}} = V_2' + \dfrac{1500}{\sqrt{3} \times 6.6} \angle +36.8 \times (.4 + J6)$

$3810 = V_2' + 131.2 \angle 36.8 \;\; 6 \angle 86.18$

$V_2' = 3810 - 787.2 \angle 122.98$

$= 3810 - 787.2 [-\cos 57 + J \sin 57]$

$= 3810 - 787.2 [-.545 + J.839]$

$= 3810 + 430 - J660$

$= 4240 - J660 = \cancel{42}\ 4290 \angle -8.85$

$E_{Line} = \sqrt{3} \times 4290 = 7400 = 7.4 kV$

(16) $E_g = IZ + V_2' = 3810 + \dfrac{1500 \angle -36.8}{\sqrt{3} \times 6.6} (.4 + J6]$

$= 3810 + 787.2 \angle 49.38$

$= 3810 + 787.2 [.653 + J.758]$

$= 4059 + J597 \; V$

$E_g = V_2 + IZ$

$4059 + J597 = V_2 + 131.2 \angle 36.8 \;\; 6 \angle 86.18$

$4059 + J597 = V_2 + [-430 + J600]$

$V_2 = 4489 - J609 = 4530 \angle 11.2$ $\quad$ $E_{line} = \sqrt{3} \times 4530 = 8220 V$

Pf .8 leading

(17) $I = \dfrac{1280{,}000}{\sqrt{3} \times 13500 \times .8} = \dfrac{1280{,}000}{18700} = 68.5$ amp

$V_{ph} = \dfrac{13500}{\sqrt{3}} = 7780 V$

$E_g = \sqrt{(V_{ph} \cos\theta + I_a R_s)^2 + (V_{ph} \sin\theta - I_a X_s)^2}$

$= \sqrt{(7780 \times .8 + 68.5 \times 1.5)^2 + (7780 \times .6 - 68.5 \times 30)^2}$

$= \sqrt{(6230 + 102.5)^2 + (4670 - 2050)^2}$

$= \sqrt{6332.5^2 + 2620^2} = 6850 V$

$\% \text{Reg} = \dfrac{6850 - 7780}{7780} \times 100 = -11.95\%$

Pf .8 lagg:

$E_g = \sqrt{(V_{ph} \cos\theta + I_a R_s)^2 + (V_{ph} \sin\theta + I_a X_s)^2}$

$= \sqrt{6332.5^2 + 6720^2} = 9230 V$

$\% \text{Reg} = \dfrac{9230 - 7780}{7780} \times 100$

$= \dfrac{1450{,}00}{7780} = 18.6\%$

Pf unity $\quad I = \dfrac{1280000}{\sqrt{3} \times 13500} = \dfrac{1280000}{23400} = 54.7$ amp

$E_g = \sqrt{(V_{ph} \cos\theta + I_a R_s)^2 + (-I_a X_s)^2}$

$= \sqrt{[7780 + 54.7 \times 1.5)^2 + (-54.7 \times 30)^2}$

$= \sqrt{7862.2^2 + 1640^2} = 8030 V$

$\% \text{Reg} = \dfrac{8030 - 7780}{7780} \times 100 = \cancel{\dfrac{1250{,}00}{7780}} = -\cancel{18.35}\%$

$= \dfrac{250{,}00}{7780} = 3.21\%$

(18) 4/98

(m) $x_2 = 2\pi f l = 2 \times 3.14 \times 25 \times .64 \times 10^{-3}$

$= .157 \times 64 = .1005\ \Omega$

$Z = \frac{1000}{\sqrt{3}[I]} = \frac{1000}{\sqrt{3} \times 300} = \frac{577}{300} = 1.925\ \Omega$

~~E I cos θ = 746 × 200 watts~~ $x_2' = a^2 x_2 = 3.6^2 \times .1005 = 1.305\ \Omega$

~~cos θ = 746 × 200 / 1000 × 300~~ $R_2' = a^2 R_2 = 3.6^2 \times .01 = .1296\ \Omega$

$Z^2 = R_e^2 + x_2'^2$

$R_e = \sqrt{Z^2 - x_2'^2} = \sqrt{1.925^2 - 1.305^2} = \sqrt{3.71 - 1.7} = \sqrt{2.1}$

$\therefore R_e = 1.448$

$\therefore$ [illegible] $R = 1.448 - .1296 = 1.318\ \Omega$ Pri. [illegible]

sec. [illegible] $= \frac{1.318}{(3.6)^2} = \frac{1.318}{12.96} = .102\ \Omega$

(2) $I_{st} = \frac{1000}{\sqrt{3}[.1296 + J1.305]} = \frac{577}{1.305 \angle 84.32} = 443 \angle -84.32$ I_1'

sec. [illegible] $= \frac{443 \angle -84.32}{\cancel{300}} \times 3.6 = 1600$ amp I_2

(3) 3% slip $pf = ?\ I_2 ?$

$I = \frac{1000}{\sqrt{3}\left[\frac{.1296}{.03} + J1.305\right]} = \frac{577}{4.32 + J1.305} = \frac{577}{4.5 \angle 16.85} = 128 \angle -16.85$ amp

$I_2 = 128 \times 3.6 = 462$ amp

rotor pf $= \cos 16.85 = .957$ lagging

(19) Example/page (103) $S_m = R_2'/x_2' = \frac{.016}{.265} = .0605$

$N_s = \frac{120 f}{P} = \frac{120 \times 50}{24} = 250$ r.p.m

$S_f = \frac{N_s - N_f}{N_s} \times \cancel{100} = \frac{250 - 247}{250} = \frac{3}{250} = .012$

$\frac{T_m}{T_f} = \frac{S_m^2 + S_f^2}{2 S_m S_f} = \frac{(.0605)^2 + (.012)^2}{2 \times (.0605)(.012)} = 2.62$

$\frac{T_{st}}{T_f} = \frac{S_m^2 + S_f^2}{S_f(S_m^2 + 1)} = \frac{(.0605)^2 + (.012)^2}{.012[.0605^2 + 1]} = \frac{.00366 + .000144}{.012[.00364 + 1]}$

$= \frac{.003744}{.012 \times 1.00364} = \frac{.003744}{.012} = .312$

$\frac{T_m}{T_{st}} = \frac{S_m^2 + 1}{2 S_m}$ $\frac{T_{st}}{T_m} = \frac{2 S_m}{S_m^2 + 1} = \frac{2 \times .0605}{.00364 + 1} = .121$

$N_m = 250(1 - .0605) = 250 \times .9395 = 234.8$ r.p.m

(20) 3/page (104) $T_{st} = T_f$

$\frac{V^2 R_e}{R_e^2 + x_2'^2} = \frac{V^2 R_2' s}{R_2'^2 + s^2 x_2'^2}$

$\frac{R_e}{R_e^2 + (.02)^2} = \frac{.04 \times .03}{(.04)^2 + (.03)^2 (.02)^2}$

$\frac{R_e^2 + .0004}{R_e} = \frac{.0016 + .0009 \times .0006}{.0012} = 1.333$

$R_e^2 + .0004 = 1.333 R_e$

$R_e = \frac{-(-1.333) \pm \sqrt{1.333^2 - 4 \times .0004}}{2 \times 1}$

$= 1.333\ \Omega$ $\therefore R_2 = 1.333 - .04$

$= 1.293\ \Omega$

$I_2 =$ $pf = \frac{R_2'}{s \times Z_2'} =$

$Z_2' = \sqrt{1.333^2 + .02^2} = \cancel{1.333}$ (or) $Z_2' = 1.333 + J.02$

$= 1.333 \angle .86$

$\therefore pf = \cos .86 = .998$ lagg.

(21) 3/page (104) $N_s = \frac{120 f}{P} = \frac{120 \times 50}{4} = 1500$ r.p.m

$S_m = \frac{N_s - N_m}{N_s} = \frac{1500 - 1365}{1500} = \frac{135}{1500} = .09$

$\frac{R_2'}{x_2'} = S_m$

$\therefore x_2' = \frac{.2}{.09} = 2.225\ \Omega$

$T_{st} = \frac{V^2 R_e}{R_e^2 + x_2'^2}$ $T_m = \frac{V^2}{2 x_2'} \times \frac{1}{2}$

$\therefore \frac{V^2 R_e}{R_e^2 + (2.225)^2} = \frac{V^2}{2 \times 2.225} \times \frac{1}{2}$

$\frac{R_e}{R_e^2 + 4.95} = \frac{1}{4.45 \times 2}$

$\therefore 8.9 R_e = R_e^2 + 4.95$

$R_e = \frac{-(-8.9) \pm \sqrt{8.9^2 - 4 \times 4.95}}{2 \times 1}$

$= \frac{8.9 \pm \sqrt{59.4}}{2}$

$R_e = \frac{8.9 \pm 7.75}{2}$

$= 8.325$ (or) $.595$

[illegible] $= 8.325 - .02 = 8.13\ \Omega$ or $.595 - .02 = .395\ \Omega$

(22) 4/page (105) $T_1 = \frac{V^2 R_2' s}{R_2'^2 + s^2 x_2'^2}$ Start torque: $\frac{V^2 R_2'}{R_2'^2 + x_2'^2}$

$T_2 = 1.5\, T_1$ (or) $1.5 \frac{V^2 R_2' s}{R_2'^2 + s^2 x_2'^2} = 1.5 \frac{V^2 R_2'}{R_2'^2 + x_2'^2}$

$\therefore \frac{V^2 R_e}{R_e^2 + x_2'^2} = \frac{1.5\, V^2 R_2'}{R_2'^2 + x_2'^2}$

$\frac{R_e}{R_e^2 + .2^2} = \frac{1.5 \times .04}{.04^2 + .2^2}$

$\frac{R_e}{R_e^2 + .04} = \frac{.06}{.0016 + .04}$

$\frac{R_e^2 + .04}{R_e} = \frac{.0416}{.06} = .693$

$R_e^2 + .04 = .693 R_e$

$R_e = \frac{-(-.693) \pm \sqrt{.693^2 - 4 \times 1 \times .04}}{2 \times 1}$

$= \frac{.693 \pm \sqrt{.48 - .16}}{2}$

$R_e = \frac{.693 \pm .566}{2} = \frac{1.259}{2} = .6295\ \Omega$

or $R_e = \frac{.693 - .566}{2} = .0635\ \Omega$

ωr ... $= .0635 - .04 = .0235\ \Omega$ or $.6295 - .04 = .589\ \Omega$

$T_2 = \frac{V^2 R'}{R_2'^2 + x_2'^2} = \frac{V^2 \times (1.04)}{1.04^2 + .2^2} = \frac{1.04 V^2}{1.08 + .04} = \frac{1.04 V^2}{1.12}$

$T_2 = .93 V^2$

$T_1 = \frac{V^2 R_2' s}{R_2'^2 + x_2'^2} = \frac{.04 V^2}{.0016 + .04} = \frac{.04}{.0416} V^2 = .962 V^2$

$\therefore$ .962 V^2 ... 100%

.93 V^2 ... $= \frac{.93}{.962} \times 100 = 96.8\%$ (T_2)

(23) 3/page (103) $N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000$ r.p.m

$S_f = \frac{N_s - N_f}{N_s} = \frac{1000 - 960}{1000} = \frac{40}{1000} = .04$

O/p $= 25 \times 746 = 18650$ watts

~~I/p~~ rotor o/p $= 18650 + 1000 = 19650$ watts

$3 I_2^2 R_2' \left(\frac{1-s}{s}\right) = 19650$

$3 I_2^2 R_2' = \frac{19650 \times .04}{1 - .04} = \frac{19650}{24} = 818$ watts

Total cu loss − gear copper loss $= 3 I_2^2 R_2'$

$818 - 250 = 3(35)^2 R_2'$

$\therefore R_2' = \frac{568}{3 \times 1225} = \frac{568}{3675} = .152\ \Omega$

(24) Example | page (113) $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ r.p.m

$S_f = \frac{1500 - 1440}{1500} = \frac{60}{1500} = .04$

$S_2 = \frac{1500 - 1200}{1500} = \frac{300}{1500} = .2$

$T_1 = \frac{V^2 R_2' s}{R_2'^2 + s^2 x_2'^2} = \frac{V^2 \times .25 \times .04}{.25^2} = \frac{.01 V^2}{.0625}$ —— (1)

$T_2 = \frac{V^2 R_2'' s}{R_2''^2 + s^2 x_2''^2} = \frac{V^2 R_2'' \times .2}{R_2''^2} = \frac{.2 V^2}{R_2''}$ —— (2)

$T_1 = T_2$ $\therefore \frac{.01 \cancel{V^2}}{.0625} = \frac{.2 \cancel{V^2}}{R_2''}$

$R_2'' = \frac{.2 \times .0625}{.01} = 6.25 \times .2 = 1.25$

ωr ... $= 1.25 - .25 = 1\ \Omega$ Ans

(25) Example / page (...)

$R_2' = a^2 R_2 = (.67)^2 \times .1 = .0448\ \Omega$

$X_2' = a^2 x_2 = (.67)^2 \times .9 = .404\ \Omega$

$T = \frac{V^2 R_2' s_f}{R_2'^2 + s_f^2 x_2'^2} = \frac{200^2 \times .0448 \times .04}{(.0448)^2 + (.04)^2 \times (.404)^2}$

$T = \frac{400,00 \times .001793}{.00201 + .0016 \times .1636} = \frac{40000 \times .001793}{.002272} = 40000 \times .79 = 31600$ watts

~~Total~~ Torque in lb-ft $= \frac{7.04}{N_s} \times T$ in watts

$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$

$\therefore$ T in lb-ft $= \frac{7.04}{1500} \times 31600 = 7.04 \times 21.1$

(25) Example | page (...) rotor to stator turn ratio $= \frac{1}{...} = .67$

$\therefore a = \frac{1}{.67} = 1.49$

$\therefore R_2' = a^2 R_2 = (1.49)^2 \times .1 = 2.205 \times .1 = .2205\ \Omega$

$x_2' = a^2 x_2 = (1.49)^2 \times .9 = 2.205 \times .9 = 1.985\ \Omega$

$T = \frac{V^2 R_2' s}{R_2'^2 + s^2 x_2'^2} = \frac{40000 \times .2205 \times .04}{.2205^2 + (.04)^2 \times 1.985}$

$= \frac{1600 \times .2205}{.0486 + .0016 \times 1.985} = \frac{353}{.05178} = 6830$ watts

T in lb-ft $= \frac{7.04}{1500} \times 6830 = \frac{48000}{1500} = 30$ lb-ft Ans

~~Hp~~ $N_r = N_s(1-s) = 1500(1 - .04) = 1440$ r.p.m

$Hp = \frac{2\pi N_r T}{33000} = \frac{2 \times 3.14 \times 1440 \times 30}{33000} = 6.28 \times 1.31 = 8.29$ HP

$T_m = \frac{V^2}{2 x_2'} = \frac{400,00}{2 \times 1.985} = \frac{200,00}{1.985} = 10050$ watts

T in watt $= \frac{7.04}{1500} \times 10050 = 47$ lb-ft

$S_m = \frac{R_2'}{x_2'} = \frac{.1}{.9} = 1/9$

$N_m = N_s(1 - s_m) = 1500(1 - 1/9) = 8/9 \times 1500 = \frac{12000}{9}$

$= 1335$ r.p.m

$Hp_m = \frac{2\pi N_m T}{33000}$

$= \frac{2 \times 3.14 \times 1335 \times 47}{33000} = \frac{6.28 \times 62800}{33000} = 11.94$ H.P

full load HP $Hp = \frac{2\pi N_f T_f}{33000}$ T_f T_m ...

maximum Hp $= \frac{2\pi N_m T_m}{33000}$

(26) (2)/page (129) Starting torque $= \dfrac{V^2 R_1'}{R_1'^2 + X_2'^2} + \dfrac{V^2 R_2''}{R_2''^2 + X_2''^2}$

$T_{st} = \dfrac{V^2 \times 3.5}{3.5^2 + 1.5^2} + \dfrac{V^2 \times .6}{.6^2 + 7^2} = \dfrac{3.5V^2}{12.25 + 2.25} + \dfrac{.6V^2}{.36 + 49}$

$= \dfrac{3.5V^2}{15} + \dfrac{.6V^2}{49.36} = .233V^2 + .01218V^2 = .245V^2$

$T_{full\ load} = \dfrac{V^2 \times 3.5 \times .06}{3.5^2 + 1.5^2 \times .06^2} + \dfrac{V^2 \times .6 \times .06}{.6^2 + 7^2 \times .06^2}$

$= \dfrac{V^2 \times .21}{12.25 + 2.25 \times .0036} + \dfrac{V^2 \times .036}{.36 + 49 \times .0036}$

$= \dfrac{.21V^2}{12.258} + \dfrac{.036V^2}{.5317} = .01715V^2 + .066V^2 = .083V^2$

$\dfrac{T_{st}}{T_f} = \dfrac{.245}{.0838} = \dfrac{245}{.083} \times 100 = 300\%$

(27) 9/page 158 $I_A = \dfrac{15000}{\sqrt{3} \times 500} = \dfrac{30}{\sqrt{3}}$ amp $I_{dc} = \dfrac{30}{\sqrt{3}}$ amp

$E_{do} = 500 + 15 = 515V$

$E_{do} = \sqrt{2}\, V_s \dfrac{N}{\pi} \sin\dfrac{\pi}{N}$

$515 = 1.4142 \times V_s \times \dfrac{3}{3.14} \sin\dfrac{180}{3}$

$515 = V_s \times 1.4142 \times .955 \times .866$

$\therefore V_s = \dfrac{515}{1.4142 \times .829} = \dfrac{515}{1.172} = 440V$

KVA rating $= \dfrac{\sqrt{3}\, V_s I_{dc}}{1000} = \sqrt{3} \times 440 \times \dfrac{30}{\sqrt{3} \times 1000} = .763 \times 30$

$= 22.9$ KVA

(28)

$E_{do} = 500 + 15 = 515V$

Rect. Effy $= \dfrac{500}{515} \times 100 = 97\%$

Output power $= I_{dc} \times V = 30 \times 500 = 15000$ watts

Arc loss $= 15 \times 30 = 450$ watts

$R_e'' = \dfrac{600}{20^2} = \dfrac{600}{400} = 1.5\Omega$

Cu loss $= \left(\dfrac{I_{dc}}{\sqrt{N}}\right)^2 \times R_e'' = \left(\dfrac{30}{\sqrt{3}}\right)^2 \times 1.5 = \dfrac{900 \times 1.5}{3} = 450$ watts

effy $= \dfrac{o/p}{o/p + losses} = \dfrac{15000}{15000 + 450 + 450 + 70 + 500} \times 100$

$= \dfrac{15000}{16470} \times 100 = 91.2\%$

(29) $E_{do} = \sqrt{2}\, V_s \dfrac{N}{\pi} \sin\dfrac{\pi}{N}$

$= 1.4142 \times \dfrac{1300}{\sqrt{3}} \times \dfrac{6}{3.14} \sin\dfrac{180}{6}$

$= 1.4142 \times 750 \times 1.91 \times .5$

$= 2.7 \times 375 = 1025V$

No load output terminal voltage $= 1025 - 25 = 1000V$

full load o/p $E_{dn} = \sqrt{2}\, V_s \dfrac{N}{\pi} \sin\dfrac{\pi}{N} \cos^2 \mu/2$

$= 1025 \cos^2(10)$

$= 995V$

Full load output terminal voltage $= 995 - 25 = 970V$

% Reg. $= \dfrac{E_{do} - E_{dn}}{E_{do} - \text{arc drop}} \times 100$

$= \dfrac{1025 - 970}{1025 - 25} \times 100 = \dfrac{55}{1000} \times 100 = 5.5\%$

FIJI (2)

KN 80

Power wiring & Installation

2nd Year Electrical Power

G.T.I

Mg Kyaw Naing

2E.P(A)

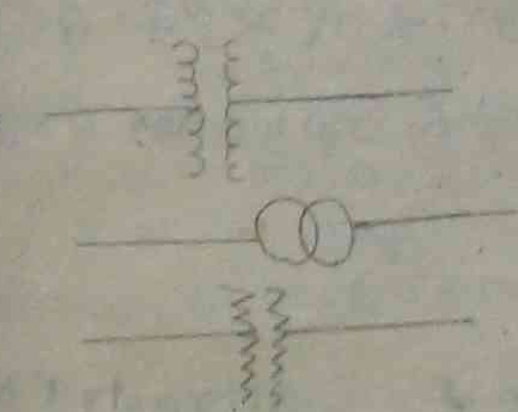
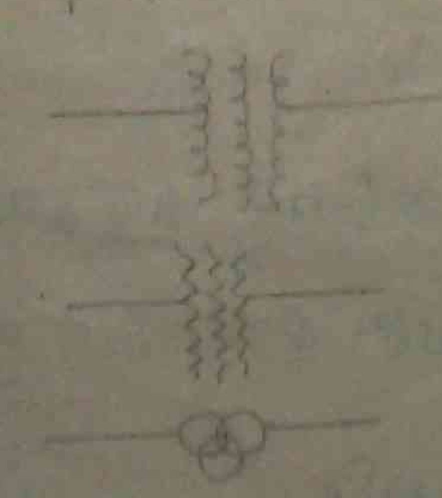
G.T.I (Prome)

* kVAများကို Base *

Power wiring & Installation

One line diagram (တစ်ချောင်းဆွဲပုံ)

ဤမျှသော စနစ်သွင် 3φ ဝန်စနစ်ကို ဖိကသွင် (1φ) လျှပ်စီးပတ်လမ်း၌ သုံးချောင်းအစား တချောင်းနှင့်ဆွဲလေ့ရှိပြီး မြေငြင်းတွက်ချက်လေ့ရှိပါ။ မကြာခဏ တစ်ဆင့်ပြင်သို့စုံသောလျှပ်စီး ပတ်လမ်းကို ချန်လှပ်ထားပြီး ဝံအဖြစ်သတ်မှတ်ထားသော သင်္ကေတများကို သုံး၍ ပိုမိုရှင်းလင်း သောပုံများကို ဖြည့်ပြုပါ။ ယင်းကဲ့သို့ ရှင်းလင်းအောင်ဆွဲသော လျှပ်စီးပတ်လမ်းကို (one line diagram) တစ်ချောင်းဆွဲပုံဟုခေါ်သည်။ တစ်ချောင်းဆွဲပုံ၌ သုံးရှိသော လျှပ်စစ် စနစ်တွင် အကြီးဝင်သည့် သင်္ကေတများကို အောက်ပါအတိုင်း တွေ့ရှိရပေမည်။

1.  = ဝိုင်း (cable)
2.  = ဓာတ်လည်ပတ်သော အာမေချာ (Armature)
3.  = မြို့ကျော်
4.  = ကြိုးနှစ်ခွေလျှပ်စစ်ဓာတ်အားပြောင်း (Transformer)
5.  = circuit breaker
6.  = ~~Transformer~~ Power circuit breaker oil or other liquid
7.  = Air circuit breaker
8.  = wye or star
9.  = ကြိုးသုံးခွေလျှပ်စစ်ဓာတ်အားပြောင်း (Transformer)
10.  = delta
11.  = ground or Earth
12.  = Resistance Grounding

13. = Reactor grounding

14. or = current Transformer (C.T)

15. or = potential transformer (P.T)

16. (A) (V) = Ammeter voltmeter etc

Relay (ဆင့်ကမ်းကရိယာ)

Relay ဆိုသည်မှာ ဓါတ်အားပေးဝေသော ပင်မလျှပ်စီးပတ်လမ်းကို အခြေအနေ ဆိုးရွားသောအခါ ဝင်ရောက်ဖြတ်တောက်ခြင်းဖြစ်စေ ဖယ်ရှားခြင်းဖြစ်စေ ကာကွယ်မှုပေးနိုင်ရန်အတွက် စီစဉ်ထားသော ကရိယာကို ခေါ်သည်။

ကာကွယ်မှုဆင့်ကမ်းများသည် အခြေအနေ ဆိုးရွားမှုကို သိရှိနိုင်ခြင်း၊ လှုပ်ရှားခြင်း၊ ဓါတ်ကျိုးခြင်းတို့ကြောင့် ကျယ်ပြန့်စွာ သုံးစွဲလာနိုင်ခဲ့ကြသည်။ ယခုခေတ်တွင် ကျယ်ပြန့်စွာ အသုံးပြုလာနိုင်သော ဆင့်ကမ်းများတွင် -

(1) Armature ကိုဆွဲငင်သောဆင့်ကမ်း (attracted Armature relay)

(2) ရွေ့လျားသောအခွေဆင့်ကမ်း (moving coil relays)

(3) ဦးခွက်ဆင့်ကမ်း (Induction cup relay)

(4) ဦးပြားဝိုင်းဆင့်ကမ်း (Induction dish relay)

(5) အပူသုံးဆင့်ကမ်း (Thermal relays)

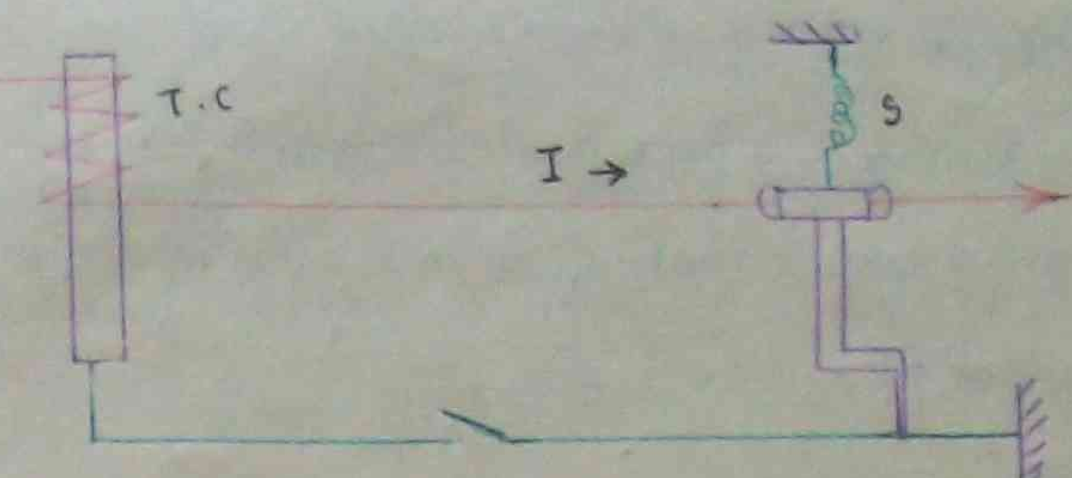
ဆင့်ကမ်းနှင့် လျှပ်စီးပတ်လမ်း

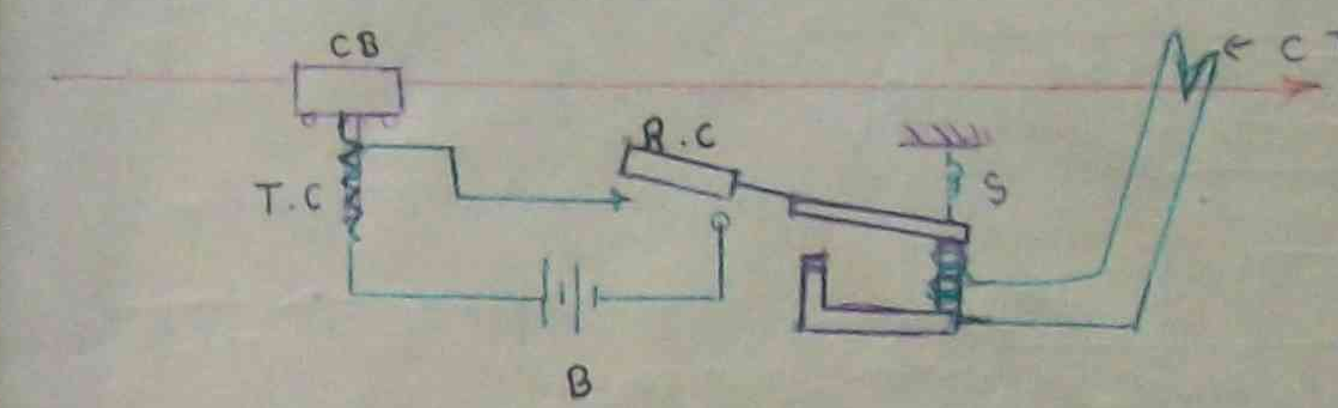
ဆင့်ကမ်းတွင် ပထမဆင့်ကမ်းနှင့် ဒုတိယဆင့်ကမ်း ဟူ၍ ၂ မျိုးရှိသည်။

ပထမဆင့်ကမ်းသည် ကာကွယ်မှုပြုလိုသော လျှပ်စီးပတ်လမ်းရှိ လျှပ်စီးကို အသုံးပြု၍ ဝင်ရောက်ဖြတ်တောက်ခြင်းဖြစ်စေ ဆောင်ရွက်စေသော ဆင့်ကမ်းမျိုးဖြစ်သည်။

ဒုတိယဆင့်ကမ်းမှာ ကာကွယ်မှုပြုလိုသော လျှပ်စီးပတ်လမ်းတွင် current ~~to~~ transformer (C.T) ဖြင့် ဆင့်ကမ်းလုပ်ဆောင်ပြီးနောက် သံလိုက်အား ထွင်းပေး၍ အထက်ပါနည်းအတိုင်း ဆောင်ရွက်စေသည်။

ပထမဆင့်ကမ်း ဆောင်ရွက်ခြင်း





ဒုတိယဆင့်ကမ်း ဆောင်ရွက်ခြင်း

CB = circuit Breaker

C.T = circuit Transformer

S = spring

R.C = Relay contact

B = Battery

ဆင့်ကမ်း၏ အခြေခံဆောင်ရွက်ပုံနှင့် လျှပ်စီးပတ်လမ်းများ ဆင့်ကမ်းရှိသည့် ကျိုးကြောင်းဖော်တွင် လုပ်ဆောင်နေသော သံလိုက်ဓါတ်အား ထွင်းပေးသော coil ဟူ၍သည် ပုံမှန်အခြေအနေတွင် ရှိသော လျှပ်စီးနှင့် ဖြစ်ပေါ်သော သံလိုက်ဆွဲငင်အားကို spring ဖြင့်ဖြစ်စေ အလေးချိန်ကြောင့်ဖြစ်စေ မရွေ့လျားနိုင်ရန် ထိန်းကျင်ထားသည်။ ထို့ကြောင့် ပုံမှန်ထက်ပိုမိုများသော ဆင့်ကမ်းမှတဆင့် မှုမှန်ပေပါက်အားလိုင်းတွင် ချို့ယွင်းသောအခါ လျှပ်စီးပိုများလာပြီး ဆွဲငင်အား ပိုကြီးလာသည့်အတွက် ထိန်းကျင်ထားသော အားများကို ကျော်လွန်ပြီး ဆွဲငင်ပေးမည်ဖြစ်ပြီး အခါမှာ ... သောကြောင့် ဆောင်ရွက်မှုများ ဖြစ်လာပေမည်။

ဆင့်ကမ်းလျှပ်စီးပတ်လမ်းတွင် (1) ပင်မဓါတ်အားလိုင်း

(2) ဒုတိယလျှပ်စီးပတ်လမ်း

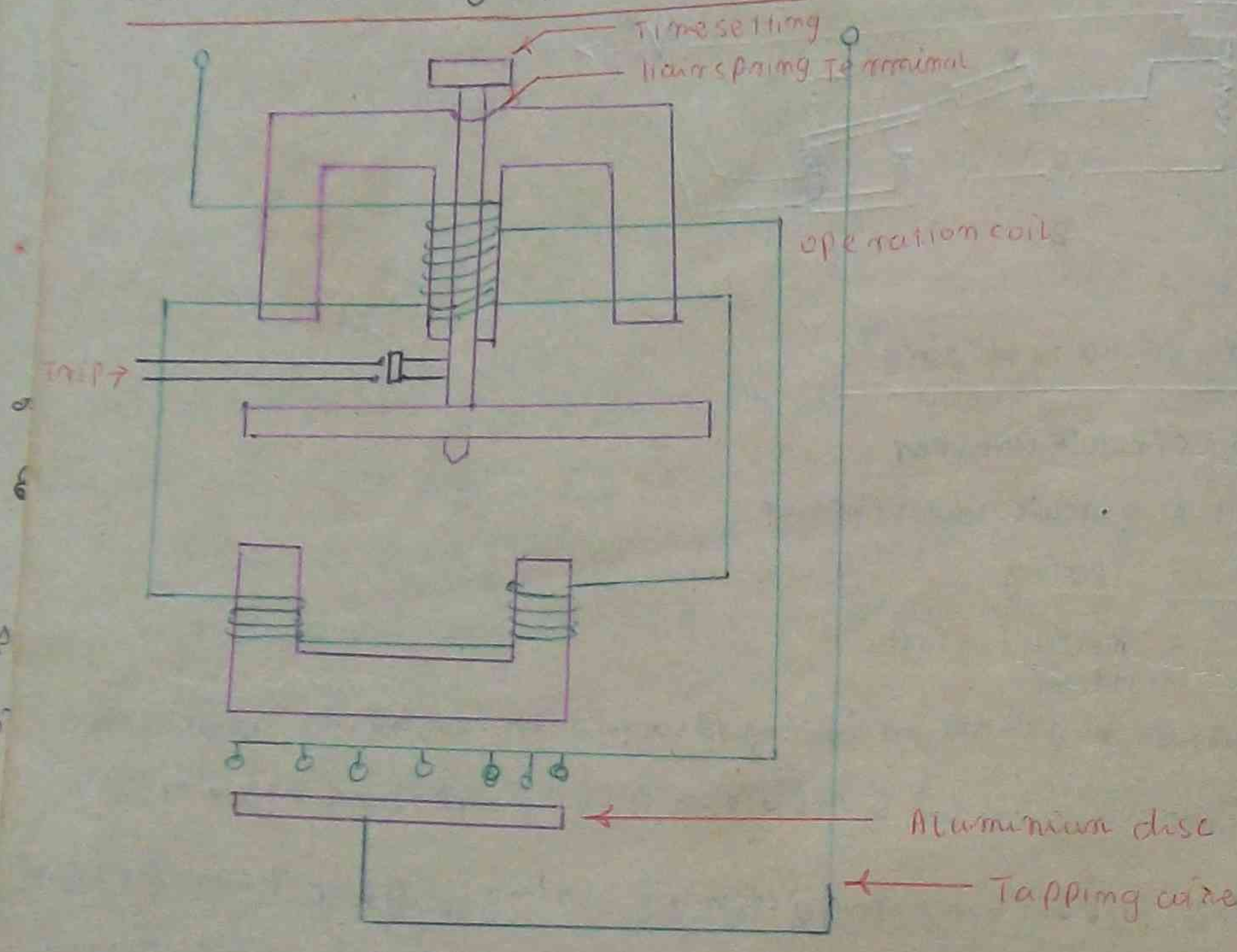
(3) DC လျှပ်စီးပတ်လမ်း ဟူ၍ ၃ ပိုင်းပါသည်။

ပင်မဓါတ်အားပေးလိုင်းမှာ ကာကွယ်လိုသော လျှပ်စီးပတ်လမ်း ဖြစ်သည်။ ဒုတိယ လျှပ်စီးမှာလည်း အကွာအဝေးနှင့် ... များကို ဖြစ်သည်။ ၎င်းတွင်

PT နှင့် C.T များ၏ ... 110 volt 5 amp သို့ လျော့ချသည်။ ဆင့်ကမ်း လုပ်ဆောင်ပြီး ... သည် ဝိုင်နှင့် လျှပ်စီးပတ်လမ်း ... ဖြစ်သော ... ထားသည်။ ၎င်းလျှပ်စီးပတ်လမ်းကို ဒုတိယလျှပ်စီးပတ်လမ်း ဟုခေါ်သည်

ဆင့်ကမ်းလျှပ်စီးပတ်လမ်း ဟုခေါ်သည်။ D.C လျှပ်စီးပတ်လမ်းတွင် Battery နှင့် ပင်မ ဆင့်ကမ်းခလုတ်တို့ကို လျှပ်စီးပတ်လမ်းဖြင့် စီး C.B အတွင်းရှိ ဖြတ်ပစ်ကြိုးချွေတွင် ... ဒုတိယလျှပ်စီး ဖြစ်အောင်ဆက်သွယ်ထားသည်။ ချွတ်ယွင်းမှုကျရောက်လာသောအခါ ဒုတိယလျှပ်စီး ပတ်လမ်းတွင် လျှပ်စီးများပြီး ချွဲအားကောင်းသောကြောင့် ဆင့်ကမ်းခလုတ်ကို ဖိတ်စေကာ D.C လျှပ်စီးကိုကြိုးစေပြီး ပင်မခလုတ်ကို ဖွင့်စေသည်။

Over current relay (လျှပ်စီးလွန်ဆင့်ကမ်း)



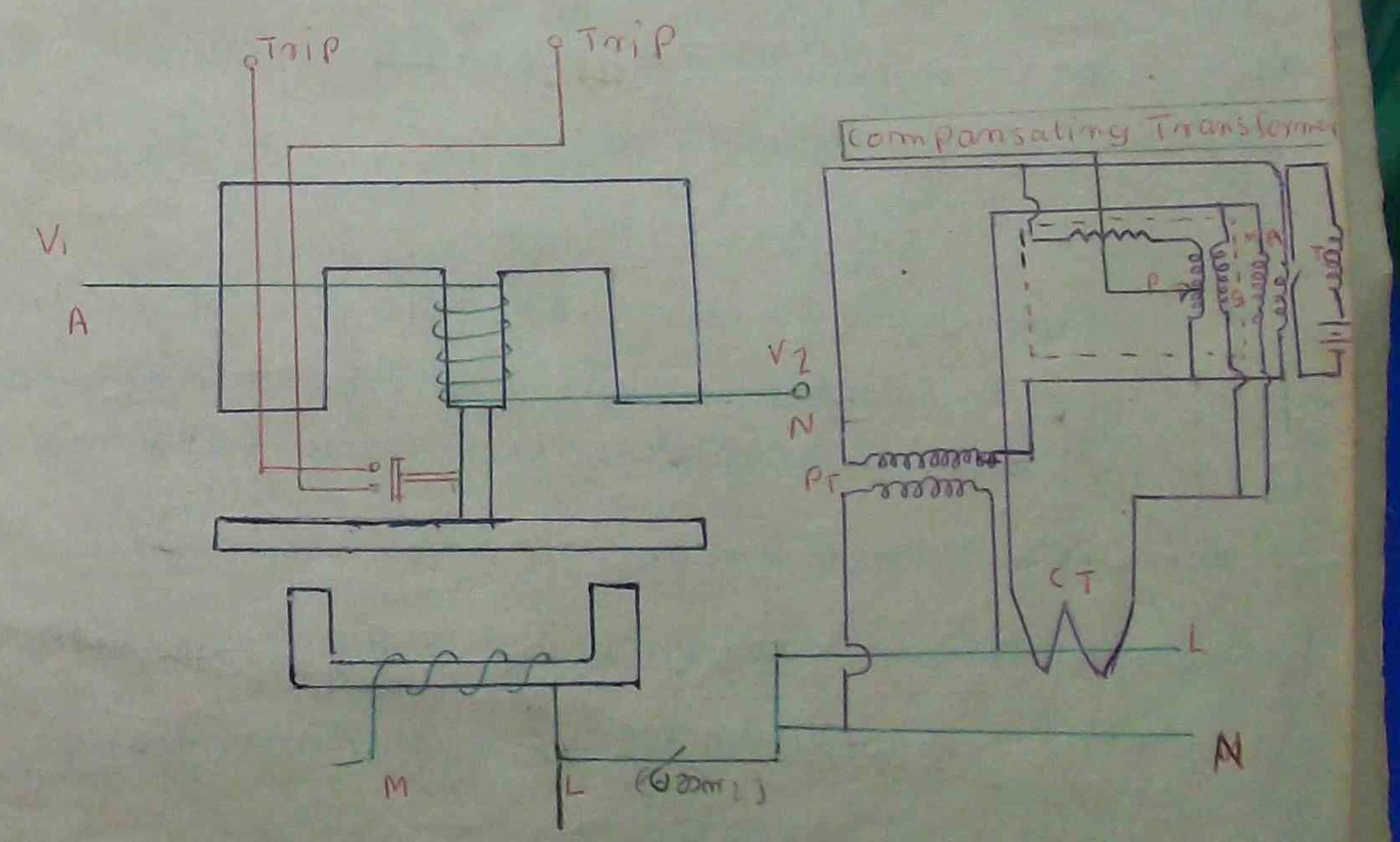
Induction Type

လျှပ်စီးလွန်ဆင့်ကမ်းတွင် E ပုံသဏ္ဍာန်နှင့် U ပုံသဏ္ဍာန် လျှပ်စစ်သံလိုက်နှစ်ခု အကြားတွင်လည်ပတ်နိုင်သော အလူမီနီယံပြားဝိုင်းတစ်ခုရှိသည်။ ပထမလျှပ်စစ်သံလိုက်၏ ပေါ်တွင် အဝေါ်ပတ်ထားသော ကွိုင်ကို ... plug ဖြင့် ချိတ်ဆက်ထားသည်။ ဒုတိယကြိုးချွေတစ်ခုမှာ ပထမသံလိုက်နှင့် ဒုတိယသံလိုက်ကြား ကြိုးချွေတို့ကို လျှပ်စီးပတ်လမ်းပြည့်ဖြစ်အောင် ပြုလုပ်ထားသည်။ ... ဒုတိယကြိုးချွေ၌ လျှပ်စီးဖြစ်ပေါ်စေမည်ဖြစ်သည်။ လျှပ်စီးတို့ဖြင့်တွက်ပေါ်လာသော သံလိုက်ဖိုင်းများသည် phase နှင့် နေရာခြားနားသောကြောင့် ... သဏ္ဍာန်ပြားဝိုင်း လည်စေသောဉာဏ်ကန်အား ထွက်ပေါ်လာပါ။

သဏ္ဍာန်ပြားဝိုင်းသည် လျှပ်စီးအပေါ်အခြေခံ၍ ဉာဏ်ကန်အား ထွက်ပေါ်လာ

လှုပ်ရှားသောအားရှိသောအခါ ဖိန်းချုပ်ထားသော spring ~~ကြိုး~~ ဝင်း အားကို ခံနိုင်ကျွံပြီး လှည့်သွားသည်။ ယင်းလှည့်သွားမှုသည် သတ်မှတ်အချိန်တွင် ဖွင့်ပေးသော ခလုတ် (SPST) ကို ပိတ်စေခြင်းဖြင့် ဆင့်ကမ်းခလုတ်ဖွင့်ပေးသည်။ ဆင့်ကမ်း၏ခလုတ်လက် တံသည် စက်ဝန်းပုံလှည့်သည်ဖြစ်ရာ အဝေးအနီး ကွာခြားခြင်းဖြင့် အချိန် အနှေးအမြန် ချိန်ညှိနိုင်သည်။ ... လျှပ်စီးပမာဏ အားထည့်စေရန် ... အညွှန်းကန်အား လာသည့် အတွက် ဆင့်ကမ်းတွင် အချိန်နှင့် ပြောင်းပြန်ကျသော သဘော ... ဖြစ်သည်။ အနည်းဆုံး အချိန်ပုံသေရှိ၍ လျှပ်စီးနှင့် အချိန် ပြောင်းပြန်အချိုးကျသော သဘော ... (Inductrion mortar) ဆင့်ကမ်းအ ... ဟုခေါ်သည်။ ဆင့်ကမ်းခလုတ်သည် လျှပ်စီးအနည်းငယ်သာစီးနိုင်သဖြင့် ... ဆင့်ကမ်းပါရှိသည်။ ... (Flat) သို့မဟုတ် ... (Indicator) သို့မဟုတ် (Target) ပါရှိသည်။ ... ဆင့်ကမ်း၏ ... သိနိုင်သည်။

** Reberse power relay (ပြန်အားပြန်ဆင့်ကမ်း)



Reberse power relay သည် watt meter နှင့် kilowatt power meter များ၏ အခြေခံသဘောတရားပေါ်တွင် အခြေခံ၍ ... လျှပ်စီးပြောင်းပြန်စီး ... အခြေခံတည်ဆောက်ထားသည်။ ... ဆင့်ကမ်းကို ... လျှပ်စစ်သံလိုက် ... အကြောင်းပေါ်တွင် ... ထားသည်။ ... ထားသည်။

[illegible]

[illegible]

[illegible] spring [illegible]

[illegible]

[illegible] (compensating Transformer) [illegible]

[illegible] PT [illegible] CT [illegible]

[illegible] PT [illegible]

[illegible]

Circuit Breaker (လျှပ်စီးပတ်လမ်းဖြတ်ကိရိယာ)

(Electric arc) - Electric contact [illegible] Fuse [illegible]

Electric arc [illegible] Electric arc [illegible]

[illegible]

[illegible] Circuit Breaker (C.B) [illegible] circuit [illegible] current [illegible] short circuit [illegible] C.B [illegible] rating operation characteristic [illegible] short circuit [illegible] C.B [illegible] short circuit [illegible] maxium [illegible] ~~3 phase~~

3 phase [illegible] short circuit [illegible] line to line, line, neutral [illegible] Phase to earth [illegible] C.B [illegible] fault current [illegible]

Type of AC circuit Breaker
(AC လျှပ်စီးပတ်လမ်းဖြတ်ကိရိယာ အမျိုးအစားများ)

- AC circuit breaker
  - None arc control Type
    - Plain oil Break C.B
    - Plain air break C.B
  - Arc control Type
    - Self blast Type
      - Cross Jet Pot oil C.B
      - Explosion Pot oil C.B
    - External Blast Type
      - Impulse Type oil C.B
      - Air Blast C.B

[illegible] — ① Electric arc [illegible] C.B [illegible]
② Electric arc [illegible] C.B [illegible]

[illegible]

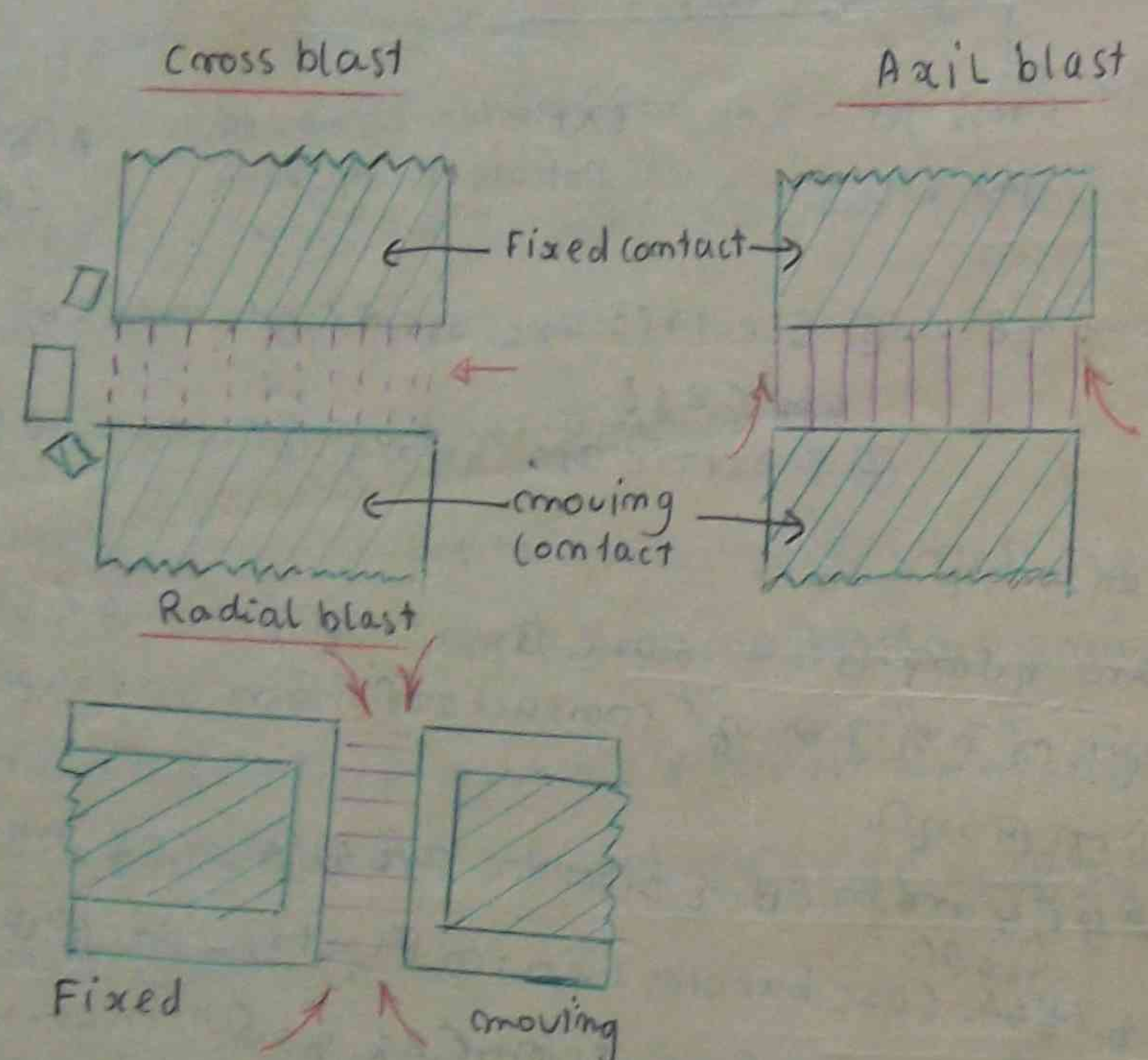
Electric arc [illegible] C.B [illegible] contact [illegible]

[illegible] C.B [illegible] Electric arc [illegible] (gas bubbles) [illegible] Electric arc [illegible] ~~Electric arc~~ [illegible] Electric arc [illegible]

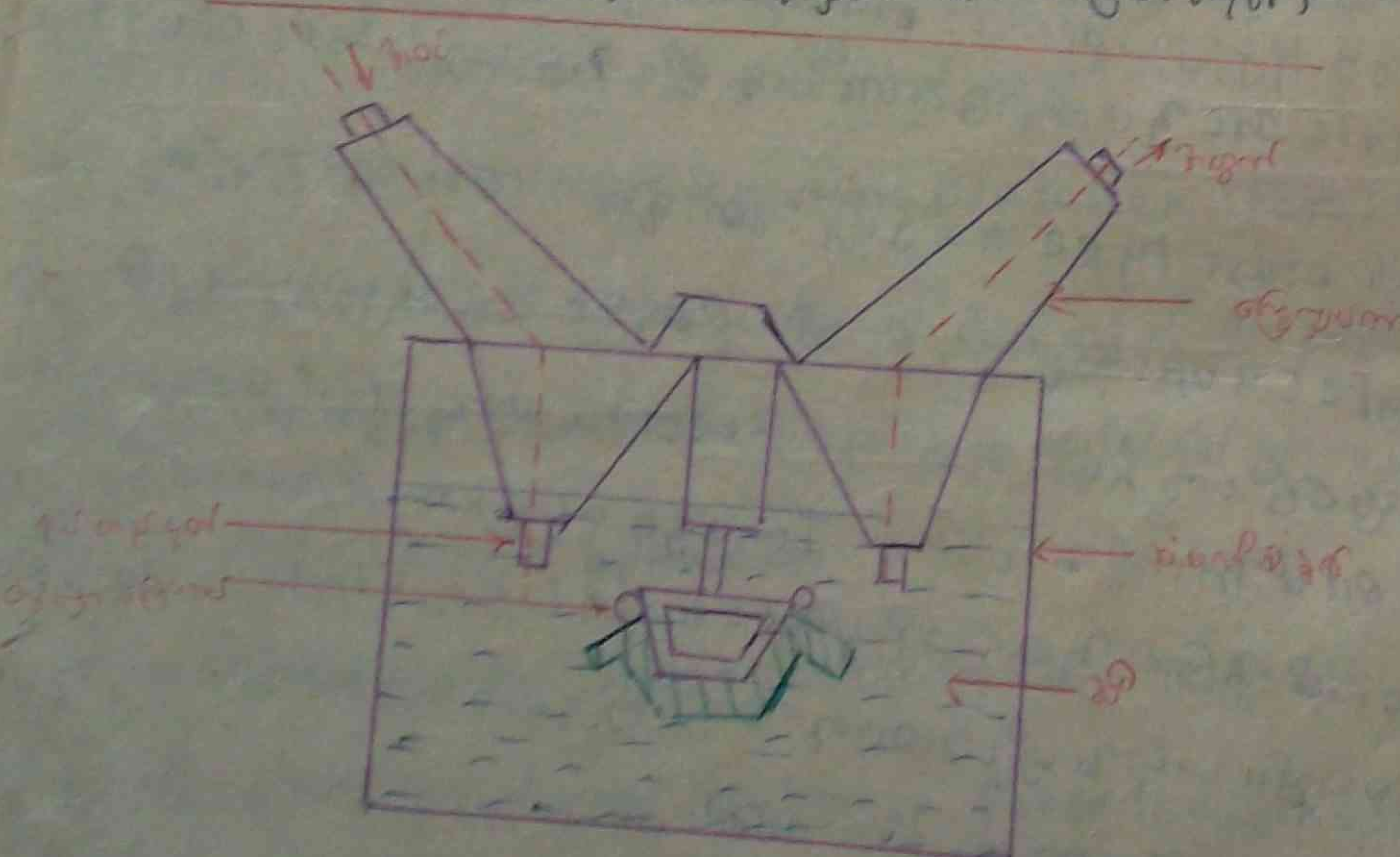
Electric arc [illegible] self blast type [illegible] External blast type [illegible] Self blast Type C.B [illegible] Electric arc [illegible] Ionize [illegible] Electric arc [illegible] Electric arc [illegible] 30% [illegible] (arcing time) [illegible]

Impulse oil CB များတွင် Electric arc ငြိမ်းစေခြင်း များတွင် [illegible] ဆီကို ဖိအားဖြင့် [illegible] သည်။ ထို့ကြောင့် [illegible] ဖြတ်တောက်ခြင်း [illegible] ပေါ်ပေါက်သည် [illegible] မြန်မြန် [illegible] ဖြတ်တောက်ပါသည်။

air circuit Breaker တွင် လေမှုတ်၍ လျှပ်စီးပတ်လမ်းဖြတ်ကိရိယာတွင် [illegible] Electric arc ကို ငြိမ်းသတ်သည် [illegible] [illegible] သည်။ [illegible] လေမှုတ်ခြင်း [illegible] သည်။



oil circuit breaker (ဆီသုံးလျှပ်စီးပတ်လမ်းဖြတ်ခလုတ်)



လျှပ်စစ်ဓာတ်အားပေးစက်ရုံများရှိ လျှပ်စီးပတ်လမ်း ဖြတ်ခလုတ်များကို [illegible]

၁။ ဓါတ် Electric ~~Earth~~ arc များကို ငြိမ်းသတ်နိုင်သော OCB (oil circuit Breaker) ဆီသုံးခလုတ်များ [illegible] ဖြစ်သည်။ [illegible]

[illegible]

ဆီကုန်သည် [illegible] KVA နှင့် [illegible] ဆီသုံး [illegible] လျှပ်စီးပတ်လမ်းဖြတ်ခလုတ်များ [illegible] ဖြစ်သည်။ လျှပ်စီးပတ်လမ်း [illegible] arc များ [illegible] ငြိမ်းသတ်သည် [illegible] သည်။

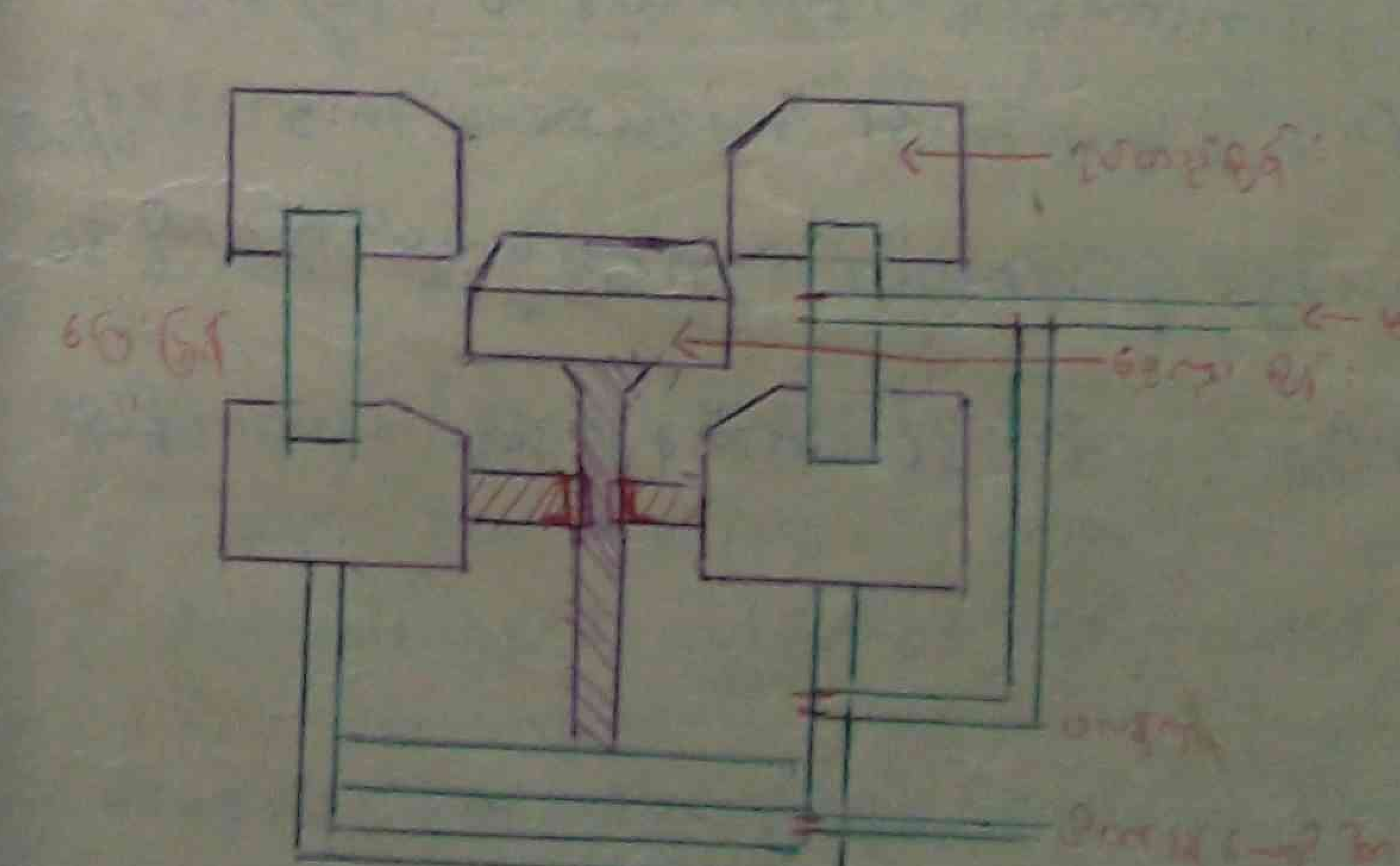
① ဆီ:ဆီ:ဖြတ်ခလုတ်

② အလွန်ဆီအားသုံးခလုတ်

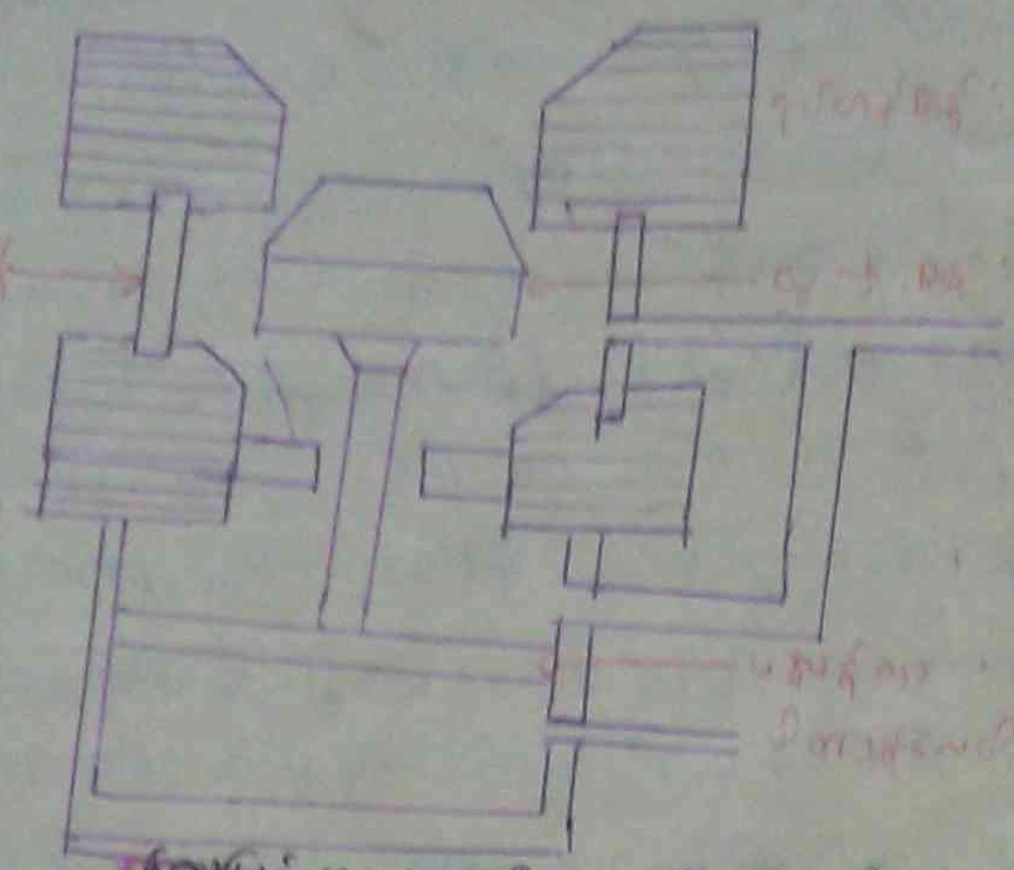
③ [illegible] ဆီသုံးဖြတ်ခလုတ်များကို pole တခု 1 unit နှင့် pole 3 ခု 1 unit [illegible] သည်။ [illegible] ① [illegible] ② [illegible] သည်။

Air blast circuit ~~bre~~aker (A.B.CB)

(လေမှုတ်အား လျှပ်စီးပတ်လမ်းဖြတ်ကိရိယာ)



*



[illegible]

[illegible] 450 psi [illegible] 250 psi [illegible] 600 psi [illegible] 355 psi [illegible] 33 KV [illegible]

[illegible] 15 kg/cm² [illegible] 300 KV [illegible] 30 kg/cm² [illegible] OCB [illegible]

calculation short circuit current

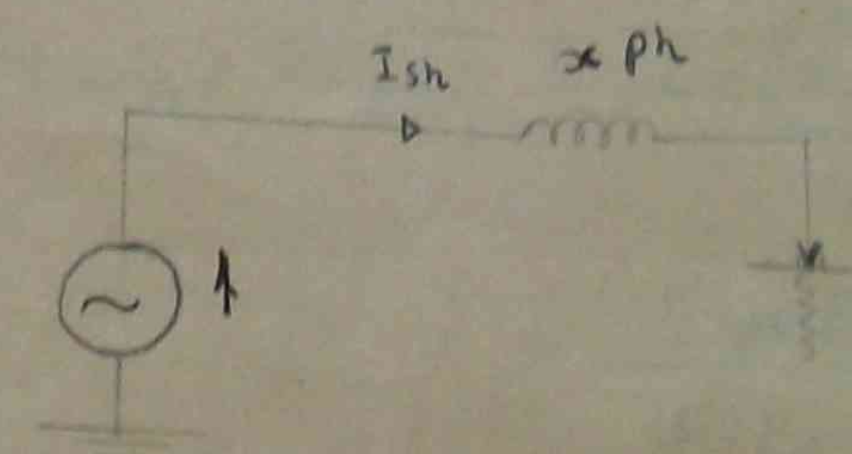
AC network current သည် Fault ဖြစ်သွားသောအခါ current များ [illegible] Fault [illegible] ဖြစ်သည်။

① neutral earth [illegible] earth နှင့် phase [illegible] fault ဖြစ်[illegible]သည်။

② 2 phase or 3 phase to earth fault

③ Phase ၂ခု [illegible] short circuit နှင့် Phase ၃ခု [illegible] short circuit ဖြစ်[illegible]သည်။

[illegible] short circuit ဖြစ်[illegible] supply network [illegible] current [illegible]သည်။ short circuit current [illegible] short circuit [illegible] circuit breaker rating [illegible] short circuit current [illegible] current limiting reactor [illegible]သည်။ AC [illegible] network [illegible] fault ဖြစ်[illegible] fault ဖြစ်[illegible] alternator, Transformer, နှင့် line [illegible] reactance [illegible] Phase to phase fault current [illegible]သည်။ Phase to earth fault [illegible] earth resistance [illegible] short circuit current [illegible]သည်။



$I = \frac{E}{x}$ $\quad I_{sh} = \frac{E_{ph}}{x_{ph}}$ (R is negligble when short circuit across)

where I_{sh} = Short circuit current

E_{ph} = Phase voltage

Reactance /ph (x_{ph})

Percentage Reactare of Alternator Transformer and line

[illegible] percentage Reactance [illegible] normal rated current [illegible] Reactance voltage drop [illegible] Normal rated voltage [illegible] ဖြစ်သည်။

$\therefore$ Percentage Reactance = $\dfrac{\text{Reactance due to FL current}}{\text{Full load voltage}} \times 100$

$$\therefore \boxed{\% x = \frac{I(FL)\, x_{ph}}{E_{ph}} \times 100} \text{ — ①}$$

ϕ

$$\therefore x_{ph} = \frac{\% x \; E_{ph}}{I(FL) \times 100}$$

[illegible]

$$I_{sh} = \frac{E_{ph}}{x_{ph}} \text{ [illegible] } x_{ph} \text{ [illegible]}$$

$$I_{sh} = \frac{E_{ph}\, I_{FL} \times 100}{\% x \; E_{ph}}$$

$$\therefore \boxed{I_{sh} = \frac{I(FL)}{\% x_T} \times 100} \text{ — ②}$$

single ~~phase~~ (ϕ)

[illegible] $\% x_1$ $\% x_2$ $\% x_3$ - - series [illegible]

$$\% x_T = \% x_1 + \% x_2 + \% x_3 - -.$$

$\% x_1$, $\% x_2$, $\% x_3$ - - parallel [illegible]

$$\frac{1}{\% x_T} = \frac{1}{\% x_1} + \frac{1}{\% x_2} + \frac{1}{\% x_3} - -.$$

② $\%\, x$ [illegible] $\lambda \Delta$ [illegible]

Full load kVA

$$kVA = \frac{E I (FL)}{1000}$$

$$\therefore \boxed{I_{FL} = \frac{kVA \times 1000}{E}}$$

$$I_{sh} = \frac{I(FL)}{\% x} \times 100 \quad \text{Eq ② } \text{[illegible]}$$

Eq ② [illegible] Eq ② [illegible] $\frac{E}{1000}$ [illegible]

$$I_{sh} \times \frac{E}{1000} = \frac{I(FL)\, 100}{\% x} \times \frac{E}{1000}$$

Base kVA or MVA

[illegible] plant (Generator, Transformer line [illegible] motor [illegible] Gen-Trans line [illegible] motor [illegible] kVA or MVA ~~Reading~~ rating [illegible] % Resistance [illegible] common base [illegible] common base [illegible] % Resistance [illegible]

$$\boxed{\therefore \% x = \% x \text{ at} \times \frac{kVA(\text{base})}{kVA(\text{act})}}$$

$\%\, x$ [illegible] kVA [illegible]

$$\boxed{x = \frac{\% x \times E_{ph}}{I(FL) \times 100}}$$

circuit [illegible] $\% x$ [illegible]

x [illegible] $\% x$ [illegible] $x = \dfrac{\% x \times E_{ph}}{I_{FL} \times 100}$

[illegible] $I_{FL} = \dfrac{kVA \times 10^3}{\sqrt{3}\, E_L}$

$$\therefore x = \frac{\% x \times E_{ph}}{\frac{kVA \times 10^3}{\sqrt{3}\, E_L} \times 100}$$

$kVA \times 10^3$ [illegible]

$$\therefore x = \frac{\% x \times E_L \times \sqrt{3}\, E_L}{\sqrt{3} \times kVA \times 10^3 \times 100} = \frac{\% x \times (E_L)^2}{kVA \times 10^3 \times 100}$$

$$\boxed{\therefore \% x = \frac{x \times kVA \times 10^3 \times 100}{(E_L)^2}}$$

L.L voltage

a

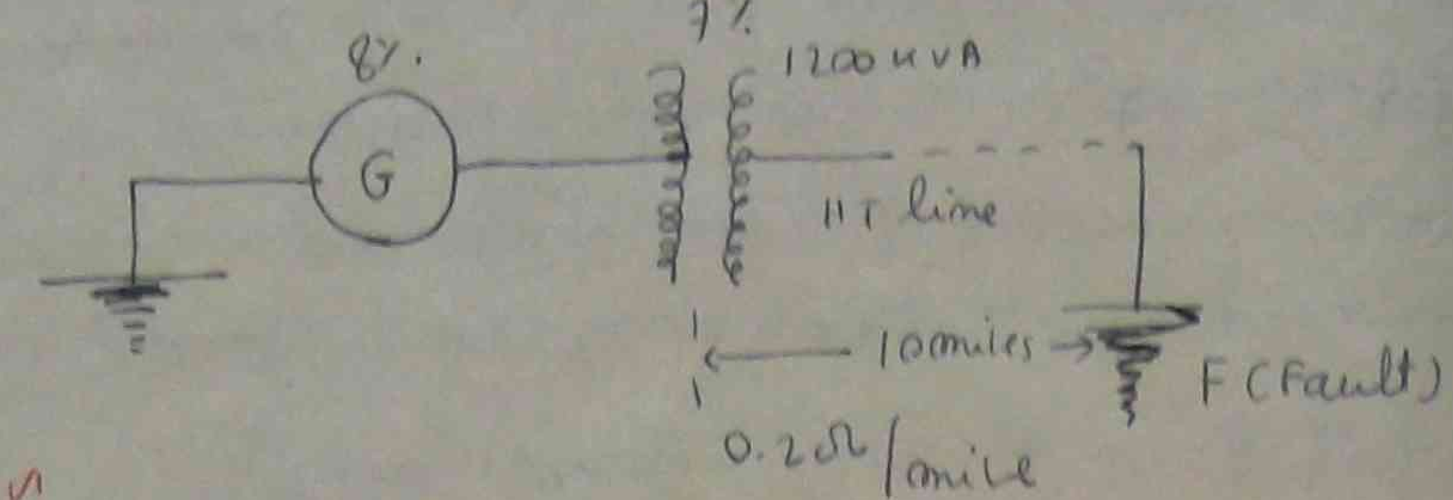
3 Phase (3ϕ)

$(\because E_{ph} = \frac{E_L}{\sqrt{3}})$

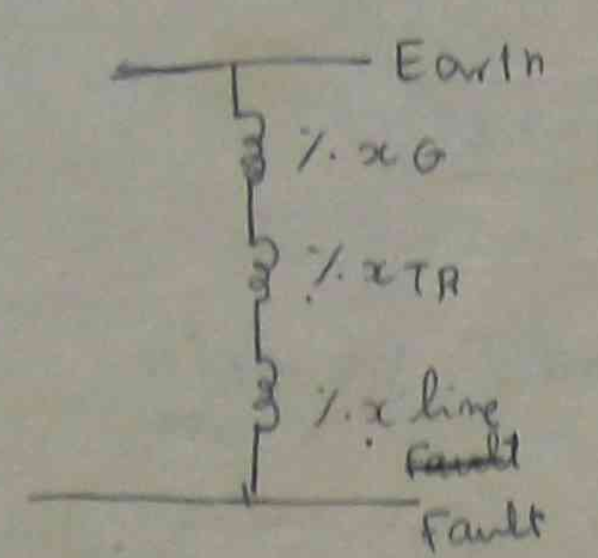
ပုံစံ ① ✓

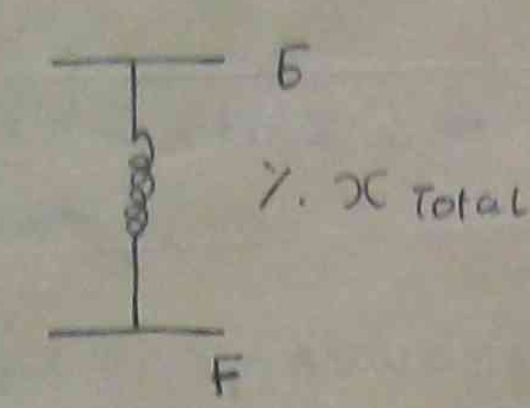
ပုံတွင်ဖော်ပြထားသော ... F ... Short circuit ဖြစ်သည်။ Transformer မှ 10mile အကွာတွင်ရှိသော HT Line တွင် ~~raise~~ resistance/mile မှာ 0.2Ω ဖြစ်သော် Short circuit current ကိုရှာပါ။

2 MVA
6.6 kV
1φ 50Hz



* ... 3φ ...





1MVA = 1000 kVA

* Base ... % x ...

