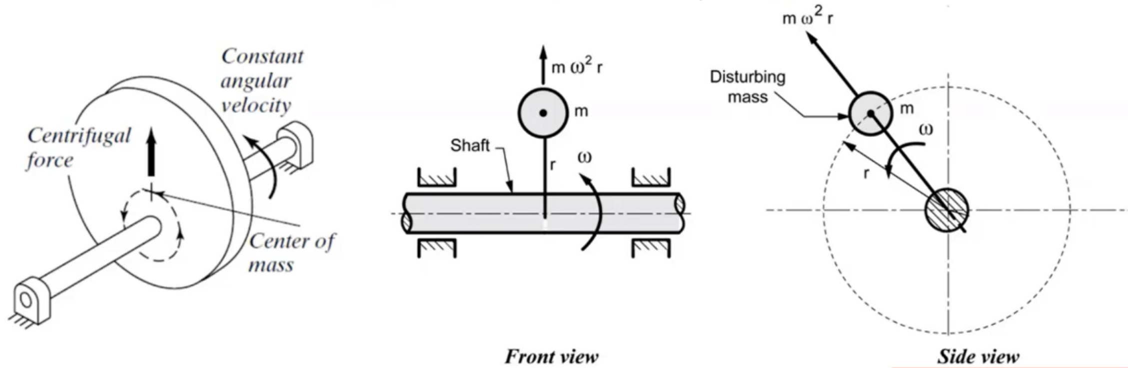
Balancing of Single Rotating Mass



Out-of-balance force = Inertia force = Centrifugal force $F_C = m\,\omega^2\,r$

Two ways to balance the out-of-balance force:

Method 1: By Introducing Single Revolving Mass in the Same Plane

Method 2: By Introducing Two Revolving Masses in Different Planes

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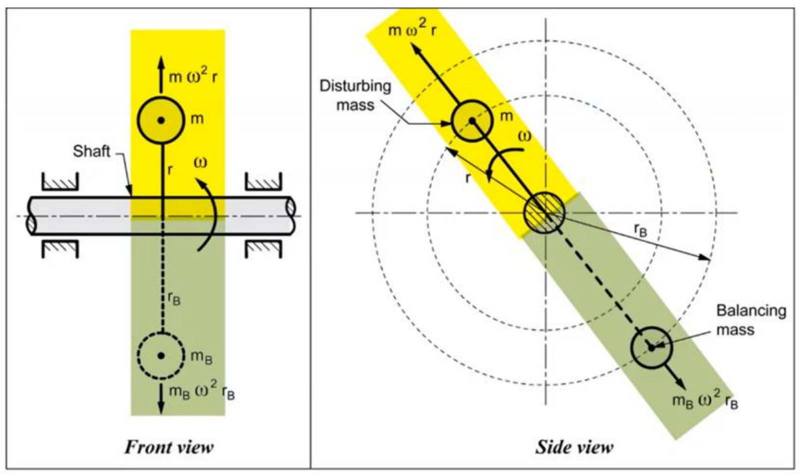
Balancing of Single Rotating Mass

Method 1: By Introducing Single Revolving Mass in the Same Plane

Let

mB = Mass of balancing mass

rB = Radius of rotation of mB



$$\text{Disturbing force, } F_{C1} = m\,\omega^2\,r$$

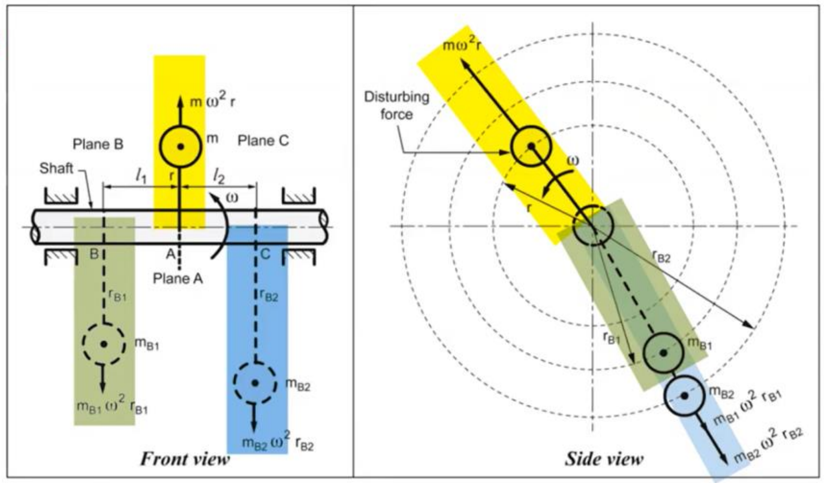
$$\text{Balancing force, } F_{C2} = m_B\,\omega^2\,r_B$$

$$\text{But for balancing, } F_{C1} = F_{C2} \quad \text{or} \quad m\,\omega^2\,r = m_B\,\omega^2\,r_B$$

$$\therefore \quad m\,r = m_B\,r_B$$

Balancing of Single Rotating Mass

Method 2: By Introducing Two Revolving Masses in Different Plane

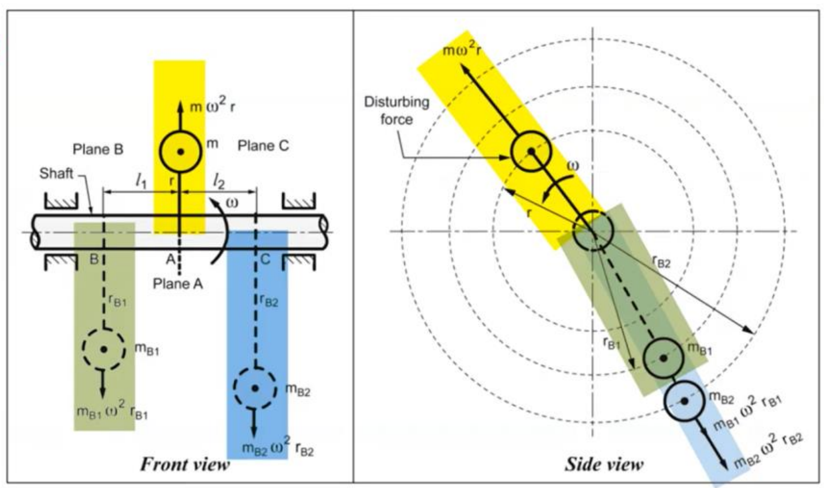


Conditions for balancing of the system:

