UNIT-4

Gear Box

1. Nine Speed Gear box output speed from 180 rpm to 1800 rpm

Given :-

$n = 9$

$N_1 = 1800$ rpm

$N_2 = 180$ rpm.

1. Speed Ratio :- ϕ

$$\phi = \left(\frac{N_{max}}{N_{min}}\right)^{\frac{1}{n-1}}$$

$$\boxed{\phi = 1.33}$$

2. Spindle Speed :-

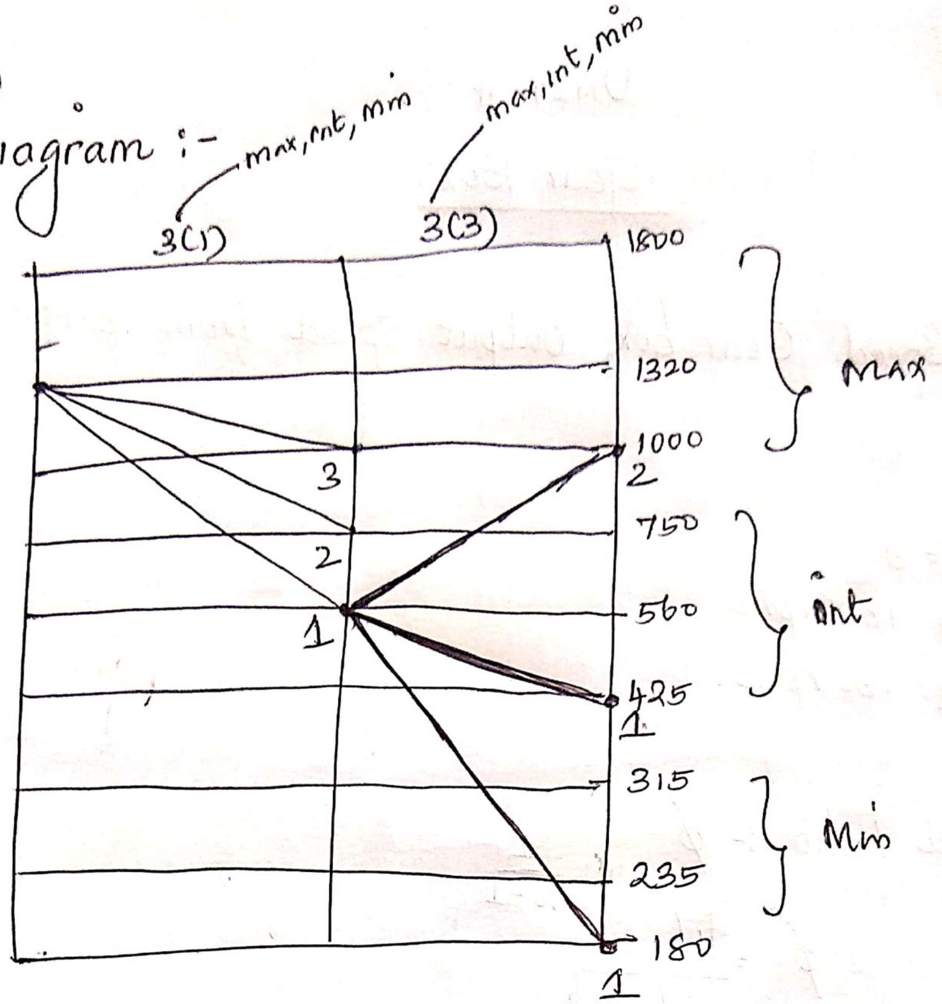
$\phi = 1.33$ is not available in ϕ. but its available in R_{40} Series by skipping 4 values.

