B.Tech.

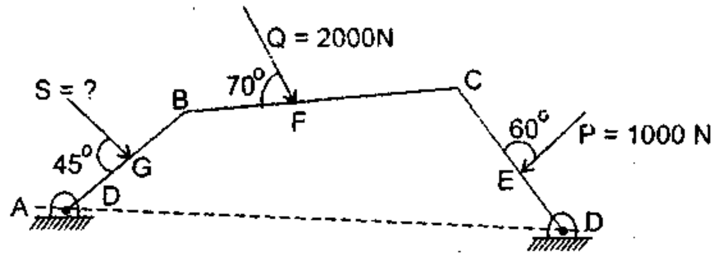
Fifth Semester Examination

Dynamics of Machines (ME-301-F)

Q. 1. Calculate the values of force S for the system.

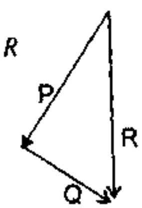
AB = 100 mm; BC = 80 mm; CD = 120 mm

AG = 20 mm; BF = 40 mm; CE = 50 mm



Ans. The forces *P* and *Q* can be combined into a single force *F* by obtaining their resultant. Let the resultant be *R*.

Now the question reduces two force member with for *R* and *S*. So, for the equilibrium *R* should be equal in magnitude to *S*.



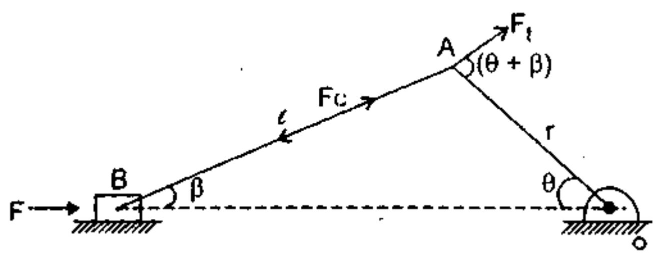
∴ By measurement on scale,

$$R = 1732\,N$$

$$\therefore \quad S = 1732\,N$$

Q. 2. (a) Derive an expression for the force acting on the crank by the connecting rod for an engine.

Ans. Figure shows a slider crank mechanism in which the crank *OA* rotates in the clockwise direction. *l* and *r* are the lengths of the connecting rod and the crank respectively.



Velocity of piston, $v = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2n}\right] \quad \therefore \left[n = \frac{l}{r}\right]$

Acceleration of piston $f = r\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$

Force along the piston, $F = F_P$

Where F_P is force due to pressure due to gas.

Force in the connecting rod $F_c = \frac{F}{\cos\beta}$

∴ Force exerted to the crank can be found as

Let F_t = crank effort

$$F_t \times r = F_c r \sin(\theta + \beta)$$

$$F_t = F_c \sin(\theta + \beta)$$

$$\boxed{F_t = \frac{F}{\cos\beta}\sin(\theta + \beta)}$$

Q. 2. (b) Describe all types of engine shaking forces in brief.

Ans. There are mainly two engine shaking forces :

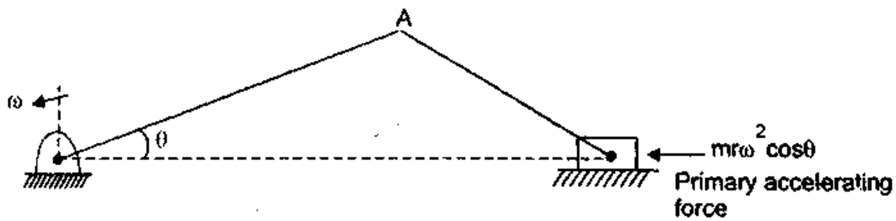
(i) Unbalanced primary force (ii) Unbalanced secondary force

Acceleration of the reciprocating mass of a slide crank mechanism is

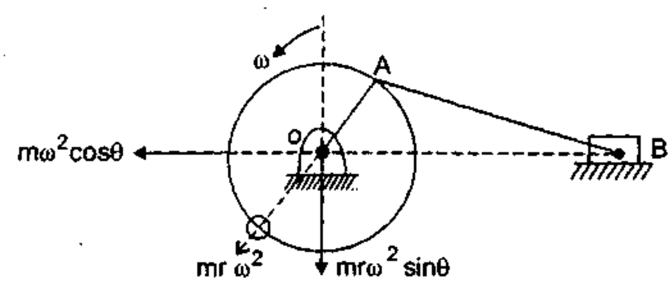
$$f = r\omega^2\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

$$= r\omega^2 \cos\theta + r\omega^2 \frac{\cos 2\theta}{n}$$

$mr\omega^2 \cos\theta$ is called primary accelerating force and $mr\omega^2 \frac{\cos 2\theta}{n}$ is called secondary accelerating force.



