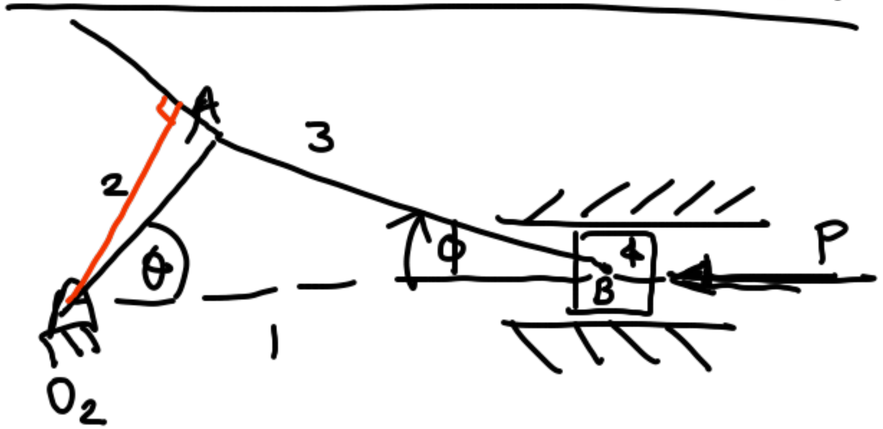
Tutorial # 8 : Kinematic Analysis

① Static analysis of mechanism

Slider - crank mechanism



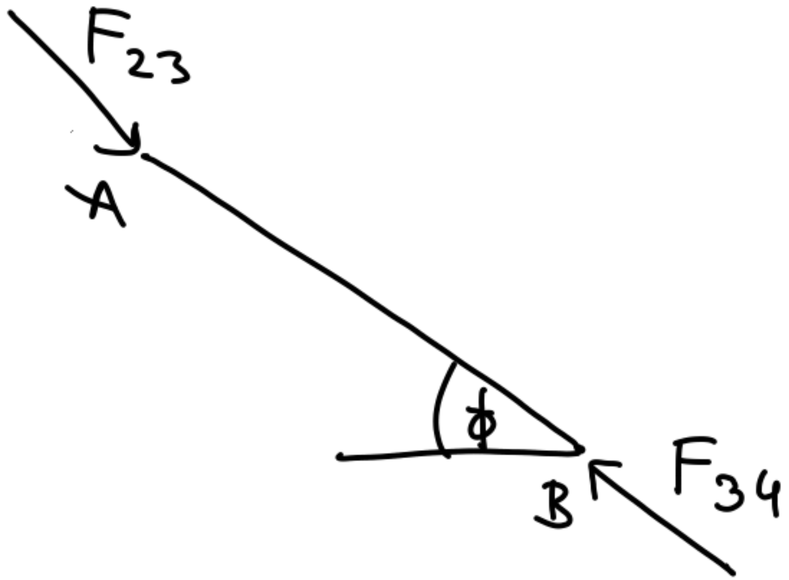
Holding torque on link 2?

No friction. Ignore gravity effect.

We are going to assume that Kinematic analysis i.e. Position, Velocity, Acceleration analysis has been carried out.

As the mechanism is under Static equilibrium, any part of the mechanism e.g. any link is also under static equilibrium.

For connecting rod



2 force member

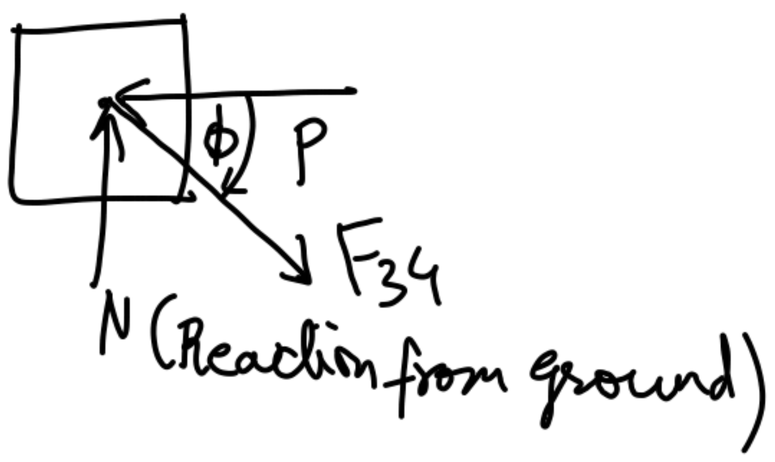
$$\Sigma F_x = 0 \Rightarrow -P + F_{34}\cos\phi = 0$$