180, 236, 315, 425, 560, 750, 1000, 1320, 1800

3. Structural Formula :-

$n = 3(1)\ 3(3)$

4. Ray diagram :-

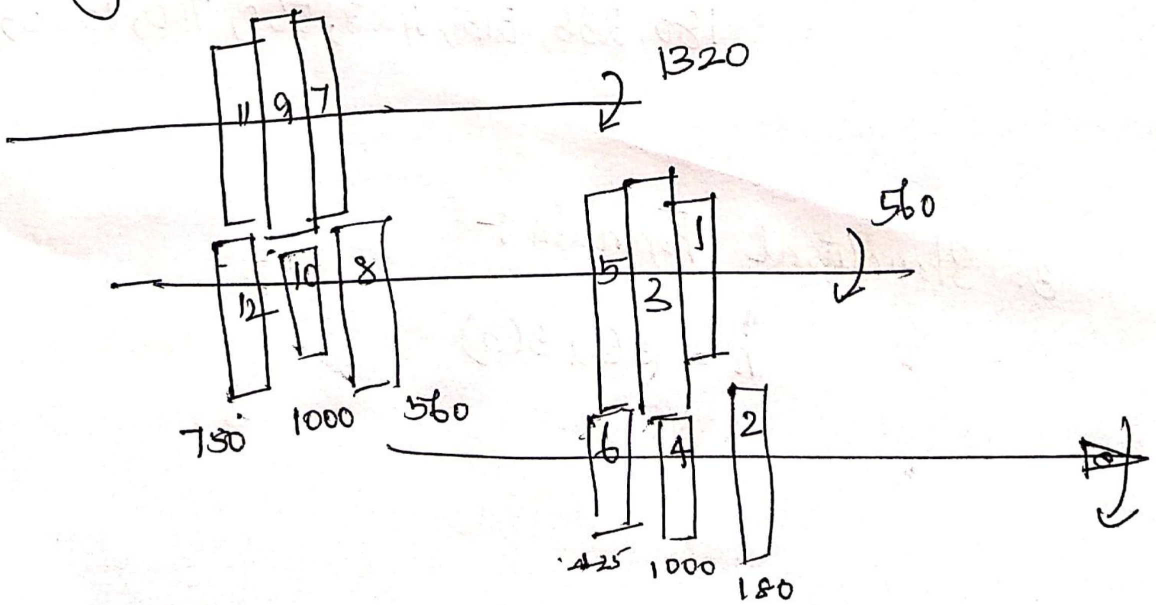


Rule :-

$$N_{max}/N_{i/p} \ngtr 2$$

$$N_{min}/N_{i/p} \nless 0.25$$

5. Gear Arrangement :-



Stage III

1-2

$N_1 / N_2 = \frac{180}{560}$

$Z_2 = 63$

$Z_1 = 20$

3-4

$\frac{N_4}{N_3} = Z_3 / Z_4$

$Z_3 = 0.76 Z_4$

$Z_4 = 48$

$Z_3 = 35$

5-6

$Z_5 / Z_6 = \frac{N_6}{N_5}$

$Z_6 = 30$

$Z_5 = 53.$

Stage I

7-8

$Z_7 / Z_8 = N_8 / N_7$

$Z_7 = 20$

$Z_8 = 48$

9-10

$N_7 / N_{10} = \frac{Z_{10}}{Z_{11}}$

$Z_{10} = 44$

$Z_9 = 24$

11-12

$\frac{N_{11}}{N_{12}} = Z_{12} / Z_{11}$

$Z_{12} = 37$

$Z_{11} = 31$ //

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2. Design 12 Speed Gear box with 12 Speed from 160 rpm to 2000 rpm.

Given :-

$i = 12$

$N_1 = 2000$ rpm

$N_2 = 160$ rpm.

1. Step ratio :- ϕ :-

$$\phi = \left(\frac{N_{max}}{N_{min}}\right)^{\frac{1}{n-1}}$$

$$= \left(\frac{2000}{160}\right)^{1/12-1}$$

$$\boxed{\phi = 1.25}$$

2. Spindle Speed :-

$\therefore$ $\phi = 1.25$ from R_{20} Series.

↳ 160, 200, 256, 320 — min

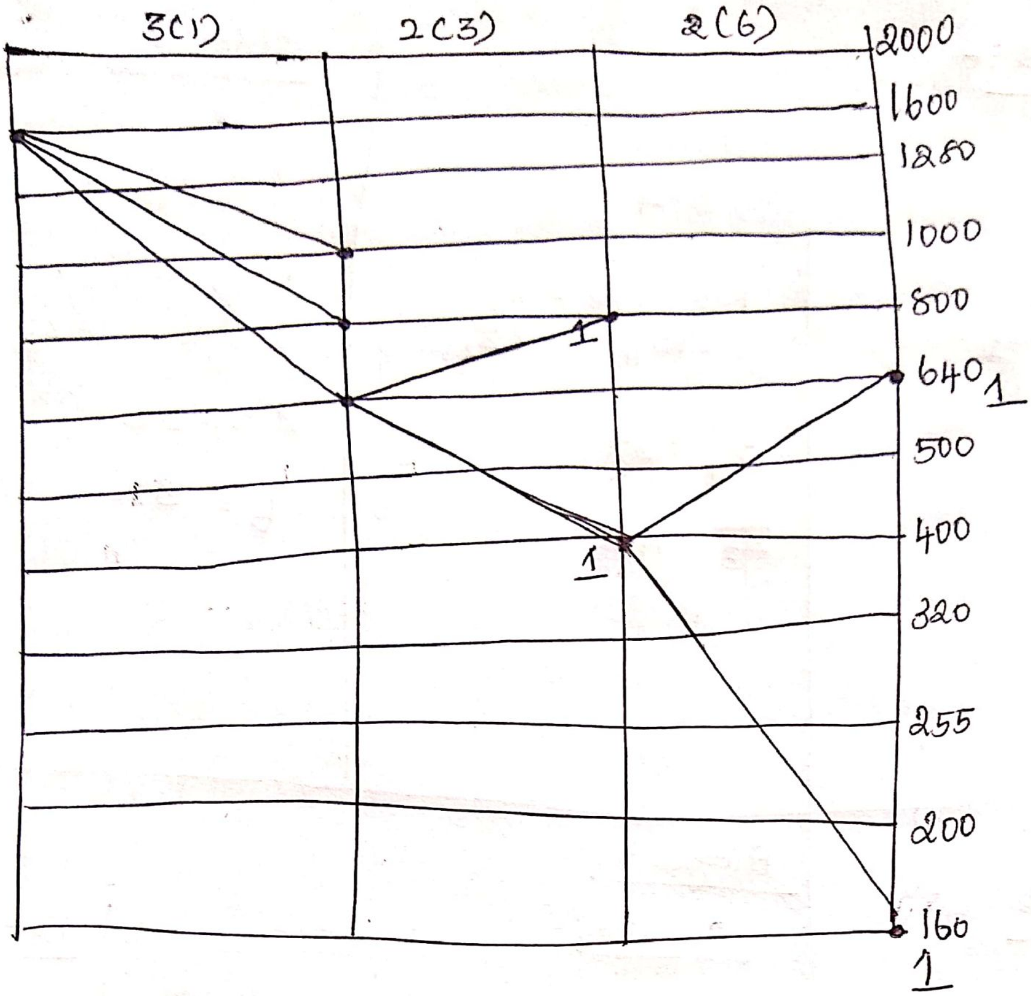
400, 505, 640, 800 — int

1008, 1280, 1600, 2000. — max.