To balance these forces we add a balancing mass on the crank.



By adding the mass horizontal component is balanced only, vertical component is still unbalanced. So, effective forces just shifts from horizontal tc vertical direction.

So, only partial balancing is done using partial mass cm

Primary unbalanced force $= (1-c)mr\omega^2 \cos\theta$

Secondary unbalanced force $= cmr\omega^2 \sin\theta$

Q. 3. Three masses of 8 kg, 12 kg and 15 kg attached at radial distances of 80 mm, 100 mm and 60 mm respectively to a disc on a shaft are in complete balance. Determine the angular positions of the masses 12 kg and 15 kg relative to 8 kg mass.

Ans. Showing the planes of unbalanced masses

$\therefore$ $$m_1 r_1 = 8 \times 80 = 640$$

$$m_2 r_2 = 12 \times 100 = 1200$$

$$m_3 r_3 = 15 \times 60 = 900$$

Now, $$\Sigma mr = 0$$

$$640 \cos 0^\circ + 1200 \cos\theta_2 + 900 \cos\theta_3 = 0$$

$\Rightarrow$ $$1200 \cos\theta_2 = -(640 + 900 \cos\theta_3) \quad \text{... (i)}$$

& $$640 \sin 0^\circ - 1200 \sin\theta_2 + 900 \sin\theta_3 = 0$$

$$1200 \sin\theta_2 = -900 \sin\theta_3 \quad \text{... (ii)}$$

Squaring and adding equation (i) and (ii)

$$1200^2 = 640^2 + 900^2 \cos^2\theta_3 + 2 \times 640 \times 900 \times \cos\theta_3 + 900^2 \sin^2\theta_3$$

$$= 640^2 + 900^2 + 2 \times 640 \times 900 \times \cos\theta_3$$

$$\cos\theta_3 = 0.1913$$

$$\theta_3 = 79^\circ \text{ or } 281^\circ$$

When $\theta_3 = 79^\circ$, $1200 \sin\theta_2 = -900 \sin 79^\circ \Rightarrow \sin\theta_2 = -0.756$

$$\theta_2 = -47.4^\circ \text{ or } 132.6^\circ \text{ or } 227.4^\circ$$

But $\sin\theta_2$ is negative and $\cos\theta_2$ is also negative.

So $$\theta_2 = 227.4^\circ$$

Similarly, $\theta_3 = 281^\circ$, θ_2 can be found to be 132.6°

Q. 4. (a) Describe the following terms with respect to an engine :

(i) Hammer Blow **(ii) Variation of Tractive Force**

(iii) Swaying Couple

Ans. (i) Hammer Blow : Hammer blow is the maximum vertical unbalanced force caused by the mass provided to balance the reciprocating masses. It's value is $mr\omega^2$. At higher speeds, its magnitude is very high.

(ii) Variation of Tractive Force : A variation in the tractive force of an engine is caused by the unbalanced portion of the primary force which acts along the line of stroke of a locomotive engine. Total unbalanced primary force or the variation in the tractive force

$$= (1-C)mr\omega^2 (\cos\theta - \sin\theta)$$

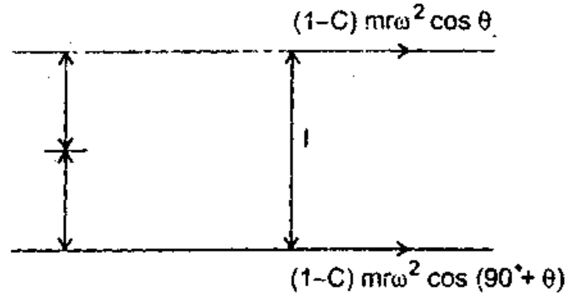
Maximum variation in tractive force occurs at $\theta = 135^\circ$ and 315°

Maximum variation $= \pm\sqrt{2}(1-C)mr\omega^2$

(iii) Swaying Couple : Unbalanced primary forces along the lines of stroke are separated by a distance l apart and thus constitute a couple. This tends to make the leading wheels say from side to side.

