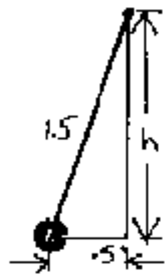
1)

$$CF \times h = W \times r$$
$$m\omega^2 r \times h = mg \times r$$
$$\omega^2 h = g$$
$$\omega^2 = \frac{g}{h}$$
$$\omega^2 = \frac{9.81}{\sqrt{2}}$$
$$\omega = \sqrt{\frac{9.81}{\sqrt{2}}}$$
$$\omega = \underline{\underline{2.6337}}\ rad/s$$

$$h^2 = 1.5^2 - .5^2$$
$$h^2 = 2$$
$$h = 1.4142$$



$$t = \frac{2\pi}{\omega}$$
$$t = \frac{2\pi}{2.6337}$$
$$t = \underline{\underline{2.3856}}\ s$$

$$TENSION^2 = W^2 + CF^2$$
$$T^2 = (mg)^2 + (m\omega^2 r)^2$$
$$T^2 = (2 \times 9.81)^2 + (2 \times 2.6337^2 \times .5)^2$$
$$T^2 = 433.06245$$
$$T = \underline{\underline{20.81\ N}}$$

2

$T = I \omega \Omega$

$I = mk^2$

$I = 50{,}000 \times 1525^2$

$I = 116281.25 \ kg/m^2$

$\omega = \dfrac{2\pi \times 900}{60}$

$\omega = 94.2477 \ rad/s$

$\Omega = \dfrac{\text{TAN } 1^\circ}{1 \text{ SECOND}}$

$\Omega = .017455 \ rad/s$

$T = 116281.25 \times 94.2477 \times .017455$

$T = 191294.25 \ Nm$

$T = \underline{\underline{191.29 \ kNm}}$

$P = I \alpha \omega$

$\alpha = \dfrac{P}{I\omega}$

$\alpha = \dfrac{75000}{116281.25 \times 94.2477}$

$\alpha = 6.84354 \times 10^{-3}$

$\alpha = \dfrac{\omega_2 - \omega_1}{2t}$

$t = \dfrac{\omega_2 - \omega_1}{2\alpha}$

$t = \dfrac{94.2477 - 0}{2 \times 6.84354}$

$t = 6885.88 \ s$

$t = \underline{\underline{1.913 \text{ hours}}}$

3

$$U = \frac{\tau^2}{2G} \times VOLUME$$

$$KE = U$$

$$KE = \frac{1}{2} m V^2$$

$$KE = \frac{1}{2} \times 10000 \times .91^2$$

$$KE = 4140.5 \text{ J}$$

$$U = KE$$

$$\frac{\tau^2}{2G} \times VOLUME = 4140.5$$

$$VOLUME = 4140.5 \times \frac{2G}{\tau^2}$$

$$VOLUME = \frac{4140.5 \times 2 \times 85 \times 10^9}{(280 \times 10^6)^2}$$

$$VOLUME = .008978$$

$$m = V\rho$$

$$m = .008978 \times 7380$$

$$m = \underline{\underline{66.26}} \text{ Kg}$$

4)

$\text{POWER} = T\omega$

$T = F \times d$

$F = \mu N$

$F = .02 \times 50 \times 10^3$

$F = 1000$

$T = 1000 \times d$

$d = \dfrac{r_1 + r_2}{2}$

$d = \dfrac{.2 + .125}{2}$

$d = .1625$

$T = 1000 \times .1625$

$T = 162.5$

$\text{POWER} = 162.5 \times \omega$

$\omega = 2\pi \times \dfrac{120}{60}$

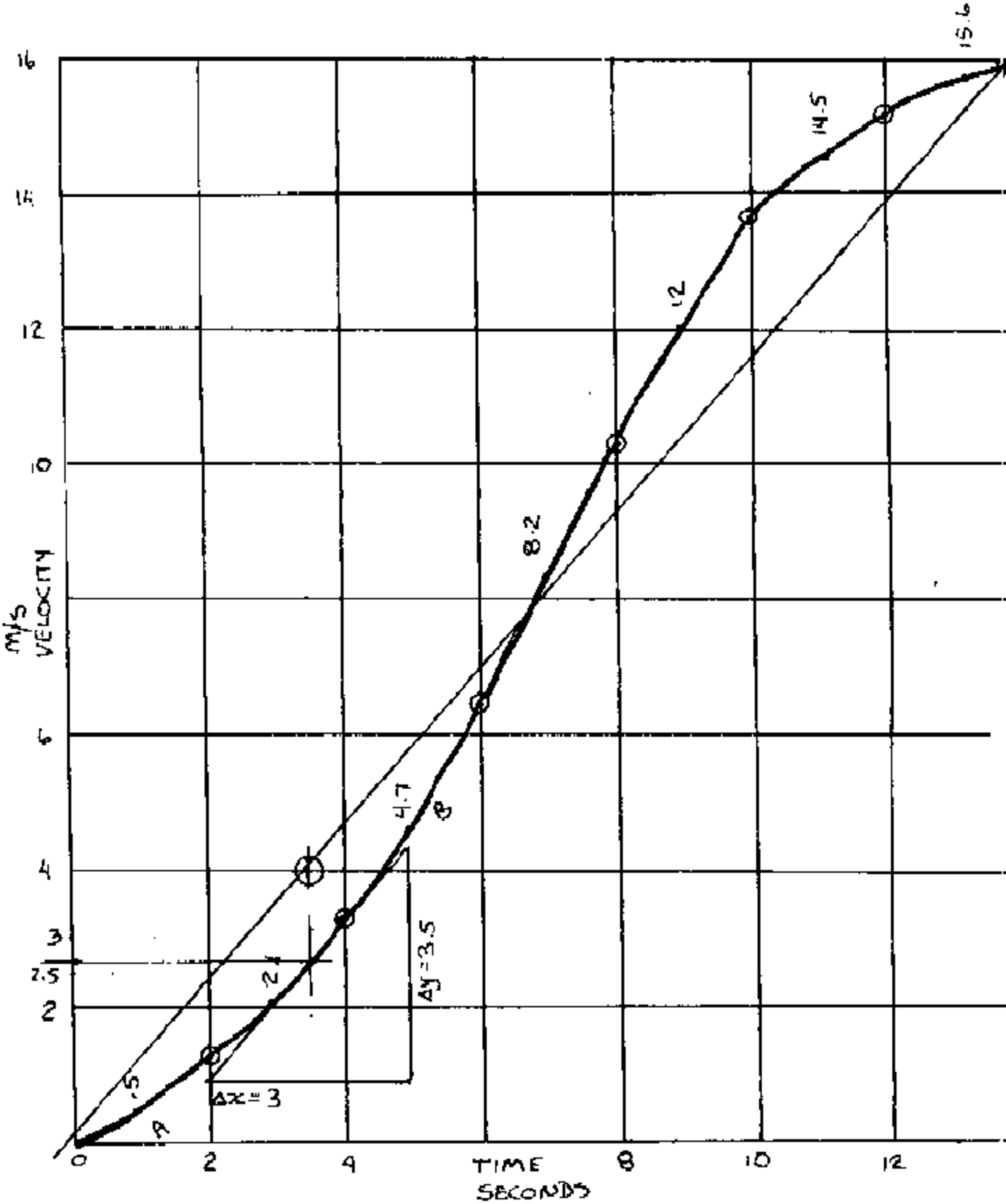
$\omega = 12.566$

$\text{POWER} = 162.5 \times 12.566$

$= 2042.03 \text{ W}$

$= \underline{\underline{2.04 \text{ kW}}}$

5


M/S
VELOCITY
TIME
SECONDS
0
2
4
8
10
12
2
2.5
3
4
6
10
12
16
15.6
14.5
12
8.2
4.7
2
.5
A
B
Δx = 3
Δy = 3.5

5

$$a_{(3.5)} = \frac{\Delta y}{\Delta x}$$

$$a = \frac{3.5}{3}$$

$$a = \underline{1.166\ m/s^2} \qquad 1.166 \times 3.5 = \underline{\underline{4.081\ m/s}}$$

DISTANCE TRAVELLED = AREA UNDER CURVE

$$AREA = LENGTH \times \frac{\Sigma \text{ MID ORDINATES}}{\#\text{ MID ORDINATES}}$$

$$A = 14 \times \left(\frac{.5 + 2.1 + 4.7 + 8.2 + 12 + 14.5 + 15.6}{7}\right)$$

$$A = 14 \times \frac{57.6}{7}$$

$$A = 115.2$$

DISTANCE TRAVELLED = $\underline{\underline{115.2\ m}}$

6)

$\theta = 165°$

$\theta = \frac{165}{360} \times 2\pi$

$\theta = 2.87979$ radians

$I_{fw} = 4 \text{ kg} \cdot m^2$

$\omega_2 = 300 \times \frac{2\pi}{60}$

$\omega_2 = 31.4159$

$\omega_2 = \omega_1 + \alpha t$

$31.4 = 0 + (\alpha \times 8)$

$31.4 = 8\alpha$

$\frac{31.4}{8} = \alpha$

$3.925 = \alpha$ rad/s²

$T = I\alpha$ (ACCELERATING TORQUE)

$T = 4 \times 3.925$

$T = 15.7$

APPLIED TORQUE = ACCEL TORQUE + FRICTION TORQUE

$(T_1 - T_2) r = 15.7 + 4$

$(T_1 - T_2) r = 19.7$

$T_1 - T_2 = \frac{19.7}{.15}$

$T_1 - T_2 = 131.4$

$T_1 = 131.4 + T_2$

6(cont)

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$\frac{T_1}{T_2} = e^{.28 \times 2.88}$$

$$\frac{T_1}{T_2} = 2.24$$

$$T_1 = T_2 \times 2.24$$

$$2.24\,T_2 = 131.4 + T_2$$
$$2.24\,T_2 - T_2 = 131.4$$
$$1.24\,T_2 = 131.4$$
$$T_2 = \frac{131.4}{1.24}$$
$$T_2 = \underline{\underline{105.97}}\ N$$

$$T_1 = T_2 \times 2.24$$
$$T_1 = 105.97 \times 2.24$$
$$T_1 = \underline{\underline{237.37}}\ N$$

$$\theta = \frac{\omega_1 + \omega_2}{2} \times t$$
$$\theta = \frac{31.4 + 0}{2} \times 8$$
$$\theta = 125.6$$
$$S = \theta r$$
$$S = 125.6 \times .150$$
$$S = \underline{\underline{18.85}}\ m$$

ENERGY LOST $= T\theta$
$= 19.71 \times 125.6$
$= 2475.576$
$= \underline{\underline{2.4\ kJ}}$

7)

$$T_c = \frac{T_1}{3}$$

$$T_c = \frac{5250}{3}$$

$$T_c = 1750$$

$$T_c = m v^2$$

$$v^2 = \frac{T_c}{m}$$

$$v^2 = \frac{1750}{.9}$$

$$v^2 = 1944.44''$$

$$v = 44.09$$

$$V = \omega r$$

$$\omega = \frac{v}{r}$$

$$\omega = \frac{44.09}{.15}$$

$$\omega = 293.97$$

$$RPM = \frac{\omega \times 60}{2\pi}$$

$$RPM = \frac{293.97 \times 60}{2\pi}$$

$$RPM = \underline{\underline{2807.2}}$$

7)

$V = \omega r$

$V = \frac{2\pi}{60} \times 1500 \times .15$

$V = 23.6 \text{ m/s}$

$m = \rho V$

$m = 1.2 \times 10^3 \times 1 \times 750 \times 10^{-6}$

$m = .9 \text{ kg/m}$

$T_c = m v^2$

$T_c = .9 \times 23.6^2$

$T_c = 502 \text{ N}$

$T_1 = 7 \times 10^6 \times 750 \times 10^{-6}$

$T_1 = 5250 \text{ N}$

$e^{\mu\theta \operatorname{cosec} \beta} = e^{0.12\pi \operatorname{cosec} 15}$

$= 4.291$

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu\theta \operatorname{cosec} \beta}$$

$$\frac{5250 - 502}{T_2 - 502} = 4.291$$

$T_2 = 1610$

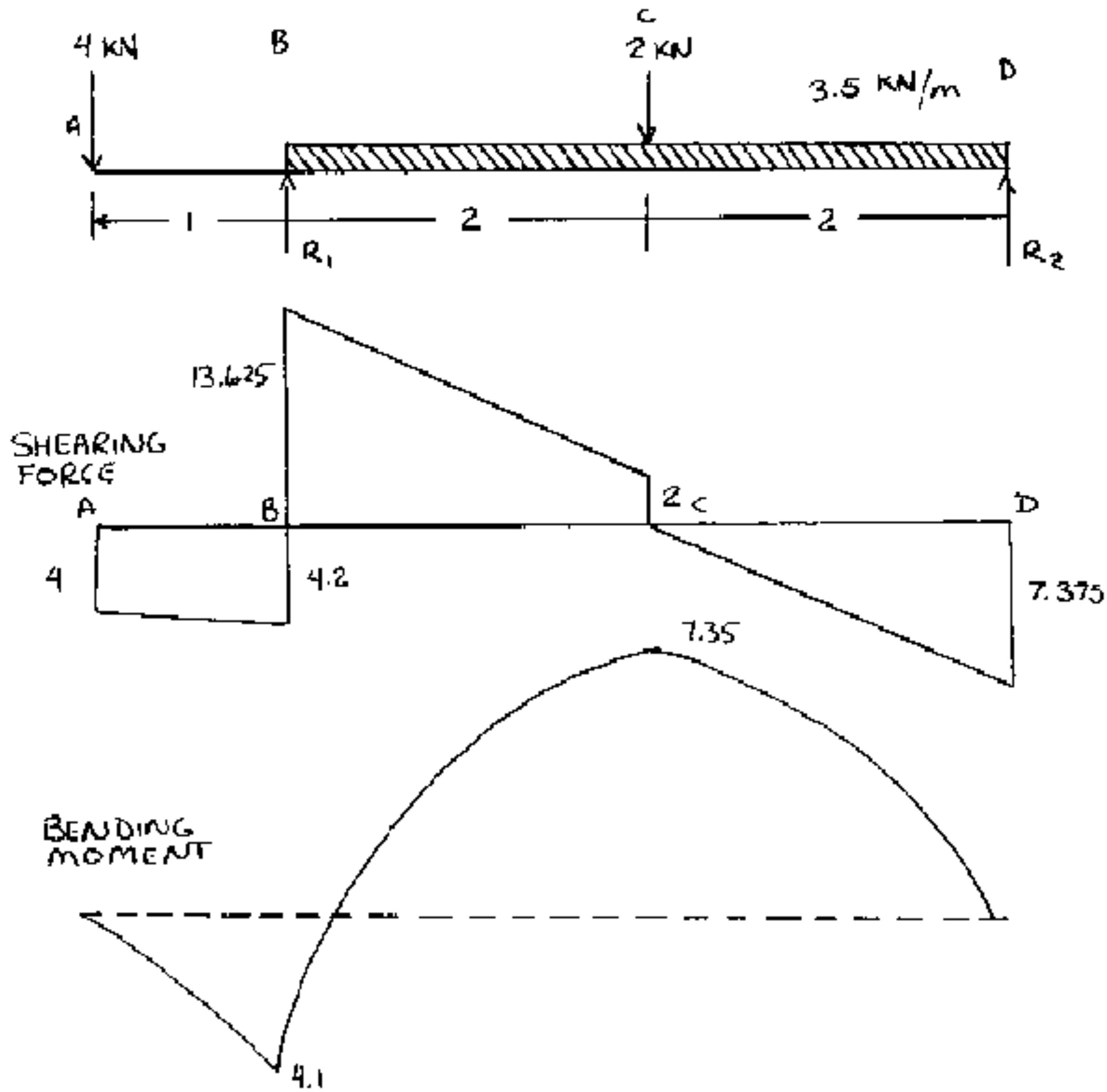
$\text{Power} = (T_1 - T_2) v \times 2$ ← TWO PULLEYS

$= (5250 - 1610) \times 23.6 \times 2$

$= 172\,000 \text{ W}$

$= \underline{\underline{172 \text{ kW}}}$

8


4 KN
B
C
2 KN
3.5 KN/m
D
A
1
2
2
R1
R2
13.625
SHEARING FORCE
A
B
2 C
D
4
4.2
7.375
7.35
BENDING MOMENT
4.1

9)

$\omega_{MOTOR} = 600 \times \frac{2\pi}{60}$

$\omega = 62.83$

POWER AVAILABLE $= 37\ kW - .15 \times 37$
$= 37 - 5.55$
$= 31.45 \times 10^3\ W$

POWER $= T\omega$

$T = \frac{Power}{\omega}$

$T = \frac{31.45}{62.83}$

$T = .5005\ kNm$

$T = 500.5\ Nm$

FRICTION
FORCE TO LIFT GATE $= \mu N$
$= .1 \times 2.5 \times 10^6$
$= 250 \times 10^3$