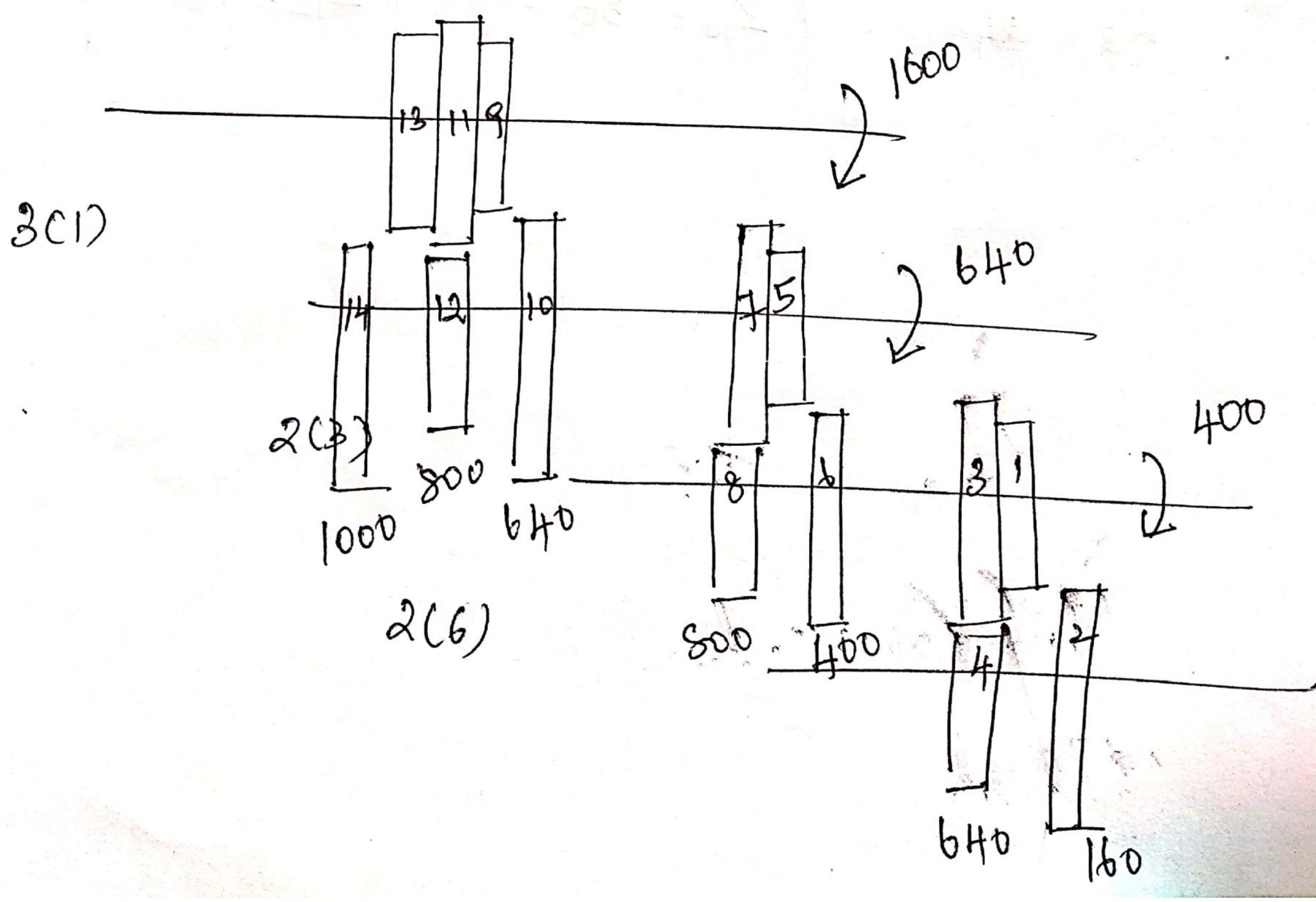
3. Structural formula :-

~~P = X,~~ $P_1(X_1) P_2(X_2) P_3(X_3) = n$

$n = 3(1)\, 2(3)\, 2(6)$.