Swaying couple $= (1-C)mr\omega^2(\cos\theta + \sin\theta)\frac{l}{2}$

Maximum occurs at $\theta = 45^\circ$ and 225°



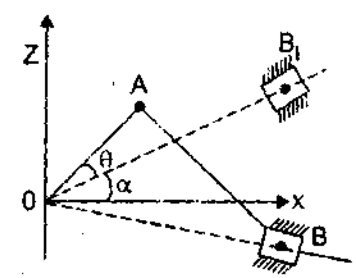
Maximum swaying couple $= \pm\frac{1}{\sqrt{2}} mr\omega^2 l$

Q. 4. (b) Explain how V-Engines are balanced.

Ans. Balancing of V-Engines : In V-engines, a common crank OA is operated by two connecting rods OB_1 and OB_2. Figure shows a symmetrical two cylinder V cylinder, the centre lines of which are inclined at angle α to the x-axis.

Let θ be the angle moved by the crank from the x-axis.

Primary Force : Primary force of 1 along line of stroke



$$OB_1 = mr\omega^2\cos(\theta-\alpha)$$

Primary force of 1 along x-axis

$$= mr\omega^2\cos(\theta-\alpha)\cos\alpha$$

Primary force of 2 along line of stroke

$$OB_2 = mr\omega^2\cos(\theta+\alpha)$$

Primary force of 2 along x-axis

$$= mr\omega^2\cos(\theta+\alpha)\cos\alpha$$

Total primary force along x-axis

$$= mr\omega^2\cos\alpha[\cos(\theta-\alpha)+\cos(\theta+\alpha)]$$

$$= 2mr\omega^2\cos^2\alpha\cos\theta$$

Total primary force along z-axis

$$= mr\omega^2[\cos(\theta-\alpha)\sin\alpha - \cos(\theta+\alpha)\sin\alpha]$$

$$= 2mr\omega^2\sin^2\alpha\sin\theta$$

Resultant primary force $= \sqrt{(2mr\omega^2 \cos^2 \alpha \cos \theta)^2 + (2mr\omega^2 \sin^2 \alpha \sin \theta)^2}$

$$= 2mr\omega^2 \sqrt{(\cos^2 \alpha \cos \theta)^2 + (\sin^2 \alpha \sin \theta)^2}$$

It will be at an angle β with the x-axis, given by

$$\tan \beta = \frac{\sin^2 \alpha \sin \theta}{\cos^2 \alpha \cos \theta}$$

If $2\alpha = 90°$

Resultant force $= 2mr\omega^2 \sqrt{(\cos^2 45° \cos \theta)^2 + (\sin^2 45° \sin \theta)^2}$

$$= mr\omega^2$$

$$\tan \beta = \frac{\sin^2 45° \sin \theta}{\cos^2 45° \cos \theta} = \tan \theta$$

$\beta = \theta$ or its acts along the crank and therefore can be completely balanced by a mass at a suitable radius diametrically opposite to the crank such that $m_r r_r = mr$.

Q. 5. (a) Classify different types of Governors.

Ans. Different types of Governors are :

(i) Centrifugal Governor (ii) Inertia Governor

Subclassification under are :

(i) Watt Governor (ii) Porter Governor (iii) Proell Governor

(iv) Hartnell Governor (v) Hartung Governor (vi) Wilson Hartuell Governor

(vii) Pickering Governor (viii) Spring Controlled Gravity Governor.

Q. 5. (b) Explain sensitiveness, stability, isochronism and hunting in context of governors.

Ans. Sensitiveness : A governor is said to be sensitive when it readily responds to a small change of speed. The movement of the sleeve for a fractional change of speed is the measure of sensitivity. Sensitiveness is the ratio of the difference between the maximum and the minimum speeds to the mean equilibrium speed.

∴ Sensitiveness $= \frac{N_2 - N_1}{N} = \frac{2(N_2 - N_1)}{(N_1 + N_2)}$

N = Mean speed

N_1 = Minimum speed corresponding to full load conditions.

N_2 = Maximum speed corresponding to no load conditions.