WEIGHT OF GATE $= 6 \times 10^3 \times 9.81$
$= 58.86 \times 10^3\ N$

FORCE TO LIFT GATE = FRICTION FORCE + WEIGHT
$= 250 \times 10^3 + 58.86 \times 10^3$
$= 308.86 \times 10^3\ N$

9) cont

FORCE REQUIRED AT SCREW

$F = W \tan(\theta + \phi)$

$\tan^{-1}\theta = \frac{PITCH}{\pi D}$ $\tan^{-1}\phi = .08$

$\phi = 4.57$

$\tan^{-1}\theta = \frac{25}{\pi \times 125}$

$\theta = 3.64°$

$F = 308.86 \times \tan(3.64 + 4.57)$

$F = 308.86 \times \tan 8.21°$

$F = 44.56 \times 10^3$

$T = Fr$

$T = 44.56 \times 10^3 \times .0625_m$

$T = 2785$ Nm

$P = T\omega$

$\omega = \frac{P}{T}$

$\omega = \frac{31.45 \times 10^3}{2785 \times 10^3}$

$\omega = 11.29$ rad/s

$\omega_1 r_1 = \omega_2 r_2$

$r_1 = Teeth_1$ $r_2 = Teeth_2$

$\omega_1 T_1 = \omega_2 T_2$

$62.83 \times T_1 = 11.29 \times 80$

$T_1 = \frac{11.29 \times 80}{62.83}$

$T_1 = 14.375$

$T_1 = \underline{\underline{14 \text{ TEETH}}}$

10

$$A+B = C+D = E+F = G+H = J+K = 180/2\times\frac{1}{6} = 60$$

$$A+B=60$$

$$\frac{B}{A} = \frac{K}{J} = \frac{2400}{1600} = \frac{3}{2}$$

$B = K$

$A = J$

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

$3A = 2B$

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

$A+B=60$

$\frac{2}{3}B+B=60$

$\frac{5}{3}B = 60$

$B = 60/\frac{3}{5}$

$\underline{\underline{B = 36 \text{ TEETH}}}$

$\underline{\underline{K = 36 \text{ TEETH}}}$

$3A = 2B$

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

$A+B=60$

$A+\frac{3}{2}A=60$

$\frac{5}{2}A=60$

$A = 60/\frac{2}{5}$

$\underline{\underline{A = 24 \text{ TEETH}}}$

$\underline{\underline{J = 24 \text{ TEETH}}}$

COMMON RATIO "r"

$\frac{1}{4}r^3 = \frac{3}{2}$

$r^3 = \frac{3}{2}\times 4$

$r^3 = 6$

$r = \sqrt[3]{6}$

$$\frac{D}{C} = \frac{400}{1600} = \frac{1}{4}$$

10 cont

$$\frac{F}{E} = r \times \frac{1}{4}$$

$$\frac{F}{E} = \sqrt[3]{6} \times \frac{1}{4}$$

$$\frac{F}{E} = .454$$

$$\frac{H}{G} = r^2 \times \frac{1}{4}$$

$$\frac{H}{G} = (\sqrt[3]{6})^2 \times \frac{1}{4}$$

$$\frac{H}{G} = .825$$

$E + F = 60$

$F = .454E$

$E + .454E = 60$

$1.454E = 60$

$E = \frac{60}{1.454}$

$E = 41.26$

$E = 41$ TEETH

$F + E = 60$

$F = 60 - E$

$F = 60 - 41$

$F = 19$ TEETH

$G + H = 60$

$H = .825G$

$G + .825G = 60$

$1.825G = 60$

$G = \frac{60}{1.825}$

$G = 32.876$

$G = 33$ TEETH

$G + H = 60$

$H = 60 - G$

$H = 60 - 33$

$H = 27$ TEETH

POWER $= T\omega$ (DRIVING SHAFT)

$T_1 = \frac{P}{\omega}$

$T_1 = \frac{30 \times 10^3 \times 60}{2\pi \times 2400}$

$T_1 = 119.4$ Nm

DRIVEN SHAFT TORQUE

$T = T_1 \times \frac{2400}{400}$

$T = 119.4 \times \frac{2400}{400}$

$T = 716.4$ Nm

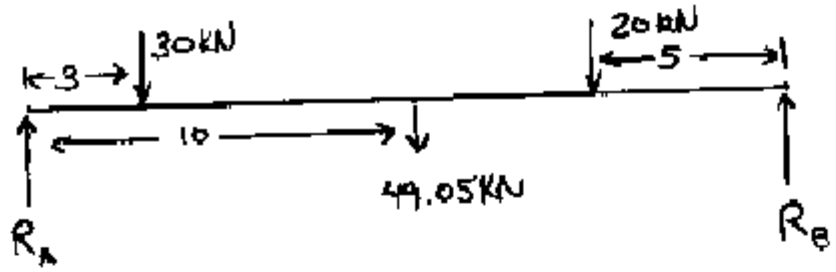
$T_F = T - T_1$

$T_F = 716.4 - 119.4$

$T_F = 597$ Nm

11

BEAM FORCE = 5000 kg × 9.81
= 49050 N
= 49.05 kN



MOMENTS ABOUT R_A $\overset{\curvearrowright}{M} = \overset{\curvearrowleft}{M}$

$30 \times 3 + 49.05 \times 10 + 20 \times 15 = R_B \times 20$

$880.5 = 20 R_B$

$R_B = \dfrac{880.5}{20}$

$R_B = 44.025$

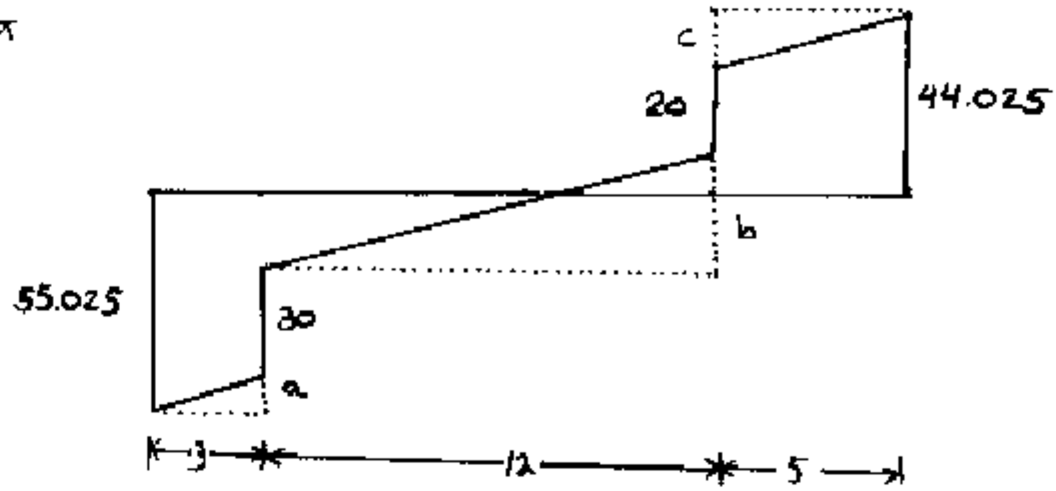
$R_A + R_B =$ BEAM FORCE $+ 30 + 20$

$R_A =$ BEAM FORCE $- R_B + 50$

$R_A = 49.05 - 44.025 + 50$

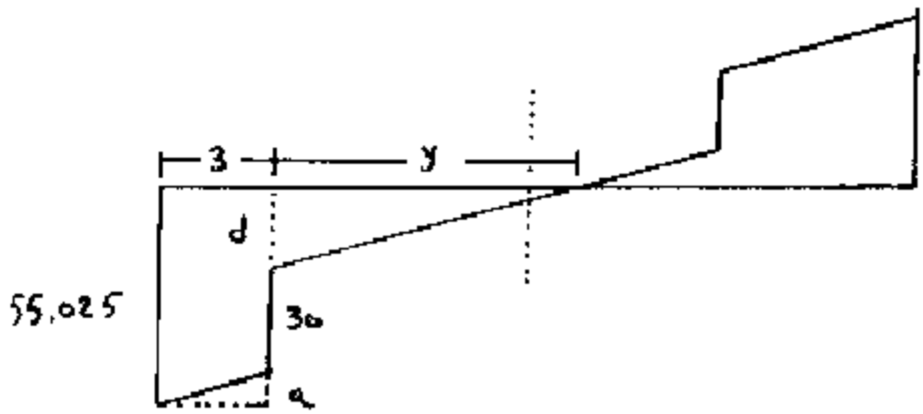
$R_A = 55.025$

11 cont



$$\frac{49.05\,N}{20\,m} = 2.4525\,N/m$$

a = 2.4525 × 3 b = 2.4525 × 12 c = 2.4525 × 5
a = 7.3575 b = 29.43 c = 12.2625



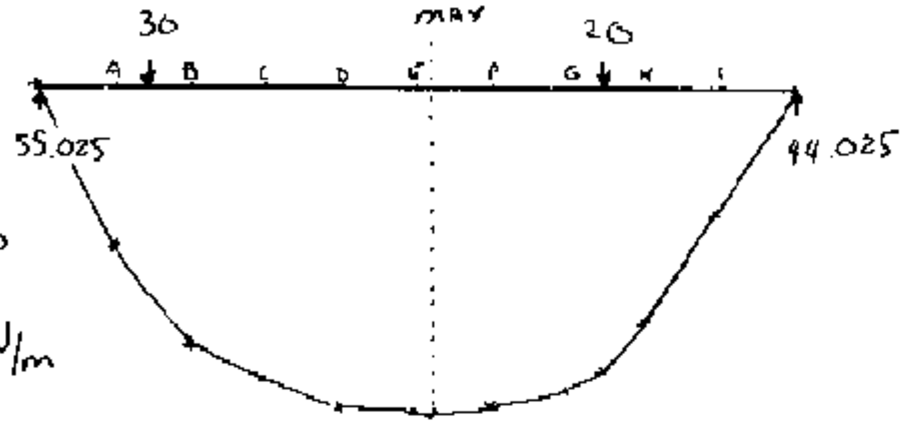
d = 55.025 − a − 30
d = 55.025 − 7.3575 − 30
d = 17.6675 N

$$y = \frac{17.6675}{2.4525}$$
y = 7.2

MAXIMUM MOMENT = 3 + y
= 10.2 m FROM END CLOSEST TO 30N WEIGHT

11 CONT

BENDING MOMENT DIAGRAM



$\frac{49.05}{20\ m} = \frac{kN}{}$

2.4525 kN/m

MOMENTS

30 → A = 2 × 2.4525 × 1 = 4.905 − R_A × 2 = −105.145

B = 4 × 2.4525 × 2 = 19.62 + 30 × 1 − 55.025 × 4 = −170.48

C = 6 × 2.4525 × 3 = 44.145 + 30 × 3 − 55.025 × 6 = −196.005

D = 8 × 2.4525 × 4 = 78.48 + 30 × 5 − 55.025 × 8 = −211.72

E = 10 × 2.4525 × 5 = 122.625 + 30 × 7 − 55.025 × 10 = −217.625

F = 12 × 2.4525 × 6 = 176.58 + 30 × 9 − 55.025 × 12 = −213.72

G = 14 × 2.4525 × 7 = 240.345 + 30 × 11 − 55.025 × 14 = −200.005

20 → H = 4 × 2.4525 × 2 = 19.62 + − 44.025 × 4 = −156.48

I = 2 × 2.4525 × 1 = 4.905 − 44.025 × 2 = −83.145

30 = 3 × 2.4525 × 1.5 = 11.03625 − 50.025 × 3 = −154.038

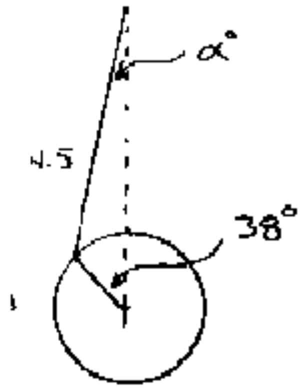
20 = 5 × 2.4525 × 2.5 = 30.65625 − 44.025 × 5 −189.46875

MAX MOMENT = 10.2

9.8 × 2.4525 × 4.9 = 117.76905 + 20 × 4.8 − 44.025 × 9.8 =

−217.67595

12



$$\frac{\sin\alpha}{1} = \frac{\sin 38}{4.5}$$

$$\sin\alpha = \frac{1 \times \sin 38}{45}$$

$$\sin\alpha = 0.13681366$$

$$\alpha = 7.8635$$

FORCE ON PISTON = A × P

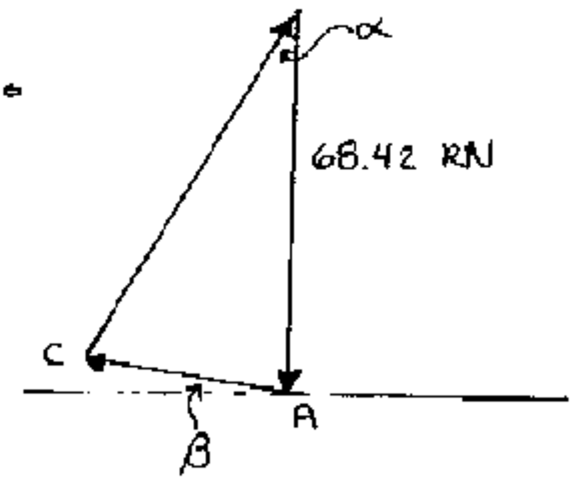
$$F = .7854 \times .22^2 \times 1800 \times 10^3$$

$$F = 68.42 \times 10^3 \text{ N}$$

$\mu = .02$

$\tan\beta = .02$

$\beta = 1.14°$



$\angle A = 90 - \beta$

$\angle A = 90 - 1.14$

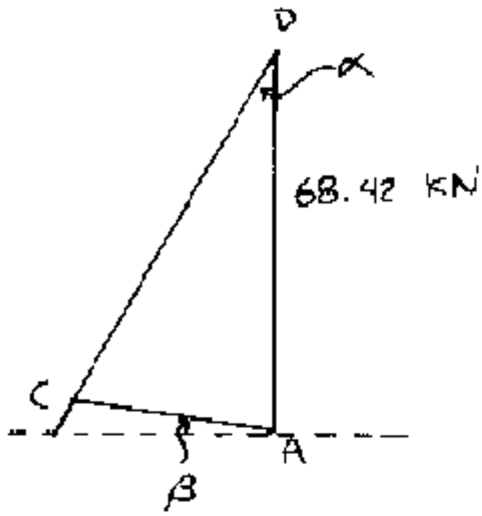
$\angle A = 88.86°$

$\angle B = 180 - (\alpha + \beta)$

$\angle B = 180 - (7.86 + 88.86)$

$\angle B = 83.28$

12 CONT



∠D = 7.86
∠A = 88.86
∠C = 83.28

AD = PISTON FORCE
CD = CON ROD FORCE
AC = GUIDE FORCE

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

$$\frac{CD}{\sin A} = \frac{AD}{\sin C}$$

$$CD = \frac{AD \times \sin A}{\sin C}$$

$$CD = 68.42 \times \frac{\sin 88.86^\circ}{\sin 83.28^\circ}$$

$$CD = \underline{\underline{68.87\ KN}}$$

$$\frac{AC}{\sin D} = \frac{AD}{\sin C}$$

$$AC = AD \times \frac{\sin D}{\sin C}$$

$$AC = 68.42 \times \frac{\sin 7.86}{\sin 83.28}$$

$$AC = 9.42\ KN$$

FORCE TO OVERCOME FRICTION
CON ROD FORCE WITHOUT FRICTION - CON ROD FORCE WITH

$$F = \frac{68.42}{\cos 7.86} - 68.87$$

$$F = 69.07 - 68.87$$

$$F = .19889\ KN$$

$$F = \underline{\underline{.199\ KN}}$$

14)

$$CF \times h = mg \times \tfrac{1}{2}\ \text{TRACK}$$

$$\frac{mv^2}{r} h = mg \times \tfrac{1}{2}\ \text{TRACK}$$

$$v^2 = \frac{mg \times \frac{1}{2}\text{TRACK} \times r}{mh}$$

$$v^2 = \frac{g \times \frac{1}{2}\text{TRACK} \times r}{h}$$

$$v^2 = \frac{9.81 \times .5 \times 2.56 \times 50}{2.45}$$

$$v^2 = 256.26$$

$$v = 16.01\ \text{m/s} \times \frac{3600}{1000}$$

$$v = \underline{\underline{57.63}}\ \text{km/hr}$$

15)