5. Gear Arrangement :-



6. Teeths :-

Stage 3 :-

Stage 2

1–2

$Z_1/Z_2 = N_2/N_1$

$Z_1 = 18$

$Z_2 = 50$

3-4

$N_3/N_4 = Z_4/Z_3$

$Z_4 = 27$

$Z_3 = 43$

5 – 6

$N_5/N_6 = Z_6/Z_2$

$Z_5 = 20$

$Z_6 = 32$

$Z_7 - Z_8$

$Z_8/Z_7 = N_7/N_8$

$Z_7 = 28$

$Z_8 = 24$

Stage 3

9 – 10

$\frac{Z_9}{Z_{10}} = \frac{N_{10}}{N_9}$

$Z_9 = 20$

$Z_{10} = 50$

11 – 12

$Z_{11}/Z_{12} = N_{12}/N_{11}$

$Z_{11} = 9$

$Z_{12} = 70$

13 – 14

$N_{13}/N_{14} = \frac{Z_{14}}{Z_{13}}$

$Z_{13} = 27$

$Z_{14} = 43$

3. Design 18 speed gear box from source 1000 rpm. min speed 35 rpm and max. speed 650 rpm.

Given :-

$N_{max} = 650$ rpm

$N_{min} = 35$ rpm

$n = 18$

1. Step Ratio :- ϕ

$$\phi = \left(\frac{650}{35}\right)^{1/18-1}$$

$$\boxed{\phi = 1.187}.$$

2. Spindle Speed :-

$\phi = 1.18$ not available in std. ratio, but its available in R_{40} Series.

35, 43, 50, 60, 71, 85 ⟶ min. speed

100, 118, 140, 170, 200, 236 ⟶ int "

280, 335, 400, 475, 560, 650. ⟶ max ".