$$F_{34} = \frac{P}{\cos\phi} = P\sec\phi$$

$$N - F_{34}\sin\phi = 0$$

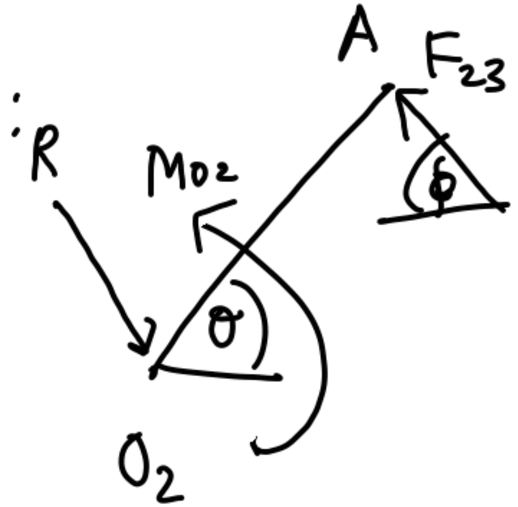
$$N = P\tan\phi$$

Slider :



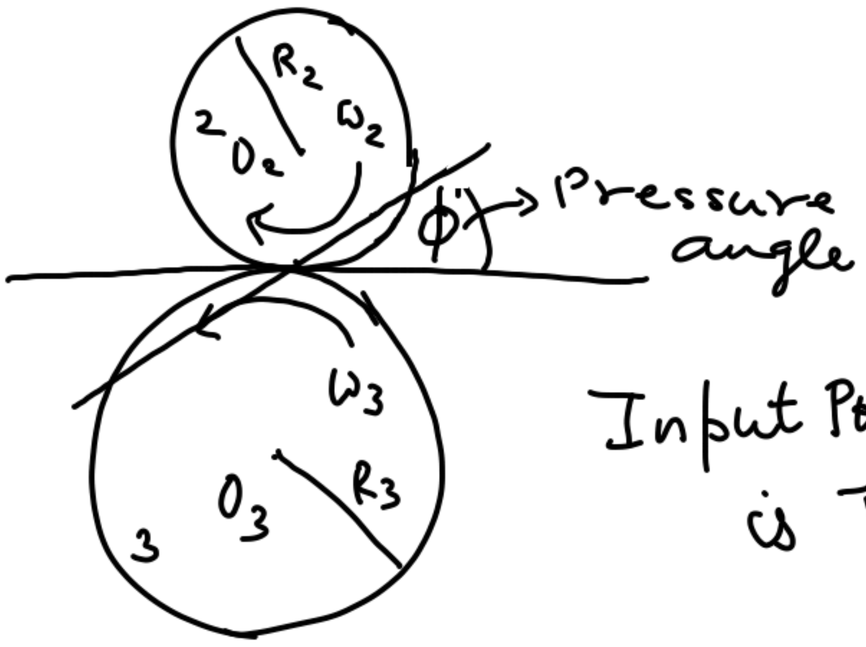
M_{O_2} = Holding torque = $AO_2 \times F_{23}$

Crank :



$R = F_{23}$ (magnitude and orientation)

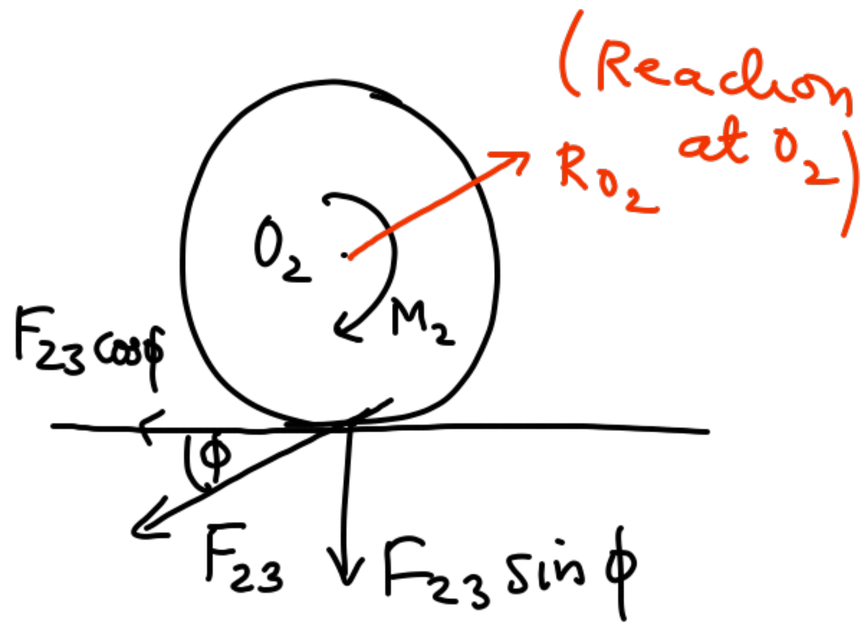
§2. Static analysis of spur gears :