$F = m \times a \qquad a = \frac{F}{m}$

$$a = 9.81 \times \frac{(2.5 - (2.0 \times .02) - 1.5}{2.5 + 2.0 + 1.5}$$

$$a = \frac{5.886}{6}$$

$$a = 0.981 \ m/s^2$$

$$V^2 = u^2 + 2as$$

$$V^2 = 0^2 + 2 \times .981 \times 1$$

$$V^2 = 2 \times .981$$

$$V = \underline{\underline{1.4}} \ m/s$$

16

PERIODIC TIME = $\frac{2\pi}{\omega}$

$\omega = \frac{2\pi}{t}$

$\omega = \frac{2\pi}{12}$

$\omega = .5236$ rad/s

$\Omega_{(max)} = \omega \theta$

$\frac{\theta}{2\pi} = \frac{10}{360}$

$\theta \times 360 = 2\pi \times 10$

$\theta = \frac{20\pi}{360}$

$\theta = .1745$

$\Omega_{(max)} = .5236 \times .1745$

$\Omega_{max} = \underline{\underline{.0914 \text{ rad}}}/s$

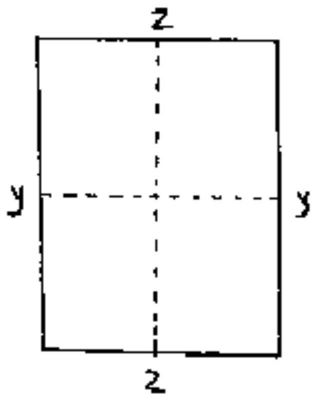
$\alpha_{(max)} = \omega^2 \theta$

$\alpha_{(max)} = .5236^2 \times .1745$

$\alpha_{(max)} = \underline{\underline{.04784}} \text{ rad}/s^2$

17

THE MOMENT OF INERTIA OF A BODY ABOUT ANY AXIS IS EQUAL TO THE MOMENT OF INERTIA OF THE BODY ABOUT A PARALLEL AXIS THROUGH THE CENTRE OF MASS TOGETHER WITH THE PRODUCT OF THE MASS AND THE SQUARE OF THE DISTANCE BETWEEN THE AXIS



$$I_{yy} = \frac{BD^3}{12}$$

$$I_{yy} \text{ (SQUARE)} = \frac{S \times S^3}{12} = \frac{S^4}{12}$$

POLAR SECOND MOMENT $= I_P$

$$I_P = I_{yy} + I_{zz}$$

$$I_P = \frac{S^4}{12} + \frac{S^4}{12}$$

$$I_P = \frac{2S^4}{12}$$

$$I_P = \frac{S^4}{6}$$

18)

$$m_1 u_1 + m_2 u_2 = m_1 V_1 + m_2 V_2$$

$$2 \times 22 + 4 \times 10 = 2 \times V_1 + 4 \times V_2$$

$$84 = 2V_1 + 4V_2$$

$$V_1 = 42 - 2V_2$$

$$V_1 - V_2 = -e\,(u_1 - u_2)$$

$$V_1 - V_2 = -.08\,(22 - 10)$$

$$V_1 - V_2 = -9.6$$

$$(42 - 2V_2) - V_2 = -9.6$$

$$-3V_2 = -9.6 - 42$$

$$3V_2 = 9.6 + 42$$

$$V_2 = \underline{\underline{17.2}}\ m/s$$

$$V_1 = V_2 - 9.6$$

$$V_1 = 17.2 - 9.6$$

$$V_1 = \underline{\underline{7.6}}\ m/s$$

19) FREQUENCY = $\frac{1}{\text{PERIODIC TIME}}$

PERIODIC TIME = $2\pi\sqrt{\frac{I\ell}{GJ}}$

$T = 2\pi\sqrt{\frac{.06 \times .5}{44 \times 10^9 \times \frac{\pi \times .01^4}{32}}}$

$T = 2\pi\sqrt{\frac{.06 \times .5 \times 32}{44 \times 10^9 \times \pi \times .01^4}}$

$T = .16558$

$f = \frac{1}{T}$

$f = \frac{1}{.16558}$

$f = 6.039_s$

PERIODIC TIME = $\frac{2\pi}{\omega}$

$\omega = \frac{2\pi}{T}$

$\omega = \frac{2\pi}{.16558}$

$\omega = 37.9465$ rad/s

MAX ω $= \omega \times \phi$

$= 37.9465 \times 5 \times \frac{2\pi}{360}$

$= \underline{\underline{3.31 \text{ rad/s}}}$

MAX α $= \omega^2 \phi$

$= 37.9465^2 \times 5 \times \frac{2\pi}{360}$

$= \underline{\underline{125.64}}$ rad/s

20

$$P_1 V_1 - P_2 V_2 = \tfrac{1}{2} m v_2^2 - \tfrac{1}{2} m v_1^2$$

$$V(P_1 - P_2) = \tfrac{1}{2} m (v_2^2 - v_1^2)$$

$$P_1 - P_2 = \tfrac{1}{2} \frac{m}{V} (v_2^2 - v_1^2)$$

$$P_1 - P_2 = \tfrac{1}{2} \rho \, (v_2^2 - v_1^2 \qquad \left[\frac{m}{V} = \rho\right]$$

$$2(P_1 - P_2) = \rho (v_2^2 - v_1^2)$$

$$v_2^2 - v_1^2 = \frac{2(P_1 - P_2)}{\rho}$$

$$V_2^2 - (.25 V_2)^2 = \frac{2(700 - 650)}{1}$$

$$.9375\, V_2^2 = 100$$

$$V_2^2 = 106.666\ldots$$

$$v_2 = 10.32795559$$

$$a_1 \times V_1 = a_2 \times V_2$$

$$D_1^2 \times V_1 = D_2^2 \times V_2$$

$$V_1 = \frac{D_2^2}{D_1^2} \times V_2$$

$$V_1 = \left(\frac{60}{120}\right)^2 V_2$$

$$V_1 = .25 V_2$$

VOLUME FLOW $= a \times v$

$$= .7854 \times .06^2 \times 10.33$$

$$= .029201674$$

ACTUAL DISCHARGE $= V \times .98$

$$= .0292 \times .98$$

$$= .028617641$$

$$= \underline{\underline{.0286\ m/s}}$$

20)

$$P_1 - P_2 = \tfrac{1}{2}\rho\left(V_2^2 - V_1^2\right)$$

$$V_1 A_1 = V_2 A_2$$

$$V_1 \times .7854\, d_1^2 = V_2 \times .7854\, d_2^2$$

$$V_2 = V_1 \times \frac{.7854\, d_1^2}{.7854\, d_2^2}$$

$$V_2 = V_1 \times \frac{d_1^2}{d_2^2}$$

$$V_2 = V_1 \times \frac{120^2}{60^2}$$

$$V_2 = 4V_1$$

$$P_1 - P_2 = \tfrac{1}{2}\rho\left((4V_2)^2 - V_1^2\right)$$

$$P_1 - P_2 = \tfrac{1}{2}\rho\left(16V_1^2 - V_1^2\right)$$

$$P_1 - P_2 = \tfrac{1}{2}\rho\left(15V_1^2\right)$$

$$15V_1^2 = \frac{P_1 - P_2}{\tfrac{1}{2}\rho}$$

$$V_1^2 = \frac{P_1 - P_2}{7.5\rho}$$

CONT

CONT

$$V_1^2 = \frac{P_1 - P_2}{7.5\rho}$$

$$V_1^2 = \frac{700-650}{7.5}$$

ASSUME $\rho = 1$
FRESH WATER

$$V_1^2 = 6.666\ldots$$

$$V_1 = 2.582 \text{ m/s}$$

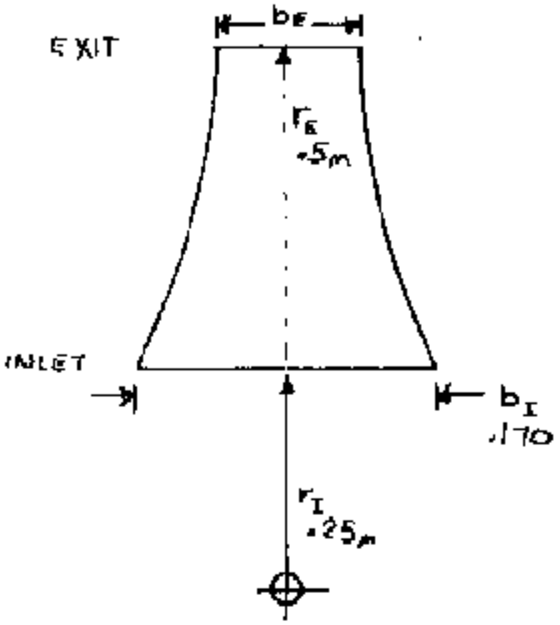
ACTUAL FLOW = THEORETICAL FLOW × COEFF. DISCHARGE

$$AF = V_1 \times A_1 \times C_D$$

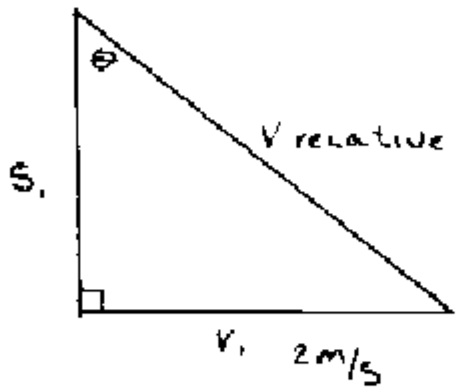
$$AF = 2.582 \times .7854 \times .12^2 \times .98$$

$$AF = \underline{\underline{.0286}} \text{ m}^3/\text{s}$$

21



$$A_{EXIT} = A_{INLET}$$
$$2\pi \times r_E \times b_E = 2\pi \times r_I \times b_I$$
$$r_E \times b_E = r_I \times b_I$$
$$b_E = \frac{r_I \times b_I}{r_E}$$
$$b_E = \frac{.25 \times .170}{.5}$$
$$b_E = .085\ m$$
$$b_E = \underline{\underline{85\ mm}}$$



INLET VELOCITY

$$S_1 = \pi D \times \frac{RPM}{60}$$
$$S_1 = \pi .5 \times \frac{300}{60}$$
$$S_1 = 7.853981634$$
$$S_1 = 7.85$$

$$TAN\,\phi = \frac{V_1}{S_1}$$
$$TAN\,\phi = \frac{2}{7.85}$$
$$TAN\,\phi = .2546$$
$$\phi = 14.2866$$
$$\phi = \underline{\underline{14.29^\circ}}$$

22

ACCELERATING FORCE = $m \times a$

$a = \omega^2 x$

$\omega = \dfrac{2\pi}{PT}$

$PT = \dfrac{1}{f}$

$f = \dfrac{130}{60}$

$f = 2.166\dots$

$PT = .4615$

$\omega = 13.613$

$\omega^2 = 185.329$

$a = 185.329 \times .4$

$a \doteq 74.13$

$F = ma$

$F = 2.5 \times 74.13$

$\underline{\underline{F = 185.329}}$ N

WHEN $x = .3$

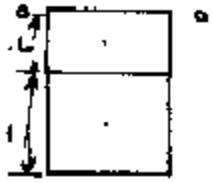
$F = m \times a$

$F = 2.5 \times 185.329 \times .3$

$F = 138.996$

$\underline{\underline{F = 139 \text{ N}}}$

23



FORCE BY OIL $= h a \rho g$

$= .3 \times .6 \times 2 \times .8 \times 9.81$

$= 2.82528 \text{ KN}$

$COP_{OIL} = \frac{2}{3} D$

$= \frac{2}{3} \times .6$

$COP_{OIL} = .4$

EQUIVALENT HEAD OF OIL $= .6 \times \frac{.8}{1.024}$

$= .46875 \text{ m}$

FORCE BY WATER $= h a \rho g$

$= (.5 + .46875) \times 1 \times 2 \times 1.024 \times 9.81$

$= 19.46304 \text{ KN}$

$COP_{WATER} = \frac{2^{ND} \text{ MOMENT}}{1^{ST} \text{ MOMENT}}$

[FROM EQUIV HEAD] $= \frac{I_G}{AH} + H$

$= \frac{B D^3}{12 \times 1 \times 2 \times (.5 + .46875)} + (.5 + .46875)$

$= \frac{2 \times 1^3}{24 \times .96875} + .96875$

$= 1.054771505$

FROM SURFACE $= 1.055 + [.6 - .46875]$

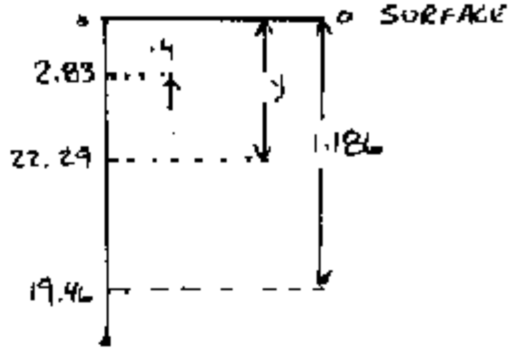
$= 1.186021505$

$= 1.186 \text{ m}$

23 cont

TOTAL LOAD = $LOAD_{OIL}$ + $LOAD_{WATER}$
= 2.83 + 19.46
= 22.29 kN

COP_{WHOLE}



$(2.83 \times .4) + (19.46 \times 1.186) = y \times 22.29$

$y = \dfrac{1.132 + 23.08}{22.29}$

$y = \underline{\underline{1.086\,m}}$

25

$$I_0 \omega_0 = I_1 \omega_1$$

$$\omega_1 = \frac{I_0 \omega_0}{I_1}$$

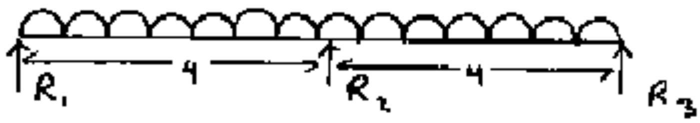
$$\omega_1 = \frac{4.5 \times 2\pi}{1.2}$$

$$\omega_1 = \underline{\underline{23.56}}\ \text{rad/s}$$

2L

LOAD PER METER = $\frac{400\ kN}{8\ m}$

$= 50\ kN/m$

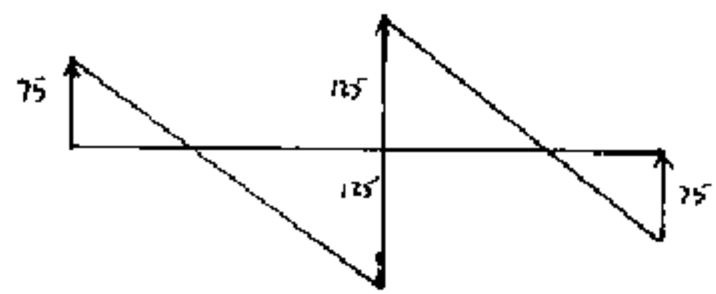


$R_1 = \frac{3}{8} wL$ $\qquad$ $R_2 = \frac{5}{4} wL$

$R_1 = \frac{3}{8} \times 50 \times 4$ $\qquad$ $R_2 = \frac{5}{4} \times 50 \times 4$

$R_1 = 75\ kN$ $\qquad$ $R_2 = 250\ kN$

S.F.



B.M 0 $= 0$

1 $(75 \times 1) - (1 \times 50 \times .5)$ $= 50$

2 $(75 \times 2) - (2 \times 50 \times 1)$ $= 50$

3 $(75 \times 3) - (3 \times 50 \times 1.5)$ $= 0$

4 $(75 \times 4) - (4 \times 50 \times 2)$ $= -100$

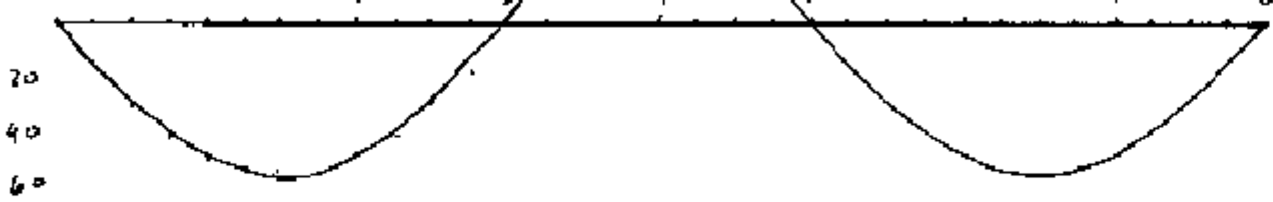
5 $(75 \times 5) + (250 \times 1) - 5 \times 50 \times 2.5$ $= 0$

SEE DETAIL CALC.