3. Structural Formula :-

$n \Rightarrow P_1(X_1)\,P_2(X_2)\,P_3(X_3)$

$18 = 2(1)\;3(2)\;3(6).$

$X_1 = 1$

$X_2 = P_1$

$X_3 = P_1 P_2.$

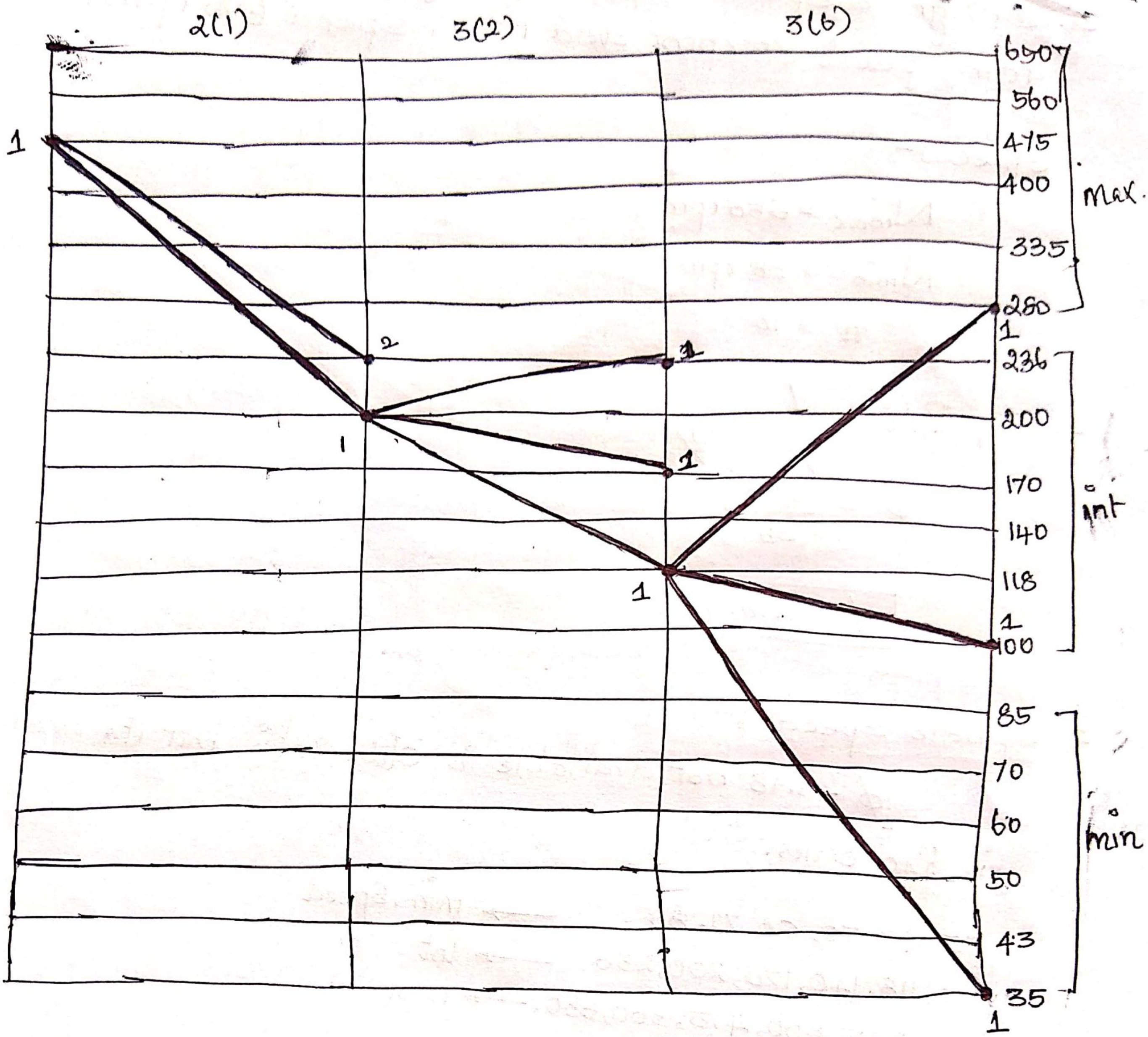
4. Ray Diagram :-

Rule :-

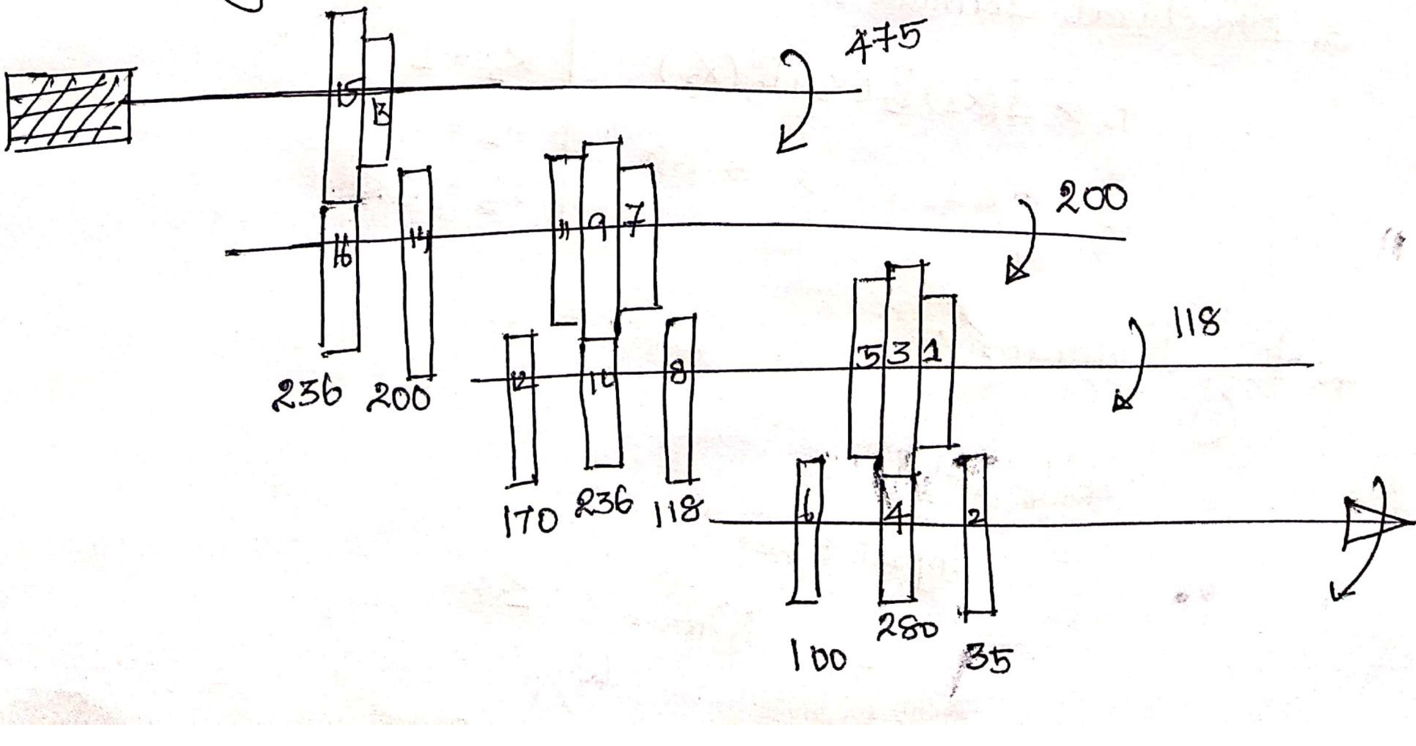
Input Speed ratio :

↳ $N_{max}/N_{I/P} \leq 2$

↳ $N_{min}/N_{I/P} \geq 0.25$



5. Gear Arrangement :-



6. No. of teeth :-

Stage 3 :-

1–2

$N_1/N_2 = Z_1/Z_2$

$Z_1 = 20$

$Z_2 = 80$

3–4

$N_3/N_4 = Z_4/Z_3$

$Z_4 + Z_3 = 100$

$Z_4 = 60$

$Z_3 = 40$

5–6

$N_5/N_6 = \frac{Z_6}{Z_5}$

$Z_5 + Z_6 = 100$

$Z_5 = 34$

$Z_6 = 66$

Stage 2 :-

7–8

$\frac{Z_7}{Z_8} = \frac{N_8}{N_7}$

$Z_7 = 20$

$Z_8 = 34$

9–10

$\frac{Z_9}{Z_{10}} = \frac{N_{10}}{N_9}$

$Z_9 + Z_{10} = 64$

$Z_9 = 24$

$Z_{10} = 30$

11–12

$\frac{Z_{11}}{Z_{12}} = \frac{N_{12}}{N_{11}}$

$Z_{11} + Z_{12} = 64$

$Z_{11} = 29$

$Z_{12} = 25$

Stage 1 :-

13–14

$\frac{Z_{13}}{Z_{14}} = \frac{N_{14}}{N_{13}}$

$N_{13} = 20$

$N_{14} = 41$

15–16

$\frac{Z_{15}}{Z_{16}} = \frac{N_{16}}{N_{15}}$

$Z_{15} + Z_{16} = 61$

$Z_{15} = 22$

$Z_{16} = 39$ //

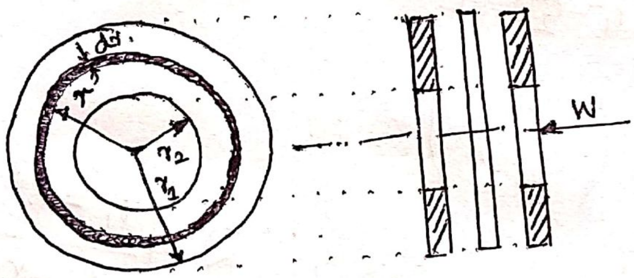
Clutch :-

↳ Engage (or) disengage the power from the engine.