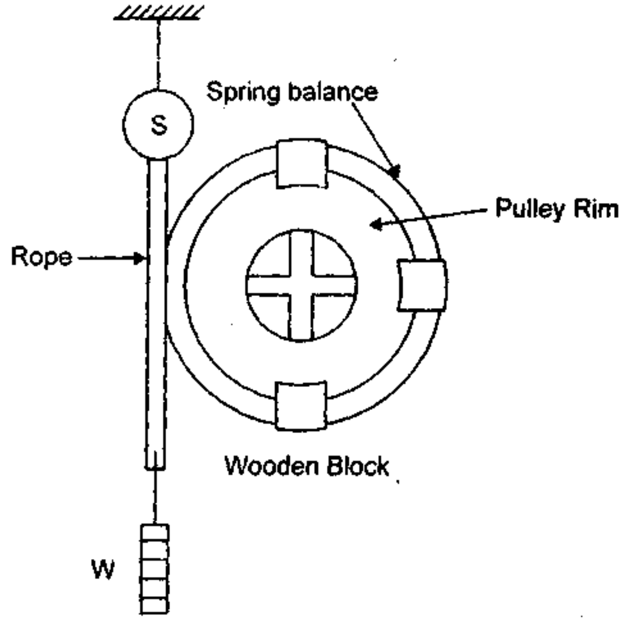
Stability : A governor is said to be stable if it brings the speed of the engine to the required value and there is not much hunting. The ball masses occupy a definite position for each speed of the engine within the working range.

Isochronism : A governor with a range of speed zero is known as an isochronism. This means that for all positions of the sleeve or the balls, the governor has the same equilibrium speed. Any change of speed results in moving the balls and the sleeve to their extreme positions. However, an isochronous governor is not practical due to friction at the sleeve.

Hunting : Sensitiveness of a governor is a desirable quality. However, if a governor has the same equilibrium speed. Any change of speed results in moving the balls and the sleeve to their extreme positions. If a governor is too sensitive, it may fluctuate continuously, because when the load on the engine falls, the sleeve rises rapidly to a maximum position. This shuts off the fuel supply to the extent to affect a sudden fall in the speed. This goes on continuously. This process is known as hunting.

Q. 6. (a) Explain the working of rope brake dynamometer.

Ans. Rope Brake Dynamometer : In a rope brake dynamometer, a rope is wrapped over the rim of a pulley keyed to the shaft of the engine. The diameter of the rope depends upon the power of the machine. The spacing of the ropes on the pulley is done by 3 to 4 U shaped wooden blocks which prevents rope from slipping off the pulley. The upper end of the rope is attached to a spring balance, whereas the lower end supports the weight of suspended mass.



Power of the machine $= T_\omega = (F_t \times r)\omega = (Mg - S)r\dfrac{2\pi N}{60}$

A rope brake absorption dynamometer is frequently used to test the power of engines. It is easy to manufacture, inexpensive and requires no lubrication.

Q. 6. (b) Describe in brief a hydraulic dynamometer.

Ans. Hydraulic Dynamometers : Hydraulic dynamometers are also wheel to measure the power of the machine under test. The basic principle of working of hydraulic dynamometer is based upon the pressure exerted by the fluid rotating inside a drum and force measured is used to calculate power.

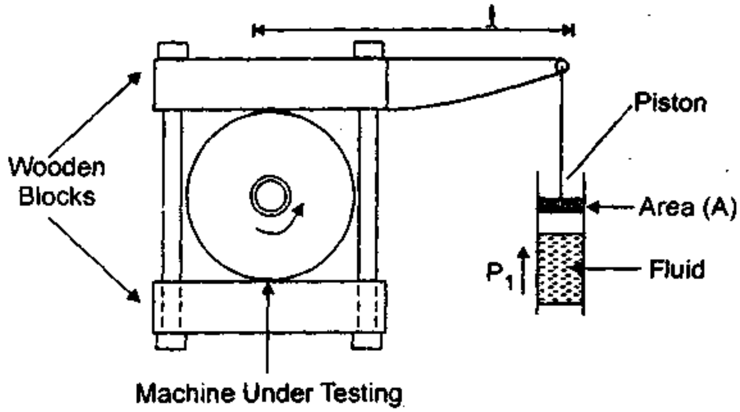
When fluid pressure is applied, the rotating wheel is slowed down due to frictional torque exerted by wooden blocks

Frictional torque $= P_1 A \times l$

$\therefore$ Power of the machine under test $= T^{\omega}$

$$= P_1 A \times l \times \frac{2\pi N}{60} = P_1 \times N \times K$$

Where K is a constant for a particular as brake.