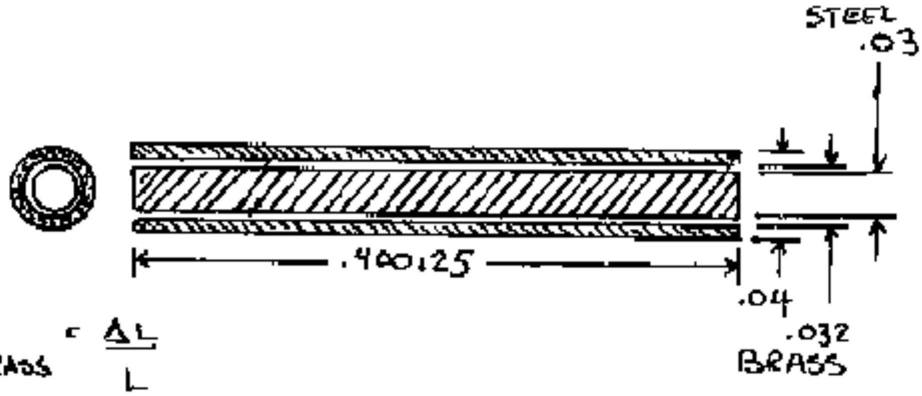
26 CONT

BENDING MOMENTS

0	0			= 0
.25	.25 x 75	+	.25 x 50 x .125	= 17.19
.5	.5 x 75	+	.5 x 50 x .25	= 31.25
.75	.75 x 75	+	.75 x 50 x .375	= 42.19
1	1 x 75	+	1 x 50 x .5	= 50.00
1.25	1.25 x 75	+	1.25 x 50 x .625	= 54.69
1.5	1.5 x 75	+	1.5 x 50 x .75	= 56.25
1.75	1.75 x 75	+	1.75 x 50 x 8.75	= 54.69
2	2 x 75	+	2 x 50 x 1	= 50
2.25	2.25 x 75	+	2.25 x 50 x 1.125	= 42.19
2.5	2.5 x 75	+	2.5 x 50 x 1.25	= 31.25
2.75	2.75 x 75	+	2.75 x 50 x 1.375	= 17.19
3	3 x 75	+	3 x 50 x 1.5	= 0
3.25	3.25 x 75	+	3.25 x 50 x 1.625	= -20.3
3.5	3.5 x 75	+	3.5 x 50 x 1.75	= -43.75
3.75	3.75 x 75	+	3.75 x 50 x 1.875	= -70.3
4	4 x 75	+	4 x 50 x 2	= -100



27



$\varepsilon_{BRASS} = \frac{\Delta L}{L}$

$\varepsilon_B = \frac{.000125}{.400125}$

$\varepsilon_B = 312.4024 \times 10^{-6}$

$\sigma_B = E_B \varepsilon_B$

$\sigma_B = 90 \times 10^9 \times 312.4024 \times 10^{-6}$

$\sigma_B = 28.116216 \times 10^6 \ N/m^2$

LOAD $= \sigma \times A$ (TO COMPRESS BRASS TO LENGTH OF STEEL)

$= 28.116216 \times 10^6 \times .7854 \times (.04^2 - .032^2)$

$= 12.7195 \times 10^3 \ N$

FORCE ACTING ON BOTH $= 50 \times 10^3 - 12.7195 \times 10^3$

$= 37.2805 \times 10^3$

$E = \frac{\sigma}{\varepsilon}$ $\quad \frac{\sigma}{E} = \varepsilon$ $\quad \varepsilon_{BRASS} = \varepsilon_{STEEL}$

$\frac{\sigma_B}{E_B} = \frac{\sigma_S}{E_S}$

$\sigma_B = \frac{E_B}{E_S} \times \sigma_S$

27 CONT

$$\sigma_B = \frac{E_B \times \sigma_S}{E_S}$$

$$\sigma_B = \frac{90}{200} \times \sigma_S$$

$$\sigma_B = .45\sigma_S$$

LOAD CARRIED BY BRASS + STEEL = TOTAL LOAD

LOAD = σ × AREA

$$\sigma_B \times A_B + \sigma_S A_S = 37.28 \times 10^3$$

$$.45\sigma_S \times .7854 \times (.04^2 - .032^2) + \sigma_S \times .7854 \times .03^2 = 37.28 \times 10^3$$

$$2.0357568 \times 10^{-4} \sigma_S + 7.0686 \times 10^{-4} \sigma = 37.28 \times 10^3$$

$$9.1043568 \times 10^{-4} \sigma_2 = 37.28 \times 10^3$$

$$\sigma_S = 40947428.6$$

$$\sigma_S = \underline{\underline{40.95 \times 10^6 \ N/m^2}}$$

$$\sigma_{B_2} = .45\,\sigma_S$$

$$\sigma_{B_2} = .45 \times 40.95 \times 10^6$$

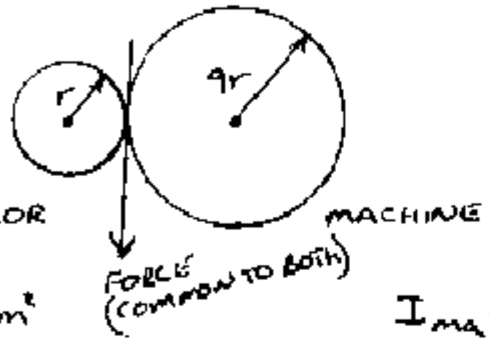
$$\sigma_{B_2} = 18.43 \times 10^6 \ N/m^2$$

$$\sigma_B \text{ TOTAL} = \sigma_{B_1} + \sigma_{B_2}$$

$$\sigma_B = 28.12 \times 10^6 + 18.43 \times 10^6$$

$$\sigma_B = \underline{\underline{46.55 \times 10^6 \ N/m^2}}$$

28



$I_{mo} = .5\ kg\ m^2$ $I_{ma} = 40\ kg\ m^2$

$\omega_{mo} = 9\ \omega_{ma}$

$\alpha_{mo} = 9\ \alpha_{ma}$

$$POWER = \frac{T\omega}{\eta}$$

$$POWER = \frac{100 \times 2\pi \times \frac{160}{60}}{.95}$$

$$POWER = \frac{1676}{.95}$$

$POWER = 1763.7$

$= \underline{1.764}\ kW$

29

$$P_1 - P_2 = \rho g h$$
$$P_1 - P_2 = (13.6 - .85) \times 9.81 \times .2$$
$$P_1 - P_2 = 25.0155 \ kN/m^2$$

$$V_1 a_1 = V_2 a_2$$
$$V_2 = V_1 \frac{a_1}{a_2}$$
$$V_2 = V_1 \times \frac{.7854 \times .1^2}{.7854 \times .03^2}$$
$$V_2 = V_1 \times 11.11$$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$
$$\frac{P_1}{\rho} + \frac{V_1^2}{2} = \frac{P_2}{\rho} + \frac{V_2^2}{2}$$
$$\frac{P_1}{\rho} - \frac{P_2}{\rho} = \frac{V_2^2}{2} - \frac{V_1^2}{2}$$

$$2(P_1 - P_2) = \rho(V_2^2 - V_1^2)$$

$$\frac{2 \times 25.0155}{.85} = (11.11 V_1)^2 - V_1^2$$

$$58.86 = (123.456 - 1) V_1^2$$

$$.48065934 = V_1^2$$
$$.6933 = V_1$$

29 CONT

VOLUME FLOW = $A_1 \times V_1$

= $.7854 \times .1^2 \times .6933$

= 5.4451782×10^{-3} m^3/s

ACTUAL VOLUME FLOW = VOL FLOW × DISCH COEFF

= $5.44 \times 10^{-3} \times .98$

= $5.336274636 \times 10^{-3}$

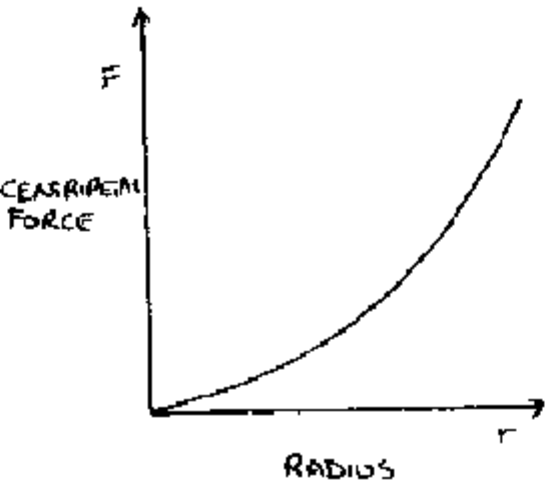
MASS FLOW = VOL FLOW × ρ

= $5.34 \times 10^{-3} \times 850$

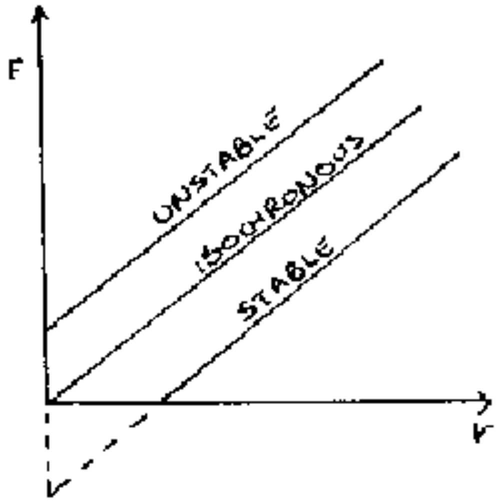
= 4.535833441

= 4.536 kg/m^3

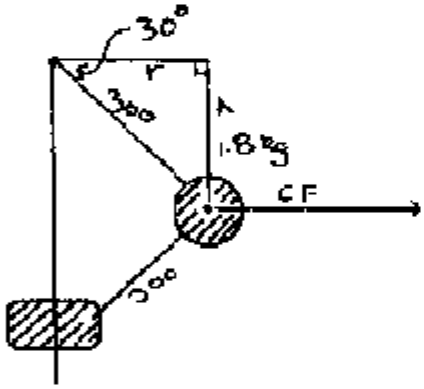
30



PORTER



HARTNELL



$$\omega = 120 \times \frac{2\pi}{60}$$

$$\omega = 12.566 \text{ rad/s}$$

$$h = 300 \cos 30^\circ$$

$$h = 300 \times .866$$

$$h = 259.8 \text{ mm}$$

$$h = .2598 \text{ m}$$

$$h = \frac{g}{\omega^2}\left[\frac{m+M}{m}\right]$$

$$\frac{h\omega^2}{g} = \frac{m+M}{m}$$

$$\frac{h\omega^2 m}{g} = m+M$$

30 cont

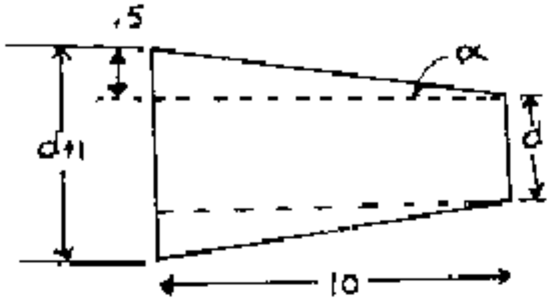
$$\frac{h\omega^2 m}{g} = m + M$$

$$M = \frac{h\omega^2 m}{g} - m$$

$$M = \frac{.2598 \times 12.566^2 \times 1.8}{9.81} - 1.8$$

$$M = \underline{\underline{5.727}} \text{ kg}$$

31



$\tan\alpha = \frac{O}{A}$

$\tan\alpha = \frac{.5}{10}$

$\tan\alpha = .05$

$\tan\phi$ = COEFFICIENT OF FRICTION

$\tan\phi = \mu$

$\tan\phi = .18$

FORCE TO DRIVE IN = $2 \times W \times \tan(\phi + \alpha)$

$$W = \frac{F}{2 \times (\tan\phi + \tan\alpha)}$$

$$W = \frac{500}{2 \times (.18 + .05)}$$

$$W = 1086.956$$

$$W = \underline{\underline{1086.96}}\ N$$

FORCE TO DRIVE OUT = $2 \times W \times \tan(\phi - \alpha)$

$$F = 2 \times 1086.96 \times (.18 - .05)$$

$$F = \underline{\underline{282.6}}\ N$$

32

$$T = \frac{\pi}{16} d^3 \tau \qquad T = WR$$

W = AXIAL LOAD
D = MEAN DIA.
R = MEAN RADIUS
d = dia of coil
τ = STRESS

$$WR = \frac{\pi}{16} \times d^3 \tau$$

$$\tau = \frac{WR}{\frac{\pi}{16} \times d^3} \qquad D = 2R$$

$$R = .5D$$

$$\tau = \frac{WR16}{\pi d^3} \qquad \tau = \frac{W\,.5\,D16}{\pi d^3}$$

$$\tau = \frac{WD8}{\pi d^3}$$

$$\tau = \frac{WD8}{\pi d^3}$$

$$\tau \pi d^3 = WD8$$

$$d^3 = \frac{WD8}{\tau \pi}$$

$$d^3 = \frac{90 \times 8d \times 8}{105 \times 10^6 \times \pi}$$

$$d^3 = 1.7461 \times 10^{-5} d$$

$$d^2 = 1.7461 \times 10^{-5}$$

$$d = \underline{\underline{4.1787\text{ mm}}}$$

33

$$\omega_{(mean)} = \frac{2\pi}{60} \times 1000$$

$$\omega_{(mean)} = 104.72 \text{ rad/s}$$

$$\omega_{(max)} = 104.72 \times 1.015$$
$$= 106.29$$

$$\omega_{(min)} = 104.72 \times (1 - .015)$$
$$= 103.15$$

$$\text{FLUCTUATION} = .9 \times \frac{\text{WORK DONE}}{\text{RPM}}$$

$$\text{FLUCTUATION} = \frac{10 \times 10^3 \times 60}{1000}$$

$$\text{FLUCTUATION} = 540 \text{ J}$$

$$\text{FLUCTUATION} = I\omega \times (\omega_1 - \omega_2)$$

$$I = \frac{\text{FLUCTUATION}}{\omega \times (\omega_1 - \omega_2)}$$

$$I = \frac{540}{104.72 \times (106.29 - 103.15)}$$

$$I = \underline{\underline{1.64}} \text{ kg m}^2$$

34

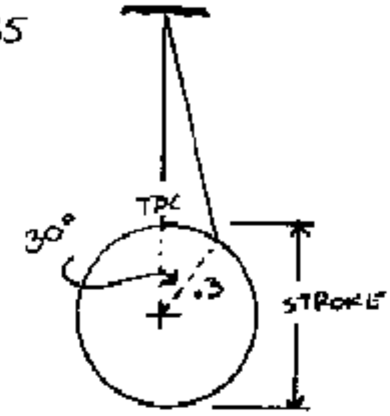
VOLUME FLOW $= \text{AREA} \times \text{VELOCITY}$
$= .7854 \times d^2 \times v$
$= .7854 \times .025^2 \times 28$
$= .0137445 \ m^3/s$

MASS FLOW $= \text{VOLUME FLOW} \times \text{DENSITY}$
$= .0137445 \times 1000$
$= \underline{\underline{13.7445}} \ kg/s$

POWER $= \Delta PE/s$
$= mgh/s$
$= m/s \ g \ h$

$= 13.7445 \times 9.81 \times 30$
$= 4045 \ J/s$
$= \underline{\underline{4045 \ W}}$

35



$\omega = 400 \times \frac{2\pi}{60}$

$\omega = 41.89$ rad/s

PISTON VELOCITY $= \omega r \sin\theta$

$= 41.89 \times .3 \times \sin 30°$

$= \underline{\underline{6.2832}}$ m/s

PISTON ACCELERATION $= \omega^2 r \cos\theta$

$= 41.89^2 \times .3 \times \cos 30°$

$= \underline{\underline{455.8575}}$ m/s²

36)

$$f = \frac{1}{2\pi}\sqrt{\frac{s}{m}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{200}{5}}$$

$$f = \underline{\underline{1.0066}}\ Hz$$

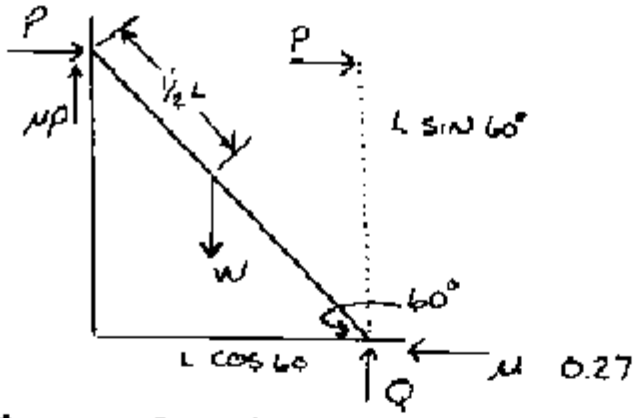
$$f_1 = \frac{1}{2\pi}\sqrt{\frac{s}{m + \frac{m_s}{3}}}$$

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{200}{5 + \frac{.75}{3}}}$$

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{200}{5.25}}$$

$$f_1 = \underline{\underline{.982}}\ Hz$$

37



UP = DOWN

$\mu P + Q = W$

MOMENTS ABOUT FOOT (Q)

$P \times L\sin 60° + \mu P \times L\cos 60° = W \times \frac{1}{2} L\cos 60°$

$P \times \frac{L\sin 60°}{L\cos 60°} + \mu P \times \frac{L\cos 60°}{L\cos 60°} = W \times \frac{1}{2}\frac{L\cos 60°}{L\cos 60°}$