Let 2000 kVA is Basic kVA

$\therefore \%x_G = 8\%$

$\therefore \%x_{TR} = \%x_{TR(act)} \times \dfrac{kVA\ (base)}{kVA(act)}$

$= 7\% \times \dfrac{2000}{1200} = 11.66\%$

$I_{FL} = \dfrac{kVA \times 1000}{E}$

$= \dfrac{2 \times 1000}{6.6kV} = 303\ amps$

x = Transmission line Reactance $= 0.2 \times 10 = 2\Omega$

$\therefore \%x_{Line} = \dfrac{I_{FL} \times x \times 100}{E} = \dfrac{303 \times 2 \times 100}{6.6 \times 1000} = 9.2\%$

$\therefore x_{Total} = \%x_G + \%x_{TR} + \%x_{Line}$

$= 8\% + 11.66\% + 9.2\% = 28.86\%$

$\therefore I_{sh} = \dfrac{I_{FL}}{\%x_T} \times 100 = \dfrac{303 \times 100}{28.86} = 1050\ amps$ (Ans)

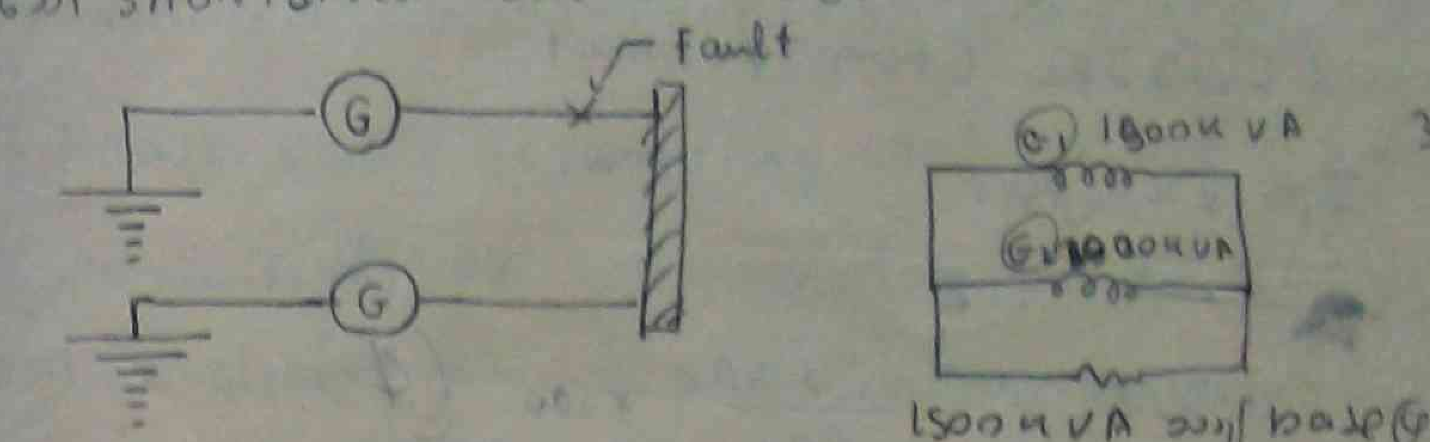
* $I_{FL} = \dfrac{kVA \times 1000}{E}$ single

* $I_{FL} = \dfrac{kVA \times 10^3}{\sqrt{3} E_L}$ 3φ

$I = \dfrac{P}{E}$

Exercise

✓ 1000 kVA နှင့် 1500 kVA အသီးသီးရှိသော 3φ Generator နှစ်လုံးတွင် 3.3 kV 50Hz ဖြစ်၍ % Reactance မှာ 8% နှင့် 10% အသီးသီးရှိကြသည်။ ... common bus bar အပြိုင် phase အားလုံး short circuit ဖြစ်သော် Short circuit current မည်မျှဖြစ်မည်နည်း။



1500 kVA ကို base ယူပါ။

$I_{sh} = \dfrac{I_{FL}}{\%x_T} \times 100$

$\%x_T = ?, \quad I_{FL} = ?$

$I_{FL} = \dfrac{kVA \times 1000}{\sqrt{3} E_L}$

$I_{FL} = \dfrac{1500 \times 1000}{\sqrt{3} E_L}$

$I_{FL} = \dfrac{\cancel{3.3 \times 100}0 \times 1500}{1.7321 \times 3.3 \times 100\cancel{0}}$

$= \dfrac{1500}{3.3 \times 1.7321} = \dfrac{1500}{5.721}\ amp$

$\%x_T = ?, \quad \dfrac{1}{x_T} = \dfrac{1}{\%x_1} + \dfrac{1}{\%x_2}$

$\%X_{G_1} = 10\%$

$\%x_{G_2} = \%x_{G_2(act)} \dfrac{kVA\ base}{kVA\ act}$

$= 8 \times \dfrac{1500}{1000}$

$= 12\%$

$\dfrac{1}{x_T} = \dfrac{1}{10} + \dfrac{1}{12}$

$x_T = \dfrac{120}{22}\%$

$\therefore I_{sh} = \dfrac{I_{FL}}{\%x_T} \times 100$

$= \dfrac{1500}{5.721} \times 100 \times \dfrac{22}{120} = \dfrac{15000 \times 22}{12 \times 5.721}$

330000

$P = VI$ ရှ - $I = \frac{P}{E}$ (ϕ)

I $I = \frac{P}{E\sqrt{3}}$ 3ϕ

$\%x = \frac{I_{FL}}{E_{ph}} \times 100$ (ϕ)

① $P = VI$

$\therefore$ Power = $E_L \times I_{FL}$ (for ϕ circuit)

Power = $E_L \sqrt{3} I_{FL}$ (for 3ϕ circuit)

② E_{ph} မှာ - $I_{FL} \times x_{ph}$ ရှိ။

—— 100 —————— ? =

$\%x = \frac{I_{FL} \times x_{ph}}{E_{ph}} \times 100$ —— ①

E_{ph} မှာ $(\sqrt{3})$ ရှိ။

E_{PL} မှာ $I_{FL} \times x_{ph} \sqrt{3}$

—— 100 —————— ? =

$\%x = \frac{I_{FL} \times x_{ph} \times \sqrt{3}}{E_{PL}} \times 100$ —— ②

ဒို့ပြောင် $I_{FL}\sqrt{3} = \frac{\text{Power}}{E_L}$ ကို ① တွင်အစားသွင်းသော်

$\%x = \frac{I_{FL} \times x_{ph} \times \text{Power}}{E_L^2} \times 100$ (3ϕ)

③ Base ရှိ၍

Ⓖ A $x\%$ Base E_1 (Power)

Ⓖ B $y\%$ act E_2 (Power)

E_1 ကို base ထားလျှင်

$E_2 = y\%$

E_1 ——? = $\%x = y \times \frac{E_1}{E_2}$ base act

④ $\%x_T = \%x_1 + \%x_2 + \%x_3$ (Series)

$\frac{1}{\%x_T} = \frac{1}{\%x_1} + \frac{1}{\%x_2} + \frac{1}{\%x_3}$ (Parallel)

Line တွင် $\%x$ အတွက် base ရှိရမည်

$P = VI$ VA or watt

P = kVA or kW

③ 3ph 11kV system တစ်ခုတွင် 2500 kVA, 12% ရှိသော Turbo Alternator ၃ လုံး ရှိသည်။ Busbar ၂ ခုကို Reactance 1.22Ω ရှိသော Transmission line ၂ ခုဖြင့် Substation သို့ ရောက်ရှိသည်။ Transformer Bank ၂ ခုဖြင့် voltage ကိုချသည်။ တစ်ခုတွင် 3 MVA 6% Reactance ရှိ၍ ကျန်တစ်ခုတွင် 2 MVA 5% Reactance ရှိသည်။ (က) Death earth သည် Generator Busbar ၏ phase အားလုံးတွင် Fault ဖြစ်လျှင် (ခ) Substation ၏ Busbar တွင် Fault ဖြစ်လျှင် Generator တစ်ခု၏ Short circuit current ကိုရှာပါ။

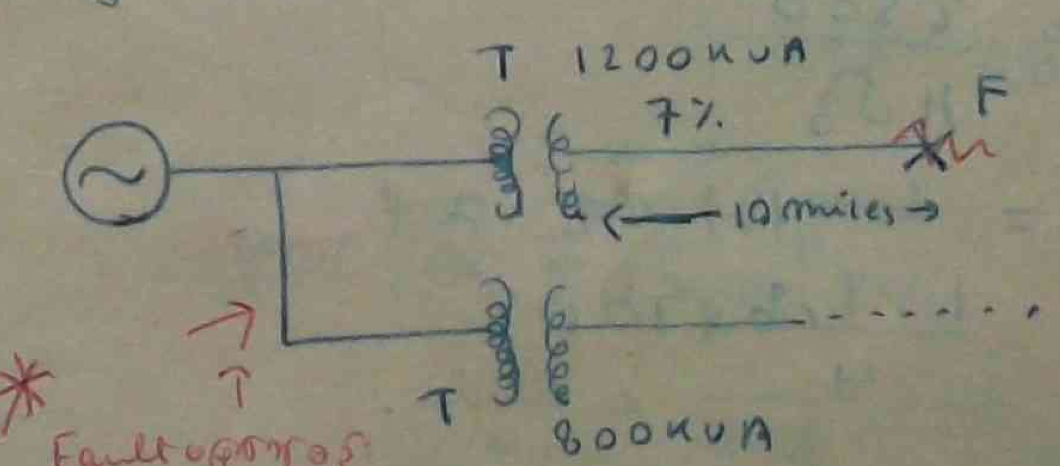
④ 3 Phase 50Hz Generating station တစ်ခု၌ 8000 kVA 14.5% Reactance ရှိသော Generator ၂ လုံးနှင့် 4000 kVA 9.5% Reactance ရှိသော Generator တစ်လုံးကို Bus Bar တစ်ခုတည်းတွင် ချိတ်ဆက်ထားသည်။ ၎င်းတို့သည် 3000 kVA 4% Reactance ရှိသော Step up transformer ၁ လုံးကို ဖြတ်၍ Load ကိုပေးသည်။ OCB ၏ maximum MVA ကိုရှာပါ။ (8000 base)

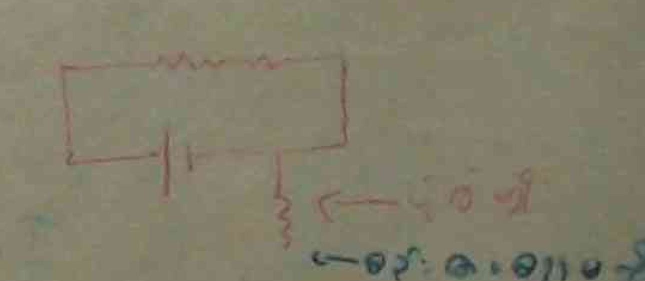
(က) LB size OCB

(ခ) HB size OCB

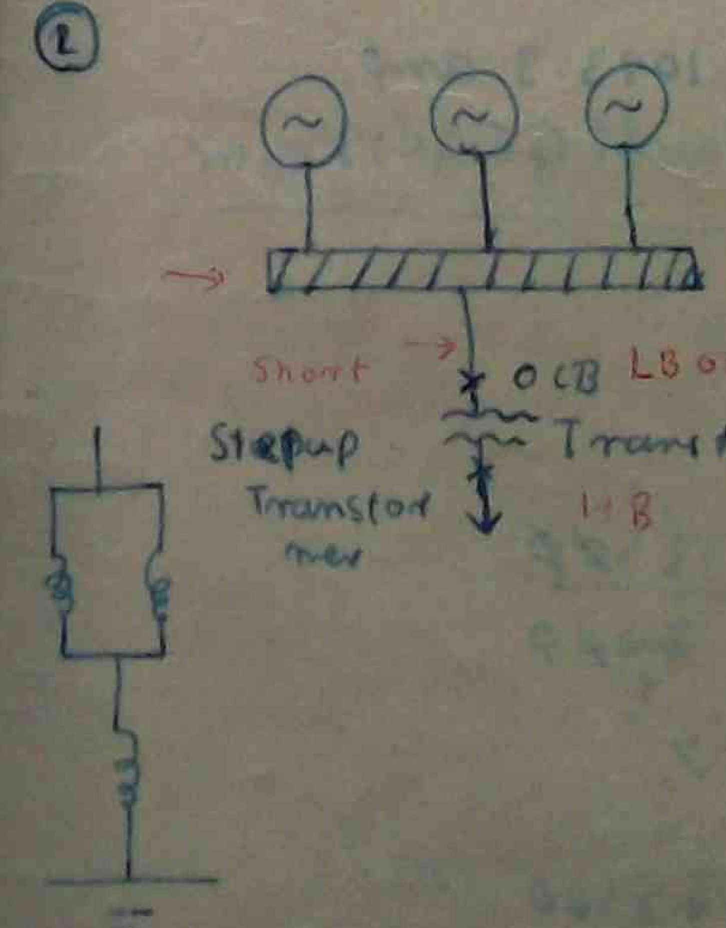
⑤ ပေးထားသော single phase system ၏ short circuit current ကိုရှာပါ။ Fault မှာ Trans T ၏ 10 miles အကွာ F တွင်ဖြစ်သည်။ Line တွင် 1 mile လျှင် (Reactance) 0.2Ω ရှိသည်။ ပို့လွှတ်မှာ 66 kV ဖြစ်သည်။

⑤

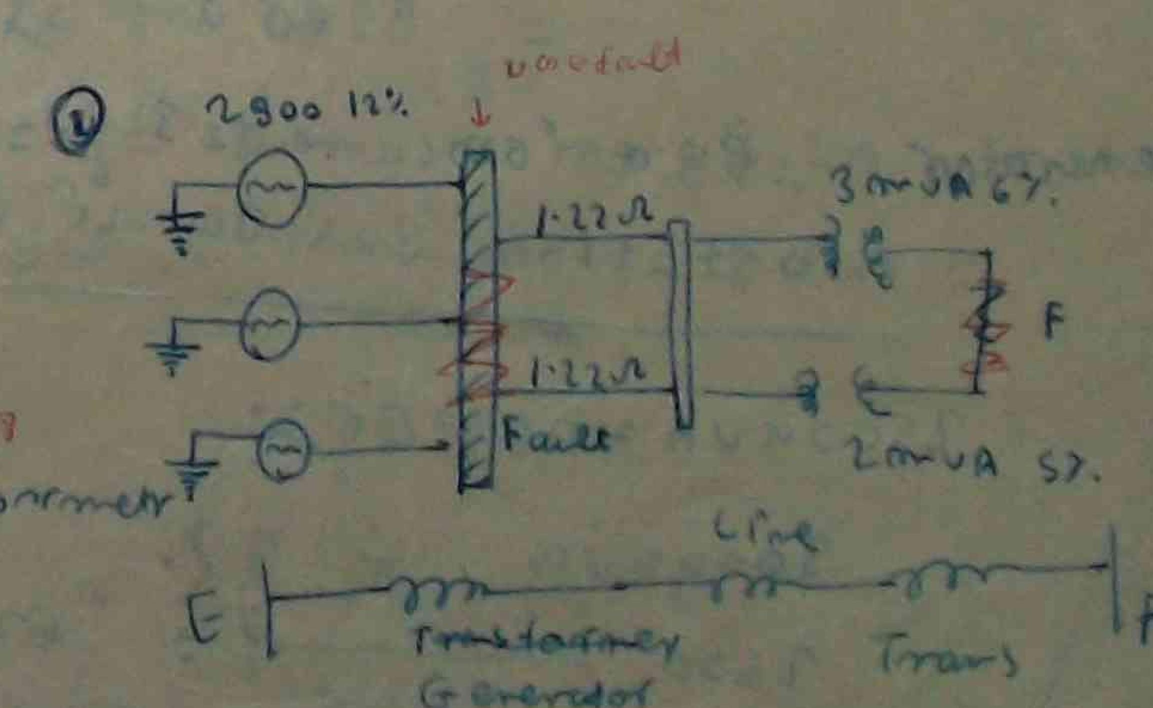




④

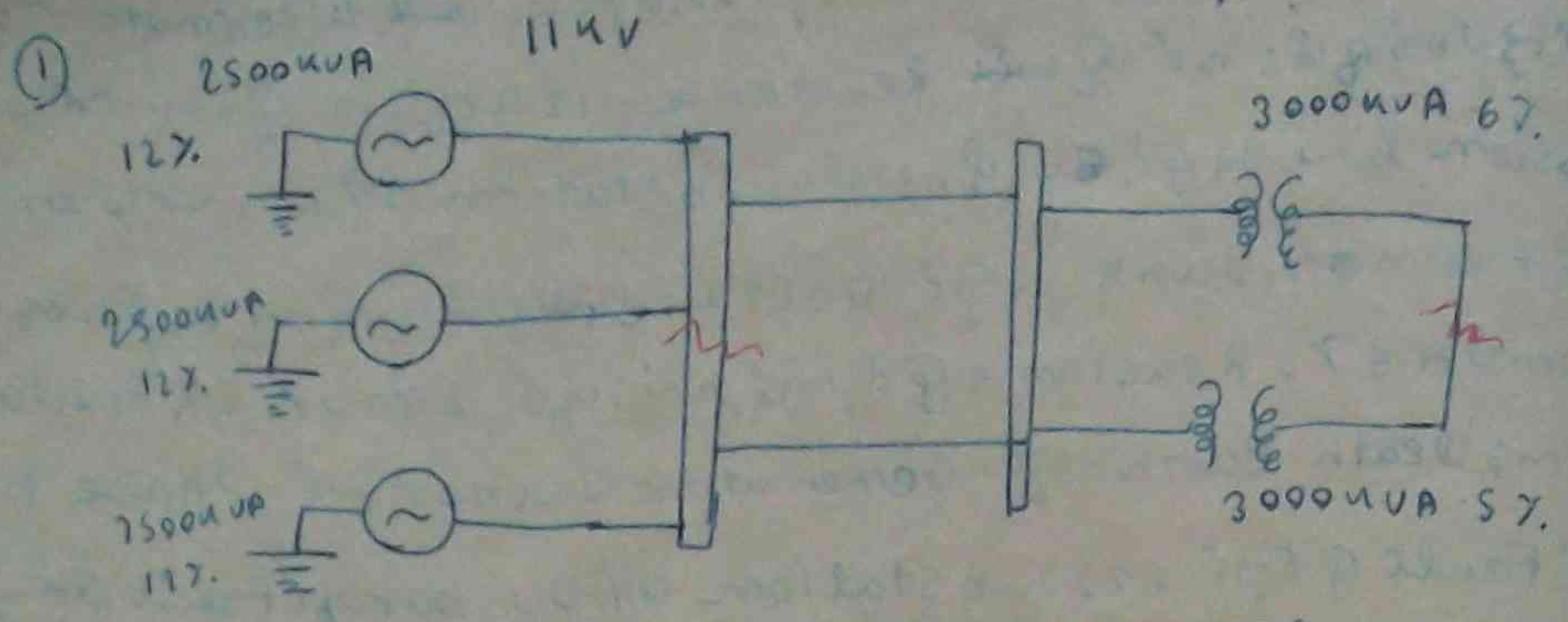


③



3 φ

①



Generator Bus Bar [illegible] fault [illegible]

2500 kVA = Base [illegible]

$I_{sh} = ?$ $\quad I_{sh} = \frac{I_{FL}}{\%x_T} \times 100$

$\%x_T = ?, \; I_{FL} = ?$

$\frac{1}{\%x_T} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12}$

$\frac{1}{\%x_T} = \frac{3}{12}$

$\therefore \%x_T = 4$

$P = EI\sqrt{3}$

$\therefore 2500 \times \cancel{1000} = 11 \times \cancel{1000} \times I_{FL} \times \sqrt{3}$

$\therefore I_{FL} = \frac{2500}{11\sqrt{3}}$

$I_{FL} = \cancel{2500}\, 131.\cancel{02}$ amp

$\therefore I_{sh} = \frac{131.2}{4} \times 100$

$= 3280$ amp $\cancel{\times 1} = \cancel{100}$

Generator [illegible] current $= \frac{3280}{3} = 1093.3$ amp

Substation Bus Bar [illegible] fault [illegible]

Tras

2500 kVA = base [illegible]

3000 kVA = 6%

2500 —— ? : $\frac{6 \times 2500}{3000}$

$= 5\%$

3000 = 5%

2500 —— ? : $\frac{5 \times 2500}{3000}$

Transformer [illegible] $\%x_T$ [illegible]

$\frac{1}{\%x_{t_1}} = \frac{1}{5} + \frac{1}{4.16}$

$\frac{1}{\%x_{t_1}} = \frac{4.16+5}{5 \times 4.16}$

$\therefore \%x_{t_1} = \frac{5 \times 4.16}{9.16} = \frac{20.8}{9.16}\%$

Line [illegible] $\%x$ [illegible]

Line [illegible] Resistance = 1.22 Ω

Line 1 line [illegible] $\%x_1 = \frac{I_{FL} \times x_{ph}}{\sqrt{3}\, E_{ph}} \times 100$ $\qquad \%x = \frac{x_{ph} \times Power}{E_L^2} \times 100$

$\%x_1 = \frac{x \times kVA \times 10^3 \times 100}{E_L^2}$

$\%x_1 = \frac{1.22 \times 2500 \times \cancel{10^3} \times 100}{(11)^2 \times 10^6}$

$\%x_1 = \frac{1.22 \times 2500 \times 100}{121 \times 10^3}$

$\%x_1 = \frac{122 \times 2500}{121 \times 10^3}$

$= \frac{305000}{121000}$

$= \cancel{1.18}\; 2.525$

$\therefore \cancel{\%x = 1.}$

~~[illegible]~~ $\frac{1}{\%x_T} = \frac{1}{\%x_1} + \frac{1}{\%x_2}$

$\frac{1}{\%x_T} = \frac{1}{2.52} + \frac{1}{2.52}$

$\therefore \%x_T = 1.76\%$

~~3000 kVA~~ Generator [illegible] $\%x_T$ [illegible]

$\%x_T = 4\%$

$\therefore \%x_T = 4 + 1.76 + 20.8$

$= 26.56\%$

$\therefore I_{sh} = \frac{I_{FL}}{\%x_T} \times 100 = \frac{131.2 \times 100}{26.56} = \frac{13120}{26.56} =$ 5?? amp

2.3

Line $\% x$:

$$\% x = \frac{I_{FL} \times x}{E_L} \times 100$$

$$I_{FL} = \frac{P}{\sqrt{3}E} = \frac{2500}{11\sqrt{3}}$$

$$\therefore \% x = \frac{\frac{2500}{11\sqrt{3}} \times 1.22 \times 100}{11 \times 1000}$$

$$= \frac{2500 \times 1.22}{121\sqrt{3}} = 1.48\%$$

$$\frac{1}{x_T} = \frac{1}{x_1} + \frac{1}{x_2}$$

$$\therefore \% x_T = \frac{1.48}{2} = .74\%$$

$$\% X_T = .74 + 4 + 20.8$$

$$= 25.54\%$$

$$\therefore I_{sn} = \frac{I_{FL} \times 100}{\% x_T}$$

$$I_{sn} = \frac{131.2 \times 100}{25.54} = \frac{13120}{25.53}$$

Substation Busbar fault

2500 kVA = base

3000 kVA 6%

2500 —— ? $= \frac{6 \times 2500}{3000} = 5\%$

2000 kVA 5%

2500 —— ? $= \frac{5 \times 2500}{2000} = 6.25$

$$\therefore \% x_T = \frac{5 \times 6.25}{11.25}$$

$$= \frac{31.25}{11.25} = 2.725$$

one line $\% x_T = \frac{I_{FL} \times x}{E_{pn}} \times 100$

$I = \frac{P}{E}$

$$I_{FL} = \frac{2500}{\sqrt{3}E} = \frac{2500}{11\sqrt{3}}$$

$$\therefore \% x_T = \frac{\frac{2500}{11\sqrt{3}} \times 1.22 \times 100}{11 \times 1000}$$

$$= \frac{2500 \times 1.22 \times 100}{121 \times \sqrt{3} \times 1000} = \frac{250 \times 1.22}{121\sqrt{3}}$$

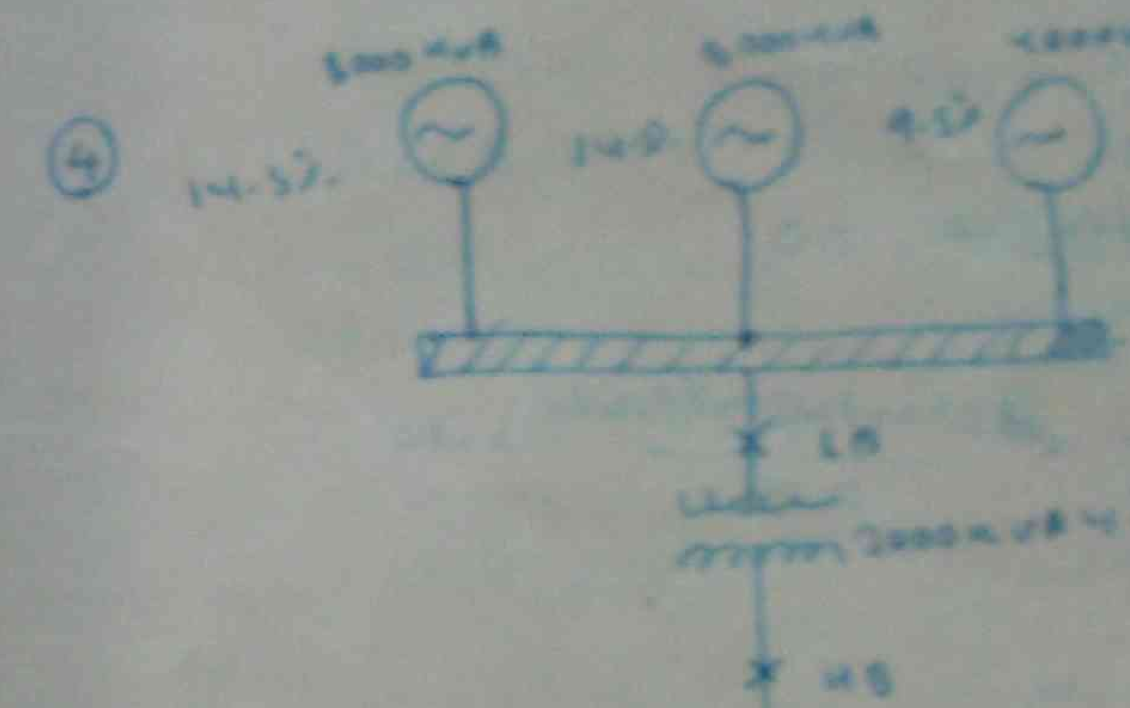
$$= 1.44\%$$

$$\therefore \text{Line } \% x_{Total} = \frac{1.44}{2} = .72\%$$

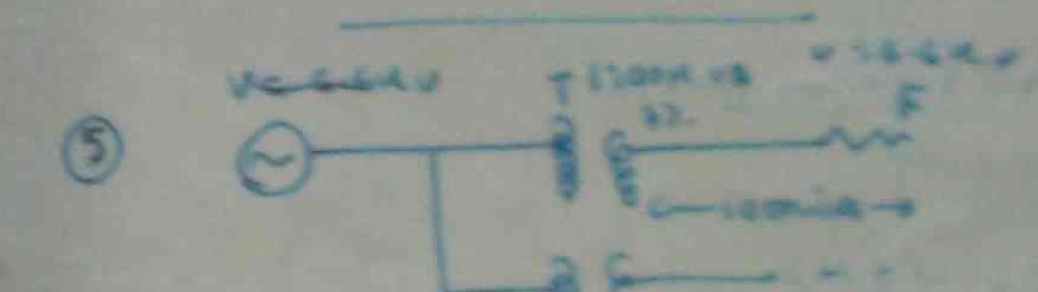
Generator $\% x_1 = 4\%$

$$\therefore \% X_T = 4 + .72 + 2.725 = 7.445$$

$$I_{sn} = \frac{I_{FL} \times 100}{\% x_T} = \frac{2500 \times 100}{11\sqrt{3} \times 7.445}$$



LB



$$I_{sn} = \frac{I_{FL}}{\% x_T} \times 100$$

$I_{FL} = ?$, $\% x_T = ?$

$\% x_T$ = Transformer $\% x$ + Line $\% x$

$$\text{Line } \% x = \frac{x \cdot I_{FL}}{E} \times 100$$

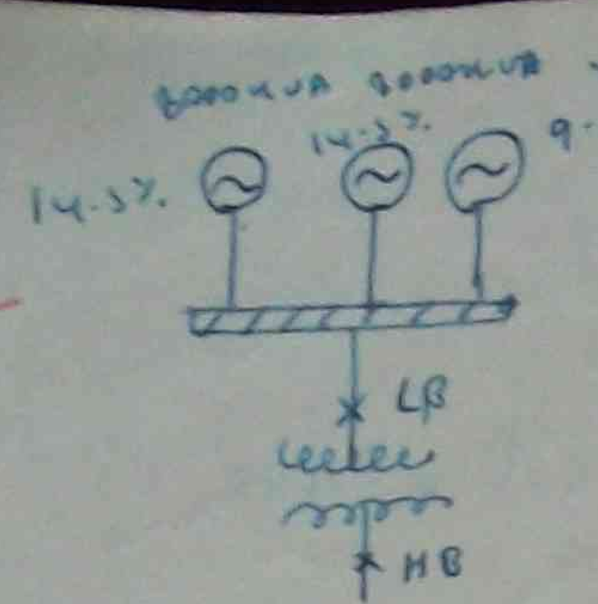
$$\% x = \frac{10 \times 0.2 \times \frac{1500}{6.6}}{6.6 \times 1000} \times 100$$

$$\% x = \frac{2 \times 1500}{6.6 \times 6.6} = \frac{240}{6.6 \times 6.6}$$

$$\therefore \% x_T = 7 + \frac{240}{6.6 \times 6.6}\%$$

$$I_{sn} = \frac{I_{FL}}{\% x_T} \times 100$$

$$I_{sn} = \frac{\frac{1500}{6.6}}{7 + \frac{240}{6.6 \times 6.6}} \times 100$$



$E_{ph} = I_{FL} \times x_{ph}\sqrt{3}$

$100 \;\text{———}\; ?$

$\%x = \dfrac{I_{FL} \times x_{ph}\sqrt{3}}{E_{ph}}$

$\%x = \sqrt{3}\,\dfrac{I_{FL} \times x_{ph}}{E_{ph}} \times 100$

$\%x = \sqrt{3}\,\dfrac{I_{FL}}{I_{sh}} \times 100$

$\%x = \sqrt{3}\,\dfrac{V \times I_{FL}}{V \times I_{sh}} \times 100$

$P = VI\sqrt{3}$

$\%x = \dfrac{\text{Short power}}{\text{Short power}} \times 100$

$\therefore$ Short power $= \dfrac{\sqrt{3}\,\text{short power}}{\%x} \times 100$

8000 kVA = base ဖြစ်.

$\therefore$ 4000 kVA = 19%.

$\therefore \dfrac{1}{\%x_T} = \dfrac{1}{14.5} + \dfrac{1}{14.5} + \dfrac{1}{19}$

$\dfrac{1}{\%x_T} = \dfrac{14.5 \times \cancel{14.5} + 19 \times 14.5 + 14 \times 19}{14.5 \times 14.5 \times 19}$ $= 5.25$

$\therefore \%x_T = \dfrac{14.5 \times 14.5 \times 19}{48}$

$\therefore$ Power $= \dfrac{\sqrt{3} \times 8000 \times 100 \times 47}{14.5 \times 14.5 \times 19}$ Power sh $= \dfrac{8000}{5.25} \times 100 = 152.75$

$= 166000\,\text{kVA} = 272\,\text{mVA}$

3000 kVA = 4%.

$8000 \;\text{———}\; ? = \dfrac{4 \times 8000}{3000} = \dfrac{32}{3} = 10.66\%$

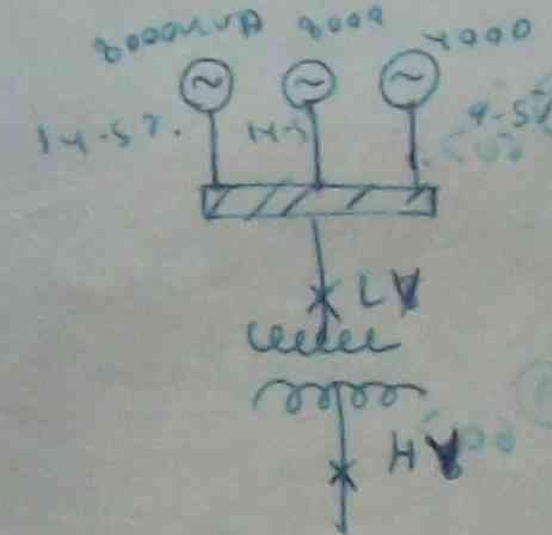
$\therefore \%x_T = \dfrac{14.5 \times 14.5 \times 19}{19 + 19 + 14.5} + 10.66 = 15.91$

$= \cancel{43.5}\%$

$\therefore$ Power $= \dfrac{\cancel{665000000}}{} \quad \dfrac{\sqrt{3} \times 8000 \times 100}{15.91}$

$= 18808\,\text{mVA}$

$\dfrac{1}{\%x_1} = \dfrac{1}{14.5} + \dfrac{1}{14.5} + \dfrac{1}{19}$ $\quad \dfrac{14.5 + 14.5 + 19}{14.5 \times 14.5 \times 19}$



$\%x = \dfrac{\sqrt{3}\, I_{FL} \times x_{ph}}{E_{ph}} \times 100$

$\%x = \dfrac{\sqrt{3}\, I_{FL}}{I_{sh}} \times 100$

$\%x = \dfrac{\sqrt{3}\, V I_{FL}}{V I_{sh}} \times 100$

$\%x = \dfrac{\sqrt{3} \times \text{Short power}}{\text{Short power}} \times 100$

2000 kVA = base ဖြစ်.

8000 kVA = 14.5

$2000 \;\text{———}\; ? = \dfrac{14.5}{4} = 3.625\%$

4000 kVA = 9.5%

$2000 \;\text{———}\; ? = \dfrac{9.5}{2} = 4.75\%$

Generator ... $\%x_T = ?$

$\dfrac{1}{x_{t_1}} = \dfrac{1}{3.625} + \dfrac{1}{3.625} + \dfrac{1}{4.75}$

$= \dfrac{2}{3.625} + \dfrac{1}{4.75}$

$= \dfrac{1}{1.8125} + \dfrac{1}{4.75}$

$\therefore x_{t_1} = \dfrac{1.8125 \times 4.75}{1.8125 + 4.75} = \dfrac{1.8125 \times 4.75}{6.5625}\%$ (1)

3000 kVA = 4%

$2000 \;\text{———}\; ? = \dfrac{4 \times 2000}{3000} = \dfrac{8}{3} = 2.667\%$

$\therefore x_T = \dfrac{1.8125 \times 4.75}{6.5625} + 2.667$

$= \dfrac{8.55}{6.56} + 2.667 = 1.28 + 2.67$

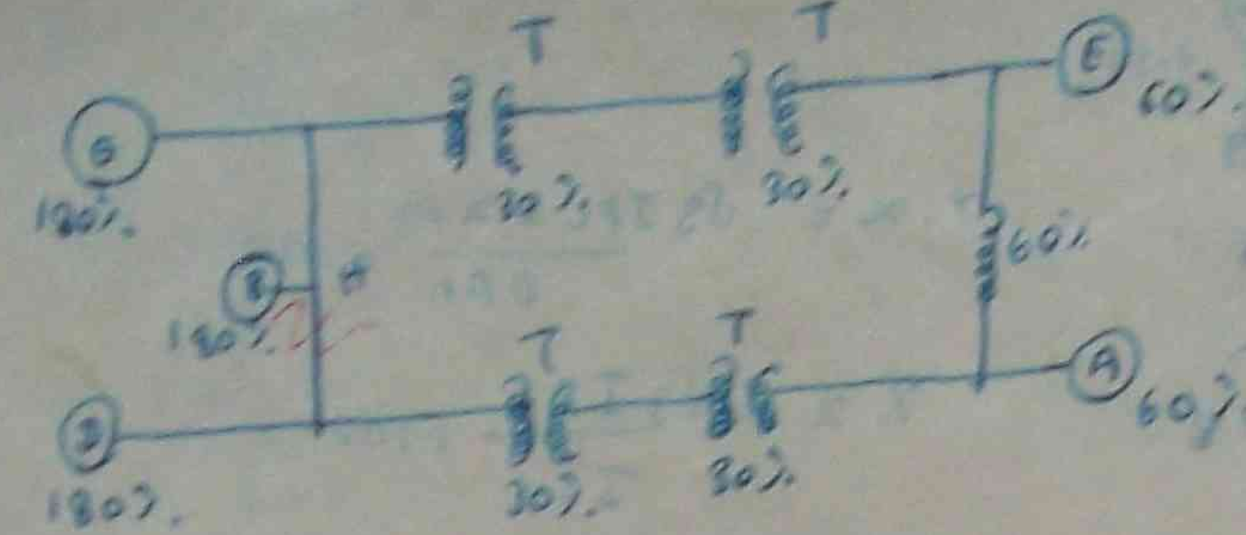
$= 3.95\%$

$\therefore$ HB ... kVA ?

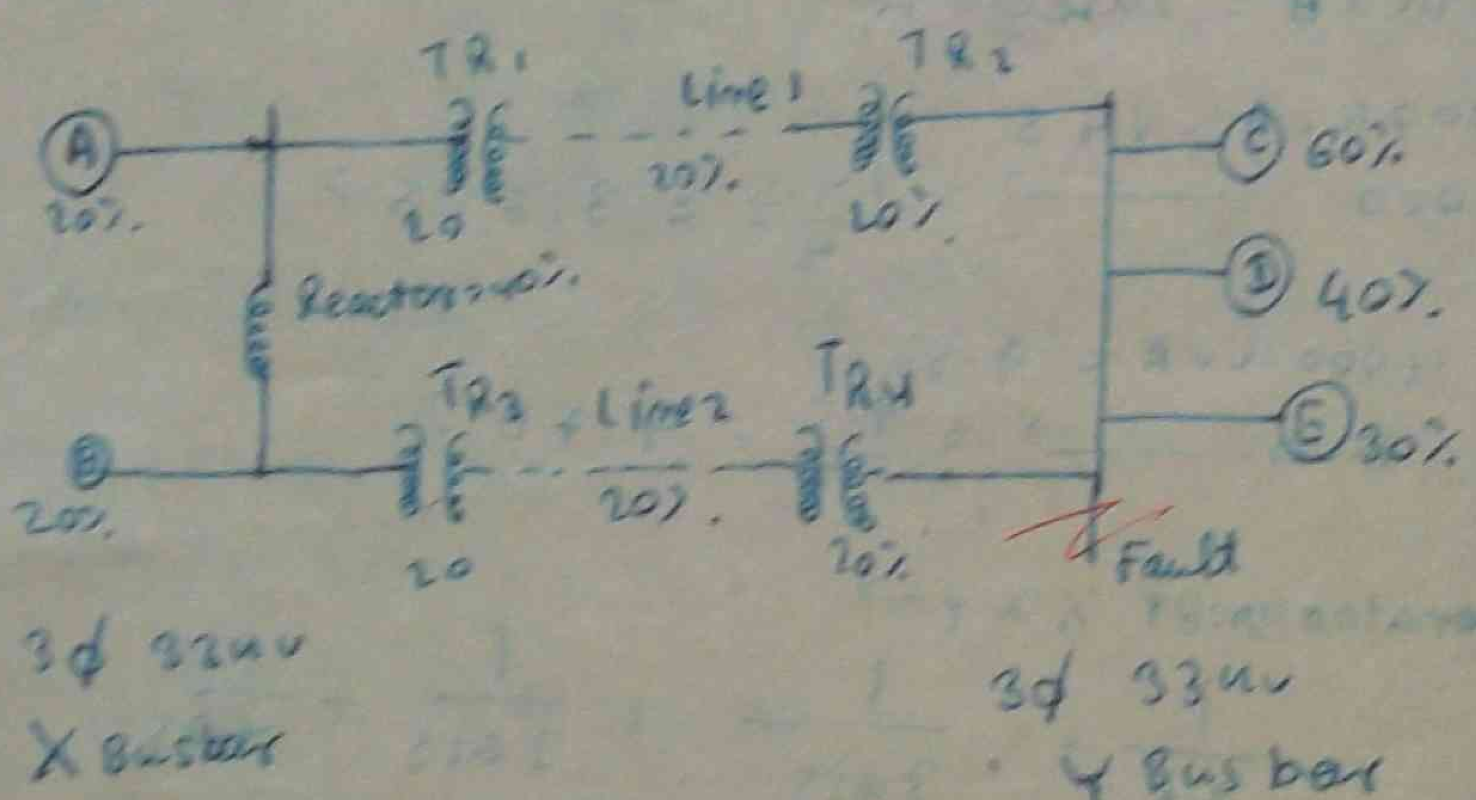
$3.95 = \dfrac{\sqrt{3} \times 2000}{\text{Power (Short)}} \times 100$

Power $= \dfrac{173.21 \times 2000}{3.95} = 87500\,\text{kVA} = 87.5\,\text{mVA}$

LB ... kVA $= \dfrac{173.21 \times 2000}{1.28} = 272000 = 272\,\text{mVA}$



[illegible] percentage reactance [illegible] 100 MVA [illegible] Busbar B [illegible] fault current [illegible] fault [illegible] Busbar System voltage [illegible] 6.6 kV [illegible] A, B, C, D [illegible] E [illegible] generator [illegible] Transformer [illegible]



[illegible] Bus Bar Y [illegible] 3φ fault [illegible] short circuit current per phase [illegible] % reactance [illegible] 100 MVA [illegible] Base [illegible]

① Power $= 100 \times 10^6$ volt ampere

generator Ⓑ, Ⓓ [illegible] Total $\%x_T$?

$$\frac{1}{\%x_T} = \frac{1}{180} + \frac{1}{180}$$

$$\%x_T = 90\%$$

[illegible] 90% [illegible] $\%x_T = 90 + 180 = 270\%$ —①

(Trans) 60% [illegible] $\%x_T = 30\%$ —①

E [illegible] $\%x_T = 30\%$ —①

Total $\%x_T = 270 + 30 + 30 = 330\%$

Busbar [illegible] fault [illegible]

$$\%x = \frac{I_{FL} \times 100}{I_{sh}}$$

$$I_{sh} = \frac{I_{FL}}{\%x_T} \times 100$$

$$I_{sh} = \frac{I_{FL}}{330} \times 100$$

$\sqrt{3} I_{FL} \times E =$ Power

$\sqrt{3} \times I_{FL} \times 6.6 \times 1000 = 100 \times 10^6$ VA

$\sqrt{3}\, I_{FL} \times 66 = 10^6$

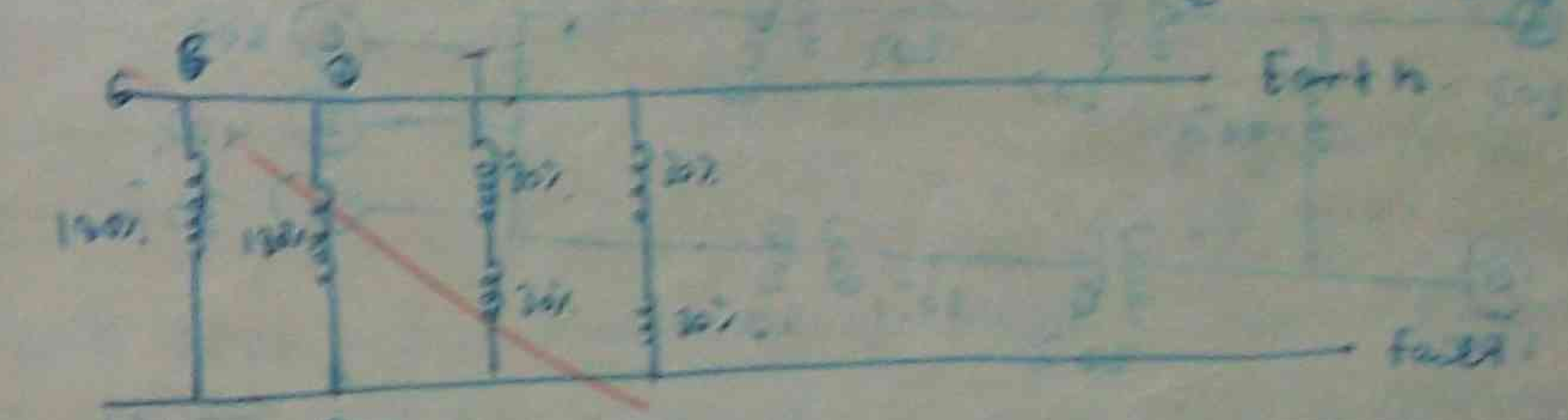
$I_{FL} = \frac{10^6}{66\sqrt{3}}$

$$I_{sh} = \frac{\frac{10^6}{66\sqrt{3}}}{330} \times 100$$

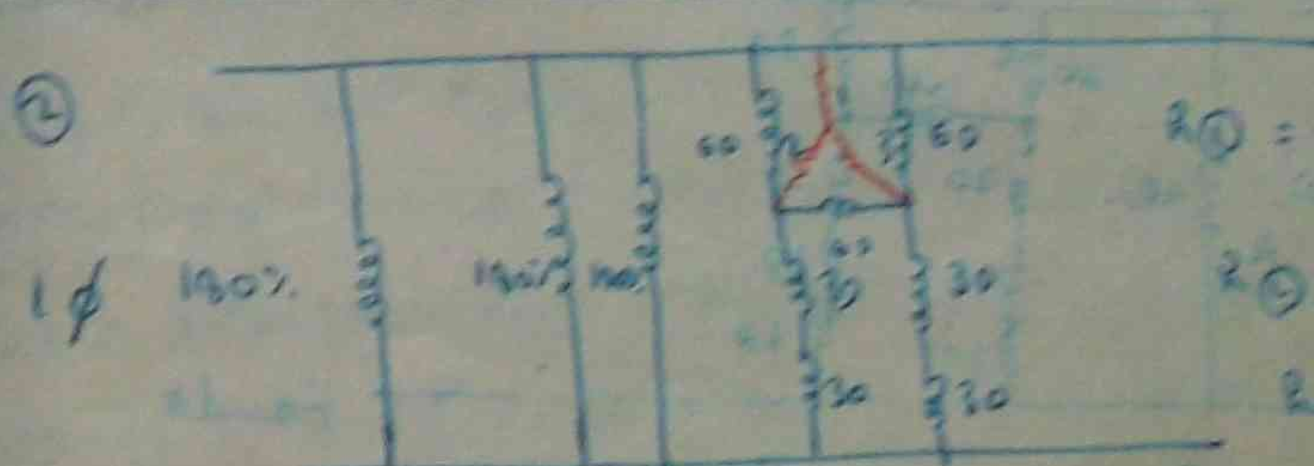
$$= \frac{10^6}{66\sqrt{3}} \times \frac{100}{330} = \frac{10^3}{21.78\sqrt{3}} \text{ amp}$$

amp

①



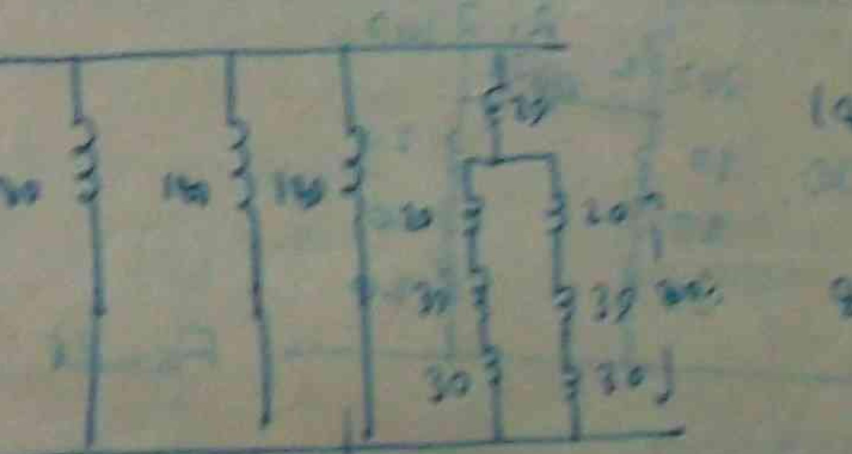
②



$R_1 = \frac{60 \times 60}{180} = 20\%$

$R_2 = 20\%$

$R_3 = 20\%$



180% [illegible] $\%x_T = \frac{180}{3} = 60\%$ —①

80% [illegible] $\%x_T = 40\%$

20% [illegible] 40% [illegible] $\%x_T = 40 + 20 = 60\%$ —①

$$\text{Total } \frac{1}{\%x_T} = \frac{1}{60} + \frac{1}{60}$$

$$\%x_T = 30\%$$

$$I_{sh} = \frac{I_{FL} \times 100}{\%x_T}$$

[illegible] $I_{sh} = \frac{I_{FL}}{30} \times 100 = [illegible] I_{FL}$

$I_{FL} = \frac{\text{Power}}{\sqrt{3} E} = \frac{100 \times 10^6}{6.6 \times 1000} = \frac{10^3}{66 \times [illegible]}$

$I_{FL} = \frac{10^4}{66\sqrt{3}} = \frac{10000}{66\sqrt{3}}$

$I_{sh} = \frac{\frac{10000}{3}}{66\sqrt{3}} = \frac{5000}{33\sqrt{3}} = \frac{5000}{11\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}}$

$I_{sh} = \frac{5000 \times 1.7321}{33}$

$I_{sh} = \frac{8660.5}{33} = 262$

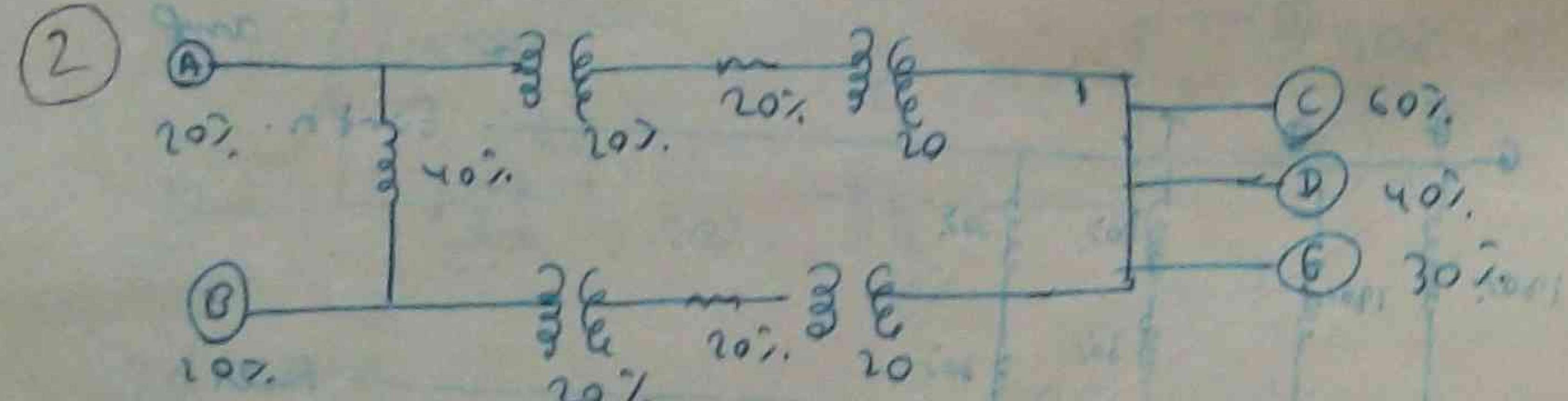
$I_{FL} = \frac{10^5}{6.6}$

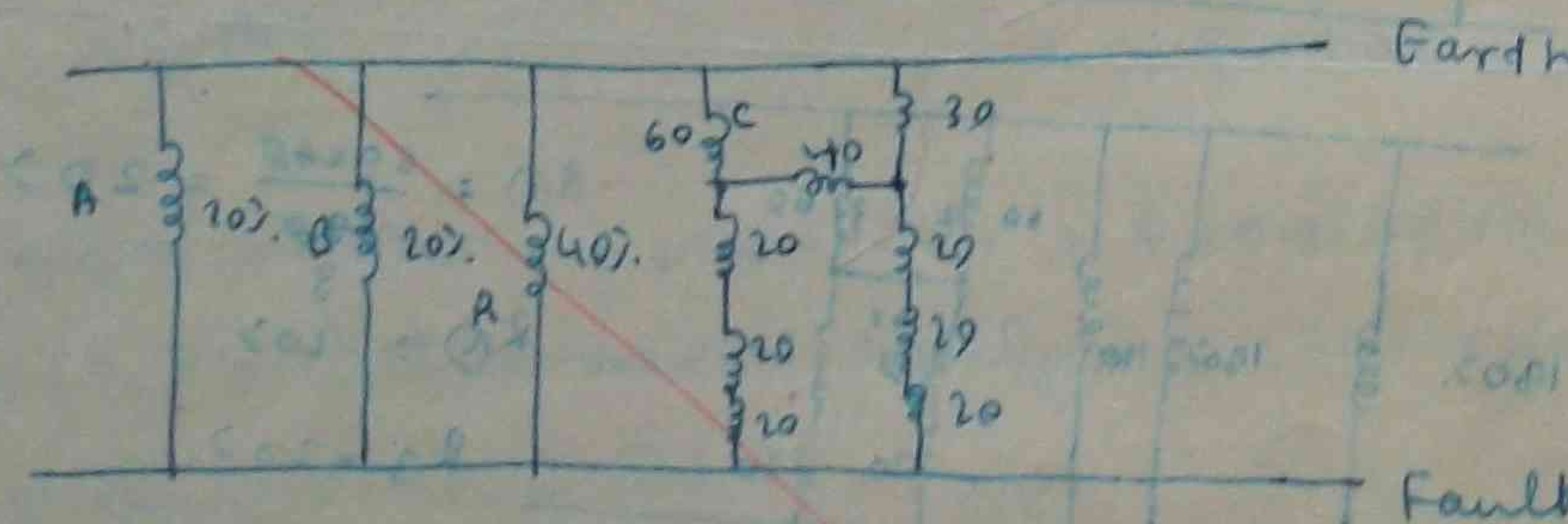
$I_{sh} = \frac{10}{3} \times \frac{10^5}{6.6} = \frac{10^6}{19.8} = 50500\,amp$ 1ϕ [illegible]

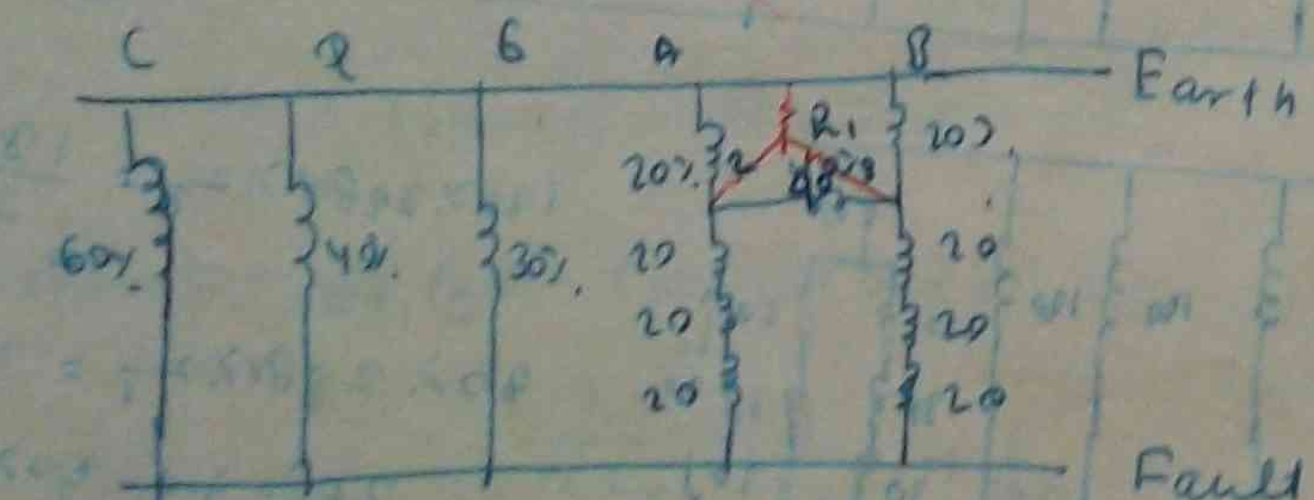
3ϕ [illegible] $= \frac{10^5}{66\sqrt{3}}$ $I_{sh} = \frac{10}{3} \times \frac{10^5}{66\sqrt{3}} = \frac{50500}{\sqrt{3}}$

$= 29150\,amp$

(2)







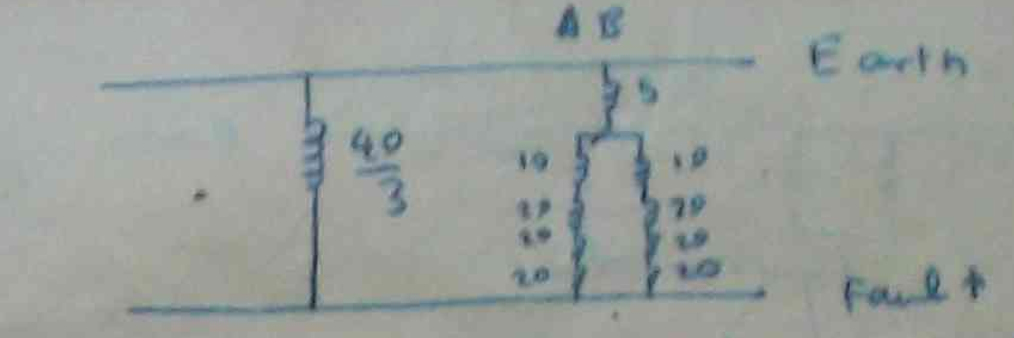
[illegible] R_t =

$\frac{1}{R_t} = \frac{1}{60} + \frac{1}{40} + \frac{1}{30}$

$= \frac{2+3+4}{120} = \frac{9}{120}$

$R_t = \frac{120}{9} = \frac{40}{3}\,\Omega$

$R_1 = \frac{20\times20}{80} = 5\,\Omega$ $R_2 = \frac{20\times40}{80} = 10\,\Omega$ $R_3 = \frac{40\times20}{80} = 10\,\Omega$



$\frac{1}{20} + \frac{1}{20} = \frac{1}{R_{t_1}}$ $R_{t_1} = 35\,\Omega$

$R_t = 35 + 5 = 40\,\Omega$

Total Resistance $\Rightarrow \frac{1}{R_T} = \frac{1}{40} + \frac{3}{40} = \frac{4}{40}$

x_T $R_T = 10\,\Omega\,\%$

$I_{sh} = \frac{I_{FL}}{\%x_T} \times 100$

$I_{sh} = \frac{I_{FL}}{10} \times 100$ $I_{sh} = 10\,I_{FL}$

$V \times \sqrt{3}\,I_{FL}$ = Power

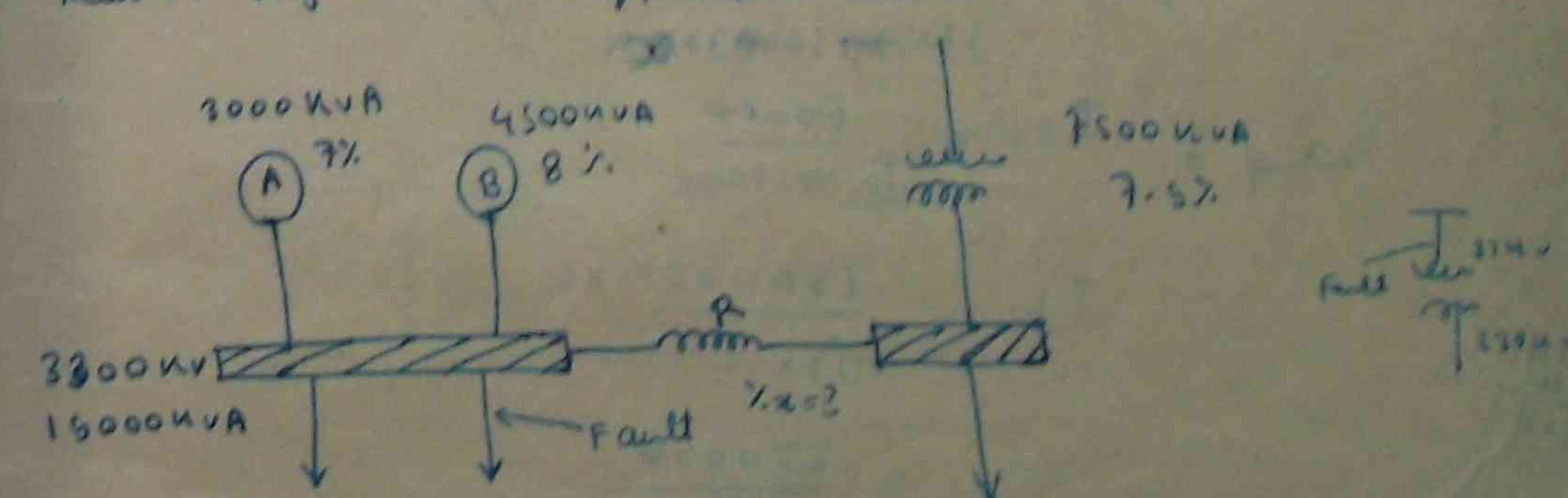
$33 \times 10^3 \times \sqrt{3}\,I_{FL} = 100 \times 10^6$

$33\sqrt{3}\,10^3\,I_{FL} = 10^8$ $\therefore I_{FL} = \frac{10^5}{33\sqrt{3}} = \frac{100000 \times \sqrt{3}}{33 \times 3}$

$\therefore I_{FL} = \frac{173210}{99} = 1750\,amp$

$I_{sh} = 17500$

3ϕ 50Hz 3300 V powerstation [illegible] 3000 kVA [illegible] 4500 kVA alternator [illegible] % Reactance [illegible] 7% [illegible] 8% [illegible] circuit Breaker [illegible] repturing capacity [illegible] 150000 kVA [illegible] 7500 kVA 7.5% Reactance [illegible] Transformer [illegible] // [illegible] Fault [illegible] switch gear [illegible] Reactor R [illegible] Reactance/phase [illegible]



$3000\,kVA = 7\%$

$150000\,kVA = ? = 7 \times \frac{150000}{3000} = 350\%$

$4500\,kVA = 8\%$

$150000 \rightarrow ? = 8 \times \frac{150000}{4500} = \frac{800}{3}\,\%$

$7500\,kVA = 7.5\%$

$150000 \rightarrow ? = 7.5 \times \frac{150000}{7500} = 150\%$

$5\times 560x - 37x = 58\times 15 + 560 - 75\times 560$

$2800x - 37x = 870 + 560 -$

$$\frac{1}{\%x_T} = \frac{58}{560} + \frac{1}{7.5+x}$$

$$\frac{1}{\%x_T} = \frac{58\times 7.5 + 58x + 560}{560\times 7.5 + 560x}$$

$$\frac{1}{5} = \frac{58\times 7.5 + 58x + 560}{560\times 7.5 + 560x}$$

$$112\times 7.5 + 112x = 58\times 7.5 + 58x + 560$$

$$112x - 58x = 58\times 7.5 + 560 - 112\times 7.5$$

$$54x = 58\times\frac{15}{2} + 560 - 112\times 7.5$$

$$x = \frac{29\times 15 + 560 - 112\times 7.5}{54}$$

$$= \frac{435 + 560 - 840}{54}$$

$$= \frac{995 - 840}{54} = \frac{155}{54} = 2.8\Omega$$

$$\%x = \frac{I_{FL}\times x_{ph}}{E_{ph}}$$

$$\frac{\%x\times E_{ph}}{I_{FL}} = x_{ph}$$

$$\frac{2.6\times 3300}{\frac{7500}{\sqrt{3}\times 3.3}} = x_{ph}$$

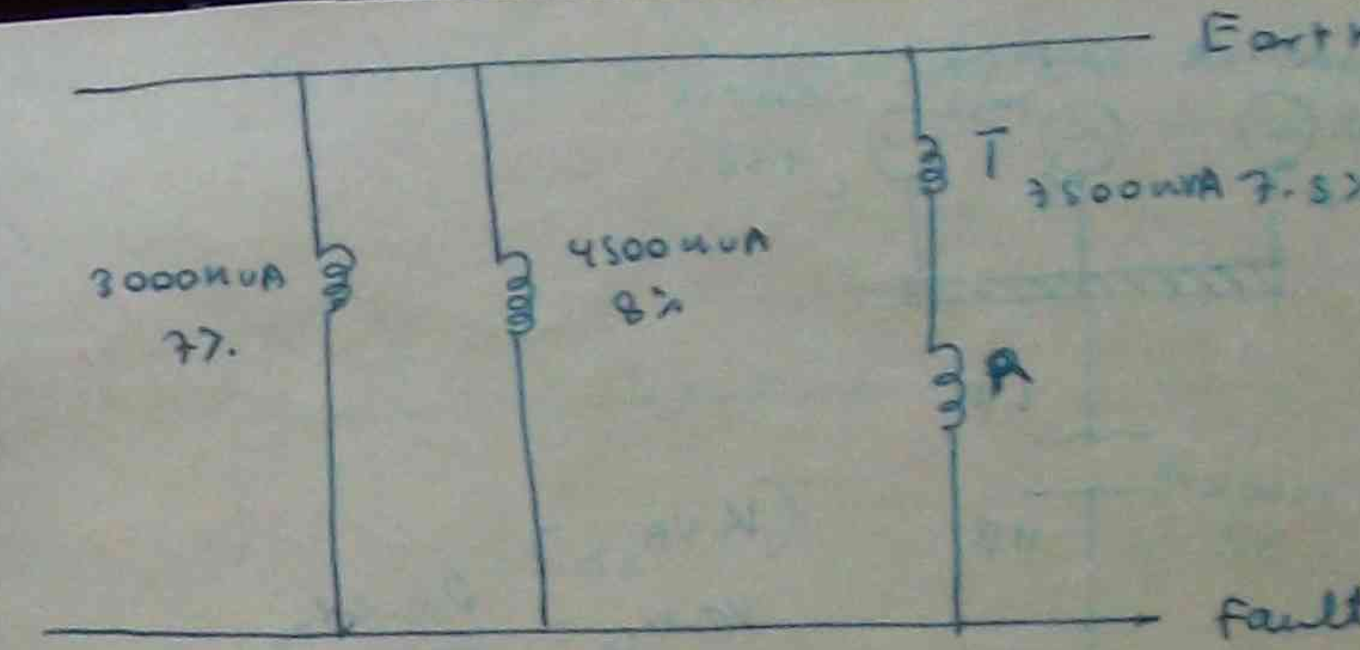
$$\frac{2.6\times 3300}{1310} = \frac{858}{131} = 6.54$$

$$\%x = \frac{x_{ph}\ \text{Power}}{E_L^2}\times 100$$

$$7.25 = \frac{x_{ph}\times 150000\times 100}{3300\times 3300}$$ ← VA ← V

$$\frac{7.25\times 1089}{1500} = x_{ph} = .105$$

7.25
3
2175
2175
23925



7500kVA = base of %

3000kVA : 7%

$7500 \longrightarrow ? = \frac{7\times 7500}{3000} = \frac{35}{2}\%$

R of %x = y of %

4500kVA : 8%

$7500 \longrightarrow ? = 8\times\frac{7500}{4500} = \frac{40}{3}\%$

$$\frac{1}{\%x_t} = \frac{2}{35} + \frac{3}{40}$$

$$\frac{1}{\%x_t} = \frac{16+21}{280}$$

$$\%x_t = \frac{280}{37}\%$$

$$\frac{1}{\%x_T} = \frac{37}{280} + \frac{1}{7.5+y}$$

$$kVA_{sh} = \frac{kVA\times 100}{\%x_T}$$

$$150000 = \frac{7500\times 100}{\%x_T}$$

$$\%x_T = 5\%$$

$$\frac{1}{5} = \frac{37}{280} + \frac{1}{7.5+y}$$

$$\frac{1}{5} - \frac{37}{280} = \frac{1}{7.5+y}$$

$$\frac{56-37}{280} = \frac{1}{7.5+y}$$

$$\frac{19}{280} = \frac{1}{7.5+y}$$

$$I_{FL} = \frac{\text{Power}}{\sqrt{3}E} = \frac{7500}{\sqrt{3}\times 3.3} = 1318\ \text{amp}$$

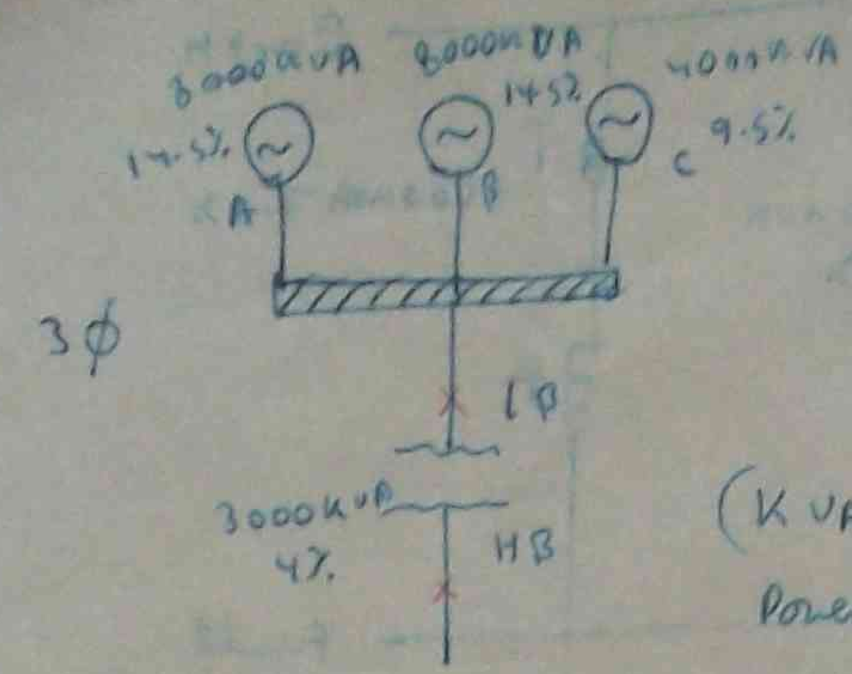
$$7.5+y = \frac{280}{19}$$

$$7.5+y = 14.75$$

$$\therefore y = 7.25\%$$

$$\%x = \frac{I_{FL}\, x_{ph}}{E_{ph}}\times 100$$

$$7.25 = \frac{1318\times x_{ph}}{3300}\times 100 \qquad x_{ph} = \frac{7.25\times 33}{1318} = \frac{239.25}{1318}$$



(KVA_{sh})

$$Power_{sh} = \frac{Power_{FL}}{\%x} \times 100$$

2000 KVA = base ဖြစ်ပါ။

$$\%x_1 = \frac{KVA\ base}{KVA\ act} \times \%x_{act}$$

∴ A ၏ $\%x = 3.625\%$

B $\%x = 3.625\%$

C ၏ $\%x = 4.75\%$

Trans ၏ $\%x = 2.667\%$

Generator များ၏ $\%x_T$

$$\frac{1}{\%x_{t_1}} = \frac{1}{3.625} + \frac{1}{3.625} + \frac{1}{4.75}$$

$$\%x_{t_1} = 1.28\%$$

$$\%x_T = 1.28 + 2.667 \text{ or } 1.28 + 2.67$$

$$= 3.95\%$$

$$Power(sh) = \frac{Power\,FL}{\%x} \times 100$$

LB တွင် 1.28%

$$Power\,sh = \frac{2000\ kVA}{1.28} \times 100$$

$$= \frac{200000}{1.28} = 156000\ kVA$$

156 mVA

HB တွင်

$$Power\,sh = \frac{Power\,FL}{\%x} \times 100$$

$$= \frac{200000}{3.95} \cancel{\times 100} = \frac{200000}{3.95}$$

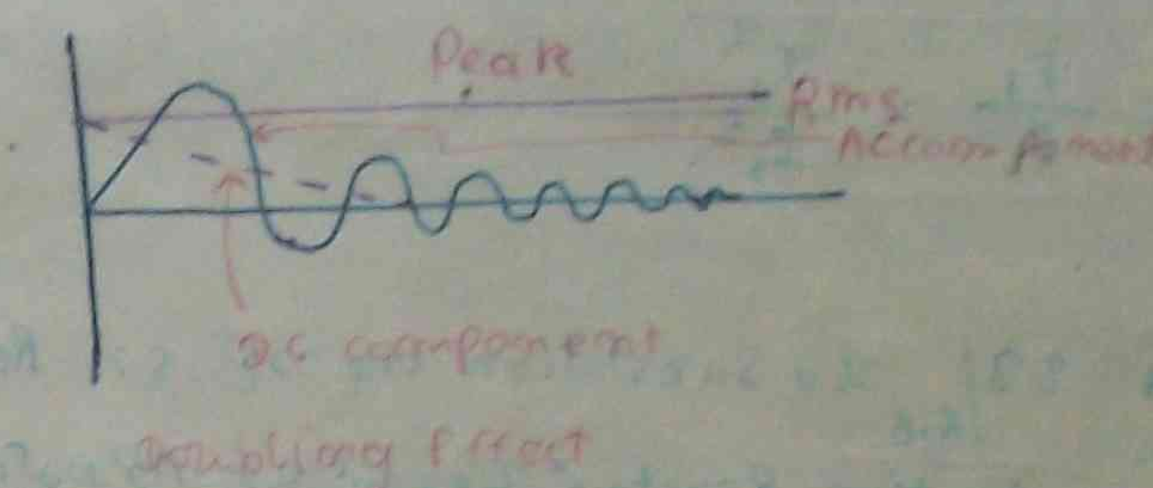
$= 50700$ kVA

$= 50.7$ mVA

$$\%x = \frac{x \times Power}{EL^2}$$

2.

Peak value and Doubling Effect



Short circuit ဖြစ်သောအခါ အမြင့်ဆုံးသော current သည် ပုံမှန်ရှိသော current ထက် များစွာကြီး နေရှိသည်။ အကြောင်းမှာ ထွက်လာချိန်တွင် R.m.s တန်ဖိုး ရှိသောကြောင့် ဖြစ်သည်။ ထို့ကြောင့် အများဆုံး တန်ဖိုးကို လည်း √2 နှင့် မြှောက်ပေးရသည်။ ၄င်းကို Peak Value ဟုခေါ်သည်။

Short circuit ဖြစ်သောအခါ alternatory A.C current သာမက armature Reaction နှင့် Peak Reaction များကြောင့် DC wave ကဲ့သို့သော သက်ရောက်မှုကြောင့် DC component ပါဝင်လာသည်။ ၄င်းဖြင့် Line များ Busbar များ cable များမှတဆင့် D.C Back current ဖြစ်ပေါ်လာသည်။ ထို့ကြောင့် Short circuit ဖြစ်တွင် Short circuit current ၏ တန်ဖိုးထက် ပိုများ ဖြစ်ပေါ်လာသည်။ ပျမ်းမျှ အားဖြင့် 1.8 နှင့် မြှောက်ပေးရ၍ Doubling effect ပါဝင်ဖြစ်သည်။

$$\boxed{\begin{aligned} I_{sh_{peak}} &= \sqrt{2}\, I_{sh} \\ I_{sh_{Doubling}} &= 1.8\, I_{sh} \end{aligned}}$$

* mechanical Stress

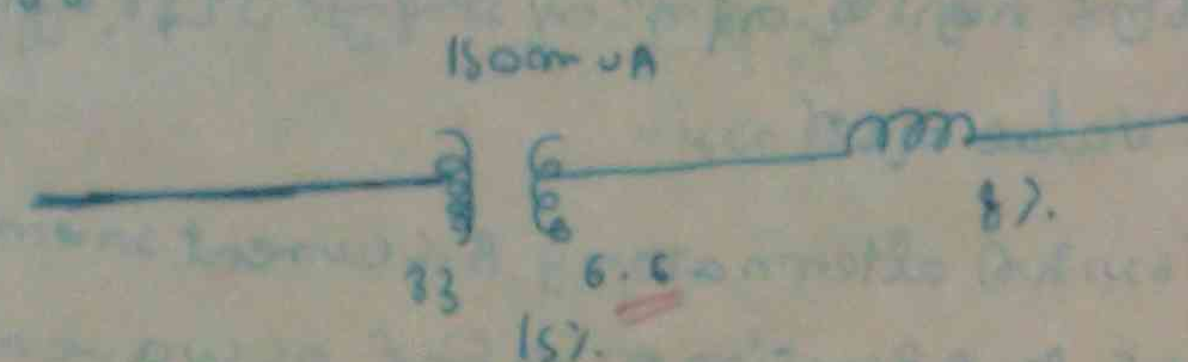
Short circuit များ ဖြစ်သောအခါ ပါဝင်သော လျှပ်စီး field ဖြစ်ပေါ်လာသည်။ ယင်း field တို့သည် အခြား field တစ်ခုနှင့် ထိတွေ့သောအခါ ဖြစ်စေ၊ ... သက်ရောက်မှု အား (Force) ဖြစ်လာသည်။ ယင်း Force သည် current ၏ နှစ်ထပ်ကိန်းနှင့် တိုက်ရိုက် အချိုးကျသည်။

Mechanical stress အကျိုးသက်ရောက်မှု current ၏ တန်ဖိုး အပေါ်မူတည်ပါသည်။ ထို့ကြောင့် Force များ လျှော့ချရန် I_{sh} တန်ဖိုးကို လျှော့ချပေးသော Reactance ရှိသည့် Reactor ခေါ် Inductive coil ကြီးများကို ... series တွဲ တပ်ဆင်ပေးနိုင်သည်။

$$F \propto I^2$$

$$\boxed{\frac{F_1}{F_2} = \frac{I_1^2}{I_2^2}}$$

Ex. 150 MVA 33/6.6 kV Substation တစ်ခုသည် 15% Reactance ရှိ၍ protective Reactor အနေဖြင့် 8% ကိုတပ်ဆင်ထားသည် (က) Reactor မပါလျှင် (ခ) Reactor ပါလျှင် mechanical stress အချိုးကို ရှာဖော်ပါ။



$$\boxed{\text{mech. stress} = \frac{I_{sn}^2}{I_{FL}^2}}$$

(က) Reactor မပါလျှင်   8%   ဒုံးမား side အတွက် 6.6 ဖြင့် I_{FL} ရှာ

$$\sqrt{3}\, E_L I_L = 150 \times 10^6$$

$$I_L = \frac{150 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 13.1 \times 10^3 \text{ amps}$$

$$I_{sh} = \frac{13.1 \times 10^3}{15} \times 100 = 87.3 \times 10^3 \text{ A}$$

$$\therefore \text{mechanical stress} = \frac{(87.3 \times 10^3)^2}{(13.1 \times 10^3)^2} = 44.4 \text{ (ans)}$$

(ခ) Reactor ပါလျှင်

$$I_{sh} = \frac{13.1 \times 10^3}{15 + 8} \times 100 = 57 \times 10^3 \text{ amp}$$

$$\therefore \text{Mechanical stress} = \frac{(57 \times 10^3)^2}{(13.1 \times 10^3)^2} = 18.9 \text{ (Ans)}$$

Surge Reactor

Reactor ဆိုသည်မှာ Resistance နည်း၍ Inductive Reactance များသော coil ကြီးများပင် ဖြစ်သည်။ Short circuit ကြောင့် ဖြစ်ပေါ်လာနိုင်သော Distribution Line များကို ဝိုင်း၍ ခွဲထားသော Parallel ဖြစ်သည့် Reactance ရှိ၍ Reactor တပ်ဆင်ထားသည့် circuit Breaker ကိုကာကွယ်ပေးနိုင်ပါ။

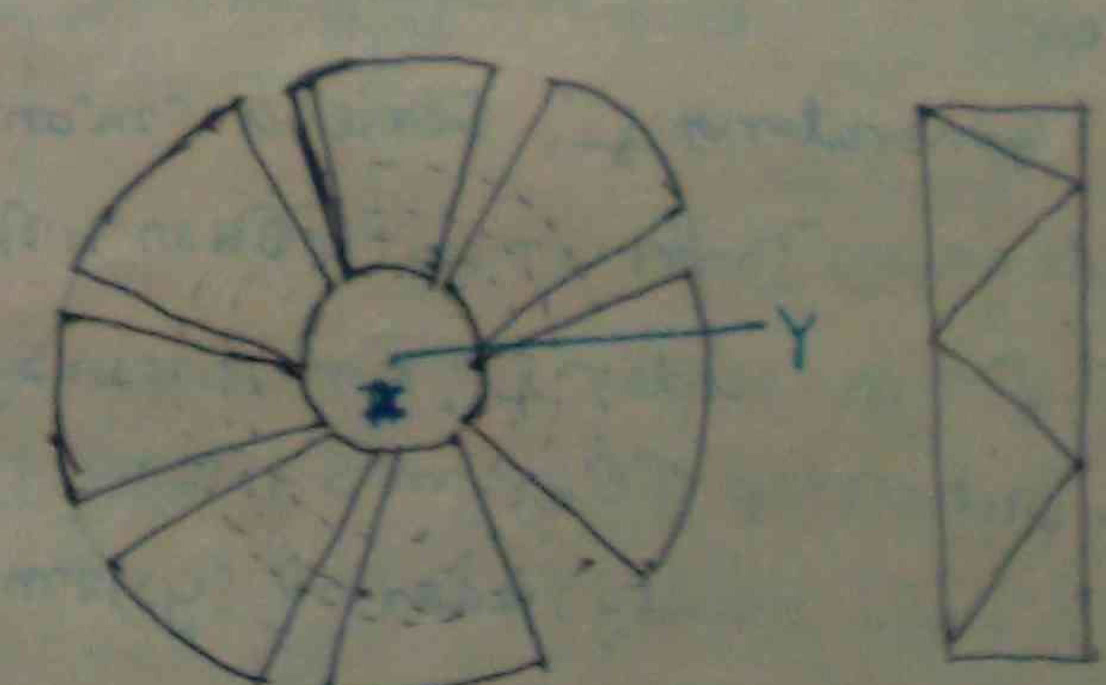
Reactor ၂ မျိုးရှိသည်။ (၁) Air Insulated Type
(2) Oil Immersed Type

~~[illegible]~~ copper strip wire များကို concrete piller ပေါ်တွင် conductor ၌ piller တိုင်ကို porcelain Insulation ဖြင့် ... generator ၏ earth ချထားသော star point ၌ Reactor တပ်ဆင် ~~Fixed Volt~~ phase ... ဖြစ်သည်။

Oil Immersed Type

ငြင်းသည် Transformer နှင့် အလားတူသည်။ ... Oil Immersed Type ထက် air core Reactor များ ... 33 kV အထက်ရှိ High Voltage Line များ အတွက် air core Reactor များကို အသုံးပြုသည်။

Air Core concrete Reactor



Section on XY

Limitation of Short circuit current Reactor

Electrical System တခုတွင် Reactance များ၏ သော Short circuit current ဖြစ်ပေါ်လာလျှင် ကြီးမားသည့် ရှာတွေ့ပေ။ ထို့ကြောင့် Generator များ ရှုပ်ထွေးသော network တခုတွင် rating capacity အမြင့်များ ပေးကြ၍ Fault ဖြစ်ပေါ်လျှင် Short circuit current သည် အလွန်ကြီးမား၍ Fault current ကို ကန့်သတ်ခြင်း ပြုလုပ်ပေးရန် လိုအပ်သည်။ Reactor များကို အသုံးပြုသည် -

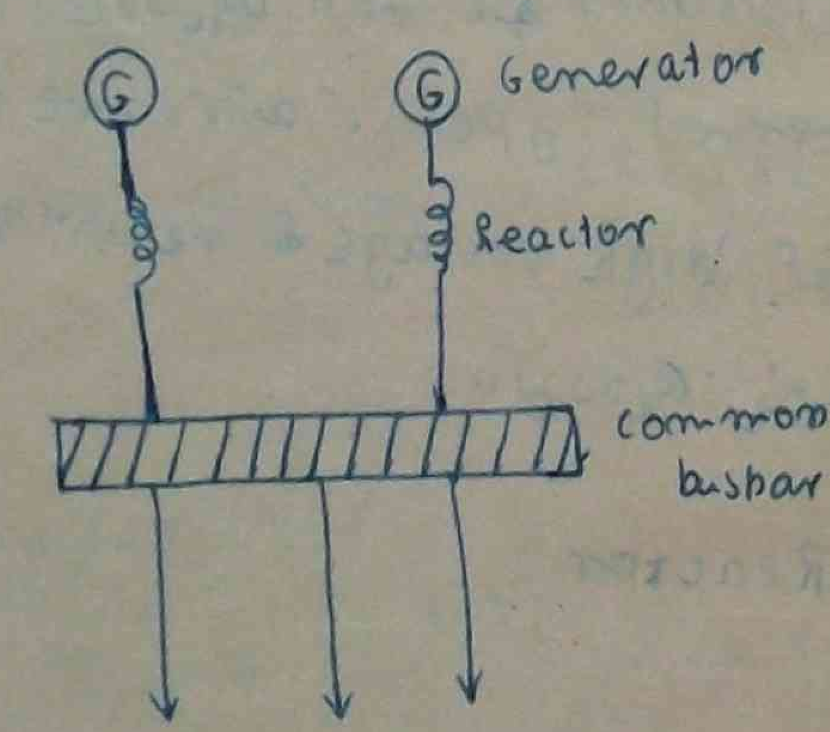
ရှိ၍ Circuit breaker များ၏ capacity သည် System တခုလုံး ထိခိုက်စေနိုင်သော ကြီးမားသော

System တခုလုံးကို ထိခိုက်စေနိုင်သော Circuit breaker များကို ရှောင်ရှားရန် Short circuit current limitation Reactor များကို အသုံးပြုခြင်းအားဖြင့် ထိန်းချုပ်ထား နိုင်သည်။ Short circuit current ဖြစ်သောအခါ ထို Reactor ၏ ကြီးမား Reinforce concrete frame များပေါ်တွင် တပ်ဆင်ထားရမည်။

Position of Reactor (Reactor များ တပ်ဆင်ရမည့် နေရာများ)

Current limiting reactor များကို အောက်ပါအတိုင်း တပ်ဆင်နိုင်ပေသည်။

(1) Generator Reactor

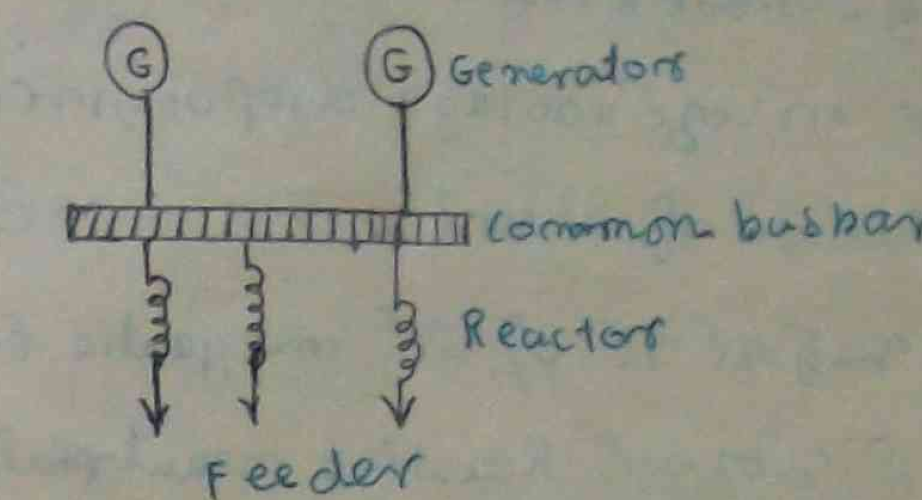


Reactor များကို generator များနှင့် Series တပ်ဆင်ထားခြင်း ဖြင့် Feeder တခုတွင် Short circuit ဖြစ်သောအခါ common busbar voltage ကျဆင်း၍ အခြား Feeder နှင့် ဆက်ထားသော Synchronous machine များ အားလုံး out of step ဖြစ်သွားကာ System တခုလုံး break down ဖြစ်သွားနိုင်သည်။ Faulty Feeder ကို System မှ ဖြုတ်ပြီးနောက် synchronous machine များကို တဖန် Re-Synchronous ပြုလုပ်ရသည်။

မူလတည်ဆောက်ပုံအားဖြင့် alternator များမှာ Transient Reactance များသောကြောင့် Short circuit current ကို အကန့်အသတ်ပြု

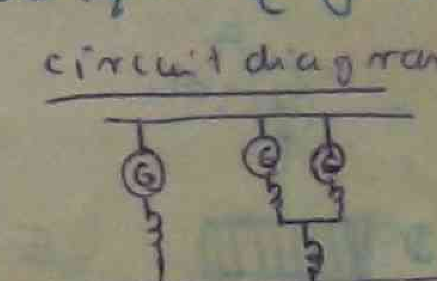
နိုင်စွမ်းရှိသော ကာကွယ်ရေးများ ရှိသော Reactor ကို အသုံးပြုရန် မလိုပေသည်။

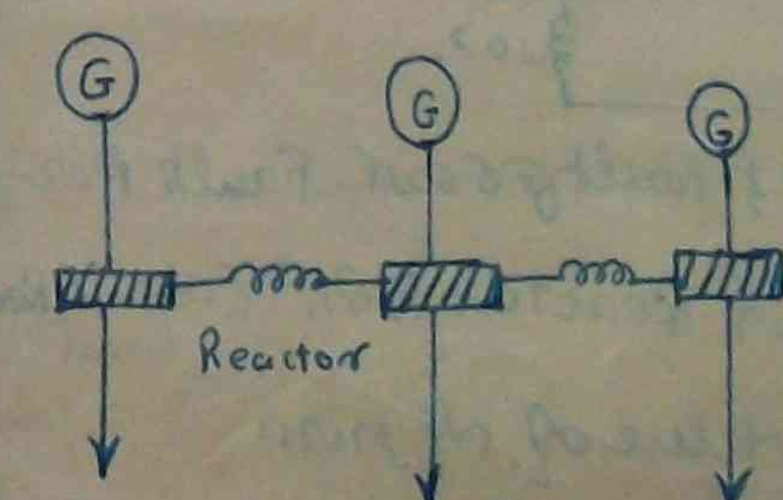
(2) Feeder Reactor

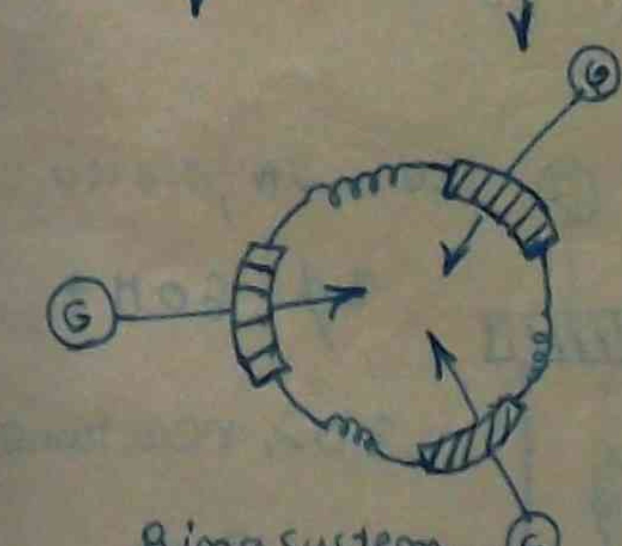


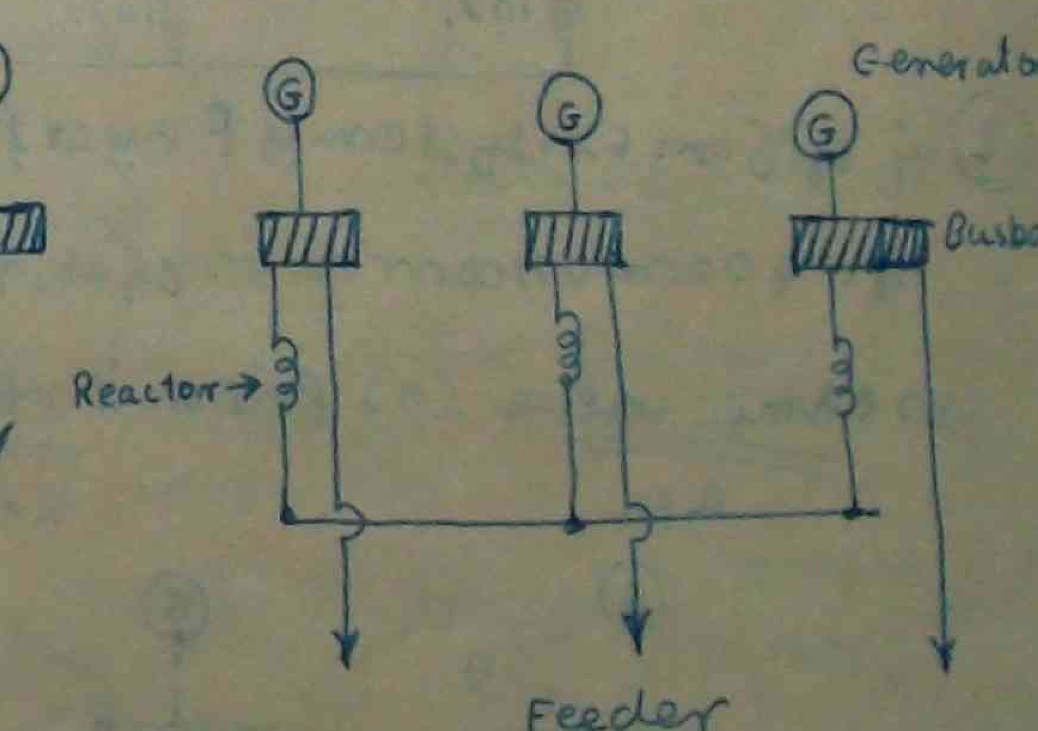
Feeder များနှင့် Series တပ်ဆင်ခြင်း ဖြင့် အလားတူအကျိုးကျေးဇူးများ ရရှိနိုင်သည်။ Short circuit ဖြစ်သောအခါ voltage drop များမှာ ~~Fee~~ Faulty feeder Reactor များ ပေါ်တွင်သာ ကျရောက်သောကြောင့် System ပေါ်တွင်ကျန်ရှိသော load နှင့် Plant များသည် သက်ရောက်မှုမရှိပေ။ Busbar များတွင် Short circuit ဖြစ်သောအခါ ၎င်းသည် alternator များတွင် Protection မရှိသောကြောင့် ဖြစ်သည်။ Busbar short circuit မှာ အလွန်ဖြစ်ခဲပေသည်။ ထို့ကြောင့် alternator တို့၏ ပင်ကိုယ် Reactor များကြောင့် ကာကွယ်မှုကို အလိုအလျောက် ပေးနိုင်မည်ဖြစ်သည်။

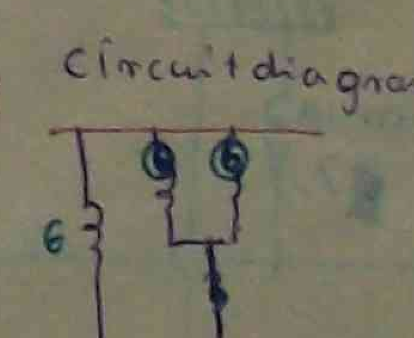
(3) Busbar Reactor











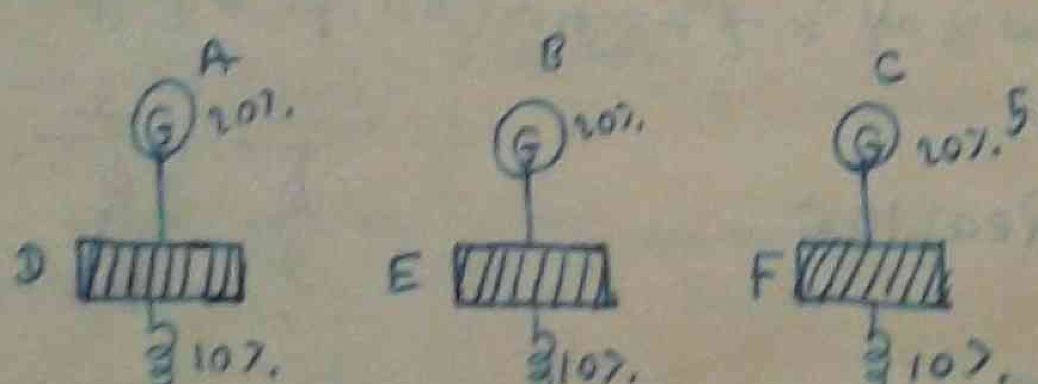
Tie bar or star system

[illegible] Generator Reactor [illegible] Feeder Reactor [illegible] normal [illegible] Full load current [illegible] constant loss [illegible] Tie bar system [illegible] Reactor [illegible] voltage drop [illegible] Short circuit [illegible] generator [illegible] current [illegible]

[illegible] voltage drop [illegible]