Types :-

1. Single plate clutch
2. Multiple " "
3. Cone " "
4. Centrifugal " "

1. Design of Single plate clutch :-



↳ Area of the ring (circumference) $= 2\pi r . dr$

↳ Axial Force $(\delta W) \Rightarrow p \times A$

$\Rightarrow p \times 2\pi r dr.$

↳ Frictional Force

$(F_r) = \mu . \delta W$

$\Rightarrow \mu . p . 2\pi r . dr$

↳ Torque due to friction :-

$T_r = F_r \times r$

$\Rightarrow \mu . p . 2\pi r^2 dr$ ——— (1)

∴ Here, clutch designed by following assumption.

1. Uniform pressure
2. Uniform Wear

1. Uniform Pressure :-

$$p \Rightarrow W/A \Rightarrow \frac{W}{\pi(r_1^2 - r_2^2)}.$$

$$T \Rightarrow \int_{r_2}^{r_1} 2\pi\mu . p . r^2 dr.$$

$$\Rightarrow 2\pi\mu p \left[\frac{r^3}{3}\right]_{r_2}^{r_1}$$

$$\Rightarrow \frac{2\pi\mu . W}{\pi(r_1^2 - r_2^2)} . \left[\frac{r_1^3 - r_2^3}{3}\right]$$

$$\Rightarrow 2/3\ \mu . W . \left(\frac{r_1^3 - r_2^3}{3}\right)$$

$$\boxed{T = \mu . W . R}$$

$$\because R = \left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right) 2/3.$$

2. Uniform Wear :-

$$P . r = C \quad \boxed{P_1 r_1 = P_2 r_2 = C}$$

$$P = C/r$$

W.K. that, $\delta W = 2\pi p r\, dr$

$$\delta W = 2\pi C\, dr$$

∴ Total Force acting on the friction.

$$W = \int_{r_1}^{r_2} 2\pi c\, dr$$

$$W = 2\pi C(r_1 - r_2)$$

$$C = \frac{W}{2\pi(r_1 - r_2)} \quad \text{—— (3)}$$

Fritional torque for wear :-

$$T_r = 2\pi\mu . pr^2 dr \qquad \because P.r = C$$

$$= 2\pi\mu C . rdr$$

$$= 2\pi\mu C \int_{r_1}^{r_2} rdr$$

$$\Rightarrow 2\pi\mu C \left[\frac{r_1^2 - r_2^2}{2}\right]$$

Sub equ^3 (3) in above

$$T_r = 2\pi\mu . \frac{W}{2\pi(r_1 - r_2)} \left(\frac{r_1^2 - r_2^2}{2}\right)$$

$$T_r \Rightarrow \mu . W . \frac{(r_1 + r_2)}{2}$$

$$\therefore T = \mu . W . R \qquad \because R = \left(\frac{r_1 + r_2}{2}\right)$$

↳ $T = \mu . W . R$

└→ $\frac{2}{3}\left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$ (Pressure).

└→ $\left[\frac{r_1 + r_2}{2}\right]$ (Wear)

2. Single plate clutch consists of two pairs of connecting surface. The inner and outer radii of friction plate are 120mm and 250mm resp. The co-efficient of friction is 0.25 and total axial for 15KN. Cal. power transmitting capacity of the clutch plate at 500 rpm. Using pressure and wear.

Given :-

$n = 2$

$r_1 = 250mm = 0.25m$

$r_2 = 120mm = 0.12m$

$\mu = 0.25$

$W = 15KN \Rightarrow 15 \times 10^3 N$

$N = 500$ rpm

(i) Uniform Pressure :-

$T \Rightarrow n.\mu.W.R$

$$R \Rightarrow \left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right) \times 2/3$$

$$\Rightarrow \left(\frac{0.25^3 - 0.12^3}{0.25^2 - 0.12^2}\right) \times 2/3$$

$\Rightarrow 2 \times 0.25 \times 15 \times 10^3 \times$

$T \Rightarrow 1444.6 \; N-m$

(ii) Uniform Wear :-

$T = n.\mu.W.R$

$$R = \frac{r_1 + r_2}{2} \Rightarrow \frac{0.25 + 0.12}{2}$$

$\Rightarrow 0.155$

$\therefore T = 2 \times 0.25 \times 15 \times 10^3 \times 0.155$

$\Rightarrow$

3. A Single plate clutch transmits 25 KW at 900 rpm. The max. pressure intensity b/w the plates is 85 kN/m². The ratio of radii is 1.25. Both side of the plates are effective and the $\mu = 0.25$. Deter. (i) The inner diameter of the plate (ii) the axial Force to engage the clutch. Assume uniform wear.