$P \times \frac{\sin 60°}{\cos 60°} + \mu P = \frac{1}{2} W$

$P \times \tan 60° + \mu P = \frac{1}{2} W$

$2P\tan 60° + 2\mu P = W$

$2P\tan 60° + 2\mu P = \mu P + Q$

37 CONT

LEFT = RIGHT

$\mu Q = P$

$.27Q = P$

$Q = \dfrac{P}{.27}$

$Q = 3.7P$

$2P \tan 60° + 2\mu P = \mu P + Q$

$2P \tan 60° + 2\mu P = \mu P + 3.7P$

$2 \tan 60° + 2\mu = \mu + 3.7$

$2\mu - \mu = 3.7 - 2\tan 60°$

$\mu = 3.7 - 2\tan 60°$

$\mu = .2358$

$\mu = \underline{\underline{.24}}$

38

$\mu = .15$

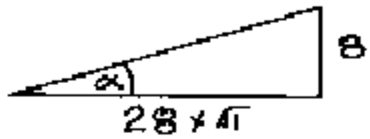
TAN $= .15$

$= 8.53^\circ$

$\sin\alpha = \dfrac{8}{28\pi}$

$\sin\alpha = .09$

$\alpha = 5.21^\circ$



$\text{STRAIN} = \dfrac{\Delta L}{L}$

$\Delta L = 2\ \text{PITCH}$

$= 2 \times .008$

$= .016$

$\varepsilon = \dfrac{.016}{46}$

$\varepsilon = 347.8 \times 10^{-6}$

$\text{STRESS} = E \times \varepsilon$

$\sigma = 140 \times 10^{9} \times 347.8 \times 10^{-6}$

$\sigma = 48.692 \times 10^{6}$

$\text{LOAD} = \sigma \times A$

$= 48.692 \times 10^{6} \times 80 \times 10^{-6} (m^2)$

$= 3895.36$

$\text{MEAN TENSION} = \dfrac{1800 + 3895.36}{2}$

$= 3747.68$

$\text{TORQUE} = 2 \times \dfrac{WD}{2} \times \dfrac{\tan(\phi + \alpha)}{1 - .15 \tan 5.21^\circ}$

38 CONT

$$\text{TORQUE} = \frac{2 \times 3747.68 \times .028}{2} \times \frac{\tan(8.53 + 5.21)}{1 - .15 \tan 5.21}$$

$$T = 104.935 \times \frac{0.2445}{0.9863}$$

$$T = 26.01 \text{ Nm}$$

WORK DONE TO TIGHTEN 1TURN $= 26.01 \times 2\pi$
$= 163.4$ J

WORK DONE TO TO STRETCH ROPE $= 3747.68 \times .016$
$= 59.96$ J

WORK DONE AGAINST FRICTION $= 163.4 - 59.96$
$= 103.44$ J

39

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$$

$$Tr = \tau J$$

$$T = \frac{\tau J}{r} \qquad r = \frac{D}{2}$$

$$T = \frac{2}{D} \times \tau J$$

$$T = \left(\frac{2\tau}{D}\right) \times J \qquad J = \frac{\pi}{32}(D^4 - d^4)$$

$$T = \left(\frac{2\tau}{D}\right) \times \frac{\pi}{32}(D^4 - d^4)$$

$$T = \frac{2\tau\pi}{32D} \times (D^4 - d^4)$$

$$T = \frac{\tau\pi}{16D} \times (D^4 - d^4)$$

$$U = \frac{1}{2}T\theta \qquad \frac{\tau}{r} = \frac{G\theta}{L}$$

$$\theta = \frac{\tau L}{rG}$$

$$U = \frac{\tau\pi}{16D} \times (D^4 - d^4) \times \frac{2\tau L}{DG} \times \frac{1}{2} \qquad \theta = \frac{2\tau L}{DG}$$

39 CONT

$$U = \frac{\tau \pi}{16 D} \times (D^4 - d^4) \times \frac{2 \tau L}{DG} \times \frac{1}{2}$$

$$U = \frac{\tau^2 \pi L}{16 D^2 G} \times (D^4 - d^4)$$

$$U = \frac{\tau^2 \pi L}{16 D^2 G} \times (D^2 - d^2)(D^2 + d^2)$$

$$U = \frac{\tau^2}{4G} \left[\left(\frac{\pi}{4}\right) (D^2 - d^2) L \right] \frac{D^2 + d^2}{D^2}$$

VOLUME OF SHAFT = AREA $\times$ LENGTH

$$= \frac{\pi}{4} \times (D^2 - d^2) \times L$$

$$U = \left[\frac{\tau^2}{4G}\right] \times \left[\frac{D^2 + d^2}{D^2}\right] \times \text{VOLUME OF SHAFT}$$

AREA HOLLOW SHAFT = AREA SOLID SHAFT

$$\frac{\pi}{4} (D^2 - d^2) = \frac{\pi}{4} d_s^2$$

$$D^2 - d^2 = d_s^2$$

$$D^2 - d^2 = (150)^2$$

$$D^2 - d^2 = 22500 \text{ mm}$$

39 CONT

STRAIN ENERGY HOLLOW = STRAIN ENERGY SOLID

$$\frac{\tau^2}{4G}\left(\frac{D^2+d^2}{D^2}\right) \times \text{VOLUME} = 1.2 \times \frac{\tau}{4G} \times \text{VOLUME}$$

$$\left(\frac{D^2+d^2}{D^2}\right) = 1.2$$

$$D^2 + d^2 = 1.2D^2$$

$$D^2 + d^2 = 1.2D^2$$

$$+\ D^2 - d^2 = 22500$$

$$2D^2 = 1.2D^2 + 22500$$

$$2D^2 - 1.2D^2 = 22500$$

$$.8D^2 = 22500$$

$$D^2 = \frac{22500}{.8}$$

$$D^2 = 28125$$

$$D = \underline{\underline{167.7\ mm}}$$

$$D^2 - d^2 = 22500$$

$$28125 - d^2 = 22500$$

$$d^2 = 28125 - 22500$$

$$d^2 = 5625$$

$$d = \underline{\underline{75\ mm}}$$

40)

$P = \rho g H A$

$P = .9 \times 9.81 \times \left(\frac{6}{2} + 5\right) \times 4 \times 6$

$P = \underline{\underline{1695.168}}$ kN

$P = \rho g h A$

$P = .9 \times 9.81 \times (6 + 5) \times 10 \times 4$

$P = \underline{\underline{3884.76}}$ kN

43)

$$\sigma_1 = \frac{P \times d}{2S}$$

$$\sigma_1 = \frac{3500 \times 10^3 \times 1.8}{2 \times .03}$$

$$\sigma_1 = 105 \times 10^6 \ N/m^2$$

$$\sigma_1 = 105 \ MN/m^2$$

SEAM $\sigma_{seam} = \frac{\sigma}{2}$

$$= \frac{105}{2}$$

$$\sigma_s = \underline{\underline{52.5 \ MN}}/m^2$$

$$\sigma_{normal} = \sigma_1 \cos^2\theta + \sigma_s \sin^2\theta$$

$$\sigma_N = 105 \cos^2 34 + 52.5 \sin^2 34$$

$\theta = 90° - 56°$

$\theta = 34°$

$$\sigma_N = \underline{\underline{88.58 \ MPa}}$$

44)

$R_E = 6380$

$R_S = R_E + 650$

$R_S = 6380 + 650$

$R_S = 7030$

$$V = R_E \sqrt{\frac{g}{R_s}}$$

$$V = 6380 \sqrt{\frac{9.81}{7030}}$$

$V = 7535.3487$ m/s

SATELLITE ORBIT $= 2 \times R_s$

$= 2 \times 7030$

$= 14060$ km

CIRCUMFERENCE $= \pi \times D$

$= \pi \times 14060$

$= 44170.7927$ Km

$$V = \frac{D}{t} \qquad t = \frac{D}{V}$$

$$t = \frac{44170.7927 \times 10^3}{7535.3487}$$

$t = 5861.8$ s

$$t = \frac{5861.8}{3600}$$

$t = \underline{\underline{1.628}}$ hours

45)

ENERGY ABSORBED BY CABLE = Δ KINETIC ENERGY

$$\frac{\sigma^2 \times V}{2E} = \frac{mv^2}{2}$$

$$\sigma^2 \times V = mv^2 E$$

$$\sigma^2 = \frac{mv^2 E}{V}$$

$$\sigma^2 = \frac{2000 \times .6^2 \times 200 \times 10^9}{1200 \times 10^{-6} \times 15}$$

$$\sigma^2 = 8 \times 10^{15}$$

$$\sigma = 89.44 \times 10^6 \ N/m^2$$

$$\sigma = \underline{\underline{89.44 \ MN/m^2}}$$

$$E = \frac{\frac{FORCE}{AREA}}{\frac{\Delta L}{L}}$$

$$E = \frac{FORCE \times L}{AREA \times \Delta L}$$

$$E \times AREA \times \Delta L = FORCE \times L$$

$$\Delta L = \frac{FORCE \times L}{E \times AREA} \qquad \frac{FORCE}{AREA} = \sigma$$

$$\Delta L = \frac{89.44 \times 10^6 \times 15}{200 \times 10^9}$$

$$\Delta L = 6.708 \times 10^{-3} \ m$$

$$\Delta L = \underline{\underline{6.7 \ mm}}$$

46)

$$\omega_2 = \omega_1 + \alpha t$$

$$\alpha t = \omega_2 - \omega_1$$

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

$$\alpha = \frac{2\pi\, 2000}{60 \times 10} - \frac{2\pi\, 50}{60 \times 10}$$

$$\alpha = 20.94 - .52$$

$$\alpha = 20.42 \ rad/s^2$$

$$T = I\alpha$$
$$T = mR^2\alpha$$
$$T = 100 \times .8^2 \times 20.42$$
$$T = \underline{\underline{1306.9 \ Nm}}$$

47)

$$P = \frac{4\,T \times \sigma}{d} \times E_{(\text{WELDS})}$$

$$\sigma = \frac{\text{YIELD STRENGTH}}{\text{SAFETY FACTOR}}$$

$$\sigma = \frac{245}{2.5}$$

$$\sigma = 98 \text{ MPa}$$

$$P = \frac{4 \times .018 \times 98 \times 10^3}{25} \times .9$$

$$P = \underline{\underline{254 \text{ kPa}}}$$

48

TIME TO STOP ASCENDING

$V_2 = V_1 - at$

$at = V_1 - V_2$

$t = \frac{V_1 - V_2}{a}$

$t = \frac{5 - 0}{9.81}$

$t = .51$ (TIME UP)

DISTANCE TRAVELLED ASCENDING

$S = \frac{V_1 + V_2}{2} \times t$

$S = \frac{5 + 0}{2} \times .51$

$S = 1.275$

TOTAL DISTANCE TO GROUND = HEIGHT + DISTANCE TRAV

$= 420 + 1.275$

$= 421.275$

TIME TO DECEND FROM MAXIMUM HEIGHT

$S = V_1 t + \frac{1}{2} at^2$

$S = 0 + \frac{1}{2} at^2$

$\frac{1}{2} at^2 = S$

$t^2 = \frac{2S}{a}$

$t^2 = \frac{2 \times 421.275}{9.81}$

$t^2 = 85.8868$

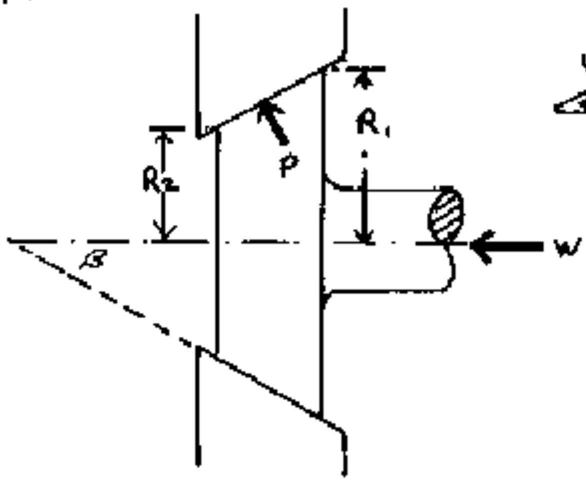
$t = 9.27\,s$ (TIME DOWN)

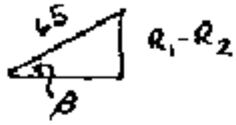
TOTAL TIME = TIME UP + TIME DOWN

$= .51 + 9.27$

$= \underline{\underline{9.78}}\,s$

49





$\beta = \frac{30}{2}$

$\beta = 15°$

$R_1 - R_2 = 65 \sin 15°$

$R_1 - R_2 = 16.82323$ mm

$R_1 = 16.823 + R_2$

$\frac{R_1 + R_2}{2} = 150$

$\frac{16.823 + R_2 + R_2}{2} = 150$

$16.823 + 2R_2 = 150 \times 2$

$2R_2 = 150 \times 2 - 16.823$

$R_2 = 150 - 8.4115$

$R_2 = 141.5885$ mm

$R_1 = 16.823 + R_2$

$R_1 = 16.823 + 141.5885$

$R_1 = 158.4115$ mm

UNIFORM WEAR THEORY

$T = \frac{\mu W R_m}{\sin 15°}$

$W = 2\pi c (R_1 - R_2)$

$c = P \times R_2$

$W = 2\pi \times 70 \times 10^3 \times .1416 \times 16.823$

$W = 1.0477 \times 10^6$

$T = \frac{.3 \times 1.0477 \times 10^6 \times .15}{\sin 15°}$

49 CONT

$$T = \frac{.3 \times 1.0477 \times 10^6 \times 1.5}{\sin 15^\circ}$$

$T = 182163.3$ Nm

$$\text{POWER} = \frac{2 \pi T N}{60}$$

$$= \frac{2 \pi \times 182.16 \times 1200}{60}$$

$= 22891.3$ W

$= \underline{\underline{22.89 \text{ kW}}}$

50

MOMENTS ABOUT PIVOT

$P \times 300 = 1800 \times 400$

$P = \dfrac{1800 \times 400}{300}$

$P = 240\ N$

$R = 240 \sec 15^\circ$

$R = 249\ N$

$R = \operatorname{cosec} 45^\circ \times T$

$T = \dfrac{R}{\operatorname{cosec} 45^\circ}$

$T = \underline{\underline{176\ N}}$ INITIAL BELT TENSION

ANGLE OF LAP DRIVING PULLEY $= 180 + 30$
$= 210^\circ$

$\dfrac{210}{360} = 3.66$ rad

$\dfrac{T_1}{T_2} = e^{\mu\theta}$

$.3 \times 3.66$

$\dfrac{T_1}{T_2} = 2.71828$

$\dfrac{T_1}{T_2} = 3$

$T_1 = T_2 \times 3$

$T_1 = 176 \times 3$

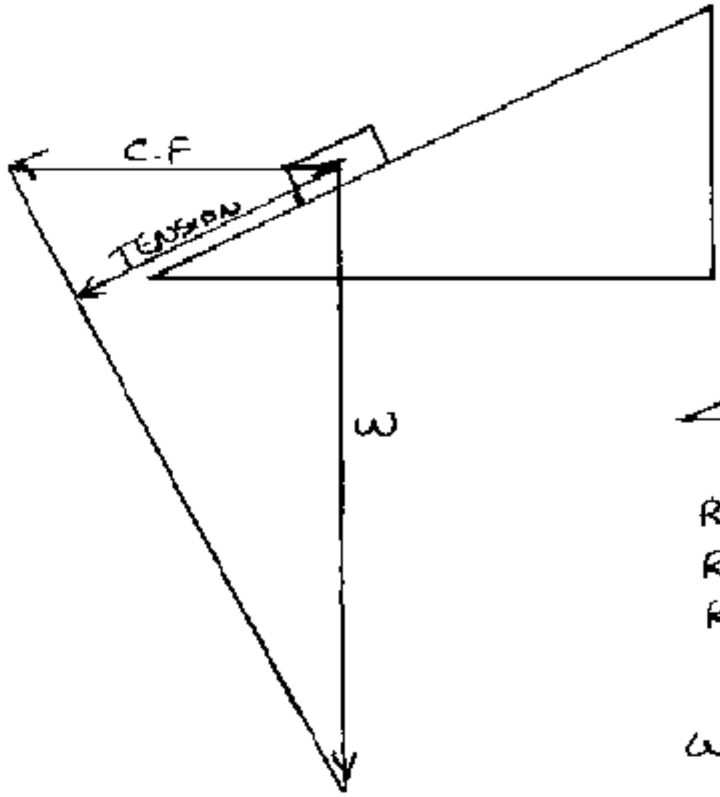
$T_1 = 528\ N$

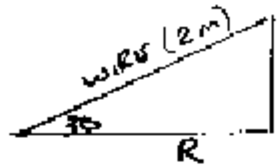
POWER $= (T_1 - T_2)V$ AND $(T_1 - T_2)\,\omega r$