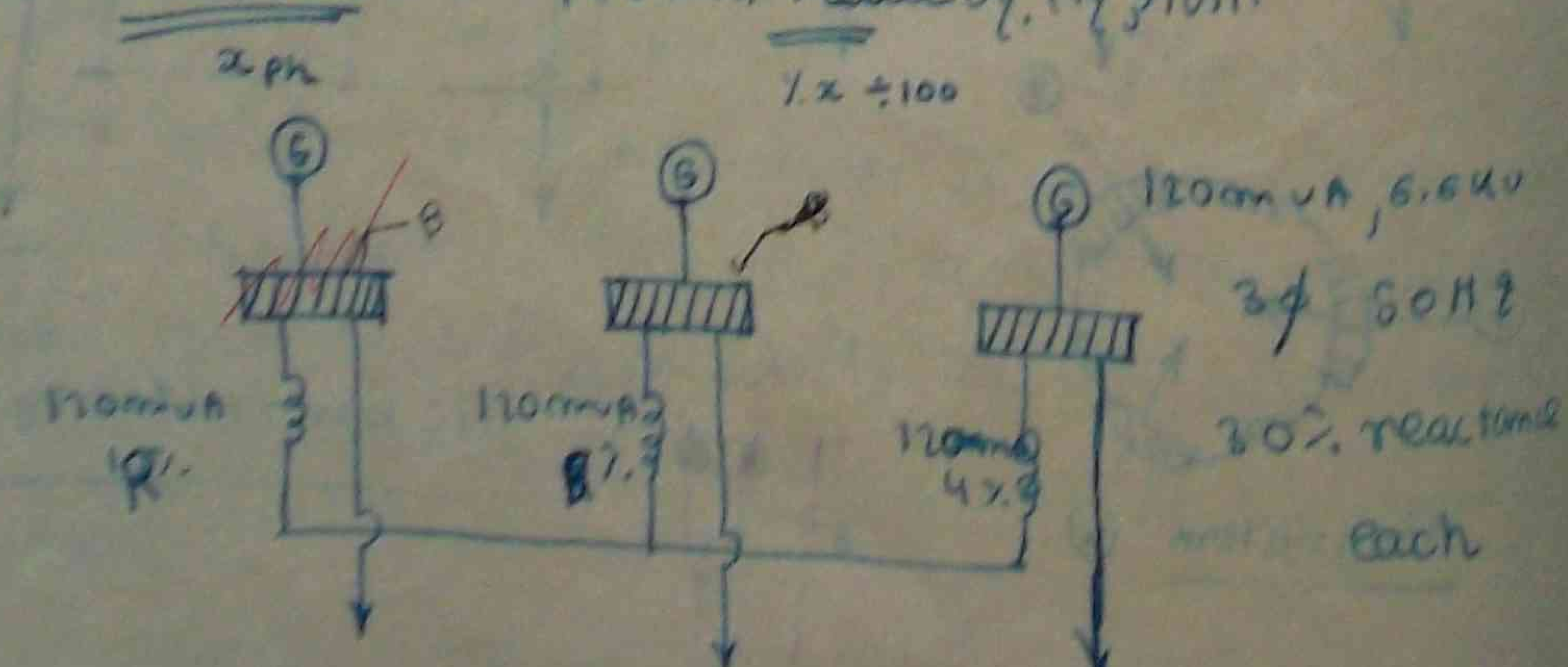
[illegible] Reactor [illegible] Fuse [illegible] Shunt [illegible] magnetic field [illegible] normal operating [illegible] Reactive neutralize [illegible] Fault [illegible] Fuse [illegible] circuit [illegible] Reactance [illegible] Reactor [illegible]

(1) [illegible] Busbar section [illegible] Generating plant [illegible] Generating [illegible] Rating [illegible] 50 mVA 20% [illegible] Tie bar Reactor [illegible] 10% [illegible] section [illegible] Short [illegible] Short Circuit mVA [illegible]

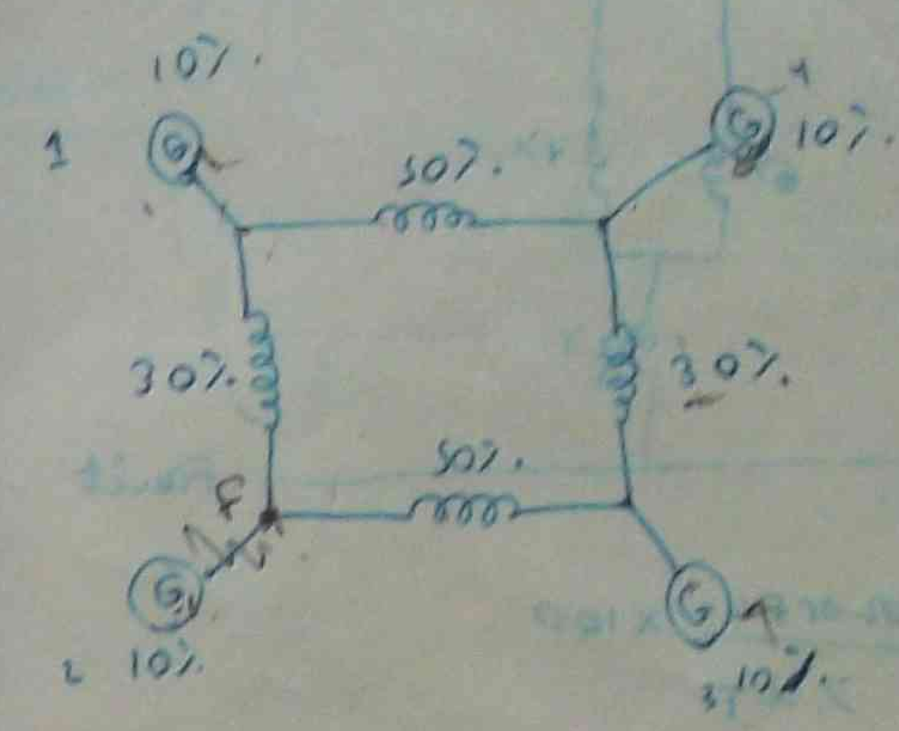


(2) [illegible] system [illegible] F [illegible] fault [illegible] Fault Power [illegible] 400 mVA [illegible] Reactor R [illegible] (a) % Reactance (b) ohmic value (c) per unit value [illegible]

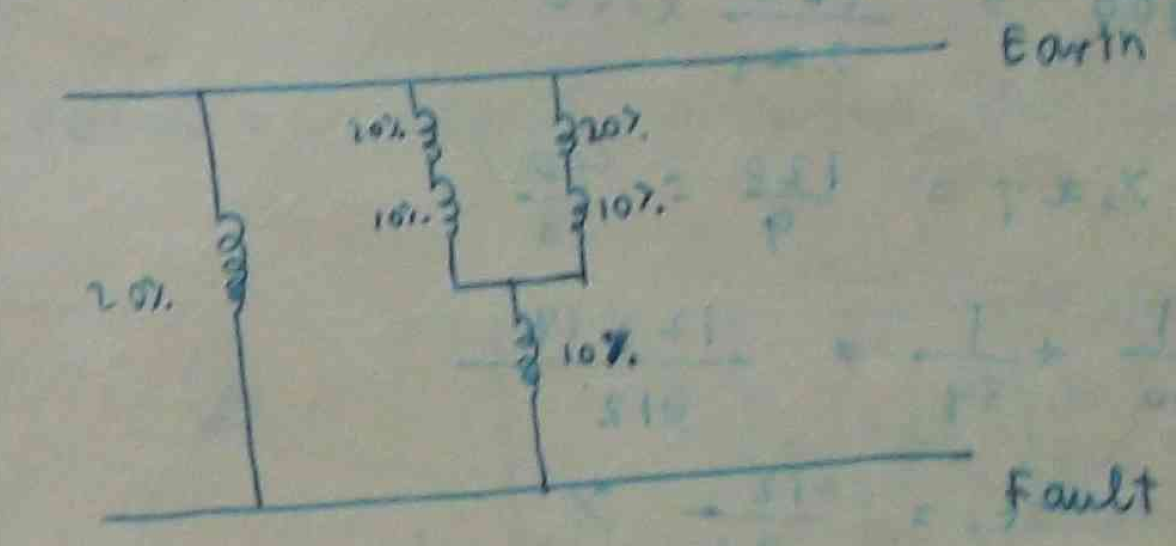
x_{ph} $\%x \div 100$



(3) [illegible] network [illegible] 3ϕ fault [illegible] F [illegible] mVA [illegible] % Reactance [illegible] 100 mVA [illegible]



(1)



$$\frac{1}{x_{t_1}} = \frac{1}{20} + \frac{1}{300} = \frac{1}{15} \qquad x_{t_1} = 15\%$$

$$Rt_2 = 25\%$$

$$\frac{1}{x_T} = \frac{1}{25} + \frac{1}{20} = \frac{20+25}{500} = \frac{45}{500}$$

$$x_T = \frac{100}{9}\,\%$$

~~$\sqrt{3}$ $I_{FL} \times E_{ph}$ = Power~~

~~$\sqrt{3} \times I_{FL} \times$~~

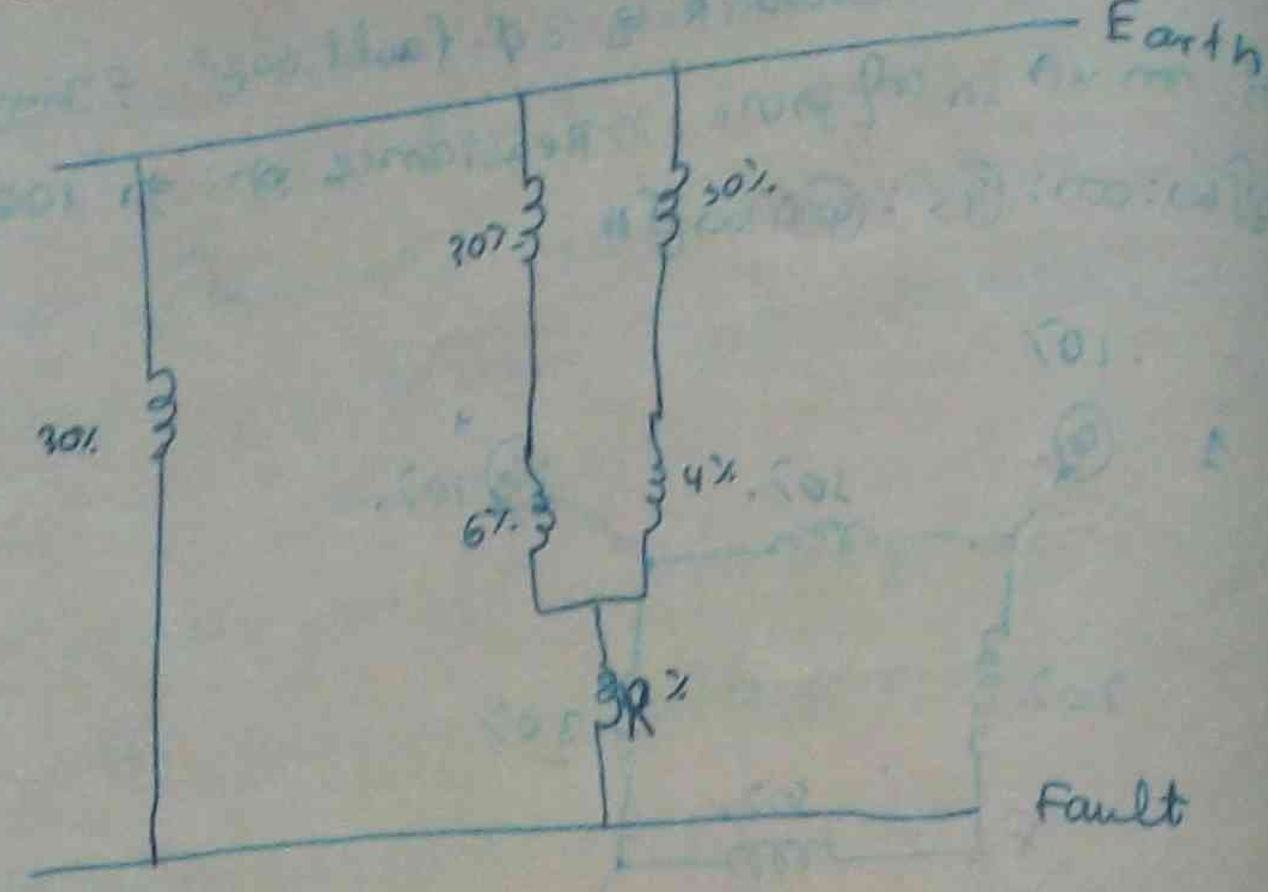
$$\text{mVA (Power}_{sh}) = \frac{\text{Power}_{FL} \times 100}{\%x_T}$$

$$\text{Power}_{sh} = \frac{50 \times 100}{\frac{100}{9}}$$

$$\text{Power}_{sh} = 450\ \text{mVA}$$

(Ans)

(2)



$$Power_{sn} = \frac{Power_{FL}}{\%x_T} \times 100$$

$$900 = \frac{120}{\%x_T} \times 100$$

$$\%x_T = \frac{120}{9} = \frac{40}{3}$$

$$\frac{1}{x_{t_1}} = \frac{1}{30} + \frac{1}{34} = \frac{17+18}{612}$$

$$\%x_{t_1} = \frac{612}{35}\ \%$$

$$x_{t_1} + R = \frac{612}{35} + R = \frac{612+35R}{35}$$

$$\frac{1}{\%x_T} = \frac{1}{30} + \frac{35}{612+35R}$$

$$\frac{3}{40} = \frac{1}{30} + \frac{35}{612+35R}$$

$$\frac{3}{40} - \frac{1}{30} = \frac{35}{612+35R}$$

$$\frac{9-4}{120} = \frac{35}{612+35R}$$

$$\frac{5}{120} = \frac{35}{612+35R}$$

$$612 + 35R = 840$$

$$35R = 228 \qquad R = \frac{228}{35} = 6.525\%$$

$$\%x_T = \frac{x \cdot Power\ 10^3}{EL^2} \times 100$$

$$\frac{40}{3} = \frac{x \times 120 \times 10^3 \times 10^3 \times 100}{(6.6 \times 10^3)^2}$$

$$\frac{40}{3} = \frac{x \times 12 \times 10^8}{43.6 \times 10^6}$$

$$\frac{40}{3} = \frac{12x \times 10^2}{43.6}$$

$$\frac{40 \times 43.6}{\frac{36}{9} \times 100} = x \qquad x = .484\%$$

R ohmic value

$$\%x = \frac{Power \times x_{pn} \times 100}{EL^2}$$

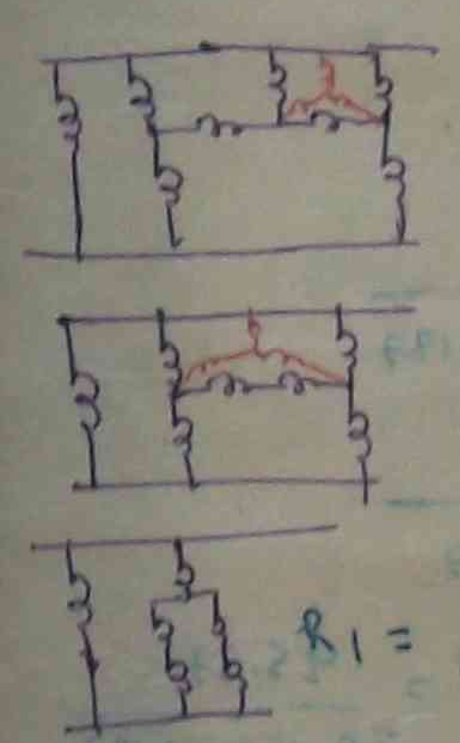
$$6.525 = \frac{120 \times 10^3 \times 10^3 \times x_{pn} \times 100}{(6.6 \times 10^3)^2}$$

$$6.525 = \frac{120 \times 10^8 \times x_{pn}}{43.6 \times 10^6}$$

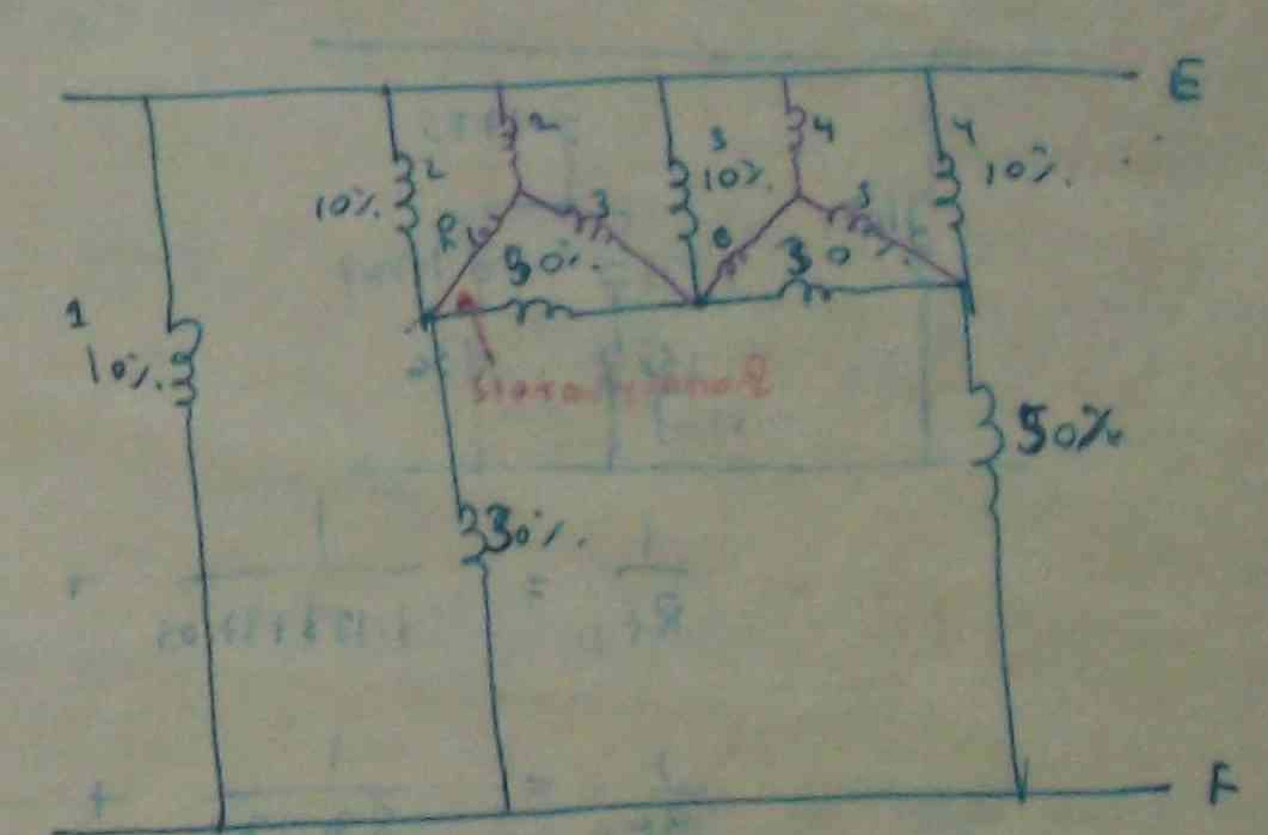
$$x_{pn} = \frac{6.525 \times 43.6}{12 \times 1000} = \frac{284.5}{12000} \approx .0237$$

$$\text{per unit} = \frac{6.525}{100} = .06525\ \Omega$$

(3)



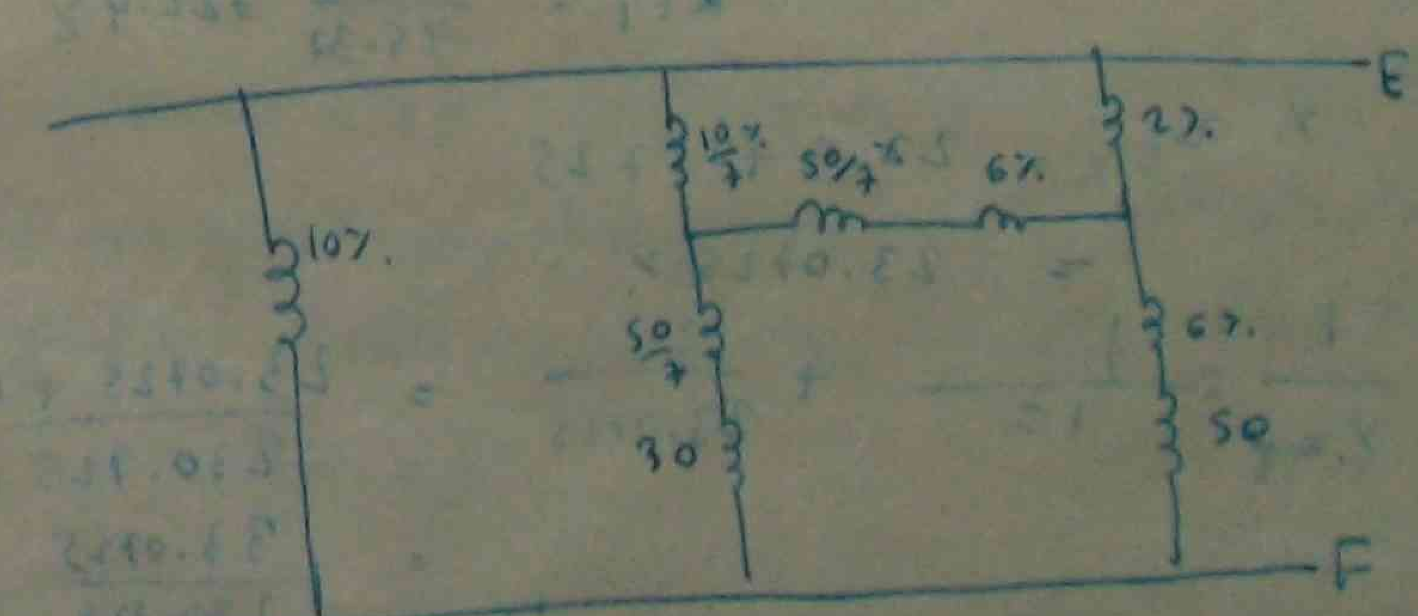
(4)

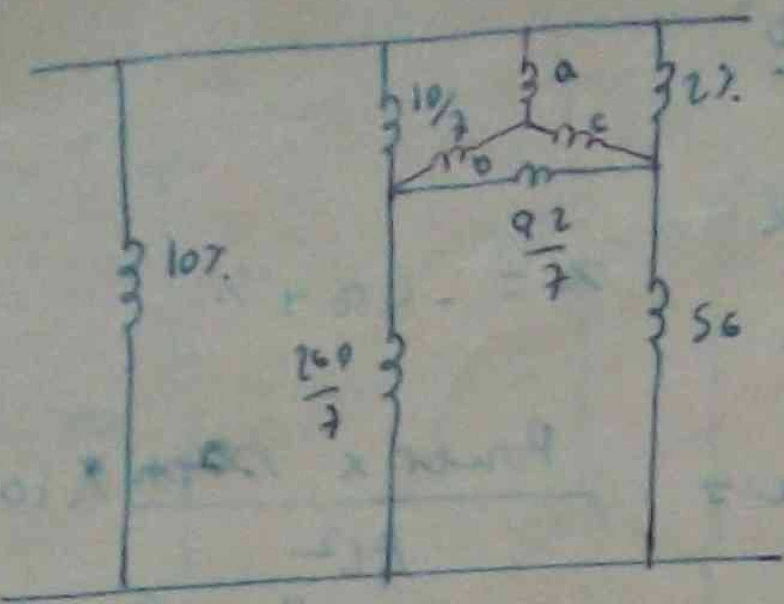


$$R_1 = \frac{10 \times 50}{70} = \frac{50}{7}\% \qquad R_4 = \frac{10 \times 10}{30} = 2\%$$

$$R_2 = \frac{10 \times 10}{70} = \frac{10}{7}\% \qquad R_5 = \frac{10 \times 30}{50} = 6\%$$

$$R_3 = \frac{10 \times 50}{70} = \frac{50}{7}\% \qquad R_6 = \frac{10 \times 30}{50} = 6\%$$

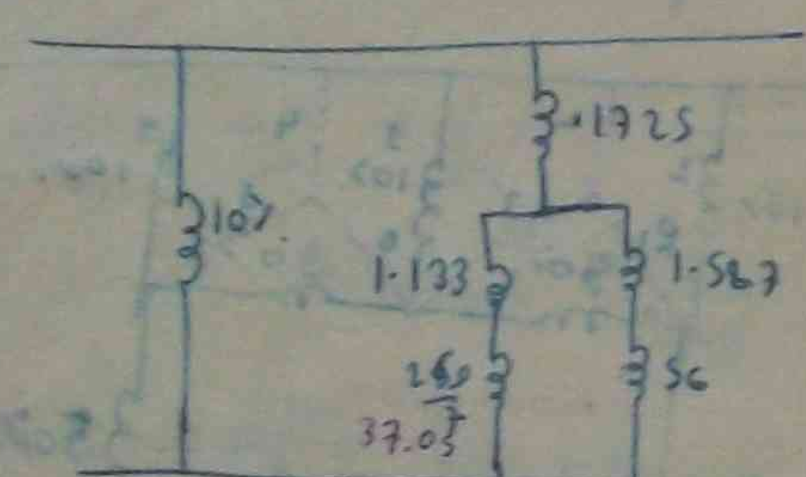




$$a = \frac{\frac{10}{7}\times 2}{\frac{116}{7}} = \frac{20}{116} = .1725$$

$$b = \frac{\frac{10}{7}\times\frac{92}{7}}{\frac{116}{7}} = \frac{920}{116\times 7} = \frac{920}{812} = 1.133$$

$$c = \frac{\frac{92}{7}\times 2}{\frac{116}{7}} = \frac{184}{116} = 1.587$$



$$\frac{1}{R_{t_1}} = \frac{1}{1.133+37.05} + \frac{1}{56+1.187}$$

$$\frac{1}{R_{t_1}} = \frac{1}{38.183} + \frac{1}{57.187}$$

$$\frac{1}{R_{t_1}} = \frac{57.187+38.183}{38.183\times 57.187} = \frac{95.37}{38.183\times 57.187}$$

$$\frac{1}{R_{t_1}} = \frac{95.37}{2182}$$

$$X_{t_1} = \frac{2182}{95.37} = 22.9\%$$

$$\%x_{t_2} = 22.9 + .1725 = 23.0725\%$$

$$\frac{1}{\%x_T} = \frac{1}{10} + \frac{1}{23.0725} = \frac{23.0725+10}{230.725} = \frac{33.0725}{230.725}$$

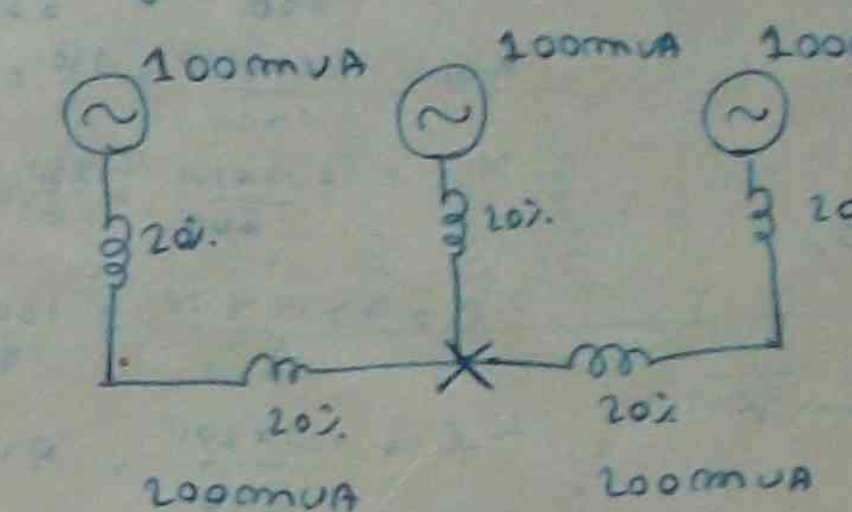
$$\%x_T = \frac{230.725}{33.0725} = 6.98$$

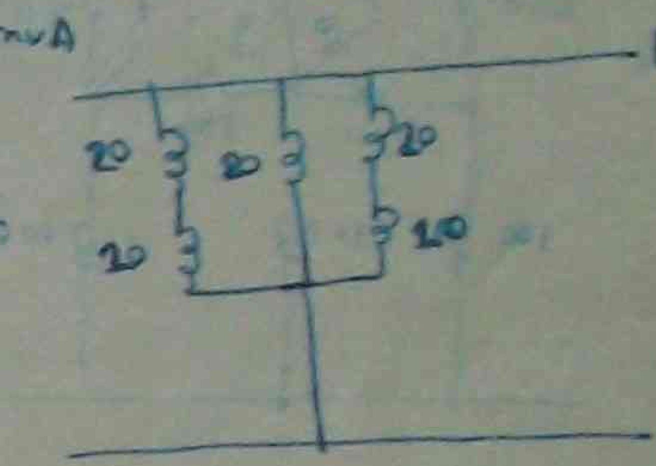
$$Power_{sh} = \frac{Power_{FL}}{\%x_T} \times 100$$

$$Power_{sh} = \frac{100}{6.98\%} \times 100 = 1430\ mVA$$

gen: ၏ Reactor

④ ဓါတ်အားပေးစက်တခုရှိသည့် busbar section ၃ ခုရှိသည်။ 200m.VA ရှိ 20% Reactance ရှိသော Reactor ၂ ခုဖြင့် ဆက်ထားသည်။ generator တခုစီ၏ 100m.VA နှင့် 20% Reactance ရှိကြပါက ၎င်းတို့၏ busbar တွင် fault ဖြစ်သောအခါ fault ကိုပေးသော m.V.A ကိုရှာပါ။





100mVA = base ဖြစ်သော

200mVA တွင် = 20%

$$\therefore 100 \text{———} ?,\quad 20\ \frac{\times 100}{200} = 10\%$$

$$\frac{1}{\%x_T} = \frac{1}{30} + \frac{1}{20} + \frac{1}{30}$$

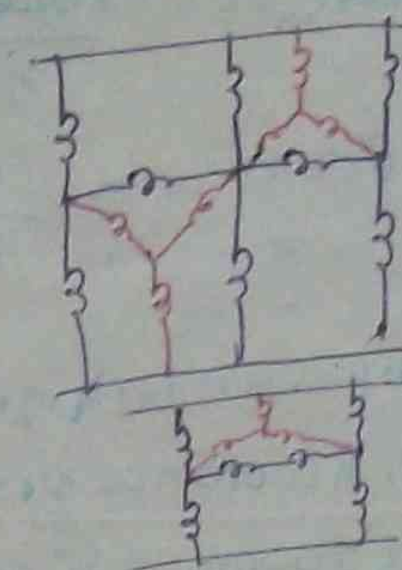
$$= \frac{2+3+2}{60} = \frac{7}{60}$$

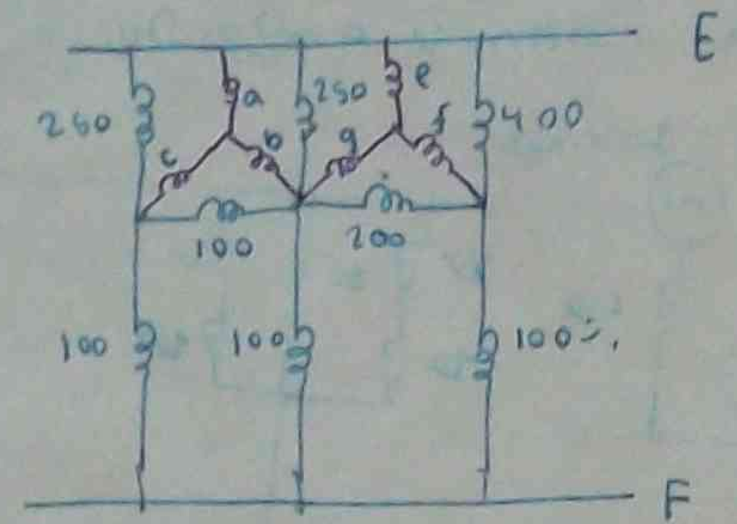
$$\therefore \%x_T = \frac{60}{7}\%$$

$$Power\ Sh = \frac{Power\ FL}{\%x_T} \times 100$$

$$= \frac{100\times 7}{6\cancel{0}} \times 10\cancel{0} = \frac{7000}{6} = 1166.6\ mVA$$

⑤ လျှပ်စစ်ဓါတ်အား (generator) ၃ လုံးပါဝင်သော လျှပ်စစ်ဓါတ်အားပေးစနစ် တခု၏ one line diagram ကို ဖော်ပြထားသည်။ ... ဖြစ်သည်။ ... line volt မှာ 11000 volts ဖြစ်သည်။ F ... 3φ fault ဖြစ်လျှင် fault current ကိုရှာပါ။ ၎င်း Reactance များကို % ဖြင့်ပေးထားသည်။





$x_a = \frac{250 \times 250}{600} = \frac{62500}{600} = 104.2\%$

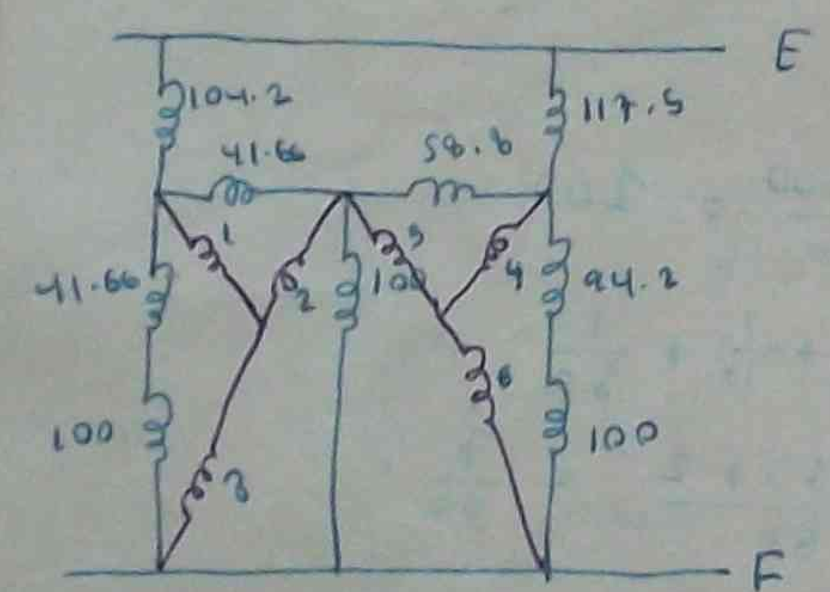
$x_b = \frac{250 \times 100}{600} = \frac{250}{6} = 41.66\%$

$x_c = \frac{250 \times 100}{600} = \frac{250}{6} = 41.66\%$

$x_e = \frac{250 \times 400}{850} = \frac{10000}{85} = 117.5\%$

$x_f = \frac{400 \times 200}{850} = 94.2\%$

$x_g = \frac{250 \times 200}{850} = \frac{5000}{85} = 58.8\%$



$x_1 = \frac{141.66 \times 41.66}{283.32} = 20.8\%$

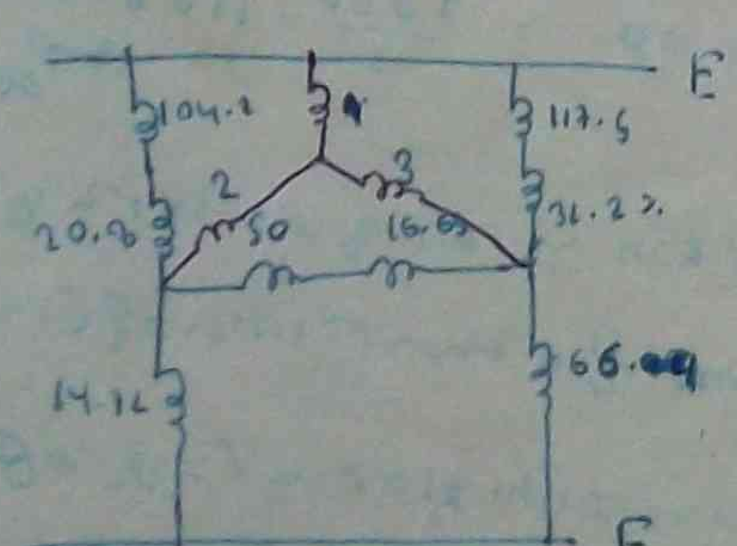
$x_2 = \frac{141.66 \times 100}{283.32} = 50\%$

$x_3 = \frac{41.66 \times 100}{283.32} = 14.72\%$

$x_4 = \frac{58.8 \times 194.2}{353} = 32.2\%$

$x_6 = \frac{100 \times 194.2}{353} = 55.0$

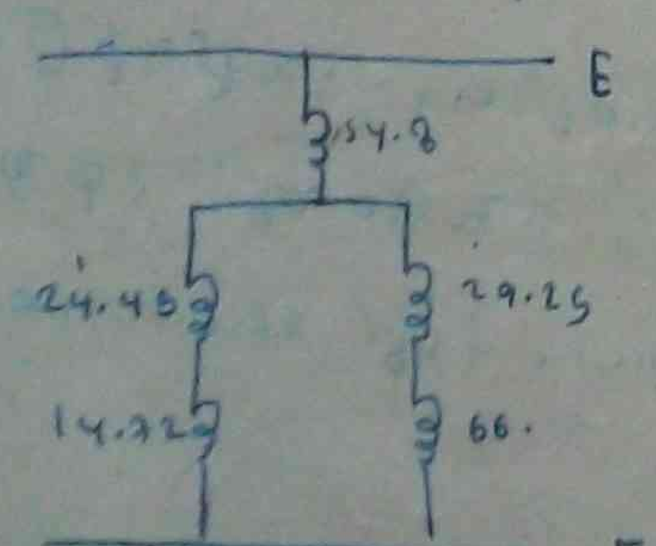
$x_5 = \frac{100 \times 58.8}{353} = 16.65\%$



$x_1 = \frac{125 \times 149.7}{341.35} = 54.8\%$

$x_2 = \frac{125 \times 66.65}{341.35} = \cancel{24.45}\%$

$x_3 = \frac{149.7 \times 66.65}{341.35} = 29.25$



$\frac{1}{x_{t_1}} = \frac{1}{39.17} + \frac{1}{95.25}$

$x_{t_1} = \frac{39.17 \times 95.25}{39.17 + 95.25} = \frac{39.17 \times 95.25}{134.42}$

$= 27.75\%$

$\%x_T = 27.75 + 54.8 = 82.55\%$

$I_{sh} = \frac{I_{fl}}{\%x_T} \times 100$

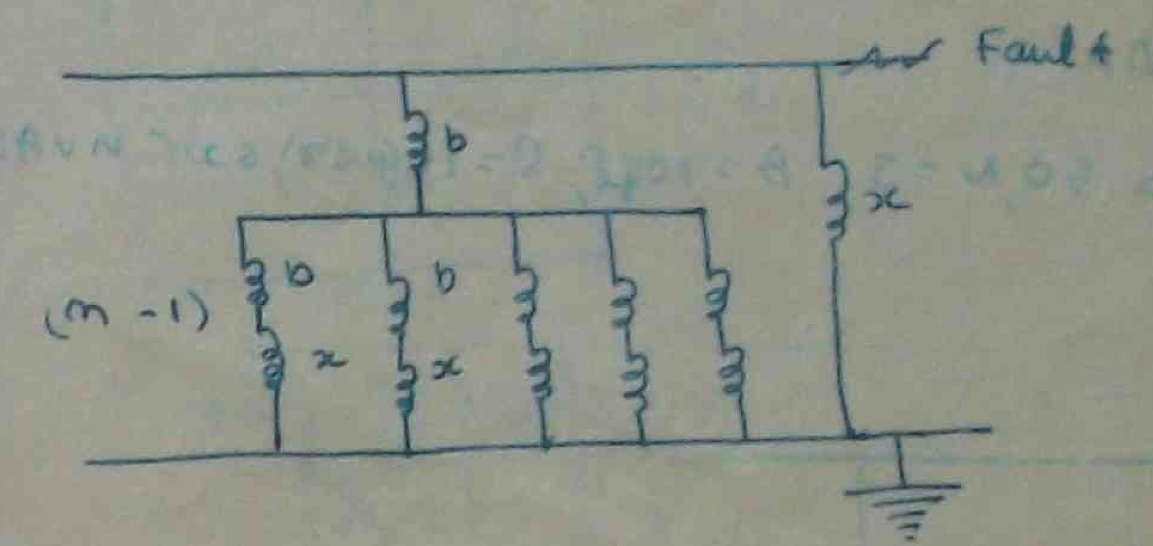
$I_{sh} = \frac{100 \times 10^6}{11000\sqrt{3}} \times 100$

$I_{sh} = \frac{10^7}{11 \times 82.55\sqrt{3}}$

$= 112.0$ amp

6

1. m section busbar ရှိသော section တစ်ခုတွင် Generator တစ်လုံး Q kVA ရှိသည်။ % Reactance သည် %x ဖြစ်၍ ရှိသည်။ tie bar သို့ ဆက်ရာတွင် b% ရှိသော Reactor များ ကိုဖြတ်၍ ဆက်သွယ်ထားသည်။ busbar section တစ်ခု၌ short circuit ဖြစ်သော short circuit kVA သည် $\left[\frac{Q}{x} + \frac{Q(m-1)}{(bm+x)}\right] \times 100$ ဖြစ်ကြောင်း သက်သေပြပါ။



$\therefore \ \%x_{GT} = \frac{x+b}{m-1}$

$\%x_{GT}$ နှင့် b% သည် series

$\therefore \ \frac{x+b}{m-1} + b = \frac{x+bm}{m-1}$

SC ... $\%x$ နှင့် parallel

$$\%x_{Total} = \frac{\frac{x+bm}{m-1} \times x}{\left(\frac{x+bm}{m-1} + x\right)} = \frac{x(x+bm)}{m(b+x)}$$

$$\therefore \ kVA_{sh} = \frac{Q}{\%x_{Total}} \times 100 = \frac{Q \times m(b+x)}{x(x+bm)} \times 100$$

$$= \left\{\frac{Qmb + Qmx + Qx - Qx}{x(x+bm)}\right\} \times 100$$

$$= \left[\frac{Qmb + Qx + Qmx - Qx}{x(x+bm)}\right] \times 100$$

$$kVA_{sh} = \left[\frac{Q(mb+x) + Qx(m-1)}{x(x+bm)}\right] \times 100$$

$$\boxed{kVA_{sh} = \left[\frac{Q}{x} + \frac{Q(m-1)}{(x+bm)}\right] \times 100}$$

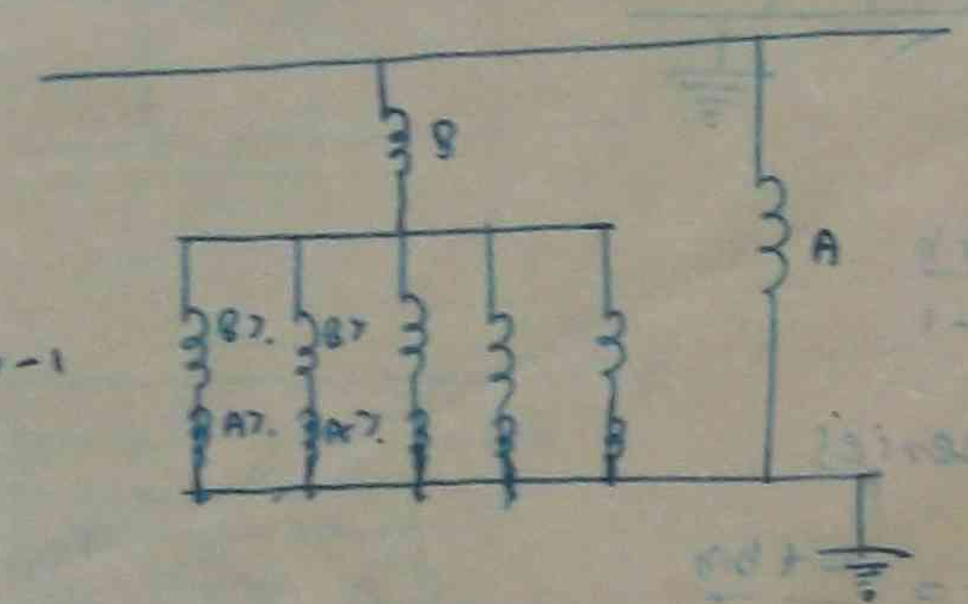
* b - Reactor Reactance

x - Generator Reactance

Q - kVA (FL)

(2) [illegible] Tiebar [illegible] KVA [illegible] sectional busbar [illegible] gen: [illegible] section [illegible] Tiebar [illegible] B % Reactance [illegible] Reactor [illegible] A % [illegible] section [illegible] generator [illegible] Reactance [illegible] short circuit [illegible] KVASh = $\left[\dfrac{KN(A+B)}{A(A+BN)}\right] \times 100$

[illegible] $K = 50, N = 3, A = 20$ [illegible] $B = 10$ [illegible] KVASh [illegible]



section 1 [illegible] Reactor [illegible]

$$\%x_{GT} = \frac{A+B}{N-1}$$

% GT [illegible] B% [illegible] series

$$\therefore \frac{A+B}{N-1} + B = \frac{A+B+BN-B}{N-1} = \frac{A+BN}{N-1}$$

[illegible] A % [illegible]

$$\therefore \%x\ \text{Total} = \frac{\left(\frac{A+BN}{N-1}\right) \times A}{\frac{A+BN}{N-1} + A} = \frac{A(A+BN)}{N(B+A)}$$

$$\therefore KVASh = \frac{K}{\%x\ \text{Total}} \times 100$$

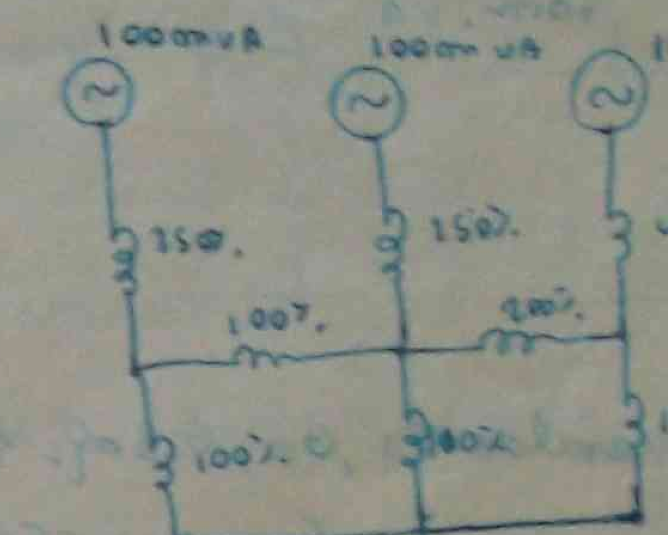
$$= \frac{K}{\frac{A(A+BN)}{N(A+B)}} \times 100$$

$$KVASh = \frac{KN(A+B)}{A(A+BN)} \times 100$$

$$KVASh = \frac{50 \times 3\,(20+10)}{20\,(20+10\times 3)} \times 100$$

$$= 4.5 \times 100 = 450\ \text{KVA}$$

(Ans)



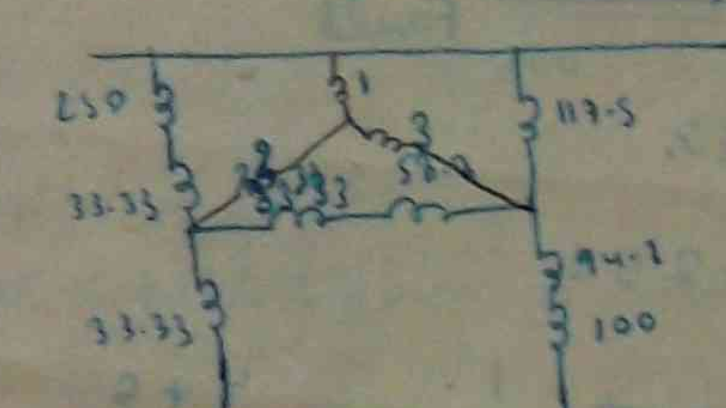
$$x_e = \frac{250\times 400}{850} = 117.5\%$$

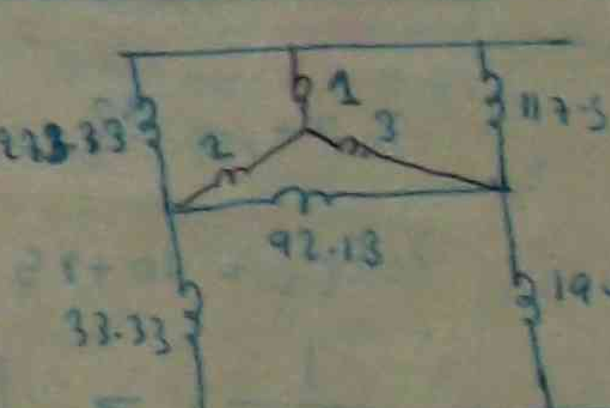
$$x_f = \frac{200\times 400}{850} = 94.2\%$$

$$x_g = \frac{250\times 200}{850} = \frac{5000}{85} = 58.9\%$$

$$R_c = \frac{100\times 100}{300} = 33.33$$

$R_b = 33.33$, $R_a = 33.33\ \%$

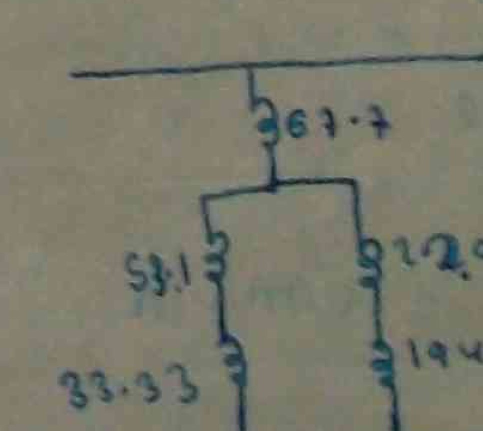




$$R_1 = \frac{283.33\times 117.5}{492.96} = 67.7\%$$

$$R_2 = \frac{283.33\times 92.13}{492.96} = 53.1\%$$

$$R_3 = \frac{92.13\times 117.5}{492.96} = 22.05\%$$



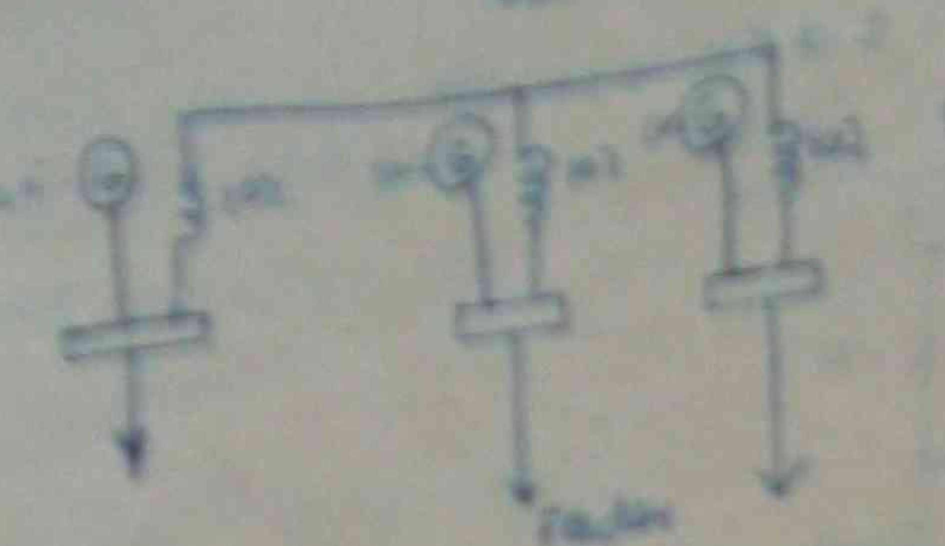
$$\frac{1}{R_{t_1}} = \frac{1}{86.43} + \frac{1}{216.25}$$

$$= \frac{216.25 + 86.43}{86.43\times 216.25}$$

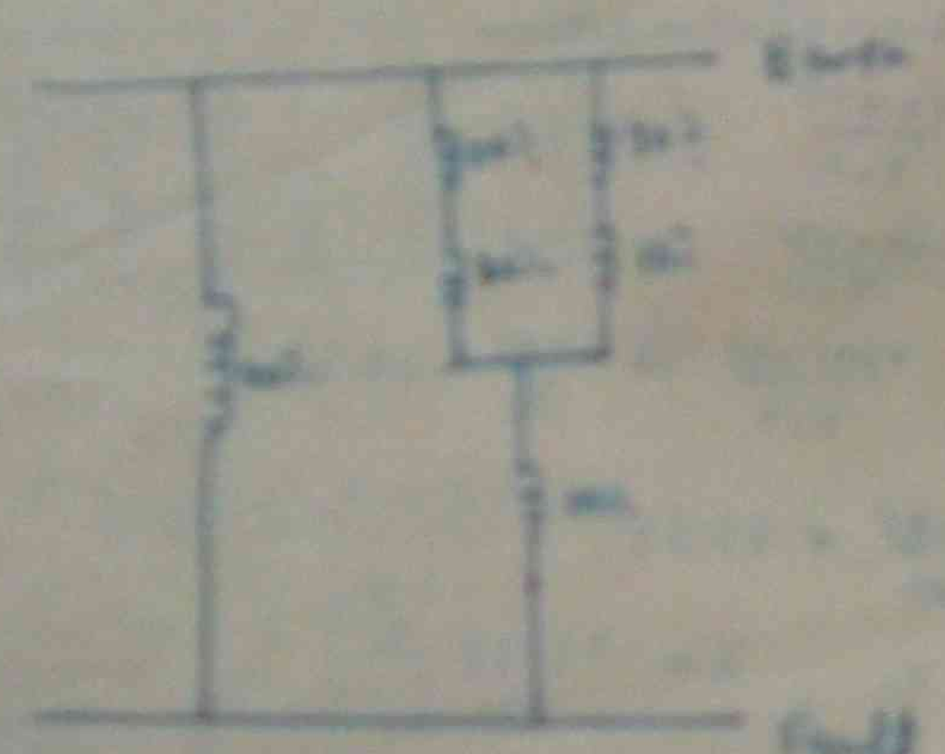
$$R_{t_1} = \frac{86.43\times 216.25}{302.68} = 41.7$$

$$\therefore \%x_T = 41.7 + 67.7$$

$$= 109.4$$



50 m.v.a, 20% Reactance [illegible] generator G_1, G_2, G_3 [illegible]
[illegible] 10% [illegible] bus-bar section [illegible] short [illegible]
[illegible] fault [illegible] section [illegible]
[illegible]



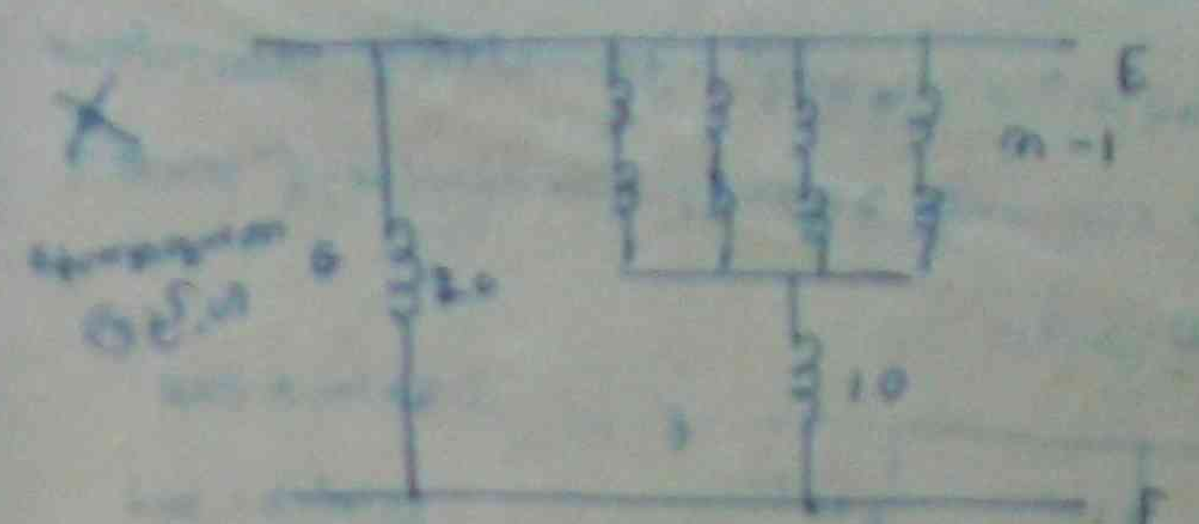
$\% X_{T_2} = 10 + 15 = 25\%$

$$\frac{1}{\% X_T} = \frac{1}{25} + \frac{1}{20} = \frac{4+5}{100}$$

$$Power_{sc} = \frac{Power_b}{\% X_{T}} \times 100$$

$$Power_{sc} = \frac{50}{\frac{100}{9}} \times 100$$

Sum of Power [illegible]



[illegible] = 50 m.v.A , section [illegible]

$$\% X_{t_1} = \frac{30}{n-1}$$

$\frac{30}{n-1}$ [illegible] 10 [illegible] series

$$\% X_{t_2} = \frac{30}{n-1} + 10$$

$$= \frac{30 + 10n - 10}{n-1} = \frac{20 + 10n}{n-1}$$

$\% X_{t}$ [illegible] 20 [illegible] parallel

$$\frac{1}{\% X_t} = \frac{n-1}{20+10n} + \frac{1}{20}$$

$$= \frac{20n - 20 + 20 + 10n}{400 + 200n}$$

Ans:

$$= \frac{20 + 10n}{400 + 200n} = \frac{10(2+n)}{200(2+n)} = \frac{1}{20}$$

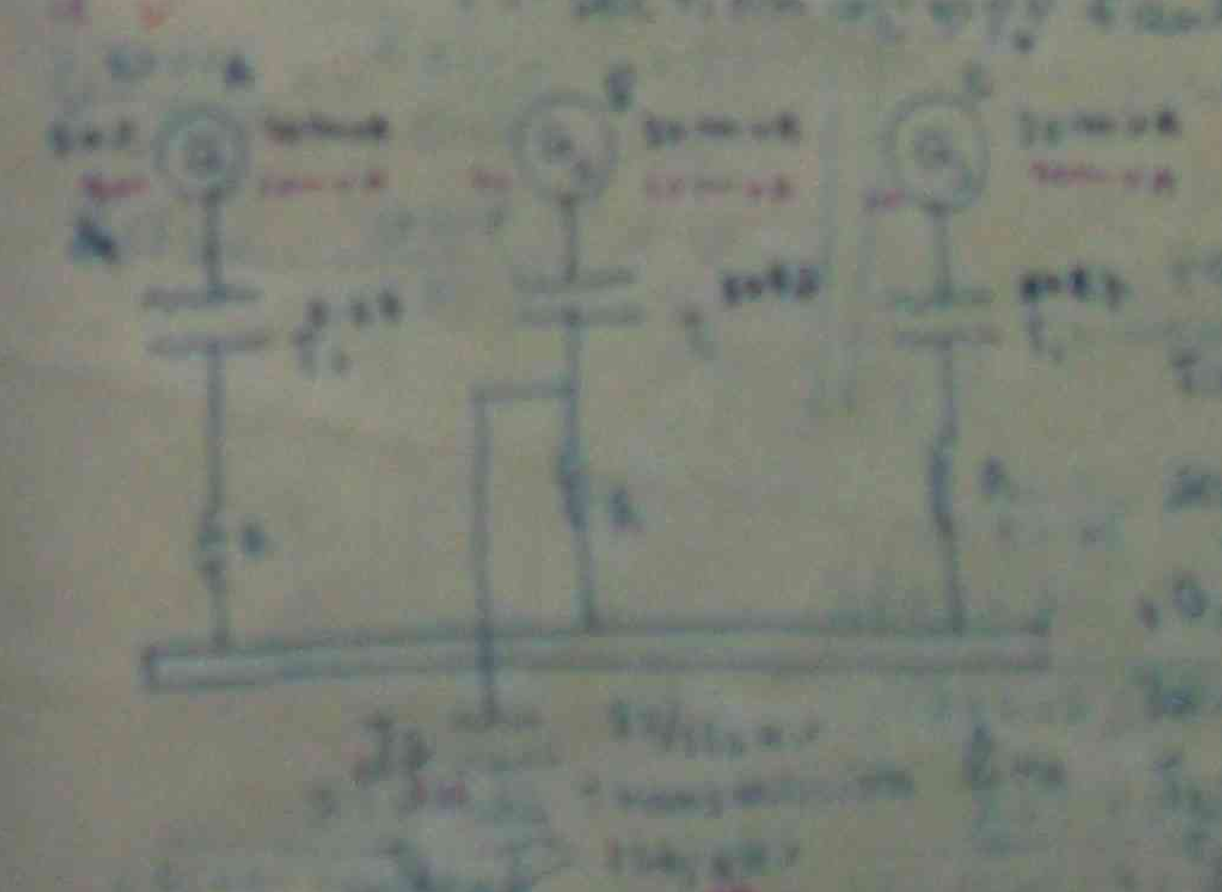
$\% X_t = 20\%$

$$Power_{sc} = \frac{Power_b}{\% X_t} \times 100$$

$$= \frac{50}{20} \times 100$$

$= 250$ m.v.A

[illegible] section [illegible] fault [illegible] m.v.A [illegible]



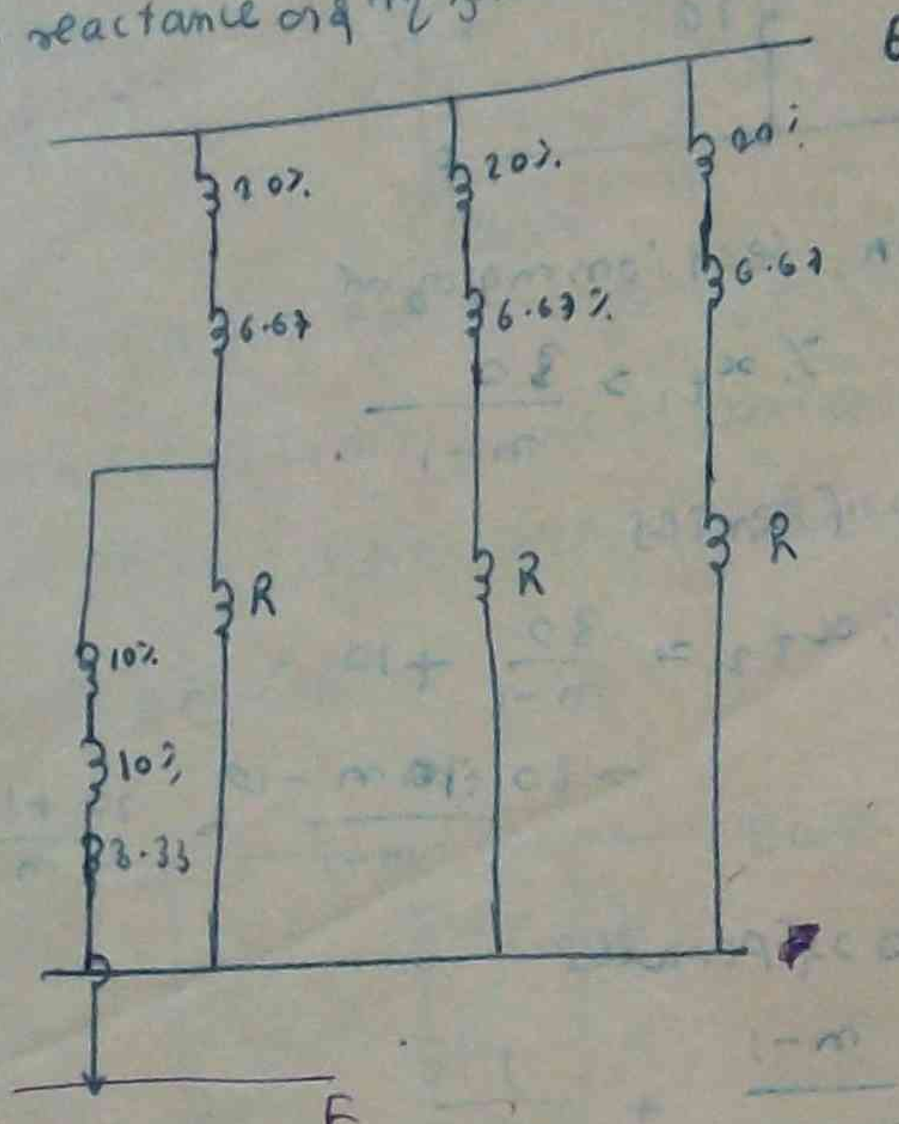
[illegible] G_1, G_2, G_3 = 50 m.v.A [illegible]
[illegible]

Transmission line = 30 mVA 5% reactance [illegible] symmetrical Short circuit

working m.V.A 30 [illegible] F [illegible] [illegible] 3000 amp [illegible] reactor

[illegible] Short circuit current 3000 amp [illegible] reactor

[illegible] % reactance [illegible]



20 mVA base

30 mVA : 30%

20 —— ?

$= 30 \times \frac{20}{30}$

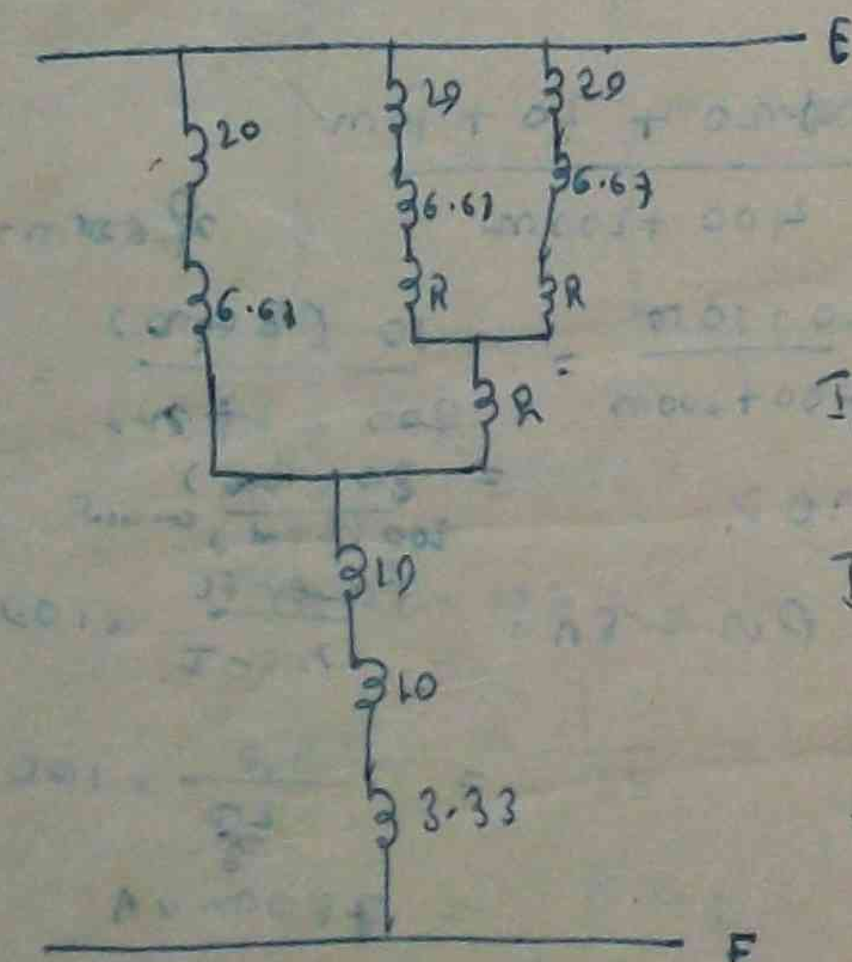
$= 20\%$

30 mVA : 5%

20 —— ?

$= 5 \times \frac{20}{30}$

$= \frac{10}{3} = 3.33\%$



E = 11 KV

= 11000 volt

$Power = 20 \times 10^6$ KVA

$I_{SN} = 3000 amp$

$I_{SN} = \frac{I_{FL}}{\% x_T} \times 100$

$I_{SN} = \frac{\frac{Power\ FL}{\sqrt{3} EL}}{\% x_T} \times 100$

$3000 = \frac{20 \times 10^6}{\sqrt{3} \times 11000 \times \% x_T} \times 100$

$\% x_T = \frac{2 \times 10^7}{33\sqrt{3} \times 10^4}$

$\% x_T = \frac{2 \times 10^3}{33\sqrt{3}} = \frac{2000}{33\sqrt{3}} \frac{\sqrt{3}}{\sqrt{3}}$

$= \frac{3464.2}{99} = 35$

26.67 + R [illegible] $\% x_t = \frac{26.67 + R}{2}$

$\frac{26.67+R}{2}$ [illegible] ~~26.67~~ R series

$\% x_{t_2} = \frac{26.67 + 3R}{2}$

$\frac{26.67+3R}{2}$ [illegible] 26.67 [illegible] parallel

$\frac{1}{\% x_T} = \frac{2}{26.67+3R} + \frac{1}{26.67}$

$\frac{1}{\% x_T} = \frac{2 \times 26.67 + 26.67 + 3R}{26.67 (26.67 + 3R)}$

$= \frac{3 \times 26.67 + 3R}{26.67 (26.67 + 3R)} = \frac{26.67 + R}{8.89 (26.67 + 3R)}$

$\% x_T = \frac{8.89 (26.67 + 3R)}{26.67 + R} + 23.33$

$35 = \frac{8.89 (26.67 + 3R)}{26.67 + R} + 23.33$

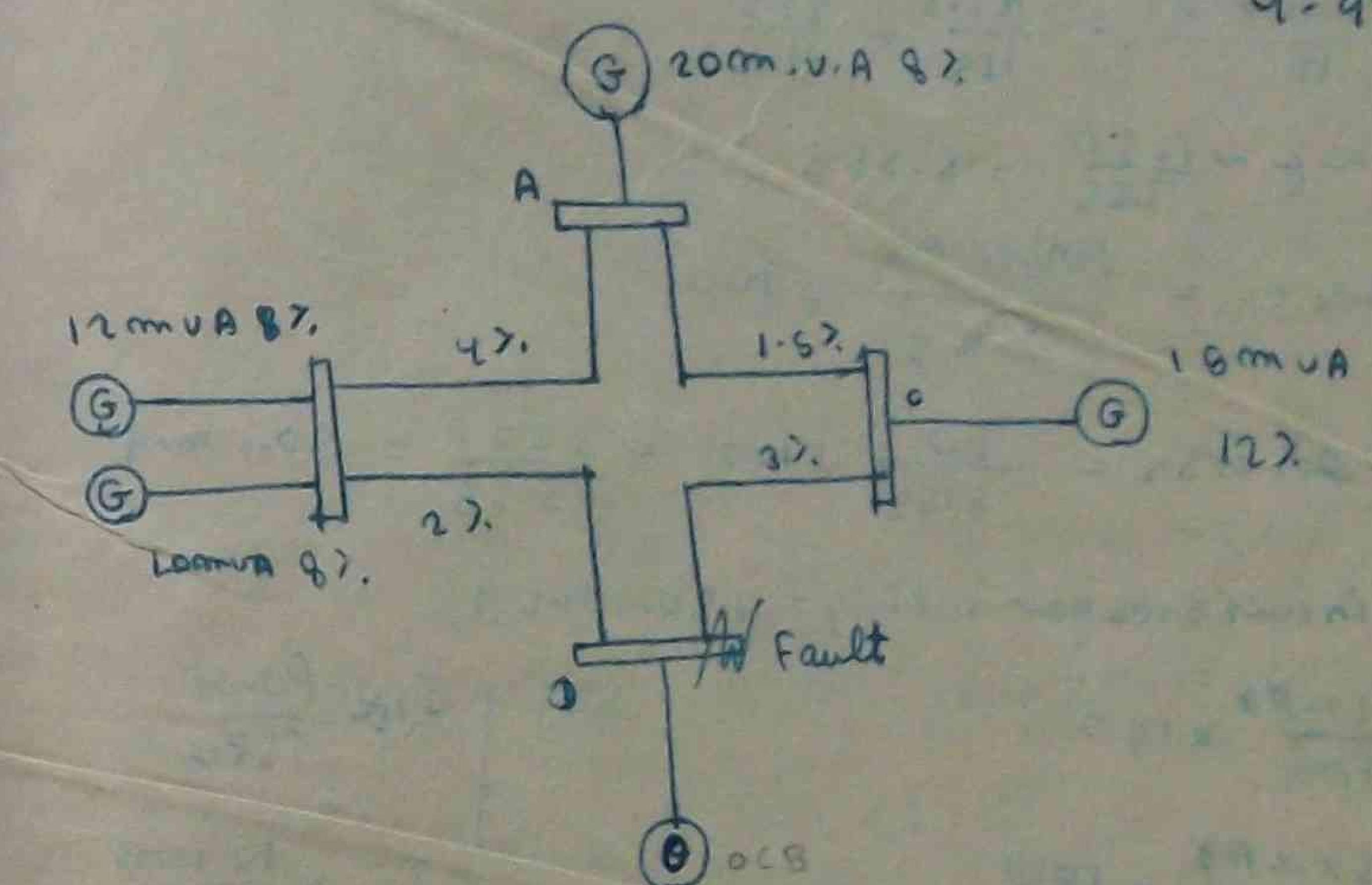
$11.67 = \frac{8.89 (26.67 + 3R)}{26.67 + R}$

$1.31 \times (26.67 + R) = 26.67 + 3R$

$1.31 \times 26.67 + 1.31R = 26.67 + 3R$

$26.67 \times .31 = (3 - 1.31) R$

$26.67 \times .31 = 1.69 R$ $R = $ ~~2.16~~ % 4.94%



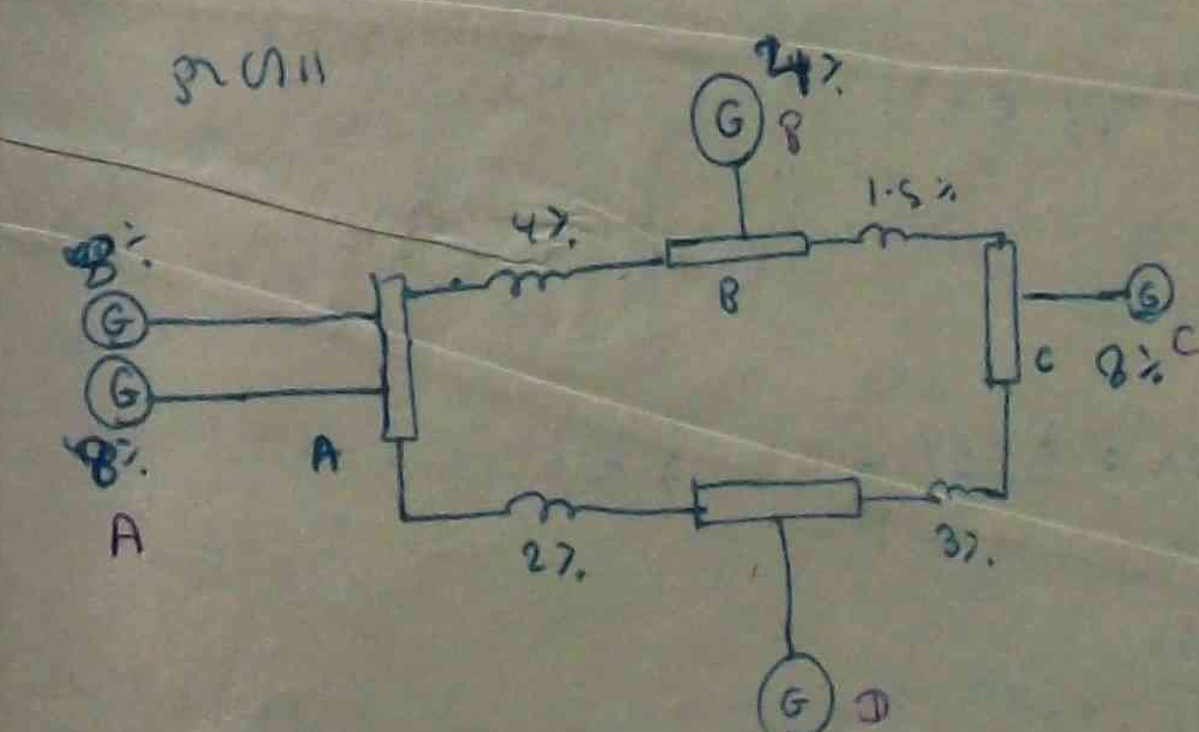
10 33 KV [illegible] 3φ dead Short circuit [illegible] station [illegible] breaker rating

[illegible] line [illegible] line [illegible] circuit [illegible] ISN

[illegible] Generator [illegible] rated out put [illegible] % Reactance

[illegible] 10 mVA [illegible] base [illegible] line [illegible] % x [illegible]

[illegible]



60 mVA : base [illegible]

20 mVA - 8%

60 ——— ? = 24% 10 mVA - 24%

12 mVA - 8%

60 ——— ? $8 \times 5 = 40\%$

10 mVA - 8%

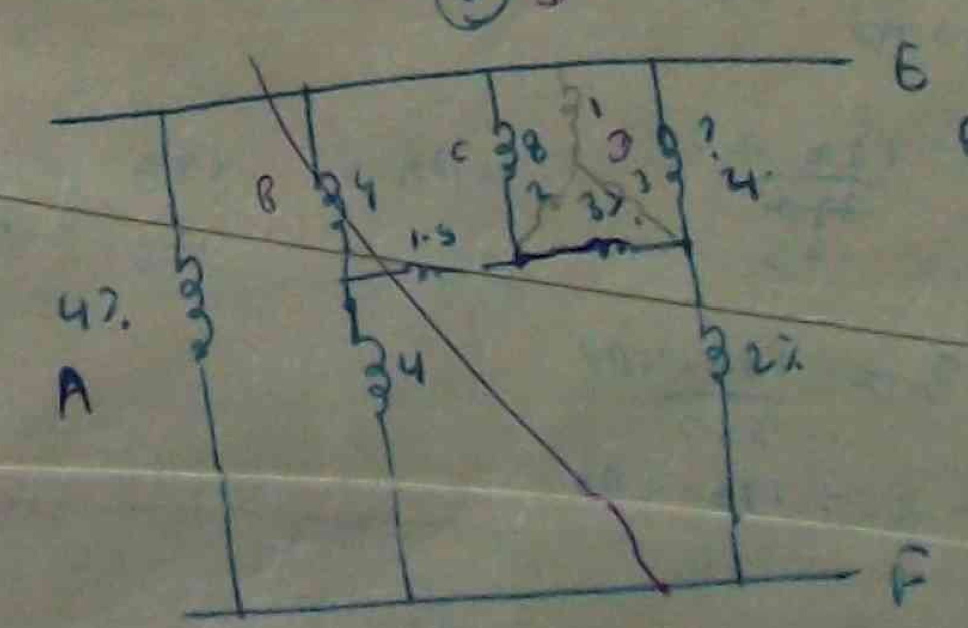
60 mVA = 48%

16 mVA = 12%

60 ——— ? = 48%

10 mVA = 8%

10 mVA = 8%



$R_1 = \frac{8 \times 4}{15} = \frac{32}{15} = 2.1$

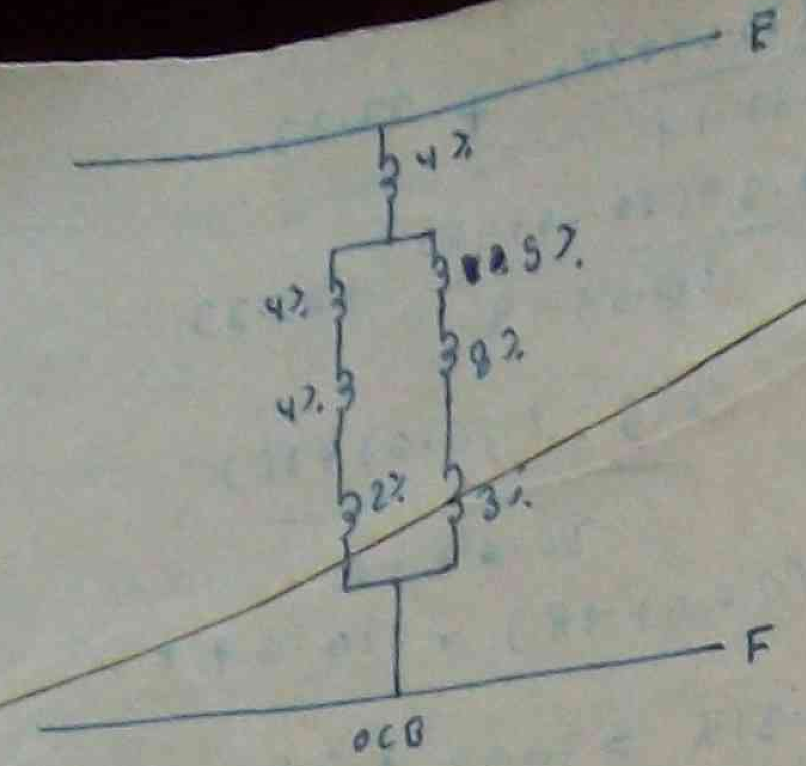
$R_2 = \frac{8 \times 3}{15} = 1.6$

$R_3 = \frac{4 \times 3}{15} = .8$

% x T 2.26%

$Power\ sn = \frac{Power\ fl}{\% x_T} \times 100$

$= \frac{10}{...} \times 100 = 4...$



$\frac{1}{\%x_t} = \frac{1}{10} + \frac{1}{12.5}$

$\frac{1}{\%x_t} = \frac{12.5+10}{125} = \frac{22.5}{125} = \frac{225}{1250}$

$\%x_t = \frac{1250}{225} = 5.55\%$

$Power_{sh} = \frac{Power_{FL}}{\%x_T} \times 100$

$Power_{sh} = \frac{10}{5.55} \times 100 = \frac{1000}{5.55} = 180.1\,mVA$

circuit breaker rating: 180.1 mVA

$\%x = \frac{I_{FL} x_{ph}}{E_{ph}} \times 100$

$I_{FL} = \frac{Power}{\sqrt{3}E_L}$

$I_{FL} = \frac{10 \times 1000}{\sqrt{3} \times 33}$

$= \frac{10000 \times \sqrt{3}}{99}$

$= \frac{17321}{99}$

$= 175\,amp$

$4 = \frac{175 \times x_{ph}}{33000} \times 100$

$\frac{1320}{175} = x_{ph}$

$x_{ph} = 7.54$

$8 = \frac{175 \times x_{ph}}{33000} \times 100$

$\frac{2 \times 1320}{175} = x_{ph} = 15.08$

$I_{sh} = \frac{17500}{5.55}$

$= 3150\,amp$

$x = \frac{175 \times x_{ph}}{33000} \times 100$

$\frac{1}{2}\left\{\frac{4 \times 330000}{100 \times 175}\right\} = x_{ph} = \frac{7.54}{2} = 3.77$

$1.5 = \frac{175 \times x_{ph}}{33000} \times 100$

$\rightarrow \frac{3}{2} = \frac{175\,x_{ph}}{330}$ 165

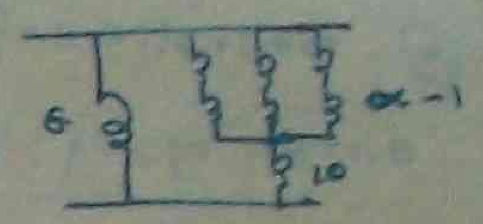
$x_{ph} = \frac{495}{175} = 2.825$

$3 = \frac{175 \times x_{ph}}{330}$

$2x\} = \frac{175\,x_{ph}}{330}$

ဥပမာ:

$kVA_{sh} = \left[\frac{a}{x} + \frac{a(m-1)}{x+bm}\right] \times 100$



$= \left[\frac{50}{20} + \frac{50(\alpha-1)}{20+10\alpha}\right] \times 100$

10 ကို ထုတ်ပါ။

$= \left[\frac{5}{2} + \frac{50}{10}\frac{(\alpha-1)}{(2+\alpha)}\right] \times 100$

$= \left[\frac{5}{2} + 5\right] 100$

$= \frac{15}{2} \times 100 = 750\,mVA$

AC motor controllers

AC mortar များကို ထိန်းချုပ်မောင်းနှင်သော ကိရိယာများ သည် အသုံးပြုမည့် mortar ၏ design ပေါ်မူတည်၍ ပုံစံအမျိုးမျိုးကို ဖော်ထုတ်ထားသော ပစ္စည်းများ ဖြစ်ကြသည်။

① motor ထိန်းချုပ်မောင်းနှင်သော ကိရိယာကို အောက်ပါ ရည်ရွယ်ချက် များအတွက် အသုံးပြုနိုင်သည်။

(က) starting (ခ) stopping (ဂ) Reversing (ဃ) Running (င) speed control (စ) Plugging (ဆ) Inching or jogging

② လက်ဖြင့်မောင်းနှင်ရသော အောက်ပါပစ္စည်းများကို အသုံးပြုနိုင်သည်။

(က) safety switch (ခ) drum controller (ဂ) Face Platetype

ဥပမာ

Motor ကို အကွာအဝေးမှ မောင်းနှင် (Remote control) ရာတွင် နှိပ်ခလုတ်များ အား အသုံးပြုနိုင်သည်။

③ Motor များကို အလိုအလျောက် (automatically) control လုပ်ရန် အောက်ပါ ကိရိယာများကို လုပ်ငန်းအလိုက် အသုံးပြုနိုင်သည်။

(က) Float switch (ခ) Pressure switch (ဂ) Time switch (ဃ) Thermostat (င) Electrical or mechanical inter lock

(၄) controller ကိုရွေးချယ်သောအခါ motor နှင့်တွဲဖက်၍ အသုံးပြုမည့် [illegible] motor [illegible]

(၅) motor ကာကွယ်နည်းများ

motor [illegible] controller ကိုရွေးချယ်ရာတွင် motor ကိုကာကွယ်ရန် [illegible] ကာကွယ်နည်းများကိုသုံးသင့်သည်။

(က) Branch circuit protection (Fuse rating [illegible])

(ခ) under voltage protection (voltage [illegible] ကာကွယ်ရန်)

(ဂ) over Load protection ([illegible] controller [illegible])

(ဃ) open field protection

(င) over travel protection

(စ) over speed protection (Integral HP [illegible])