Input Power to 2 is W.

R_2, R_3 } Pitch circle radius

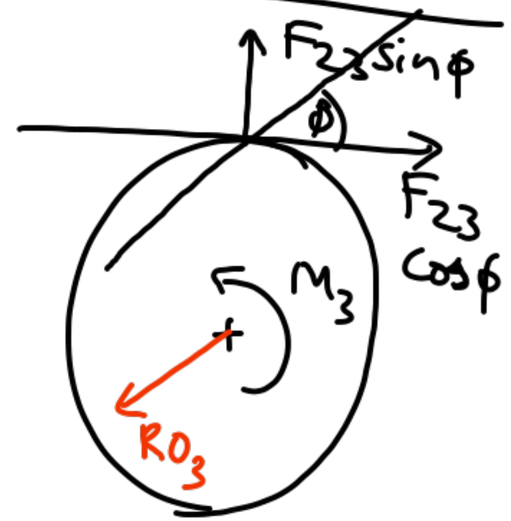
F.B.D of Gear 2 :



$$(F_{23}\cos\phi)\,R_2 + M_2 = 0$$

$$F_{23} = \frac{-M_2}{R_2\cos\phi}$$

F.B.D of Gear 3



R_{O_3} : Reaction at O_3

Input Power

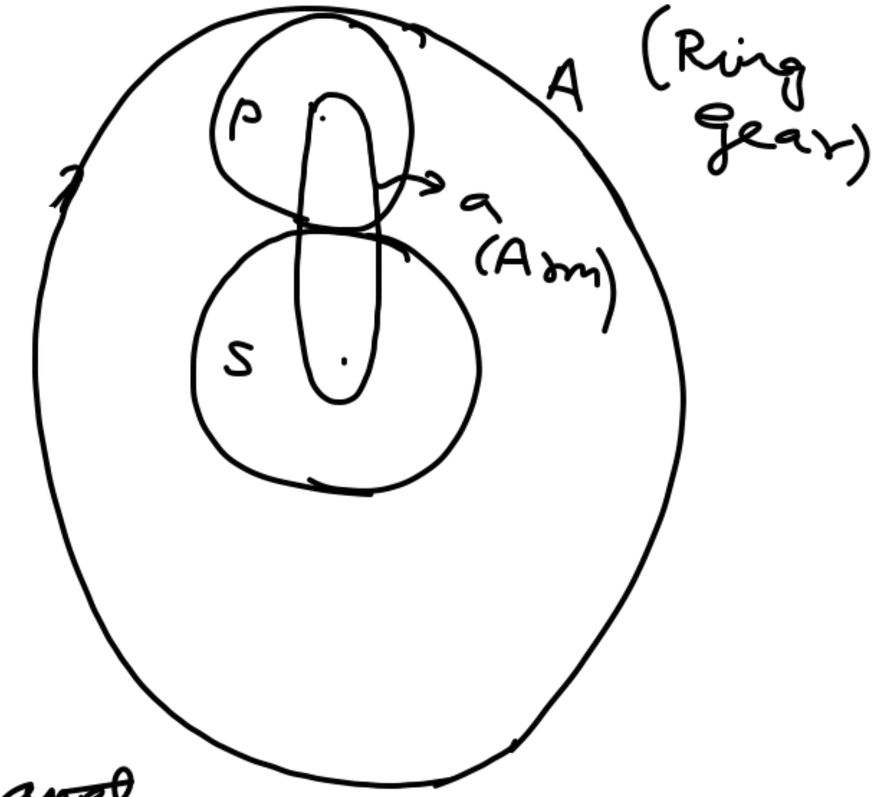
$W = M_2 \omega_2$

$$\frac{\omega_3}{\omega_2} = -\frac{R_2}{R_3}$$

$$\omega_3 = -\frac{\omega_2 R_2}{R_3}$$

$$M_3 - F_{23}\cos\phi R_3 = 0$$

Q3.