$P = (528 - 176) \times 2\pi \times \dfrac{360}{60} \times .15$

$P = \underline{\underline{1990\ W}}$

51





$R = \text{WIRE} \times \cos 30$

$R = 2 \times \cos 30$

$R = 1.732$

$\omega = 2\pi \times \frac{10}{60}$

$\omega = 1.0472 \text{ rad/s}$

$CF = m\omega^2 r$

$CF = 10 \times (1.0472)^2 \times 1.732$

$CF = 18.99 \text{ N}$

(CF) TENSION $= 18.99 \times \cos 30$

$T_{cf} = 16.445 \text{ N}$

(GRAVITY) TENSION $= 10 \times 9.81 \times \cos 60$

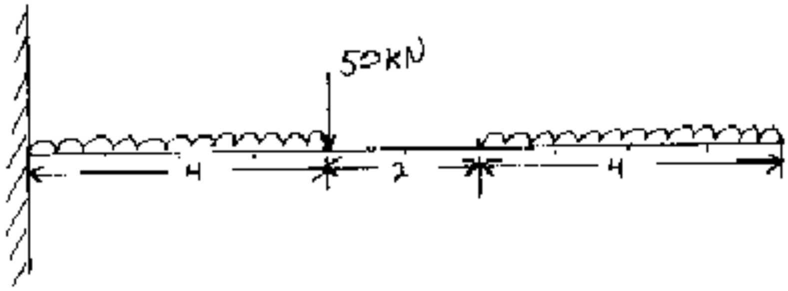
$T_g = 49.05$

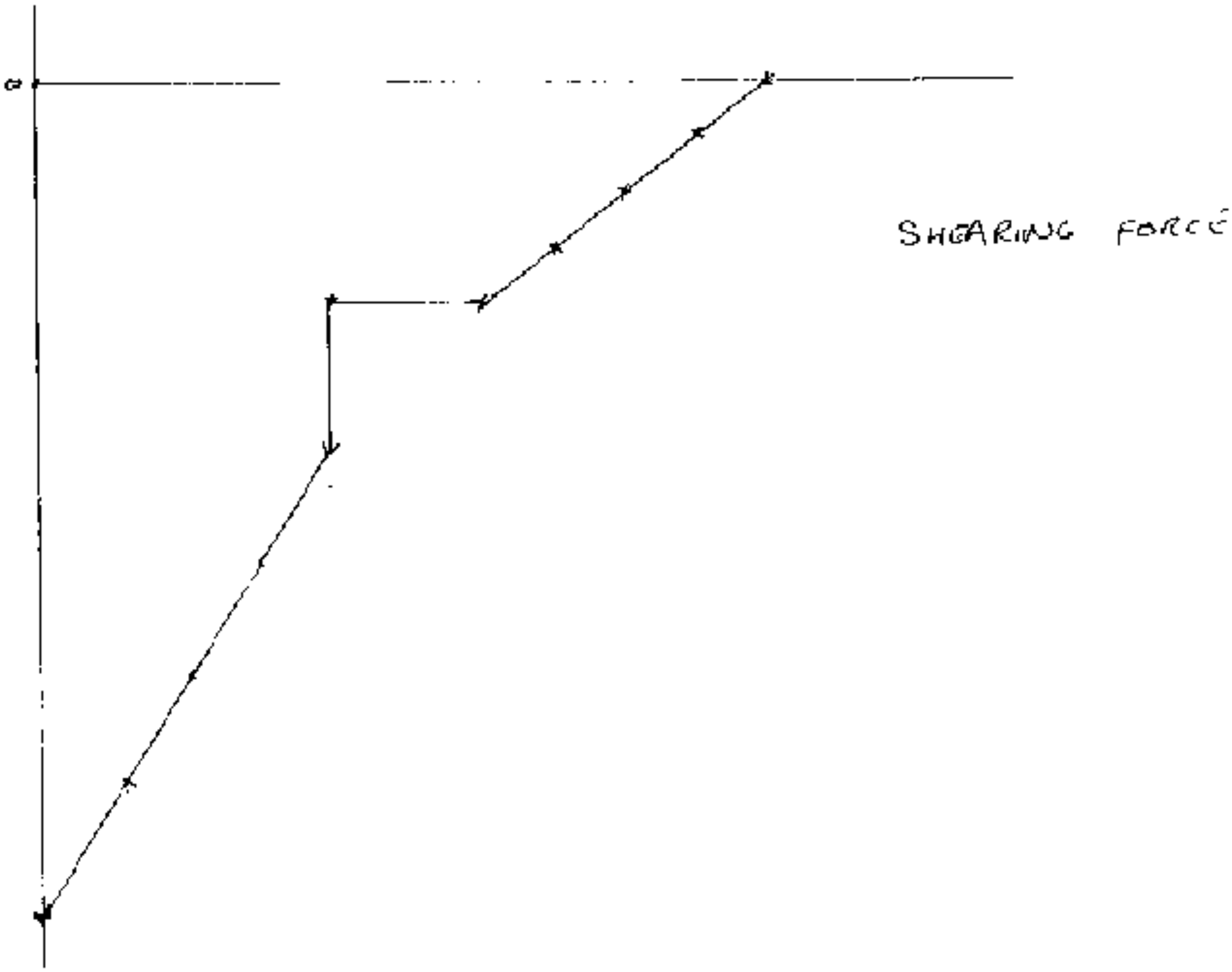
TOTAL TENSION $= T_{CF} + T_G$

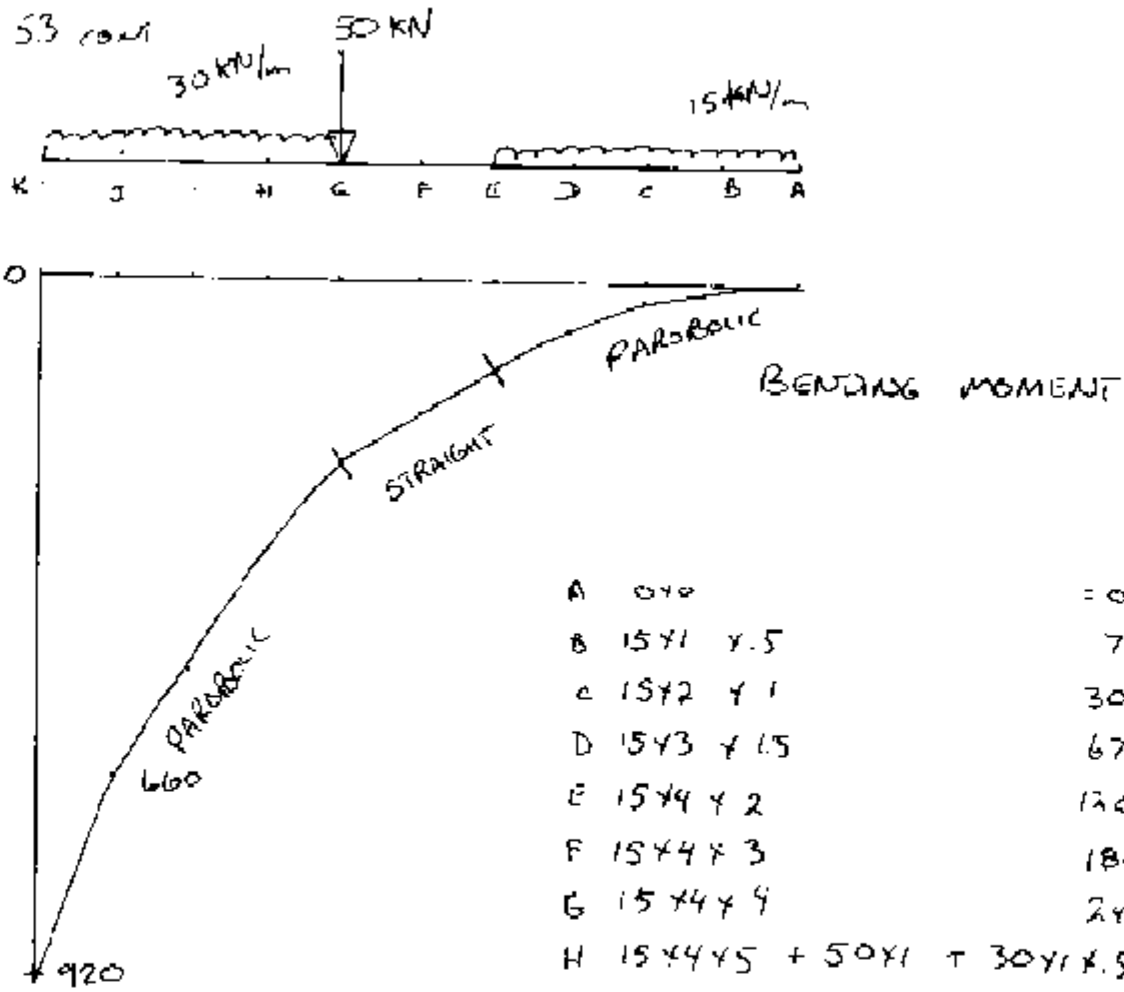
$= 16.445 + 49.05$

$= \underline{\underline{65.49 \text{ N}}}$

53

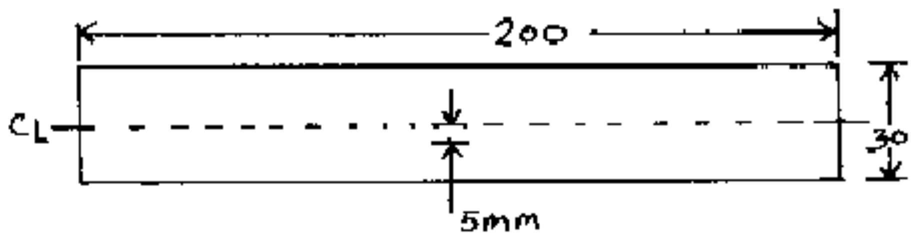






A	0 × 0	= 0
B	15 × 1 × .5	7.5
C	15 × 2 × 1	30.0
D	15 × 3 × 1.5	67.5
E	15 × 4 × 2	120.
F	15 × 4 × 3	180
G	15 × 4 × 4	240
H	15 × 4 × 5 + 50 × 1 + 30 × 1 × .5	= 365
I	15 × 4 × 6 + 50 × 2 + 30 × 2 × 1	= 520
J	15 × 4 × 7 + 50 × 3 + 30 × 3 × 1.5	= 660
K	15 × 4 × 8 + 50 × 4 + 30 × 4 × 2	= 920

54



$$\sigma_D = \frac{\text{FORCE}}{\text{AREA}}$$

$$\sigma_D = \frac{500 \times 10^3}{.2 \times .03}$$

$$\sigma_D = 83.33 \times 10^6 \text{ N/m}^2$$

$$M_{OFFSET} = 500 \times 10^3 \times .005$$

$$M_O = 2500 \text{ Nm}$$

$$\frac{M}{I} = \frac{\sigma_B}{y}$$

$$I\sigma_B = My$$

$$\sigma_B = \frac{M}{I} y$$

$$\sigma_B = \frac{M}{\frac{BD^3}{12}} \times \frac{D}{2}$$

$$\sigma_B = \frac{MD \times 12}{BD^3 \times 2}$$

$$\sigma_B = \frac{6M}{BD^2}$$

$$\sigma_B = \frac{6 \times 2500}{.2 \times .03^2}$$

$$\sigma_B = 83.333 \times 10^6 \text{ N/m}^2$$

54 CONT

MAXIMUM $\sigma = \sigma_B + \sigma_D$

$= (83.333 + 83.333) \times 10^6$

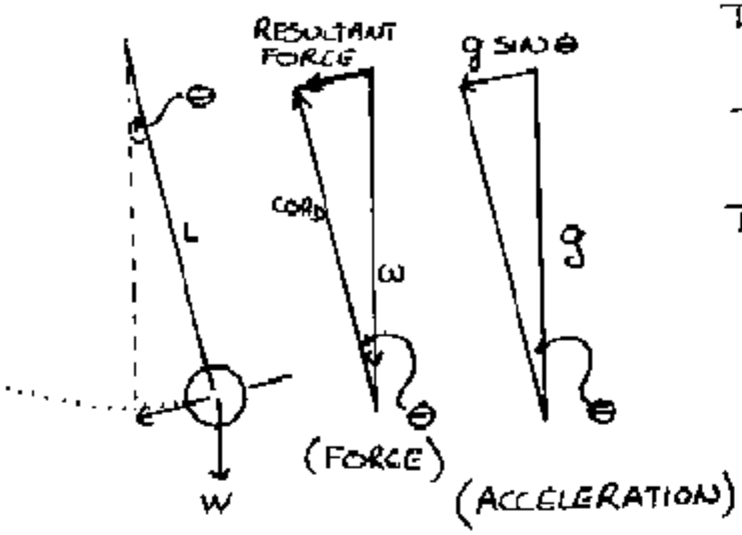
$= \underline{\underline{166.666 \times 10^6}}\ N/m^2$

MINIMUM $\sigma = \sigma_D - \sigma_B$

$= (83.333 - 83.333) \times 10^6$

$= \underline{0\ N/m^2}$

56)



$f = .1\ Hz$

$T = \frac{1}{f}$

$T = \frac{1}{.1}$

$T = 10_s$

$T = 2\pi\sqrt{\frac{L}{g}}$

$\frac{T}{2\pi} = \sqrt{\frac{L}{g}}$

$\left(\frac{T}{2\pi}\right)^2 = \frac{L}{g}$

$\left(\frac{T}{2\pi}\right)^2 \times g = L$

$\left(\frac{10}{2\pi}\right)^2 \times 9.81 = L$

$L = \underline{\underline{24.849\,m}}$

$\alpha = \frac{g}{L} \sin\theta$

$\alpha = \frac{9.81}{24.849} \times \sin 1.5^\circ$

$\alpha = \underline{\underline{.01026\ rad/s^2}}$

57)

$$f = \frac{1}{t}$$

$$t = \frac{1}{f}$$

$$t = \frac{1}{.1}$$

$$t = 10\,s$$

$$t = 2\pi\sqrt{\frac{l}{g}}$$

$$10 = 2\pi\sqrt{\frac{l}{9.81}}$$

$$\frac{10}{2\pi} = \sqrt{\frac{l}{9.81}}$$

$$\left(\frac{5}{\pi}\right)^2 = \frac{l}{9.81}$$

$$\left(\frac{5}{\pi}\right)^2 \times 9.81 = l$$

$$l = \underline{\underline{24.85}}\,m$$

$$a = g \sin\theta$$

$$a = 9.81 \times \sin 1.5^\circ$$

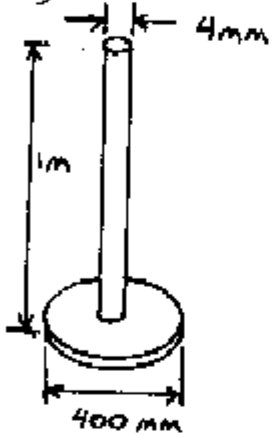
$$a = .2567\,m/s^2$$

$$\alpha = \frac{a}{r}$$

$$\alpha = \frac{.2567}{24.85}$$

$$\alpha = \underline{\underline{.01033}}\,rad/s^2$$

60)



PERIODIC TIME $= \frac{62}{20}$

$T = 3.1\,s$

$I_o = mK^2$

$I_o = 8 \times \frac{.2^2}{2}$

$I_o = .16\ kgm^2$

$J = \frac{\pi}{32} D^4$

$J = \frac{\pi}{32} \times (.004)^4$

PERIODIC TIME $= 2\pi\sqrt{\frac{I_o L}{JG}}$

$$\frac{T}{2\pi} = \sqrt{\frac{I_o L}{JG}}$$

$$\left(\frac{T}{2\pi}\right)^2 = \frac{I_o L}{JG}$$

$$\frac{JG}{I_o L} = \left(\frac{2\pi}{T}\right)^2$$

$$G = \frac{I_o L}{J} \times \left(\frac{2\pi}{T}\right)^2$$

$$G = \frac{.16 \times 1}{\frac{\pi}{32} \times (.004)^4} \times \left(\frac{2\pi}{3.1}\right)^2$$

$$G = 2.615269 \times 10^{10}\ Pa$$

$$G = \underline{\underline{26.15}}\ GPa$$

64)

ACCELERATING

$$S_A = \frac{V_1 + V_2}{2} t$$

$S_A = .5$

$$\frac{2S - V_1}{t} = V_2$$

$$\frac{2 \times .5 - 0}{\frac{1}{60}} = V_2$$

$$V_2 = \underline{\underline{60\ km/h}}$$

CONSTANT SPEED

$$S_C = Vt$$

$$S_C = 60 \times \frac{2}{60}$$

$$S_C = 2$$

DECELERATING

$$S_D = \frac{V_2 + V_1}{2} t$$

$$S_D = \frac{60 + 0}{2} \times \frac{30}{3600}$$

$$S_D = .25$$

TOTAL DISTANCE TRAVELLED $= S_A + S_C + S_D$

$= .5 + 2 + .25$

$S = \underline{\underline{2.75\ km}}$

65)