Fractional Horse power motor များ [illegible] ကာကွယ်နည်း [illegible]

(က) branch circuit protection

(ခ) undervoltage protection

(ဂ) over load protection

* (က) branch circuit protection

motor များတွင် branch circuit protection ထား [illegible]

[illegible] — ① motor ကိုသွယ်ယူထားသော wire ကြိုး (Feder) [illegible]

② motor [illegible] short circuit ဖြစ်သော [illegible]

③ motor [illegible] grounded stator coil, short circuit

Stator coil [illegible] mechanical Load

[illegible] ထို့ကြောင့် motor [illegible] branch circuit protection [illegible] branch circuit protection [illegible] main switch [illegible] fuse [illegible]

Squirrel cage motor များ [illegible] starting current သည် motor full load current ၏ ၅၀၀ မှ ၇၀၀ [illegible] Fuse [illegible] Fuse [illegible] starting current [illegible] normal full load current [illegible] fuse [illegible]

*

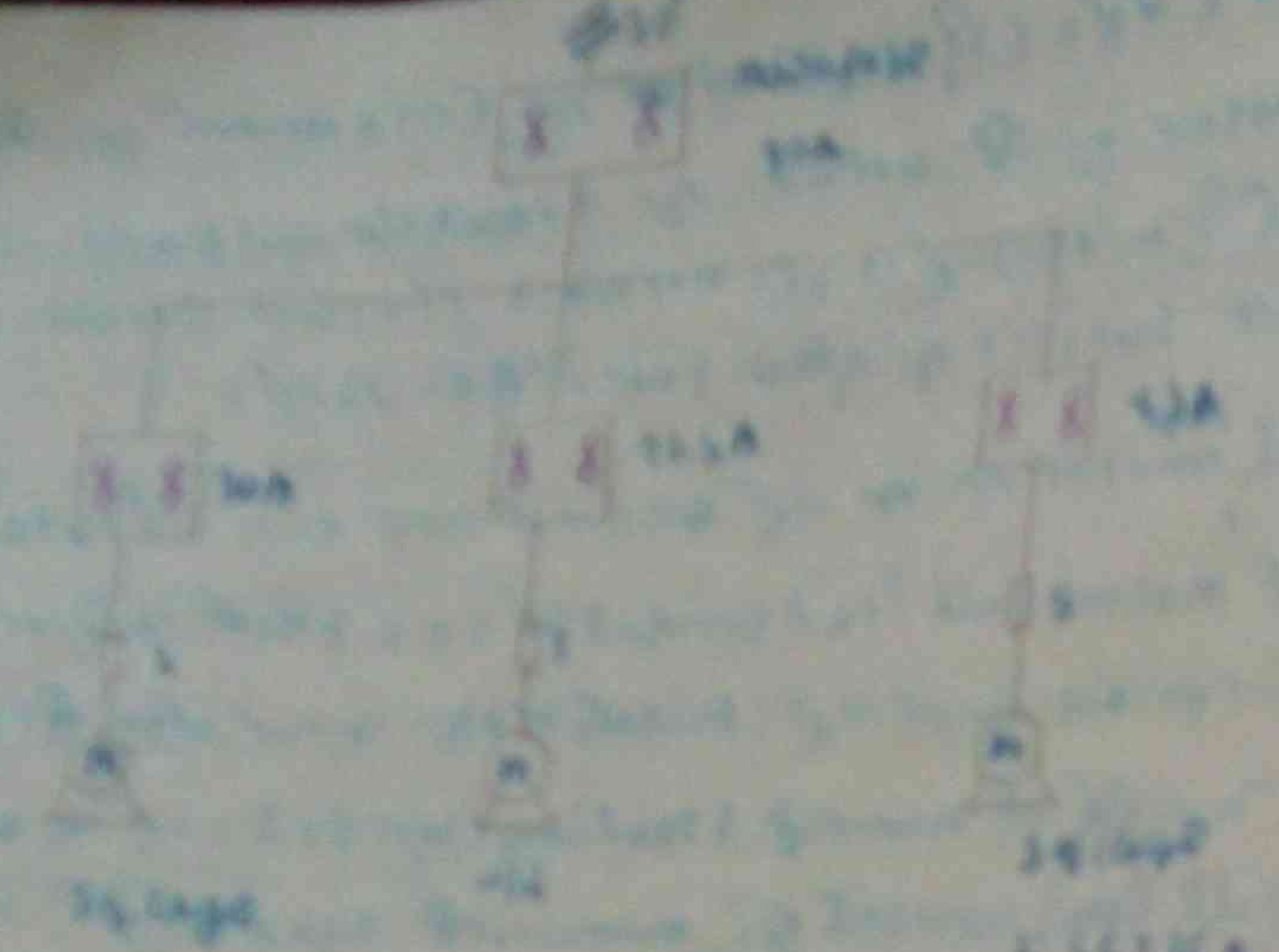
Sr No	[illegible]	[illegible] fuse
①	Squirrel cage motor	300% of full load current
②	wounded Rotor motor	150% of full load current
③	Auto transformer (OR)	250% of full load current (30A [illegible])
④	compensator	200% of full load current

Main Fuse ([illegible])

Main fuse [illegible] motor [illegible] Motor [illegible] main fuse [illegible] motor [illegible] main fuse [illegible] motor များ [illegible] current [illegible]

Single motor start

motor [illegible] full load current [illegible] motor [illegible]



$F_{LC} = 10A$ $\quad F_{LC} = 15A$

① Single motor start

main fuse = [illegible]

② Two motor start

main fuse = [illegible]

= 40 Amp

[illegible]

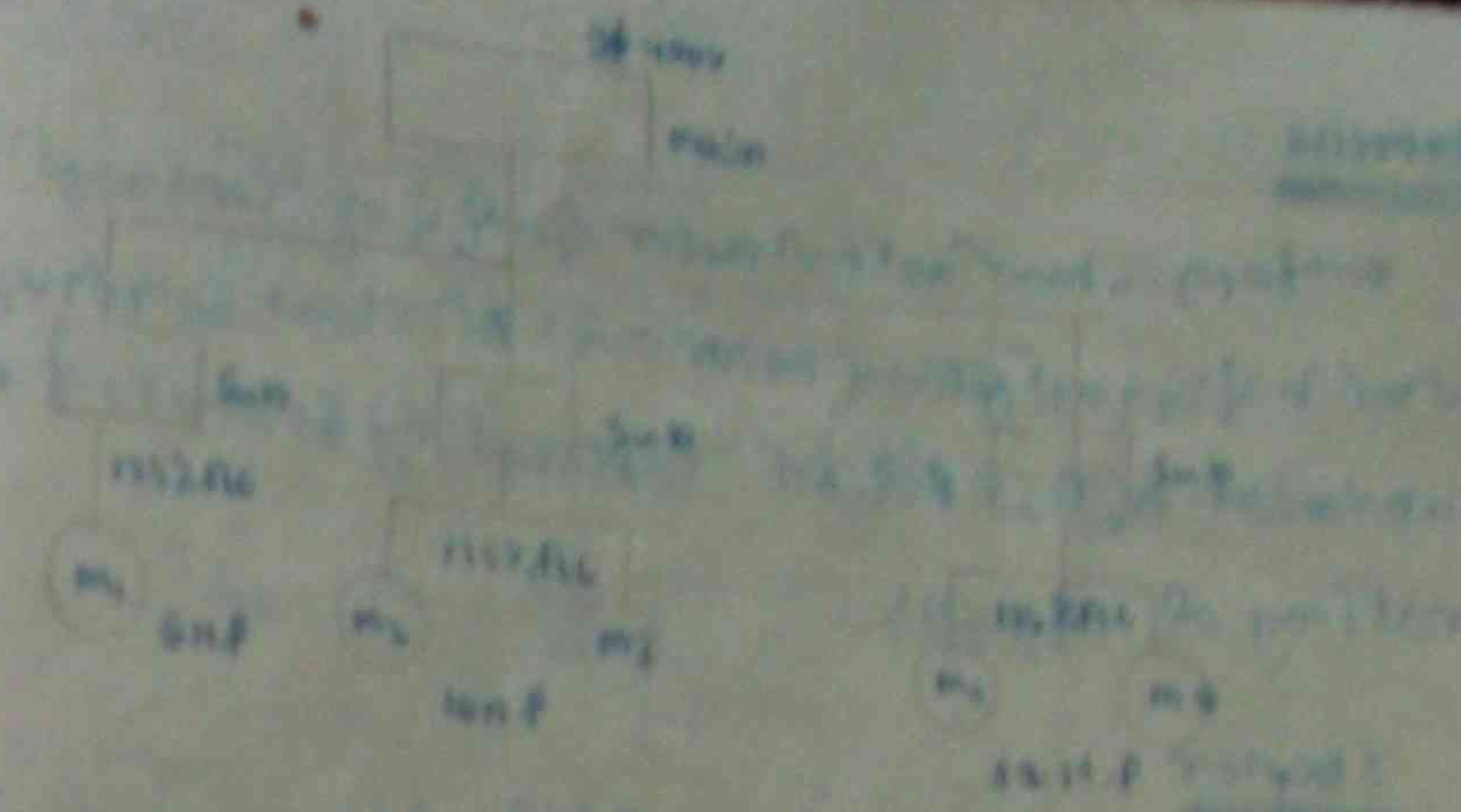
③ [illegible]

[illegible]

(a) [illegible] HP, [illegible] squirrel cage induction motor [illegible]

(b) 10 HP, [illegible] squirrel cage induction motor [illegible]

[illegible] squirrel cage induction motor [illegible]



(a) 5 HP motor [illegible]

$I_{FL} = \frac{[illegible]}{[illegible]} = 8.9A$

(b) 10 HP motor [illegible]

$I_{FL} = \frac{10 \times 746}{\sqrt{3} \times 400 \times [illegible]} = 16.36A$

Sub feeder B rating = $1.25 \times 16.36 + 16.36 = 37.9A$

(c) 11 HP motor, $I_{FL} = \frac{[illegible]}{\sqrt{3} \times 400 \times [illegible]} = 16.5A$

∴ Sub-feeder rating = $1.25 \times 16.6 + 16.5 = 37.A$

Main feeder rating [illegible]

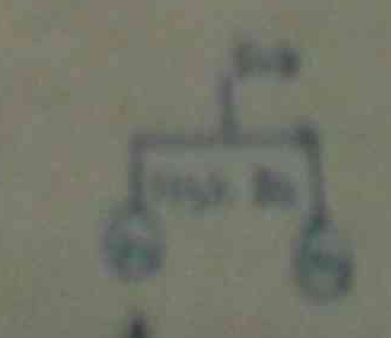
5 HP Starting = $11.2 + 16.36 + 16.36 + 16.6 + 16.5 = 77.0A$

10 HP starting = [illegible] = 79.[illegible]A

11 HP starting = [illegible] = 78.[illegible]A

∴ Main feeder B rating = 79.[illegible] A Ans

③ [illegible] Power input [illegible]



Exercise

[illegible] motor [illegible] start [illegible] motor [illegible] motor ၏ feeder fuse subfeeder A, B, C ရဲ့ fuse rating နှင့် motor ၏ feeder fuse rating ကို ရှာပါ။

Starter

$S_1 \longrightarrow$ star delta ; $I_{start} = 250\%$ FLC

S_2 & $S_3 \rightarrow$ Direct on line $I_{start} = 300\%$

$S_4 \longrightarrow$ slip rating motor starter $I_{start} = 150\%$ FLC

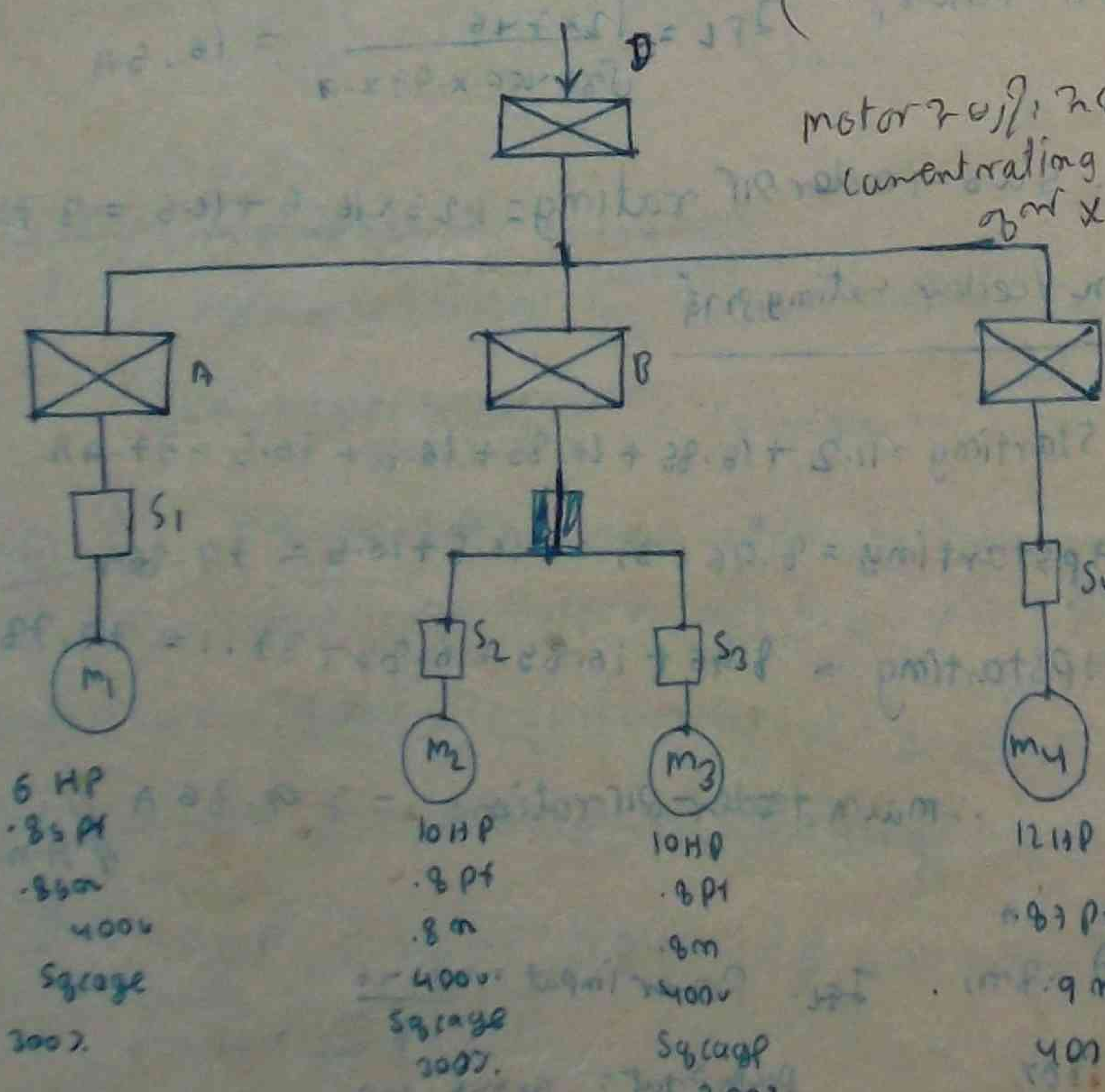
$m_1 \rightarrow$ Sq cage induction motor 6 HP, .85 pf 85% η 400 V

m_2 & m_3 = Sq cage induction motor 10 HP 0.8 pf 80% η 400 V

m_4 = slip ring motor 12 H.P, 0.87 pf 90% η, 400 V

(starter ရဲ့ current rating [illegible])

motor [illegible] current rating [illegible] feeder rating [illegible] $\times 1.25$ [illegible]]



m_1 အတွက်

Power = $\sqrt{3}\, E_L \cos\theta\, I$

$\frac{6\times 746}{.85} = \sqrt{3}\times 400\times I\times .85$

$\therefore I = \frac{6\times 746}{\sqrt{3}\times .85\times .85\times 400} = \frac{4476}{501} = 8.94$ amp

$I_{fuse} = 8.94\times \cancel{\frac{250}{100}}\ \frac{300}{100}$ ~~22.35 amp~~

$= 26.82$ amp

m_2 အတွက်

Power = $\sqrt{3}\, E_L \cos\theta\, I$

$\frac{10\times 746}{.8} = \sqrt{3}\times 400\times I\times .8$

$\frac{7460}{.64\times 400\sqrt{3}} = I$, $I = 16.8$ amp

$I_{fuse} = 16.8\times \frac{300}{100} = 50.4$ amp

m_3 အတွက် I fuse = 16.8 amp

m_4 အတွက်

Power = $\sqrt{3}\, E_L I \cos\theta$

$\frac{12\times 746}{.9} = \sqrt{3}\times 400\, I\times .87$

$I = \frac{12\times 746}{400\times .9\times\sqrt{3}\times .87} = \frac{8950}{542} = 16.5$

$I_{fuse} = 16.5\times\frac{150}{100} = 1.5\times 16.5 = 24.75$ amp

A ရဲ့ fuse rating = ~~22.35~~ 26.82 amp + 16.8 + 16.8 + 16.5 = 77.92 amp

B ရဲ့ fuse rating = 24.75 amp + 16.8 + 26.87 8.94 = 67.29 amp

B ရဲ့ fuse rating = 50.4 + 16.8 = ~~67.2 amp~~ = 92.64 amp
+ 8.94 + 16.5

D ရဲ့ motor feeder fuse rating = 67.2 + 8.94 + 16.5

= 92.64 amp

// Ans

* (၁) over load protection

motor တို့တွင်ပါရှိသော winding ကြိုးများသည် Full load current အတွင်း normal current စီးနေသောအခါ စီးနေရုံဖြင့်ပင် ၎င်း motor မှာ ပူလာစေနိုင်သည်။ winding ကြိုးများ၏ Resistance ကြောင့် I^2R loss ဖြစ်ပေါ်သည့်အတွက် winding ကြိုးများ ပူလာသည်။ ထို့အပြင် Eddy current နှင့် Hysteresis loss တို့ကြောင့်လည်း ပူလာသည်။ ထို့ကြောင့် motor တစ်လုံးကို ပြုလုပ်ရာတွင် ထိုပူလာမှုကို ခံနိုင်ရန် ဒီဇိုင်းလုပ်ထားသည်။ ထို့ကြောင့် full load current ထက် ကျော်လွန်စီးပါက motor မှာ ပူလာမည်ဖြစ်သည်။ motor ကို ပူလွန်းခြင်းမှ ကာကွယ်ရန် motor ၏ အပူချိန်ကို ထိန်းထားနိုင်သည်။ ထို့ကြောင့် over load Relay ကို အသုံးပြု၍ motor သို့ စီးသော current ကို ကာကွယ်နိုင်သည်။ အသုံးပြုသော over load Relay နှစ်မျိုးမှာ Thermal over load Relay နှင့် magnetic over load Relay တို့ ဖြစ်သည်။

over load protection မှာ motor full load current ၏ 125% ဖြစ်သည်။ IEE Regulation အရ 140% အထိ အများဆုံး သုံးနိုင်သည်။

* (၂) under voltage Protection

under voltage protection (သို့မဟုတ်) no volts Release ဟုလည်းခေါ်သည်။ volt အား 10% ထက်ပို၍ ကျသွားပါက starter အလိုအလျောက် ဖြုတ်ပေးသောကိရိယာ ဖြစ်သည်။ ဗို့အား ကျသွားသောအခါ motor ၏ လည်ပတ်အား ကျသွားသည်။ motor သည် line current ပိုစီးယူသည်။ current များလာ၍ motor winding ကြိုးများ လောင်ကျွမ်းသွားနိုင်သည်။

Feeder နှင့် sub feeder တွက်ချက်ခြင်း

Sub feeder

main switch မှ motor တစ်လုံးစီသို့ သွားသော sub feeder (သို့မဟုတ်) branch circuit feeder ၏ wire ကြိုး အရွယ်အစားမှာ ၎င်း motor တွင် အများဆုံးစီးသည့် current ကို သယ်ဆောင်နိုင်ရမည်။ wire ကြိုးတွင် current အများဆုံးစီးသည့်အချိန်မှာ motor စတင်လည်ပတ်ချိန် (Starting period) နှင့် over load ဖြစ်သောအချိန် ဖြစ်သည်။ motor စတင်လည်ချိန်၌ စီးသော current မှာ full load current ၏ 6 ဆ မှ 7 ဆ အထိ ရှိသော်လည်း ခဏသာ ကြာမြင့်သောအချိန် စီးသောကြောင့် effective value မှာ full load current ၏ 125% သာ ဖြစ်သည်။ ထို့ကြောင့် Sub feeder ၏ motor သို့ သွယ်တန်းသည့် wire ကြိုး၏ အရွယ်အစားမှာ ~~full~~ motor full load current ၏ 125% သာ ဖြစ်ရမည်။

* Direct On Line Starter *

(သို့မဟုတ်)

Across The Line Starter

၎င်း Direct on line Starter များမှာ Squirrel Cage motor အရွယ်အစား အသေးများ အတွက် အသုံးပြုနိုင်သော လည်ပတ်ပေးသည့် starter များကို အကြမ်းအားဖြင့် သုံးသပ်ပါမည်။ ၎င်း Starter အား သုံး၍ သတ်မှတ်ချက်ကို ဖော်ပြပါမည်။

(1) ကွန်ထရက်သုံးပြီး motor ၏ အရွယ်အစားနှင့် motor ကို ဖြတ်ပေးသော Design ။

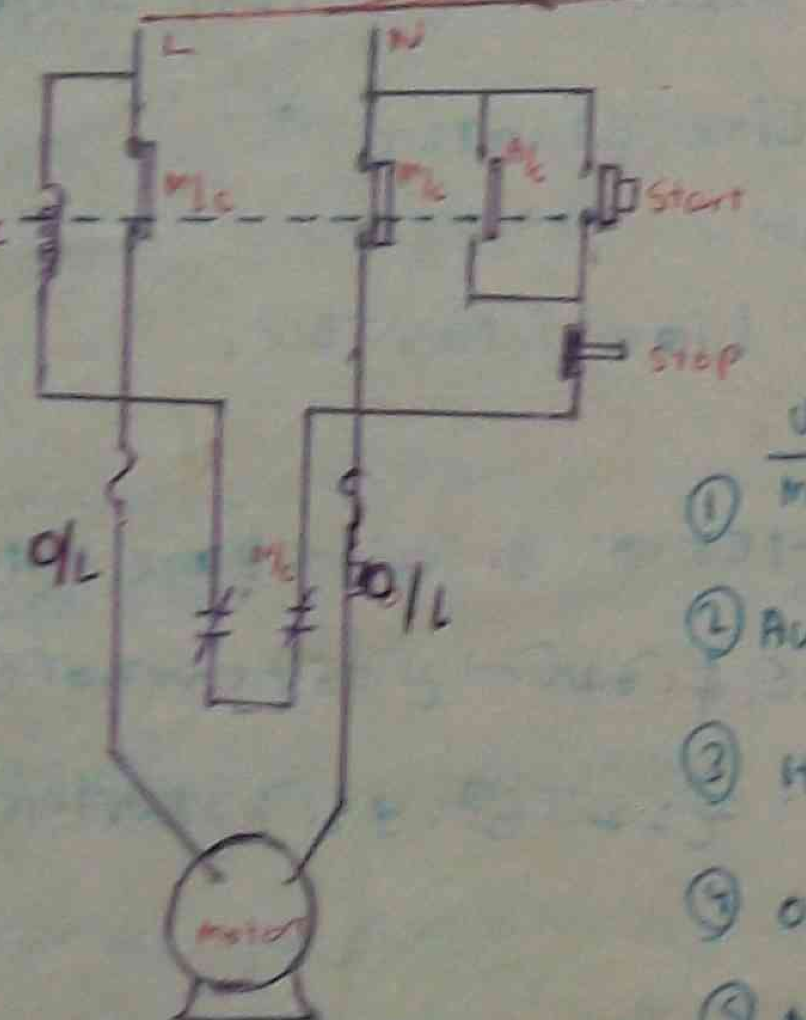
(2) အသုံးပြုမည့် motor ၏ အရွယ်အစားမှာ သေးငယ်ရမည် Supply မှ motor starting အချိန်တွင် ကြီးမားသော current ကို ခံနိုင်ရမည်။ ဤနှစ်ချက်ကြောင့် Direct on line starter များကို အသုံးပြုသင့်ပေ။ Squirrel Cage motor များသည် High starting current ဖြစ်သော ကြောင့် အရွယ်အစားသေးသည်။ အရွယ်ကြီးသော Direct on line starter ကြောင့် supply line ကို ပြင်းထန်စွာ ထိခိုက်စေသည်။

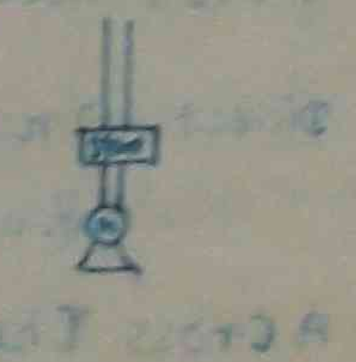
② တိုက်ရိုက်ပေးစက်နှိုးကိရိယာ

Motor ကို အသုံးပြုမည့်နေရာနှင့် တိုက်ရိုက်ပေးစက်နှိုးကိရိယာ၏ ... motor starting အချိန်တွင် voltage drop အား ... full load speed သို့ရောက်ပြီး ... motor သည် ... ။

DOL starter များတွင် manually operate နှင့် magnetically operate ... manually ... magnetically operate ... starter ... ဖြစ်သည်။

Magnetically operated D.O.L starter





ပါဝင်သောအစိတ်အပိုင်းများ

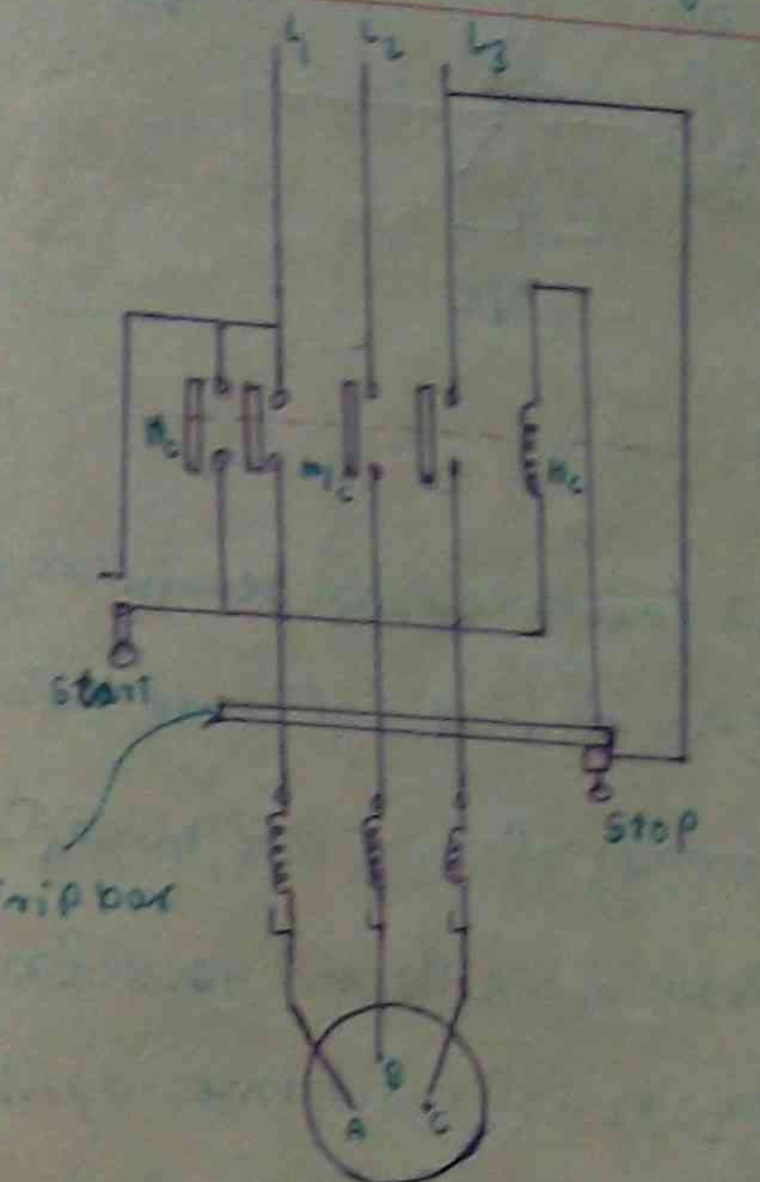
① Main contact M/C
② Auxiliary contact M/C
③ Holding coil HC
④ Over load Relay O/L
⑤ Normally closed contact M/C
⑥ Spring load start stop switch

တို့ဖြစ်ပါ

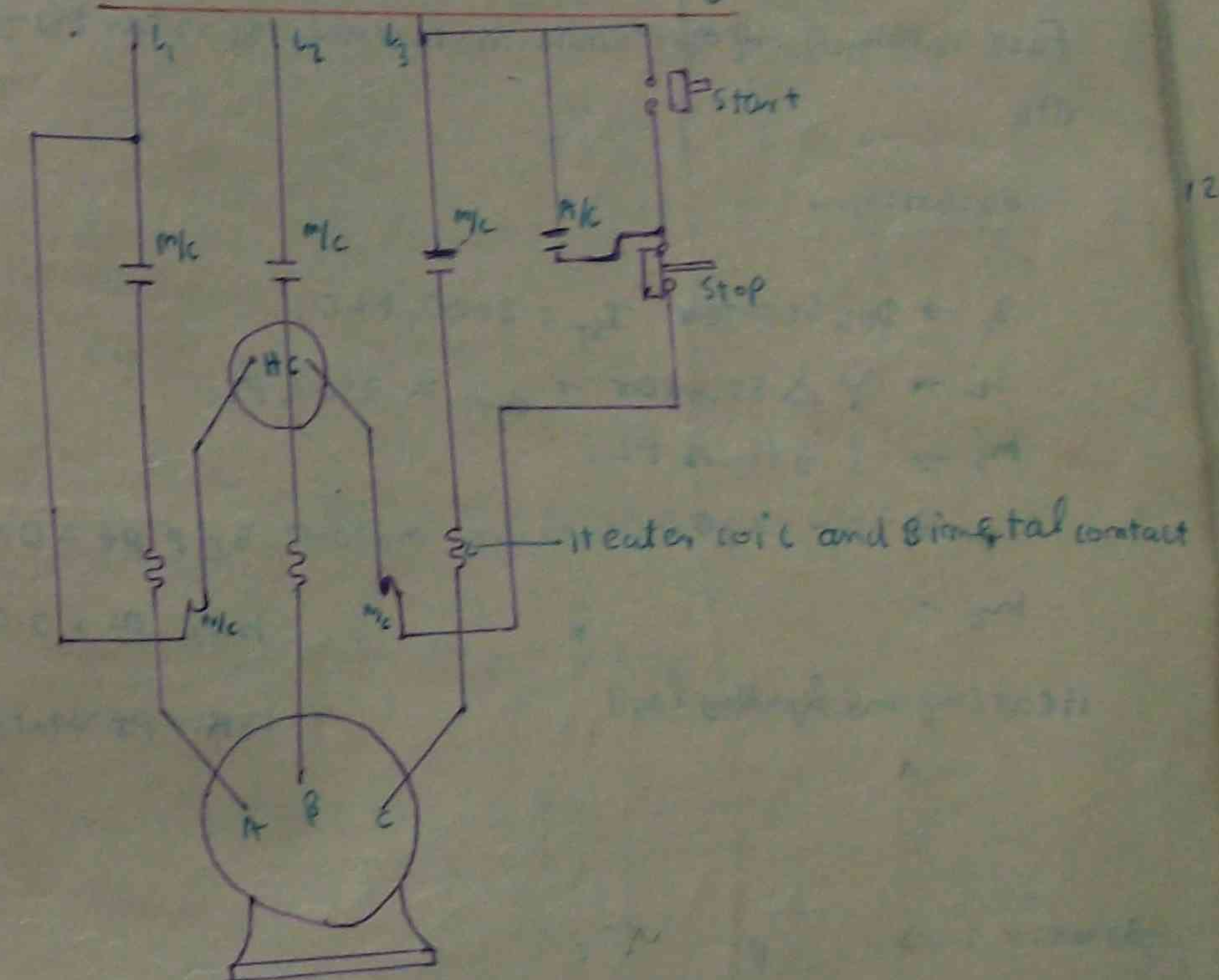
ဤ DOL starter များတွင် - ① Energising circuit
② Holding coil circuit
③ Power circuit ဟူ၍ရှိသည်။

DOL starter with magnetic O/L Relay

DOL starter with magnetic O/L Relay.

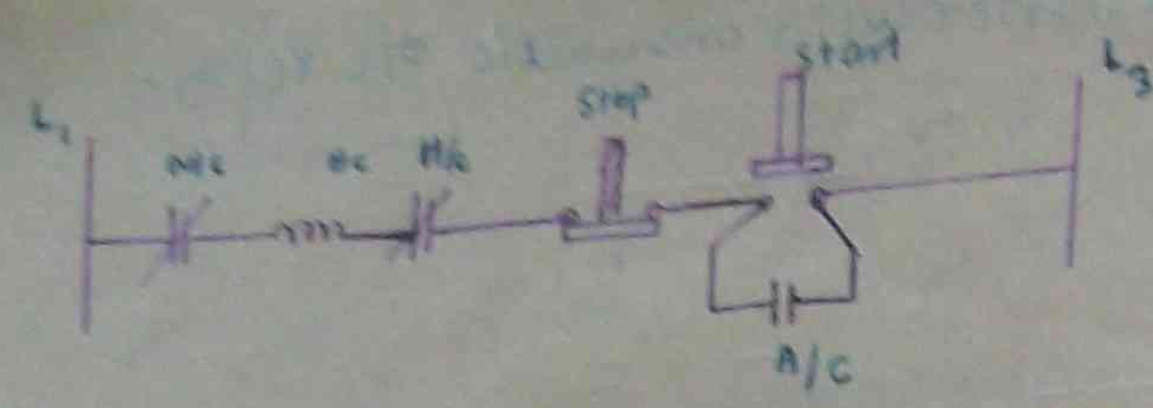


DOL starter with Thermal O/L Relay



Line diagram

Line diagram ဆိုသည်မှာ starter ... holding coil circuit ... ဖြစ်သည်။



Line diagram

① 3φ station [illegible] 30 mVA [illegible] 15% Reactance [illegible] generator [illegible] 10 mVA 12.5% Reactance [illegible] generator [illegible] 3300 V switch Board [illegible] 5 m.V.A Transformer [illegible] 100 mVA Rupturing capacity [illegible] switch Board [illegible] CB [illegible] Transformer [illegible] Reactance [illegible]

② [illegible] System [illegible] main feeder [illegible] branch circuit [illegible] Fuse rating [illegible] motor [illegible] start [illegible]

[illegible]

$S_1 \rightarrow$ DOL Starter $I_{ST} = 300\%$ FLC

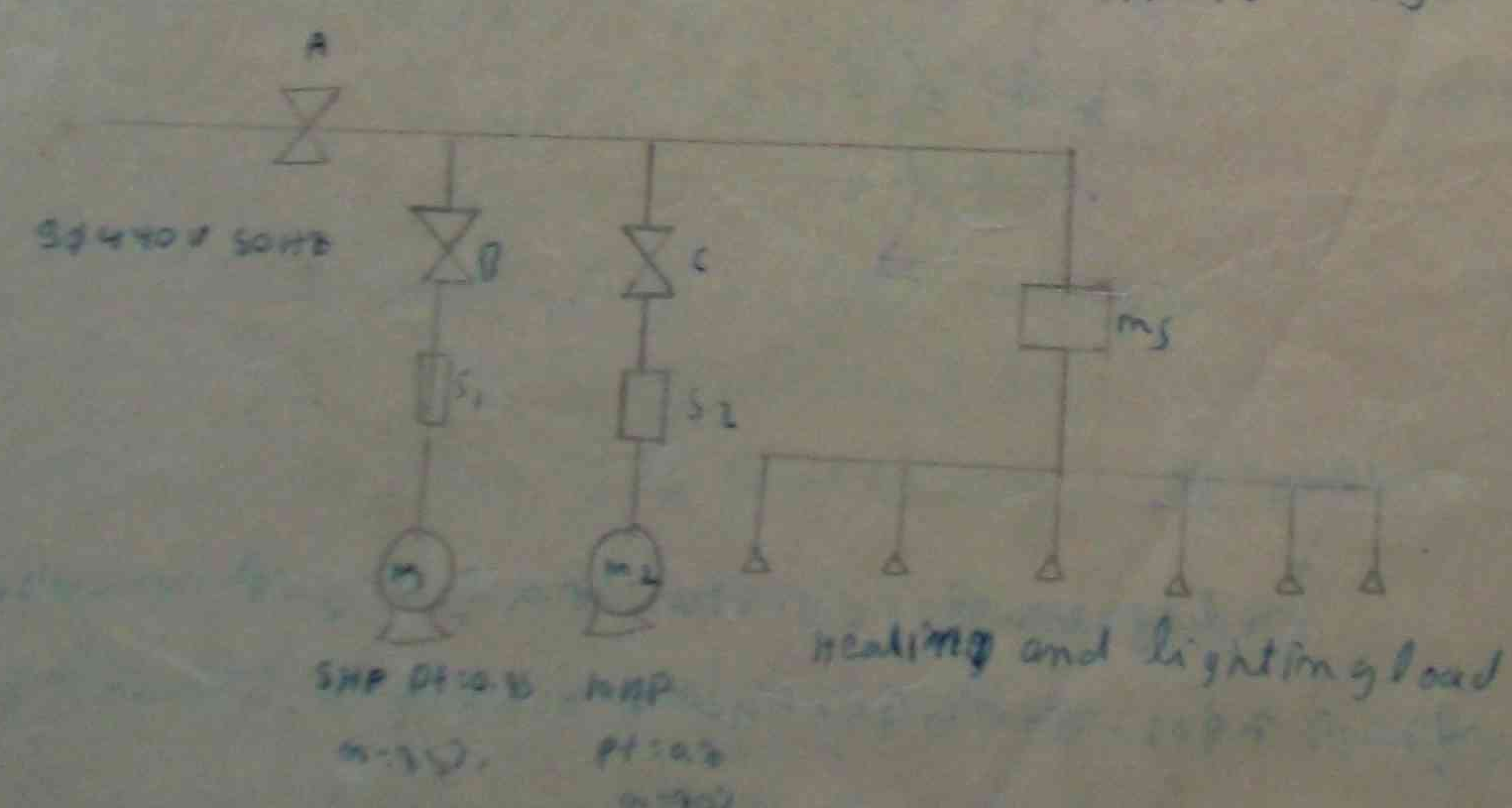
$S_2 \rightarrow Y\Delta$ Starter $I_{Start} = 250\%$ FLC

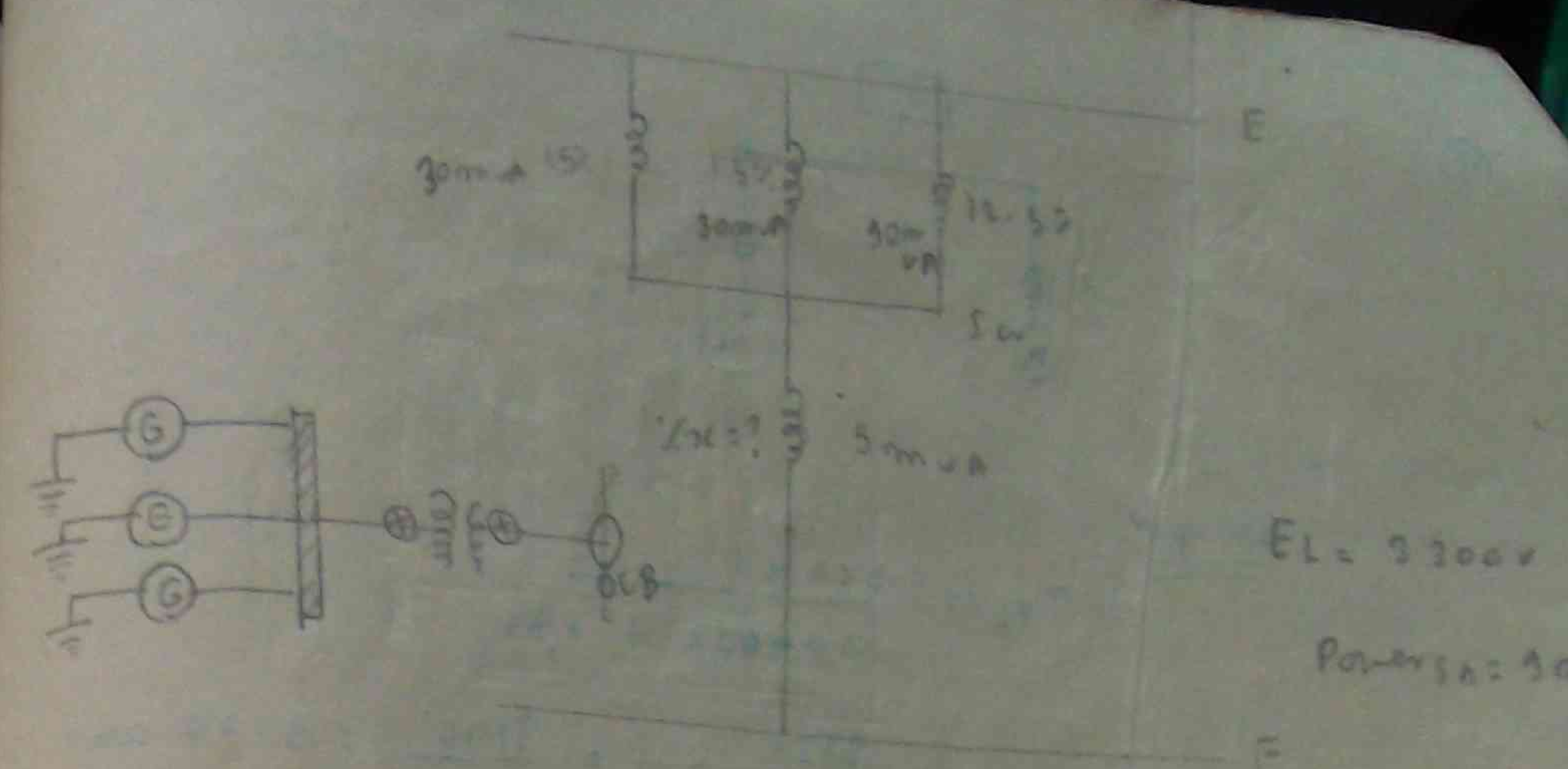
$m_s \rightarrow$ 1.5 times FLC

$m_1 \rightarrow$ Sq-cage induction motor, 5 HP pf = 0.95 η = 8?%

m_2 " " " 10 HP pf = 0.9 η = 80%

Heating and lighting load " " 15 kW pf unity





$E_L = 3300\,V$

$Power_{sh} = 100$

5 mVA = base [illegible]

30 mVA = 15%

$5 \text{ ———— } ? = \frac{15 \times 5}{30} = \frac{5}{2}\% = 2.5\%$

10 mVA = 12.5%

$5 \text{ ———— } ? = \frac{12.5}{2} = 6.25\%$

$$\frac{1}{\%x_{t1}} = \frac{1}{2.5} + \frac{1}{6.25} + \frac{1}{2.5}$$

$$= \frac{2.5 + 2.5 + 1}{6.25} = \frac{6}{6.25}$$

$$\%X_T = \frac{6.25}{6} + x\ \%$$

$$Power_{sh} = \frac{Power_{FL}}{\%X_T} \times 100$$

$$100 = \frac{5}{\%x_T} \times 100$$

$\%x_T = 5\%$

$$\frac{6.25}{6} + x = 5$$

$\%x = 5 - 1.04$

$= 3.96\%$

$$\%x = \frac{I_{FL}\, x_{ph}}{E_{ph}} \times 100$$

$$3.96 = \frac{\frac{5 \times 1000 \times 1000}{\sqrt{3} \times 3300} \times x_{ph}}{3300} \times 100$$

$$3.96 = \frac{50}{[illegible]\sqrt{3} \times 1000}\, x_{ph}$$

$x_{ph} = \frac{3.9 \times [illegible]}{50 \times 1000}$

$= .149$

[illegible]

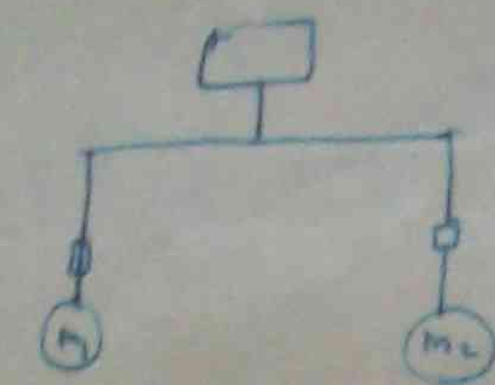
$$\%x = \frac{x \times Power \times 100}{E_L^2}$$

$$3.96 = \frac{x \times 5 \times 10^6 \times 100}{(3300)^2}$$

$$\therefore x = \frac{4320}{5 \times 10^4}$$

$= .0864$

(2)



5HP အတွက်

$$I_{FL} = \frac{5\times 746}{\sqrt{3}\times 440\times .85\times .85}$$

$$= \frac{3730}{762\times .7230} = \frac{3730}{550} = 6.78 \text{ amp}$$

$$\therefore I_{Fuse} = 6.78\times\frac{300}{100} = 20.34 \text{ amps subfeeder}$$

10HP အတွက်

$$I_{FL} = \frac{10\times 74.6}{\sqrt{3}\times 440\times .8\times .8}$$

$$= \frac{7460}{762\times .64} = \frac{7460}{477} = 15.6 \text{ amp}$$

Ifuse =

$$I_{Fuse} = 15.6\times \cancel{3}\,2.5 = \cancel{39.9} \text{ amps subfeeder}$$

$$= \cancel{46.8}$$

$$39.85$$

Heating and lighting

$$I = \frac{Power}{\sqrt{3}E_L} = \frac{15\times 1000}{\sqrt{3}\times 440}$$

$$= \frac{15\times 1732.1}{1320} = \frac{26600}{1320} = 19.7$$

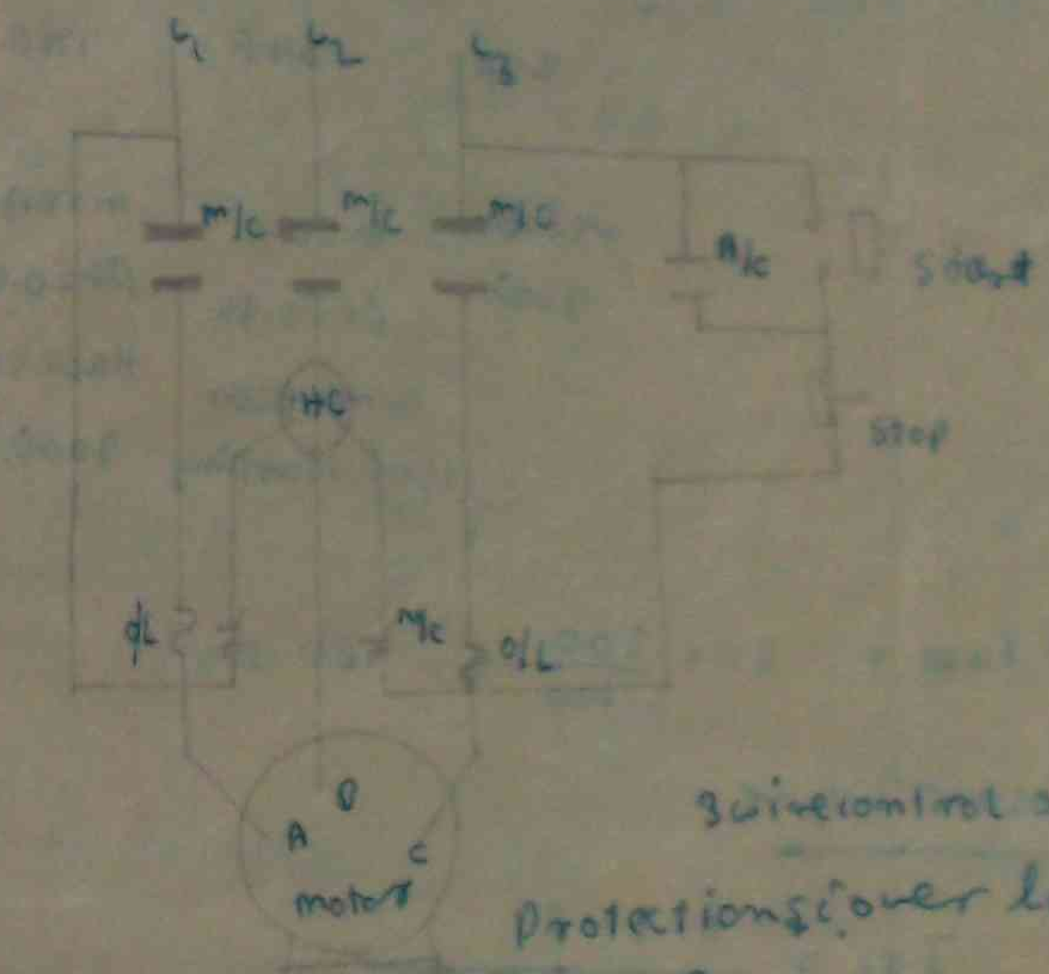
$$\therefore \text{Fuse rating} = 19.7 + 6.78 + \cancel{39.9}\ 38.25$$

$$= \cancel{\text{amps}}\ 64.1 \text{ amp}$$

2 wire control

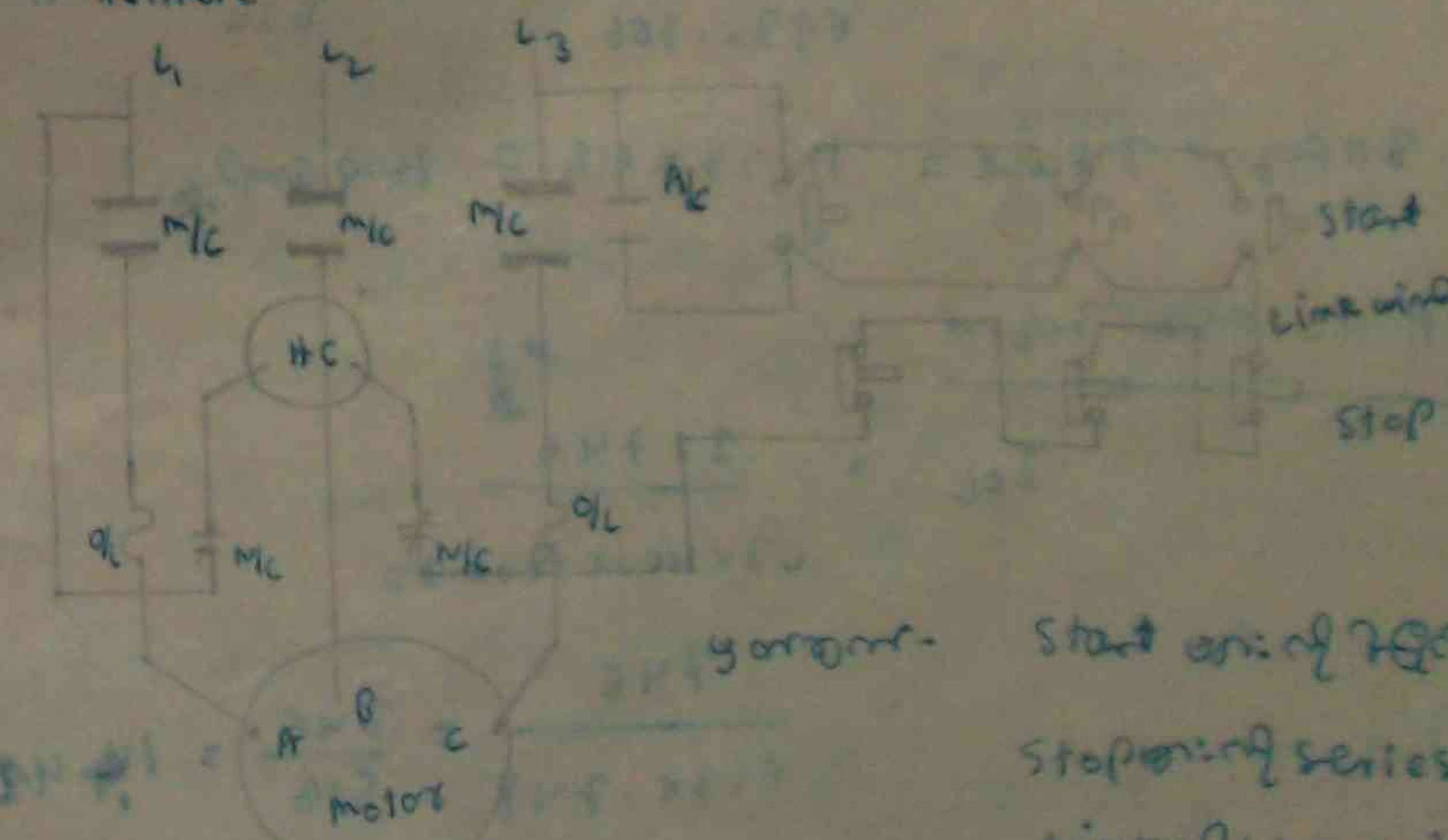
2 wire control သည် under voltage protection မပေးနိုင်ပေ။ over load protection ကိုသာ ပေးနိုင်သည်။

3 wire control



3 wire control သည် under voltage protection နှင့် over load protection တို့ကို ပေးနိုင်သည်။

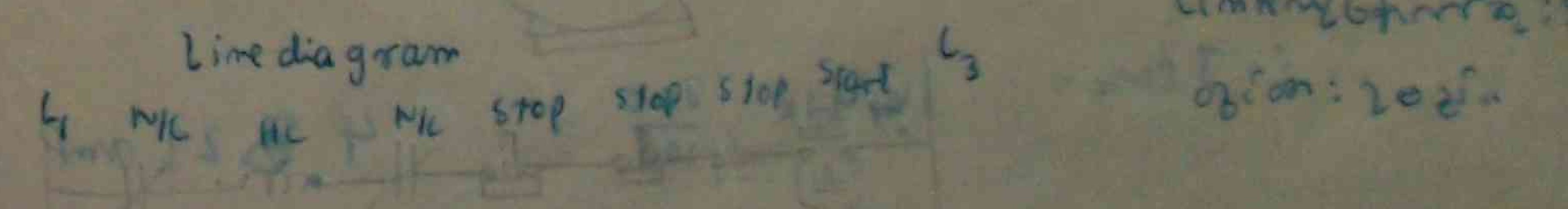
Remote control ပြုလုပ်ပုံ



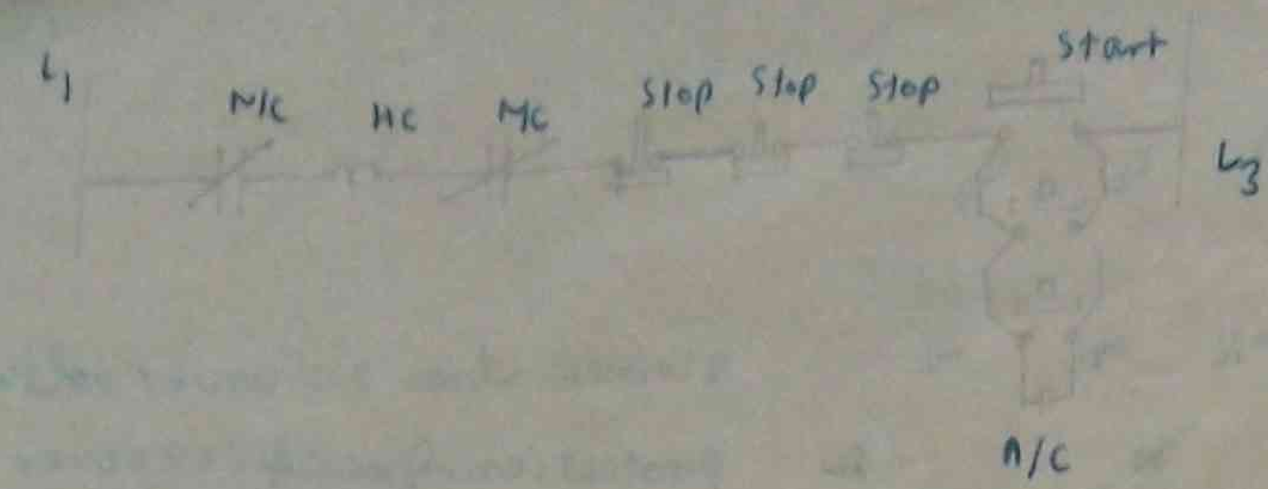
10 mark

မှတ်ချက်- Start ခလုတ်များကို parallel ဆက်ရမည်။
Stop ခလုတ်များကို series ဆက်ရမည်။
Line wire ကို ... station
ဖြင့် ... ။

Line diagram

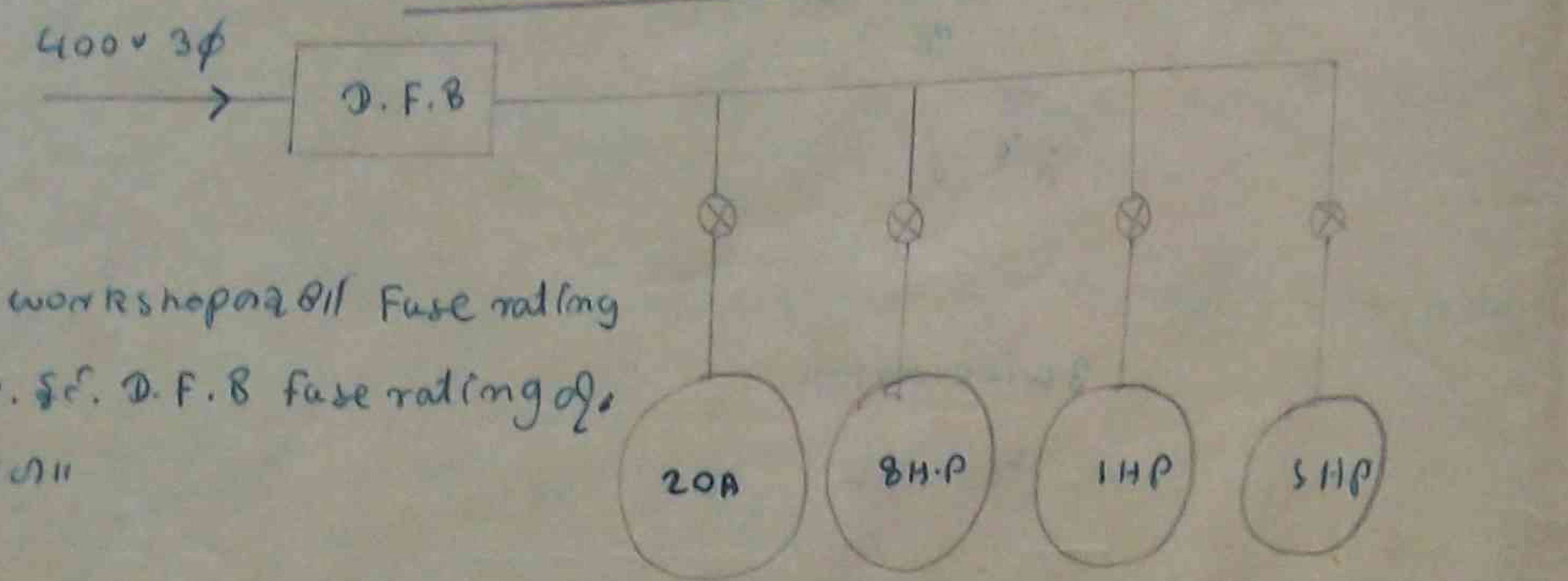


Line diagram



ဒီဇိုင်းပုစ္ဆာများ

① အောက်ပါ workshop အတွက် Fuse rating အသီးသီးနှင့် D.F.B fuse rating ကို ရှာပါ။



welder 300%

m = 0.9, pf = 0.85, compressor 150% starting

m = 0.86, pf = 0.88, Hacksaw 300% starting

m = 0.89, pf = 0.86, lathe 250% starting

welder အတွက် $I_{fuse} = 20 \times \frac{300}{100} = 60$ amp

8HP compressor အတွက်

$$I_{FL} = \frac{8 \times 746}{\sqrt{3} \times 400 \times .9 \times .85}$$

$$= \frac{5968}{693 \times .765} = \frac{5968}{530} = 11.27 \text{ amp}$$

∴ 8HP အတွက် $I_{fuse} = 11.27 \times 1.5 = 16.9$ amp

1HP Hacksaw အတွက်

$$I_{FL} = \frac{1 \times 746}{\sqrt{3} \times 400 \times .86 \times .88}$$

$$= \frac{746}{693 \times .748} = \frac{746}{518} = 1.441 \text{ amp}$$

$$\therefore I_{fuse} = 1.441 \times \frac{300}{100} = 4.323 \text{ amp}$$

(4.323)

5HP lathe အတွက်

$$I_{FL} = \frac{5 \times 746}{\sqrt{3} \times 400 \times .89 \times .86} = \frac{3730}{693 \times .765} = \frac{3730}{530}$$

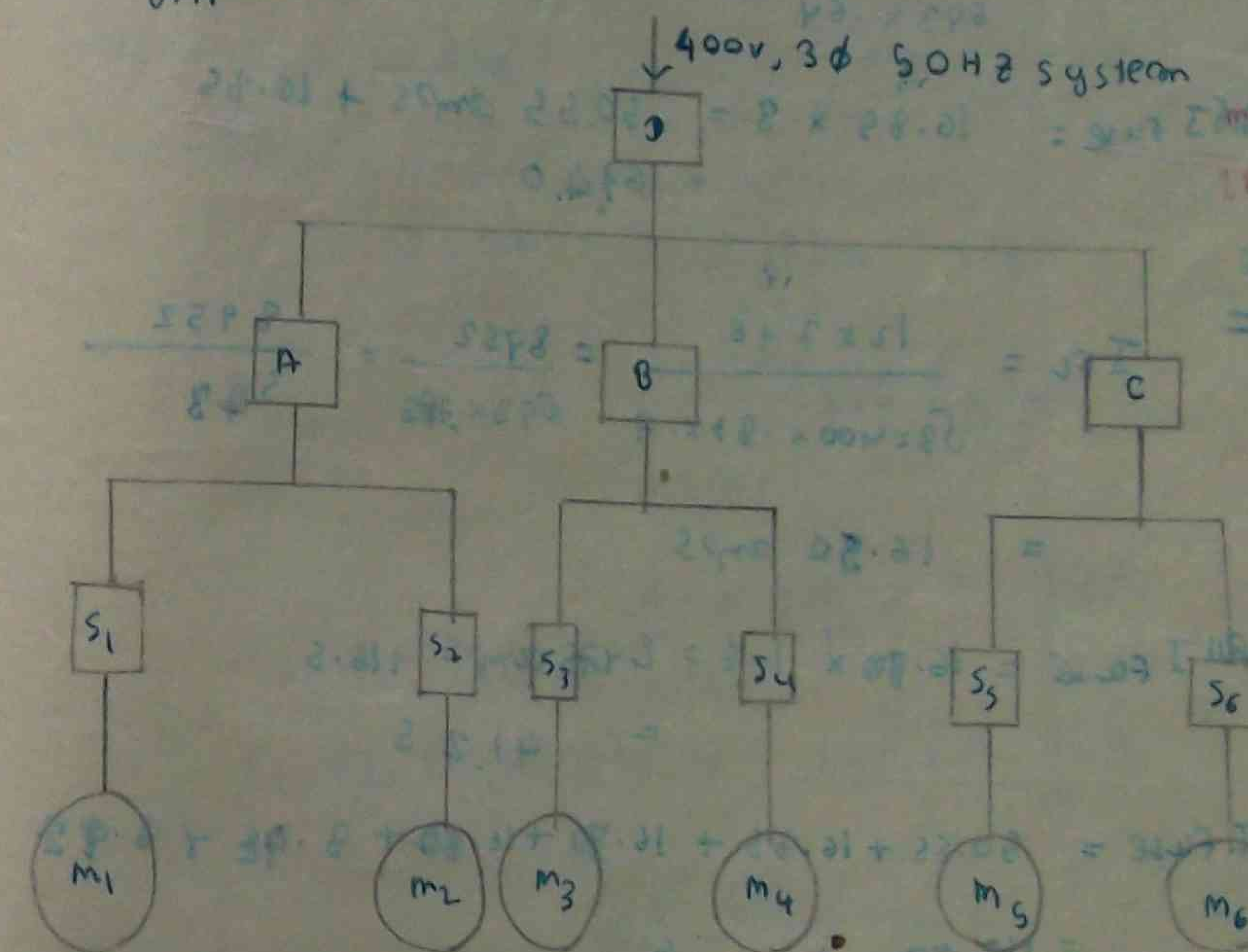
$$= 7.04 \text{ amp}$$

$$\therefore I_{fuse} = 7.04 \times 2.5 = 17.6 \text{ amp}$$

D.F.B fuse rating = 60 + 11.27 + 1.441 + 7.04

= 79.751 amp

② အောက်ပါ diagram တွင် motor များ၏ အမည်ပြ start ... sub feeder A, B, C နှင့် main feeder D တို့အတွက် fuse rating ကို ရှာပါ။



$S_1 = S_2 = 250\%$ FLC

$S_3 = S_4 = 300\%$ FLC

$S_5 = S_6 = 150\%$ FLC

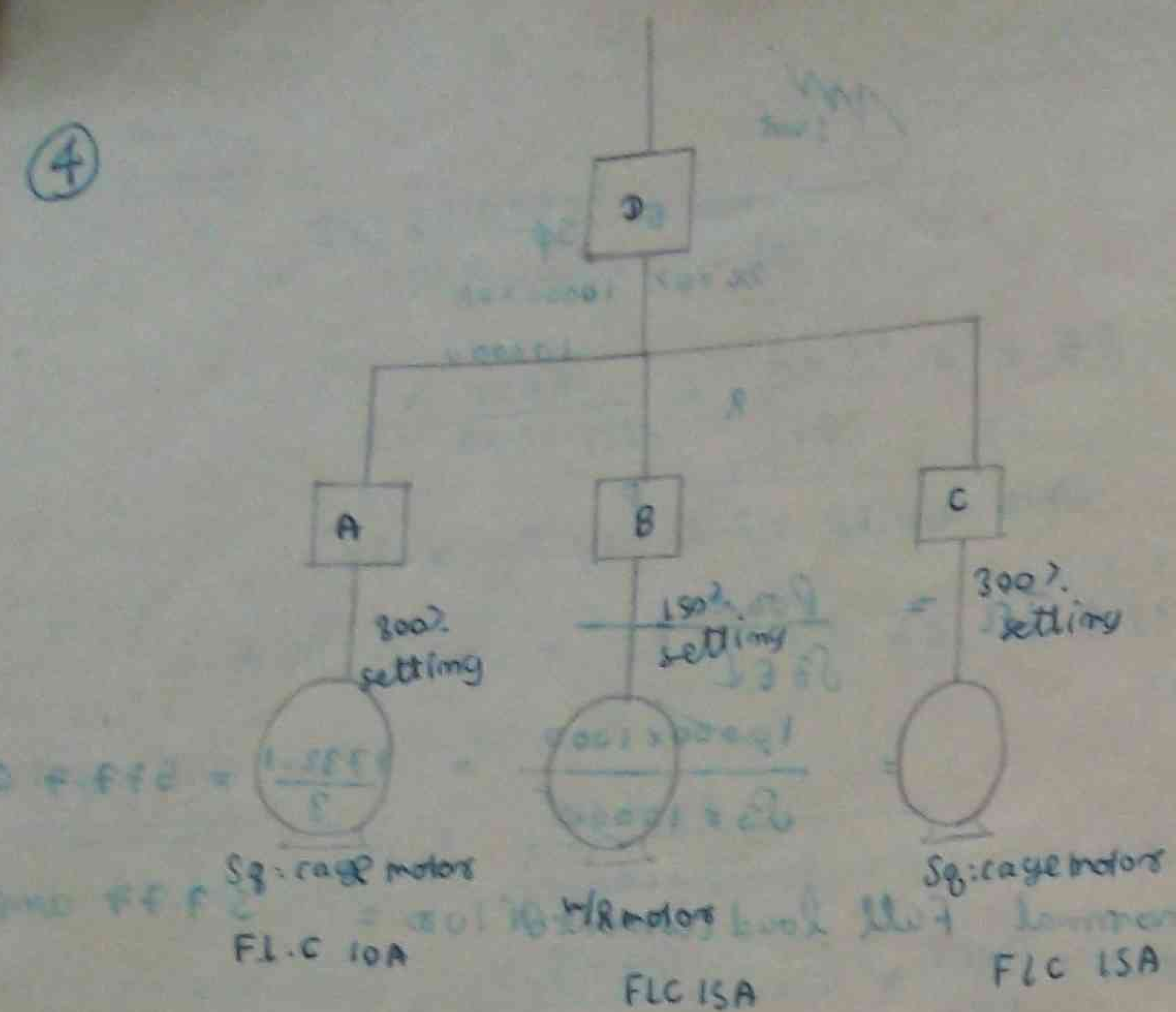
3φ motors

$m_1 = m_2 =$ 6 H.P .85 pf, lagging eff 86%

$m_3 = m_4 =$ 10 HP .84 " 80%

$m_5 = m_6 =$ 12 HP .87 pf " 90%

4



[illegible] motor [illegible] Start [illegible] motor [illegible] Start [illegible] main disconnecting switch [illegible] fuse Rating [illegible]

A [illegible] $I_{fuse} = 3 \times 10 = 30A$

B [illegible] $I_{fuse} = 15 \times 1.5 = 22.5A$

C [illegible] $I_{fuse} = 3 \times 15 = 45A$

~~one~~ single motor start [illegible]

$$\text{main Fuse} = 45 + 10 + 15$$
$$= 70A$$

Double motor start

$$\text{main fuse} = 45 + 30 + 15$$
$$= 90A$$

5 [illegible] Busbar [illegible] 50m.v.A, 20% reactance generator [illegible] m.v.A [illegible] 10% [illegible] Busbar reactor [illegible] Tie bar [illegible] Short circuit m.v.A [illegible] 750 m.v.A [illegible] short circuit k.v.A [illegible]

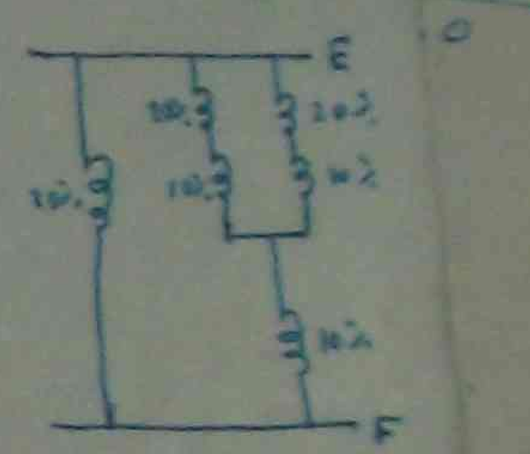
$$KVA_{Sh} = \left[\frac{Q}{x} + \frac{Q(n-1)}{x+bn}\right] \times 100$$

Q = Full load K.V.A x = generator Reactance

b = Reactor Reactance n = sections

$Q = 50m.v.A$ $x = 20\%$ $b = 10\%$

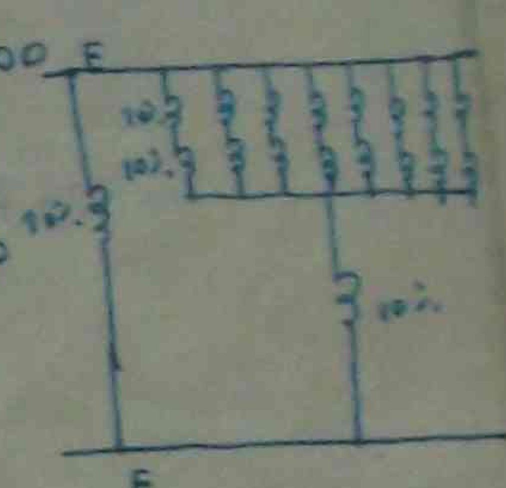
$$KVA_{Sh} = \left[\frac{50}{20} + \frac{50(3-1)}{20+10\times3}\right] \times 100$$



$$= \left[2.5 + \frac{50 \times 2}{50}\right] \times 100$$

$$= 4.5 \times 100 = 450m.v.A$$

$$KVA_{Sh} = \left[\frac{50}{20} + \frac{50(9-1)}{20+10\times9}\right] \times 100$$



$$= \left[2.5 + \frac{50 \times 8}{110}\right] \times 100$$

$$= [2.5 + 3.636] \times 100$$

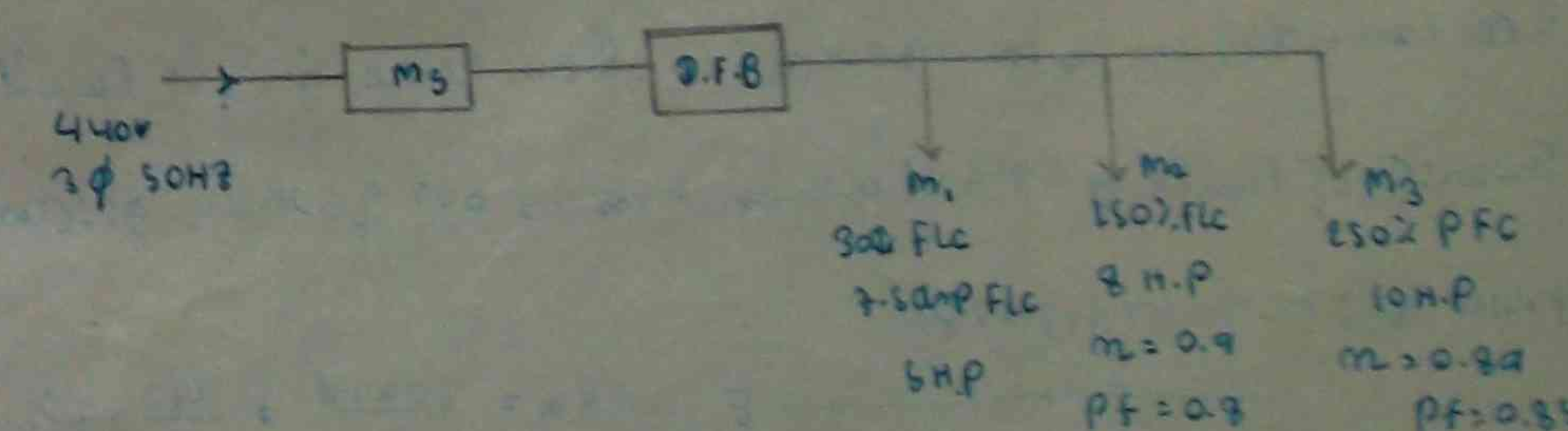
$$= 6.136 \times 100 = 613.6m.v.A$$

$$KVA_{Sh} = \left[\frac{50}{20} + \frac{50(\alpha-1)}{20+10\alpha}\right] \times 100$$

$$= \left[2.5 + \frac{50}{10}\frac{(\alpha-1)}{(2+\alpha)}\right] \times 100$$

$$= (2.5 + 5) \times 100 = 750m.v.A$$

6



[illegible] feeder [illegible] current rating [illegible]

m1 22.5

m2 16.3

m3 32.4

main 90.75

M1

$I_{fuse} = \frac{7.5 \times 300}{100} = 22.5$ amps (fuse rating)

M2

$I_{FL} = \frac{8 \times 746}{440 \times \sqrt{3} \times .9 \times .8}$

$I_{FL} = \frac{5968}{763 \times .72} = \frac{5968}{548} = 10.89$

$I_{fuse} = 10.89 \times \frac{150}{100} = 16.32$ amps (16.3)

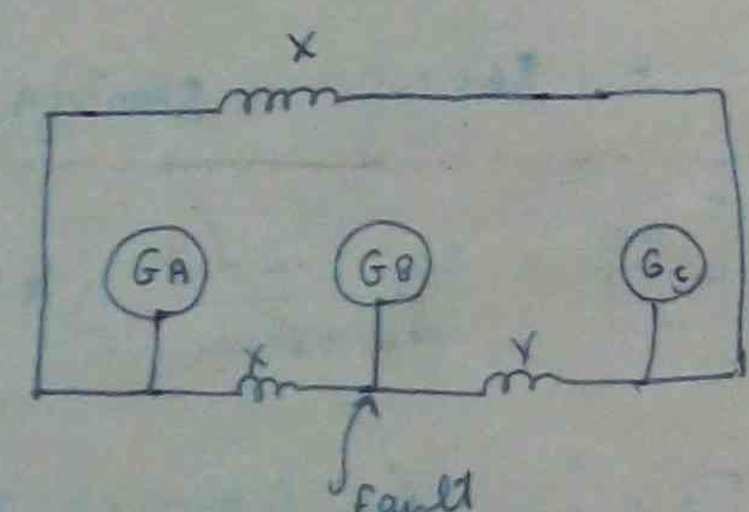
M3 $I_{FL} = \frac{10 \times 746}{440 \times \sqrt{3} \times .89 \times .85} = \frac{7460}{763 \times .7565} = \frac{7460}{577} = 12.93$

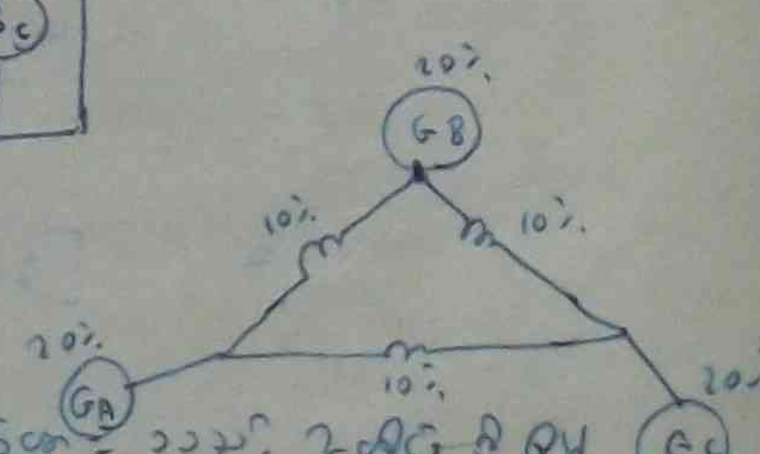
$I_{fuse} = 12.93 \times 2.5 = 32.38$ (32.4)

main fuse rating $= 32.35 + 7.5 + 10.89$

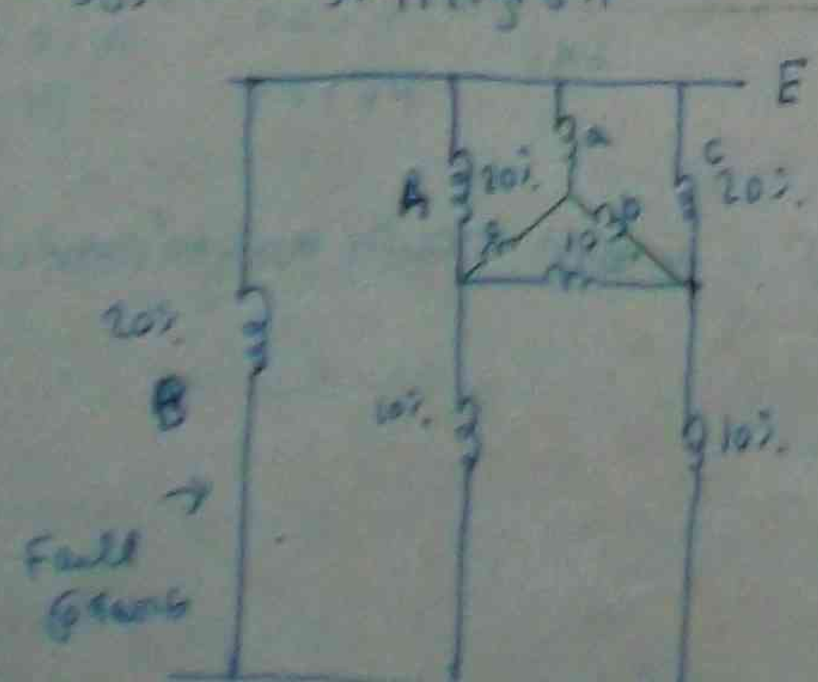
$= 50.74$ amps (50.75)

7





3φ [illegible] generator GA, GB [illegible] 20 [illegible] 20% Reactance [illegible] busbar Reactance [illegible] 10% Reactance [illegible] fault [illegible] fault [illegible] generator [illegible] current [illegible] system [illegible] 11 [illegible]



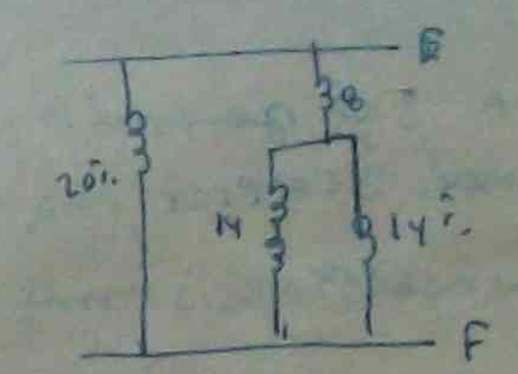
$R_a = \frac{20 \times 20}{50} = \frac{40}{5} = 8\%$

$R_b = \frac{20 \times 10}{50} = 4\%$

$R_c = \frac{20 \times 10}{50} = 4\%$

GA 3500.5A

GB 5250 A



$x_{t_1} = 8 + 7 = 15\%$

$\frac{1}{\% x_T} = \frac{1}{20} + \frac{1}{15} = \frac{3+4}{60}$

$\% x_T = \frac{60}{7}\%$

$I_{FL} = \frac{Power}{E_L \times \sqrt{3}} = \frac{20 \times 10^6}{11 \times 10^3 \times \sqrt{3}}$

$= \frac{20{,}000}{11 \times \sqrt{3}} = \frac{20{,}000 \times 1.7321}{33}$

$= \frac{34642}{33} = 1050$ amps

B

$I_{sh} = \frac{1050}{20} \times 100$

$= 5250$ amps

$I_{sh} = \frac{I_{FL}}{\% x_T} \times 100$

$= \frac{1050 \times 7}{60} \times 100$

$= \frac{10500 \times 7}{6} = \frac{73500}{6}$

$= 12250$ amps ([illegible] I)

$\therefore$ B+C current $= 12250 - 5250 = 7000$ $\therefore A = C = 3500$ amps

~~[illegible] current $= \frac{12250}{4} = 3062.5$ amps~~

~~GA: $I_{sh} = \frac{1050}{20} \times 100$~~

~~$= \frac{10500}{2} = 5275$ amp (A [illegible] I)~~

~~GB $I_{sh} = \frac{1050}{30} \times 100$~~

~~$= \frac{10500}{3} = 35$~~

~~$\frac{60}{7}\% = 12250$~~

~~$20\% \longrightarrow ? = 12250 \times 20 \times \frac{7}{60}$~~

[illegible]

$35\% = 12250$

$15\% \longrightarrow ? = \frac{12250 \times 15}{35} = \frac{36750}{7}$

$= 5250$ amps

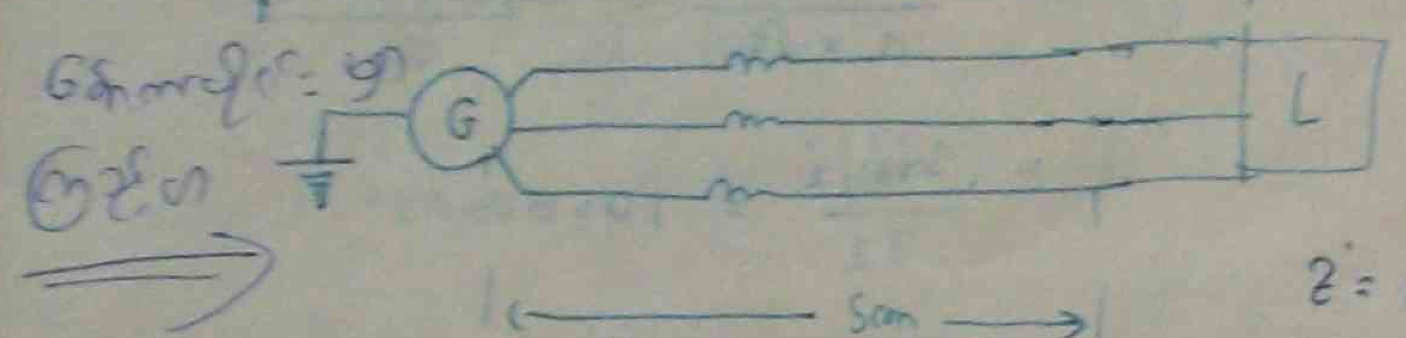
$35\% = 12250$

$10\% \longrightarrow ? = \frac{12250 \times 10}{35} = \frac{49000}{7} = $

$\therefore = 3500$ amps

(8) 10% reactance [illegible] 15000 kVA 3 ϕ generating station [illegible] Power 6.6 kV 50 Hz [illegible] Busbar [illegible] 3 core cable [illegible] supply [illegible] core [illegible] resistance [illegible] 0.2196 Ω/mile [illegible] reactance [illegible] .1277 Ω/mile [illegible] cable [illegible] load current 200 amp [illegible] station [illegible] 5 mile [illegible]
dead 3 ϕ short [illegible] ~~a~~ short circuit current [illegible]