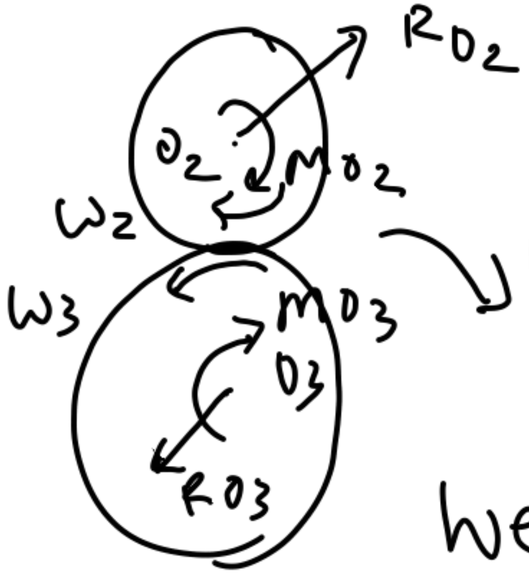
P : Planet

S : Sun

$\omega_P, \omega_S, \omega_a, \omega_A$ are speeds of Planet, Sun, Arm and Ring gear.

M_S, M_P, M_a, M_A are the moments:

F.B.D of the gear system removed from the frame:



2nd eqm:

$$M_{O_2}\omega_2 + M_{O_3}\omega_3 = 0$$

we can show

In case arm is held retained but the system is removed from ground,

$$\Sigma M = 0 \Rightarrow M_S + M_a + M_A = 0 \quad \hookrightarrow ①$$

$$M_S\omega_S + M_a\omega_a + M_A\omega_A = 0 \quad \hookrightarrow ②$$

Given one of the torques, ①, ② can be solved to give the remaining torques.