TIME TO REACH GROUND

$$S = V_1 t + \frac{1}{2} a t^2$$

$$80 = 0 + \frac{1}{2} 9.81 t^2$$

$$80 = 4.905 t^2$$

$$t^2 = \frac{80}{4.905}$$

$$t = \underline{\underline{4.03855}}\ s$$

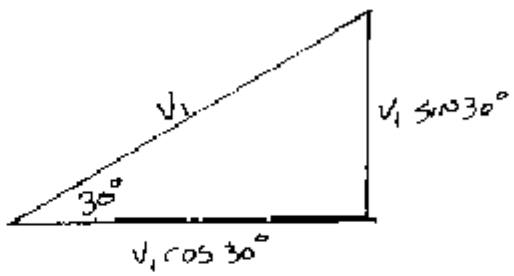
HORIZONTAL DISTANCE

$$S = Vt$$

$$S = 20 \times 4.0385$$

$$S = \underline{\underline{80.77}}\ m$$

66



VERTICAL VELOCITY $= V_1 \sin 30°$

$= 900 \sin 30°$

$= 450 \, m/s$

TIME TO MAX HEIGHT $= \dfrac{450}{9.81}$

$t = 45.87 \, s$

$S = \dfrac{V_1 + V_2}{2} t$

$S = \dfrac{450 + 0}{2} \times 45.87$

$S = \underline{\underline{10321.1 \, m}}$

TIME OF FLIGHT $= 2 \times t$

$= 2 \times 45.87$

$= 91.74 \, s$

HORIZONTAL DISTANCE $= Vt$

$= V_1 \cos 30° \times 91.74$

$= 71506.68 \, m$

$= \underline{\underline{71.5 \, km}}$

67

MOMENTUM BEFORE = MOMENTUM AFTER

$$9.5\times10^3 \times 18 + 5\times10^3\times -10.8 = (9.5+5)\times10^3\times V$$
$$9.5\times18 + 5\times -10.8 = (9.5+5)\,V$$
$$171 - 54 = 14.5V$$
$$117 = 14.5V$$
$$V = \frac{117}{14.5}$$
$$V = \underline{8.069\ km/h} \quad \text{IN DIRECTION OF LARGER MASS}$$

BEFORE IMPACT

$$\frac{1}{2}\times\left(\frac{18\times10^3}{3600}\right)^2\times 9.5\times10^3 + \frac{1}{2}\,5\times10^3\times\left(\frac{10.8\times10^3}{3600}\right)^2$$

$$KE = 118750 + 22500$$
$$= 141250\ J$$
$$= 141.25\ kJ$$

AFTER IMPACT

$$\frac{1}{2}\times\ 9.5\times10^3\times\left(\frac{8.069\times10^3}{3600}\right)^2 + \frac{1}{2}\ 5\times10^3\times\left(\frac{8.069\times10^3}{3600}\right)^2$$
$$KE = \frac{1}{2}\times\left(\frac{8.069\times10^3}{3600}\right)^2\times\left(9.5\times10^3 + 5\times10^3\right)$$
$$KE = 36422.7$$
$$= 36.4\ kJ$$

$$\text{LOSS OF KE} = 141.25 - 36.4$$
$$= \underline{104.85\ kJ}$$

68

$$V_2^2 = V_1^2 + 2as$$

$$2as = V_2^2 - V_1^2$$

$$s = \frac{V_2^2 - V_1^2}{2a}$$

$$s = \frac{2^2 - 0^2}{2 \times .1 \times 9.81}$$

$$s = \underline{\underline{2.0387\,m}}$$

$$G_{(RATIO)} = \frac{r_D}{r_g} = \frac{1}{12}$$

SYSTEM EQUIVALENT

$$I_S = I_{MOTOR} + I_{DRUM} + I_{CAGE} + I_{BALANCE}$$

$$I_S = I_m + \frac{1}{G^2} I_D + \frac{1}{G^2} m_c r_D^2 + \frac{1}{G^2} m_B r_D^2$$

$$I_S = (300 \times .12^2) + \left(\frac{1}{12^2} \times 2000 \times .18^2\right) + \left(\frac{1}{12^2} \times 1800 \times .15^2\right) + \frac{1}{12^2} \times 1000 \times .15^2$$

$$I_S = 5.2075\ kg\,m^2$$

70

$$T = \mu \omega r^2 \left(\frac{\cos\theta_1 - \cos\theta_2}{\sin\theta_m} \right) (P_m + P'_m)$$

$\theta_1 = 10°$
$\theta_2 = 130°$

$\theta_m = 90°$ IF θ_2 GREATER THAN $90°$
$\theta_m = \theta_2$ IF θ_2 LESS THAN $90°$

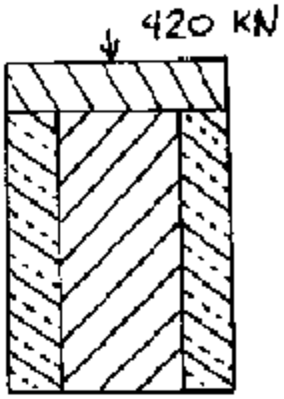
$$T = \mu \omega r^2 \left[\frac{\cos 10° - \cos 130°}{\sin 90°} \right] \times (1520 + 480)$$

$$T = .3 \times .05 \times .15^2 \times \left[\frac{.984 - (-.642)}{1} \right] \times 2000$$

$$T = 3.375 \times 10^{-4} \times 1.6276 \times 2000$$

$$T = \underline{\underline{1.09863}} \text{ kNm}$$

71



$$STRAIN_{(STEEL)} = STRAIN_{(BRASS)}$$

$$\frac{STRESS_{(STEEL)}}{E_{(STEEL)}} = \frac{STRESS_{(BRASS)}}{E_{(BRASS)}}$$

$$\sigma_{(STEEL)} = \sigma_{(BRASS)} \times \frac{E_{(STEEL)}}{E_{BRASS}}$$

$$\sigma_{(STEEL)} = \sigma_{(BRASS)} \times \frac{207 \times 10^9}{92 \times 10^9}$$

$$\sigma_S = \sigma_B \times 2.25$$

$$TOTAL\ LOAD = LOAD_{(STEEL)} + LOAD_{(BRASS)}$$

$$420 \times 10^3 = (\sigma_S \times A_S) + (\sigma_B \times A_B)$$

$$420 \times 10^3 = (\sigma_S \times 2580 \times 10^{-6}) + (\sigma_B \times 3225 \times 10^{-6})$$

$$420 \times 10^3 = (2.25\sigma_B \times 2580 \times 10^{-6}) + (\sigma_B \times 3225 \times 10^{-6})$$

$$420 \times 10^3 = 5.805 \times 10^{-3}\sigma_B + 3.225 \times 10^{-3}\sigma_B$$

$$420 \times 10^3 = 9.03 \times 10^{-3}\sigma_B$$

$$46511627.9 = \sigma_B \qquad \sigma_B = \underline{\underline{46.51\ MN/m^2}}$$

$$\sigma_S = \sigma_B \times 2.25$$

$$\sigma_S = 46.51 \times 2.25$$

$$\sigma_S = 104651162.8 \qquad \sigma_S = \underline{\underline{104.65\ MN/m^2}}$$

72

$$AREA_{(BRASS)} = .7854 \times (D^2 - d^2)$$
$$= .7854 \times (40^2 - 32^2)$$
$$= 452.39 \ mm^2$$

$$AREA_{(STEEL)} = .7854 \times D^2$$
$$= .7854 \times 30^2$$
$$= 706.86 \ mm^2$$

FORCE TO COMPRESS BRASS TUBE TO STEEL LENGTH

$$F_{B_1} = \frac{A E \Delta L}{L}$$

$$F_{B_1} = \frac{452.39 \times 10^{-6} \times 90 \times 10^{9} \times .125 \times 10^{-3}}{400.125 \times 10^{-3}}$$

$$F_{B_1} = 12719.49391 \ N \qquad F_B = 12.72 \ kN$$

FORCE RESISTED BY STEEL BAR = 50 - F_B

$$F_R = 50 - 12.72$$
$$= 37.28 \ kN$$

$$E = \frac{\frac{FORCE}{AREA}}{\frac{\Delta L}{L}}$$

$$\frac{\Delta L}{L} \times E = \frac{FORCE}{AREA}$$

$$\Delta L = \frac{FORCE \times L}{AREA \times E}$$

$$\Delta L_B = \Delta L_S$$

72 CONT

$$\Delta L = \frac{FORCE \times L}{AREA \times E}$$

$$\Delta L_B = \frac{F_{B_2} \times L}{A_B \times E_B} \qquad \Delta L_S = \frac{F_S \times L}{A_S \times E_S}$$

$$\frac{F_{B_2} \times L}{A_B \times E_B} = \frac{F_S \times L}{A_S \times E_S}$$

$$F_{B_2} = \frac{F_S \times L}{A_S \times E_S} \times \frac{A_B \times E_B}{L}$$

$$F_{B_2} = \frac{F_S \times A_B \times E_B}{A_S \times E_S}$$

$$\text{TOTAL FORCE} = F_{B_2} + F_S$$

$$F_T = \left[\frac{F_S \times A_B \times E_B}{A_S \times E_S}\right] + F_S$$

$$F_T = \left[\frac{A_B \times E_B}{A_S \times E_S} + 1\right] \times F_S$$

$$F_S = \frac{F_T}{\left[\frac{A_B \times E_B}{A_S \times E_S}\right]}$$

$$F_S = \frac{37280}{\frac{(452.39 \times 10^{-6}) \times (90 \times 10^{9})}{(706.86 \times 10^{-6}) \times (200 \times 10^{9})}}$$

72 CONT

$F_S = 28944\ N$
$F_S = 28.944\ kN$

$F_{B_2} = F_T - F_S$
$F_{B_2} = 37.28 - 28.944$
$F_{B_2} = 8.336\ kN$

TOTAL FORCE TO COMPRESS BRASS $= F_{B_1} + F_{B_2}$
$= 12.72 + 8.336$
$= 21.056\ kN$

$\sigma_B = \dfrac{LOAD}{AREA}$

$\sigma_B = \dfrac{21.056 \times 10^3}{452.39 \times 10^{-6}}$

$\sigma_B = 46543911\ N/m^2$

$\sigma_B = \underline{\underline{46.544\ MN/m^2}}$

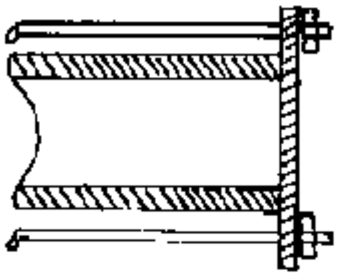
$\sigma_S = \dfrac{LOAD}{AREA}$

$\sigma_S = \dfrac{28.944 \times 10^3}{706.86 \times 10^{-6}}$

$\sigma_S = 40947288$

$\sigma_S = \underline{\underline{40.947\ MN/m^2}}$

73



STRESS IN CYLINDER DUE TO TIGHTENING

AREA OF CYLINDER

$A_c = .7854 \times (D^2 - d^2)$

$A_c = .7854 \times (90^2 - 70^2)$

$A_c = 2.51328 \times 10^3 mm^2$

AREA OF BOLTS

$A_B = 4 \times .7854 \times (D^2)$

$A_B = 4 \times .7854 \times 12^2$

$A_B = 452.3904\ mm^2$

$A_B = 452.39 \times 10^{-6} m^2$

$\sigma_{c_1} \times A_c = \sigma_B \times A_B$

$\sigma_{c_1} = \dfrac{\sigma_B \times A_B}{A_c}$

$\sigma_{c_1} = \dfrac{30 \times 10^6 \times 452.4 \times 10^{-6}}{2513.28 \times 10^{-6}}$

$\sigma_{c_1} = 5400114.591\ N/m^2$

$\sigma_{c_1} = 5.4\ MN/m^2$ (COMPRESSIVE)

$\sigma_{B_1} = 30\ MN/m^2$ (TENSILE)

AREA OF ENDPLATE $= .7854\ D^2$

$= .7854 \times 70^2$

$= 3848.46\ mm^2$

$= 3848.46 \times 10^{-6} m^2$

73 CONT

LOAD ON BOLTS = LOAD ON CYLINDER

$$\sigma_B A_B = \sigma_c A_c + P_c A_c$$

$$\sigma_B = \frac{\sigma_c A_c + P_c A_c}{A_B}$$

$$\sigma_B = \frac{(\sigma_c \times 2513.3 \times 10^{-6}) + (3 \times 10^{6} \times 3849 \times 10^{-6})}{452.4 \times 10^{-6}}$$

$$\sigma_B = 5.555\,\sigma_c + 25.524 \times 10^{6}$$

ΔL IS COMMON TO BOLTS AND CYLINDER

ΔL CYLINDER = COMPRESSION BY BOLTS − EXPANSION BY PRESS

$$\Delta L_c = \Delta L_{cc} - \Delta L_{cE}$$

ΔL BOLTS = RESULTANT BY PRESSURE − INITIAL BY TENSION

$$\Delta L_B = \Delta L_{BP} - \Delta L_{BT}$$

$$\Delta L_c = \Delta L_B$$

$$\Delta L_{cc} - \Delta L_{cE} = \Delta L_{BP} - \Delta L_{BT}$$

$$\frac{\sigma_{cc} L_c}{E} - \frac{\sigma_{cE} L_c}{E} = \frac{\sigma_{BP} L_B}{E} - \frac{\sigma_{BT} L_B}{E}$$

$$\sigma_{cc} L_c - \sigma_{cE} L_c = \sigma_{BP} L_B - \sigma_{BT} L_B$$

$$L_c(\sigma_{cc} - \sigma_{cE}) = L_B(\sigma_{BP} - \sigma_{BT})$$

$$L_B = 1.1\,L_c$$

$$L_c(\sigma_{cc} - \sigma_{cE}) = 1.1\,L_c(\sigma_{BP} - \sigma_{BT})$$

$$\sigma_{cc} - \sigma_{cE} = 1.1(\sigma_{BP} - \sigma_{BT})$$

$$5.4 \times 10^{6} - \sigma_{cE} = 1.1(\sigma_{BP} - 30 \times 10^{6})$$

$$\sigma_{cE} = 5.4 \times 10^{6} - 1.1(\sigma_{BP} - 30 \times 10^{6})$$

$$\sigma_{cE} = 5.4 \times 10^{6} + 33 \times 10^{6} - 1.1_{BP}$$

$$\sigma_{cE} = 38.4 \times 10^{6} - 1.1\,\sigma_{BP}$$

73 CONT

$$\sigma_B = 5.555\sigma_C + 25.524\times10^6$$
$$\sigma_B = 5.555\times(38.4\times10^6 - 1.1\sigma_B) + 25.524\times10^6$$
$$\sigma_B = 213.32\times10^6 - 6.1105\sigma_B + 25.524\times10^6$$
$$\sigma_B + 6.1105\sigma_B = 213.32\times10^6 + 25.524\times10^6$$
$$7.1105\sigma_B = 238.844\times10^6$$
$$\sigma_B = 33590324.17$$
$$\sigma_B = \underline{\underline{33.6\ MPa}}\ \text{(TENSILE)}$$

$$\sigma_C = 38.4\times10^6 - 1.1\sigma_B$$
$$\sigma_C = 38.4\times10^6 - 1.1\times33.6\times10^6$$
$$\sigma_C = 1440000$$
$$\sigma_C = \underline{\underline{1.44\ MPa}}\ \text{COMPRESSIVE}$$