2450 amp



$Z = ~~.21~~ .2196 + j .1277$
$= .582$

5 miles [illegible] Resis $= ~~.22~~ .2196 \times 5\ \Omega$

one line ~~Resis~~ $\%X = \dfrac{I_{FL} \times Z_{ph}}{E_{ph}} \times 100$

$= \dfrac{\frac{200}{3} \times .2196 \times 5}{6.6 \times 1000} \times 100$

$= \dfrac{200 \times .5880 \times 5 \times 100}{3 \times 6.6 \times 1000}$

$= \dfrac{100 \times .5820}{19.8} = \dfrac{58.20}{19.8}$

$\% X_T = \dfrac{58.20}{19.8 \times 3}$

$\% X_T = \dfrac{58.20}{19.8 \times 3} + ~~10~~ = \dfrac{58.2}{59.4} + 10$

$= .978\ \%$

$I_{sh} = \dfrac{I_{FL}}{\%}$

Busbar power $= 6.6 \times \dfrac{200}{3} = 1320$ kVA

1320 kVA [illegible]

15000 kVA = 10%

$\dfrac{1320}{3}$ —— ? $= \dfrac{13200}{15000 \times 3} = .~~88~~\%$
$= .0293$

$\% X_T = .88 + .978 = 1.858$

$I_{sh} = \dfrac{I_{FL}}{\% X_T} \times 100$

$= \dfrac{200}{.0827} \times 100 = 2420$

Power sh $= \dfrac{\text{Power}_{FL}}{\% X_T} \times 100 = \dfrac{1320000}{.0293} = 450000$

$Z = .2196 \times 5 + .1277 \times 5$

$= 1.0980 + .6385$

$= 1.27$

$\% X_T = \dfrac{200 \times 1.27}{3 \times 19.8 \times 1000} \times 100$

$= \dfrac{200 \times 1.27}{19.8 \times 3} = \dfrac{12.7 \times 2}{59.4} = .214 = .428$

$\% X_T = .428 + .0293 = .4573$

$I_{sh} = \dfrac{200}{.4573} \times 100$

$Z = 1.27 \quad \% X_T = \dfrac{I_{FL} \times Z_{ph}}{E_{ph}} \times 100$

$= \dfrac{200}{3} \times \dfrac{1.27}{6.6 \times 1000} \times 100$

$= \dfrac{25.4}{19.8} = 1.280$

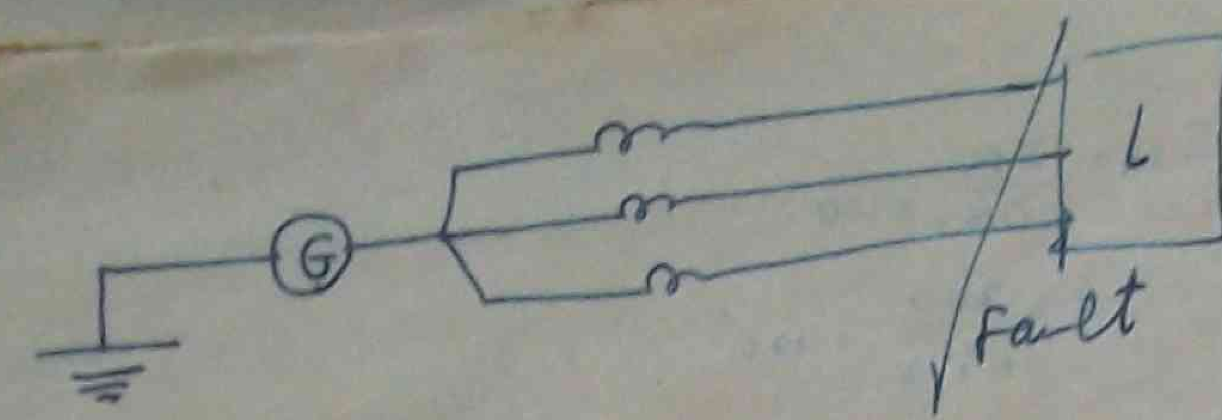
$\%$ 3 ϕ [illegible] $= \dfrac{1.28}{3} = .428\ \%$

$\% X_T = .428 + .0293 = .721$

$I_{sh} = \dfrac{I_{FL}}{\% X_T} \times 100 = \dfrac{200}{.721} \times 100$

$= \dfrac{200}{.721} \times 100$

$= 2450$ amp



Line [illegible] $Z = R + jX_L$

$= .2196 + j.12770 \times 5$

$= 1.0980 + j.6385$ 3 [illegible] $Z_T = \frac{1.27}{3} = .423$

$= 1.27\Omega$

~~3 lines~~: $\% X_T = \frac{I_{FL} \times .423}{E_{ph}} \times 100$

$= \frac{200 \times .423}{6.6 \times 1000} \times 100$

$= \frac{8.46}{6.6} = 1.281\%$

$Power_{FL} = \sqrt{3}EI$

$= \sqrt{3} \times 6.6 \times 200$

$= 1.7321 \times 1320 = 2285$ KVA

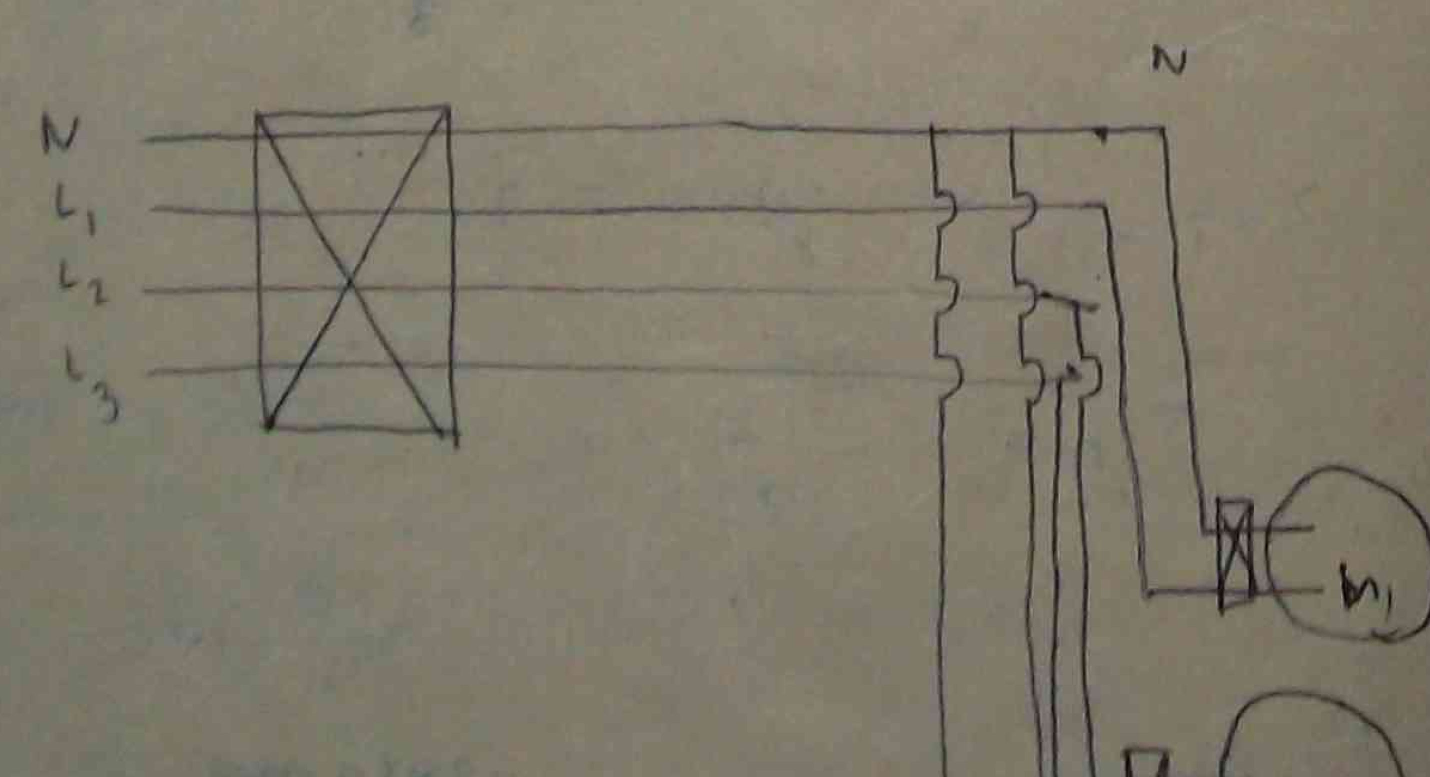
$15000KVA = 10\%$

$2285 \longrightarrow ? = \frac{22850}{15000} = 1.521\%$

$\% X_T = 1.281 + 1.521 = 2.803\%$

$I_{Sh} = \frac{I_{FL}}{\% X_T} \times 100 =$ 2—8. $\frac{200,00}{2.803}$

$Power_{Sh} = \frac{Power_{FL}}{\% X_T} \times 100 =$



✓

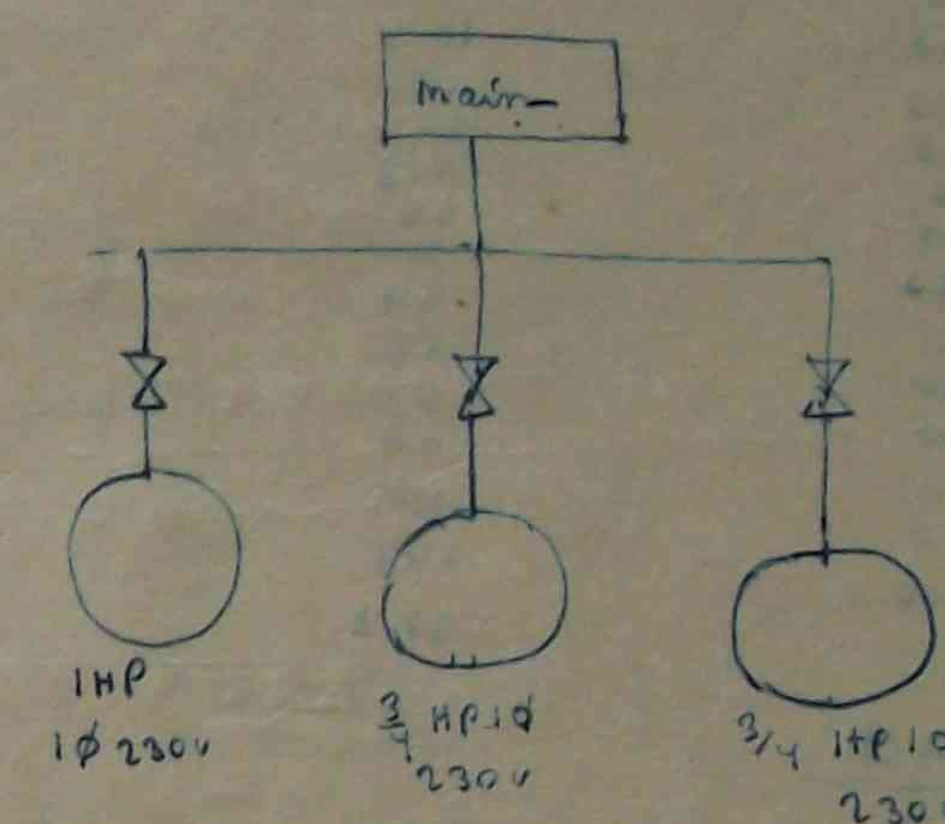
(9) [illegible] motor [illegible] 3ϕ supply [illegible] line [illegible] neutral balance [illegible] motor [illegible] start [illegible] main feeder [illegible] rating [illegible] main fuse [illegible] motor [illegible] Sq cage motor [illegible] $\eta = 90\%$ [illegible] P.f 0.9 [illegible]

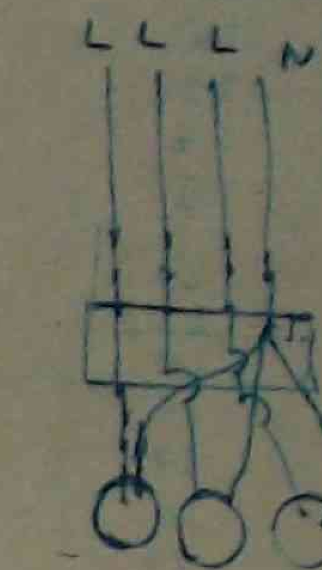
(က) 1HP 1ϕ [illegible] 230 V

(ခ) $3/4$ HP 1ϕ 230 V grinding machine [illegible]

(ဂ) $3/4$ HP 1ϕ 230 V Drill press [illegible]

(ဃ) [illegible]





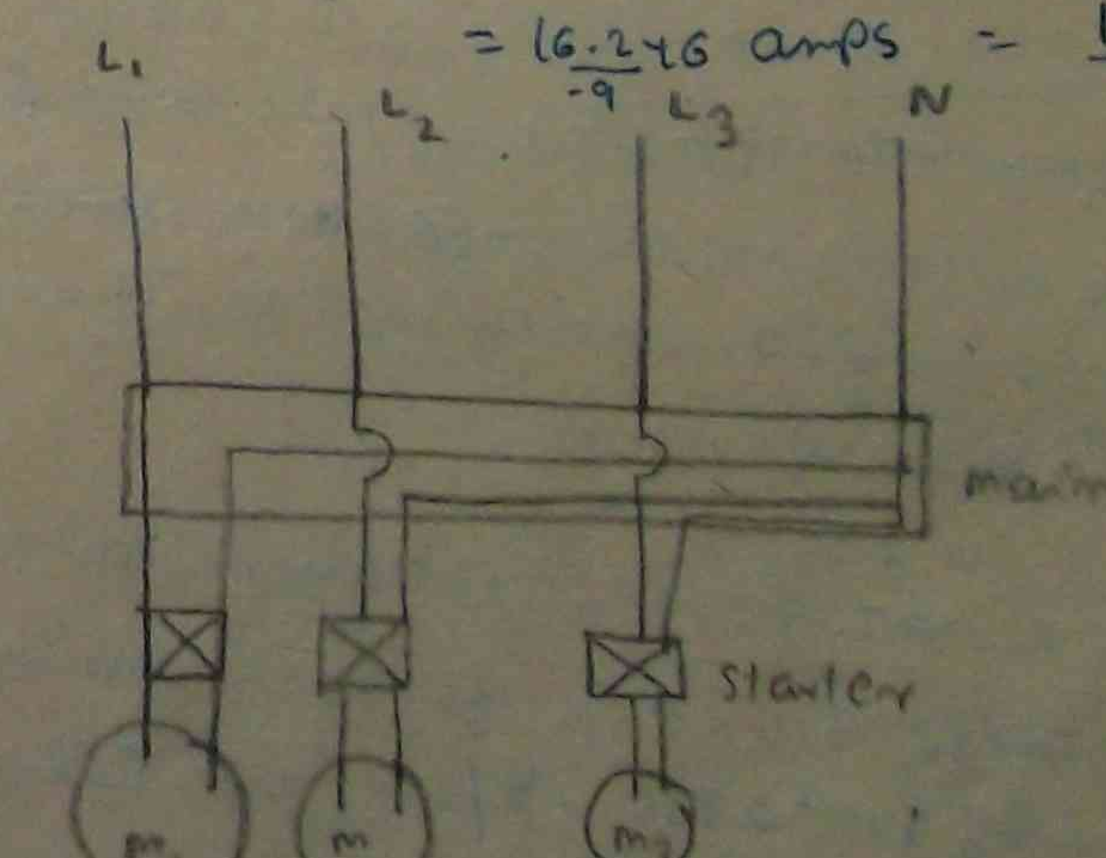
$I_{FL} = \frac{1 \times 746}{230 \times .9} = \frac{746}{207 \times .9} = \frac{3.61}{.9}$ amp $I_{Fuse} = \frac{3.61 \times 300}{100} = \frac{10.83}{.9}$

$I_{FL} = \frac{746 \times \frac{3}{4}}{230 \times .9 \times .9} = \frac{746 \times .75}{207} = \frac{560}{207} = 2.708$ I_F $2.708 \times 3 = \frac{8.124}{.9}$

$I_{FL} = \frac{746 \times .75}{230 \times .9 \times .9} = \frac{560}{207 \times .9} = \frac{2.708}{.9}$ I_{Fuse} $\frac{8.124}{.9}$

main feeder rating $= \frac{10.83 + 2.708 + 2.708}{.9}$

$= \frac{16.246}{.9}$ amps $= \frac{16.246}{.9} = \frac{16246}{900} = 18.05$



[illegible] SWG NO 28, wire [illegible] .0148" wire

(8) 10% rea

6. Gu

Supp

load cur

load

3φ short

Seriel

One

[illegible]

wire NO SWG	[illegible]	[illegible]	[illegible]
34	.0092	4.5	9
33	.0100	5	10
32	.0108	5.7	11.5
31	.0116	6.4	12.8
30	.0124	7	14
29	.0136	8	16
28	.0148	9	18.5
27	.0164	10.7	21.5
26	.0180	12.4	24.7
25	.0200	14.5	29
24	.0220	16.5	33
23	.0240	19	35
22	.0280	24	48
21	.0320	29.3	58.6
20	.0360	35	70
19	.0400	41	82
18	.0480	54	108
17	.0560	68	136
16	.0640	83	166
15	.0720	99	198
14	.0800	116	232
13	.0920	143	286
12	.1040	172	344

$$I_{fuse} = \frac{a d^3}{2}$$

$$I_{fuse} = \frac{10244\, d^3}{2}$$

Measurement

(1) 10 amp Electrodynamics ammeter [illegible] Torsion const 1 dyne-cm/degree [illegible] spring [illegible] control [illegible] meter [illegible] Full scale deflection [illegible] 110 degree [illegible] Inductance [illegible] 2 µH [illegible] Inductance [illegible] 10 amp [illegible] meter [illegible] Inductance [illegible]

(2) Quadrant Electro meter [illegible] Idio static connection [illegible] pd 80 V [illegible] deflection 25 division [illegible] Hetero Static connection [illegible] 1 kV [illegible] Quadrant [illegible] V volt [illegible] deflection 15 division [illegible]

(3) [illegible] 0.5 [illegible] Full scale deflection [illegible] meter [illegible] 2.2 [illegible] 3.6 × 2.5 square cm [illegible] 26.5 [illegible] flux density [illegible] 0.135 wb/m² [illegible] full scale deflection [illegible] current [illegible] swamping Resistance [illegible] ($\rho = 1.73\ \mu\Omega/cm$)

(1)

[illegible] Induc = 2 µH

[illegible] degree = 0

I = 10 amp

[illegible] degree = 110°

$$T_D = 5100\, I^2 \frac{dM}{d(\theta+\phi)}$$

$$\frac{110\times}{980} = \frac{5100 \times 100 \times (x-2) \times 10^{-6}}{\frac{(110-0)\,\pi}{180}}$$

$$\frac{11}{98} = \frac{\cancel{5100} \times \cancel{100} \times \cancel{180} \times (x-2)}{\cancel{10^6} \times 110\,\pi}$$

$$\frac{12100\,\pi}{98 \times 51 \times 18} + 2 = x$$

$$\frac{38000}{98 \times 918} + 2 = x$$

2 µH → [illegible]

0 → 110 d

2.22

$$x = \frac{38000}{90000} + 2$$

$= .422 + 2 = \cancel{2.422}$ 2.422 µH

[illegible] Inductance = 2.422 − 2 = .422

(2)

$T \propto \theta$

$T = k\theta$

Idio = $T = C_2 V^2$

Hetero = $T = C_1 V$

$\frac{C_1}{C_2} = 2.10$

Hetero Static.

Idiostatic →

$k\theta = C_1 V$

$k \times 15 = C_1 \times 1000$

$k \times 25 = C_2 \times 80 \times 80$

$$\frac{15}{25} = \frac{C_1}{C_2} \times \frac{1000}{6400}$$

$$\frac{\cancel{15}^{3}}{25} = \cancel{2}V_0 \times \frac{5}{\cancel{32}_{16}}$$

$$\frac{48}{25} = V_0$$

$V_0 = 1.92$ volts

(3)

$$T_D = \frac{A N I B}{10 \times 980}$$

$$\frac{1}{\cancel{2}} = \frac{3.6 \times 2.5 \times 26.5 \times I \times 0.135 \times 10^4}{10 \times \cancel{980}\ 490}$$

$$\therefore I = \frac{4900}{3.6 \times 2.5 \times 26.5 \times 0.135 \times 10^4}$$

$$= \frac{4900}{3.6 \times 2.5 \times 26.5 \times 1.35} \times 10^{-3}$$

$$= \frac{4900}{9 \times 35.8}\ mA = \frac{4900}{322} = 15.2\ mA$$

$$R = \frac{\rho L}{A} = \frac{1.73 \times 10^{-6} \times 2(3.6+2.5) \times 26.5}{\frac{\pi}{4} \times \frac{.2946}{10} \times \frac{.2946}{10}}$$

$$= \frac{1.73 \times 10^{-6} \times 2 \times 6.1 \times 26.5}{.7854 \times .02946 \times .02946}\ \Omega$$

$$\therefore \text{swamping Resis} = \frac{75}{15.2} - \frac{1.73 \times 10^{-6} \times 2 \times 6.1 \times 26.5}{.7854 \times .02946 \times .02946}$$

$$= 4.93 - \frac{3.46 \times 162 \times 10^{-6}}{78.54 \times 2.946 \times 2.946 \times 10^{-6}}$$

$$= 4.93 - \frac{562}{78.54 \times 3.68}$$

$$= 4.93 - \frac{562}{633}$$

$= 4.93 - .881$

⑧ 10% reac
6. 6u
Supply
load cur
dead
3ϕ short
Series
one

$1 \times 110 = 110$ dyne-cm

$d\theta = 110 - 0 = 110 \times 0.1745$

$T_\theta = 10200 \quad I^2 \frac{dm}{d\theta}$

$dm = .211\ \mu H$

$dm = m_2 - m_1$

$= -2.2\ \mu H$

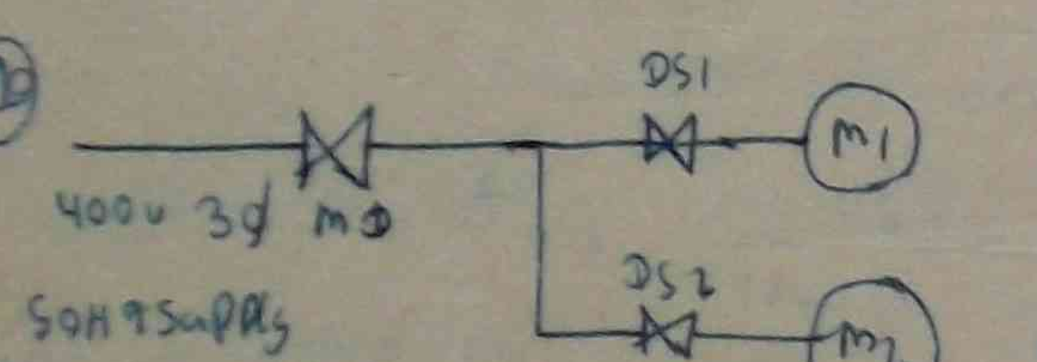
$\frac{KA}{\sigma \pi} \left(\frac{V}{300x}\right)^2$

$= \frac{\pi \times 10 \times 10}{2\pi \times 4} \times \frac{1000 \times 1000 \times 2.54 \times 2.54}{300 \times 300 \times .64 \times 2.54 \times 2.54}$

$= 54.2$ dyne $\quad \theta = .221 \times \ldots$

Powering

⑪

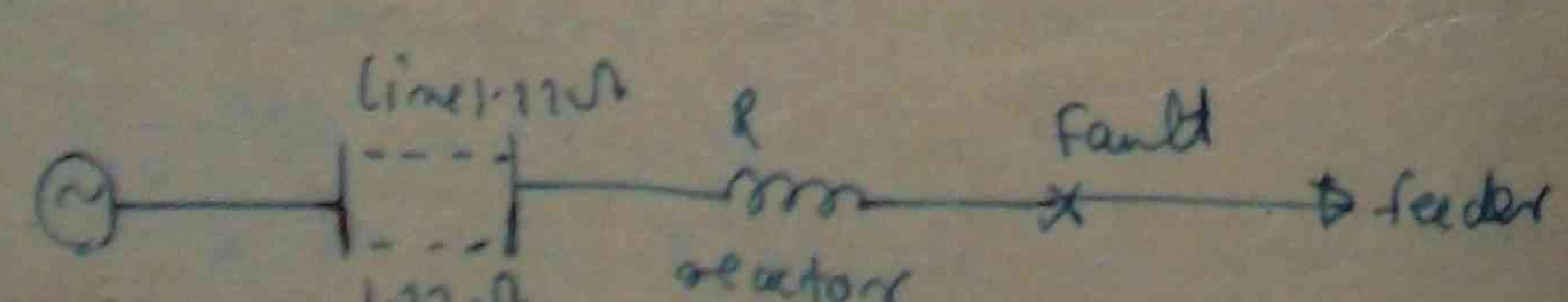


motors ... motor ... start ... Branch circ... protection ... Sub main fuse DS_1, DS_2 ... main ... ~~Sub main fuse DS_1~~ DS ...

$M_1 = 10$ HP $\eta = 0.8$ pf $= 0.8$ lagging ... squirrel cage motor

$M_2 = 12$ HP $\eta = 0.87$ pf $= .09$ lagging ... wound Rotor Induction motor.

⑫



Alternator ...
7500 kVA 11kV 3φ
... feeder ...

... reactor R ... ohmic value ...

M1 (10HP)

$I_{FL} = \frac{Power}{\sqrt{3}\, E_L}$

$= \frac{10 \times 746}{\sqrt{3} \times 400 \times .8 \times .8}$

$= \frac{7460}{693 \times .64} = \frac{7460}{444} = 16.8$ amp

$I_{fuse} = 16.8 \times \frac{300}{100} = 50.4$ amps

12HP $\quad I_{FL} = \frac{Power}{\sqrt{3}\, E_L} = \frac{12 \times 746}{693 \times .87 \times .9} = \frac{8952}{693 \times .783}$

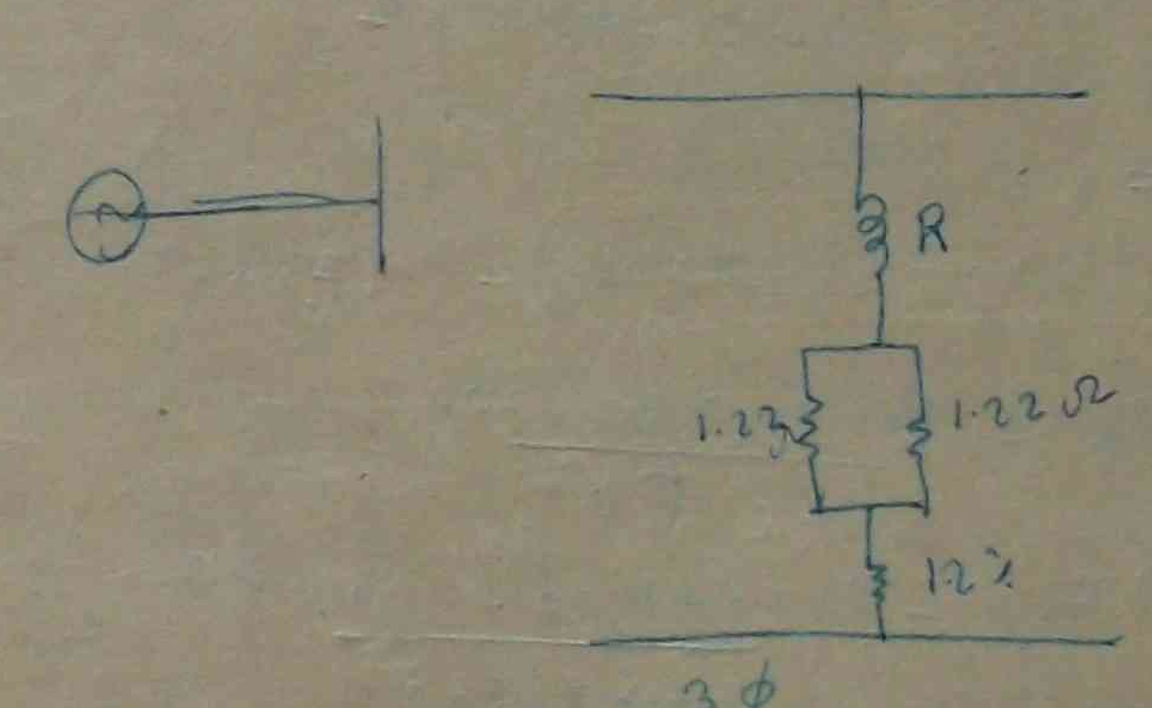
$= \frac{8952}{542} = 16.51$

$I_{fuse} = 16.51 \times \frac{300}{100}$

$= 49.53$ amps

$\therefore$ main fuse $= 50.4 + 16.51 = 66.91$ amp

②



Line ... Total Resistance $= \frac{1.22}{2} = .61\ \Omega$

$\%X =$

$I_{sh} = \frac{I_{FL}}{\%X_T} \times 100$ $\qquad$ Line $\%X_T = \frac{.61 \times 7500 \times 1000 \times 100}{11000 \times 11000}$

$3 I_{FL} = \frac{I_{FL}}{\%X_T} \times 100$ $\qquad = \frac{457}{121}$

$\%X_T = 33.33\%$ $\qquad = 3.78\%$

~~$\%X_T = \frac{x \times Power \times 100}{E_L^2}$~~

~~$\frac{100}{3} = \frac{x \times 7500 \times 1000 \times 100}{11000 \times 1000}$~~

~~$\frac{1}{3} = \frac{75x}{110}$~~ $\qquad x = \frac{22}{45}$ Ph

$I_{FL} =$

$\%x = \frac{\dots}{EL^2}$

$17.552 = \frac{7500 \times 1000 \times x_{ph} \times 100}{11000 \times 11000}$

$\frac{17.552 \times 121}{750} = x_{ph}$

$\frac{2123}{750} = x_{ph} \quad x_{ph} = 2.83\,\Omega$ (Ans)

$I_{sh} = \frac{I_{FL}}{\%x_T} \times 100$

$3 I_{FL} = \frac{I_{FL}}{\%x_T} \times 100$

$\%x_T = 33.33\%$

one line $\%x = \frac{7500 \times 1000 \times 1.22 \times 100}{11000 \times 1000 \times 2}$

line ၂ လုံး $= \frac{7500 \times 1000 \times 1.22 \times 100}{11000 \times 11000 \times 2}$

line ၏ $\%x = \frac{Power \times x_{ph} \times 100}{EL^2}$

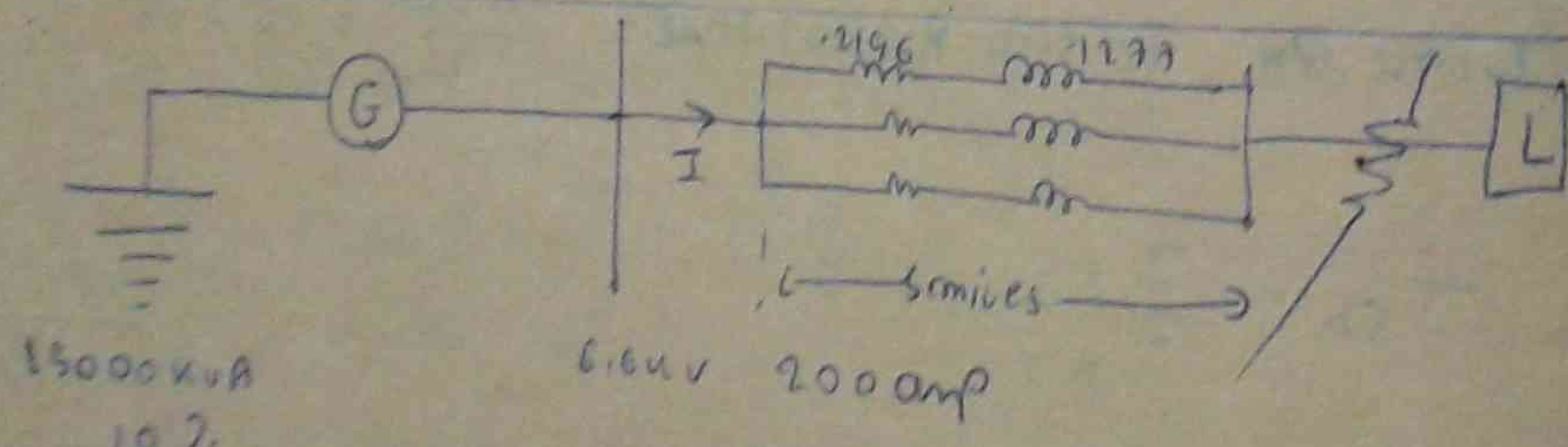
$= \frac{7500 \times 1000 \times 1.22 \times 100}{11000 \times 11000 \times 2}$

$= 3.78\%$

$\therefore$ R ၏ $\%x = 33.33 - (3.78 + 12) = 17.552$

$\%x = \frac{Power \; x_{ph} \times 100}{EL^2}$

$17.552 = \frac{7500 \times 1000 \times x_{ph} \times 100}{11000 \times 11000}$ $\quad x_{ph} = 2.83\,\Omega$



5 miles အတွက် $= .2196 \times 5$ (Resis) , $.1277 \times 5$ (Reactance)

$Z = R + jx_L$

$= .2196 \times 6 + j\,.1277 \times 6$

$= 1.27\,\Omega$

Power $= 6.6 \times 200\sqrt{3}$

$= 1320 \times 1.7321 = 2285$ kVA

3 line အတွက် $= \%x_T = \frac{7.32}{3} = 2.44\%$

2285 base

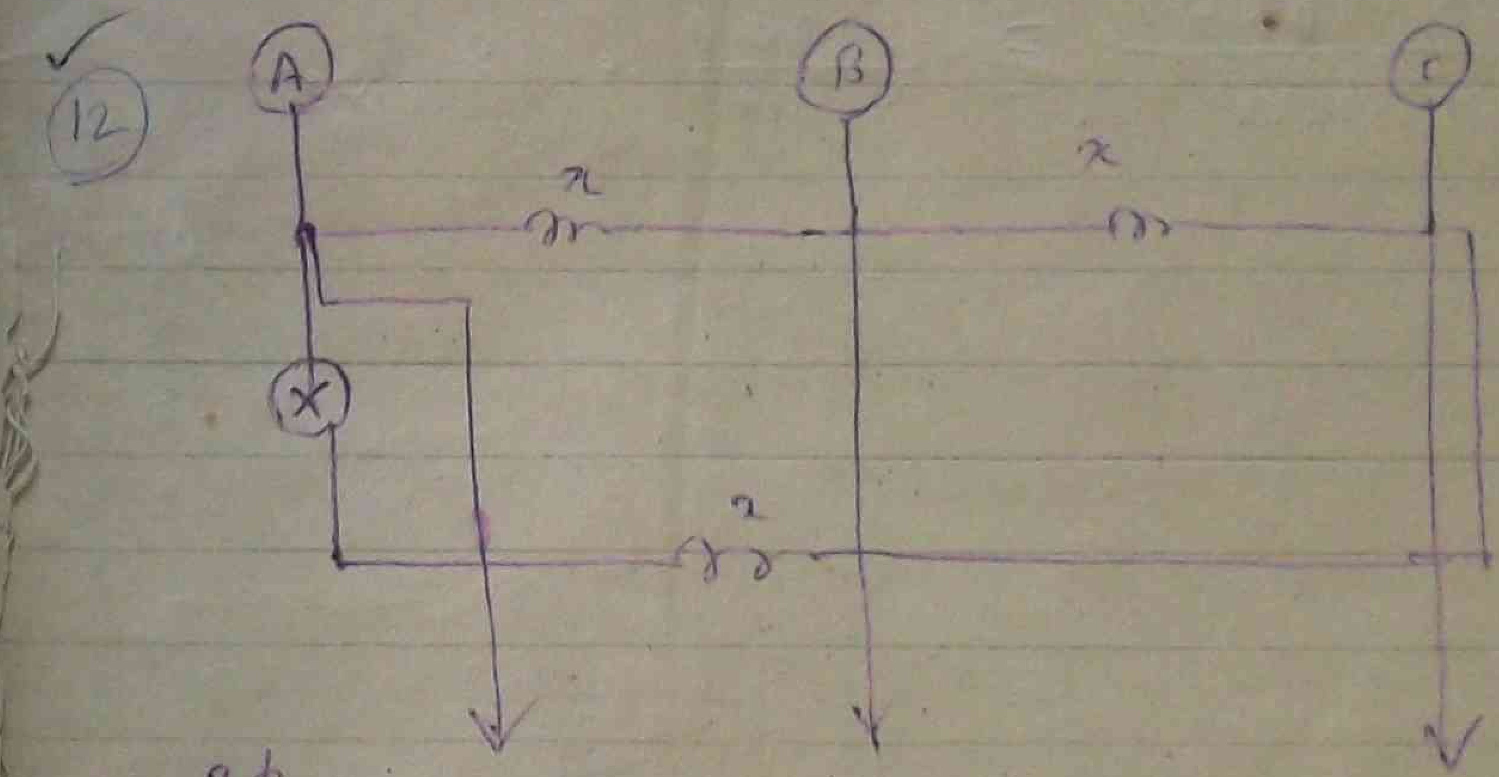
15000 kVA $\rightarrow$ 10%

2285 $\rightarrow$ % $= 1.525\%$

$\%x_T = 2.44 + 1.525 = 3.965$

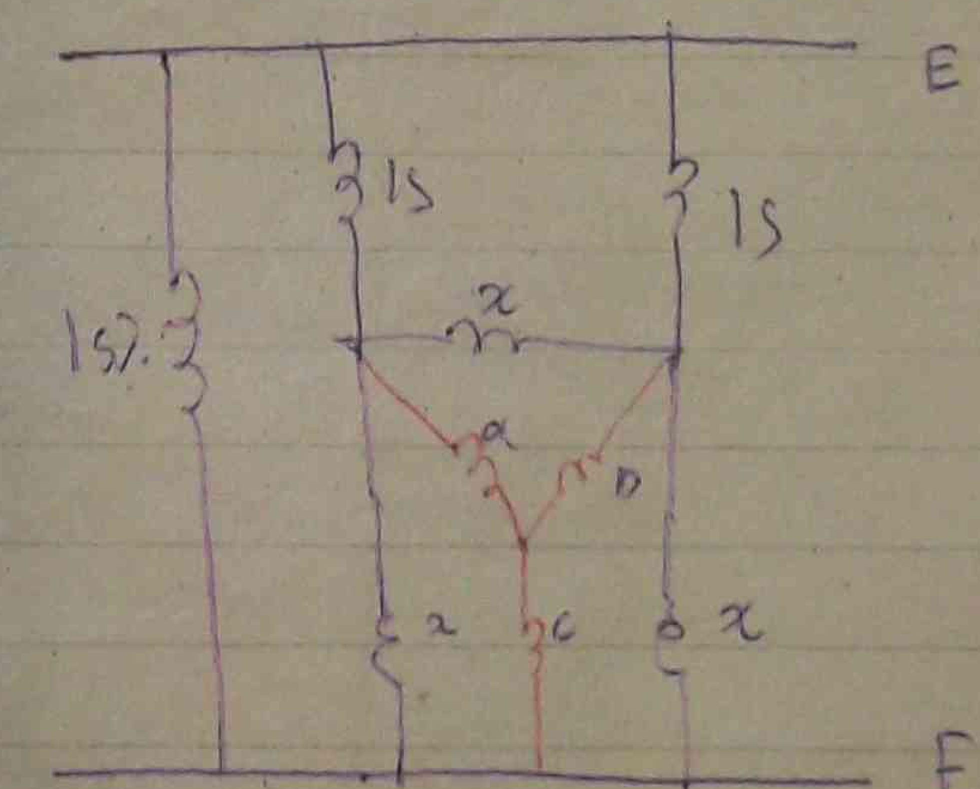
$I_{sh} = \frac{I_{FL}}{\%x_T} \times 100 = \frac{100 \times 100}{3.96} = 5050$ amp

(12)



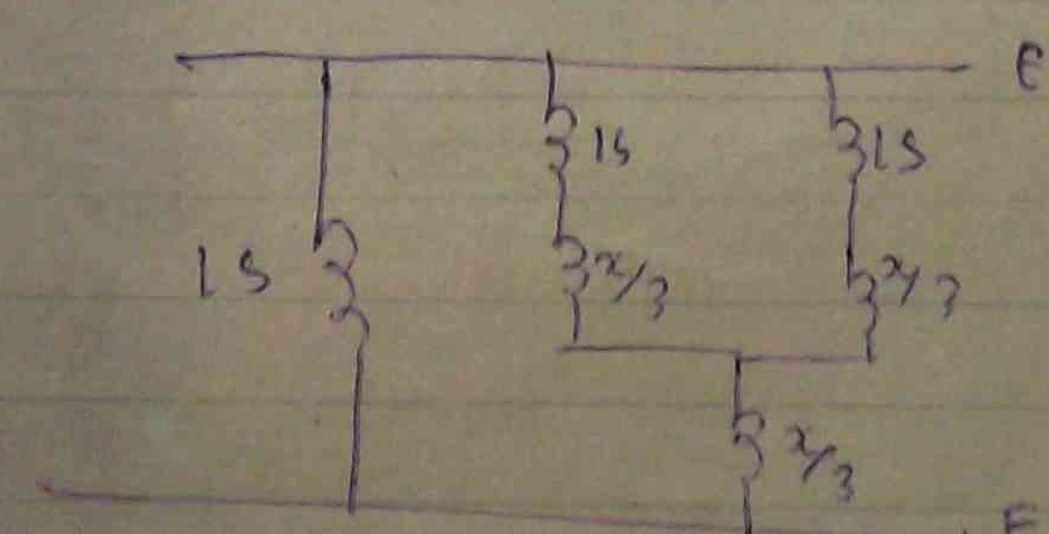
3φ short circuit ... 750 ... Reactance ... ohm ...

3φ 33 kV 50 Hz 60 MVA $x = 15\%$



$a = \frac{x \times x}{3x} = \frac{x}{3}$

/// ly $b = x/3 \quad c = x/3$



$\%x_{T_1}$

$15 + \frac{x}{3} = \frac{45 + x}{3}$

$\%x_{T_1} = \frac{45 + x}{6}$

Total $\%x_{T_2} = \frac{45 + x}{6} + \frac{x}{3}$

$= \frac{45 + 3x}{6}$

$= \frac{15 + x}{2}$

Power $I_{sh} = \frac{Power\,FL}{\%x_T} \times 100$

$750 = \frac{60}{\%x_T} \times 100 \quad \%x_T = 8\%$

KN 79

72/-

A.U

Electrical Measurement

&

measuring instruments

2nd Year Electrical Engineering (power)

course

Government Technical Institute

No	Type	Name of meter	Symbol
1	Current	Am meter	A
2	voltage	volt meter	V
3	Power	watt meter	W, KW
4	Energy	Kilowatt hour meter	K.W.H
5	Frequency	Frequency meter	F, ~
6	Power factor	Power factor meter (P.f)	Pf ~ cosθ
7	Reactive volt	Reactive volt meter	VAR, KVA[illegible]

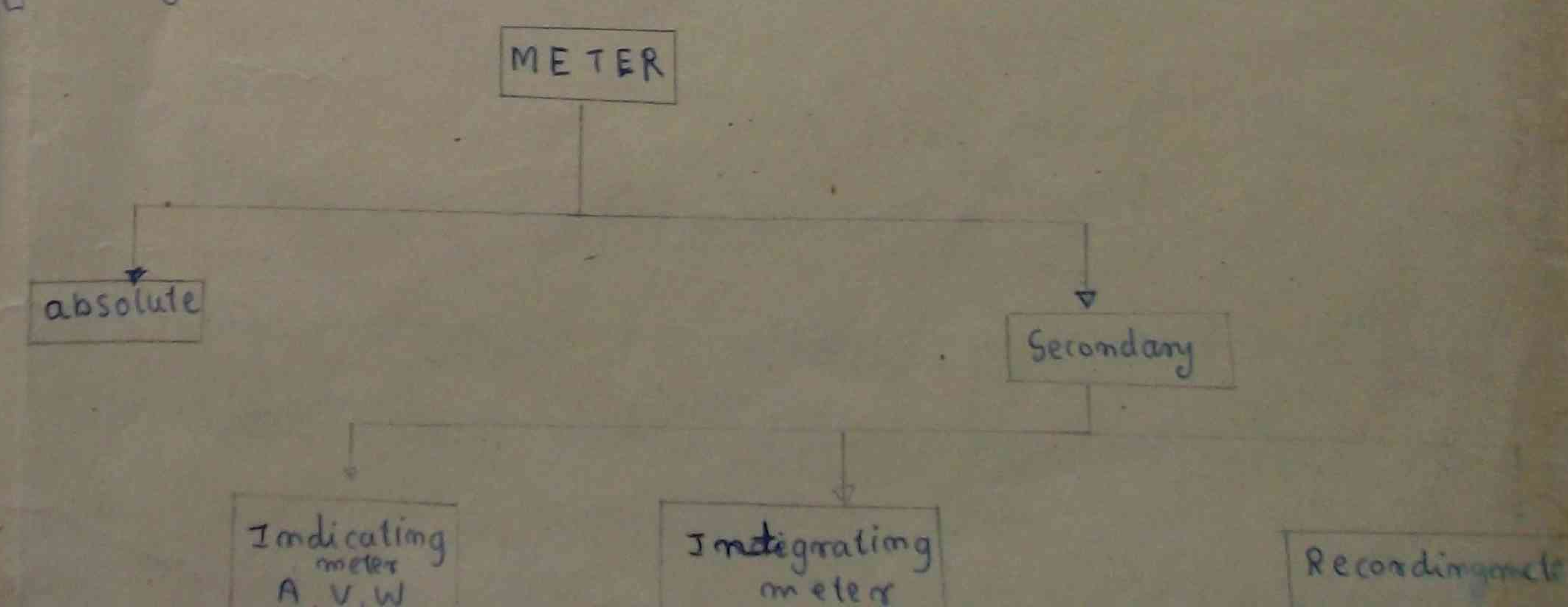
Meter အမျိုးအစားများတွင် absolute နှင့် secondary ဟု ၂မျိုး ခွဲခြားနိုင်သည်။

absolute meter (Instrument)

absolute meter ဆိုသည်မှာ တိုင်းတာလိုသော လျှပ်စစ်ဓါတ်အားကို Inst[illegible] ၏ တည်းဆောက်ပုံများနှင့် ဆိုင်နိုင်ပါ ထို meter များ၌ အခြား နှိုင်းယှဉ်စရာ မလိုပေ။ တ[illegible] တည်းကိုသာ တိုင်းနိုင်ပါ ပုံများဖြင့်သော်နှင့် တွက်ချက်ကာ လျှပ်စစ်ဓါတ်အားကို သိနိုင်[illegible]

Secondary meter (Instrument)

secondary meter ဆိုသည်မှာ တိုင်းတာလိုသော လျှပ်စစ်ဓါတ်အား အမျိုးအစား[illegible] meter ၏ အပိုင်း ရောက်ပြင့် သတ်မှတ် တွက်ချက်ထားသော Scale ပေါ်တွင် ညွှန်ပြသော meter[illegible] ဖြစ်ပါ။ ထို meter များနှင့် အခြားလိုအပ်သော ကိရိယာများကို ပူးတွဲ၍ တိုင်းတာ၍ တိုင်းတာမှု ပြုလုပ်[illegible]



Indicating meter (Instrument)

* ကျွန်ုပ်တို့အသုံးများတွင် Ammeter, voltmeter, watt meter တို့ meter များ ပါဝင်ပစ္စည်းတစ်ခုခုအား တိုင်းတာလိုသော လျှပ်စစ်ဓာတ်အား အတိုင်းအတာကို ညွှန်ပြချောင်း (Pointer) နှင့် ညွှန်ပြ ဖို့ မတိုင်းတာမီ ကာလအတွင်း ညွှန်ပြချောင်းသည် "0" အမှတ်၌ ရှိနေပေသည်။

* Integrating

Kilowatt ~~power~~ hour meter, watt hour meter, ampere hour meter တို့သည် ကျွန်ုပ်တို့ အသုံးပြုသော အချိန်ပိုင်း အတွင်း တိုင်းတာလိုသော Electrical Energy ကို ထို meter များ မှတ်သား၍ ထိုအချိန်အတွင်း သုံးစွဲသော Electrical Energy ပေါင်းချုပ်ကို ဖော်ပြပေးသည်။ ထို meter များသည် မတိုင်းတာမီ အချိန်တွင် "0" အမှတ်၌ ရှိနေသည်။ သုံးစွဲသော unit မှ ပေါင်းချုပ်သည့် Result ပေါ်ပေါက်ပါ၏။

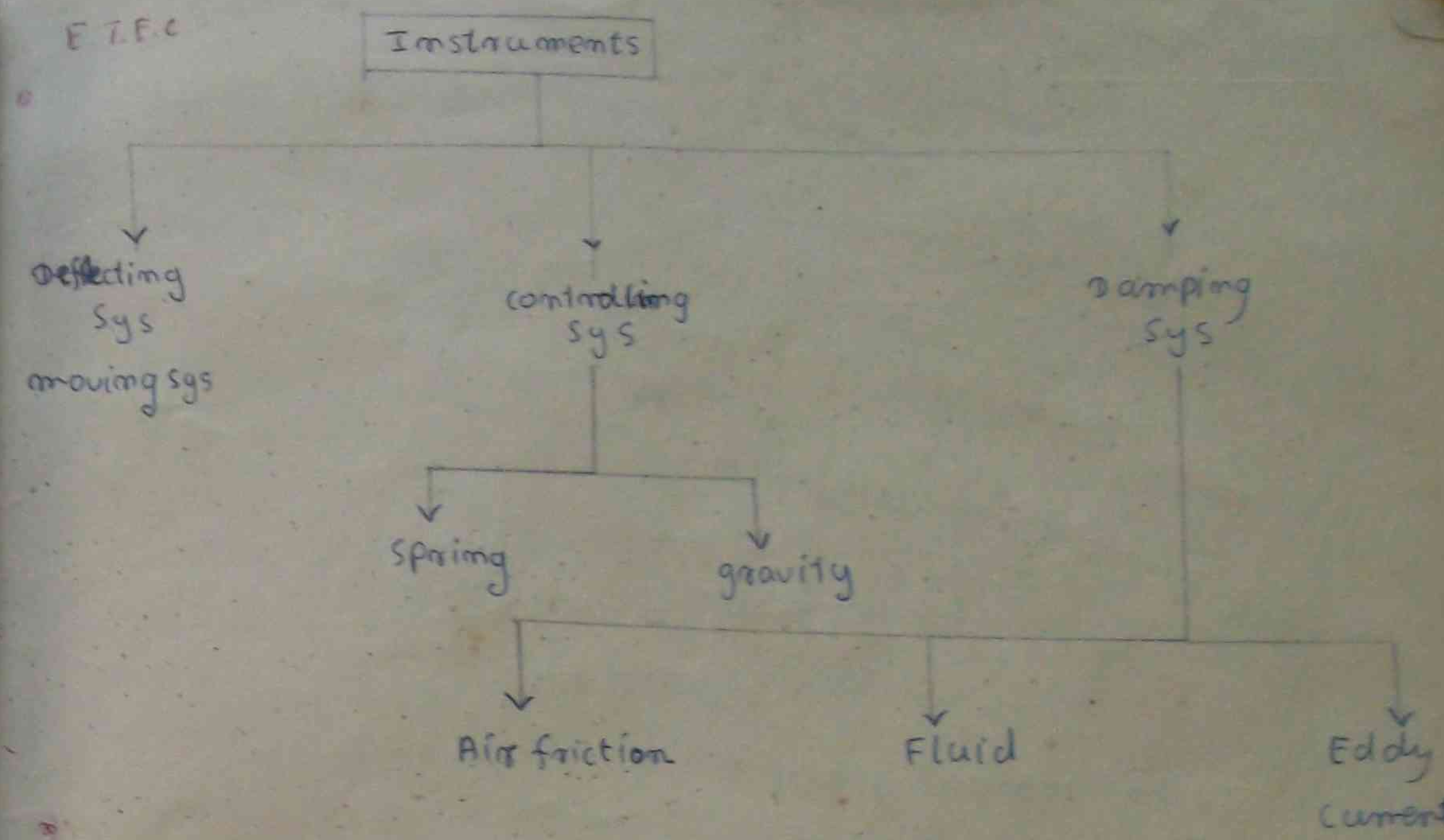
Recording meter

ထို meter များသည် လျှပ်စစ်ဓာတ်အားကို သတ်မှတ်ထားသော အချိန်အတွင်း graph paper တွင် မှတ်သား ပြထားသော meter များ ဖြစ်သည်။ ၎င်း meter တွင် 24 hour အတွက် ပေါ်ပြ မှတ်သားပေး၍ ပြောင်းလဲ ရွေ့လျားနေသော Pointer နှင့် graph စာရွက်တွင် မှတ်သားပြီး အကွက်ရှာ၍ မှတ်နိုင်အောင် ပြုလုပ်ထားပါ၏။

meter များ တွင်အသုံးပြုသော အကျိုးများ (utilizing effect)

စဉ်	အကျိုးအမျိုး	အသုံးပြု meter
1	D.C Magnet	Ammeter, voltmeter, watt meter, Integrating meter
2	Heating	Am meter
3	Chemical	Integrating meter kwh, AH
4	Electro-Static	voltmeter, Am meter, watt meter
5	Electro-magnetic	A, V, W meter Integrating meters

E.T.E.C



* Deflecting forces

Deflecting force ဆိုသည်မှာ တိုင်းတာလိုသော လျှပ်စစ်ပမာဏနှင့် အချိုးအစား ညီညီ ညွှန်ပြချောင်းကို ရွေ့လျားစေသော အားပင်ဖြစ်ပါ၏။ ၎င်းအား ရရှိအောင် စီစဉ်ထားသော အစိတ်အပိုင်းများကို moving system ဟုခေါ်ပါ၏။ ပွတ်တိုက်မှု လျော့စေရန် အတွက် jewel Bearing တပ်ဆင်ထားပါ၏။

* Controlling force

Controlling force ဆိုသည်မှာ တိုင်းတာလိုသော လျှပ်စစ်ပမာဏ အရ ညွှန်ပြချောင်းကို ထိန်းထိန်းသိမ်းသိမ်း ပြုလုပ်ပေးသော အားပင်ဖြစ်ပါ၏ controlling force သည် meter ညွှန်ပြနေသောအခါ deflecting force နှင့် ညီမျှ၍ ဆန့်ကျင်ဘက်သို့ သက်ရောက်ပါ၏။ ၎င်း force မရှိလျှင် meter ၏ ညွှန်ပြချောင်းသည် ပြန်လည်မရောက်ဘဲ ရှိနေမည်။ လျှပ်စစ်ပမာဏနှင့် မညီ ရွေ့လျားသွားမည်။ ထို့ပြင် "0" အမှတ်သို့ ပြန်လည်ရောက်ရှိနိုင်မည် မဟုတ်ပေ။

F_c = Controlling force

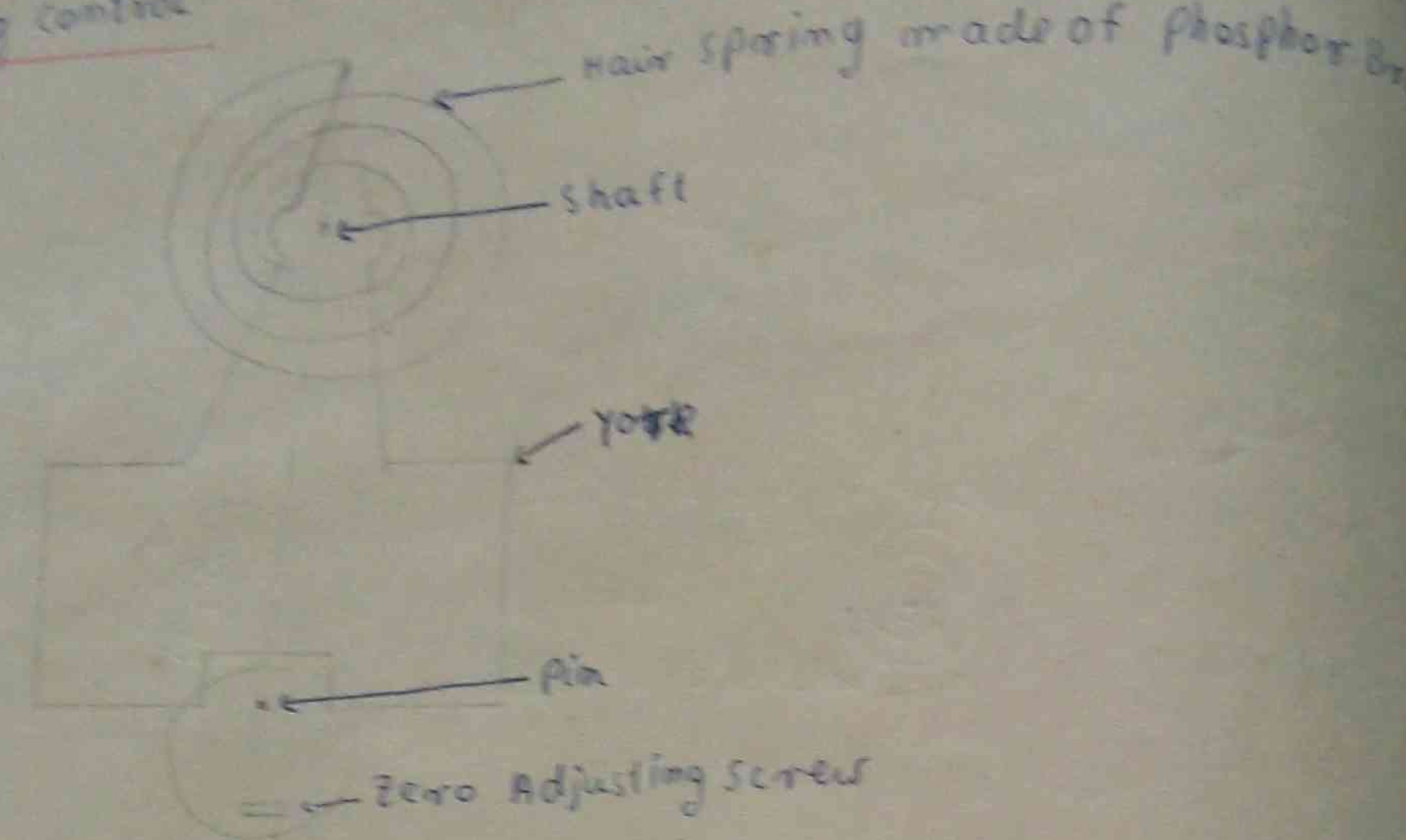
F_d = Deflecting force

မီတာညွှန်ပြနေသောအခါ $\boxed{F_c = F_d}$

$$\therefore F_c \times r = F_d \times r$$

$$\boxed{T_c = T_d}$$

Spring control



θ = angle of twist

T_C = controlling Torque

$T_C \propto \theta$

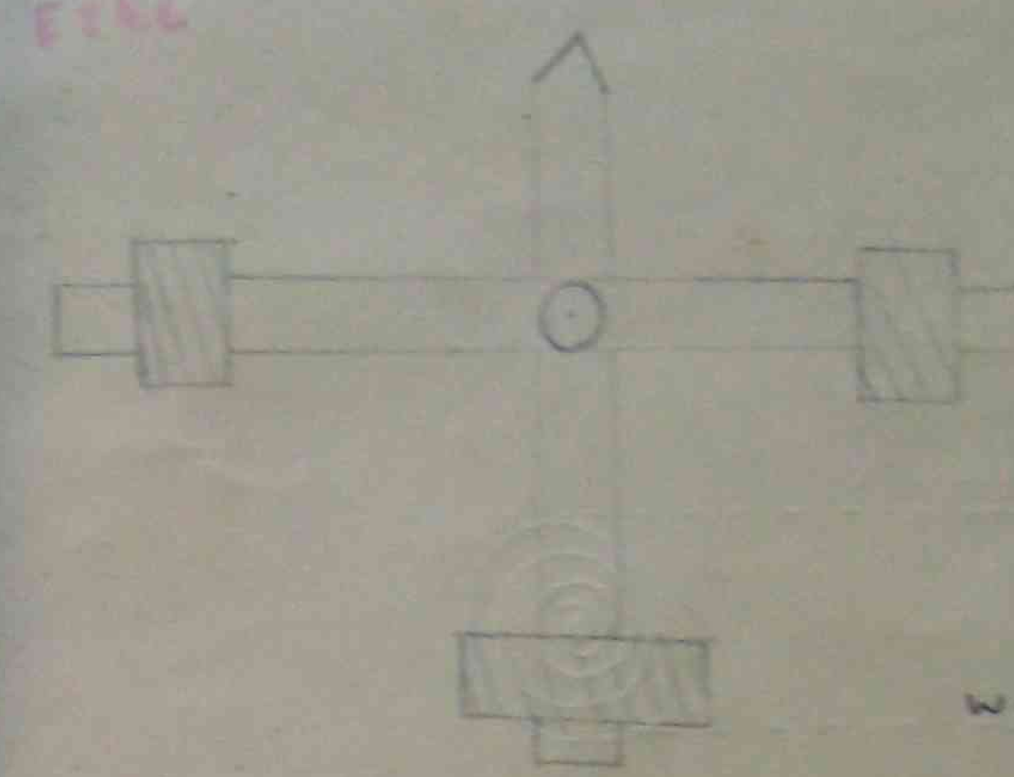
$\therefore \boxed{T_C = K\theta}$ (K = constant)

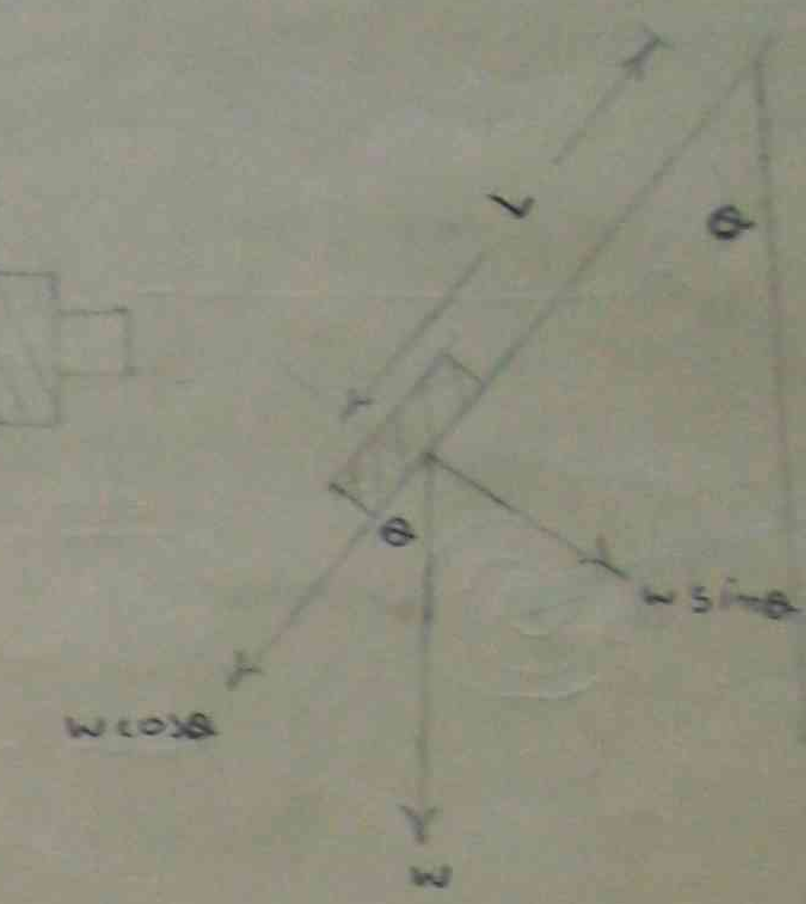
(2) Spring [illegible] Hair Spring [illegible] Spring [illegible] moving system [illegible] York [illegible]

Spring [illegible] Spring [illegible] angle [illegible] Hair spring , Suspension wire spring [illegible] equation [illegible]

Hair Spring [illegible] meter [illegible] moving system [illegible] current [illegible] current [illegible] current [illegible] conductor [illegible] 0 position [illegible] meter [illegible] spring [illegible]

Gravity control





$T_C = w\sin\theta \times L$

$= wL\sin\theta$

$= K\sin\theta$

$\therefore \boxed{T_C \propto \sin\theta}$

[illegible] $T_C = T_D$

$\therefore \boxed{T_D \propto \sin\theta}$

Gravity control [illegible] across [illegible] meter [illegible] controlling force [illegible]

[illegible] $w\cos\theta$ [illegible] $w\sin\theta$ [illegible] $w\sin\theta$ [illegible] $w\cos\theta$ [illegible] control [illegible] force [illegible] controlling Torque [illegible] constant [illegible] Torque [illegible] $\sin\theta$ [illegible]

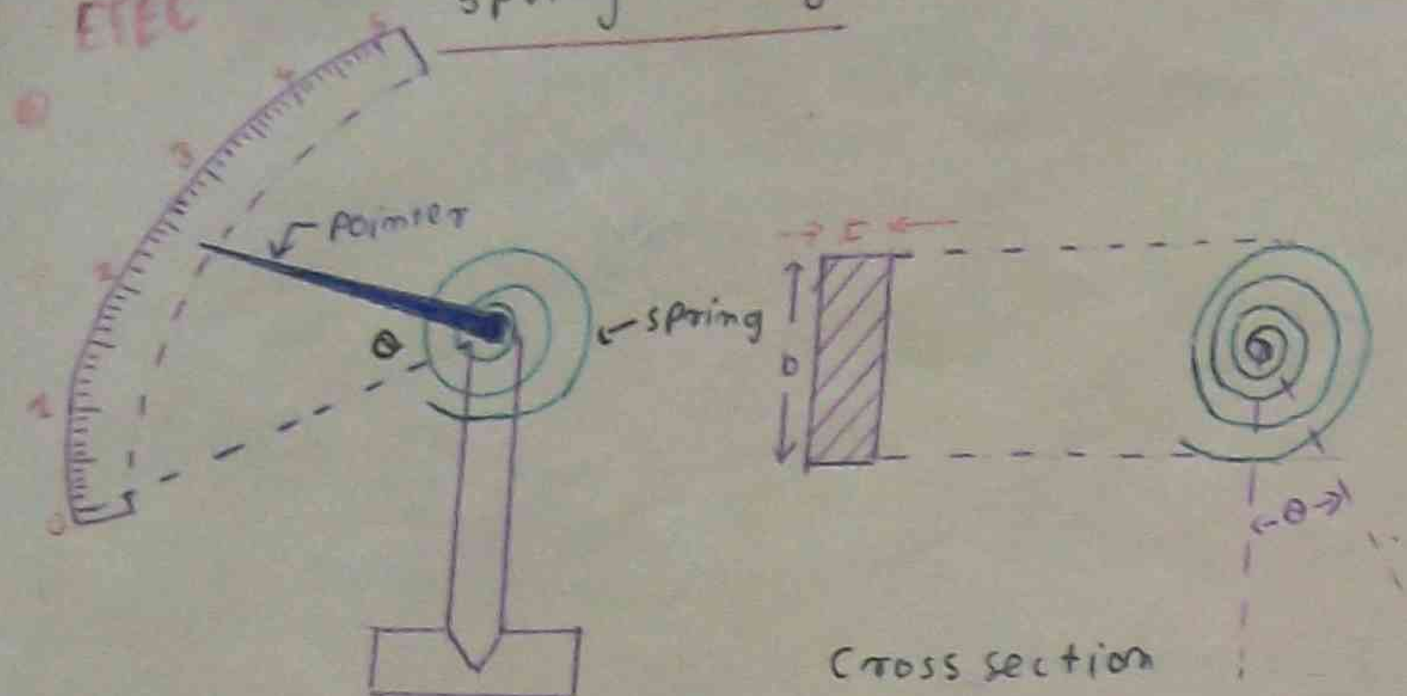
[illegible] vertical [illegible] level [illegible] gravity control Instrument [illegible]

③ [illegible]
④ [illegible]
⑤ [illegible]

([illegible])

ETEC

Spring Theory



$$* \quad \boxed{T = \frac{E b t^3 \times \theta}{12L}}$$

where, T = controlling Torque

E = young modulus in ($lb\text{-}in^2$)

b = depth OR width of spring in (in)

t = Radial thickness in (in)

L = length in (in)

θ = Angle in (Radian) * [illegible]

$$K \text{ (constant)} = \frac{Ebt^3}{12L} \text{ [illegible]}$$

$$\boxed{T_c \propto \theta}$$

Spring design [illegible]

$$** \quad \boxed{\theta = \frac{2L f_{max}}{tE}}$$

f_{max} = maximum stress in ($lb\text{-}in^2$)

[illegible]

1 $\boxed{\theta = 1.25 \frac{TL}{EI}}$ — I = amperes

2 $\boxed{I = \frac{bt^3}{12}}$

$$\boxed{\text{workstore OR Energy store in spring} = \frac{1}{2} T\theta} \ \text{in-lb} *$$

ETEC

ပုံ 1 - Flat spring [illegible] $\frac{1}{4}''$ [illegible] 0.01'' [illegible] $f_{max} = 120{,}000$ psi [illegible] Bending moment [illegible] Torque [illegible] turn [illegible] Energy store [illegible] ($E = 30 \times 10^6$ psi)

[illegible]

$b = \frac{1}{4}''$, $t = 0.01''$, $L = 8 \times 12''$, $f_{max} = 120{,}000$ psi *

$E = 30 \times 10^6$ psi , $f_{max} = \frac{12T}{bt^2}$

$$\therefore T = \frac{f_{max}\, bt^2}{12} = \frac{120{,}000 \times 1 \times 0.01 \times 0.01}{4 \times 12} = 0.25 \text{ in lbs} \quad \text{Ans 1}$$

$$\theta = \frac{2L F_{max}}{tE} = \frac{2 \times 8 \times 12 \times 120{,}000}{0.01 \times 30 \times 10^6} = \frac{384}{5} \text{ radian}$$

2π radian = 1 turn

$$\frac{384}{3} \text{ radian} = \frac{384}{5} \times \frac{1}{2\pi} = 12.5 \text{ turns} \quad \text{Ans 2}$$

$$\text{Energy store} = \frac{1}{2} T\theta = \frac{1}{2} \times 0.25 \times \frac{384}{5} = 9.6 \text{ in-lbs} \quad \text{Ans 3}$$

[illegible] ETEC

① 1 inch [illegible] 0.02 inch [illegible] spring [illegible] 6 ft-lb energy [illegible] store [illegible] stress 120000 psi [illegible] Torque [illegible] Turns [illegible] ($E = 30 \times 10^6$ psi)

b = 1'' t = .02'' Energy store = 6 × 12 in-lb f_{max} = 120000 psi

L = ? T = ? Turns = ? $E = 30 \times 10^6$ psi

* T [illegible]

$$T = \quad f_{max} = \frac{12T}{bt^2}$$

$$120000 = \frac{12 \times T}{1 \times .02 \times .02}$$

$$\therefore T = \frac{120000 \times .02 \times .02}{12} \text{ in-lbs}$$

$$= 4 \text{ in-lbs}$$

$$6\times 12 = \frac{1}{2}\times 4^2\times\theta$$

$\therefore\ \theta = 36$ radians

2π radians = 1 turns

$36 \quad \_\_\_\_ ? = \frac{36}{2\pi} = 5.727$ turns

$$\theta = \frac{2L\, f_{max}}{tE}$$

$$36 = \frac{2\times L\times 120000}{.02\times 30\times 10^6}$$

$$L = \frac{36\times .02\times 30\times 10^6}{2\times 120000} =$$

$$L = \frac{36^3\times 2\times 10^{-2}\times 3\times 10^7}{2\times 12\times 10^4}$$

$= 3\times 3\times 10$

$= 90$ inches

$=$

$\therefore$ (Ans) Torque = 4 in lbs

Length = 90 inches

Turns = 5.727

② meter တခုတွင် ပါသော spring ၏ အလျားမှာ 370 mm အထူ 0.073 mm အနံ 0.51 mm ရှိပြီး Phosphor Bronze ဖြင့်ပြုလုပ်ထားသော spring တွင် $E = 1.15\times 10^6$ kilo/cm^2 ရှိ၏ 90° ပေါ်အောင် လိုအပ်သော Torque ကို gm-cm ဖြင့် ရှာပါ။

10 mm = 1 cm

100 cm = 1 m

$l = 370$ mm $= 37$ cms

$t = 0.073$ mm $= \frac{0.073}{10}$ cms

$b = 0.51$ mm $= \frac{0.51}{10}$ cms

$E = 1.15\times 10^6\times 1000$ gms/cm^2

$\theta = 90^\circ$

π radian $= 180^\circ \quad \therefore 90^\circ = \pi/2$ radians $\quad \therefore \theta = \pi/2$

$$T = \frac{E b t^3\times\theta}{12L}$$

$$T = \frac{1.15\times 10^6\times 1000\times \frac{0.51}{10}\times\frac{0.073}{10}\times\frac{0.073}{10}\times\frac{0.073}{10}\times\frac{\pi}{2}}{12\times 37}$$

$$T = \frac{1.15\times 10^6\times 1000\times 0.51\times 0.073\times 0.073\times 0.073\times\pi}{10\times 10\times 10\times 10\times 2\times 12\times 37}$$

$$T = \frac{1.15\times 10^9\times 51\times 10^{-2}\times 73\times 10^{-3}\times 73\times 10^{-3}\times 73\times 10^{-3}\times\pi}{}$$

$$= \frac{1.15\times 10^9\times 51\times 73\times 73\times 73\times\pi\times 10}{37\times 2\times 12\times 10^4}$$

$$= \frac{1.15\times 51\times 73\times 73\times 73\times\pi\times 10^{-2}}{37\times 2\times 12\times 10^4} =$$

* slide

$$= \frac{1.15\times 51\times 73\times 73\times 73\times\pi}{37\times 2\times 12\times 10^6}\ \text{gm-cm}$$

$= .08077\times 10^{-6}$ gm-cm (Log) gm-cm $\quad .0845$ gm-cm slide

**

၄၀၂ moving coil meter တခု၏ ပြင်းအားသည် ... voltage သည် deflection Torque နှင့် တိုက်ရိုက်အချိုးကျသည်။ ထို voltmeter ကို 24 volts နှင့် ဆက်သွယ်ပါက 90° deflection ဖြစ်သည်။ 8 volts ဖြင့် ဆက်သွယ်လျှင် (က) spring control (ခ) Gravity control တို့ကို အသုံးပြု၍ ထောင့်ကို ရှာပါ။

ပေးထားချက် - $T_D \propto V$, 24 V, 90°, 8 V

ရှာရန် - $T_D\propto V \quad \therefore T_D = KV$ (K = ကိန်းသေ)

(က) for spring control

$T_C \propto \theta, \quad \therefore T_C = K_s\theta \quad (K_s = \text{constant})$

ထောင့်ဖြစ်ပေါ်သည့်အခါ $T_D = T_C$

$\therefore K\times 24 = K_s\times 90^\circ$ — ①

$K\times 8 = K_s\times\theta$ — ②

$$① \div ② \quad \frac{K\,24}{K\,8} = \frac{K_s\,90^\circ}{K_s\,\theta}$$

$3\theta = 90^\circ \quad \therefore \theta = 30^\circ$

(ခ) $T_C \propto \sin\theta$

$\therefore T_C = K_g\sin\theta$

ထောင့်ဖြစ်ပေါ်စဉ် $T_D = T_C$

$KV = K_g\sin\theta$

$\therefore K\times 24 = K_g\times\sin 90^\circ$ — ③

$K\times 8 = K_g\times\sin\theta$ — ④

$$③\div ④ \quad \frac{K\times 24}{K\times 8} = \frac{K_g\sin 90^\circ}{K_g\sin\theta}$$

$3\sin\theta = 1 \quad \sin\theta = 1/3 \quad \therefore\ \theta = 19^\circ 48'$

[illegible]

① null reading [illegible] Torsion head [illegible] moving coil [illegible] Deflecting Torque [illegible] voltage [illegible] 44 volts [illegible] 90° Deflection [illegible] voltmeter [illegible] 30 volts [illegible] (က) spring control (ခ) gravity control [illegible] Deflecting angle [illegible]

② Instrument [illegible] Deflection Torque [illegible] meter [illegible] 90° [illegible] Imax [illegible] spring control Instrament [illegible] gravity control [illegible] spring control [illegible] meter [illegible] Imax [illegible]

① $T_D \propto V$

$T_D = KV$ (K = constant)

② spring control $T_C \propto \theta$

$T_C = K_S\theta$

[illegible] $T_C = T_D$

$\therefore KV = K_S\theta$

$K \times 45 = K_S \times 90$ —①

$K \times 30 = K_S \times \theta$ —②

①÷② $\frac{45}{30} = \frac{90}{\theta}$

$\theta = \frac{2700}{45} = 60°$

gravity control $T_D = KV$

$T_C \propto \sin\theta$

$T_C = K_g \sin\theta$

$T_C = T_D \therefore KV = K_g \sin\theta$

$45K = K_g \times \sin 90$

$\therefore 45K = K_g$ —①

$30K = K_g \sin\theta_2$ —②

①÷② $\frac{45}{30} = \frac{1}{\sin\theta_2}$

$\sin\theta_2 = \frac{30}{45} = \frac{2}{3}$

② spring control

$T_D \propto I$

$T_D = KI$ (K = constant)

$T_C \propto \theta$

$T_C = K_S\theta$

$T_D = T_C$

$\therefore KI = K_S\theta$

$K \times I_{max} = K_S \times 90$ —①

$K \times \frac{I_{max}}{2} = K_S\,\theta$ —②

①÷② $\frac{I_{max}}{\frac{I_{max}}{2}} = \frac{90}{\theta}$

$2\theta = 90 \quad \therefore \theta = 45°$

gravity control

$T_D \propto I \quad \therefore T_D = KI$ (K = constant)

$T_C \propto \sin\theta \quad \therefore T_C = K_g \sin\theta$ (K_g = constant)

[illegible] $T_D = T_C$

$\therefore KI = K_g \sin\theta$

$K I_{max} = K_g \sin 90$

$K I_{max} = K_g$ —①

$K \frac{I_{max}}{2} = K_g \sin\theta$ —②

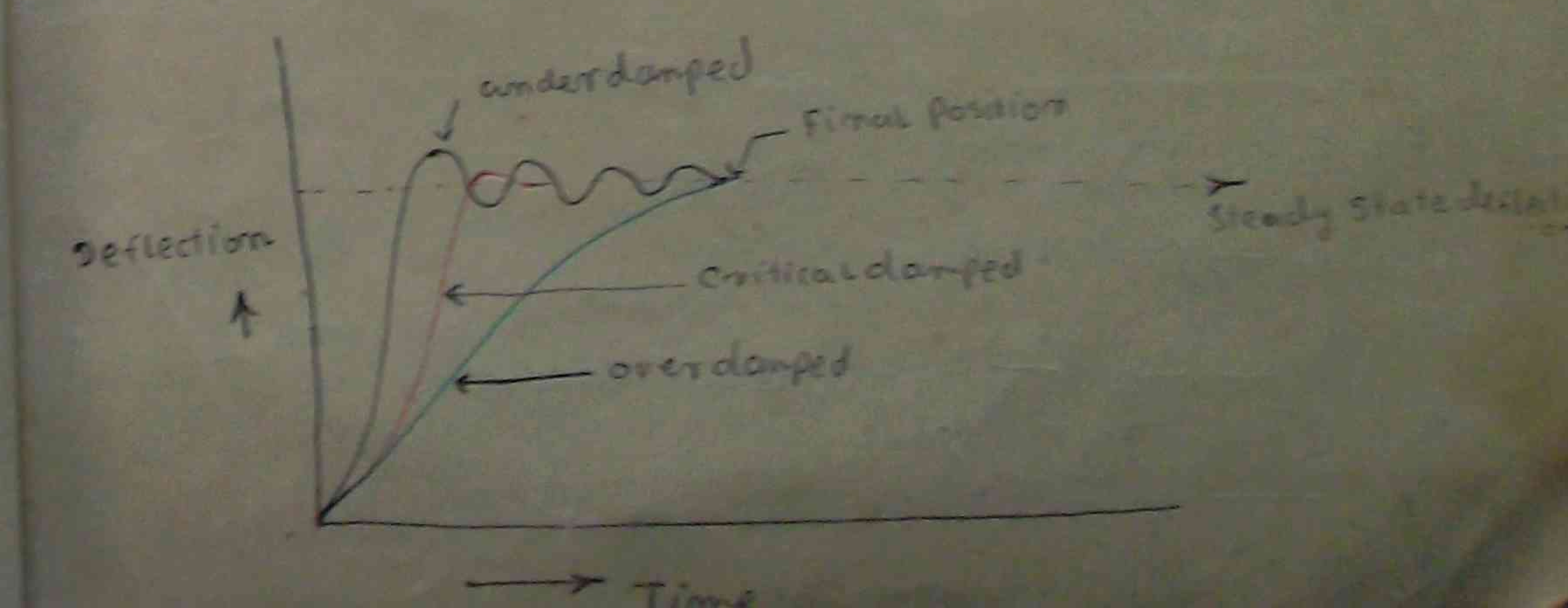
①÷② $\frac{I_{max}}{\frac{I_{max}}{2}} = \frac{K_g}{K_g \sin\theta}$

$2\sin\theta = 1 \quad \sin\theta = \frac{1}{2}$

$\therefore \theta = 30°$

ETG Damping force (meter [illegible])

(Damping force [illegible] meter [illegible] Relay [illegible] point [illegible] Damping force [illegible] pointer [illegible])



(ဂ) under damped or oscillating case

[illegible] meter [illegible] pointer [illegible]

[illegible]

(ဃ) Over damped case

[illegible] meter [illegible]

[illegible]

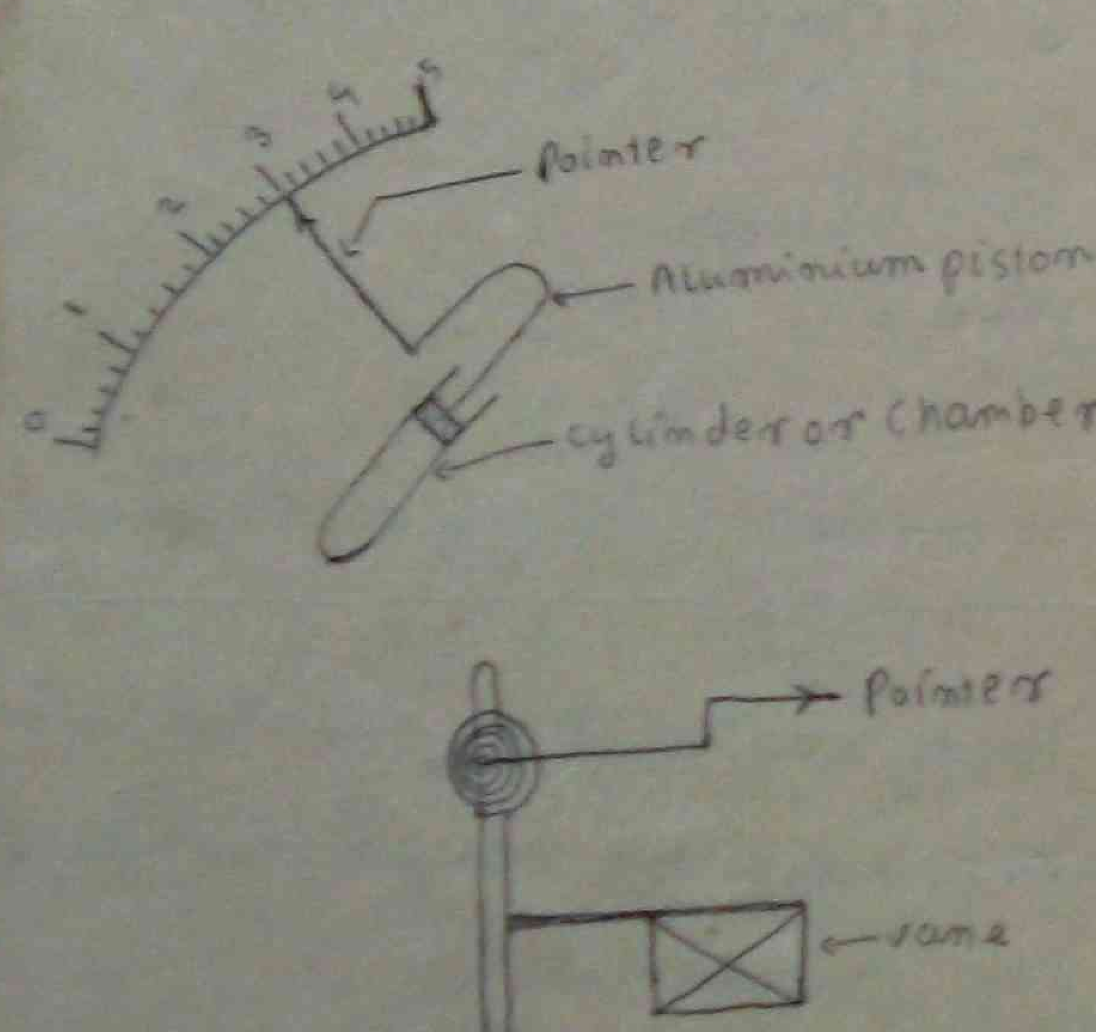
(င) Critical damped case

[illegible] meter [illegible] damping force [illegible]