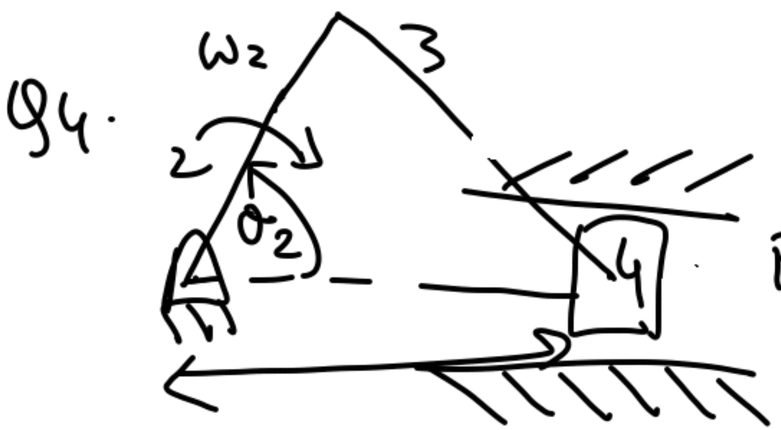
① and ② can be rewritten as

$M_a = -M_S - M_A$

$M_S\omega_S - M_S\omega_a - M_A\omega_a + M_A\omega_A = 0$

$M_S(\omega_S - \omega_a) + M_A(\omega_A - \omega_a) = 0$

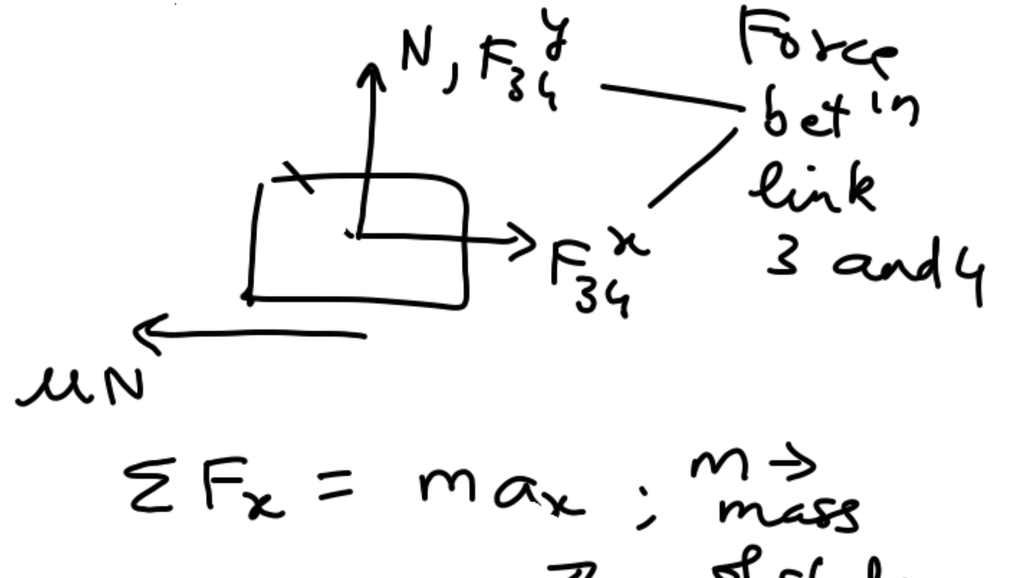
This is exactly same as Q2 when system is analy-zed w.r.t arm.



Friction
$f = \mu N$

For Dynamic analysis

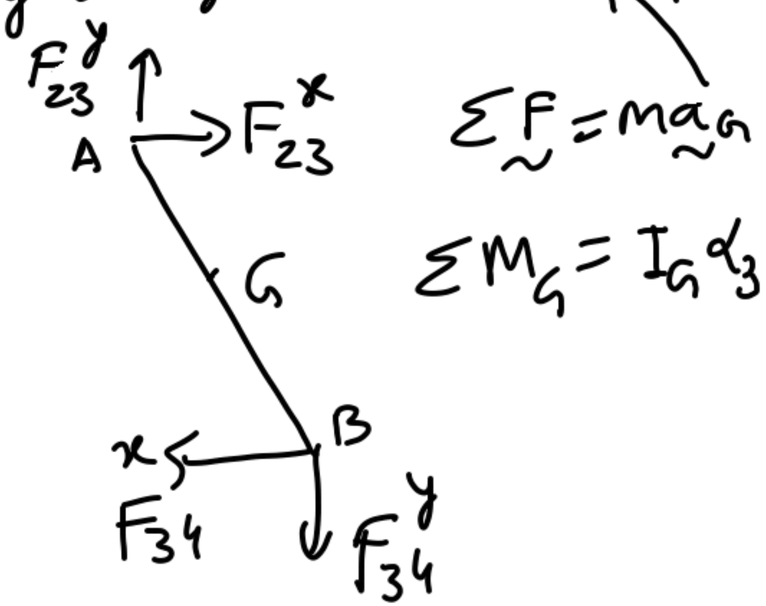
(i) For Slider :



$\Sigma F_x = m a_x$; $m \rightarrow$ mass of slider

$\Sigma F_y = m a_y = 0$

(ii) Link 3 :

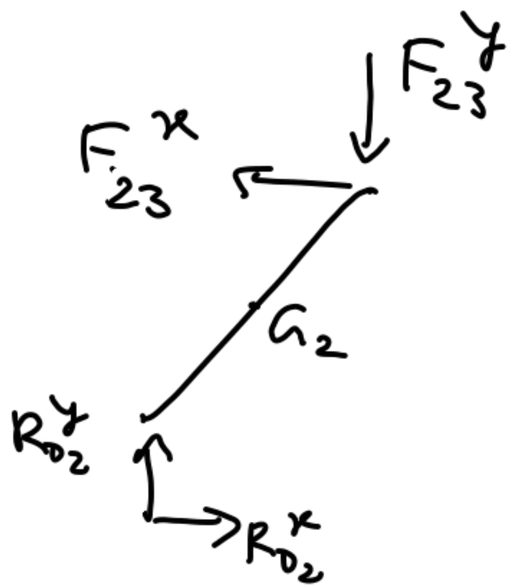


$\underset{\sim}{\Sigma F} = m \underset{\sim}{a_G}$

$\Sigma M_G = I_G \alpha_3$

$-\omega_3^2 r$ $\alpha_3 r$

(iii) Crank 2



$$\Sigma \underset{\sim}{F} = m \underset{\sim}{a}_{G_2}$$

$$\Sigma M_{G_2} = I_{G_2} \alpha_2$$

OR

$$\Sigma M_{O_2} = I_{O_2} \alpha_2$$