74 DIRECT

$$STRESS = \frac{LOAD}{AREA}$$

$$\sigma_D = \frac{400 \times 10^3}{.7854 \times (.25^2 - .02^2)}$$

$$\sigma_D = 22.63 \times 10^6\ N/m^2$$

$$\sigma_D = 22.63\ MN/m^2$$

BENDING

$$\frac{M}{I} = \frac{\sigma_B}{y}$$

$$\sigma_B I = My$$

$$\sigma_B = \frac{My}{I}$$

$$\sigma_B = \frac{400 \times .02 \times \frac{.25}{2}}{\frac{\pi}{64} \times \left[(.025)^4 - (0.2)^4\right]}$$

$$M = F \times d$$

$$M = 400 \times .02$$

$$y = \frac{D}{2}$$

$$I = \frac{\pi}{64}(D^4 - d^4)$$

$$\sigma = 8,833 \times 10^6\ N/m^2$$

$$\sigma = 8.833\ MN/m^2$$

MAXIMUM $\sigma = \sigma_B + \sigma_D$

$\sigma = 8.833 + 22.63$

$\sigma = \underline{\underline{31.463\ MN/m^2}}$

MINIMUM $\sigma = \sigma_D - \sigma_B$

$\sigma = 22.63 - 8.833$

$\sigma = \underline{\underline{13.797}}\ MN/m^2$

74 CONT

"MINIMUM STRESS = 0"

$$\sigma_D - \sigma_B = 0$$

$$\sigma_B = \sigma_D$$

$$\sigma_B = 22.63\ MN/m^2$$

$$M = \frac{I\sigma}{y}$$

$$400 \times 10^3 \times S = \frac{\frac{\pi}{64}(D^4 - d^4) \times 22.63 \times 10^6}{\frac{.25}{2}}$$

$$S = \frac{\pi \times .25^4 - .2^4 \times 22.63 \times 10^6 \times 2}{64 \times 400 \times 10^3 \times .25}$$

$$S = .05124\ m$$

$$S = \underline{\underline{51.24\ mm}}$$

75

DIRECT COMPRESSIVE STRESS = $\frac{\text{LOAD}}{\text{AREA}}$

$$\sigma_c = \frac{500 \times 10^3}{.7854(.3^2 - .25^2)}$$

$$\sigma_c = 23148000 \text{ N/m}^2$$

$$\sigma_c = 23.15 \text{ MN/m}^2$$

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\sigma I = My$$

$$\sigma = \frac{My}{I}$$

$$M = F \times d$$

$$M = 500 \times .025$$

$$y = \frac{D}{2} = \frac{.3}{2}$$

$$I = \frac{\pi}{64}(D^4 - d^4)$$

$$I = \frac{\pi}{64}(.3^4 - .25^4)$$

$$\sigma_B = \frac{500 \times .025 \times \frac{.3}{2}}{\frac{\pi}{64} \times (.3^4 - .25^4)}$$

$$\sigma_B = \frac{500 \times .025 \times .3 \times 64}{\pi \times (.3^4 - .25^4) \times 2}$$

$$\sigma_B = 9108.12 \text{ kN/m}^2$$

$$\sigma_B = 9.1 \text{ MN/m}^2$$

MAXIMUM $\sigma = \sigma_c + \sigma_B$

$$\sigma = 23.15 + 9.1$$

$$\sigma = \underline{\underline{32.25 \text{ MN/m}^2}}$$

MINIMUM $\sigma = \sigma_c - \sigma_B$

$$\sigma = 23.15 - 9.1$$

$$\sigma = \underline{\underline{14.05 \text{ MN/m}^2}}$$

75 cont

MAXIMUM ECCENTRIC LOADING $\sigma - \sigma_B = 0$

$\sigma_C = \sigma_B$

$\sigma_B = 23.15\ MN/m^2$

$$M = \frac{I\sigma}{y}$$

$$500 \times 10^3 \times S = \frac{\frac{\pi}{64} \times (.3^4 - .25^4) \times 23.15 \times 10^6}{\frac{.3}{2}}$$

$$500 \times 10^3 \times S = \frac{\pi \times (.3^4 - .25^4) \times 23.15 \times 10^6 \times 2}{64 \times .3}$$

$$S = \frac{\pi \times (.3^4 - .25^4) \times 23.15 \times 10^6 \times 2}{500 \times 10^3 \times 64 \times .3}$$

$S = .063542\ m$

$S = \underline{\underline{63.542\ mm}}$

76

FORCE TO RUPTURE STAY

TENSILE STRENGTH X (STAY AREA − COTTER AREA)

$F_s = 460 \times 10^6 \times (.7854 \times .15^2 - .15 \times T)$

FORCE TO SHEAR COTTER

SHEAR STRENGTH X COTTER AREA X SHEAR FACTOR

$F_c = 340 \times 10^6 \times 6T \times 1T \times 1.8$

$F_c = F_s$

$340 \times 10^6 \times 6T \times T \times 1.8 = 460 \times 10^6 \times (.7854 \times .15^2 - .15 \times T)$

$3672 \times 10^6 T^2 = 8.1289 \times 10^6 - 69 \times 10^6 T$

$3672 T^2 = 8.1289 - 69T$

$53.22T^2 + T - .1178 = 0$

$a = 53.22$

$b = 1$

$c = -.1178$

$$T = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$T = \frac{-1 \pm \sqrt{1^2 - 4 \times 53.22 \times (-.1178)}}{2 \times 53.22}$$

$$T = \frac{-1 \pm \sqrt{1 - (-25.077)}}{106.44}$$

$$T = \frac{-1 \pm 5.1065}{106.44}$$

$$T = \frac{4.1065}{106.44}$$

$T = .03858\ m$

76 cont

$T = .03858$

$T = \underline{\underline{38.58}}\ mm$

$D = 6T$

$D = 6 \times 38.58$

$D = \underline{\underline{231.48}}\ mm$

FORCE ON STAY = FORCE ON COTTER

$460 \times 10^6 \times .7854 \times d^2 = 340 \times 10^6 \times 38.58 \times 231.48 \times 1.8$

$361.284 \times 10^6\ d^2 = 5.465 \times 10^{12}$

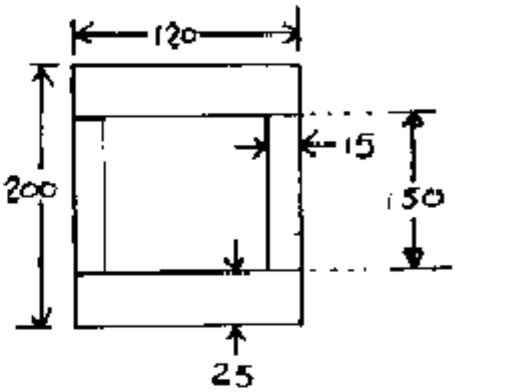
$d^2 = \dfrac{5.465 \times 10^{12}}{361.284 \times 10^6}$

$d^2 = 15.12789$

$d = 122.99$

$d = \underline{\underline{123\ mm}}$

77)



VOLUME $= (.2 \times .12) - (.15 \times .09) \times 3$

$V = .0315\ m^3$

MASS $= \rho \times V$

$= 7.86 \times 10^3 \times .0315$

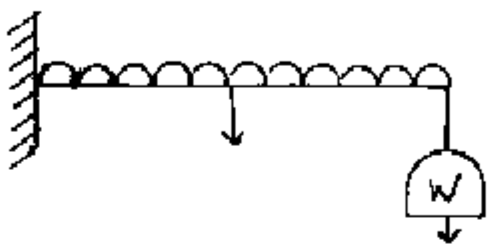
$= 247.59\ kg$

FORCE $= ma$

$= 247.59 \times 9.81$

$= 2428.8\ N$

$= 2.429\ kN$



$$\frac{M}{I} = \frac{\sigma}{y}$$

$$My = I\sigma$$

$$M = \frac{I}{y} \times \sigma \qquad \frac{I}{y} = \frac{BD^3 - bd^3}{6D}$$

$$2.429 \times 1.5 + W \times 3 = \frac{(.12 \times .2^3) - (.09 \times .15^3)}{6 \times .2} \times 45000$$

$$3.6435 + 3W = 24609375$$

$$3w = 24.6094 - 3.6435$$

$$3w = 20.965875$$

$$w = \frac{6.988}{9.81}\ kN \times 10^3$$

$$w = \underline{\underline{712.4}}\ kg$$

83

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$$

$$\frac{G\theta}{L} = \frac{\tau}{r}$$

$$\theta = \frac{\tau L}{r G}$$

$$\theta_{SHAFT} = \theta_{LINER}$$

$$\frac{\tau L}{r G} = \frac{\tau L}{r G}$$ LENGTHS SAME

$$\frac{\tau_s}{r_s G_s} = \frac{\tau_L}{r_L G_L}$$

$$\tau_s r_L G_L = \tau_L r_s G_s$$

$$\frac{\tau_s}{\tau_L} = \frac{r_s G_s}{r_L G_L}$$

$$\frac{\tau_s}{\tau_L} = \frac{.12 \times 90}{.145 \times 42}$$

$$\frac{\tau_s}{\tau_L} = 1.773$$

ratio = 1.773 : 1

B3 CONT

SHAFT $\frac{T}{J} = \frac{\tau}{r}$

$Tr = \tau J$

$T_s = \frac{\tau J}{r}$

$$T_s = \frac{\frac{\pi}{32} D^4 \times \tau}{.5 D}$$

$$T_s = \frac{\pi}{16} D^3 \tau$$

$$T_s = \frac{\pi}{16} \times .24^3 \times \tau$$

$$T_s = .002714\, \tau_s$$

FOR LINER $J = \frac{\pi}{32}(D^4 - d^4)$

$$T = \frac{J\tau}{r}$$

$$T = \frac{\pi}{32} \frac{(D^4 - d^4)\tau}{.5D}$$

$$T = \frac{\pi \times (.29^4 - .24^4) \times \tau}{16 \times .29}$$

$$T_s = .002543\, \tau_L$$

TOTAL TORQUE = $T_L + T_S$

$$160 \times 10^3 = .002714\, \tau_L + .002543\, \tau_L$$

83 cont

$100 \times 10^3 = .002714\,\tau_L + .002543\,\tau_L$

$$\left[\tau_S = 1.773\,\tau_L\right]$$

$.002714\,\tau_L + .002543(1.773\,\tau_L) = 100 \times 10^3$

$.007355\,\tau_L = 10^5$

$\tau_L = \underline{\underline{13.59 \times 10^6}}\ N/m^2$

$\tau_S = 1.773\,\tau_L$

$\tau_S = 1.773 \times 13.59 \times 10^6$

$\tau_S = \underline{\underline{24.11 \times 10^6}}\ N/m^2$

$$\theta = \frac{\tau L}{rG}$$

$$\theta = \frac{24.11 \times 10^6 \times 4}{.12 \times 90 \times 10^9} \times \frac{360}{2\pi}$$

$\underline{\underline{\theta = .5118^\circ}}$

84

$$\frac{1}{2}\rho_A v^2 = \rho g h_L$$

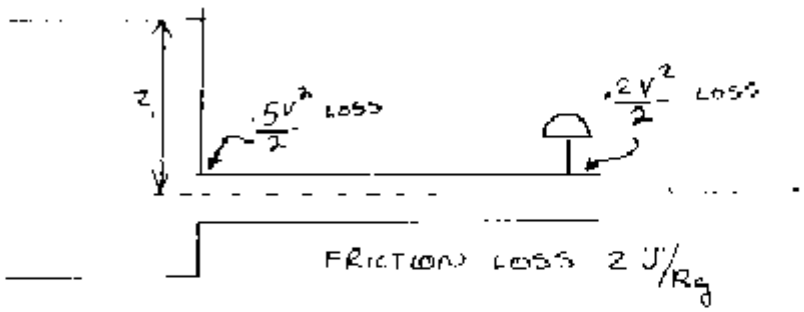
$$v^2 = \frac{\rho g h_L}{.5\,\rho_A}$$

$$v^2 = \frac{1 \times 9.81 \times .2}{.5 \times 1.3 \times 10^{-3}}$$

$$v^2 = 3018.46$$

$$v = \underline{\underline{54.94}}\ m/s$$

85



$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gZ_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + \frac{0.5V^2}{2} + \frac{.2V^2}{2} + 2 + gZ_2$$

$$0 + 0 + 9.81 \times 10 = 0 + \frac{1.7V^2}{2} + 2 + 0$$

$$98.1 = \frac{1.7V^2}{2} + 2$$

$$\frac{1.7V^2}{2} = 98.1 - 2$$

$$1.7V^2 = 2(98.1 - 2)$$

$$V^2 = \frac{2(98.1 - 2)}{1.7}$$

$$V^2 = 113.0588$$

$$V = 10.633 \text{ m/s}$$

$$\dot{m} = \rho V A$$

$$\dot{m} = .8 \times 1000 \times 10.633 \times .7854 \times .05^2$$

$$\dot{m} = \underline{16.702} \text{ Kg/s}$$

36)

$Q = \rho V A$

$Q = 1000 \times V \times .7854 \times .055^2$

$Q = 2.376\, V$ kg/s

$F = ma$

$F = m \dfrac{V}{t}$

$300 = 2.376\, V \times \dfrac{V}{1}$

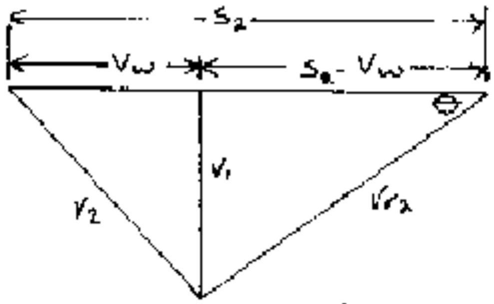
$300 = 2.376\, V^2$

$\dfrac{300}{2.376} = V^2$

$V^2 = 126.262$

$\underline{V = 11.24}$ m/s

87



$V_1 = 2.4\ m/s$

$(S_2 - V_w) \times \tan(180-150) = V_1$

$(S_2 - V_w) \times \tan 30 = 2.4$

$S_2 - V_w = \dfrac{2.4}{\tan 30}$

$S_2 - V_w = 4.157\ m/s$

$S_2 = \pi D N$

$S_2 = \pi \times .355 \times \dfrac{1000}{60}$

$S_2 = 18.5877\ m/s$

$V_w = S_2 - (S_2 - V_w)$

$V_w = 18.5877 - 4.157$

$V_w = 14.43\ m/s$

$H_T = \dfrac{V_w S_2}{g}$

$H_T = \dfrac{14.43 \times 18.5877}{9.81}$

$H_T = 27.3415\ m$

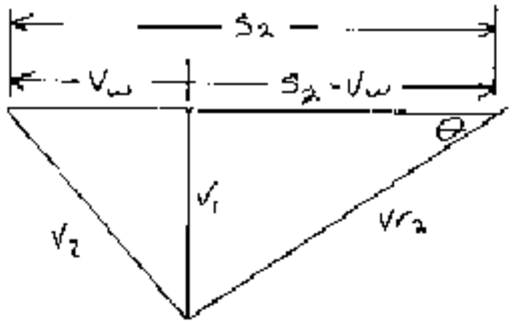
$\text{Pump}\ \eta = \dfrac{\text{ACTUAL}}{\text{THEORETICAL}}$

$\text{Pump}\ \eta = \dfrac{21.7}{27.3415}$

$\eta = .7936$

$\eta = \underline{\underline{79.36\%}}$

38



$S_2 = \text{CIRCUMFERENCE} \times \frac{\text{REV}}{\text{SEC}}$

$S_2 = \pi \times .45 \times \frac{500}{60}$

$S_2 = 11.781 \, m/s$

$\tan\theta = \frac{V_1}{S_2 - V_w}$

$S_2 - V_w = \frac{V_1}{\tan\theta}$

$S_2 - V_w = \frac{2.004}{\tan 45}$

$S_2 - V_w = 2.004$

$V_w = S_2 - (S_2 - V_w)$

$V_w = 11.781 - 2.004$

$V_w = 9.777 \, m/s$

$H_T = \frac{V_w S_2}{g}$

$H_T = \frac{9.777 \times 11.781}{9.81}$

$H_T = 11.74 \, m$

$\text{MANO } \eta = \frac{\text{ACTUAL}}{\text{THEORETICAL}}$

$\eta = \frac{8}{11.74}$

$\eta = .681$

$\eta = 68.1\%$

89

$$V = C_V \times V$$
$$= .97 \times \sqrt{2gh}$$
$$= .97 \times \sqrt{2 \times 9.81 \times 10}$$
$$= \underline{\underline{13.587}}\ m/s$$

$$A = C_A \times A$$
$$= .64 \times .7854 \times 20^2$$
$$= 201\ mm^2$$

$$\dot{V} = A \times V$$
$$= 201 \times 10^{-6} \times 13.587 \times 3600$$
$$= 9.83\ m^3/h$$

$$\dot{m} = \dot{V} \times \rho$$
$$= 9.83 \times 1$$
$$= \underline{\underline{9.83\ tonnes}}/h$$

90

LOSS of PRESSURE = GAIN IN KE

$$P_1V - P_2V = \tfrac{1}{2} m V_2^2 - \tfrac{1}{2} m V_1^2$$

$$V(P_1 - P_2) = \tfrac{1}{2} m (V_2^2 - V_1^2)$$

$$P_1 - P_2 = \tfrac{1}{2}\frac{m}{V}(V_2^2 - V_1^2)$$

$$P_1 - P_2 = \tfrac{1}{2}\rho(V_2^2 - V_1^2)$$

$$A_1 v_1 = A_2 v_2$$

$$V_2 = \frac{A_1 v_1}{A_2}$$

$$V_2 = \frac{.7854 \times .15^2}{.7854 \times .05^2} \times V_1$$

$$V_2 = 9 V_1$$

$$P_1 - P_2 = 50 \times 10^{-3} \times (13.6 - 1) \times 10^3 \times 9.81$$

$$P_1 - P_2 = 6180.3$$

$$6180.3 = \tfrac{1}{2}\rho(V_2^2 - V_1^2)$$

$$6180.3 = \tfrac{1}{2}\rho\left[(9V_1)^2 - V_1^2\right]$$

$$6180.3 = \frac{1000}{2}(80V_1^2)$$

$$6180.3 = 40000 V_1^2$$

$$.1545 = V_1^2$$

$$.3931 \text{ m/s} = V_1$$

$$\dot{m} = A v \rho$$

$$= .7854 \times .15^2 \times .3931 \times 1000 \times 3600$$

$$= 25.00 \times 10^3 \text{ kg/hr}$$

$$\text{ACTUAL} = \dot{m} \times C$$

$$= 25.00 \times 10^3 \times .9$$

$$\dot{m} = 22.51 \times 10^3 \text{ kg/hr}$$

$$m = \underline{\underline{22.51 \text{ Mg/hr}}}$$