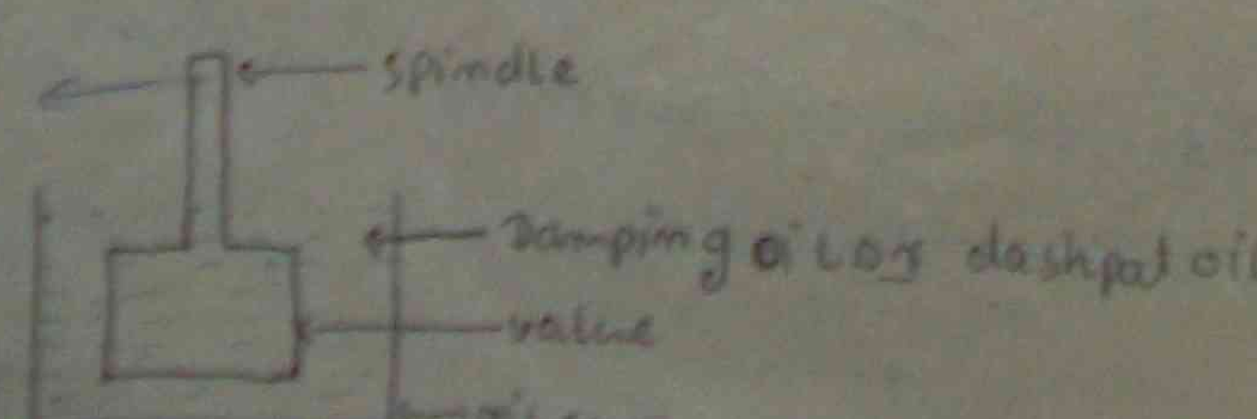
[illegible]

Damping system

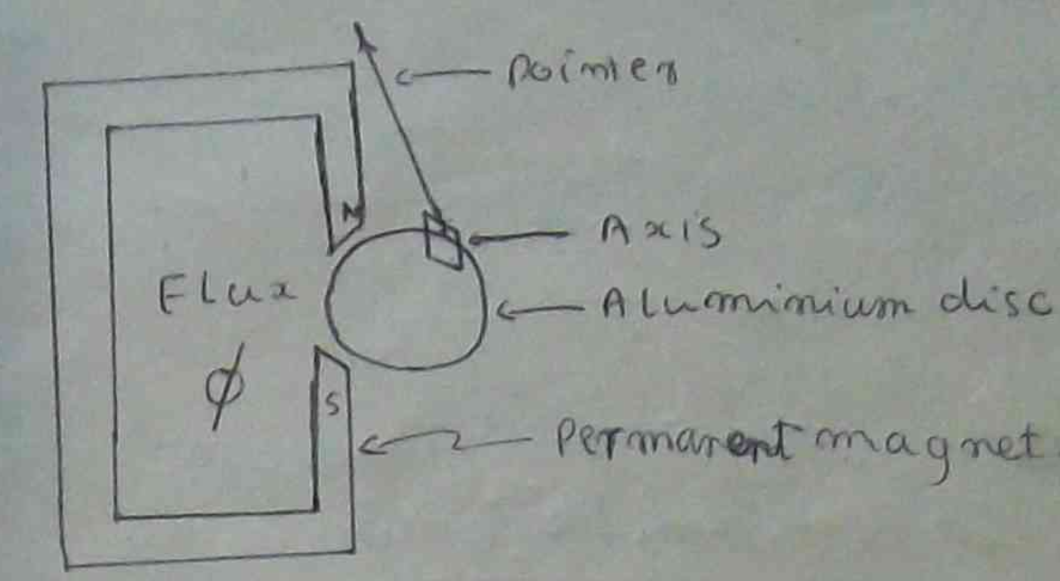
(a) Air friction Damping



(b) Fluid friction Damping



(c) Eddy current damping



(က) Air friction damping

[illegible]

piston [illegible] chamber [illegible] cylinder [illegible] cylinder

[illegible] pointer [illegible]

piston [illegible] cylinder (or) chamber [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

(ခ) Fluid friction Damping

[illegible] Damping oil

[illegible] dash pot oil [illegible]

[illegible] Damping system [illegible] meter [illegible]

[illegible] meter [illegible]

[illegible]

[illegible] motor starter [illegible] oil circuit

Breaker (OCB) [illegible]

(ဂ) Eddy current damping

[illegible] Aluminium disc [illegible] permanent magnet [illegible]

[illegible] Aluminium [illegible]

[illegible] Aluminium [illegible]

[illegible] Aluminium

disc [illegible] instrument [illegible] current

[illegible] field [illegible] field [illegible] Damping
[illegible]
force [illegible]
Aluminium [illegible]

Prob

meter [illegible] deflecting Torque [illegible] Torque [illegible] meter [illegible] meter [illegible] deflection [illegible] maximum current [illegible] meter [illegible] current [illegible] Gravity control [illegible] meter [illegible] current [illegible] maximum current angle of deflection ~~44~~ 48 [illegible] %[illegible]

$T_c \propto \sin\theta$

$T_d \propto I$ $\quad$ ~~$T_d = T_c$~~

$T_d = kI$ $\quad$ $\therefore T_c = k_2 \sin\theta$

[illegible] meter [illegible] $T_d = T_c$

$\therefore kI = k_2 \sin\theta$

$k \times I_1 = k_2 \times \sin 90$ —— (1)

$k \times I_2 = k_2 \times \sin 40°48'$ —— (2)

$\frac{I_1}{I_2} = \frac{\sin 90}{\sin 40°48'}$

$\frac{I_1}{I_2} = \frac{1}{.256}$

$\therefore$ ~~I .256 $I_1 = I_2$~~

~~100 ? = $\frac{100}{.256}$~~ =

$.256\ I_1 = I_2$

I_1 [illegible] $\quad$ $I_2 = .256$

—100 —————— ? = 25.6 %

(Ans)

[illegible] 0.2 [illegible] 0.005 [illegible]

Prob

[illegible] 0.005 [illegible] 0.2" [illegible] Hairspring [illegible] maximum Stress [illegible] 10^5 lb/in² [illegible] Strain Energy [illegible] 3.125 lb/in² [illegible] modulus of Elasticity 30×10^6 lb/in² [illegible] Hair spring [illegible] (a) Torque (b) Deflecting angle (c) length [illegible]

Prob

meter [illegible] Hairspring [illegible] 2.5 inches [illegible] 0.0025 inches × 0.5×10^{-5} inches [illegible] Hairspring [illegible] Young mod E [illegible] 0.376 lb/in² [illegible] meter deflection [illegible] controlling Torque [illegible] ~~4.1~~ × 4.1×10^{-20} lb-inches [illegible] deflection [illegible] Degree [illegible]

(1) $b = .005''$ $\quad$ $E_S = 3.125$ lb/in² $\quad$ $T = \frac{Ebt^3\theta}{12L}$

$t = 0.2''$ $\quad$ $E = 30\times10^6$ lb/in² $\quad$ $f_{max} = \frac{12T}{bt^2}$

$f_{max} = 10^5$ lb/in² $\quad$ $T = ?$ $\quad$ $\theta = \frac{2Lf_{max}}{tE}$

$\theta = ?$ $\quad L = ?$

$f_{max} = \frac{12T}{bt^2}$

$\frac{bt^2 f_{max}}{12} = T$

$\therefore T = \frac{.005 \times (0.2)^2 \times 10^5}{12}$

$T = \frac{5\times10^{-3} \times 4\times10^{-2} \times 10^5}{12} = \frac{20}{12} = 1.6$ lb-in

$E_S = \frac{1}{2} T\theta$

$3.125 = \frac{1}{2} \times \frac{5}{3} \times \theta$

$\frac{3.125 \times 6}{5} = \theta$

$\theta = 3.74$ radians

$\therefore \theta = \frac{2Lf_{max}}{tE}$

$3.74 = \frac{2 \times L \times 10^5}{0.2 \times 30 \times 10^6}$

$3.74 = \frac{2L}{2\times10^{-1} \times 3 \times 10 \times 10}$

$\therefore 30 \times 3.7 = L$ $\quad$ $L = 112$ inches

(2) $L = 2.5''$ $\quad b = .0025''$ $\quad t = 0.5\times10^{-5}$

$E = 0.376$ lb/in² $\quad T = 4.1\times10^{-20}$ lb-inches

$\theta = ?$

$\theta = \frac{2L f_{max}}{tE}$ $\quad\Big|\quad$ $\theta = \frac{2L \times 12T}{bt^3 \times E}$

$\theta = \frac{2L \times \frac{12T}{bt^2}}{tE}$

$\theta = T = \frac{Ebt^3\theta}{12L}$

$\theta = \frac{12LT}{Ebt^3}$

$\theta = \frac{12 \times 2.5 \times 4.1 \times 10^{-20}}{0.376 \times .0025 \times (0.5 \times 10^{-5})^3}$

$\theta = \frac{12 \times 25 \times \cancel{10} \times 4.1 \times \cancel{10} \times 10^{-20} \times 10^3 \times 10^4}{376 \times \cancel{10}\, 25 \times (\cancel{5} \times 10^{-6})^3}$

$\theta = \frac{12 \times 2.5 \times 4.1 \times 10^{-13}}{376 \times 25 \times 125 \times 10^{-18}}$

$\theta = \frac{12 \times 25 \times 41 \times 10^{-2} \times 10^{-13}}{376 \times 25 \times 125 \times 10^{-18}}$

$\theta = \frac{12 \times \cancel{25} \times 41}{376 \times \cancel{25} \times 125} \times 10^3$

$\theta = \frac{492}{376 \times 125}\ 10^3$

$= \frac{1.31}{125} \times 10^3$

$= \frac{131}{125} \times 10^3 \times 10^{-2} = 14.2$

π radian $= 180^\circ$

$14.2 \quad = ? = \frac{180 \times 14.2}{\pi} = 816^\circ$

(2) ~~L = 2.5"~~ $b = 0.2"$ $\quad \delta_{max} = 10^5$

$t = 0.005"$ $\quad F_s = 3.125$

$E = 30 \times 10^6 \quad T = ? \quad \theta = ? \quad L = ?$

$\delta_{max} = \frac{12T}{bt^2}$

$10^5 = \frac{12 \times T}{0.2 \times (.005)^2}$

$T = \frac{10^5 \times 0.2 \times .005 \times .005}{12}$

$F_s = \frac{1}{2} T\theta$

$3.125 = \frac{1}{2} \times 3.46 \times \theta$

$\theta = \frac{2 \times 3.125}{3.46} = \frac{\cancel{18.2}}{1.82}$ radian

$\theta = \frac{2L f_{max}}{tE}$

$1.82 = \frac{2 \times L \times 10^5}{.005 \times 30 \times 10^6}$

$\frac{1.82 \times .005 \times 30 \times 10^6}{2 \times 10^5} = L$

$10^7 \quad \frac{\cancel{182}^{91} \times 3 \times 5}{\cancel{2}} \times 10^{-8} = L$

$L = 1365 \times 10^{-3}$ inches

$\equiv 1.36$ inches

(3) ~~θ~~ E $\quad L = 2.5" \quad b = .0025" \quad t = 0.5 \times 10^{-5}"$

$E = 0.376\ lb/in^2 \quad T = 4.1 \times 10^{-20}$

~~θ~~ $T = \frac{Ebt^3\theta}{12L}$

$\theta = \frac{12LT}{Ebt^3}$

$\theta = \frac{12 \times 2.5 \times 4.1 \times 10^{-20}}{0.376 \times .0025 \times 0.5 \times 0.5 \times 0.5 \times 10^{-15}}$

$\theta = \frac{12 \times 25 \times 41}{376 \times 25 \times 125} \times \frac{10^{-22}}{10^{-25}}$

$= \frac{12 \times \cancel{25} \times 41 \times 10^3}{376 \times \cancel{25} \times 125} = \frac{492 \times 10^3}{376 \times 125}$

$= \frac{180}{\pi} \times \frac{492}{376 \times 125} \times 10^3$

$= 5.99^\circ$ degree

↑

√(3) Prob meter [illegible] Hairspring [illegible] 2.5" [illegible] .0025" x 0.5x10^-5 inches [illegible] Hairspring [illegible] Young modulus [illegible] 0.376 lb/in² [illegible] meter Deflection [illegible] controlling Torque [illegible] 4.1 x 10^-20" [illegible] Deflection [illegible] Degree [illegible]

$t = .005''$ $b = 0.1$

$T = ?$ $\theta = ?$ $L = ?$

$$f_{max} = \frac{12T}{bt^2}$$

$$T = \frac{bt^2 f_{max}}{12}$$

$$T = \frac{0.2 \times .005 \times .005 \times 10^5}{12}$$

$$= \frac{50}{1200} = .041 \text{ lb-in}$$

$$\theta = \frac{2L f_{max}}{tE} \qquad F_s = \tfrac{1}{2} T\theta$$

$$3.125 = \tfrac{1}{2} \times .041 \times \theta$$

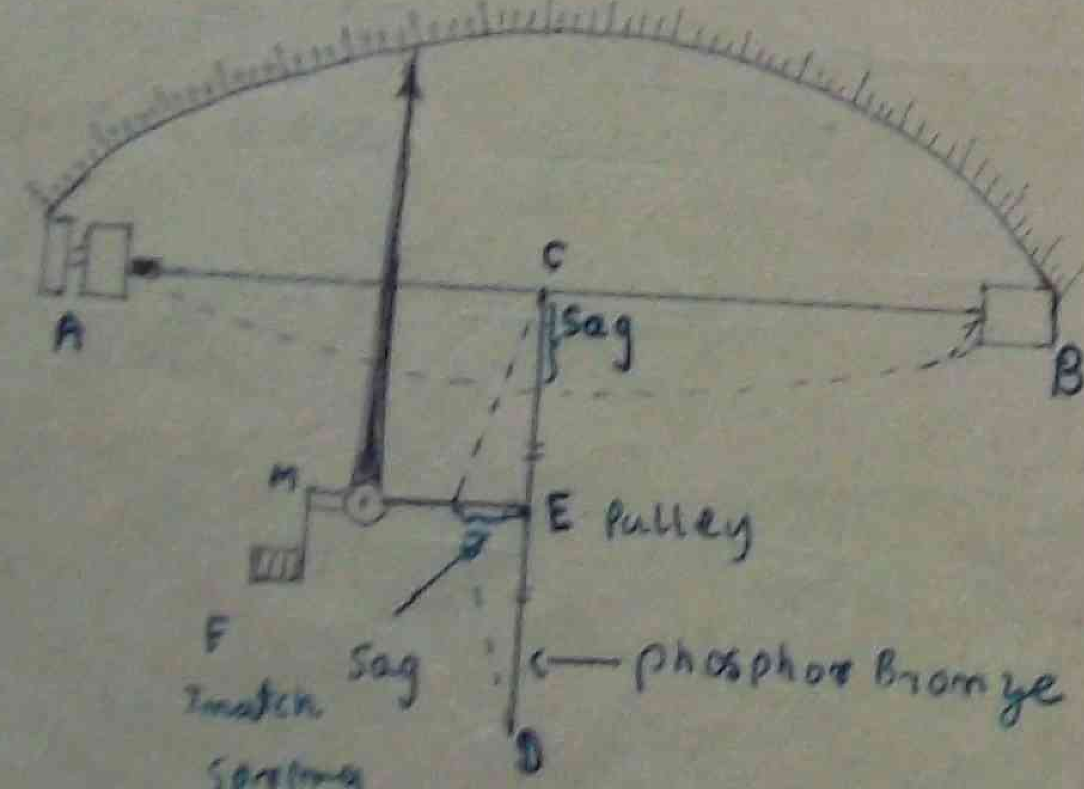
$$\theta = \frac{6.25}{.041} = 152.1 \text{ radian}$$

$$f_{max} = \frac{2L f_{max}}{tE}$$

$$152.1 \times 10^5 = \frac{2 \times L \times 10^5}{.005 \times 30 \times 10^6}$$

$$L = \frac{152.1 \times .005 \times 30 \times 10^6}{2 \times 10^5} = \frac{152.1 \times 5 \times 3}{200} = 11.42''$$

Double Sag Hot wire Instrument

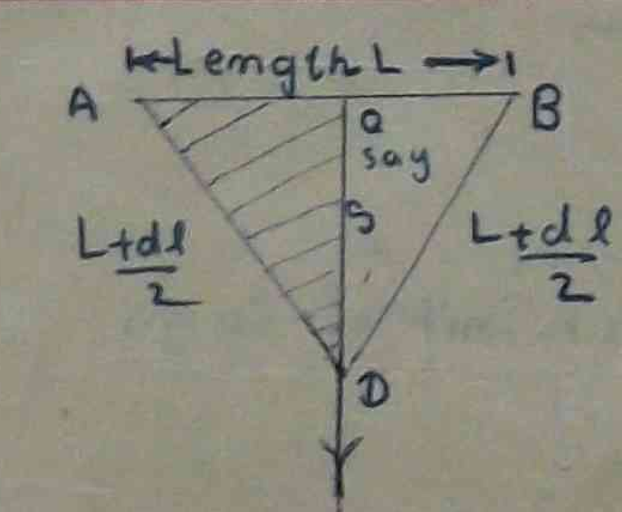


Hot wire Instrument [illegible] 6" [illegible] wire AB [illegible] A [illegible] spring [illegible] screw [illegible] screw [illegible] A [illegible] B [illegible] meter [illegible] Terminal [illegible] meter [illegible] Base plate [illegible]

E [illegible] pulley [illegible] watch spring F [illegible] pulley [illegible] Eddy current Damping [illegible] wire AB [illegible] wire [illegible] Sag [illegible] sag [illegible] Sag [illegible] Double sag Hot wire Instrument [illegible] watch spring F [illegible] controlling Force [illegible] Sag [illegible] pulley [illegible] sag [illegible] wire [illegible] "0" [illegible]

[illegible] meter [illegible] watt [illegible] I^2 [illegible] scale [illegible] AC, DC [illegible] meter [illegible] oxygen [illegible] "0" [illegible]

Magnification of Expansion



S = sag Produced

dl = Expanded length

$$\boxed{\therefore M = \frac{S}{dl}}$$

magnification [illegible] sag (S) [illegible]

[illegible] Hot wire instrument [illegible] AB [illegible] t°C [illegible] ADB [illegible] wire [illegible] α [illegible] /°C/unit [illegible]

$$dl = \alpha t L$$ [illegible]

α = [illegible] t = temp in °C L = original Length.

$$\frac{L^2}{4}+\frac{2Ld\ell}{4}+\frac{d\ell^2}{4}=\frac{L^2}{4}+S^2$$

$\frac{d\ell^2}{4}$ [illegible] neglect [illegible]

$$S^2=\frac{Ld\ell}{2}$$

$$\therefore \boxed{S=\sqrt{\frac{Ld\ell}{2}}}$$

[illegible] $m=\frac{S}{d\ell}$ $\therefore m=\frac{\sqrt{\frac{Ld\ell}{2}}}{d\ell}=\sqrt{\frac{Ld\ell}{2d\ell^2}}$

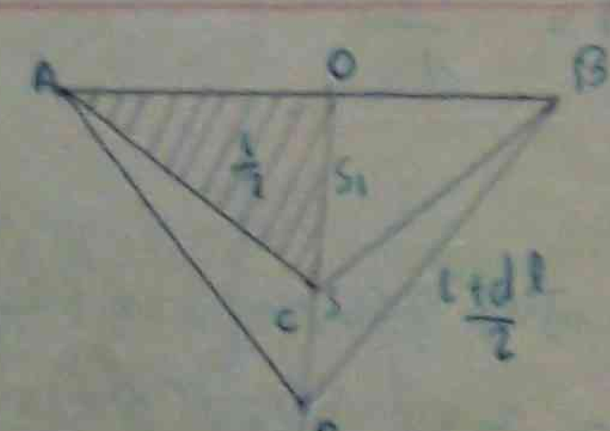
[illegible] m: $\boxed{m=\sqrt{\frac{L}{2d\ell}}}$

[illegible] $d\ell=\alpha t L \rightarrow$

$$\therefore m=\sqrt{\frac{L}{2\alpha t L}}$$

$$\therefore \boxed{m=\sqrt{\frac{1}{2\alpha t}}}$$

magnification of expansion (with initial sag)



S_1 = initial sag

S = sag

In $\Delta AOD \rightarrow AD^2=AO^2+DO^2$

$=AO^2+(S+S_1)^2$

In $\Delta AOC \rightarrow AC^2=AO^2+OC^2$

$=AO^2+S_1^2$

$\therefore AD^2-AC^2=(S+S_1)^2-S_1^2$

$\left(\frac{L+d\ell}{2}\right)^2-\left(\frac{L}{2}\right)^2=(S+S_1)^2-S_1^2$

$\frac{L^2}{4}+\frac{2Ld\ell}{4}+\frac{d\ell^2}{4}=\frac{L+d\ell}{2}+S_1^2$

① Hot wire [illegible] 10cms [illegible] 16×10^{-6}/c/unit [illegible] sag [illegible] 212F [illegible] magnification [illegible]

② Bed side Heater [illegible] Hot wire [illegible] 10cms [illegible] 16×10^{-6}/c/cm [illegible] Hot wire [illegible] sag [illegible] 0.2cms [illegible] magnification [illegible] 10 [illegible] magnification [illegible] F [illegible]

S_1 [illegible]

① $L=10\,cms$ $\alpha=16\times10^{-6}$ ~~t = 212~~

$S_1=.1\,cms$ $t=212^\circ F$

$C=\frac{5}{9}(F-32)$

$C=\frac{5}{9}(212-32)$

$C=\frac{5}{9}\times180=100^\circ C$

$d\ell=\alpha t L$

$d\ell=16\times10^{-6}\times100\times10$

$=16\times10^{-3}$

$$S=\sqrt{\frac{L\times d\ell}{2}}=\sqrt{\frac{10\times16\times10^{-3}}{2}}$$

$=\sqrt{8\times10^{-2}}$

$=10^{-1}\sqrt{8}$

$m=\frac{S}{d\ell}=\frac{10^{-1}\sqrt{8}}{16\times10^{-3}}$

$=\frac{\sqrt{8}}{16}\times100$

$=\frac{2\sqrt{2}}{16}\times100=\frac{141.4}{8}$

$=17.6$

$s = -s \pm \sqrt{\ldots}$

$s = -.1 \pm \sqrt{10\alpha \ldots + (.1)^2}$

$L = 20\,cms \quad \alpha = 16\times10^{-6} \quad s_1 = 0.3\,cms$

(2) $m = 10 \quad t = ?$

$m = \frac{s}{dl}$

$10 = \frac{s}{dl}$

$s = 10\,dl$

$s = 10 \times \alpha t L$

(1) $m = \sqrt{\frac{1}{2\alpha t}}$

$m^2 = \frac{1}{2\alpha t}$

$2\alpha t = \frac{1}{m^2}$

$2\times16\times10^{-6}\times t = \frac{1}{100}$

$t = \frac{1}{32\times10^{-4}}$

$t = \frac{10000}{32} = 312°F$

$C = \frac{5}{9}(312 - 32)$

$= \frac{5}{9}\times 280 = \frac{1400}{9} = 155.056$

[illegible]

(1) $s = -s_1 \pm \sqrt{\frac{Ldl}{2} + s_1^2}$

$s = -0.1 \pm \sqrt{\frac{10\times16\times10^{-3}}{2} + (.1)^2}$

$s = -0.1 \pm \sqrt{8\times10^{-2} + 10^{-2}}$

$s = -0.1 \pm \sqrt{0.09}$

$s = -0.1 \pm 0.3 \quad \therefore s = 0.2$

$m = \frac{s}{dl} = \frac{0.2}{10\times16\times10^{-6}\times100} = \frac{10^{-6}}{800} = 125 \; \frac{1000}{8} = 1250$

$m = \frac{-.2}{10\times16\times100\times10^{-6}} = 12.5$

(2) $L = 20\,cms \quad \alpha = 16\times10^{-6} \quad s_1 = 0.3\,cms$

$m = 10 \quad . \quad t = ?$

$m = \frac{s}{dl}$

$m = \frac{-s_1 \pm \sqrt{\frac{Ldl}{2} + s_1^2}}{dl}$

$10 = \frac{-0.3 \pm \sqrt{\frac{20\times dl}{2} + 0.09}}{dl}$

$10dl + 0.3 = \sqrt{10dl + 0.09}$

$100dl^2 + 6dl + 0.09 = 10dl + 0.09$

$100dl^2 - 4dl = 0$

$dl(100dl - 4) = 0$

$dl = 0$ or $dl = \frac{4}{100} = .04$

$L\,16\times10^{-6}\,t = .04$

$20\,t = \frac{.04}{16\times10^{-6}}$

$20t = 10^6 \times \frac{.04}{16}$

$t = \frac{10^4}{80} = 125$

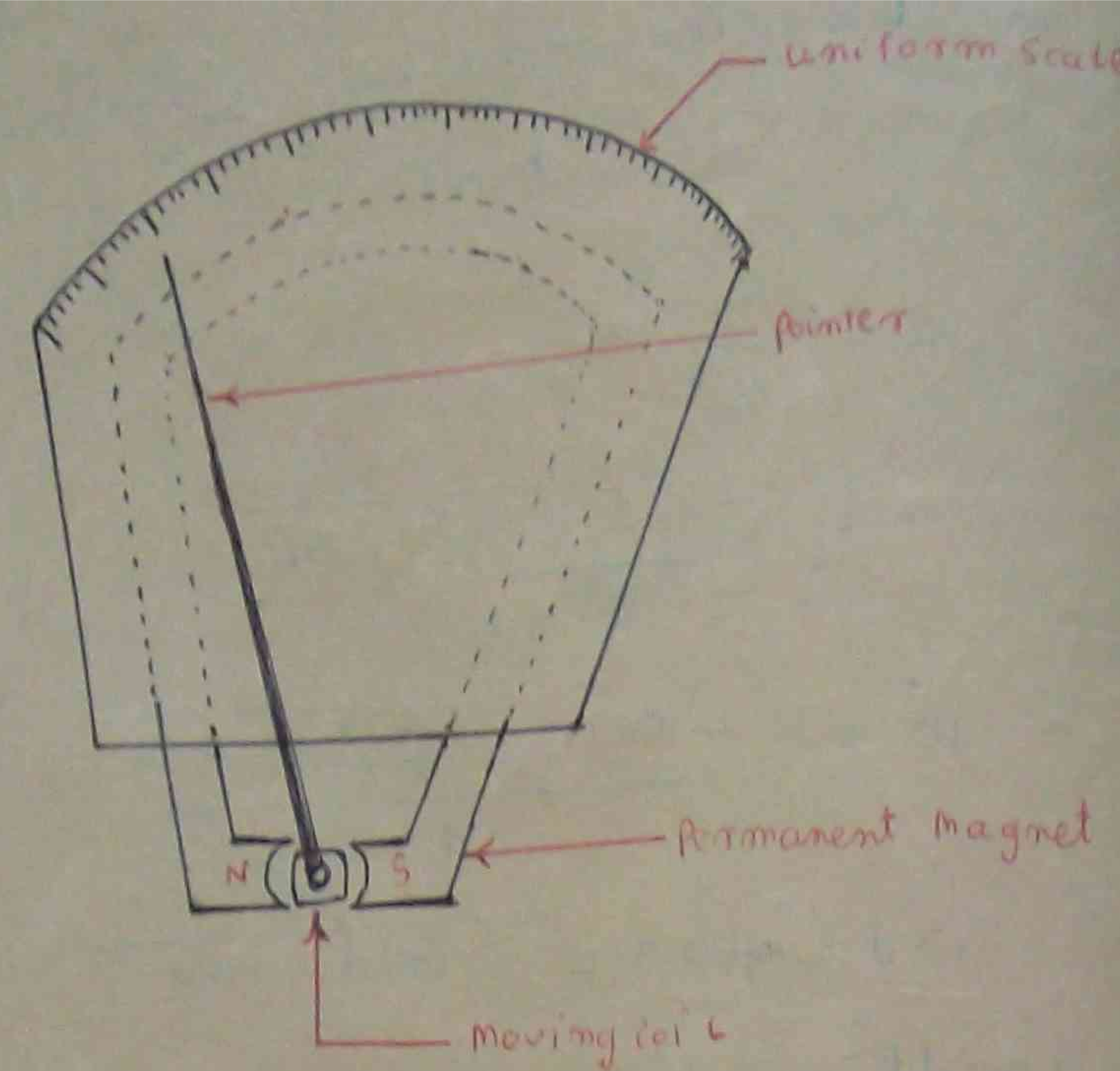
$C = \cancel{FC}\ \frac{5}{9}(F - 32)$

$\cancel{125} = \frac{5}{9}(F - 32)$

$225 = F - 32 \quad \therefore F = 257°F$

[illegible]

②



[illegible] Instrument [illegible] Horse Shoe Shaped permanent magnet pole [illegible] Aluminium former ([illegible]) [illegible] coil [illegible] Permanent magnet moving coil meter [illegible]။

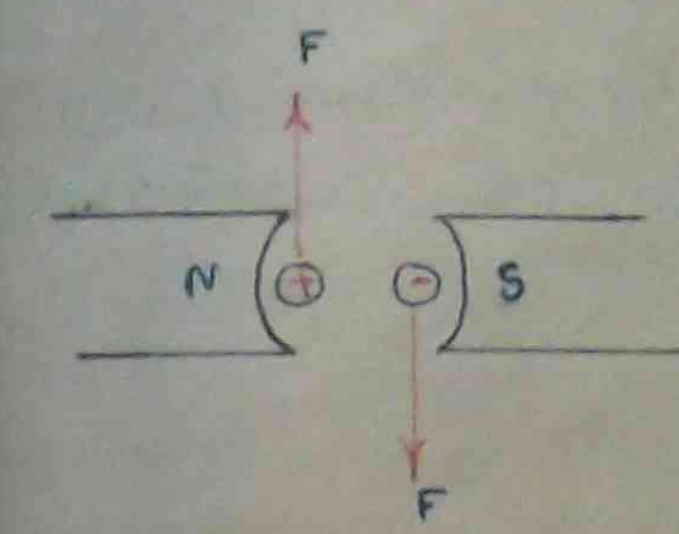
[illegible] coil [illegible] pole [illegible] 360 [illegible] Hair spring [illegible] coil [illegible] current [illegible] jewel Bearing [illegible] micro ampere [illegible] Permanent ~~magnet~~ magnet [illegible] field [illegible] conductor [illegible] current [illegible] Deflecting force [illegible] magnetic [illegible] North pole [illegible] South pole [illegible] meter [illegible] coil [illegible] current [illegible] Direction [illegible]။

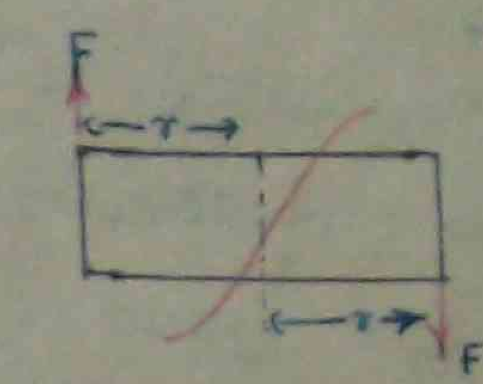
[illegible] Terminal [illegible] Positive [illegible] negative [illegible]

[illegible] meter [illegible]

[illegible] luminium former [illegible] coil [illegible] Eddy [illegible] spring control [illegible] scale [illegible] Ammeter, volt meter [illegible]။

P.M.M.C Theory





$$F = \frac{BIL}{10} \text{ dynes/turn}$$

$$T_D = 2\,(F \times r)$$

[illegible] $F = \frac{HIL}{10}$ dynes

$$\therefore T_D = 2 \times \frac{HIL}{10} \times r \times N \quad (\text{for } N \text{ turns})$$

$$2rL = \text{Area of coil}$$

$$NI = \text{Amps-turns}$$

ETEC $\therefore$ $$\boxed{T_D = \frac{\text{Area of coil} \times \text{Amps-turns} \times H}{10 \times 980} \text{ gm-cm}}$$

* dyne cm $T_D = \frac{ANIH}{10}$

$$\therefore T_D = \frac{ANIH}{10 \times 980} \text{ gm-cm}$$

current [illegible] conductor [illegible] coil [illegible] coil [illegible] deflect [illegible] $H = B$ [illegible] conductor [illegible] current [illegible] pole [illegible] conductor [illegible] Length [illegible] Force [illegible] deflecting torque [illegible] Equations [illegible]။

(1) moving ...
ပိုင်းတွင် ... moving coil ၏ 1 mili amp ... Field မှာ 500 gauss ရှိ၍ Turning moment (T_D) ကိုရှာပါ။

$\{A = 2\times3 = 6cm^2\}$

H =

(2) ... moving coil voltmeter ...
resistance = $10000\,\Omega$
coil ... = 3cms x 3cms
coil ... = 100 turns
H = 800 gauss

ဤ meter ကို 200 volts line ... Deflection Torque ... degree ကိုရှာပါ။
(T_C = 30 dynes-cm/degree)

$I = \frac{E}{R}$ $T_D = \frac{ANIH}{10}$

(3) ... moving coil meter ...
voltage = 45×10^{-3} volts
Resistance = $10\,\Omega$
N = 100 turns
A = $3\times2.5\,cm^2$
T_D = 0.5 gm-cm ဖြစ်လျှင် magnetic field ... ကိုရှာပါ။

(1) H = 500 gauss $I = \frac{1}{1000}$ amp T_D = ?
A = 2x3 = 6 cm^2 N = 60

R = $10000\,\Omega$ A = $9cm^2$ N = 100 turns
H = 800 gauss
V = 200 volts T_C = 30 dynes-cm/degree T_D = ? degree = ?

$$T_D = \frac{ANIH}{10}$$

$$T_D = \frac{9\times100\times\frac{200}{10000}\times800}{10}$$

T_D = 1440 dynes-cm

meter ... $T_D = T_C$
∴ T_D = 30 dynes-cms

∴ 30 dynes-cms ... 1 degree
1440 ————? $= \frac{1440}{30}$
= 48 degree Ans

(3) $V = 45\times10^{-3}$ volt
$R = 10\,\Omega$ $\therefore I = \frac{45\times10^{-3}}{10} = 45\times10^{-4}$ amp
N = 100 turns   A = 7.5 cms
T_D = 0.5 gmcms   H = ?

$$T_D = \frac{ANIH}{10\times980}$$

$$0.5 = \frac{7.5\times100\times45\times10^{-4}\times H}{10\times980}$$

$$\frac{98\times0.5}{7.5\times.0045} = H$$

$$\frac{49}{.03375} = H$$ ~~H = 1450 gauss~~

H = 1450 gauss   (Ans)

* 1 mili amp = $\frac{1}{1000}$ amp

H Initial Sag ... Hot wire ... 18 cms ... $16\times10^{-6}/°c/cm$ ဖြစ်သည်။ ... wire ... magnification 25 ... Farenheit degree ... ။

$$m = \sqrt{\frac{1}{2d\ell}}$$

$$m = \sqrt{\frac{1}{2\times\alpha t\ell}}$$

$$m = \sqrt{\frac{1}{2\alpha t}}$$

$$m = \frac{1}{\sqrt{2\alpha t}}$$

$$25 = \frac{1}{\sqrt{2\times 16\times 10^{-6}\, t}}$$

$$32\times 10^{-6} t = \frac{1}{625}$$

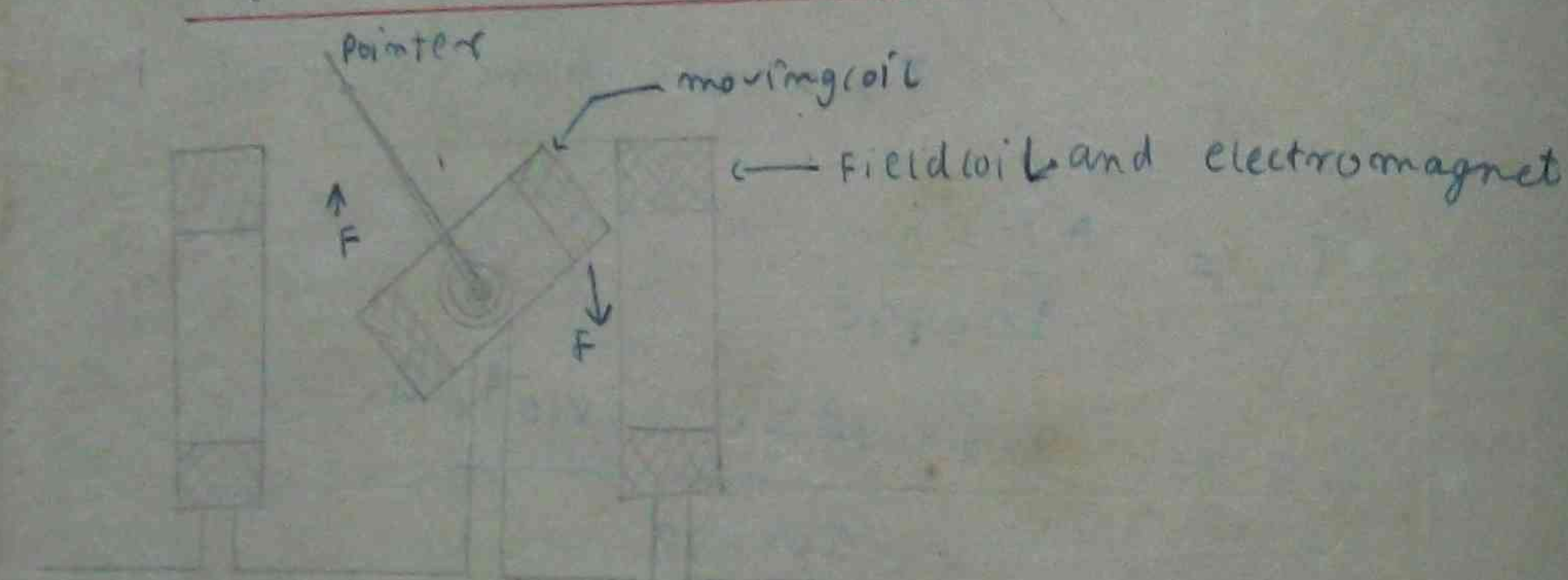
$$t = \frac{1}{625\times 32\times 10^{-6}} = \frac{1000000}{625\times 32} = \frac{1000000}{20000} = 50^{\circ}C$$

$$C = \frac{5}{9}(F-32)$$

$$50 = \frac{5}{9}(F-32)$$

$$F = 32 + 90 = \cancel{41^{\circ}F}$$
$$= 122^{\circ}F$$
(Ans)

Dyamometer Type moving coil Instrument



[illegible] permanent magnet [illegible] permanent magnet [illegible] Electromagnet [illegible] Electromagnet [illegible] coil [illegible] meter [illegible] base plate [illegible] coil [illegible] moving coil [illegible] Hair spring [illegible] controlling Torque [illegible] coil [illegible] current [illegible] wire [illegible]

Ammeter [illegible] voltmeter [illegible] series [illegible] meter [illegible] current [illegible] Fixed coil [illegible] moving coil [illegible] Reaction [illegible] Detecting Torque [illegible] Terminal [illegible] positive negative [illegible] AC DC [illegible] meter [illegible] air friction Damping [illegible] Eddy current Damping [illegible] Deflecting Torque [illegible] I^2 [illegible] scale [illegible]

Theory of Dynamometer Type moving coil Instrument

moving coil Type Permanent magnet Theory [illegible] Dymometer Type moving coil Instrument [illegible] moving coil [illegible] cosine [illegible] moving coil Type ~~for~~ permanent magnet meter [illegible] Torque [illegible]

$$\boxed{T_D = \frac{NI}{10\times 980}\times A\times H\cos\theta}\quad gm\text{-}cm$$

$$H = KI \quad (\text{Konstant})$$

$$T_D = \frac{NI}{10\times 980}\times ANI\cos\theta$$

$$T_D \propto I^2\cos\theta$$

$$T_C = T_D,\quad T_C = K\theta$$

$$\therefore K\theta = K'.\, I^2\cos\theta$$

$$\boxed{\therefore \theta = I^2\cos\theta}$$

(1) Dyamometer [illegible] moving coil [illegible] 500 Turns [illegible] 3 cms [illegible] formers [illegible] moving coil [illegible] 35 mili ~~ampere~~ ampere [illegible] Fixed coil [illegible] 100 gauss [illegible] meter [illegible] Field [illegible] 30° (a) 60° (b) 90° [illegible] torque [illegible]

(2) voltmeter [illegible] 300×10^{-3} volt [illegible] scale [illegible] moving coil [illegible] wire [illegible] 0.274 mm [illegible] wire [illegible] coil [illegible] 4 cms [illegible] coil [illegible] 4.24 [illegible]

[illegible] 300×10^{-3} volts [illegible] dyne-cm [illegible]

[illegible] controlling couple [illegible]

R [illegible] I [illegible] cm area

$R = \frac{\rho l}{a}$

(1) $N = 500$ $\quad A = \frac{\pi}{4} \times d^2 = \frac{9\pi}{4}$ $\quad I = \frac{35}{1000}$ amp

$H = 100$ gauss

$$T_d = \frac{ANIH\cos\theta}{10}$$

30° [illegible]

[illegible] angle = 60°

$$T_d = \frac{ANIH\cos 60}{10}$$

$$= \frac{\frac{9\pi}{4} \times 500 \times \frac{35}{1000} \times 100 \times \frac{1}{2}}{10}$$

$$= \frac{45 \times 35 \times \pi}{8}$$

$$= \frac{1575\pi}{8} = \frac{4950}{8} = 617 \text{ dyne-cm}$$

(2) 60° [illegible]

$$T_d = \frac{ANIH\cos 30}{10}$$

$$= \frac{\frac{9\pi}{4} \times 500 \times \frac{35}{1000} \times 100 \times \frac{\sqrt{3}}{2}}{10}$$

$$= 617 \times 1.9921 = 1070 \text{ dyne-cm}$$

90° [illegible]

angle = 90 − 90 = 0

$$T_d = \frac{ANIH\cos 0}{10}$$

$$= \frac{\frac{9\pi}{4} \times 500 \times \frac{35}{1000} \times 100 \times 1}{10}$$

$$= 1234 \text{ dyne-cm}$$

(2) $v = 300 \times 10^{-3}$ v $\quad d = .274$ mm

$T_d = \frac{ANIH}{10}$

$A = \frac{\pi}{4} \times (\cdot 274)^2$ $\quad L = 20 \times 13 = 260$ cms

$2 \times (b + t) = 13$

$2 \times (4 + t) = 13$ $\quad \therefore t = \frac{5}{2}$ cms

$H = 1500$ gauss

$R = \frac{\rho L}{A}$ $\quad$ coil area $= \frac{5}{2} \times 4 = \frac{20}{2} = 10$

$$R = \frac{\frac{.0173}{100} \Omega/\text{m} \quad 260 \text{ cms}}{\frac{\pi}{4} \times (\cdot 274)^2}$$

$$= \frac{.0173 \times 2.6}{\frac{3.1416}{4} \times (\cdot 274)^2} \Omega = \frac{.0173 \times 2.6}{3.1416 \times .0752}$$

$$R_T = \frac{.0173 \times 2.6}{\frac{3.1416}{4} \times .0752} + 4.24 \,\Omega$$

$$= \frac{.04500 \times 4}{.2359} + 4.24$$

$$= 4 \times .192 + 4.24 = 5.008$$

$$I = \frac{300 \times 10^{-3}}{5.008} = 59.9 \times 10^{-3} \text{ amps}$$

$$T_d = \frac{ANIH}{10} =$$

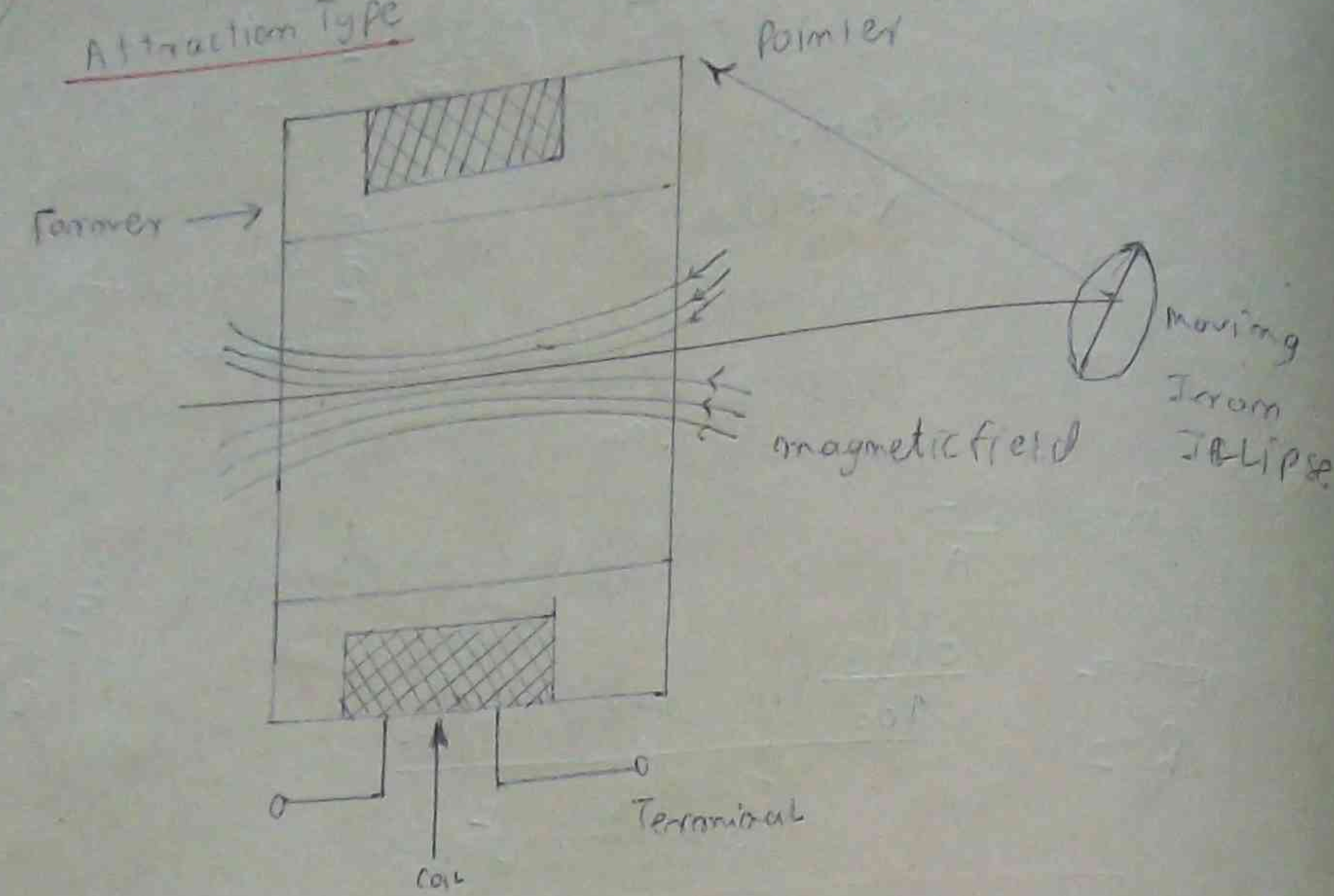
$$= \frac{\frac{20}{3} \times \cancel{1000} \times 59.9 \times 10^{-3} \times 1500}{10}$$

$$= 20 \times 59.9 = 1398 \text{ dyne-cm}$$

$$= \frac{10 \times 20 \times 59.9 \times 10^{-3} \times 1500}{10}$$

$$= 59.9 \times 30 = 1797.7$$

Attraction Type



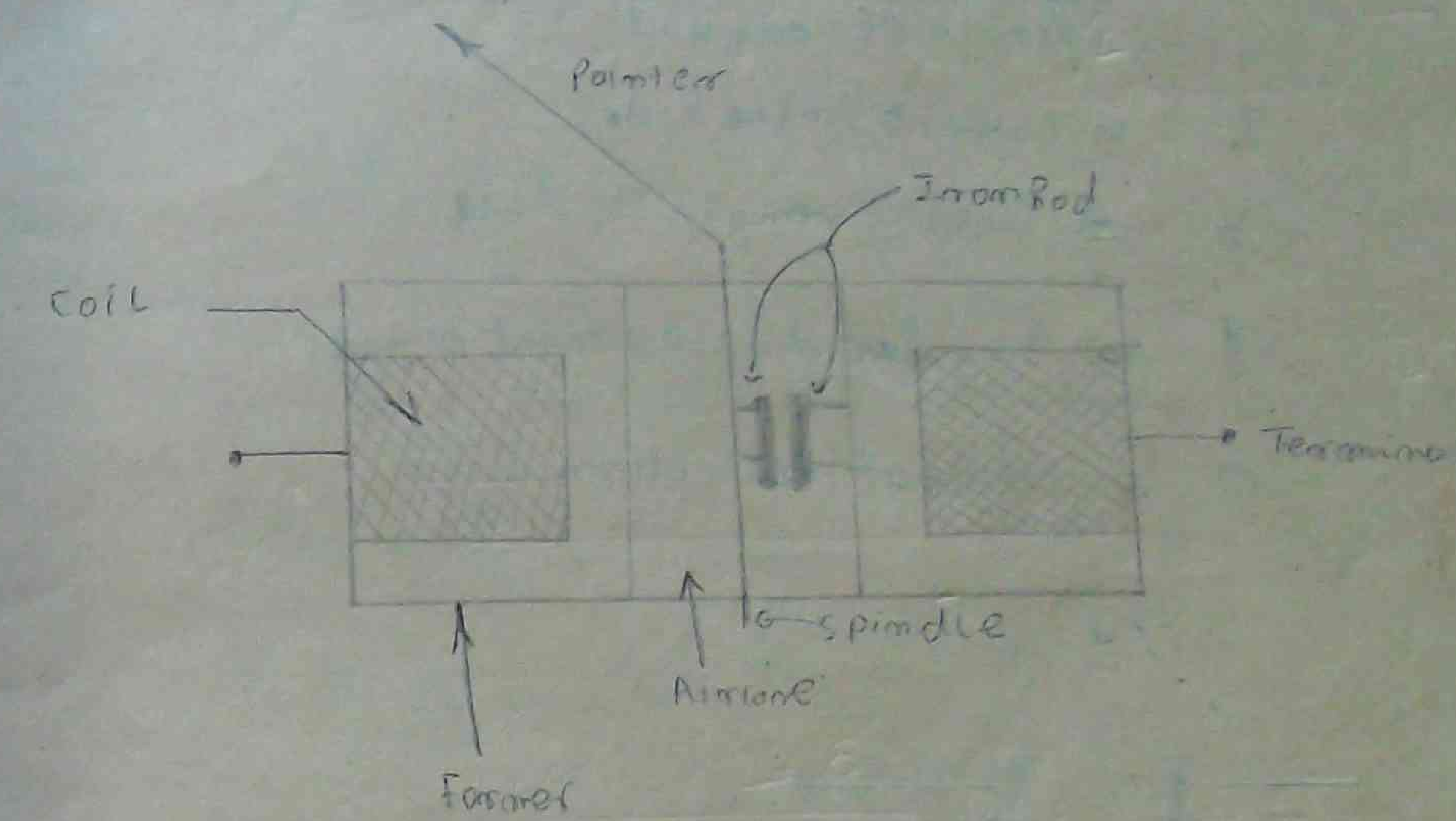
[illegible] meter [illegible] numbers of turns [illegible] coil [illegible] meter [illegible] coil [illegible] Ellipse [illegible] controlling force [illegible] Hairspring [illegible] gravity weight [illegible] Damping System [illegible] Air friction Damping [illegible] coil [illegible] current [illegible] pointer [illegible]

[illegible]

[illegible] meter [illegible] AC, DC [illegible] Terminal [illegible] Electrical power [illegible] meter [illegible] scale [illegible] I^2 [illegible] Cramp scale [illegible] meter scale [illegible] scale [illegible]

AC, DC [illegible] AC scale [illegible] DC scale [illegible] AC, DC [illegible] condenser [illegible]

Repulsion Type



[illegible] meter [illegible] coil [illegible] meter [illegible] moving Iron [illegible] former [illegible] fixed Iron [illegible] Initial position [illegible] Iron [illegible] Hairspring [illegible] coil [illegible] pole [illegible] meter [illegible] pointer [illegible]

controlling system [illegible] Hairspring [illegible] Hair friction Damping [illegible] meter [illegible] AC, DC [illegible] scale [illegible] current I^2 [illegible] scale [illegible] range [illegible] meter [illegible] scale [illegible] moving Iron [illegible] ① Rod type ② Book Type ③ Tongue shaped Type [illegible] Tongue shape piece Type [illegible] scale [illegible] meter [illegible] moving Iron [illegible] fixed Iron [illegible] coil [illegible] range [illegible]

Repulsion Type Theory

m_1, m_2 = pole strength of Rods

D = distance between

L = length of one Rod

I = current in the Rods

H = field strength of Rods

ϕ = Angular displacement of Rods

θ = angle of deflection

$L \gg D$

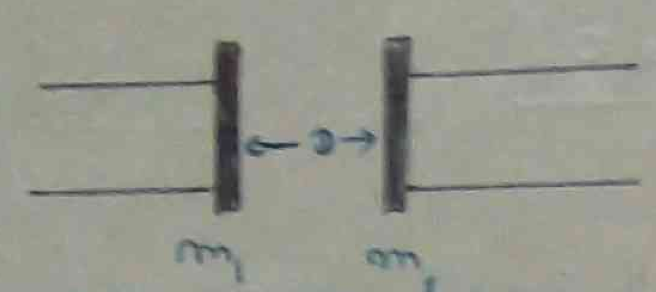
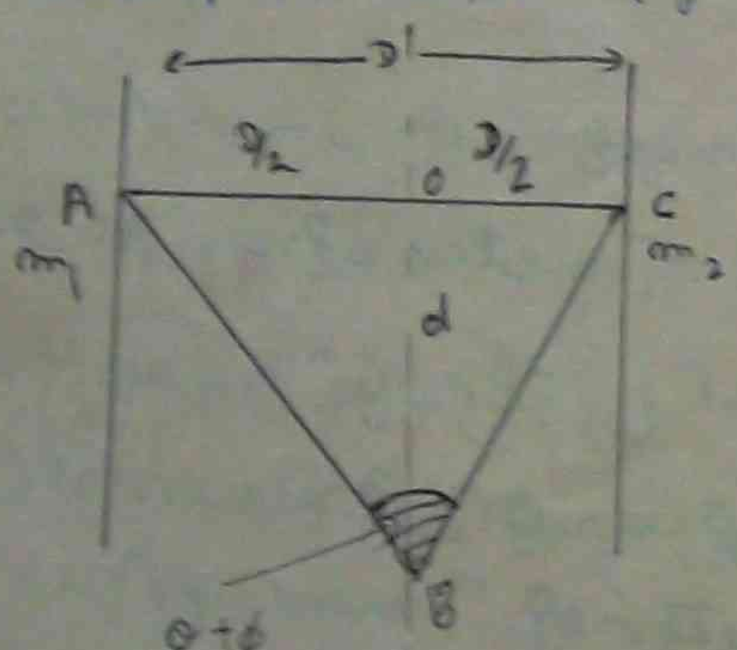


fig (1)

Rod [illegible] length [illegible] Rod [illegible] distance D [illegible] force of attraction [illegible] Rod [illegible] adjacent pole [illegible] force of Repulsion [illegible] force of Attraction [illegible]



fig(2)

from fig(2) of ΔAOB

$$d = R\cos\left(\frac{\theta+\phi}{2}\right)$$

$$\frac{D}{2} = R\sin\left(\frac{\theta+\phi}{2}\right)$$

$$D = 2R\sin\left(\frac{\theta+\phi}{2}\right)$$

Square [illegible]

$$D^2 = 4R^2\sin^2\left(\frac{\theta+\phi}{2}\right)$$

$$F_{repulsion} = \frac{2m_1m_2}{D^2}$$

$$T_D = F \times d = \frac{2m_1m_2}{D^2} R\cos\left(\frac{\theta+\phi}{2}\right)$$

$$\therefore T_D = \frac{2m_1m_2 \, R\cos\left(\frac{\theta+\phi}{2}\right)}{4R^2\sin^2\left(\frac{\theta+\phi}{2}\right)}$$

$$= \frac{m_1m_2}{2R} \times \frac{\cos\left(\frac{\theta+\phi}{2}\right)}{\sin^2\left(\frac{\theta+\phi}{2}\right)}$$

$m_1 \propto I$, $m_2 \propto I$

$\therefore m_1m_2 \propto I^2$

$\therefore m_1m_2 = PI^2$ (P = constant)

$\therefore q = \frac{P}{2}$

$$\therefore T_D = \frac{P}{2R} \times I^2 \times \frac{\cos\left(\frac{\theta+\phi}{2}\right)}{\sin^2\left(\frac{\theta+\phi}{2}\right)}$$

$$\boxed{T_D = \frac{q}{R} \times I^2 \times \frac{\cos\left(\frac{\theta+\phi}{2}\right)}{\sin^2\left(\frac{\theta+\phi}{2}\right)}}$$

dyne cm

where $\frac{P}{2} = q$, q = constant

(1) Repulsion type moving Iron meter [illegible] 2 amp [illegible] meter [illegible] angle of deflection [illegible] angle of displacement of the rod [illegible] 30° [illegible] Torque [illegible] 0.5 gm-cm [illegible] Repulsion Type moving Iron meter [illegible] 4 amp [illegible] $(\theta+\phi) = 45°$ [illegible] deplacement of Torque [illegible]

T_D = dyne cm

$$\cancel{T_D = \frac{q}{R} \times I^2 \frac{\cos\left(\frac{\theta+\phi}{2}\right)}{\sin^2\left(\frac{\theta+\phi}{2}\right)}}$$

$$.5 \times 980 = \frac{q}{R} \times 4 \times \frac{\cos 30}{\sin^2 30}$$

$$490 = \frac{q}{R} \times 4 \times \frac{\sqrt{3}/2}{1/4}$$

$$490 = \frac{q}{R} 4\sqrt{2} \qquad \frac{q}{R} = \frac{490}{4\sqrt{2}}$$

$$T_D = \frac{490}{4\sqrt{2}} \times 16 \times \frac{1}{1/\sqrt{2}}$$

$$490 = \frac{B}{\cancel{2}} \times 4 \times \frac{\sqrt{3}}{\cancel{2}} \times 4^2$$

$$\frac{B}{2} = \frac{490}{8\sqrt{3}}$$

$$T_D = \frac{490}{8\sqrt{3}} \times 16 \times \frac{1}{\frac{1}{\sqrt{2}}}$$

$$T_D = \frac{490 \times \cancel{16}^{2} \times \sqrt{2}}{\cancel{8}\sqrt{3}}$$

$$= 980 \times \frac{\sqrt{2}}{\sqrt{3}} =$$

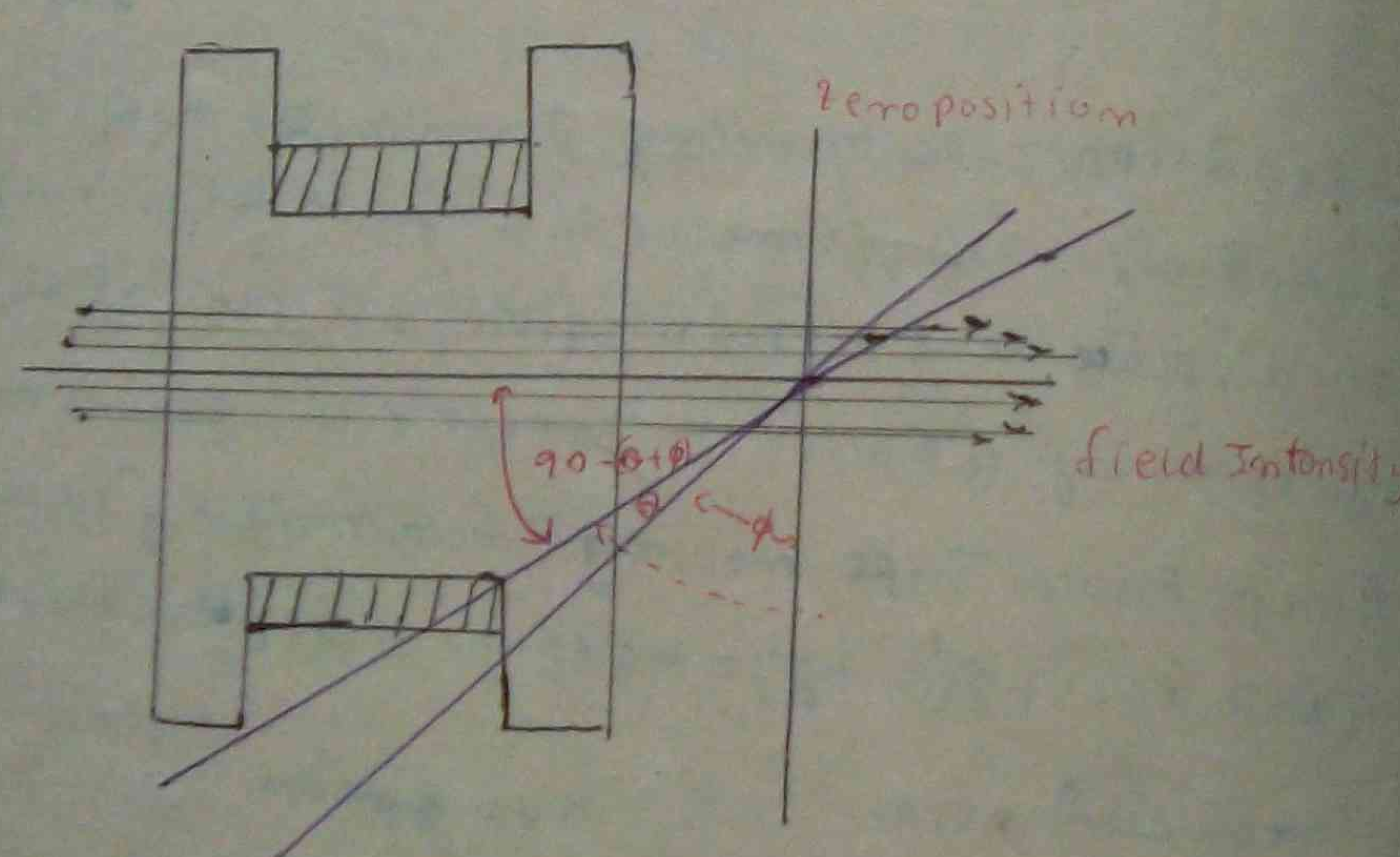
$\sqrt{2} = 1.4142$
$\sqrt{3} = 1.7321$
$\pi = 3.1416$

$$= \frac{980 \times 1.4142 \times 1.7321}{3}$$

$$= \frac{2.44 \times 980}{3} = \frac{2390}{3} = \cancel{646.6}$$

$$= 796.6 \text{ dyne-cm}$$

Theory of attraction Type



magnetization $= H\cos\{90-(\theta+\phi)\}$

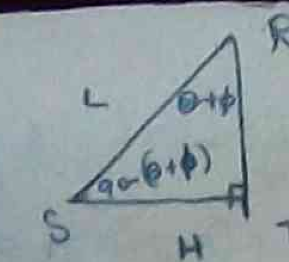
Force $= H \times H \sin(\theta+\phi)$

$\therefore$ ⊥ distance $= L\sin\{90-(\theta+\phi)\}$

$= L\cos(\theta+\phi)$

$\therefore T_D = LH^2 \sin(\theta+\phi)\cos(\theta+\phi)$

$= LH^2 \cdot$ ...



but L = constant , 2 = constant

ဟရှိ field intensity H သည် current I နှင့် တိုက်ရိုက်အချိုးကျ ပါ၏

$\therefore H \propto I, \quad H^2 \propto I^2$ —— ① $\quad \frac{L}{2} = K$ —— ②

$\therefore T_D = KI^2 \sin 2(\theta+\phi)$

$\therefore T_D \propto I^2 \sin 2(\theta+\phi)$

ဟရှိ $\sin 2(\theta+\phi) \propto \frac{dh}{d(\theta+\phi)}$ inductance

$\sin 2(\theta+\phi) \propto \frac{dF}{d(\theta+\phi)}.$

$\therefore T_D \propto I^2 \frac{dh}{d(\theta+\phi)}$

$\therefore T_D = KI^2 \frac{dh}{d(\theta+\phi)}$ $\quad K = 5100$ (practical result)

$$\therefore \boxed{T_D = 5100 \times I^2 \times \frac{dh}{d(\theta+\phi)}} \text{ gm-cm}$$

gm-cm

ဖော်ပြပါ ပုံတွင် Iron disc သည် zero position ၌ ရှိသောအခါ instrument ၏ field intensity H နှင့် ⊥ ကြား ရှိသော ထောင့် ∠φ အတိုင်းအတာ ဖြစ်သည်။

ϕ = Angular distance from ⊥ axis at zero position

θ = Angle of deflection of disc due to deflecting Torque

H = field intensity

field intensity သည် uniform ဖြစ်ရမည်။ disc ၏ magnetization သည် field intensity H နှင့် axis အကြား ... ဖြစ်သည်။

(1) 5amp moving Iron ammeter [illegible] full scale deflection [illegible] 0.1 gm-cm [illegible] Instrument [illegible] Inductance [illegible] H/radian [illegible]

$$T_d = 5100\, I^2 \frac{dL}{d(\theta+\phi)} \; H/radian$$

(2)

Deflection (degree)	20	30	40	50	60	80	90
Inductance (μH)	335	345	385.5	366.5	376.5	391.3	396

[illegible] meter [illegible] Inductance [illegible] 1 degree [illegible] torque [illegible] 4 dyne-cm/degree [illegible] (က) 30° (ခ) 60° [illegible]

1 degree [illegible] 4 dyne-cm

30° ———— ? = 120 dyne-cm

$$= \frac{120}{980}\ gm\text{-}cm$$

$$T_d = 5100 \times I^2 \times \frac{dL}{d(\theta+\phi)}$$

$$\frac{120}{980} = 5100 \times I^2 \times \frac{(345-335)\times 10^{-6}}{(30-20)\frac{\pi}{180}}$$

$$.1225 = \frac{918}{\pi} \times I^2 \times 10^{-3}$$

$$\frac{122.5}{292.5} = I^2 \qquad I = .646\ amp$$

60° [illegible] $= 60\times 4 = 240$

$$\frac{240}{980} = 5100 \times I^2 \times \frac{10 \times 10^{-6}}{10 \times \frac{\pi}{180}}$$

$$\frac{24}{98} = \frac{18\times 51 \times 10^{-3}}{\pi} \times I^2$$

$$.245 = \frac{918}{\pi} \times 10^{-3}\, I^2$$

$$.245 = 29.15\times 10^{-3}$$

$$\frac{245}{292.5} = I^2$$

$$I = .9143$$

---

(1) meter [illegible] metal [illegible]

meter [illegible] Aluminium [illegible] Torque weight Ratio [illegible]

(2) meter [illegible]

meter [illegible]

(a) deflecting force or moving system
(b) controlling force
(c) Damping force [illegible] deflecting force [illegible] meter pointer [illegible] controlling force [illegible] meter [illegible] Damping force [illegible] meter pointer [illegible] meter reading [illegible]

(3) controlling force [illegible]

controlling force [illegible] Spring control [illegible] gravity control [illegible] Spring control [illegible]

(က) Spring control [illegible] scale [illegible]

(ခ) gravity control [illegible]

(ဂ) [illegible]

[illegible]

(4) Hairspring [illegible]

[illegible]

Hairspring [illegible]

[illegible]

(က) [illegible]

(ခ) [illegible]

(ဂ) [illegible] current [illegible]

(5) [illegible] meter [illegible] Balance [illegible]

[illegible] meter [illegible]

weight [illegible]

(6) Damping force [illegible]

[illegible]

Damping force [illegible]

[illegible] (က) [illegible]

(ခ) [illegible] (ဂ) [illegible]

[illegible]

(1)

$$T_D = \frac{q}{R} \cdot I^2 \frac{\cos\left(\frac{\theta+\phi}{2}\right)}{\sin^2\frac{\theta+\phi}{2}}$$

$$490 = \frac{q}{R} \times 4 \times \frac{\cos 15}{\sin^2 15}$$

$$\frac{q}{R} = \frac{490 \sin^2 15}{4 \cos 15} = 490 \frac{\sin 15 \tan 15}{4}$$

$$T_D = \frac{q}{R} I^2 \frac{\cos\frac{45}{2}}{\sin^2\frac{45}{2}}$$

$$T_D = \frac{490 \sin^2 15}{4 \cos 15} \times 16 \times \frac{\cos\frac{45}{2}}{\sin^2\frac{45}{2}} = 490 \times \sin 15 \tan 15\, 16 \frac{\cos\frac{45}{2}}{\tan\frac{45}{2}}$$

$490 \times .853$ ... 4

$$\frac{490 \times .2199}{.1955} = \cancel{490 \times 1.55}$$

$490 \times 1.615 = 857$ dynes-cm

(1) $T_D = 5100 \; I^2 \frac{dM}{d(\theta+\phi)}$

$$\frac{1}{10} \times \cancel{} = 5100 \times 25 \times \frac{dM}{d(\theta+\phi)}$$

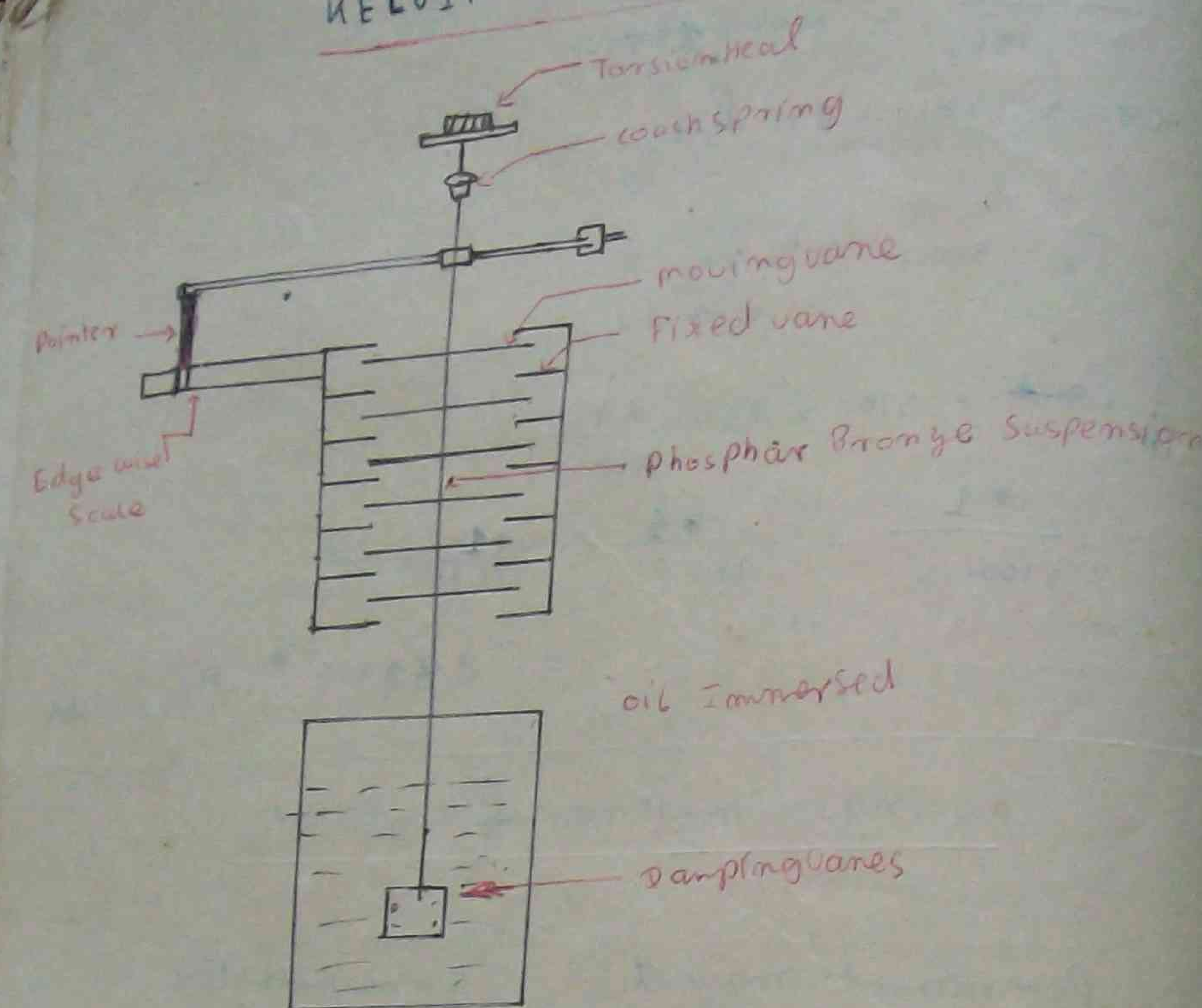
$$\frac{.01}{5100 \times 25} = \frac{.01}{127500} = \frac{.01}{12.75} \times 10^{-4}$$

$$= .783 \times 10^{-6} \text{ H/radian}$$

Moving coil meter [illegible]

	Permanent magnet	Dynamometer
1	Power losses [illegible]	Power losses [illegible]
2	Torque weight Ratio [illegible]	Torque weight Ratio [illegible]
3	[illegible] scale [illegible]	[illegible] scale [illegible]
4	ammeter, ohm meter, voltmeter, galvanometer, Frequency meter, multimeter [illegible]	ammeter, ohm meter [illegible] watt meter [illegible]
5	[illegible]	[illegible] current [illegible]
6	Damping system [illegible]	Damping system [illegible]
7	Terminal [illegible]	Terminal [illegible]
8	[illegible] DC [illegible]	AC, DC [illegible]

KELVIN MULTI CELLULAR VOLTMETER

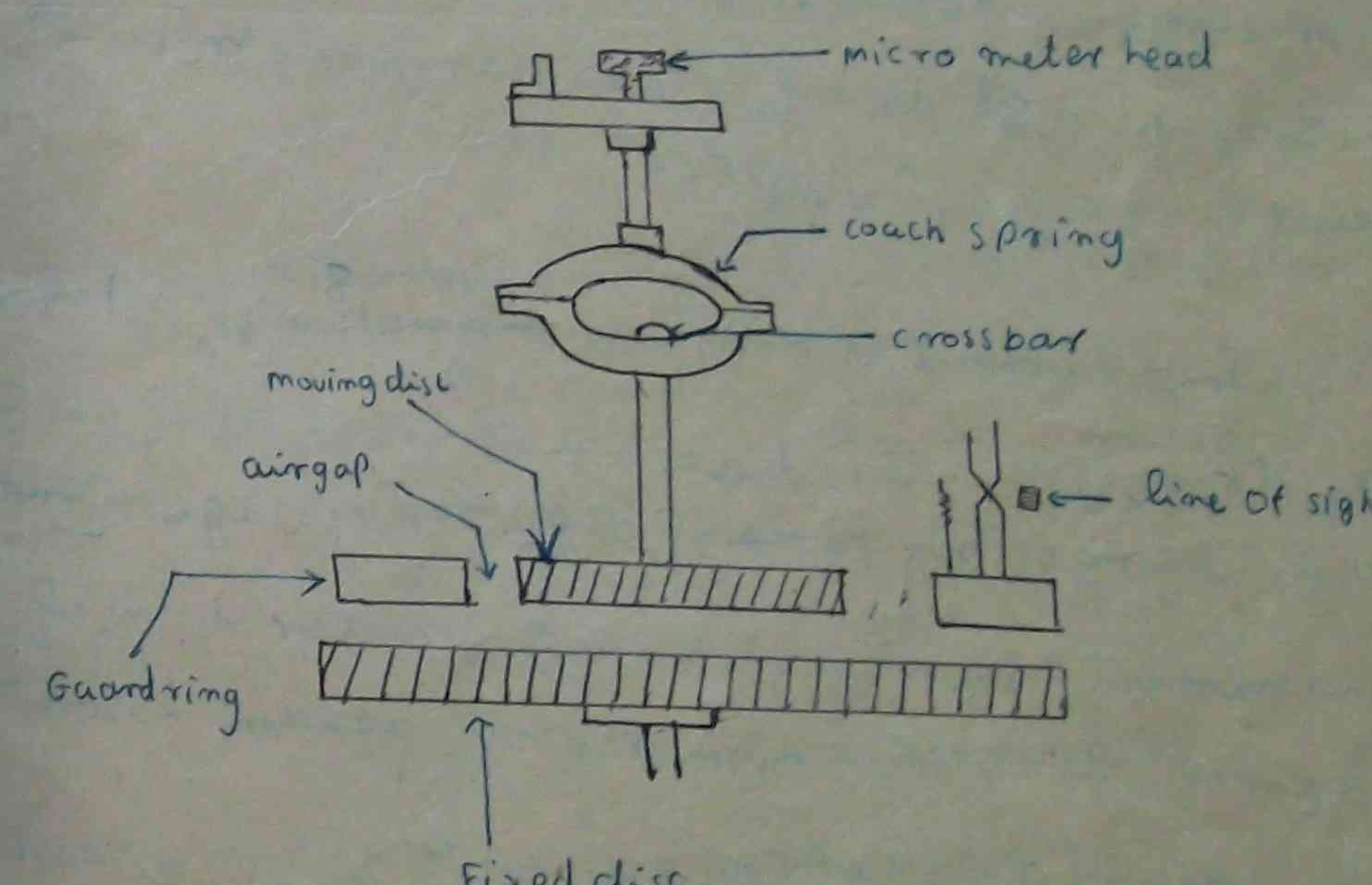


Electrostatics volt [illegible] voltmeter [illegible] Lord kelvin [illegible] kelvin multicellular voltmeter [illegible] ammeter [illegible] voltmeter [illegible] cyclinderical shaped metal [illegible] fixed vanes [illegible] moving vane [illegible] moving vane [illegible] fixed vane [illegible] phosphar bronze wire [illegible] perpendicular [illegible] distance [illegible] fixed vane [illegible] moving vane [illegible] charge [illegible]

deflecting Torque [illegible] counter balance [illegible] phosphar bronze wire [illegible] controlling Torque [illegible] phosphar bronze wire [illegible] pointer [illegible] Edge wise scale [illegible] meter [illegible] Fluid friction damping [illegible]

coach spring [illegible] zero adjusting screw [illegible] High voltage [illegible] voltage range (100 volts to 1000 volts) [illegible] meter [illegible]

KELVIN ABSOLUTE ELECTROSTATIC VOLTMETER



[illegible] meter [illegible] Electrostatics effect [illegible] meter [illegible] micrometer [illegible] coach spring [illegible] moving disc [illegible] moving disc [illegible] opposite side [illegible] Fixed disc [illegible] moving disc [illegible] guard ring [illegible]

guard ring [illegible] moving disc [illegible] air gap [illegible]

[illegible] area + $\frac{1}{2}$ area of airgap [illegible] disc [illegible] "0" ~~loading~~ [illegible]

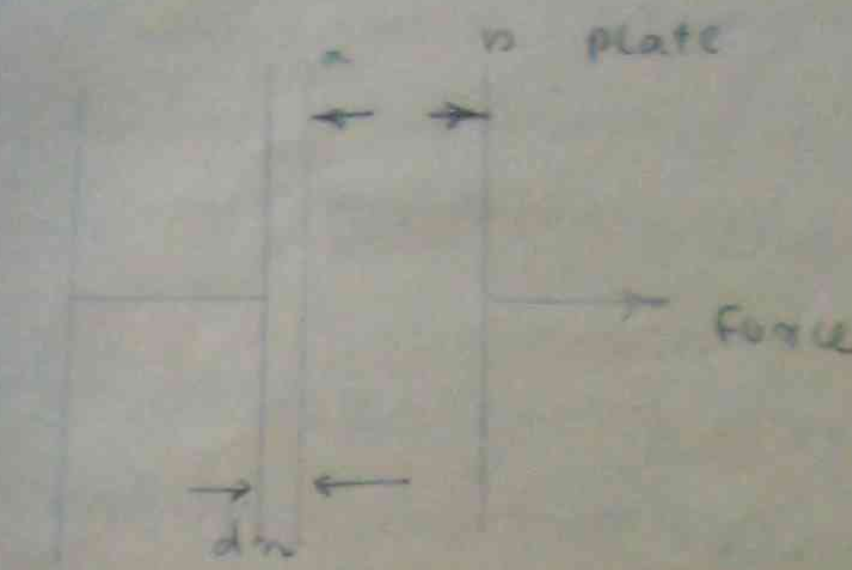
[illegible] two finely pointed rods [illegible] ~~signa~~

Signaling ~~devic~~ device [illegible]

[illegible] voltmeter [illegible] moving disc [illegible] fixed disc [illegible] potential difference [illegible] force of attraction [illegible] moving disc [illegible] "0" position [illegible] micrometer head [illegible] micrometer [illegible] ~~calibrate~~ calibrate [illegible] springs [illegible] micrometer [illegible] short circuit [illegible] Instrument [illegible] moving disc [illegible] "0" position [illegible] pd [illegible] pd [illegible] micro meter [illegible] disc [illegible] "0" position [illegible] weight [illegible]

Instrument [illegible] ~~dimension~~ dimension [illegible] pd [illegible] disc [illegible] pd [illegible] attraction force [illegible] voltage [illegible] Instrument [illegible] meter [illegible] meter [illegible] ~~absolu~~ absolute voltmeter [illegible]

Theory of absolute Electro-meter



x = distance (thickness) (cm)

A = area of plate (cm^2)

vol = $A \times x$ (cm^3)

V = applied voltage

C = capacitance between two plates (fixed)

K = constant of Electro meter

small vol = $A \times dx$

$$C = K \times \frac{A}{4\pi x \, 9 \times 10^{11}}$$

($K = 1$ for air)

$$\text{Energy } E = \frac{1}{2} C V^2$$

$$= \frac{1}{2} K \times \frac{A}{4\pi x \times 9 \times 10^{11}} \times V^2$$

$$E/_{\text{volume}} = \frac{1}{2} K \cdot \frac{1}{4\pi x^2 \, 9 \times 10^{11}} \times V^2$$

Energy for infinite small vol: $A \times dx$

$$\therefore E/_{\text{vol}} \times A \times dx = \frac{1}{2} K \frac{AV^2}{4\pi x^2 \times 9 \times 10^{11}} \times dx$$

[illegible] Force P dynes [illegible] dx cm [illegible] work done [illegible] →

$$E/_{\text{vol}} \times A \times dx = P \times dx$$

$$\therefore P \times dx = \frac{1}{2} K \frac{AV^2}{4\pi x^2 \times 9 \times 10^{11}} \times dx$$

$$P = \frac{1}{2} \times K \frac{AV^2}{4\pi x^2 \times 9 \times 10^{11}}$$

But we know one Joules = 10^7 ergs (or) dynes

$$\therefore P = \frac{1}{2} K \times \frac{AV^2}{4\pi x^2 \times 9 \times 10^4}$$

$$\therefore P = \frac{KAV^2}{8\pi (300x)^2}$$

$$\boxed{\therefore P = \frac{KA}{8\pi} \left(\frac{V}{300x}\right)^2 \text{ dynes}}$$

1. absolute electrometer [illegible] 4 cm [illegible] 0.2 gm-wt [illegible] supply [illegible] supply voltage [illegible]။

2. Area 16 sq cm [illegible] 0.5 cm [illegible] 1800 volts [illegible] gm-wt [illegible]။

3. Electrostatics voltmeter [illegible] plate [illegible] 10 cm [illegible] 104 v [illegible] plate [illegible] 10 cms [illegible] 500 dynes [illegible] plate [illegible]။ [illegible] plate [illegible]။

4. Electrometer [illegible] x cms [illegible] P [illegible] voltage [illegible] Force [illegible] meter [illegible] voltage [illegible] $x\times\sqrt{P}$ [illegible]။

(1) $P = \frac{KA}{8\pi}\left(\frac{V}{300x}\right)^2$

$P = .2\times980 = 196$ dynes

$A = \frac{\pi}{4}x^2 \qquad K = 1$

$P = \frac{1\times\frac{\pi}{4}8^2}{8\pi}\times\frac{V^2}{90000x^2}$

$196 = \frac{\cancel{\pi}\ 64}{4\times8\cancel{\pi}}\times\frac{V^2}{90000\times.16}$

$\frac{.16\times196\times4\times8\times90000}{64} = V^2$

$V = \sqrt{\frac{196\times4\times8\times90000}{64}\times.16}$

$V = \frac{14\times2\times300\times2\sqrt2}{8}\times.4$

$= \frac{56\times300\sqrt2\times.4}{8} = \frac{56\times30\cancel{0}\sqrt2}{2\cancel{0}}$

$= 15\times56\times1.414$

$= 1185$ volts

(2) $P = \frac{KA}{8\pi}\left(\frac{V}{300x}\right)^2$

$P = \frac{1\times16}{8\times\pi}\times\frac{1800\times1800}{300\times\frac12\times300\times\frac12}$

$P = \frac{16\times\cancel{1800}^{400}\times\cancel{1800}^{3}\times\cancel{2}\times2}{\cancel{2400}\ \pi\times300}$

$= \frac{14400}{150\pi} = \frac{4580}{150} = \frac{4580}{150\times\cancel{980}\times2}\times\cancel{.0470}$

$= .0436$

(3) $P = \frac{KA}{8\pi}\times\frac{V^2}{90000x^2}$

$500 = \frac{1\times\frac{\pi}{4}\times100}{8\times\pi}\times\frac{10\times1000\times10000}{90000\times x^2}$

$50\cancel{0}^{5} = \frac{\cancel{\pi}\times100\times1\cancel{0}\times1\cancel{000}\times10000}{4\times8\times\cancel{\pi}\times9\cancel{0000}\times x^2}$