Given :-

$P = 25\,KW$

$N = 900\,rpm$

$P_{max} = 85\,KN/m^2$ $\quad$ $\boxed{\because P_{max}\, r_2 = C}$

$r_1/r_2 = 1.25$, $r_1 = 1.25 r_2$.

$\mu = 0.25$

To find :-

$d_2 = ?$

$W = ?$

Sol :-

For Uniform Wear :-

$T = \mu . W . R$

where,

$\hookrightarrow T = \frac{P \times 60}{2\pi N} \Rightarrow \frac{25\times10^3 \times 60}{2\times\pi\times900} \Rightarrow 265.258\,N\text{-}m$

$\boxed{T = 265.25\,N\text{-}m}$

$\hookrightarrow W \Rightarrow 2\pi C (r_1 - r_2)$ $\quad$ | W.K. that $P_{max}\, r_2 = C$.

$\therefore W = 2\pi (85\times10^3 \times r_2)(1.25 r_2 - r_2)$ $\quad$ | $C \Rightarrow 85\times10^3 \times r_2$

$\Rightarrow$

$\hookrightarrow R = \left(\frac{r_1 + r_2}{2}\right)$

$= \frac{1.25 r_2 + r_2}{2}$

$R = \frac{2.25 r_2}{2}$

$\therefore \quad 265.28 = 0.25 x$

$r_2 = 0.152 \, m$

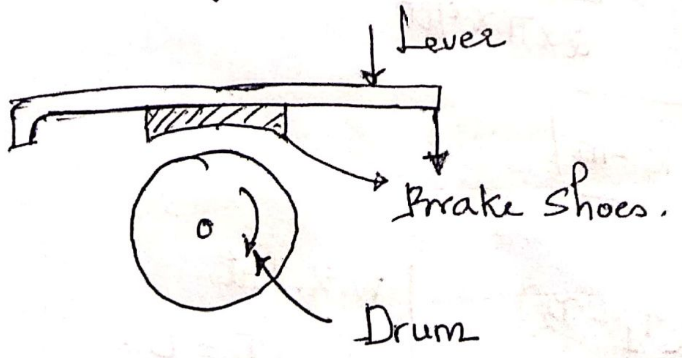
$\therefore D_2 = 0.304 \, m$ (or) $304 \, mm$ (Ans)

$\hookrightarrow W = 3.092 \, KN$

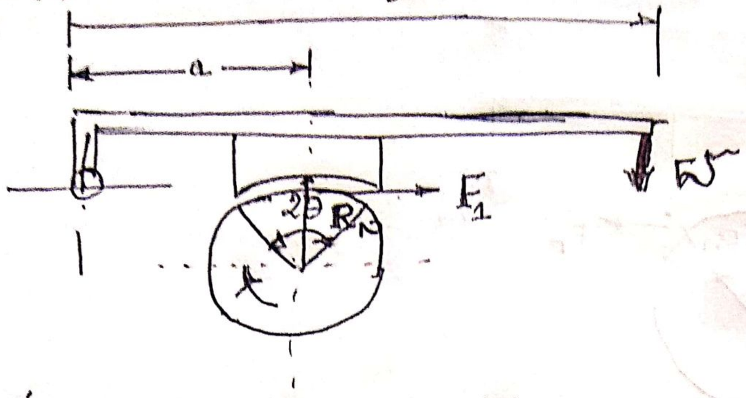
4. Single brake Shoe :-

↳ It Consists of a Single Shoe attached to the lever and rotating wheel drum.

↳ Tangential Friction force is developed at the Contact of Shoe and drum Surface.



Case (i) :-



(clockwise)

↳ $W \times l - R_N \times a - F_1 \times 0 = 0$

$$R_N = \frac{Wl}{a}$$

↳ Brake torque :-

$T_B = F_T \times r$ ∵ $F_r = \mu . R_N$

$$T_B = \mu R_N . r$$

$\therefore T_B = \mu . \frac{Wl}{a} . r$ (N-m).

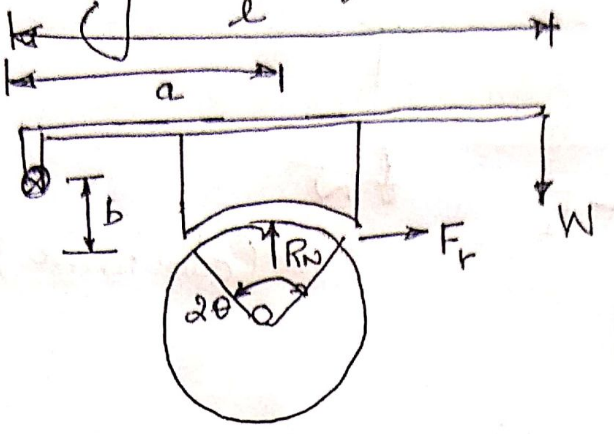
↳ Anticlockwise :-

$W \times l - R_N \times a = 0$

$\therefore R_N = \frac{W . l}{a}$

$\therefore T_B = \mu . \frac{Wl}{a} . r$ (N-m)