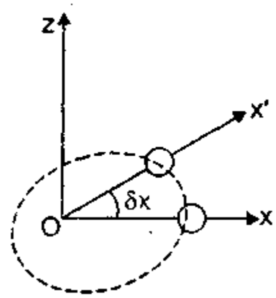


Q. 7. (a) Explain difference between spin and precision.

Ans. Spin : Spin is the rotation of the rotor about axis passing through the center and normal to the plane of rotor.

Precision : Precision is the rotation of the axis of spin of the rotor about an axis normal to the axis of rotation.

Consider, a rotor spin about the horizontal axis Ox at a speed of ω rad/s in the direction as shown



Rotation of rotor about axis Ox is called spin.

Rotation of axis Ox about axis Oz is called precision.

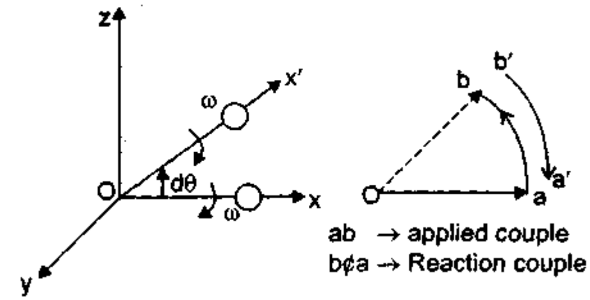
Q. 7. (b) Define and derive an expression for gyroscopic couple.

Ans. Let I be the moment of inertia of a rotor and ω its angular velocity about a horizontal axis of spin Ox in the direction as shown. Let this axis of spin turn through a small angle $\delta\theta$ in the horizontal plane (x, y) to the position Ox' in time δt.

Change in angular velocity, $\quad ab = \omega \times \delta\theta$

Angular acceleration, $\quad \alpha = \omega \frac{\delta\theta}{dt}$

In the limit, when $\delta t \rightarrow 0$, $\quad \alpha = \theta \frac{\delta\theta}{dt}$



Usually, $\delta\theta/dt$ is called velocity of precision and is denoted by ω_P

Angular acceleration, $\alpha = \omega\omega_P$

$\therefore$ Gyroscopic couple, $C = I_\alpha$, $C = I\omega\omega_P$

Q. 7. (c) Visualize the gyroscopic effect on two wheeled vehicles.

Ans. The gyroscopic effect on two wheeled vehicles :

Let a vehicle take a left turn. The vehicle is inclined to the vertical (inwards) for equilibrium. The angle of inclination of the vehicle can stay in equilibrium. The angle of inclination of the vehicle to the vertical is known as the angle of nut.

V = Linear velocity of vehicle on the track, r = Radius of the wheel,

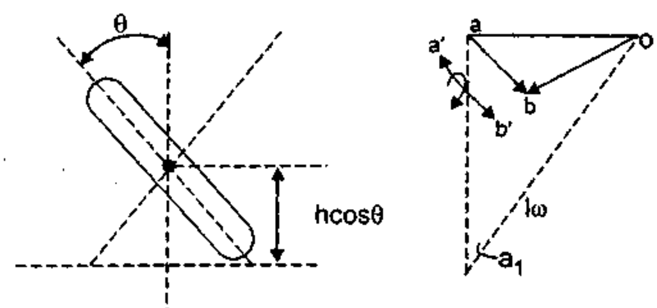
R = Radius of the track I_w = Moment of inertia of each wheel,

I_e = Moment of inertia of the engine parts. m = Total mass of the vehicle

ω_w = Angular velocity of the wheels ω_e = Angular velocity of rotating parts of the engine.

G = Gear ratio h = Height of centre of mass of the vehicle

θ = Inclination of vehicle to the verticles



As the axis of spin is not horizontal but inclined, it is necessary to take the horizontal component of spin vector.