~~5x4x8x9~~ $\qquad x^2 = \frac{1}{9\times4\times8\times5}$

$x^2 = \sqrt{\frac{1000}{9\times16\times2\times5\times2}}$

$= \sqrt{\ }$

$x = \frac{10}{3\times4\times\sqrt2} = \frac{10\sqrt{10}}{12\sqrt2} = .\cancel{84}$ cms

$= \frac{14.142\sqrt{10}}{24} = \frac{14.142\times3.033}{24}$

$= 2.6$ cms

(4) $P = \frac{KA}{8\pi}\ \frac{V^2}{90000x^2}$

$x^2P = \frac{KA}{8\pi\times90000}\ V^2$

$x\sqrt{P}\ \sqrt{\frac{8\pi\,90000}{KA}} = V$

[illegible]

$\therefore V \propto x\sqrt{P}$

(5) absolute meter [illegible] 0.5 cms [illegible] $p = 1.5 \times 10^{-11} \times 980$ dynes [illegible] voltage apply [illegible] 4.9×10^{-10} E.S.U charge [illegible]

Force = Field intensity × charge

P

(6) absolute electrometer [illegible] plate [illegible] 10 in [illegible] pd 2000 volts [illegible] 0.8 in [illegible] plate [illegible] charge [illegible] charge [illegible] coulomb [illegible]

$$P = \frac{KA}{8\pi}\left(\frac{V}{300x}\right)^2$$

$$P = \frac{KA}{8\pi} \times (\text{field indensity})^2$$

(5) P = Field indensity × charge

$$1.5 \times 10^{-11} \times 980 = \frac{V}{300 \times \frac{1}{2}} \times 4.9 \times 10^{-10}$$

$$1.5 \times 10^{-11} \times 980 = \frac{V}{150} \times 4.9 \times 10^{-10}$$

$$\frac{1.5 \times 10^{-11} \times 980 \times 150}{4.9 \times 10^{-10}} = V$$

$$\frac{1.5 \times \cancel{980}^{20} \times 150}{\cancel{49}} = \cancel{2250} \quad 1500 \times 3 = 4500 \text{ volts}$$

150 30

(6) $d = 10'' = 2.54 \times 10$ cms

$x = 0.8 \times 2.54$ cms

$V = 1000$ volts $\quad P = ?$

$$P = \frac{KA}{8\pi} \times \left(\frac{V}{300x}\right)^2$$

$$P = \frac{1 \times \frac{\pi}{4} \times \cancel{2.54 \times 2.54} \times 10 \times 10}{\ldots} \quad 1000 \times \ldots$$

$$F = \frac{Q_1 Q_2}{d^2}$$

$$54.3 = \frac{Q^2}{\ldots}$$

$$Q^2 = 54.3 \times \ldots$$

$$= 54.3 \times 2.032 \times 2.032 \ldots$$

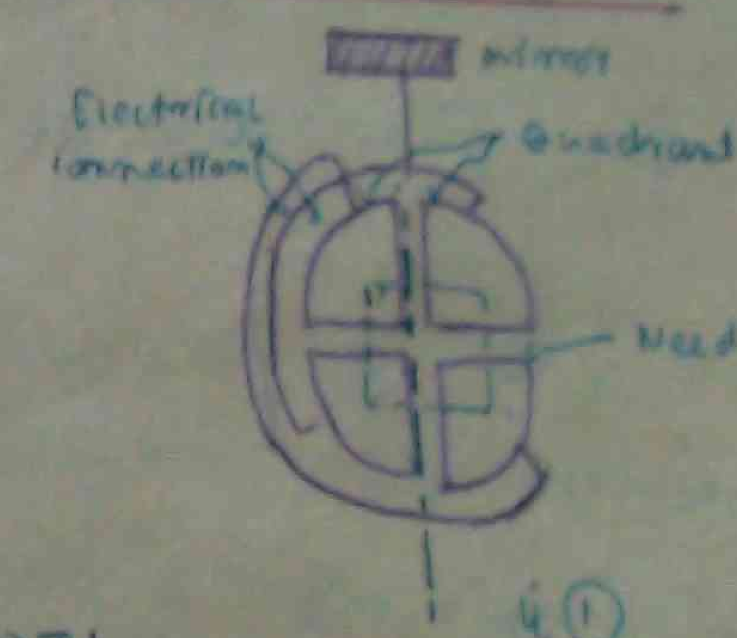
$Q = \ldots$ coulomb $\ldots$

$$P = \frac{1000}{300 \times .8 \times 2.54} \times \text{charge}$$

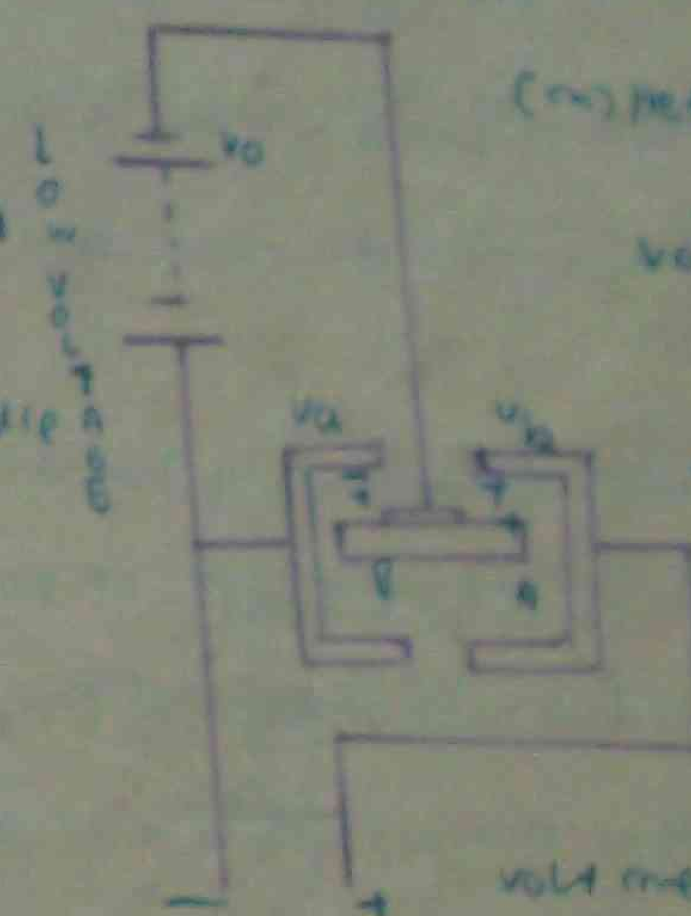
$$54.3 = \frac{10 \ldots}{\ldots 2.032} \times \text{charge}$$

$$\frac{54.3 \times 6.096}{10} = \text{charge} = 33.1 \text{ coulomb}$$

Quadrant Electrometer



ပုံ ①



(က) Hetero Statically

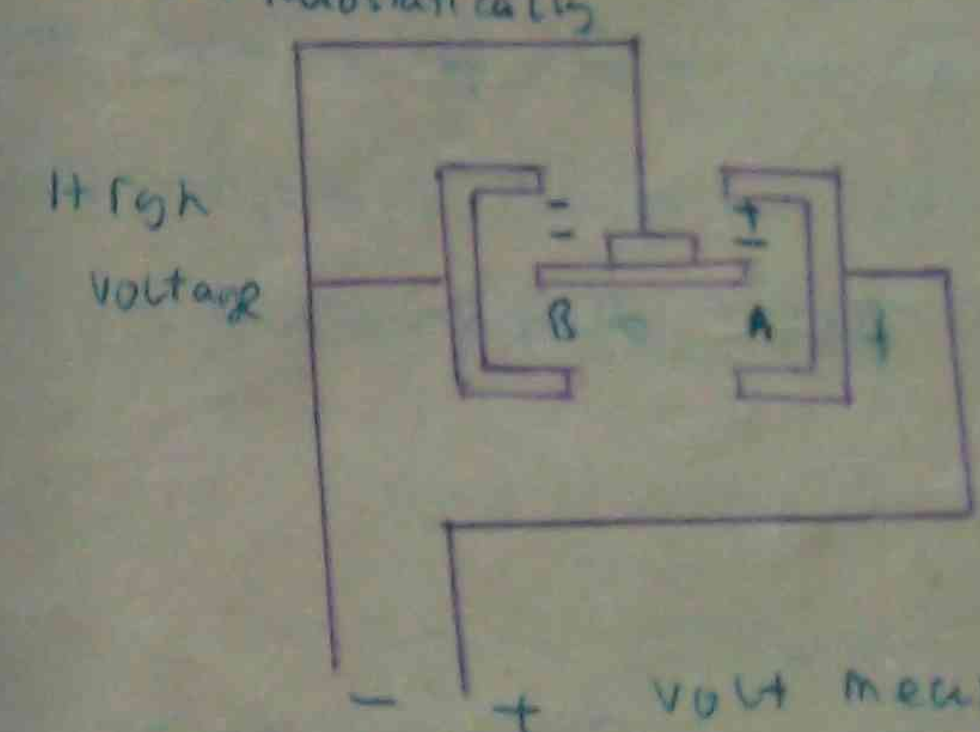
$V_0 \gg V_a, V_b$

$V_a > V_b$

$T \propto (V_a - V_b)$

ပုံ ②

(ခ) Idiostatically



$V_0 = V_a$

$T \propto (V_a - V_0)^2$

ပုံ ③

[illegible] Quadrant Electrometer [illegible] Insulating stand [illegible] diameter 6 cms [illegible] Height 1 cm [illegible] cylinder [illegible] cylinder [illegible] 1st Quadrant [illegible] 3rd Quadrant [illegible] wire [illegible] second Quadrant [illegible] fourth Quadrant [illegible] wire [illegible] Electrical connection [illegible] voltage difference [illegible] needle [illegible] needle [illegible] aluminium [illegible] or Phosphor Bronze or silver [illegible] needle [illegible]

[illegible] potential [illegible] wire [illegible] potential [illegible] needle [illegible] Area [illegible] Torque [illegible] deflection [illegible] Torque [illegible]

$\therefore T_D = k\theta$

meter [illegible] $T_D \propto \theta$, $\therefore T_D = k\theta$

$T_C \propto \theta$, $\therefore T_C = k\theta$

$\therefore T_D = T_C$

Needle ~~[illegible]~~ [illegible] calcium [illegible] mirror [illegible] current [illegible] deflection [illegible] reading [illegible] scale [illegible] voltage difference [illegible]

[illegible] Quadrant [illegible] wire [illegible] potential [illegible] potential [illegible] needle [illegible] Needle [illegible] wire [illegible] spring control [illegible] angle of deflection [illegible]

Meter [illegible]

Quadrant Electrometer [illegible] Hetero static [illegible] Idiostatic [illegible]

* Hetero static [illegible]

[illegible] Needle [illegible] Charge [illegible] voltage [illegible] Area [illegible] Torque [illegible] Torque [illegible] angle of deflection [illegible] Quadrant [illegible] V_0 [illegible]

[illegible]

$\therefore V_0 \gg V_a, V_b$

[illegible] voltage [illegible] meter [illegible]

* Idiostatic [illegible]

[illegible] $V_0 = V_a$ [illegible] needle [illegible] V_a [illegible] potential [illegible] voltage [illegible] meter [illegible] V^2 [illegible]

Theory of Quadrant Electro Meter

V_0 = Needle voltage

V_a = 2nd & 4th quadrant voltage

V_b = 1st & 3rd quadrant voltage

r = radius of needle

θ = angle of deflection of needle

[illegible] $= \frac{1}{2} r^2\theta$

[illegible] $= \frac{1}{2} r^2\theta \times 4 = 2r^2\theta$

t = distance of needle from either of plates

$\frac{K}{4\pi}$ = Quadrant Electrometer constant

A = area (Needle [illegible])

$$C = K\frac{A}{4\pi t}$$

$$\therefore C = K \times \frac{2r^2\theta}{4\pi t} = K\frac{r^2\theta}{2\pi t}$$

$$E = \frac{1}{2} CV^2$$

(1) ~~[illegible]~~ Energy loss due to sector II & IV [illegible]

(2) Energy gained due to sector I & III [illegible]

$$= \frac{1}{2}c\left[(v_a - v_b)\left\{2v_0 - (v_a + v_b)\right\}\right]$$

$$= \frac{1}{2}c\left[2(v_a - v_b)\left\{v_0 - \left(\frac{v_a + v_b}{2}\right)\right\}\right]$$

Heterostatic, $E = \kappa \frac{r^2\theta}{2\pi t}\left[(v_a - v_b)\left\{v_0 - \frac{v_a+v_b}{2}\right\}\right]$

Idio static, $E = \frac{\kappa r^2\theta}{4\pi t}\left[(v_a - v_b)\left\{2v_0 - (v_a + v_b)\right\}\right]$

Case I Heterostatic connection

$v_0 >> v_a, v_b$

$\therefore \frac{v_a + v_b}{2}$ is negligible compared to v_0

$T \times \theta$ = work done $\rightarrow$ Energy

$$T \times \theta = \kappa \frac{r^2\theta}{2\pi t}\left[(v_a - v_b)\left\{v_0 - \left(\frac{v_a+v_b}{2}\right)\right\}\right]$$

$$T = \frac{\kappa \times r^2}{2\pi t}\left[(v_a - v_b)\left\{v_0 - \left(\frac{v_a+v_b}{2}\right)\right\}\right]$$

For a given meter, $\kappa \times \frac{r^2 v_0}{2\pi t}$ is constant

$$\therefore \boxed{T \propto (v_a - v_b)} \ *$$

$$\therefore \underline{\underline{T \propto V}} \left(\because V = v_a - v_b\right)$$

*

where,

$C_1 = \frac{\kappa r^2 v_0}{2\pi t}$, $\therefore \boxed{T = C_1 V}$ *

Case II Idio static connection

$$T = \frac{\kappa r^2}{4\pi t}\left[(v_a - v_b)\left\{2v_0 - (v_a + v_b)\right\}\right]$$

$$2v_0 - (v_a + v_b) = 2v_a - v_a - v_b = v_a - v_b$$

$$T = \frac{\kappa r^2}{4\pi t}\left[v_a - v_b\right]^2$$

T =

For a given meter $\frac{\kappa r^2}{4\pi t}$ is constant

$T \propto (v_a - v_b)^2$ $\quad T \propto V^2$ $\quad \because V = (v_a - v_b)$ *

$$\boxed{T = C_2 V^2} \ *$$

C_1, C_2 Relative Ratio constant [illegible]

$C_1 = \frac{\kappa r^2}{2\pi t} v_0$, $C_2 = \kappa \frac{r^2}{4\pi t}$

$$\therefore \boxed{\frac{C_1}{C_2} = 2v_0} \ *$$

[illegible] – Quadrant Electrometer [illegible]

[illegible]

(1) Potential [illegible] (2) capacitance [illegible] (3) Dielectric constant [illegible] (4) Ionization current [illegible]

(1) Quadrant Electrometer [illegible] moveable [illegible] Idio statically 60 volt Pd [illegible] scale [illegible] 25 division [illegible] Heterostatically [illegible] needle [illegible] 900 volts [illegible] quadrant [illegible] 10 division [illegible]

$T = \kappa \times 25$
$T = C_2 V^2$
$T = C_1 (60)^2$
$T = \kappa \times 25$
$T = C_1 (\ldots)$

(2) Quadrant Electrometer [illegible] Idio static connection [illegible] potential difference 10 volt [illegible] deflection [illegible] 5 division [illegible] Hetero static connection [illegible] quadrant [illegible] 0.2 V [illegible] deflection [illegible] 3 division [illegible] needle [illegible] voltage [illegible] apply [illegible]

$\kappa \times 25 = C_2 (60)^2$

$\kappa \times 10 = C_1 (\ldots)^2$

$\frac{10}{25} = \frac{C_1}{C_2} \ldots$

$\frac{10}{25} = \ldots$

$\frac{10}{25} = \ldots$

Idiostatically   For 25 division

① $T_d \propto \theta$ $T \propto V^2$

$T_d = K\theta$ $T = C_2 V^2$

$T_d = K\times 25$

meter [illegible] $T_d = T$

$\therefore K\times 25 = C_2\times (V)^2$

$K\times 25 = C_2 (60)^2$

$K\times 25 = C_2\times 3600$ —— ①

Heterostatically
For 10 division

$K\times 10 = C_1\times V$ —— ②

② ÷ ①

$$\frac{10}{25} = \frac{C_1}{C_2}\times\frac{V}{3600}$$

$$\frac{10}{25} = 2V_0\times\frac{V}{3600}$$

$$\frac{10}{25} = \cancel{2\times 400}\times\frac{V}{\cancel{3600}\,2}$$

$$V = \frac{20}{25} = .8 \text{ volts}$$

// Ans

② For Idiostatically

$T_d = K\times 5$ $T = C_2 V^2$

$K\times 5 = C_2 V^2$ $K\times 5 = C_2\times 100$ —— ①

Heterostatically

$K\times 3 = C_1\times V$ —— ②

② ÷ ① =>

$$\frac{K\times 3}{K\times 5} = \frac{C_1\, V}{C_2\times 100}$$

$$\frac{3}{5} = 2\times V_0\times\frac{V}{100}$$

$$\frac{3}{5} = 2\times V_0\times\frac{.2}{100}\;\; \frac{50}{10}$$

$$\frac{30}{2} = V_0$$

$V_0 = 150$ volts // Ans

Apply voltage

Extension Of voltmeter, Ammeter

*** [illegible] -

① [illegible]

② [illegible]

③ [illegible] High voltage [illegible]

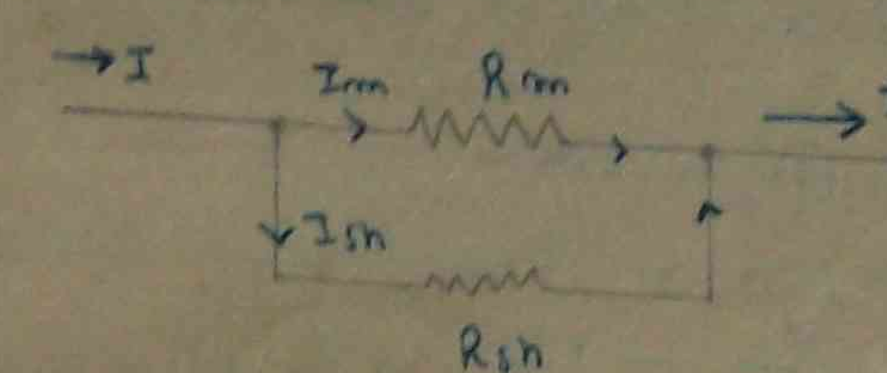
④ [illegible] Insulation [illegible]
[illegible]

voltmeter [illegible] series Resist[illegible]
Am " shunt "

[illegible] meter [illegible] extension [illegible]

ETEC

Extension of Am. meter



R_m = meter [illegible] Resistance , I_m = meter [illegible] current.

R_{sh} = Shunt Resistance , I_{sh} = Shunt [illegible] current

$$\therefore \boxed{I = I_m + I_{sh}}$$

[illegible] I_m [illegible] -

$$\frac{I}{I_m} = 1 + \frac{I_{sh}}{I_m}$$

[illegible] $\frac{I}{I_m} = m$

$$\therefore \boxed{m = 1 + \frac{I_{sh}}{I_m}}$$ m = (multiplying Power)

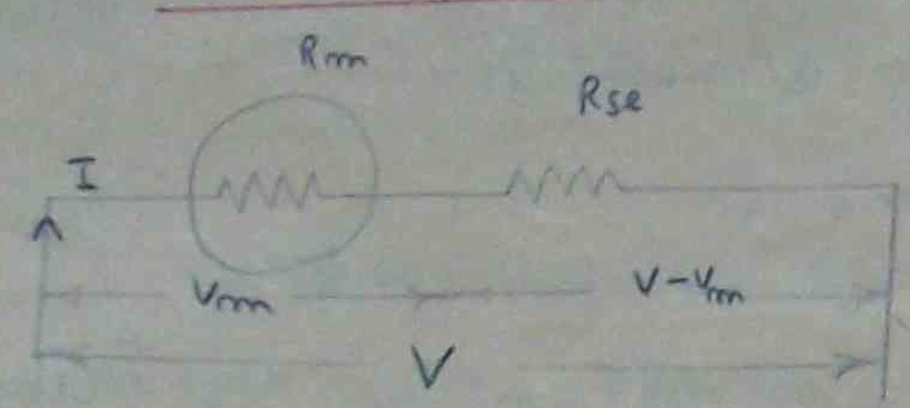
meter [illegible] Shunt Resistance [illegible] Parallel [illegible] -

$$V = I_m R_m = I_{sh}\cdot R_{sh}$$

$$\therefore \frac{I_{sh}}{I_m} = \frac{R_m}{R_{sh}}$$

$$m = \frac{I}{I_m} = 1 + \frac{R_m}{\ldots}$$

Extension Of Voltmeter



Rm = Swamp resistance

Rse = Series resistance

$$I = \frac{V_m}{R_m} = \frac{V - V_m}{R_{se}} \quad (\because \text{Series [illegible]})$$

$$\therefore V_m \times R_{se} = V R_m - V_m R_m$$

[illegible] $V_m R_m$ [illegible] –

$$\frac{R_{se}}{R_m} = \frac{V}{V_m} - 1$$

$$\therefore \frac{V}{V_m} = 1 + \frac{R_{se}}{R_m} = M$$

$$\therefore \boxed{m = 1 + \frac{R_{se}}{R_m}} \quad \text{OR} \quad R_{se} = (m-1) R_m$$

* voltmeter extension [illegible]

Voltmeter [illegible] Series Resistor [illegible] meter [illegible] meter Resistance [illegible] Resistance [illegible] swamp Resistance [illegible] Rse [illegible] voltage [illegible] drop [illegible] Rse [illegible] mica [illegible] temperature [illegible] Resistance [illegible] eureka wire [illegible] meter [illegible] heat [illegible] meter [illegible] Series Resistance [illegible] tapping [illegible] Voltage [illegible]

[illegible]

[illegible] AC [illegible] Series Resistance [illegible] inductance [illegible] mica [illegible]

[illegible]

* Ammeter extension [illegible]

Am-meter [illegible] Resistance [illegible] shunt [illegible] Shunt [illegible] Potential Terminal [illegible] Current Terminal [illegible] Potential Terminal [illegible]

Shunt [illegible] Temperature coefficient [illegible] magnesium strip [illegible] Shunt [illegible] Shunt [illegible] instrument [illegible]

[illegible]

Am-meter

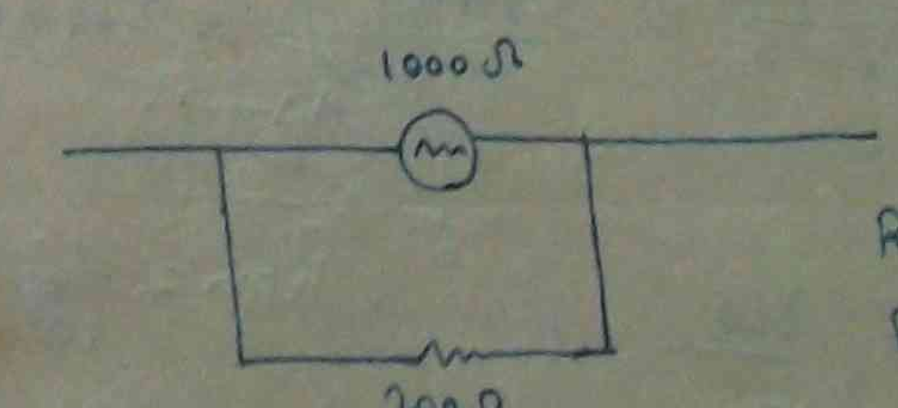
① 200Ω [illegible] shunt [illegible] 1000Ω [illegible] galvanometer [illegible] multiplying power [illegible] multiplying power 5, 10, 15 [illegible] 100 [illegible] Shunt [illegible]

② moving coil Instrument [illegible] terminal pd 72 mili Volt [illegible] 24 mili amp [illegible] scale [illegible] (က) 120 amp [illegible] Scale [illegible] shunt Resistance (ခ) 600 volts Scale [illegible] Series Resistance [illegible]

Rm =

* mili ohm × mili amp ≠ mili volt , * $\frac{\text{mili volt}}{\text{mili amp}}$ = ohm

①



$R_m = 1000\Omega$

$R_{sh} = 200\Omega$

$$m = 1 + \frac{R_m}{R_{sh}}$$

$$= 1 + \frac{1000}{200} = 6$$

$$m = 1 + \frac{R_m}{R_{sh}}$$

$$5 = 1 + \frac{1000}{R_{sh}} \qquad \therefore 4 = \frac{1000}{R_{sh}}$$

$$m - 1 = \frac{R_m}{R_{sh}} \quad R_{sh} = \frac{R_m}{m-1} \qquad R_{sh} = 250\Omega$$

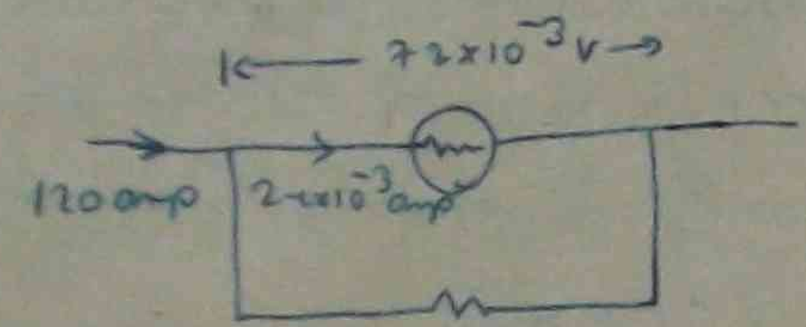
$$R_{sh} = \frac{R_m}{m-1}$$

$$R_{sh} = \frac{1000}{10-1} = \frac{1000}{9} = 111.1\ \Omega$$

$$R_{sh} = \frac{R_m}{m-1} = \frac{1000}{15-1} = \frac{1000}{14} = 71.4$$

$$R_{sh} = \frac{R_m}{m-1} = \frac{1000}{100-1} = \frac{1000}{99} = 10.1\ \Omega$$

(2)



Shunt ထဲသို့စီး current $= 120 - 24\times10^{-3}$

$= 120 - .024$

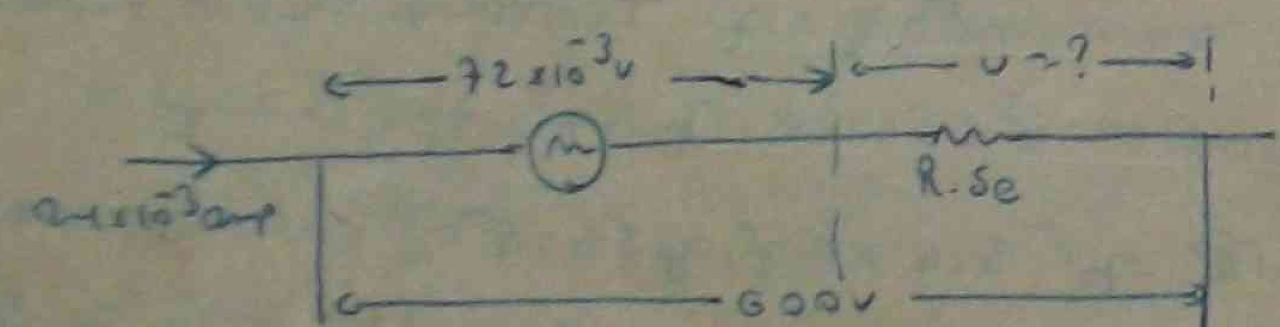
$= 119.976$ amp

$$\text{Shunt} = \frac{V}{I} = \frac{72\times10^{-3}}{119.976}$$

$= .601\times10^{-3}\ \Omega$

Shunt Resistance $= .601$ miliohm

$$m = \frac{I}{I_m} = \frac{120}{.601} = 500$$

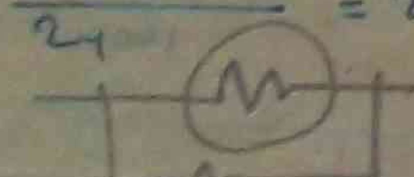


Rse ရှိ volt drop $= 600 - 72\times10^{-3}$ volts

$= 600 - .072$

$= 599.928$ volts

$$\therefore R_{se} = \frac{599.928}{24\times10^{-3}} = \frac{599928}{24} = 24990\ \Omega$$



$$m = 1 + \frac{R_{se}}{R_m}$$

$$R_m = \frac{.5}{10^3} = .5\times10^{-3}$$

$$500 = 1 + \frac{R_{se}}{24\times10^{-3}}$$

$R_{sh} = 10 - .0005$

$= 9.9995$

5×10^{-4} $R_m = .01\times9.9995$

$499\times24\times10^{-3} = R_{se}$

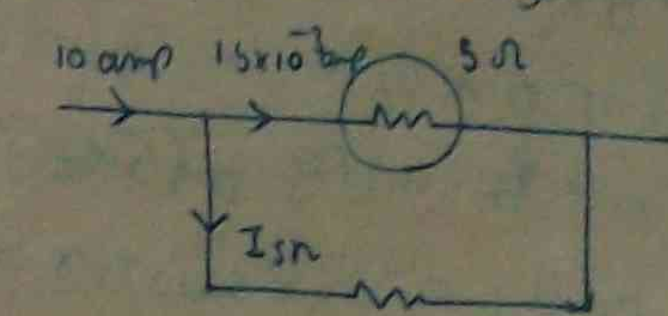
$R_m = 399.98$

$400\ \Omega$

(3) Ammeter တစ်ခု [illegible] meter ၏ maximum deflection သည် 15 mili amp ဖြစ်၍ meter ၏ Resistance 5Ω နှင့် supply 10 amp [illegible] shunt Resistance ၏ [illegible]။

(4) moving coil Ammeter [illegible] fixed shunt သည် 0.02Ω coil Resistance သည် 1000Ω meter ၏ pd သည် 0.5 volts [illegible] fullscale deflection [illegible] (က) shunt current (ခ) supply current သည် 10 amp နှင့် 75 amp ဖြစ်[illegible] fullscale deflection [illegible] coil ၏ Resistance [illegible]။

(1)



meter တွင်ကျသော voltage $= 5\times15\times10^{-3}$

$= 75\times10^{-3}$ volts

Shunt တွင်ကျသော voltage $= (10 - 15\times10^{-3})\times R_{sh}$

$\therefore 75\times10^{-3} = (10 - 15\times10^{-3})\times R_{sh}$

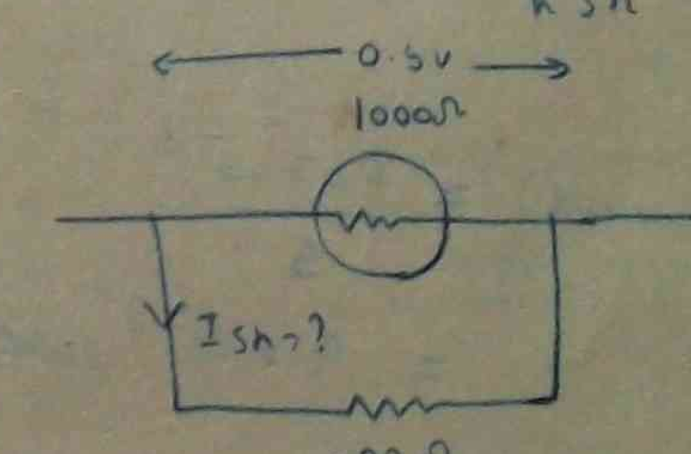
$75\times10^{-3} = (10 - .015)\,R_{sh}$

$= 9.985\ R_{sh}$

$$R_{sh} = \frac{75\times10^{-3}}{9.985} = 7.52\times10^{-3}\ \Omega$$

$= 7.52\ m\Omega$

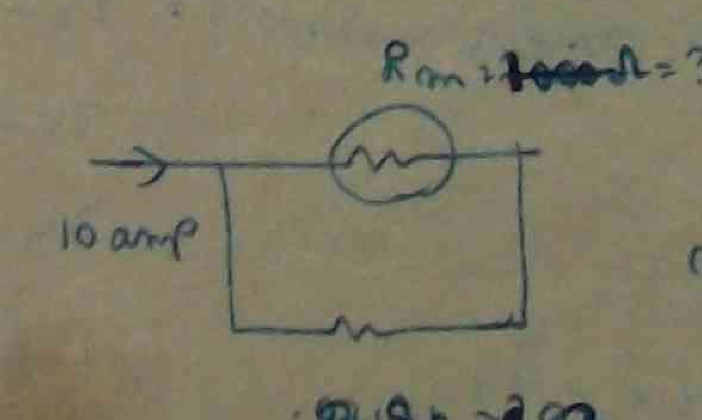
(2)



$$I_{sh} = \frac{0.5}{.02} = 25\ \text{amp}$$

$$m = 1 + \frac{R_m}{R_{sh}}$$

$$m = 1 + \frac{1000}{.02} = 5001$$



meter ထဲသို့စီးသော current $= \frac{0.5}{1000}$

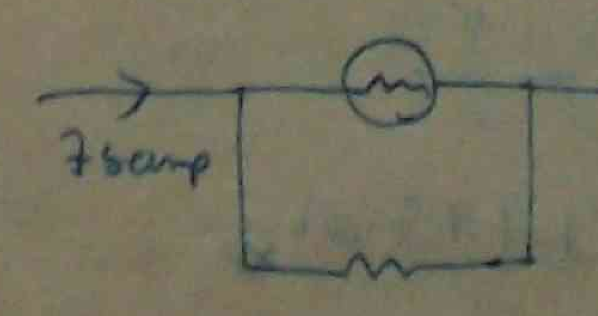
$= .5\times10^{-3}$ amp

$= .0005$ amp

$\therefore I_{sh} = 10 - .0005 = 9.9995$ amp

$$R_{sh} = \frac{.5}{9.9995} = \frac{5000}{99995}$$

$= .05001\ \Omega$



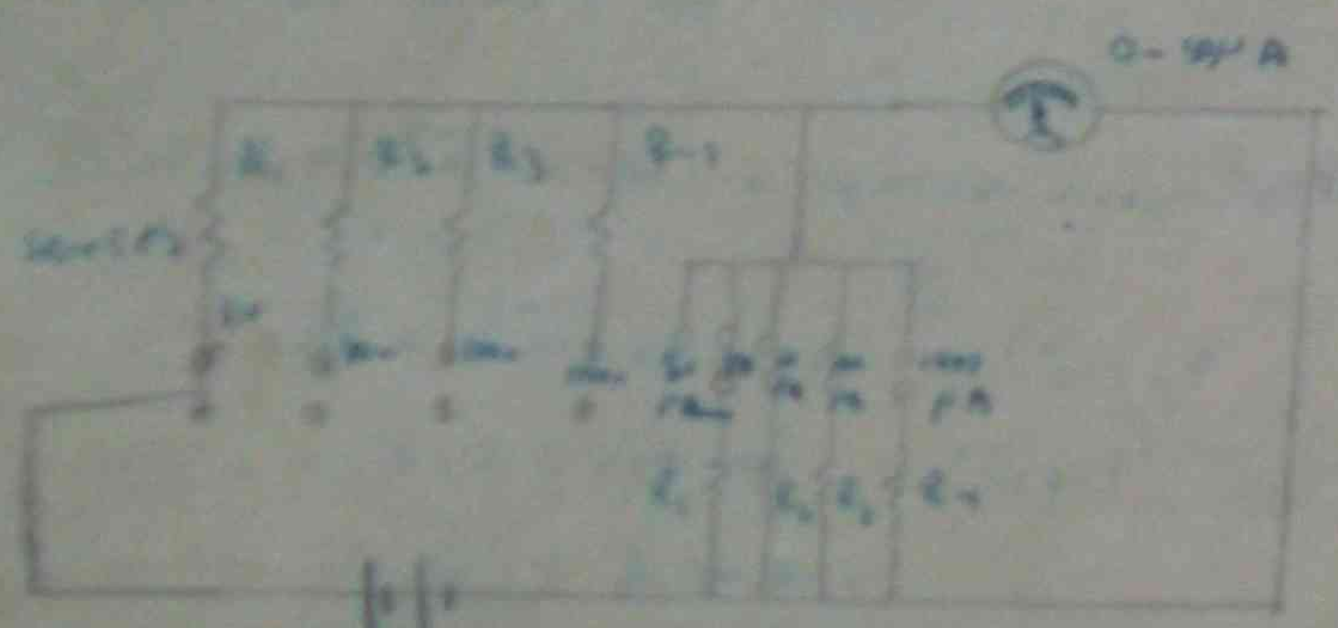
$I_{sh} = 75 - .0005 = 74.9995$

$$R_{sh} = \frac{.5}{74.9995} = .00667\ \Omega$$

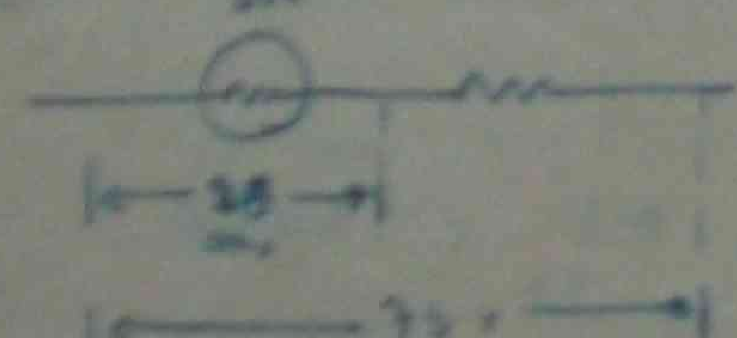
(5) moving coil DC voltmeter [illegible] Resistance [illegible] meter [illegible] Terminal [illegible] 15 m.v [illegible] max defl [illegible] meter [illegible] multi range voltmeter [illegible] 0-75, 0-150, 0-300 volts [illegible] series Resistance [illegible]

(6) 240 volts [illegible] 10000 Ω [illegible] 4000 Ω [illegible] voltmeter [illegible] 60 volts [illegible] 2500 Ω [illegible] voltmeter [illegible] volt [illegible]

(7) [illegible] DC voltmeter [illegible] Resistor [illegible]



(5)



I_m (Current) $= \frac{25 \times 10^{-3}}{5}$

$= 5 \times 10^{-3}$ amp

Series Resistance [illegible] volt $= 75 - 25 \times 10^{-3}$

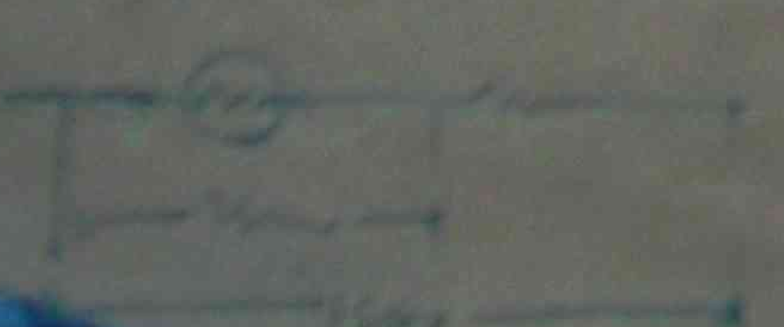
$= 75 - .025$

$= 74.975$ volts

$\therefore$ Resistance $= \frac{74.975}{5 \times 10^{-3}}$

$= \frac{74975}{5}$

$= 14995\ \Omega$



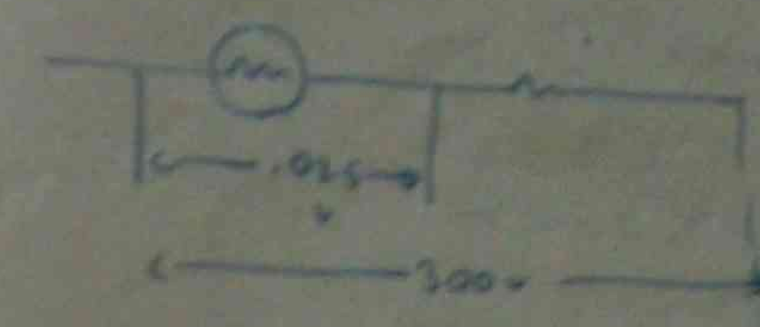
Series Resistance [illegible]

[illegible] $= 150 - .025$

$= 149.975$

Resistance $= \frac{149.975}{5 \times 10^{-3}} = \frac{149975}{5}$

$= 29995\ \Omega$



Series Resistance [illegible]

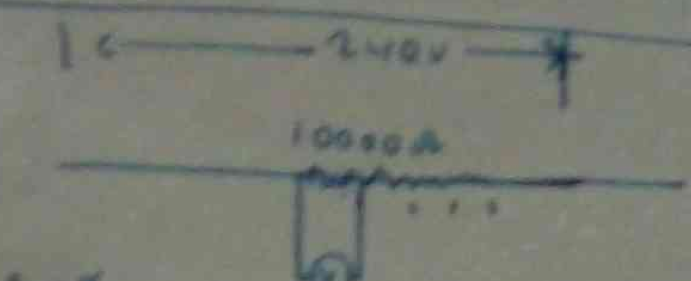
[illegible] volt $= 300 - .025$

$= 299.975$

Sr. Resistance $= \frac{299.975}{5 \times 10^{-3}} = \frac{299975}{5}$

$= 59995\ \Omega$

(6)



$I_{sh} = \frac{240}{10000} = .024$ amp

[illegible] $\frac{1}{4}$ = 2500 Ω

volt drop = 2500 × .024

= 60 v

[illegible] voltage = 240 v

[illegible] $\frac{1}{4}$ [illegible]

$\therefore$ [illegible] $\frac{1}{4}$ [illegible] voltmeter [illegible]

[illegible] voltage = 240 v

2500 Ω $= \frac{240}{4} = 60$ v

(7) $\frac{1}{R_T} = \frac{1}{50} + \frac{1}{1} + \frac{1}{10} + \frac{1}{100} + \frac{1}{1000}$

$= \frac{20 + 1000 + 100 + 10 + 1}{1000}$

$= \frac{1131}{1000}\ \mu\Omega$

$R_T = \frac{1000}{1131}\ \mu\Omega = \frac{1}{1131}\ \Omega$

$= .000884\ \Omega$

(7) Resis [illegible]

Total Current = 1000 + 100 + 10 + 50 + 1

= 1161 μ amp = 1161×10^{-6} amp

$I_t = 1161 \times 10^{-6} + 50 \times 10^{-6}$

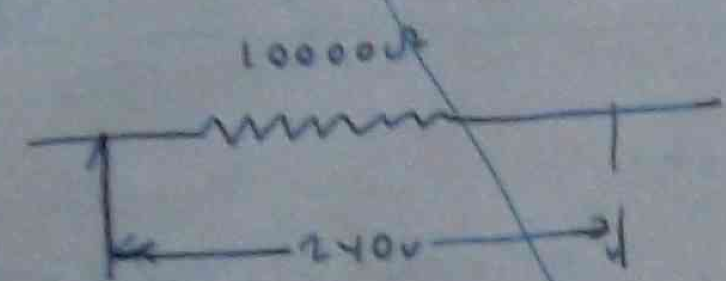
$= 1211 \times 10^{-6}$ amp

R_1 ൻ്റെ വില $= \frac{1}{1211\times10^{-6}} = \frac{1000000}{1211} = 825$ ohm Ω

R_2 ൻ്റെ വില $= \frac{10}{1211\times10^{-6}} = 8250\,\Omega$

$R_3 = \frac{100}{1211\times10^{-6}} = 82500\,\Omega$

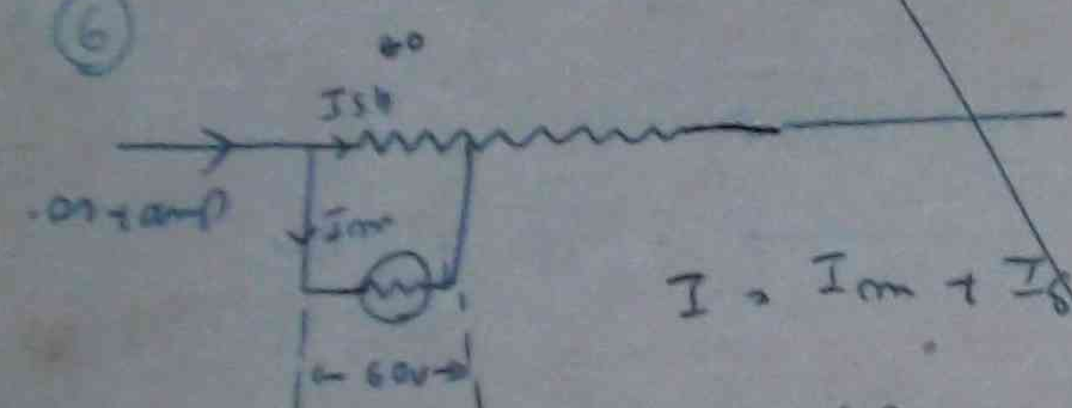
$R_4 = \frac{1000}{1211\times10^{-6}} = 825000\,\Omega$ //Ans



meterൻ്റെ filament ൽ കൂടിയുള്ള $= \frac{240}{10000}$

$= .024$ amp

(6)



$I = I_m + I_{sh}$

$.024 = \frac{60}{10000} + I_{sh}$ $\quad I_{sh} = 9\,mA$

$R_{sh} = 6666.66\,\Omega \quad \left(\frac{60\times10^3}{9}\right) = 6666.66$

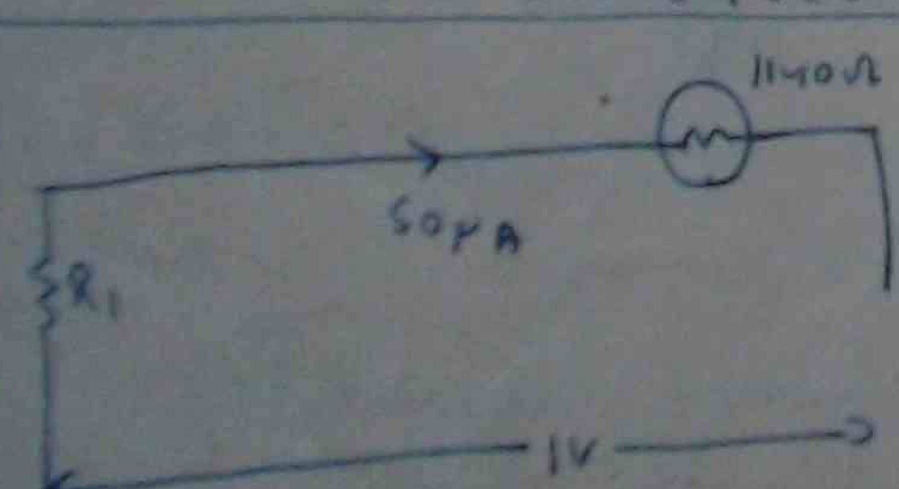
6666.66Ω ൽ കൂടി ഒഴുകുന്ന കറൻ്റ്

$I = I_m + I_{sh}$

$.024 = \frac{v}{400} + \frac{v}{2500}$

$v = 36.99$ volts

(7)



1140Ω ൻ്റെ volt drop $= 1140 \times 50 \times 10^{-6}$

$= 57000 = .057$ volts

$R = \frac{.942}{50\times10^{-6}} = \frac{943000}{50} = 18860\,\Omega$

$V = 10 - .057 = 9.943$

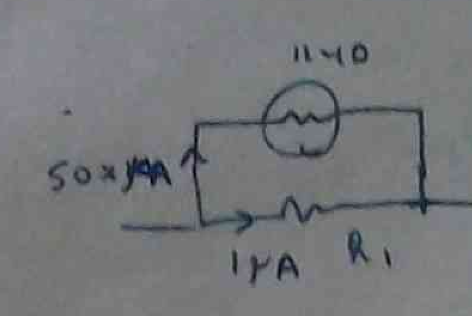
$R = \frac{9.943}{50\times10^{-6}} = \frac{9943000}{50} = 198860\,\Omega$

$V = 100 - .057 = 99.943$

$R = \frac{99.943}{5\times10^{-6}} = \frac{99943000}{50} = 1998860\,\Omega$

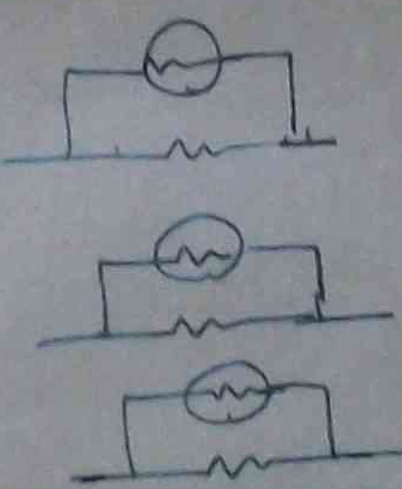
$V = 1000 - .057 = 999.943$

$R = \frac{999943000}{50} = 19998860\,\Omega$



50μA ൻ്റെ volt $= 50\times10^{-6}\times1140$

$= .057$ volt



R_1 ൻ്റെ വില $= \frac{.057}{10^{-6}} = 57000\,\Omega$

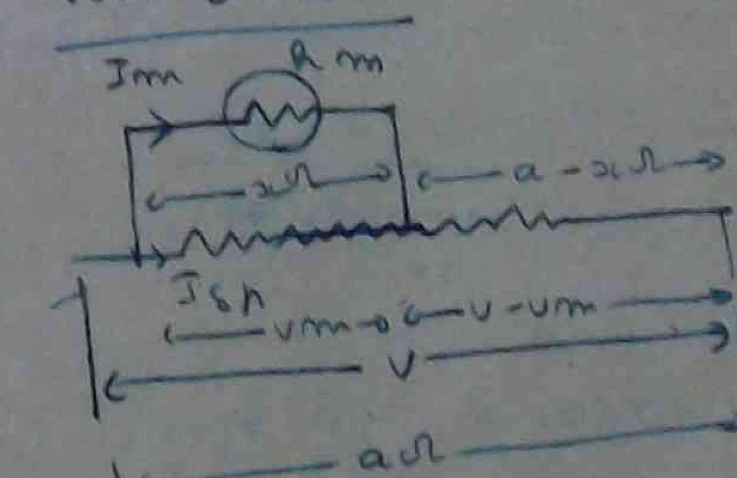
R_2 ൻ്റെ വില $= \frac{.057}{10\times10^{-6}} = 5700\,\Omega$

R_3 ൻ്റെ വില $= \frac{.057}{100\times10^{-6}} = 570\,\Omega$

R_4 ൻ്റെ വില $= \frac{.057}{1000\times10^{-6}} = 57\,\Omega$ //Ans

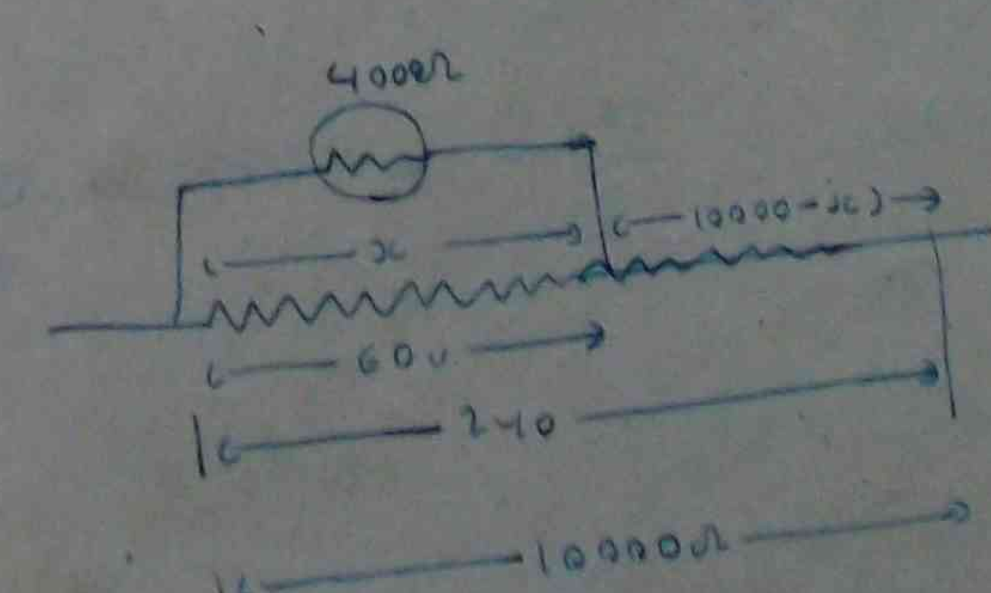
(6)

volt divider



$\therefore \frac{vm}{R_{sh}} + \frac{vm}{Rm} = \frac{v-vm}{a-x}$

$\frac{vm}{x} + \frac{vm}{Rm} = \frac{v-vm}{a-x}$



$\frac{240-60}{10000-x} = \frac{60}{4000} + \frac{60}{x}$

$\frac{180}{10000-x} = \frac{60}{4000} + \frac{60}{x}$

$\frac{3}{10000-x} = \frac{4000+x}{4000x}$

$V = 1000 - .057 = 999.943$

$R = \frac{999943000}{50} = 19998860\ \Omega$

50 μA [illegible] volt $= 50 \times 10^{-6} \times 1149$

Electrical Measurement

① [illegible] 193 Ω 197 Ω 200 Ω 203 Ω [illegible] 207 Ω [illegible] series [illegible] 811000 Ω [illegible] voltmeter [illegible] 200 Ω [illegible] (1) supply voltage (2) 200 V [illegible] volt meter [illegible] % [illegible] 60 [illegible] voltmeter resistivity [illegible] sensistivity [illegible]

② voltage current [illegible] Power [illegible] wattmeter [illegible] High Power measurement [illegible] resistance [illegible] Ammeter 0.1 Ω voltmeter 10 kΩ wattmeter [illegible] current coil 0.4 Ω Pressure coil 7500 Ω [illegible] Ammeter 2.5 amp voltmeter 225 V wattmeter 75 watt [illegible] Power factor [illegible] Power [illegible]

③ (က) moving iron ammeter [illegible] radian [illegible] inductance [illegible] $dL/d\theta$ [illegible] $(4 - \theta)\ \mu H$/radian [illegible] control spring Torque [illegible] 11×10^{-6} [illegible]-meter/radian [illegible] current 2 amp [illegible] radian [illegible]

1 newmeter = 10^7 dynes-cm

④ DC energy meter [illegible] 250 V 5 amp [illegible] meter [illegible] declared constant [illegible] 5 amp-sec/rev [illegible] (က) meter [illegible] declared constant [illegible] rev/kwh [illegible] (ခ) full load speed [illegible] r.p.m. [illegible] (ဂ) half load [illegible] Test [illegible] 119.5 sec [illegible] % [illegible]

⑤ ~~[illegible]~~ Iron [illegible] copper [illegible] Thermocouple [illegible] Hot junction [illegible] 100°C [illegible] cold junction [illegible] 0°C [illegible] metal [illegible] e.m.f constant [illegible]

Cold junction	Hot junction
± 16.7, ± (−.03)	± 2.71 ± (.008)

(က) junction point [illegible] e.m.f (ခ) neutral temperature [illegible]

③ (ခ) 10 amp Electro dynamics Ammeter [illegible] torsion constant 1 dyne cm/degree [illegible] spring [illegible] control [illegible] ~~[illegible]~~ spring [illegible] full scale deflection 110 [illegible] inductance

R_1 voltdrop $= 1 - .057 = .943$ volts

Electrical Measurement

① [illegible] 193Ω 197Ω 200Ω 203Ω [illegible] 207Ω [illegible] series [illegible] 811000Ω [illegible] voltmeter [illegible] 200Ω [illegible] (1) supply voltage (2) 200V [illegible] volt meter [illegible] 5% [illegible] 60 [illegible] voltmeter resistivity [illegible] sensitivity [illegible]

② voltage, current [illegible] Power [illegible] wattmeter [illegible] High Power measurement [illegible] resistance [illegible] Ammeter 0-1Ω voltmeter 10kΩ wattmeter [illegible] current coil 0.48Ω Pressure coil 7500Ω [illegible] Ammeter 2.5amp volt meter 225V wattmeter 75watt [illegible] Power factor [illegible] Power [illegible]

③ (က) moving iron ammeter [illegible] 0 [illegible] radian [illegible] inductance [illegible] $dL/d\theta$ [illegible] (4-θ) μH radian [illegible] control spring Torque [illegible] 12×10^{-6} new-meter/radian [illegible] current 2 amp [illegible] radian [illegible]

lewmeter = 10^7 dynes-cm

④ DC energy meter [illegible] 250V 5amp [illegible] meter [illegible] declared constant [illegible] 5amp-sec/rev [illegible] (က) meter [illegible] declared constant [illegible] rev/kwh [illegible] (ခ) full load speed [illegible] 60 rev 1 min [illegible] (ဂ) half load [illegible] Test [illegible] 119.5 sec [illegible] %. [illegible]

⑤ ~~Iron [illegible]~~ Iron [illegible] copper [illegible] Thermocouple [illegible] Hot junction [illegible] 100°C [illegible] cold junction [illegible] 0°C [illegible] metal [illegible] e.m.f constant [illegible]

Cold junction	Hot junction
±16.7 , ±(-.03)	±2.71 ±(.008)

(က) junction point [illegible] e.m.f (ခ) neutral temp [illegible]

③ (ခ) 10 amp Electro dynamics Ammeter [illegible] torsion constant 1 dyne cm/degree [illegible] spring [illegible] control [illegible] spring [illegible] full scale deflection 110 [illegible] inductance

$x = -12000 \pm$

$$12000x = 4\times10^7 + 10^4x - 4000x - x^2$$

$$12000x = 4\times10^7 + 6000x - x^2$$

$$x^2 + 6000x - 4\times10^7 = 0$$

$$\cancel{x^2 + 6000x - 40000000 = 0}$$

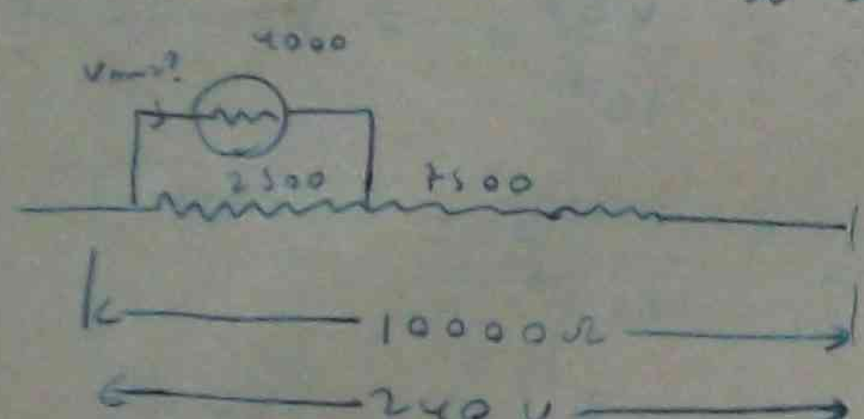
$$x^2 + 6000x = 4\times10^7$$

$$x^2 + 6000x + (3000)^2 = 4\times10^7 + 3^2\times10^6$$

$$(x + 3000)^2 = 10^6(40+9)$$

$$x + 3000 = 10^3\times7$$

$$x = 4000\,\Omega \quad //\text{Ans}$$



$$\frac{240 - V_m}{7500} = \cancel{4000}\ \frac{V_m}{4000} + \frac{V_m}{2500}$$

$$\frac{240 - V_m}{7500} = \frac{V_m(2500+4000)}{10000000}$$

$$\frac{240 - V_m}{\cancel{7500}\,3} = \frac{V_m\,65\cancel{00}}{\cancel{100000}\,40}$$

$$9600 - 40V_m = 195\,V_m$$

$$9600 = 235\,V_m$$

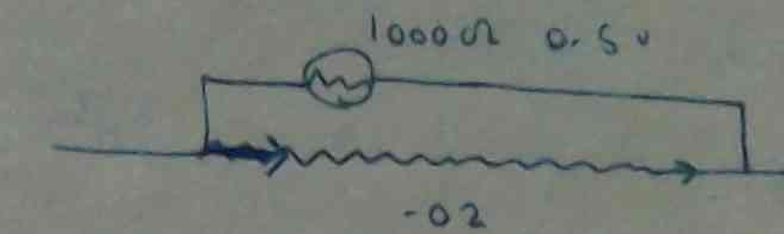
$$V_m = \frac{9600}{235} = 40.8\ \text{volts} \quad //\text{Ans}$$

moving coil Ammeter [illegible] shunt [illegible] coil [illegible] Resistance [illegible] 100 [illegible] pd 0.5 v [illegible] full deflection [illegible]

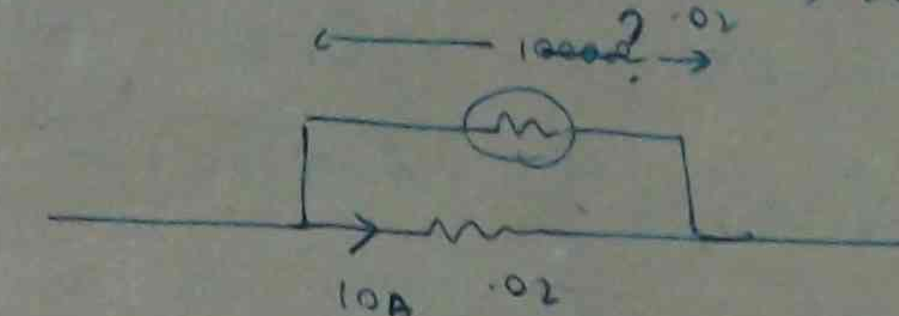
Shunt : .02 Ω

(က) shunt current [illegible]

(ခ) [illegible] shunt current [illegible] 10 A [illegible] scale [illegible] meter Resis: [illegible]



Shunt current $= \frac{.5}{.02} = 25$ amp meter current $= \frac{.5}{1000} = .0005$



voltdrop $= 10\times.02 = .2$ volts

meter [illegible] $V_m = .2$ volt

meter [illegible] current $= .0005\,\Omega$

$$\therefore R_m = \frac{.2}{.0005} = \frac{2000}{5} = 400\,\Omega \quad //\text{Ans}$$

Ammeter [illegible] voltmeter [illegible]

	Am meter	volt-meter
1	Ammeter [illegible] circuit [illegible] current [illegible] meter [illegible]	① volt meter [illegible] circuit [illegible] voltage [illegible] meter [illegible]
2	Am meter [illegible] circuit [illegible] series [illegible]	② volt meter [illegible] circuit [illegible] parallel [illegible]
3	Am meter [illegible] cross sectional area [illegible] coil [illegible]	③ volt meter [illegible] cross sectional area [illegible] coil [illegible]
4	[illegible] Resis: [illegible] shunt [illegible] parallel [illegible]	④ volt meter [illegible] series Resistor [illegible]
5	[illegible] meter [illegible] shunt [illegible]	⑤ [illegible] series Resistance [illegible] swamp Resistor [illegible]

Instrument Transformer

Instrument transformer [illegible]

① current transformer

② voltage or potential transformer [illegible]

[illegible] meter [illegible] Relay transformer [illegible]

Instrument transformer [illegible] meter [illegible]

[illegible] instrument transformer [illegible] Dry type [illegible] oil insulated type [illegible] Dry type [illegible] 6.6 kv [illegible] oil insulated type [illegible] voltage [illegible] current transformer C.T secondary [illegible] 100v, 110v, 150v [illegible]

Potential transformer [illegible] Rating [illegible] 200 volt ampere capacity [illegible]

Current transformer

[illegible] - current transformer [illegible] ring type [illegible] square type [illegible] current transformer [illegible] primary coil [illegible] secondary coil [illegible] Laminated Iron core [illegible] primary [illegible] copper [illegible] copper [illegible] secondary [illegible] 14 swg copper wire [illegible] winding [illegible] winding [illegible] insulation [illegible]

Uses - Current transformer [illegible] ammeter watt meter, [illegible] meter or k.w.h meter p.f meter Relay oil circuit Breaker

[illegible] current transformer [illegible] meter [illegible] Relay [illegible] load [illegible]

Precaution: - primary [illegible] Energized secondary [illegible] open circuit [illegible] open circuit [illegible] Iron core [illegible] Permanent magnet [illegible] C.T Ratio [illegible] meter or Relay [illegible] Short circuit [illegible] Relay [illegible] Short circuit [illegible]

Potential Transformer

[illegible] - Potential transformer [illegible] square type or shell type [illegible] primary [illegible] secondary coil [illegible] winding [illegible] Insulation [illegible] leakage reactance [illegible] Iron core [illegible] Potential transformer [illegible] flux density [illegible] 1000 lines / sq.cm [illegible] cross sectional Area [illegible] flux density [illegible] flux [illegible] exciting current [illegible] resistance [illegible] reactance [illegible] winding [illegible]

Primary winding [illegible] fuse [illegible] current limiting resistance [illegible] Auto transformer [illegible] potential transformer [illegible]

Uses :- " Potential transformer [illegible] volt meter, watt meter, [illegible] ammeter P.f meter frequency meter

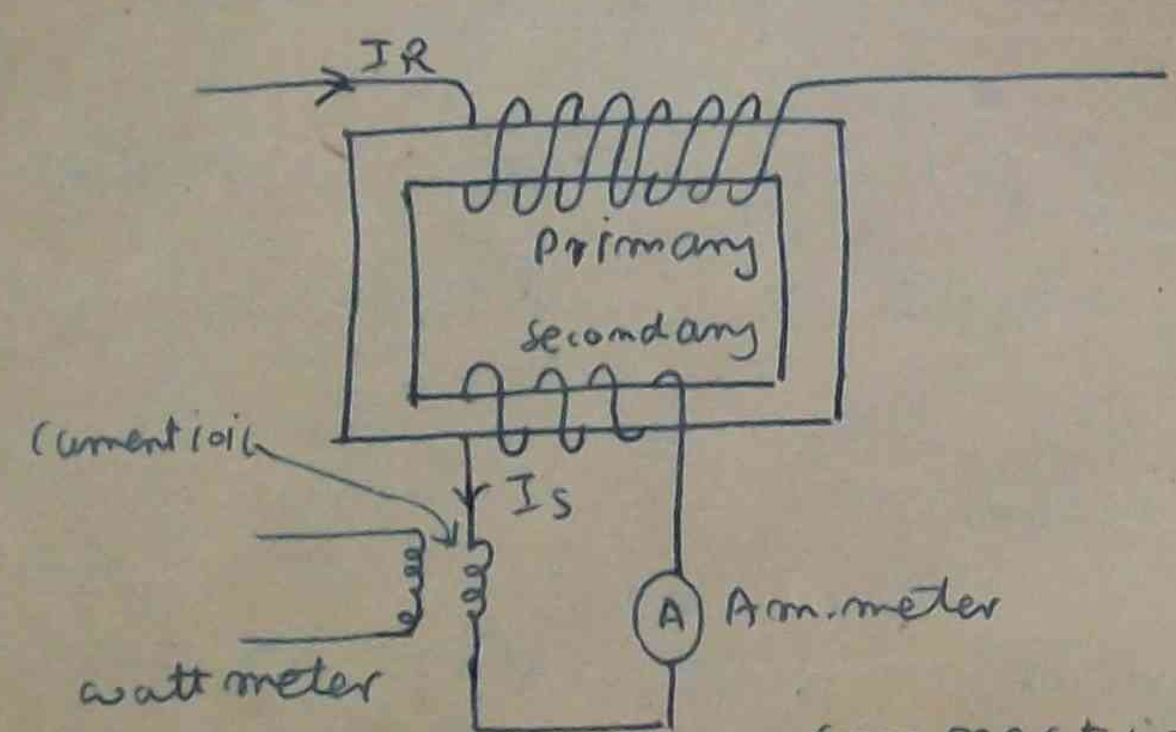
Synchro Relay oil circuit Breaker [illegible]

Potential transformer [illegible] instrument transformer [illegible] 200V maximum [illegible]

[illegible] special design [illegible]

Precaution :- " secondary [illegible] short circuit [illegible] volt [illegible] 10% [illegible]

moving Iron meter or Clampon Ammeter



connection of a current transformer.

Bus Bar , Fuse holder [illegible]

[illegible] Am. meter [illegible] current transformer or Clampon ammeter tong tester [illegible] Ammeter [illegible] AC DC [illegible] meter [illegible] AC [illegible] meter [illegible] Clamp son ammeter [illegible] current transformer [illegible] Rectifier [illegible]

[illegible] primary [illegible] current [illegible] cable [illegible] magnetic circuit [illegible]

[illegible] 600 V [illegible] insulation [illegible] split laminated core [illegible] Iron core [illegible] spring action [illegible]

current transformer [illegible] secondary side [illegible]

current transformer Ratio [illegible] current [illegible] 10, 25, 50, 100, 250, 500, 1000 [illegible]

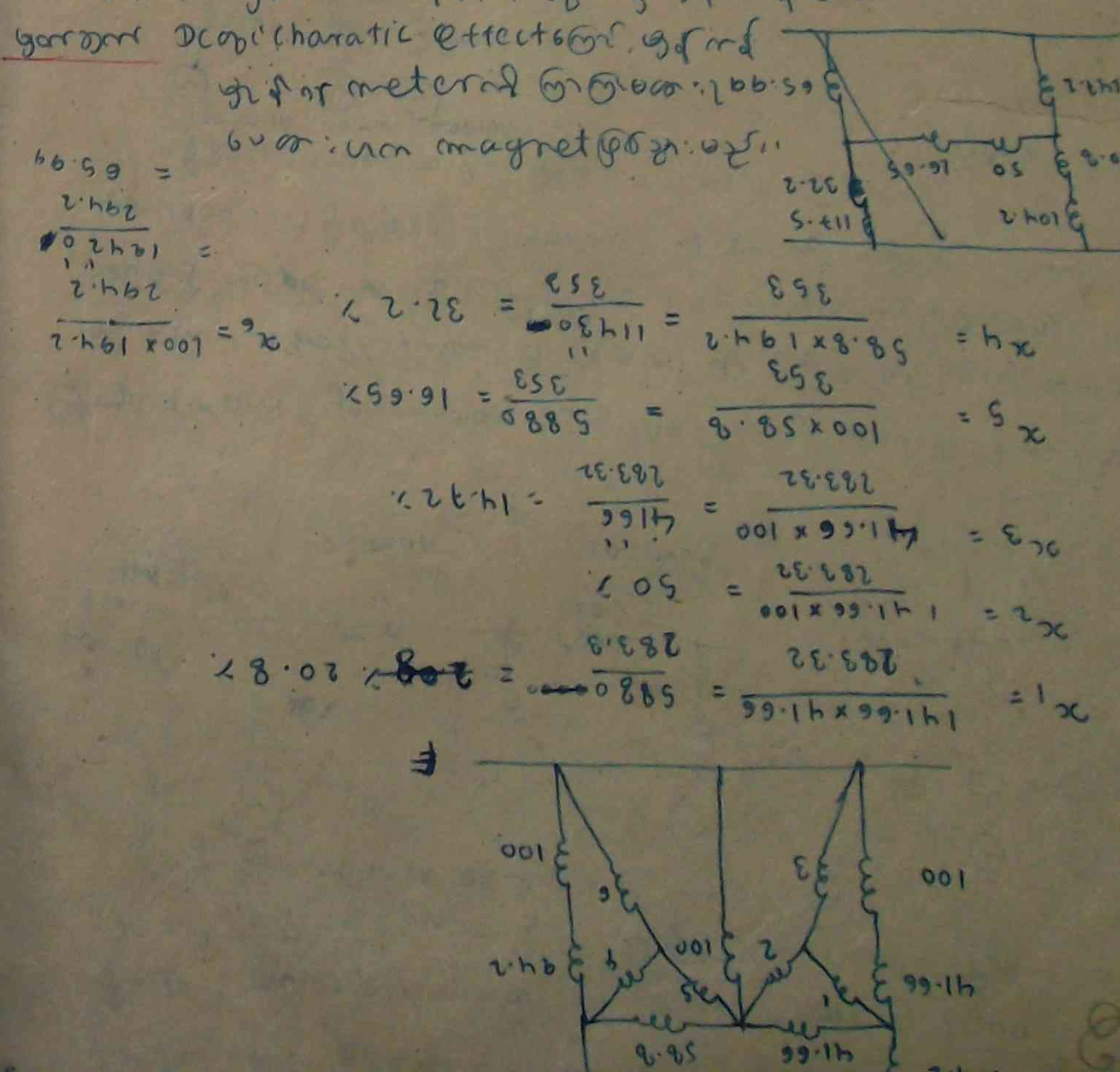
[illegible] scale [illegible] meter [illegible] selector switch [illegible] winding tapping [illegible]

Rectifier [illegible] switch [illegible] series [illegible]

Tonge tester

AC DC [illegible] Am. meter [illegible] current transformer [illegible] moving Iron [illegible] Iron core [illegible] cylinder [illegible] Am. meter [illegible] moving [illegible] meter [illegible] current [illegible] Range [illegible] current [illegible] Hollow cylinder [illegible] cylinder [illegible] moving Iron [illegible] cylinder [illegible] moving Iron [illegible] scale [illegible] positive or Negative 1% [illegible]

[illegible] DC [illegible] charactic effect [illegible] meter [illegible] magnet [illegible]



Second Year E.T.E.C (Electrical)

Electrical measurement.

(Indicating Instruments)

① Deflection (or) operating torque

② controlling torque
- spring control
- gravity control

③ damping torque
- air friction damping
- eddy current damping
- fluid friction damping

① Deflection (or) operation torque

[illegible] magnetic, electrostatic, electrodynamic, Thermal effect [illegible] Instrument [illegible] current [illegible] torque [illegible]

② controlling Torque

moving system [illegible] deflection [illegible] controlling [illegible] moving system [illegible] deflection [illegible] controlling torque [illegible] meter pointer [illegible] pointer [illegible] current [illegible] current [illegible] pointer [illegible] indicating instrument [illegible] controlling torque [illegible] spring [illegible]

Phosphor bronze [illegible] (helical) spring [illegible] instrument [illegible] moving system [illegible] pointer [illegible] spring [illegible] deflection torque [illegible] controlling torque [illegible] pointer [illegible] permanent magnet moving coil [illegible] deflection torque [illegible] current [illegible]

$T_d \propto I$ (current), $T_c \propto \theta$

But $T_c = T_d$ $\therefore \theta \propto I$

deflection (θ) [illegible] current (I) [illegible] spring control instrument [illegible] scale [illegible] linear scale [illegible]

controlling torque (T_c) [illegible]

$T_c = \frac{Ebt^3\theta}{12L}$ (θ [illegible] radian [illegible]) $= \frac{E t \theta}{2 \, S_{max}}$ cm

where
- E = Young's modulus of spring (gm/cm²)
- t = thickness of spring (cm)
- b = breadth of spring (cm)
- L = length of spring (cm)
- θ = deflection of moving system (radian)
- S_{max} = max. stress
- θ = degree

$\frac{\theta}{180} = \frac{\theta}{\pi}$

recording Instrument [illegible] phosphor bronze spring [illegible] L = 0.104 meter, b = [illegible] mm, t = 0.051 cm [illegible] Young's modulus [illegible] full scale deflection [illegible] controlling torque [illegible] current [illegible]

$$\frac{Ebt^3\theta}{12L} = \frac{1.15\times10^6\times1(0.021)^3\times22}{12\times10\times19.4\times21} = 4.7925$$

Recording Instrument [illegible] full scale deflection [illegible] torque T_c [illegible] 10gm/cm [illegible] spring control [illegible] stress [illegible] 660kg/cm² [illegible] young's modulus [illegible] 1.15×10^6 kg/cm² [illegible] spring [illegible] 0.1cm [illegible] thickness [illegible] length [illegible]

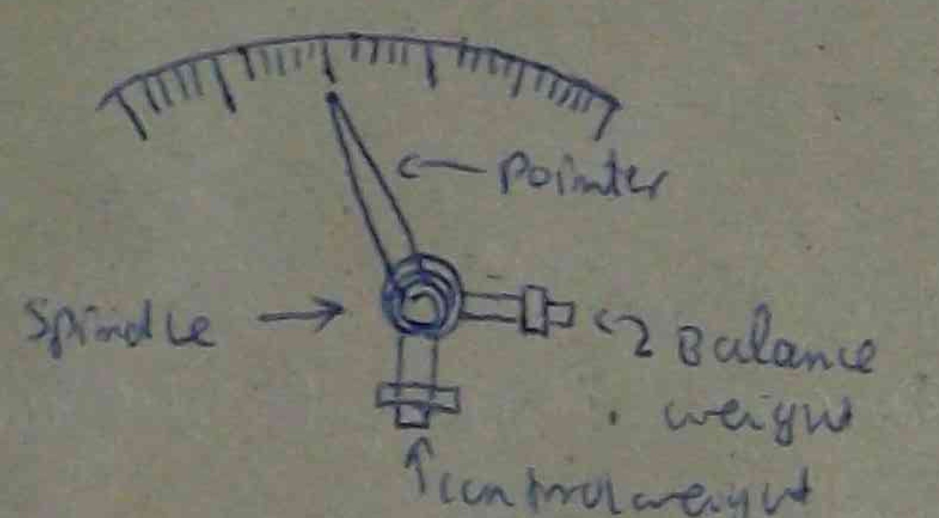
$E = 1.15\times10^6$ kg/cm², $= 1.15\times10^9$ gm/cm², $\theta = 22/21$ rad $b = 0.1$cm

Thickness? length? $S_{max} = 660\times10$ gm-cm, $T_c = 10$ gm-cm,

$T_c = \frac{Ebt^3\theta}{12L}$, $T = \frac{Et\theta}{2S_{max}}$,

Gravity control

non linear scale



[illegible] gravity control [illegible] instrument system [illegible] balancing wt [illegible] current [illegible] pointer [illegible] spindle [illegible] torque [illegible] gravity control [illegible] gravity control instrument [illegible] control [illegible]

adjust [illegible] meter [illegible] zero adjust [illegible] control [illegible] temperature [illegible] gravity control [illegible] controlling torque (Tc) [illegible] sine of the cycle [illegible]

spring control [illegible] gravity control [illegible]

[illegible] Instrument [illegible] spring control [illegible] Tc [illegible] control torque [illegible] deflection [illegible] θ [illegible] $T_c = k_s\theta$ (k_s = spring constant)

[illegible] $\rightarrow T_d = T_c$ [illegible] $\rightarrow k_s\theta = kI$

$\therefore \theta = \frac{k}{k_s}I \quad (\theta \propto I)$

[illegible] deflection [illegible] scale [illegible] current (I) [illegible]

[illegible] Instrument [illegible] gravity control [illegible]

$T_c \propto \sin\theta$ [illegible] (or) $T_c = k_g\sin\theta$ (k_g = gravity constant)

[illegible] $T_c = T_d \propto I$ $\therefore k_g\sin\theta = kI$

$\sin\theta = \frac{k}{k_g}I \quad (I \propto \sin\theta)$

Pb ① [illegible] 10mA [illegible] deflection [illegible] 90° [illegible] current 5mA [illegible] (a) spring ~~constant~~ control [illegible] (b) gravity control [illegible] deflection angle [illegible]

(a) $T = \frac{k}{k_s}I$

$90 = \frac{k}{k_s}\times10 \quad \therefore \frac{k}{k_s} = \frac{90}{10} = 9$

$\theta = k/k_s\, I' = 9\times5 = 45°$

Pb ② 1 amp current [illegible] deflection [illegible] 90° [illegible] (a) spring control (b) gravity control [illegible] deflection 45° [illegible] current [illegible]

Pb ① (b) gravity control $\sin\theta = k/k_g\, I$ | $1 = \frac{k}{k_g}\times10$ | $\sin\theta = \frac{k}{k_g}I'$ | $\sin\theta = 0.5$

$\sin 90 = k/k_g \times 10$ | $k/k_g = 1/10$ | $= \frac{1}{10}\times5$ | $\theta = 30°$

Ph ② (a) Spring control

$\theta = \frac{K}{K_S} \times I$

$\frac{K}{K_S} = \frac{\theta}{I} = 9\phi$

But $I' = \frac{K}{K_S}\,\theta$

$= \frac{1}{90} \times 45$ $\quad I = \frac{1}{2}(\ldots) 0.5\,mA$

② (b)

Gravity control

$\sin 45 = \frac{K}{K_g} \times I$

$\sin 90 = \frac{K}{K_g} \times 1$

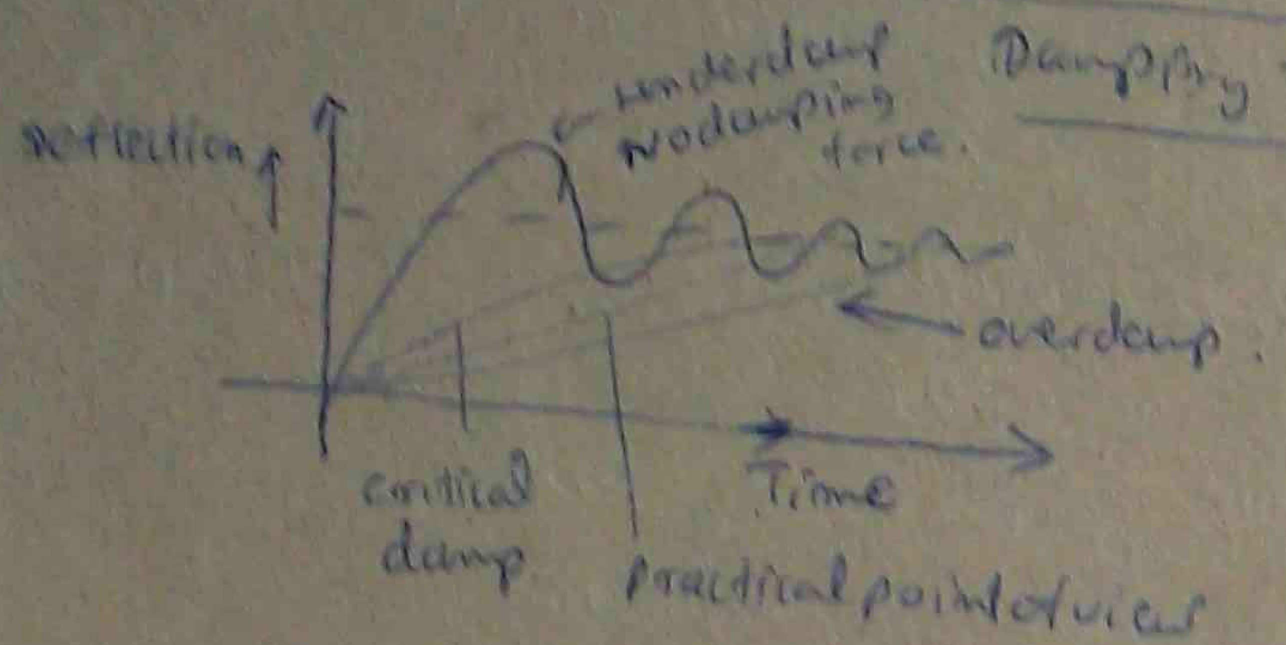
$\frac{K}{K_g} = 1$

But $\sin 45 = \frac{K}{K_g} \times I'$

$\sin 45 = 1 \times I'$

$I = \frac{1}{\sqrt{2}} = 0.707\,mA$

Damping Torque



[illegible] damping Torque [illegible] pointer [illegible] damping torque [illegible] Instrument [illegible] overdamp [illegible] pointer [illegible] moving system [illegible] zero position [illegible] final position [illegible] pointer [illegible] oscillation [illegible] critical damping [illegible] pointer [illegible] zero position [illegible] final position [illegible] oscillation [illegible] underdamp [illegible] damping position [illegible] critical damping [illegible]

Damping [illegible]

① Air friction damping ② Eddy current damping ③ Fluid friction damping.

① Air friction Damping. !