Case (ii) Tangential force at a point :-



$\Sigma M_o = 0,$

$$W l - R_N \times a - F_r \times b = 0$$

$$W l - R_N a - F_r b = 0$$

$$W l - (R_N a + \mu R_N b) = 0$$

$$R_N = \left(\frac{W l}{a + \mu b} \right)$$

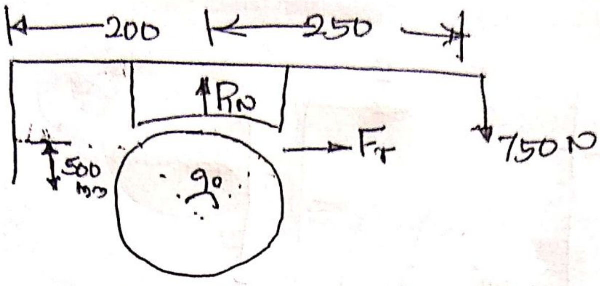
Torque,

$$T_B = F_r \times r$$

$$\Rightarrow \mu \left(\frac{W l}{a + \mu b} \right) \times r \quad \text{(clockwise)}$$

$$\therefore T_B = \frac{\mu . W l}{a - \mu b} \times r \quad \text{(anticlockwise)}.$$

5. A Single Shoe brake is shown in fig. The diameter of drum is 250 mm angle of contact 90°. If operating force of 750 N and $\mu = 0.35$. Determine the Torque :-



Given :-

$D = 250$ mm

$2\theta = 90°$ (If $\theta = 60°$, $\mu = \frac{4\mu \sin\theta}{2\theta + \sin 2\theta}$) $\mu' = 0.385$

$\theta = 45°$

$\mu = 0.35$

$T_B = 750N$

$\therefore 750 \times 0.45 - R_N \times 0.2 + F_r \times 0.5 = 0$

$337.5 - 0.2R_N + 0.192R_N = 0$

$R_N = 42185$ N

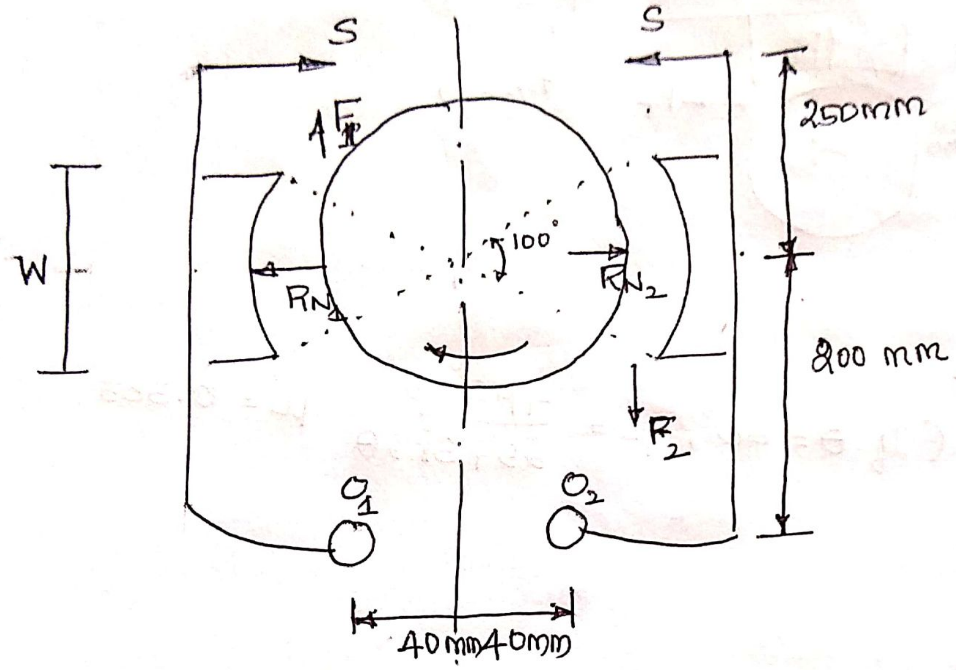
$F_r = 16218.125$ N

$\therefore$ Torque $= F_r \times r$

$\Rightarrow 16218.125 \times 0.125$

$T_1 \Rightarrow 2027.26$ N-m

6. Double Shoe brake, Torque 1500 N-m. The dia of the brake drum is 400 mm. and 100° (angle of Contact). If $\mu = 0.4$ Det (i) Spring Force (ii) Width of the brake. Pr not exceed 0.3 N/mm².



Given :-

$D = 400\ mm \Rightarrow 0.4\ m$

$2\theta = 100°,\ \theta = 50°$

$\mu = 0.4,\quad \mu' = 0.479$

$T_R = 1500\ N-m$

$P = 0.3\ N/mm^2$

Sol :-

$$S[0.45] - R_{N_1} \times 0.2 + F_1(r - 40) = 0$$

$$\therefore F_1 = 1.74S$$

$$-S(0.45) + F_2(r - 40) + R_{N_2} \times 0.2 = 0$$

$$\boxed{F_2 = 0.77 \times S}$$

W.K. that,

$$T = (F_{b_1} + F_{b_2})r$$

$$1500 = (1.74S + 0.77S)0.2$$

$$\boxed{S = 2988\,N}$$

(ii) Width of the brake :-

$$P = \frac{R_{n_1}}{2RW\sin\theta}$$

$$F_1 = 1.74 \times 2988 \Rightarrow 5199.12\,N$$

$$R_{N_1} = 5199.12 / 0.479$$

$$\boxed{R_{N_1} \Rightarrow 10854.11\,N}$$

$$\boxed{W = 118.07\,mm \simeq 120\,mm}$$