Spin vector (horizontal) $= I_\omega \cos\theta$

$= (2I_w\omega_w + I_e\omega_e)\cos\theta$

Gyroscopic couple $= 2(I_w\omega_w + I_e G\omega_w)\cos\theta\,\omega_P$

$= (2I_w + GI_e)\dfrac{V}{R} \times \dfrac{\theta}{r}\cos\theta$

$$= (2I_w + GI_e)\frac{V^2}{rR}\cos\theta$$

Over tuning couple due to centrifugal force

$$= \left(\frac{mV^2}{R}\right)h\cos\theta$$

Total overtuning couple

$$= (2I_w + GI_e)\frac{V^2}{rR}\cos\theta + \frac{mV^2}{R}h\cos\theta$$

$$= \frac{V^2}{R}\left[\frac{2I_w + GI_e}{r} + mh\right]\cos\theta$$

Balancing couple due to weight of vehicle

$$= mgh\sin\theta$$

For equilibrium,

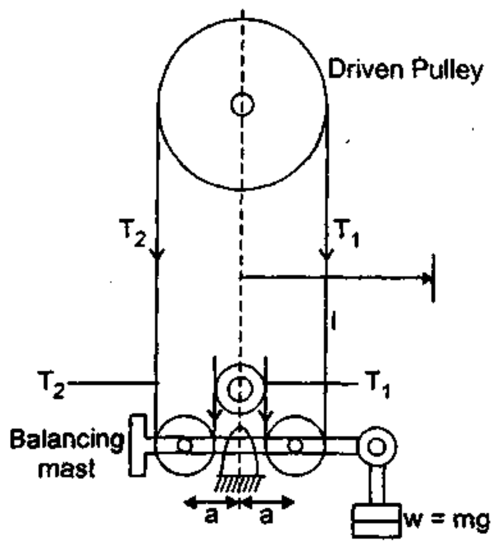
$$\frac{V^2}{R}\left[\frac{2I_w + GI_e}{r} + mh\right]\cos\theta = mgh\sin\theta$$

Angle θ can be calculated to avoid skidding of vehicle.

Q. 8. (a) Describe the working of belt transmission dynamometer.

Ans. Belt Transmission Dynamometer : The belt transmission dynamometer occupies a prominent position among transmission dynamometers. When a belt transmits power from one pulley to another, there exists a difference in tensions between the tight and slack sides.

A continuous belt runs over the driving and driven pulleys through two intermediate pulleys. The intermediate pulleys are fixed to a level having a fulcrum at the midpoint of the two pulley centers. The weight of a suspended mass at one end of the lever balances the differences in tensions of the tight and the slack sides.



Taking moments about fulcrum

$$Mgl - 2T_1 a + 2T_2 a = 0$$

$$Mgl - 2a(T_1 - T_2) = 0$$

$$(T_1 - T_2) = \frac{Mgl}{2a}$$

Power, $P = (T_1 - T_2)v$, where v = belt speed.

Q. 8. (b) Write short note on balancing of rotors.

Ans. Balancing of Rotors : Let there be a rotor revolving with a uniform angular velocity ω, m_1, m_2 and m_3 are the masses attached to the rotor at radii r_1, r_2 and r_3 respectively. The masses m_1, m_2 and m_3 rotates in planes 1, 2, 3 respectively.

Choose a reference plane at 0 so that the distances of the planes 1, 2 and 3 from 0 are l_1, l_2 and l_3 respectively.

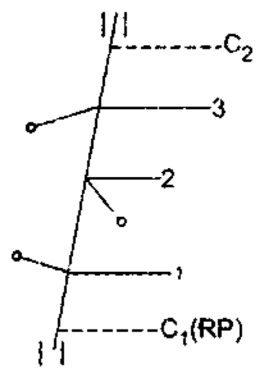
The unbalanced forces in the reference plane are $m_1 r_1 \omega^2$, $m_2 r_2 \omega^2$ and $m_3 r_3 \omega^2$ acting radially outwards.

The unbalanced couples in the reference planes are $m_1 r_1 \omega^2 l_1$, $m_2 r_2 \omega^2 l_2$ and $m_3 r_3 \omega^2 l_3$.

For complete balancing of the rotor, the resultant force and the resultant couple both should be zero.

$$m_1 r_1 \omega^2 + m_2 r_2 \omega^2 + m_3 r_3 \omega^2 = 0$$

$$m_1 r_1 l_1 \omega^2 + m_2 r_2 l_2 \omega^2 + m_3 r_3 l_3 \omega^2 = 0$$



Consider C_1 and C_2 be planes where masses m_{C1} and m_{C2} are used to balance

$$\therefore \quad \Sigma mrl \cos\theta + m_{C2} r_{C2} l_{C2} \cos\theta_{C2} = 0$$

$$\Sigma mrl \sin\theta + m_{C2} r_{C2} l_{C2} \sin\theta_{C2} = 0$$

$\therefore$ By these equation 0 for the balancing masses and their magnitude can be calculated.