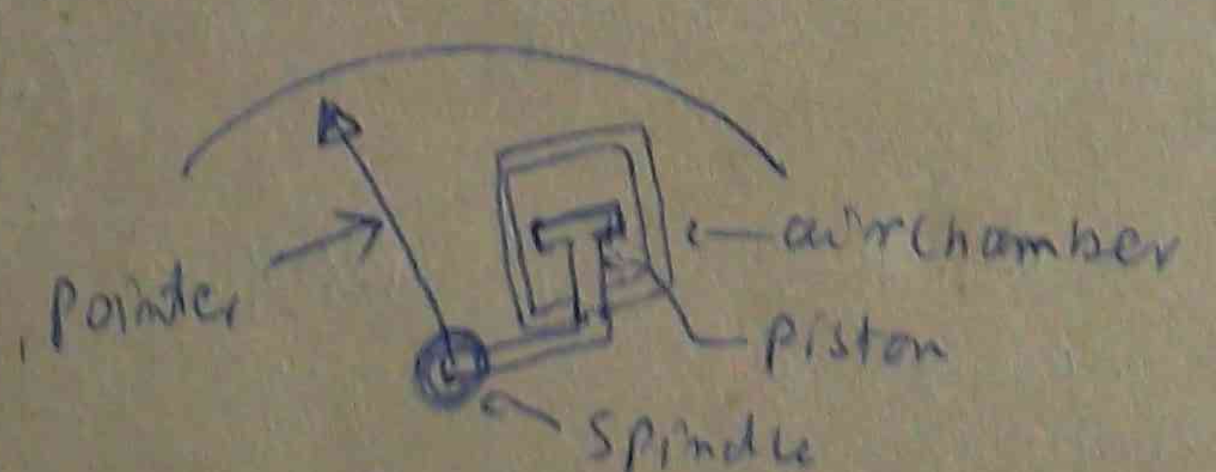
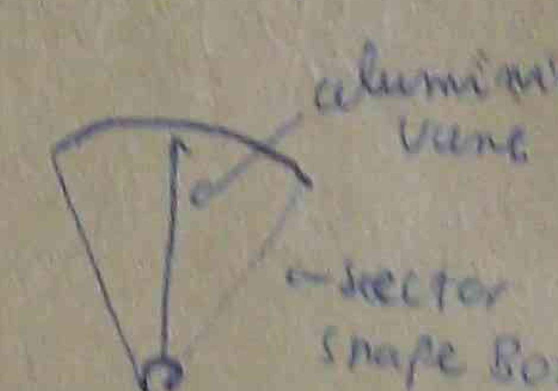


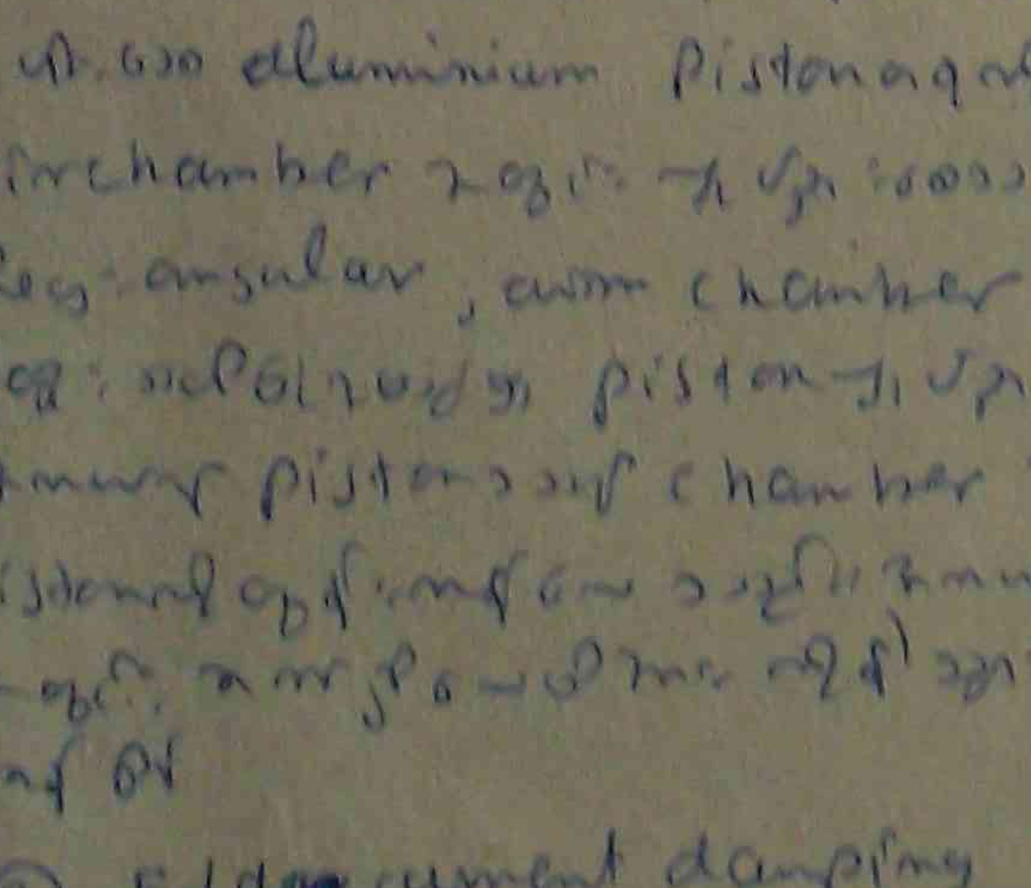
Fig (A)

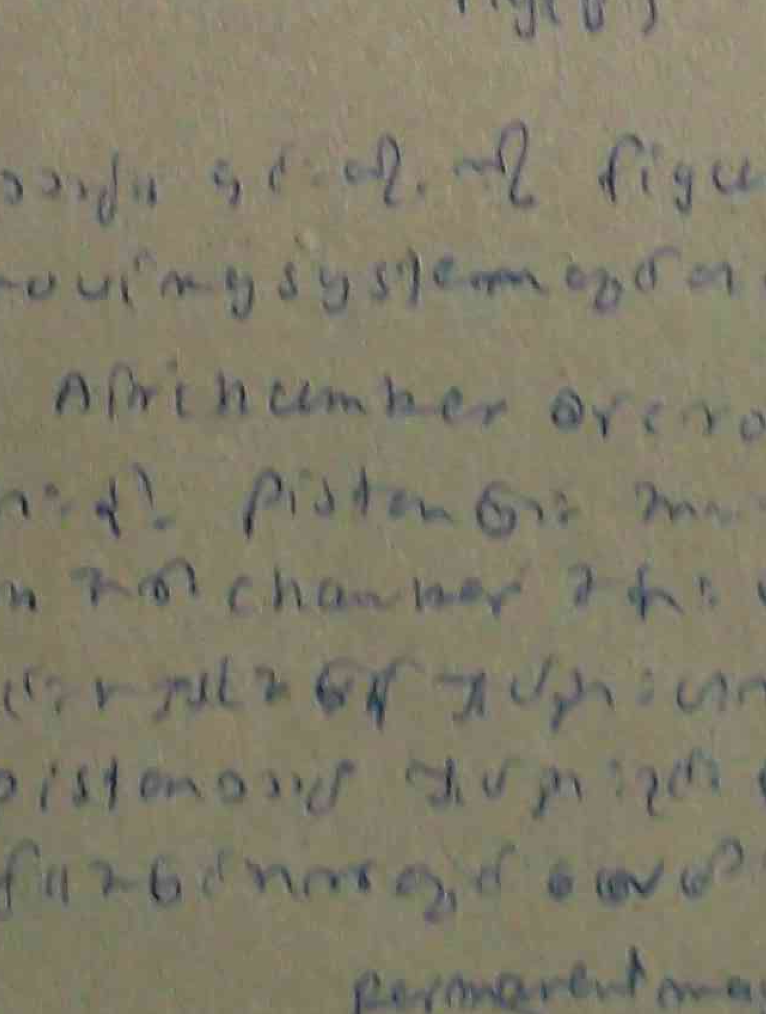
Fig (B)



Air friction damping [illegible] figure A [illegible] Fig A [illegible] aluminium piston [illegible] moving system [illegible] piston [illegible] Air chamber [illegible] Air chamber [illegible] cross section [illegible] circular [illegible] Rectangular, [illegible] chamber [illegible] piston [illegible] piston [illegible] chamber [illegible] piston [illegible] chamber [illegible] piston [illegible] piston [illegible]

② Eddy current damping



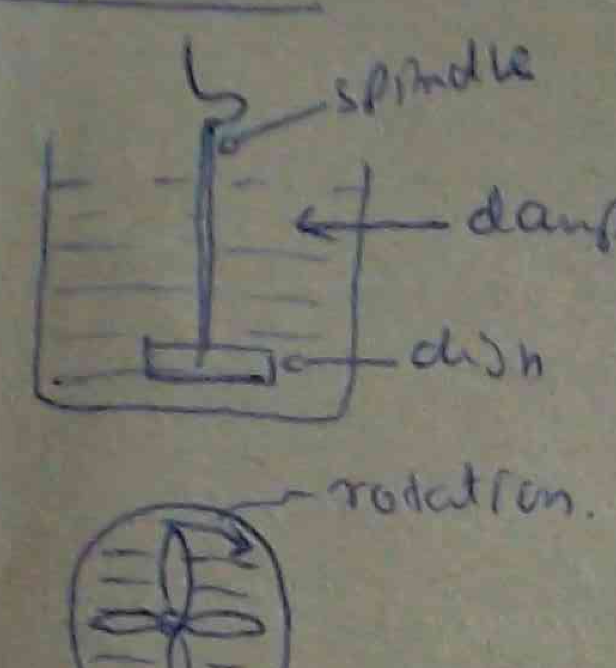


Spindle [illegible] spindle [illegible] damping disk [illegible] pole piece [illegible] magnetic lines [illegible] force [illegible]

[illegible] eddy current [illegible] eddy current [illegible] pointer [illegible] Fig (B) [illegible] moving [illegible] instrument [illegible]

[illegible] metal former [illegible] magnetic field [illegible] eddy current [illegible] metal former [illegible] eddy current [illegible] direction [illegible] pointer [illegible] direction [illegible] eddy current [illegible] damping [illegible]

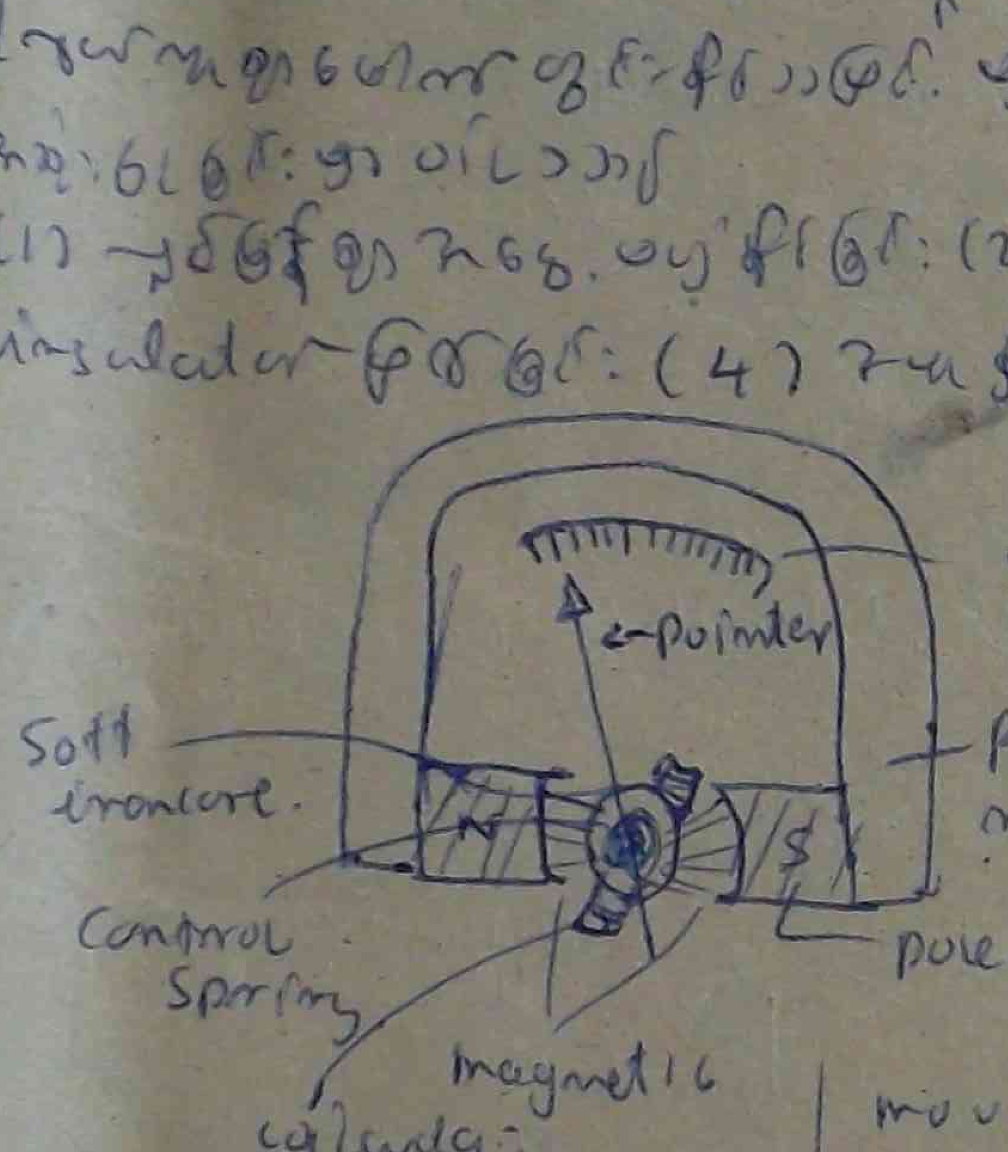
(B) Fluid damping

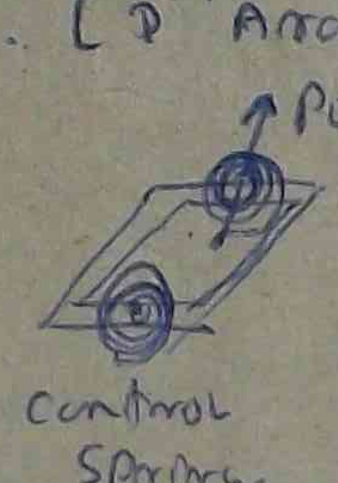


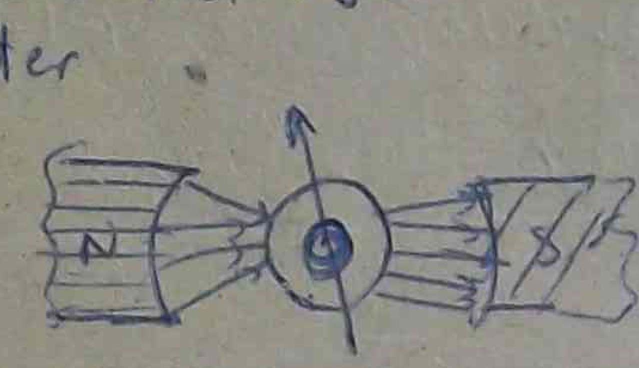
[illegible] damping [illegible] damping system [illegible] disk [illegible] moving system [illegible] spindel [illegible] damping oil [illegible] disk [illegible] damping oil [illegible] damping oil [illegible] disk [illegible] friction force [illegible]

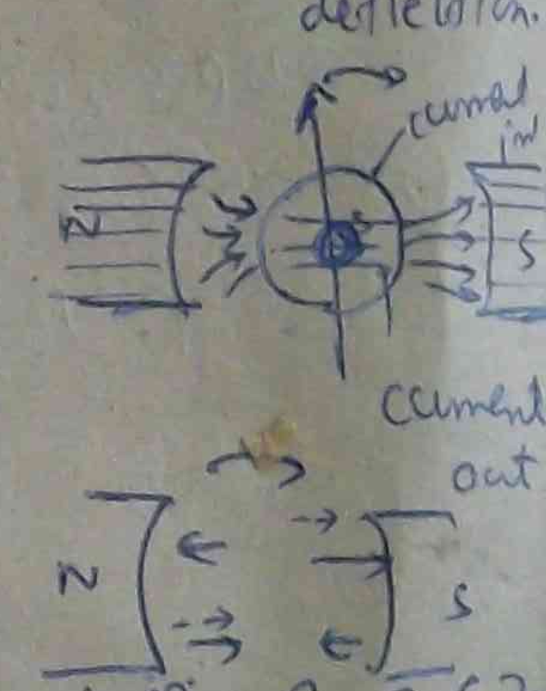
disk [illegible] suspending system [illegible] cylinder [illegible] damping oil [illegible] tension [illegible] damping [illegible] oil [illegible]

(1) [illegible] (2) metal [illegible] (3) [illegible] insulator [illegible] (4) [illegible]









moving coil meter [illegible] pole piece [illegible] magnetic flux [illegible] soft iron core [illegible] coil [illegible] pointer [illegible] controlling spring [illegible] coil [illegible] soft iron core [illegible] pole piece [illegible] magnetic flux [illegible] pole piece [illegible] magnetic flux [illegible] soft iron core [illegible]

[illegible] current [illegible] moving coil [illegible] electromagnetic flux [illegible] permanent magnetic [illegible] flux [illegible] reaction [illegible] moving coil assembly [illegible] pointer [illegible] scale [illegible] clockwise [illegible] moving coil [illegible] coil [illegible] current [illegible] spring [illegible] moving coil [illegible] moving coil [illegible] moving coil [illegible] pointer [illegible] scale [illegible] coil [illegible] current [illegible] spring [illegible] coil [illegible] current [illegible]

Coil Reactance

Soft iron core [illegible] coil [illegible] current [illegible] pointer [illegible] scale [illegible] full scale deflection [illegible] current [illegible] meter [illegible] sensitive [illegible] meter [illegible] full scale current [illegible] sensitivity [illegible] sensitive [illegible] coil [illegible] resistance [illegible] meter [illegible] coil resistance [illegible]

moving coil meter torque [illegible]

$$\text{Torque } T = \frac{BANI}{10}\ \text{dynes/cm} \rightarrow T = \frac{BANI}{10\times 981}\ \text{gm/cm}$$

where B = flux density lines/sq cm (or gauss), A = area of coil in sq cm.

$A = l \times b$ — l in cm, b in cm, N = No. of turns.

I = current through the coil in amp.

Torque $T = BANI$ (N-m, Newton meter)

where B = flux density in wb/m² (webers) N = No: of turns

I current in amp, b = breadth of coil in meter l = length of coil in meter,

1 N-m = 10^5 dynes, 1 wb = 10^8 maxwell (or) lines, 1 wb/m² = 10^4 gauss (or) lines/cm²

1 dyne cm = 10^{-7} N-m meter,

Pb ① moving coil volt meter [illegible] coil resistance [illegible] 10 [illegible] full scale deflection [illegible] 45 millivolt [illegible] coil [illegible] no: of turn [illegible] 100 [illegible] 3 cm × 2.5 cm [illegible] full scale deflection [illegible] spring [illegible] Torque [illegible] 0.5 gm/cm [illegible] air gap flux density [illegible]

$$\text{Torque } T = \frac{BANI}{10\times 981}\ \text{gm-cm} \rightarrow$$

$R = 10\Omega$, $V = 45\,mV$, $N = 100$, $L = 3\,cm$, $b = 2.5\,cm$, $T = 0.5\,gm\text{-}cm$, $B = ?$

$$B = \frac{T\times 10\times 981}{l b \times N \times I} = \frac{0.5\times 10\times 981}{2.5\times 3\times 100\times 4.5\times 10^{-3}} = 1453\ \text{gauss}.$$

Pb ② spring control [illegible] moving coil meter [illegible] full scale deflection [illegible] Torque 1.47×10^{-4} New-m [illegible] coil [illegible] current [illegible] 0.02 amp [illegible] coil [illegible] 2 cm × 1 cm [illegible] air gap [illegible] flux density [illegible] 1200 lines/cm² [illegible] coil [illegible] no: of turns [illegible] (306)

Pb ③ moving coil meter [illegible] coil [illegible] turn [illegible] 20 [illegible] 3 cm [illegible] coil [illegible] 500 gauss (5 wb/m²) [illegible] flux [illegible] current 1 ma [illegible] torque [illegible] (30 dynes)

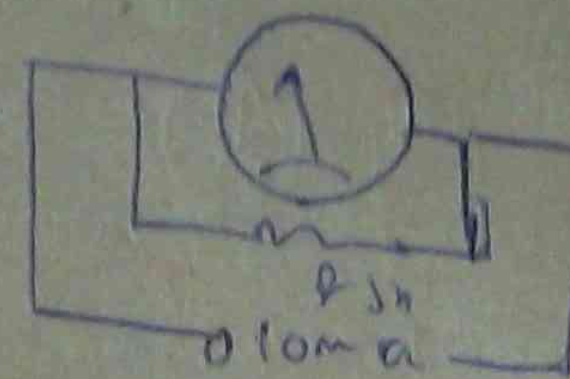
Pb ④ moving coil volt meter [illegible] coil resistance 10 [illegible] coil [illegible] 3 cm × 2 cm [illegible] no. of turn [illegible] 100 [illegible] air gap [illegible] sensitivity 800 gauss [illegible] spring control [illegible] torque [illegible] 3 dynes-cm/deg [illegible] 200 V [illegible] deflection [illegible] deg: [illegible]

Extension of moving coil meter Range

① Calculation of Shunt Resistor.

f.s. $I = 1ma$

$Rm = 100\Omega$



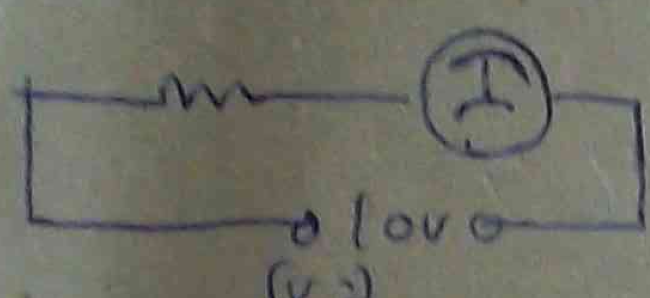
$R_{sh} I_{sh} = R_m I_m$

$R_{sh} = \frac{R_m I_m}{I_{sh}}$

$= \frac{100 \times 1 \times 10^{-3}}{9 \times 10^{-3}} = 11.11\Omega$

② Calculation of multiplier resister.

f.s. $I = 1ma$, $Rm = 100\Omega$



$R = \frac{E}{I} = \frac{9.9}{1 \times 10^{-3}} = 9900\Omega$.

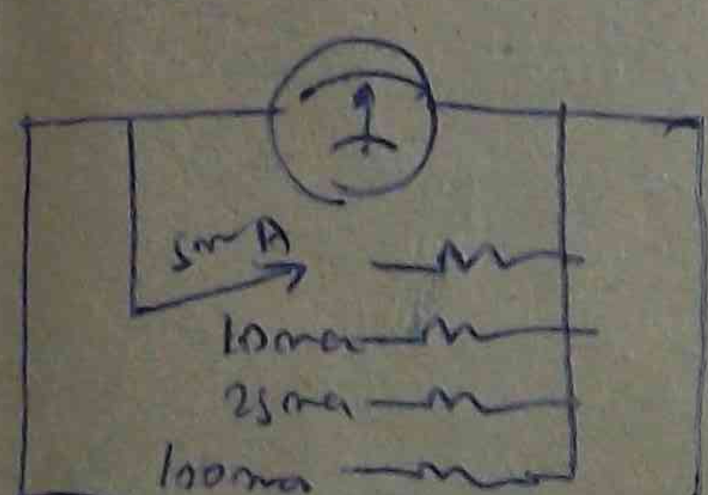
Pb ① moving coil meter [illegible] 25ma [illegible] f.s. [illegible] 85mv [illegible] meter [illegible] 100ma [illegible] 200v [illegible] resister [illegible] resistance [illegible]

Again $R = \frac{E}{I} = \frac{85 \times 10^{-3}}{25 \times 10^{-3}} =$ $R_{sh} = \frac{R_m I_m}{I_{sh}}$ $\frac{146?}{25 \times 10^{-3}} = 4915\Omega$

$= \frac{3.4 \times 25 \times 10^{-3}}{75 \times 10^{-3}} = 1.13\Omega$.

Find the value of shunt resister

Pb②



$Rm = 100\Omega$

$FSD = 1ma$

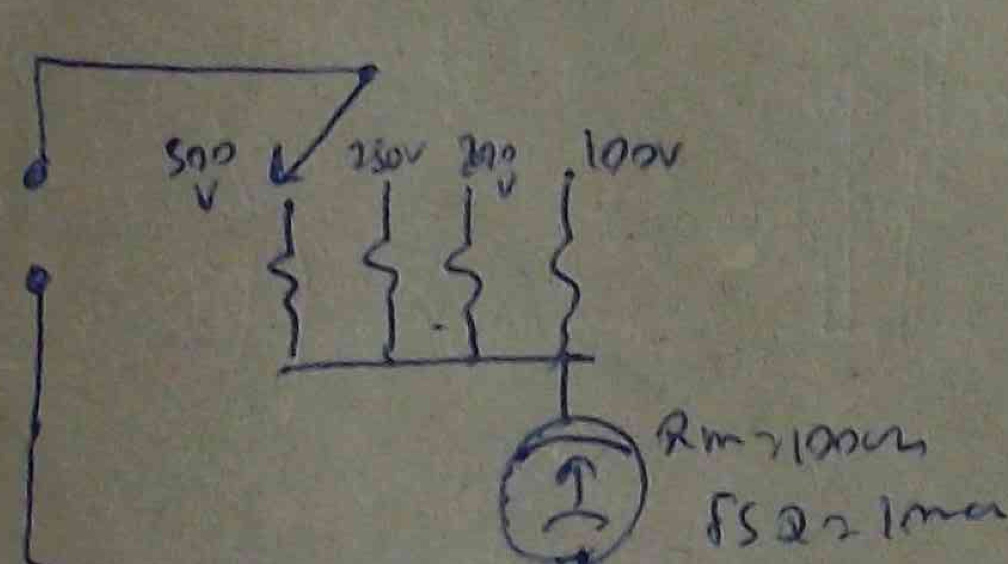
$I_{sh} = \frac{I_m R_m}{I_{sh}} = \frac{1 \times 100}{4} = 25\Omega$ ←

$= \frac{1 \times 100}{9} = 11.11\Omega$ ←

$= \frac{1 \times 100}{24} = 4.16\Omega$ ←

$= \frac{100}{99} = 1.01\Omega$ ←

Pb③



$Rm = 100\Omega$

$FSD = 1ma$

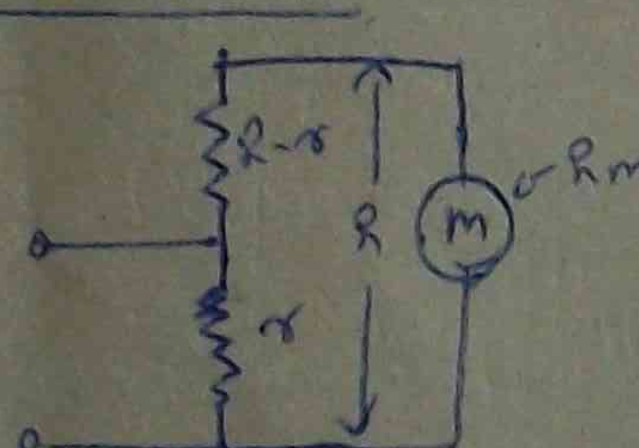
$500v = \frac{499.9}{1 \times 10^{-3}} = 499900\Omega$ ←

$250v = \frac{254.9}{1 \times 10^{-3}} = 254900\Omega$ ←

$200v = \frac{199.9}{1 \times 10^{-3}} = 199900\Omega$ ←

$100v = \frac{99.9}{1 \times 10^{-3}} = 99900\Omega$ ←

universal shunt



$r = \frac{R + Rm}{N}$

r = part of R to be shunted across

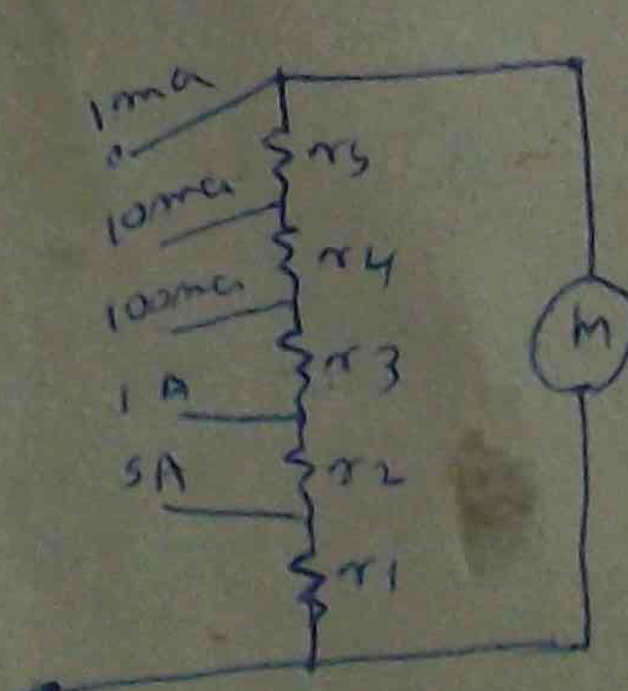
R = Total shunt resister

Rm = meter resistence

N = multiplying factor

$N = \frac{\text{New Scale}}{\text{old scale}}$.

Pb④



Find the value of r_1, r_2, r_3, r_4, r_5

$Rm = 100\Omega$

$FSI = 500\mu A$

meter resist = Total shunt resist.

$r_1 = \frac{R \times Rm}{N} = \frac{100 + 100}{10000} = \frac{200}{10000} = 0.02\Omega$ ←

$[N = \frac{5}{10 \times 10^{-3}} = 1000?]$

$r_1 + r_2 = \frac{200}{2000} = 0.1\Omega$ $[N = \frac{1}{5 \times 10^{-3}}]$

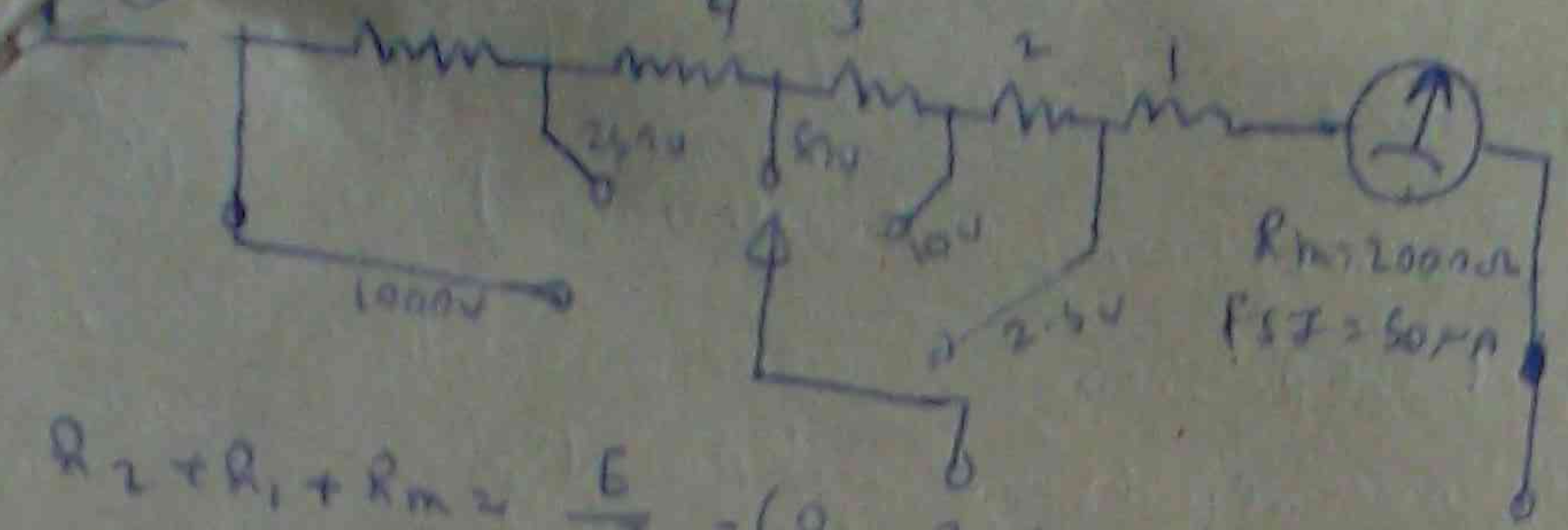
$r_2 = (0.1 - 0.2) = 0.08\Omega$ ←

$r_1 + r_2 + r_3 = \frac{200}{200} = 1\Omega$ $\therefore r_3 = (1 - 0.1) = 0.9\Omega$ ←

$r_1 + r_2 + r_3 + r_4 = \frac{200}{20} = 10\Omega$ → $r_4 = 10 - 1 = 9\Omega$ ←

$r_5 = 100 - 10 = 90\Omega$ ←

Pn ⑤



Find the value of R_1, R_2, R_3, R_4, R_5

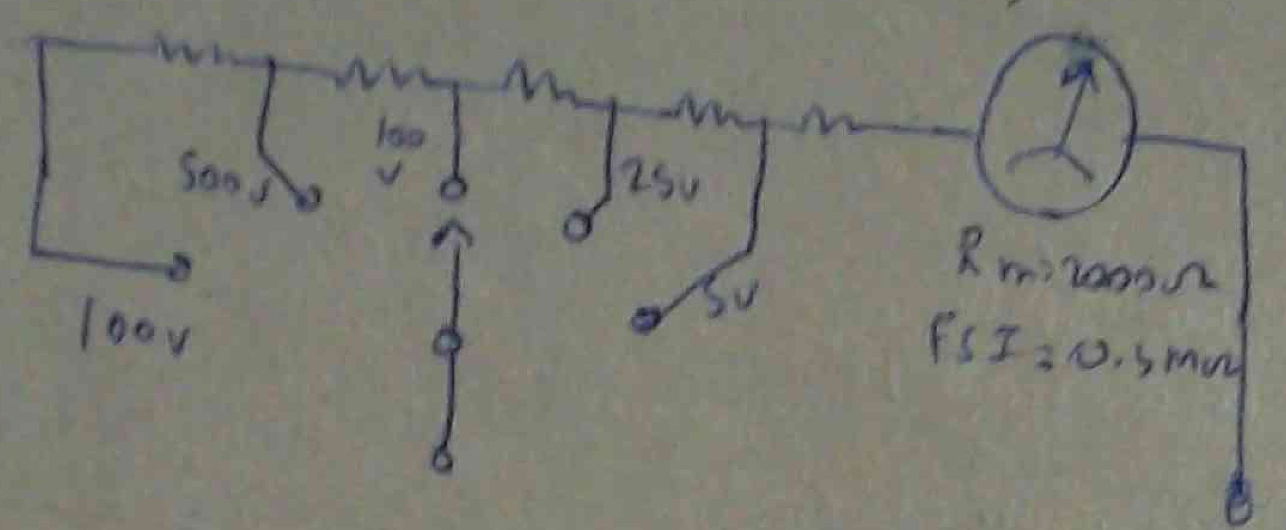
$R_1 = \frac{E}{I} - R_m$

$R_1 = \frac{2.5 \times 10^6}{50} - 2000 = 48000\Omega$

$R_2 + R_1 + R_m = \frac{E}{I} - (R_1 + R_m) = \frac{10 \times 10^6}{50} - 50000 = 150000\Omega$

$R_4 = 4M\Omega, \quad R_5 = 15M\Omega$

Pn ⑥



Find the value of R_1, R_2, R_3, R_4, R_5

R_1, R_2, R_3, R_4, R_5

$R_1 = \frac{5 \times 10^6}{500\mu A} - 2000 = \frac{50000}{5} - 2000 = 8000\Omega$

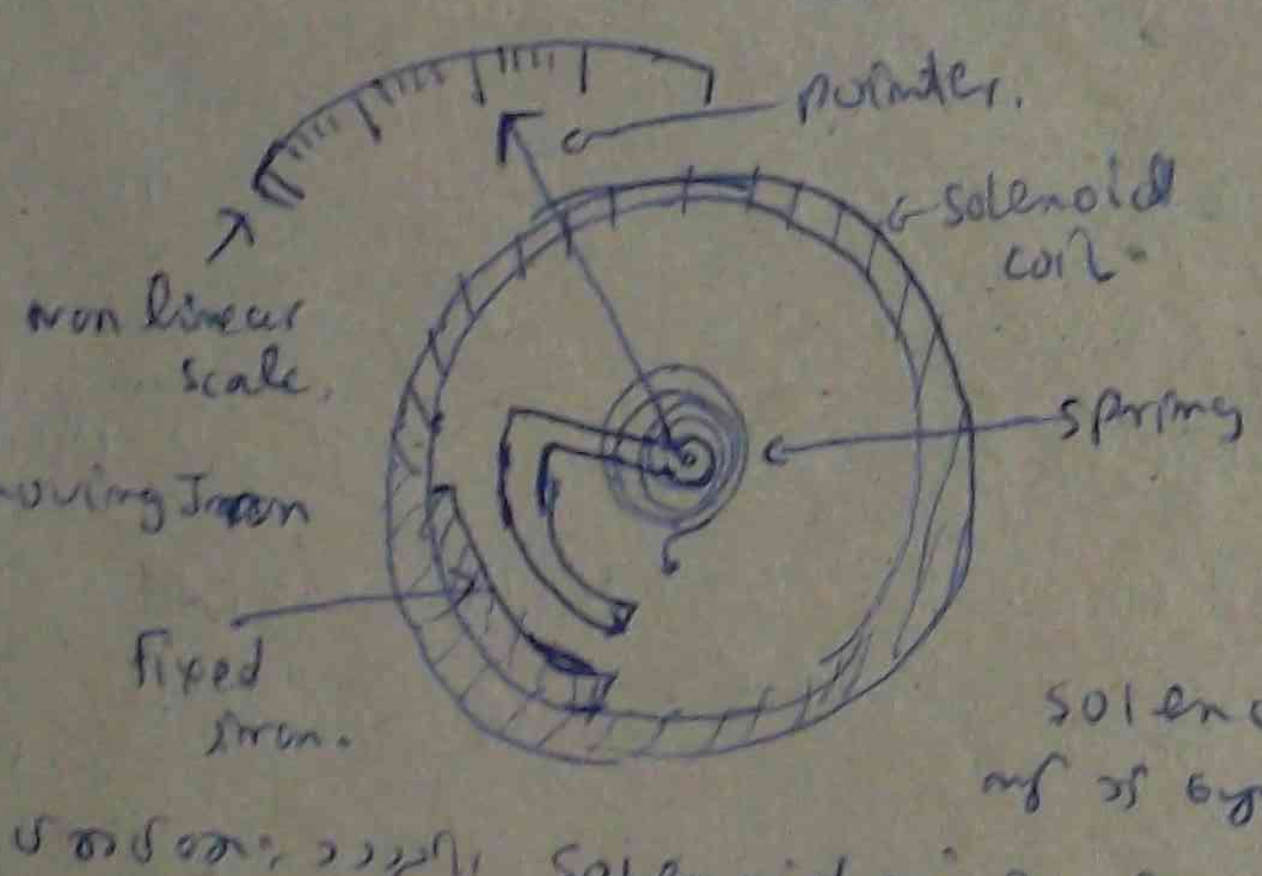
$R_2 + R_1 - R_m = \frac{250000}{500} - 10000 = 40000\Omega$

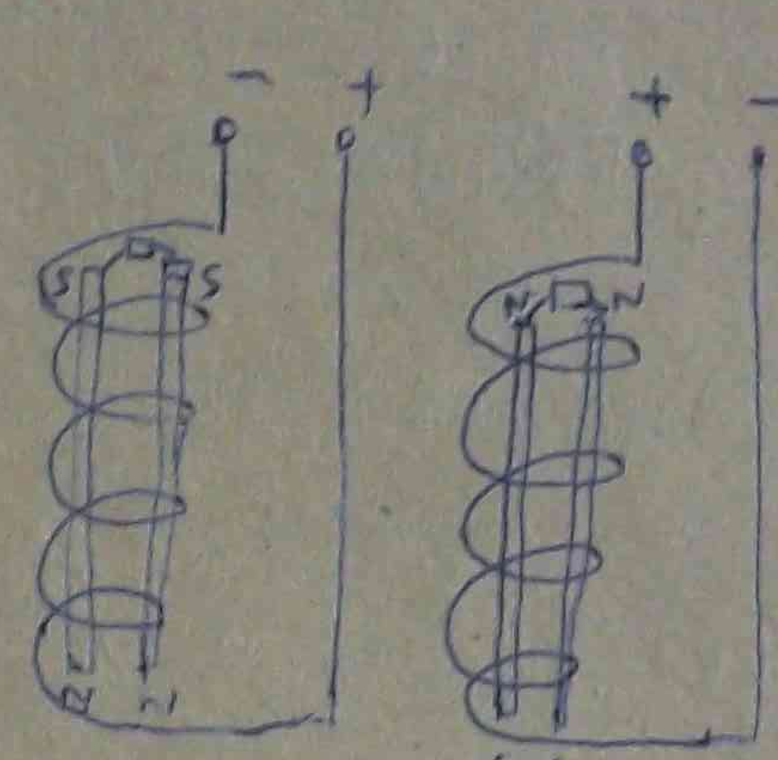
$R_3 + R_1 + R_2 + R_m = \frac{1000000}{5} - 50000 = 150000\Omega$, $R_4 + R_{123m} = \frac{500,000000}{500} - 200000 = 800000\Omega$

$R_5 + R_{1234m} = \frac{1000,0000}{500} - 1000000 = 1000,000\Omega$

ⓐ Attraction type

ⓑ Repulsion type meter

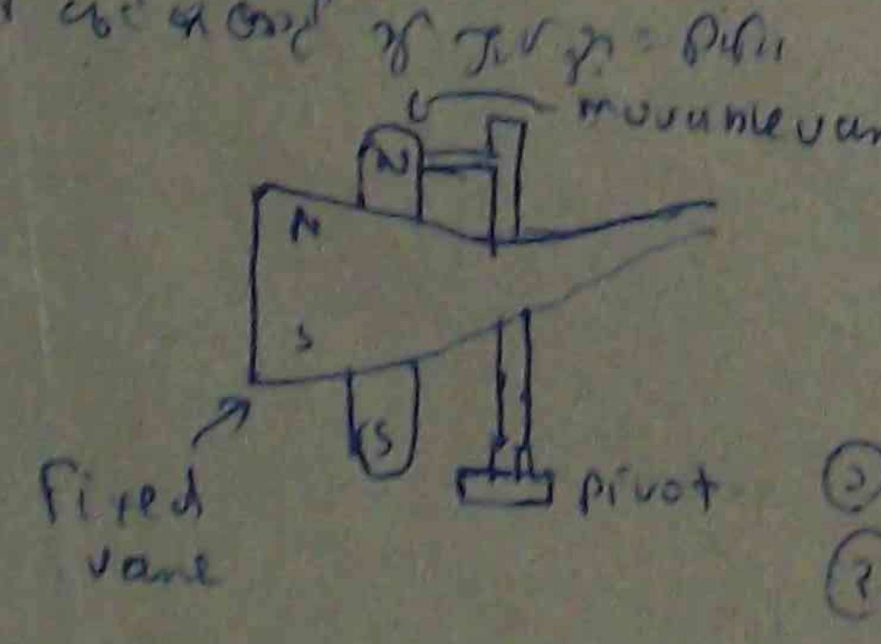




Repulsion Type meter [illegible] solenoid coil [illegible] (or) magnetic field [illegible]

solenoid coil [illegible] solenoid coil [illegible] solenoid coil [illegible] current [illegible] magnetic field [illegible] magnetic field [illegible] Induction [illegible] magnetized [illegible] pole [illegible] moving iron [illegible]

Pointer [illegible] current [illegible] current [illegible] spring [illegible] gravity control [illegible] damping system [illegible] Air damping [illegible] Pointer [illegible] deflection [illegible] current square law [illegible]



In order to achieve uniformity of scale strip of iron are used instead of iron rod.

Advantages and disadvantages of moving Iron meter

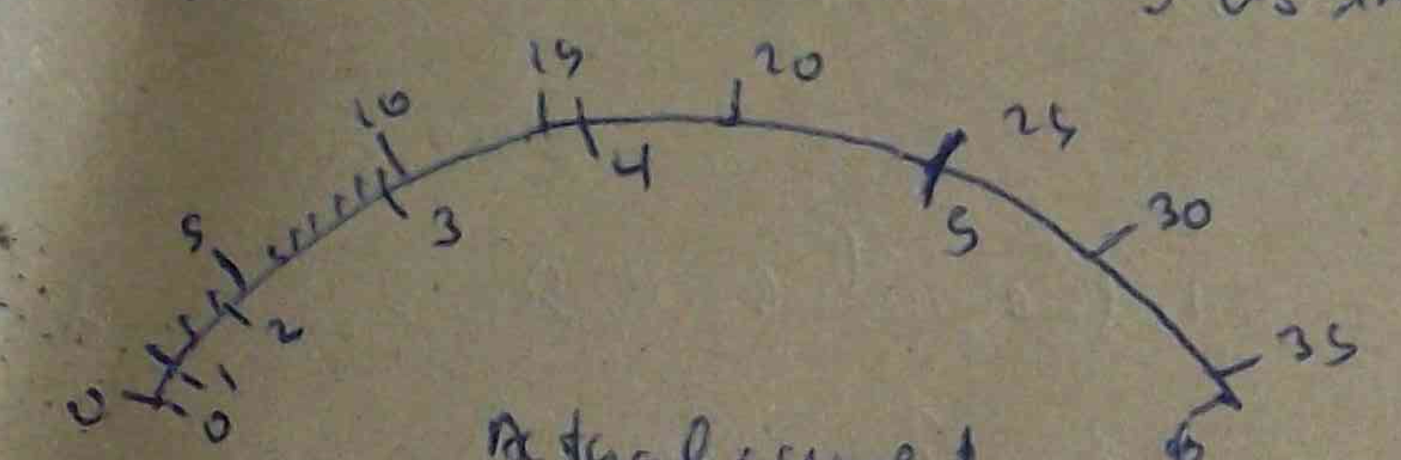
① [illegible] ① [illegible] reading

② AC [illegible] error [illegible]

④ frequency [illegible] error [illegible]

current square law

In the moving iron meter if a given current flow the cry the meter is doubled each vane is magnetized twice as strongly. Since vane then repels the other twice as much; the combined repulsion between two vane is four times as great. In other words the force of repulsion and pointer swing do not vary directly with the current vary as the 'square of the current.'

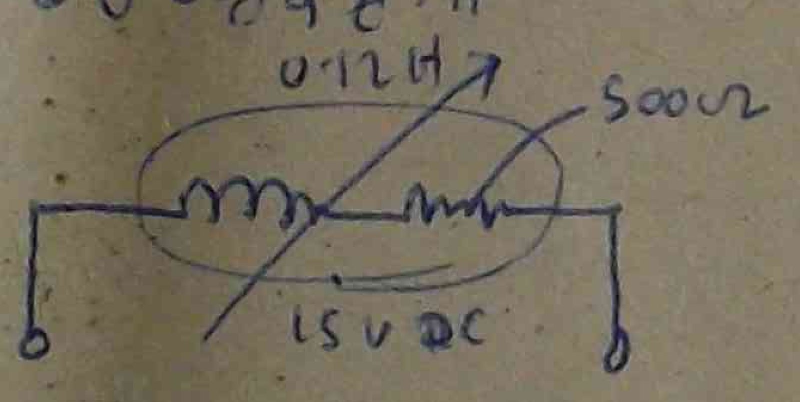


Actual current scale

(current square scale non linear scale)

Frequency effect on moving Iron meter

Pb ② [illegible] 15 volts [illegible] moving iron voltmeter [illegible] Resistance [illegible] $r = 500\Omega$ [illegible] Inductance $= 0.12$ Henry [illegible] AC [illegible] frequency 50 Hz, 100 Hz [illegible] AC 15 V [illegible] voltage [illegible]



$X_L = 2\pi f L$

$Z = \sqrt{r^2 + X_L^2}$ (AC)

$Z = \sqrt{r^2} = r$

$Z = \frac{E}{I} = \frac{15}{500} \times 1000\,ma = 30\,ma$ $f = 60\ c/s.$

$X_L = 2\pi f L = 2\pi \times 50 \times .12 = 37.7\Omega$

$Z = \sqrt{r^2 + X_L^2} = \sqrt{500^2 + 37.7^2} = 501.4\Omega$

$I = E/Z = \frac{15}{501.4} \times 1000\,ma = 29.9\,ma$

50 ma [illegible] 50 V [illegible] $\rightarrow = \frac{29.9}{30} \times 15 = 14.95\,V$ (AC) 50 Hz

AC 50 Hz 15 V

[illegible] 100 Hz [illegible] $Z = 505.6\Omega$ $I = 29.6\,A = $ ← 14.8 V AC 100 Hz 15 V

[illegible] 200 Hz [illegible] $Z = 522.2\Omega$ $I = 28.7\,A$ ← 14.36 V

AC 200 Hz 15 V //

KN 59

STRENGTH OF MATERIALS

Maung Kyaw Naing
Second Year Electrical Power (A)
G.T.I (Prome)

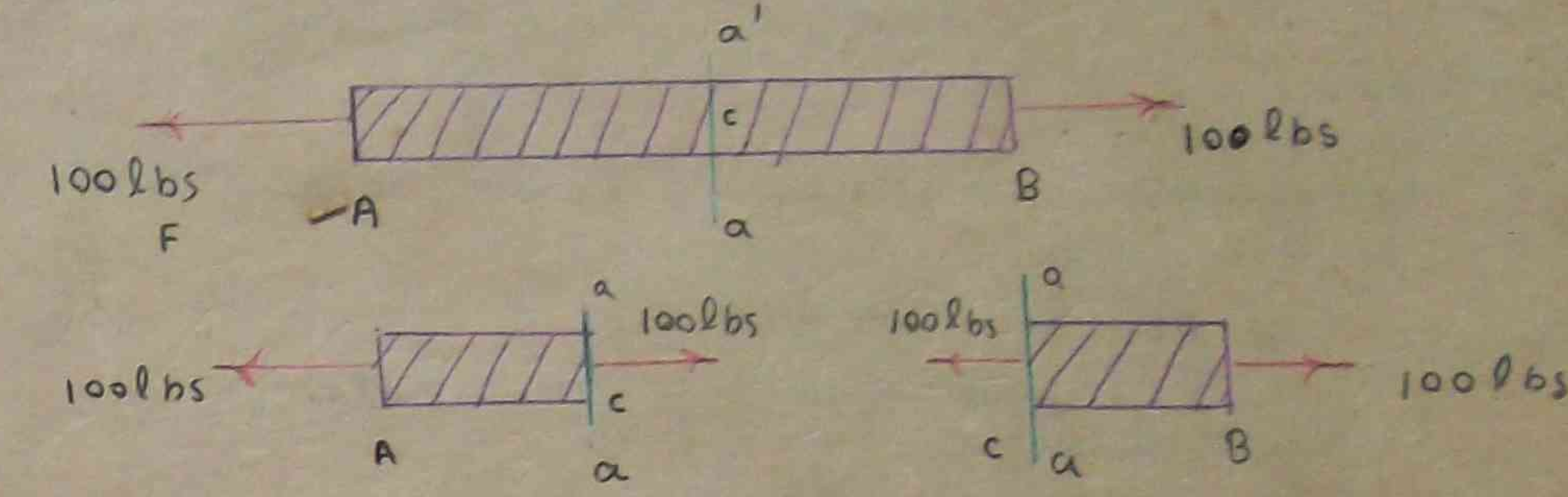
Poisiom ρ

ပစ္စည်းများ၏ခံနိုင်အား

strength of materials

ETBC

ပစ္စည်းများကိုပြင်ပမှသက်ရောက်နိုင်သော အားအမျိုးအစားတို့မှာ ဆွဲအား Tension ဖိအား (compression) နှင့် ညှပ်ဖြတ်အား (Shear) တို့ဖြစ်သည်။



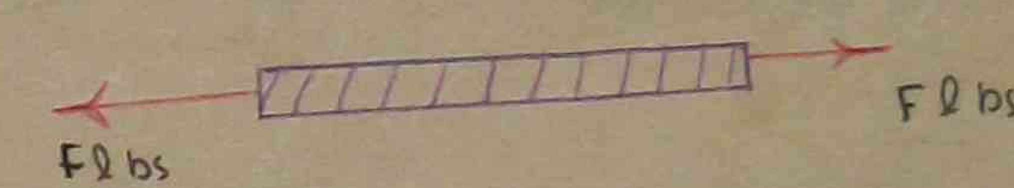
(အရာဝတ္ထုတခုပေါ်သို့ ပြင်ပမှသက်ရောက်လျက်ရှိသော ခွန်အားကြောင့် ထိုအရာဝတ္ထု၏ နေရာ ၎င်း၏အတွင်း၌ ဖြစ်ပေါ်သော ခုခံတွန်းကန်မှု ခံနိုင်အားကို ခေါ်သည်။)

A နှင့် B အစွန်းအပိုင်းများ တွင်ကန့်လန့်ဖြတ်နေရာ c ၌ F = 100 lbs ရှိသော ခံနိုင်အား ထိန်းထားရပေသည်။ F ကို AB ၏ stress ဟုခေါ်သည်။

ဥပမာ(၁)

ETBC Stress အမျိုးအစားများ

① Tension or Tensile Stress (ဆွဲခံအား)



အရာဝတ္ထုကိုဆွဲဆန့်သောအခါ၌ ဖြစ်ပေါ်သည်

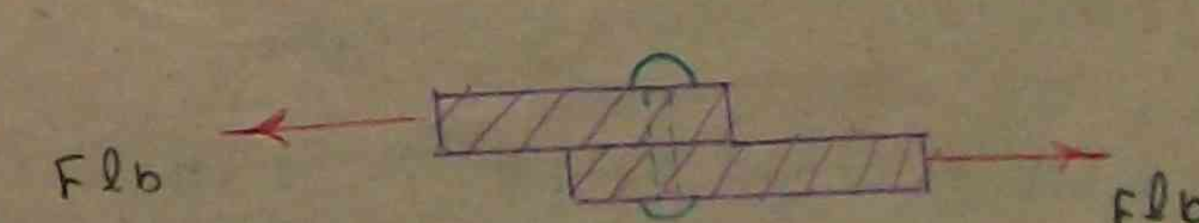
ETBC ② compressive stress

ဖိခံအား F_c

အရာဝတ္ထုတခုကိုတွန်းဖိသောအခါ၌ ဖြစ်ပေါ်လာသည်။

ETBC

③ Shear Stress (ညှပ်ဖြတ်ခံအား) F_s



မျက်နှာပြင်နှင့်ပြိုင်လျှက်သက်ရောက်သော အားကိုခေါ်သည်။

4 Bearing stress

[illegible] compressive stress [illegible]

[illegible] lb, Tom, Kg [illegible]

Ft – lb – Tom → FPS

centigrade – gm – kg – Tom – metric
centimeter

1000 gm = 1 kg

1000 metre = 1 kg

1000 kg = 1 ton

1 kg = 2.204 lb

∴ 1000 kg = 1 Ton

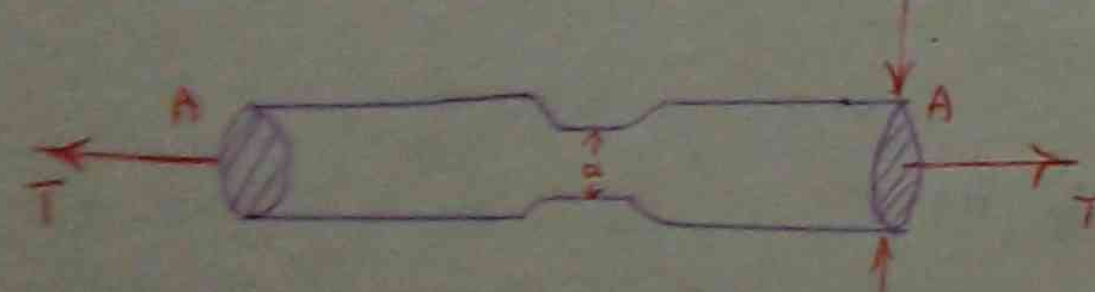
* 2204 lbs = 1 Tom (metric) — short Tom

2240 lbs = 1 Tom (English) — Long Ton

[illegible] unit area [illegible]

unit [illegible] stress [illegible]

[illegible] unit [illegible] Tensile stress [illegible] compressive stress [illegible] shearing stress [illegible] ([illegible] stress [illegible] – Tom/□" Tom/□' lb/□", lb/□' [illegible]) E TEC



[illegible] area (A) [illegible] T [illegible] area (a) [illegible] $\frac{a}{A}$ or a : A [illegible] (Strain) [illegible]

[illegible] strain [illegible]

[illegible]

$$\boxed{e = \frac{x}{L}}$$ E TEC

[illegible] Elastic Limit [illegible]

[illegible] Elastic [illegible] F [illegible] e [illegible]

$f \propto e$

or

$e \propto f$

$\therefore \boxed{f = E \times e}$ E TEC

(E = constant)

$\therefore \boxed{E = \frac{f}{e}}$ (modulus of Elasticity)

$\boxed{F = \frac{f}{A}}$ E TEC

E [illegible] Young [illegible] [Young's modulus of elasticity]

(Program ①)

Prob [illegible] $3\frac{1}{2}$" [illegible] 3' [illegible] 0.75" [illegible] Young [illegible] E = 30000 lbs/□" [illegible]

[illegible] F [illegible]

[illegible] d = $3\frac{1}{2}$" * F = ?

[illegible] = 3' = 36"

constant crosssection area = $\frac{22}{7 \times 4} \times (\frac{7}{2})^2 = [illegible]$

F = [illegible] = ?

$$E = \frac{Stress}{Strain} = \frac{f}{e} = \frac{F/A}{x/L}$$

$\frac{x}{L} = e$

$$\therefore F = E \times \frac{x}{L} \times A$$

$$F = 30000 \times \frac{0.75}{36} \times \frac{77}{8}$$

$$= 30000 \times .0208 \times \frac{77}{8}$$

$$= \frac{624 \times 77}{8}$$

$$= 6006$$

Prob

[illegible] $3\frac{1}{2}$" [illegible] 3' [illegible] 6040 lbs/□" [illegible] modulus elasticity $E = 30000$ lb/□" [illegible]

* [illegible]

$A = ?$ $L = 36"$

$F = 6040$ lb/□"

$E = 30000$ lb/□"

$$E = \frac{Stress}{Strain}$$

$$E = \frac{\frac{F}{A}}{\frac{x}{L}}$$

$$E = \frac{F}{A} \times \frac{L}{x}$$

$$A = \frac{F \times L}{E \times x}$$

$$x = \frac{6040 \times 36}{30000 \times \pi \times (\frac{7}{2})^2 \times \frac{1}{4}}$$

$$x = \frac{6040 \times 36 \times 4 \times 4}{30000 \times \pi \times 49 \times}$$

$$= .73"$$

Prob

Pipe [illegible] 1.61" [illegible] 1.91" [illegible] pipe [illegible] 125 lbs/□" [illegible] compressive stress [illegible]

$F = 125$ lbs/in^2

$$A = \frac{\pi}{4}\left[(1.91)^2 - (1.61)^2\right]$$

$$Stress = \frac{F}{A}$$

$$= \frac{125}{\frac{\pi}{4} \times (1.91^2 - 1.61^2)}$$

$$= \frac{125 \times 4}{\pi (3.65 - 2.61)}$$

$$= \frac{125 \times 4}{\pi \times 1.04}$$

$$= \frac{500}{\pi \times 1.04} = ~~156~~ \text{ lb/in}^2$$

153 lb/in^2

$= 50$

(156.1)

[illegible]

$$= \frac{125 \times 4}{\pi(1.91 + 1.61)(1.91 - 1.61)}$$

$$= \frac{500}{\pi \times 3.52 \times .30} = \frac{80}{\pi \times 1.056} = 156 \text{ lb/in}^2$$

** ① $E = \frac{stress}{strain}$

② $Strain = \frac{x}{L}$

③ Shear Area = Circumference [illegible] × [illegible]

④ Extension = Strain × [illegible]

Prob [illegible] 1.5" [illegible] punch [illegible] 0.25" [illegible] 47000 lbs [illegible] unit shear stress [illegible]

dia of hole = 1.5"

Circumference $= \pi D = \frac{22}{7} \times 1.5"$ = [illegible]

Area of Shear $= \frac{22}{7} \times 1.5 \times .25$ sq in

$$Stress = \frac{F}{A} = \frac{47000 \times 7}{22 \times 1.5 \times 0.25} = \frac{329000}{8.25} = 39800$$

(39880)

* I Area of shear = [illegible] × [illegible]

II * Extension = ~~[illegible]~~ L = Strain × L

unit shear stress $= \frac{F}{\text{shear area}} = \frac{F}{[illegible]}$

stress $= \frac{F}{A} = \frac{F}{Area}$

Prob A steel bar 2" dia. and 5' long ~~to~~ is subjected to a tension of 20 tons. It is required to find ~~a~~ stress, strain and extension

Cross sectional area of the Bar :-

$$A = \frac{22}{7} \times \frac{2}{12} \times \frac{2}{12} = \frac{11}{42 \times 12} \text{ sq in}$$

$$Stress = \frac{F}{A} = \frac{20 \times 2240}{\frac{11}{42 \times 12}}$$

$$= \frac{20 \times 2240 \times 42 \times 12}{11}$$

Prob. A steel bar 2" dia: and 5' long is subj... of 20 tons. It is required to find the stress, strain and extension $(E = 30\times10^6\ lb/\square'')$

Cross sectional area of the bar :–

$$area = \frac{22}{7\times4}\times 2^2$$

$$= \pi \text{ sq in}$$

$$\underset{\uparrow}{\text{Stress}} = \frac{F}{A} = \frac{20}{\pi} = 6.37\ tons/\square''$$

$$\text{Strain} = \frac{\text{Stress}}{E} = \frac{6.37 \times 2240}{\frac{30\times10^6}{2240}} = \frac{6.37\times2240}{30\times10^6}$$

$$\text{Strain} = \frac{14300}{3\times10^7} = 475 \times 10^{-7}$$

$$= .0000476$$

$$\text{Extension} = .000475 \times 5 \times 12$$

$$= .0285$$

$.000475$

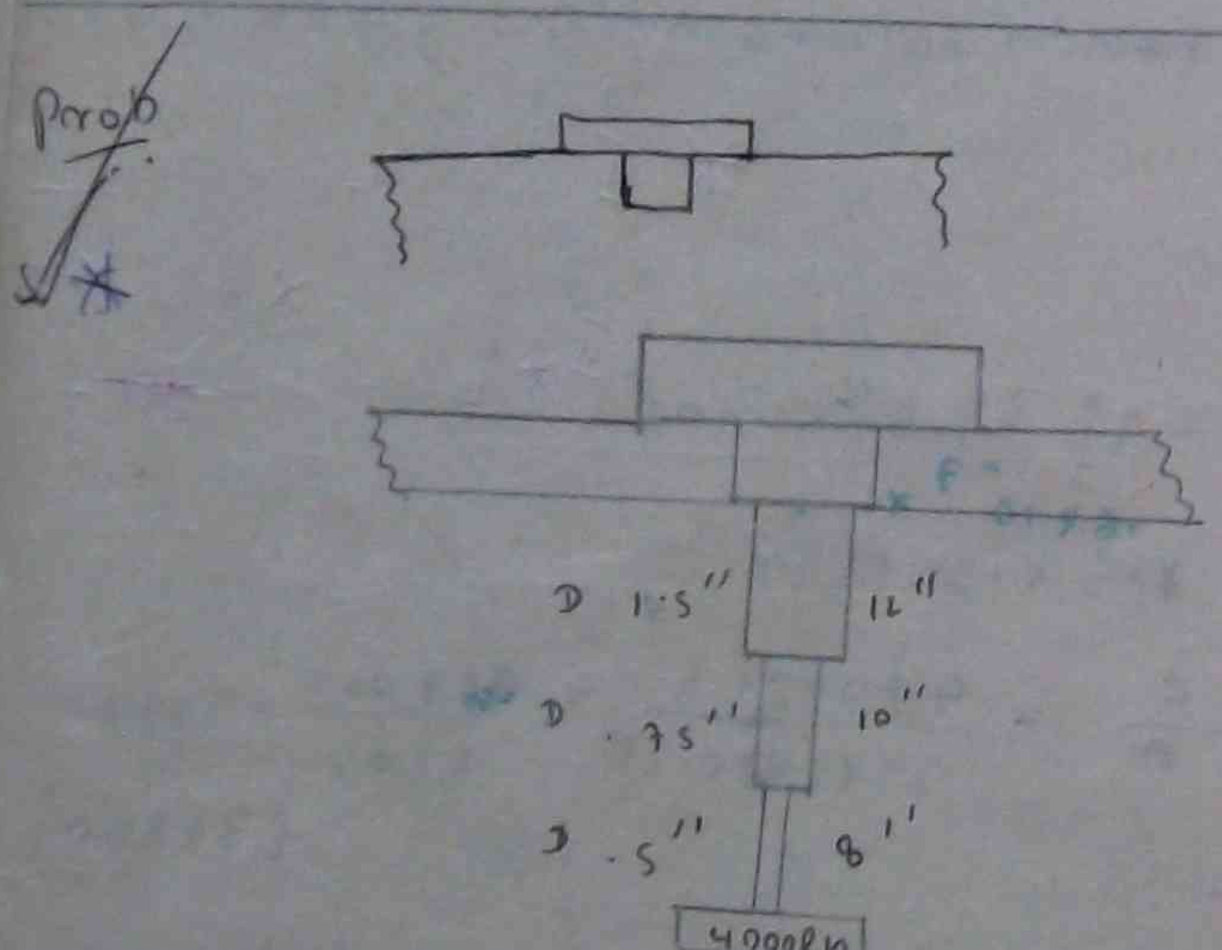
$1000000 \,|\, 4750000$

$.000475 \times 60 = 28500$

$= .028500$

$= .0285$

Prob



The vertical steel rod 30" long is secured at the top end and supports a load of 4000 lbs at the bottom end. All ~~horizontal~~ horizontal section are circular but the dia varies as shown in the figure. Calculate the tensile stress in each of these three portions of the rod and find the total extension $E = 30\times10^6\ lbs/\square''$

$E = \frac{\text{Stress}}{\text{strain}}$

Stress = ? Extension = ?

$$\text{Stress} = \frac{F}{A} = \frac{4000}{\frac{\pi}{4}\times(.5)^2} = \frac{16000}{\pi\times.25} = 20372\ lb/in^2$$

$$\text{Stress} = \frac{4000}{\frac{\pi}{4}(.75)^2} = \frac{16000}{\pi\times.5625} = 9054\ lb/in^2$$

$$\text{Stress} = \frac{4000}{\frac{\pi}{4}\times(1.5)^2} = \frac{4000}{.785\times2.25} = \frac{4000}{1.76} = 2264\ lb/in^2$$

$$\text{Strain} = \frac{\text{Extension}}{\text{original Length}} = \frac{x}{l} = \frac{x}{12}$$

$$\text{Extension} = \text{Strain}\times12$$

$$E = \frac{\text{Stress}}{\frac{x}{L}} \quad \therefore \text{Strain} = \frac{\text{Stress}}{E}$$

$$\text{Strain} = \frac{2264}{30\times10^6} = \frac{2264}{3\times10^7} = 754.6\times10^{-7}$$

$$\therefore \text{Extension} = 754.6\times10^{-7}\times12 = 10400\times10^{-7} = .00104$$

$$\text{Extension} = \text{strain}\times\text{original length}$$

$$= \frac{9054}{30\times10^6}\times10 = \frac{90540}{3}\times10^{-7} = 30180\times10^{-7} = .003018$$

$$\text{Extension} = \text{Strain}\times\text{original length} = \frac{20372}{3\times10^7}\times8$$

$$= \frac{162976}{3}\times10^{-7} = 54325.3\times10^{-7} = .0054325$$

$$\text{Total} = .0104 + .003018 + .005436 = .00936''$$

A bar having a cross sectional $4'' \times \frac{3}{8}''$ is subjected to an axial pull of 5 tons find the Tensile stress on a normal cross section

$A = 4'' \times \frac{3}{8}'' = 1.5$ sq in

Stress = ?

F = 5

$\therefore$ Stress $= \frac{F}{A} = \frac{5}{1.5} = 3.33$ Ton/in²

A steel wire 100 ft long and 0.160" dia is pulled by a force F and the tensile stress is 20 tons/in². Find the value of F and of the extension $E = 30 \times 10^6$ lbs

F = ? extension

$E = 30 \times 10^6$ lbs/in²

$d = 0.16 \quad \therefore$ Area $= \frac{\pi}{4} \times (.16)^2$

$= .785 \times (.16)^2$

~~F =~~ Stress $= \frac{F}{A}$

$\therefore F = A \times$ Stress

$= .785 \times .16 \times .16 \times 20$

$= .4920000$ Toms $\quad = .402$ toms

Extension = Strain × original length

$= \frac{\text{Stress}}{E} \times 1200$

$= \frac{.\cancel{402}^{20} \times 2240}{\times 3 \times 10^7} \times 1200$

$= \frac{2240 \times 2.4}{3} \times 10^{-7}$ $= 160.8 \times 10^{-7} \times 2240$

$= .0000\ 1612 \times 2240$

$= \frac{24 \times 224 \times 10^4}{3 \times 10^7}$ $= .036\ 1.79''$

$= 1792 \times 10^{-3} = 1.79''$

Load applied gradually.

[illegible]

Load applied suddenly - [illegible]

$$\boxed{\text{Gradually applied Load strength} = \frac{2w}{a}}$$

where w = Load applied

Gradually applied load st. $= \frac{w}{a} + \frac{\sqrt{w^2 L^2 + 2 E w a L h}}{a L}$ $\quad a$ = cross section of the bar

Prob:

[illegible] 1" [illegible] steel Rod [illegible] 3 tons [illegible] max: stress [illegible] max elongation [illegible] $E = 30,000000$ lbs/□"

$d = 1''$

$a = \frac{22}{7 \times 4} \times (1)^2 = \frac{22}{7 \times 4}$ sq in $= \frac{11}{14}$

$l = 5' = 60''$

$w = 3$ tons

max: Stress $= \frac{2w}{A} = \frac{2 \times 3 \times 2240}{\frac{11}{14}}$

$= \frac{28 \times 3 \times 2240}{11}$

max stress $= \frac{84 \times 2240}{11} = 17100$ lbs/in²

max: elongation $= x = \frac{FL}{E} = \frac{17100 \times 60}{30 \times 10^6}$

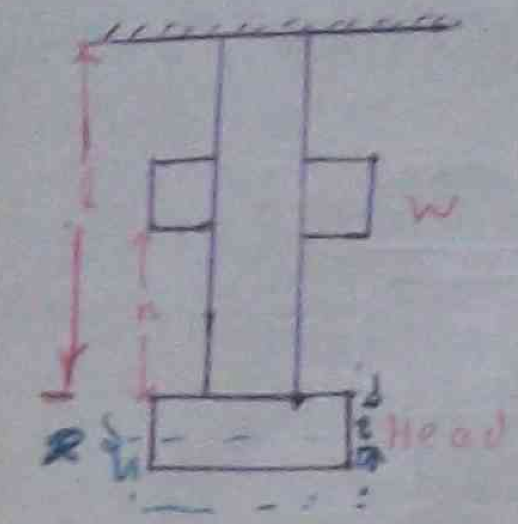
$= \frac{34200}{10^6} = \frac{342}{10^4}$

$x = .034''$

L = 72 [illegible]

$x = \frac{17100 \times 72}{30 \times 10^6} = \frac{171 \times 24}{10^5} = .041''$

*



If a bar 1/2" dia : stretched 1/8 of an inch under a steady load of 1 ton, what stress would be produced in ~~thread~~ rod by a wt: of 150 lbs ~~following~~ falling . falling through 3" before ~~commencing~~ commencing to stretch the rod

The rod is initially ~~unst~~ unstressed

$\{E = 30 \times 10^6\}$

dia = 1/2", $x = \frac{1}{8}'' = .125''$

$w = 2240$ lbs

$a = \frac{22}{7 \times 4} \left(\frac{1}{2}\right)^2 = \frac{11}{56}$ sq in

$f = \frac{P}{a} = \frac{2240 \times 56}{11} = \frac{125500}{11} = 11400$ lb/in^2

$E = 30 \times 10^6$ lbs/□" $l = ?$

$x = \frac{fl}{E}$ $\therefore l = \frac{Ex}{f} = \frac{30 \times 10^6 \times .125}{1140} = \frac{.375 \times 10^6}{1140}$

$= \cancel{.0329 \times 10^6}$

$= \frac{.375 \times 10^6}{1140}$

*

$= \frac{.375 \times 10^3}{1140} = \frac{.375 \times 1000}{1140}$

$= 329$ $x = .0329 \times 10^6 \times$

$\therefore x = 329''$ $= 27.4''$ =

Sudden fall = h

$$f = \frac{w}{a} + \frac{\sqrt{w^2 l^2 + 2wEalh}}{al}$$

$$f = \frac{150}{\frac{11}{56}} + \frac{\sqrt{(150)^2 \times (329)^2 + 2 \times 150 \times 30 \times 10^6 \times \frac{11}{56} \times 329}}{\frac{11}{56} \times 329}$$

$$= \frac{150 \times 329 + \sqrt{(150)^2 \times (329)^2 + 2 \times 100 \times 30 \times 10^6 \times \frac{11}{56} \times 329}}{\frac{11}{56} \times 329}$$

=

$$= \frac{49400 + \sqrt{22500 \times 108600 + 6000 \times 10^6 \times 64.5 \times 3}}{64.5}$$

$$= \frac{49400 + \sqrt{2440000000 + 6000,000000 \times 64.5 \times 3}}{64.5}$$

$$= \frac{49400 + \sqrt{10^7 \times 244 + 10^9 \times 64.5 \times 6 \times 3}}{64.5}$$

$$= \frac{49400 + \sqrt{244 \times 10^7 + 387 \times 10^9 \times 3}}{64.5}$$

$$= \frac{49400 + \sqrt{.244 \times 10^{10} + 38.7 \times 10^{10} \times 3}}{64.5}$$

$$= \frac{49400 + 10^5 \sqrt{11,61.344}}{64.5}$$

$$= \frac{49400 + 10^5 \times 12.25}{64.5}$$

$$= \frac{49400 + \cancel{6210000}\ 1230000}{64.5} = \frac{6259400}{64.5} = \cancel{97000}\ 21213.7 \text{ lb/in}^2$$

$$= \frac{1124400}{64.5} = 21213.7$$

49400
1075000
1124400

$$f = \frac{w}{a} + \frac{\sqrt{w^2 l^2 + 2wEalh}}{al}$$

$$f = \frac{150}{\frac{11}{56}} + \frac{\sqrt{(150)^2 \times (329)^2 + 2 \times 150 \times 30 \times 10^6 \times \frac{11}{56} \times 329 \times 3}}{\frac{11}{56} \times 329}$$

$$= \frac{150 \times 56}{11} + \frac{\sqrt{22500 \times 108500 + 60 \times 150 \times 10^6 \times 64.5 \times 3}}{64.5}$$

$$= 763 + \frac{\sqrt{2440000000 + 1785000 \times 10^6}}{64.5}$$

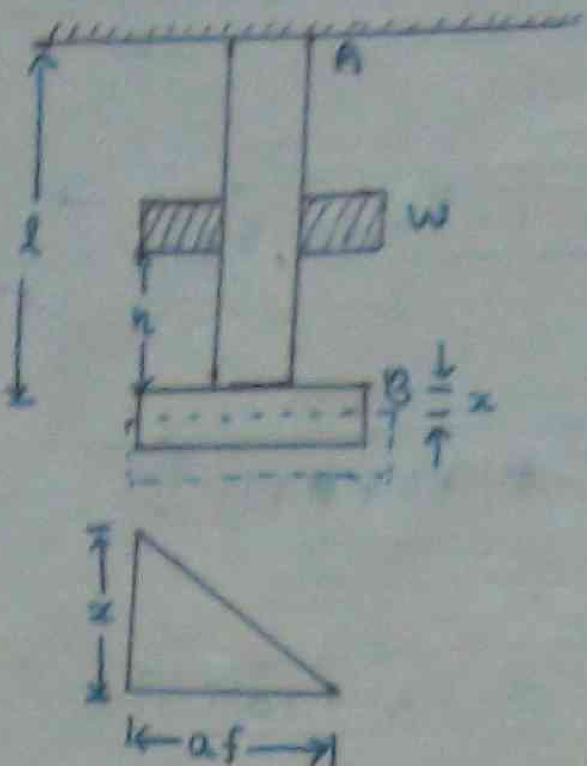
=

$$763 + \frac{\sqrt{(2440 + 1785000)10^6}}{64.5}$$

$$= 763 + \frac{\cancel{10^3 \times 143}\ 5 \sqrt{1787440 \times 106}}{64.5}$$

$$= 763 + \frac{\sqrt{178.744 \times 10^{10}}}{64.5}$$

$$= 763 + \frac{13.3 \times 10^5}{64.5} = 763 + 1330000 =$$



[illegible] a [illegible] w [illegible] h [illegible]

[illegible] $x + h$ [illegible] af [illegible]

max: stress [illegible] work done [illegible] diagram [illegible] Δ [illegible] area [illegible] $\frac{1}{2}$ $a.f.x$ [illegible] work done [illegible] $w(h+x) = \frac{1}{2}a.f.x$ [illegible]

[illegible] $x = \frac{fl}{E}$

[illegible] $w(h+\frac{fl}{E}) = \frac{af.fl}{2E}$

$$= \frac{af^2l}{2E}$$

[illegible] ⇒

$$f = \frac{w}{a} + \frac{\sqrt{w^2l^2 + 2wEalh}}{al}$$

[illegible] $h = 0$ [illegible]

$$f = \frac{2w}{a}$$

[illegible]

max: stress $= \frac{w}{a}$ [illegible]

[illegible] ~~[illegible]~~ [illegible]

[illegible] max: stress [illegible] $\frac{2w}{a}$ [illegible]

[illegible]

[illegible] 10' [illegible] 1000 lbs [illegible] 1" [illegible] ① [illegible] ② [illegible] 10000 lb/in² [illegible]

$(E = 30 \times 10^6 \text{ lbs/in}^2)$

Case I

dia = 2"

$l = 10' = 120"$

$w = 1000$ lbs

$h = 1"$

$E = 30 \times 10^6$ lbs/in²

cross sectional area $= \frac{22}{7\times4}(2)^2$

$$a = \frac{22}{7}\text{ in}^2$$

$$f = \frac{w}{a} + \frac{\sqrt{w^2l^2 + 2wEalh}}{al}$$

$$= \frac{1000}{\frac{22}{7}} + \frac{\sqrt{(1000)^2 \times (120)^2 + 2\times1000\times30\times10^6\times\frac{22}{7}\times120\times1}}{\frac{22}{7}\times120}$$

$$= \frac{1000}{3.1416} + \frac{\sqrt{10^6\times144\times10^2 + 6\times10^3\times10^7\times3.1416\times120}}{120\times3.1416}$$

$$= \frac{1000}{3.1416} + \frac{\sqrt{144\times10^8 + 6\times3.1416\times12\times10^{11}}}{120\times3.1416}$$

$$= 318.5 + \frac{10^4\sqrt{144 + 72\times3.1416\times10^3}}{377}$$

$$= 318.5 + \frac{10^4\sqrt{144 + 226.2\times1000}}{377}$$

226200
144
226344

$= 318.5 + \frac{10^4 \sqrt{\ldots}}{377}$

$$= 318.5 + \frac{10^4 \times 10^{-2} \times 4.75}{377}$$

$$= 318.5 + \frac{4.75 \times 1000000}{377}$$

$$= 318.5 + \frac{4750000}{377} = 318.5 + 12620$$

318.5

$$= \cancel{318.5 + 1262000} = \cancel{319.76} = 12938.5$$

$$= \cancel{1262318.5}$$

$$f = \frac{w}{a} + \frac{\sqrt{w^2 l^2 + 2wEalh}}{al}$$

$$10000 = 318.5 + \frac{10^4\sqrt{144 + 276.3 \times 1000 \times h}}{377}$$

$$10000 = 12938\sqrt{h}$$

$$\left(\frac{10000}{12938}\right)^2 = h$$

$$(.723)^2 = h \qquad h = .598''$$

12938 နှင့်
10000 ကိုစား: $\cancel{.000523}'' = h$

*

10' ရှည်ပြီး ဖြတ်ပိုင်း area 1 sq in ရှိသော သံချောင်း ထောင်လိုက်ထား [illegible] 560 lbs လေးသော [illegible] $1\frac{1}{2}''$ [illegible]

$l = 120'' \qquad a = 1 \text{ sq}'' \qquad w = 560 \text{ lbs}$

$h = 1'' \qquad f = ?$

$$f = \frac{w}{a} + \frac{\sqrt{w^2 l^2 + 2wEalh}}{al}$$

$$f = \frac{560}{1} + \frac{\sqrt{(560)^2 \times (120)^2 + 2 \times 560 \times 30 \times 10^6 \times 1 \times 120 \times \frac{1}{2}''}}{1 \times 120}$$

$$= 560 + \frac{\sqrt{3136000 + 72 \times 56 \times 10^4}}{120}$$

$$f = 560 + \frac{\sqrt{10^{10} \times .00003135 + 72 \times 5.6 \times 10^{10}}}{120}$$

$$f = 560 + \frac{10^5\sqrt{403.00003135}}{120}$$

$$f = 560 + \frac{10^5 \times 20.58}{120} = 533.60 \text{ lb/in}^2$$

$$f = 560 + \frac{\sqrt{3135 \times 144 \times 10^5 + 4030 \times 10^9}}{120}$$

$$f = 560 + \frac{\sqrt{4.5\cancel{02}00 \times 10^5 + 403 \times 10^{10} \times \frac{1}{2}}}{120}$$

$$f = 560 + \frac{\sqrt{4.502 + 201.5 \times 10^{10}}}{120}$$

$$f = 560 + \frac{10^5\sqrt{202.052}}{120} = 560 + \frac{\cancel{1436000}}{120}$$

5.46

$$= \frac{12500}{2240} = 5.58 \text{ lb/in}^2$$

$$f = 560 + \frac{10^5 \times \cancel{45.3}}{120} = 560 + 45300$$

$$\cancel{f = 560 + 18833 = \frac{17988}{2240}} \text{ lb/in}^2 \qquad = \frac{17860}{2240}$$

$$560 + \frac{1480000}{120}$$

$$560 + \frac{12320}{2240} = 5.46 \text{ tons} \qquad = 5.46 \text{ tons/in}^2$$

$= 5.46$ ton

$$f = \frac{\frac{1}{4}}{1} + \frac{\sqrt{(\frac{1}{4})^2 \times (120)^2 + 2 \times \frac{1}{4} \times 13 \times 10^3 \times 1 \times 120 \times .5}}{1 \times 120}$$

$$= .25 + \frac{\sqrt{\frac{1}{16} \times 14400 + \cancel{2} \times \frac{1}{\cancel{4}} \times 13 \times 10^3 \times \cancel{120}^{30} \times \frac{1}{\cancel{2}}}}{120}$$

$$= .25 + \frac{\sqrt{900 + 390 \times 10^3}}{120}$$

$$= .25 + \frac{\sqrt{.09 \times 10^4 + 39 \times 10^4}}{120}$$

$$= .25 + \frac{10^2 \times \sqrt{34.09}}{120}$$

$$= .25 + \frac{100 \times 5.84}{120}$$

$$= .25 + \frac{584}{120}$$

$.25 + 4.86$

5.11 lb

① [illegible]

* [illegible] 1/2 tons [illegible] 3/4" [illegible] $\frac{1}{1800}$

E = 12000 tons/in² [illegible] area [illegible]

1.04 [illegible]

* ① [illegible] 1/2" [illegible] 10' [illegible]

[illegible]

14 tons/□" [illegible]

(3.49")

---

①

$$x = \frac{fl}{E}$$

$$\frac{1}{1800} = \frac{f \times 120''}{\cancel{12000} \times 2240}$$

f =

①

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$12000 \times 2240 = \frac{\text{Stress}}{\frac{1}{1800}}$$

$$\text{Stress} = \frac{\cancel{12000} \times 2240}{\cancel{1800}} = \frac{44800}{3}$$

$$f = \frac{w}{a} + \frac{\sqrt{w^2 l^2 + 2wEalh}}{al}$$

$$\frac{44800}{3} = \frac{1120}{a} + \frac{\sqrt{(1120)^2 \times (72)^2 + 2 \times 1120 \times 12000 \times a \times}}{a \times 72''}$$

$$\frac{44800}{3} - \frac{1120}{a} = \frac{\sqrt{(1120)^2 \times (72)^2 + 108 \times 1120 \times 12000a}}{72a}$$

$$\frac{4480a - 1120}{\cancel{3a}} = \frac{\sqrt{(1120)^2 \times (72)^2 + 108 \times 1120 \times 12000a}}{\cancel{72a}}$$

$$24(4480a - 1120) = \sqrt{(1120)^2 \times (72)^2 + 108 \times 1120 \times 12000a}$$

$$(24)^2(4480a - 1120)^2 = (1120)^2 \times (72)^2 + 108 \times 1120 \times 12000a$$

$$(24)^2\left\{(4480a)^2 - 2 \times 4480 \times 1120a + (1120)^2\right\} = (1120)^2 \times (72)^2 + 108 \times 1120 \times 12000a$$

$$(4480)^2 \times (24)^2 a^2 - 2 \times 4480 \times 1120a - 108 \times 1120 \times 12000a + (1120)^2 - (1120)^2 \times (72)^2 = 0$$

$\cancel{2240}$ $(1120)^2$. a : [illegible]

$$(4)^2 \times 24^2 a^2 - 2 \times 4a - \frac{108 \times 1120 \times 12000}{1120}a + 1 - (72)^2 = 0$$

$$16 \times 576a^2 - 8a -$$

---

①

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$12000 = \frac{\text{Stress}}{\frac{1}{1800}}$$

$$\text{Stress} = \frac{1200\cancel{0}}{180\cancel{0}} = \frac{20}{3}$$

$$\frac{20}{3} = \frac{\frac{1}{2}}{a} + \frac{\sqrt{(\frac{1}{2})^2 \times (72)^2 + 2 \times \frac{1}{2} \times 12000 \times a \times}}{a \times 72}$$

$$\frac{20}{3} = \frac{1}{2a} + \frac{\sqrt{18 \times 72 + 54 \times 12000a}}{72a}$$

$$\frac{20}{\cancel{3}} = \frac{36 + \sqrt{18 \times 72 + 54 \times 12000a}}{\cancel{72a}_{24}}$$

$$480a = 36 + \sqrt{18 \times 72 + 54 \times 12000a}$$

$$444a = \sqrt{18 \times 72 + 54 \times 12000a}$$

$$(444)^2 a^2 = 18 \times 72 + 54 \times 1200a$$

$$(444)^2 a^2 - 54 \times 1200a - 18 \times 72 = 0$$

$$a = \frac{-(-54 \times 1200) \pm \sqrt{(54 \times 1200)^2 - 4 \times (444)^2 \times -18 \times 72}}{2 \times (444)^2}$$