1. The resultant centrifugal force must be zero.
2. The resultant couple (about a reference plane) must be zero.

Balancing of Single Rotating Mass

Method 2: By Introducing Two Revolving Masses in Different Plane



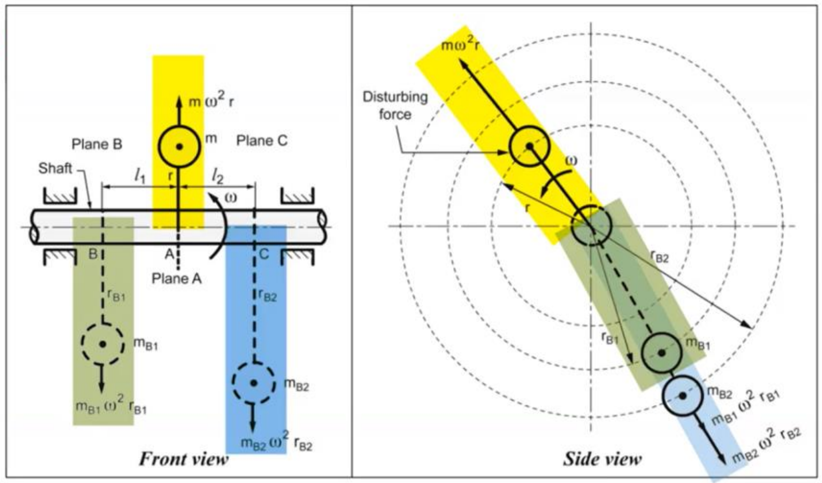
Applying Condition 1 of Force Balancing:

$$F_C = F_{C1} + F_{C2} \text{ or } m\,\omega^2\,r = m_{B1}\,\omega^2\,r_{B1} + m_{B2}\,\omega^2\,r_{B2}$$

$$\boxed{m\,r = m_{B1}\,r_{B1} + m_{B2}\,r_{B2}}$$

Balancing of Single Rotating Mass

Method 2: By Introducing Two Revolving Masses in Different Plane



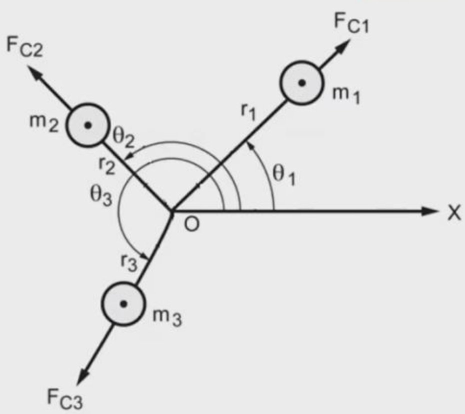
Applying Condition 2 of Couple Balancing:

Taking moments about C, we get

$F_{C1}\, l = F_C\, l_2$ or $(m_B\, \omega^2 r_{B1})\, l = (m\, \omega^2 r)\, l_2$ or $\boxed{m_{B1}\, r_{B1}\, l = m\, r\, l_2}$ → 2

Balancing of Several Masses Revolving in the Same Plane

Consider a three-rotor system in the same plane.



Angular position of planes

Given Data:

Masses - m1, m2, m3

Radius of rotations - r1, r2, r3

Relative anglular positions - theta1, theta2, theta3

To Find:

Magnitude of Balancing Mass (mB)

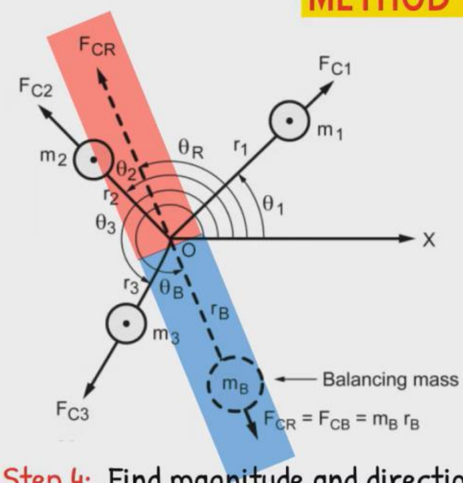
Position of Balancing Mass (thetaB)

Method 1: Analytical Method

Method 2: Graphical Method

Balancing of Several Masses Revolving in the Same Plane

METHOD 1: ANALYTICAL METHOD



Step 1: Find centrifugal forces exerted by each rotating mass. Fc1 = m1.r1; Fc2 = m2.r2; Fc3 = m3.r3.

Step 2: Resolve the centrifugal forces horizontally and vertically and find their sums.

$$\therefore \quad \Sigma F_H = m_1 r_1 \cos\theta_1 + m_2 r_2 \cos\theta_2 + m_3 r_3 \cos\theta_3$$

$$\text{and} \quad \Sigma F_V = m_1 r_1 \sin\theta_1 + m_2 r_2 \sin\theta_2 + m_3 r_3 \sin\theta_3$$

Step 3: Find magnitude and direction of resultant force.

$$F_{CR} = \sqrt{(\Sigma F_H)^2 + (\Sigma F_V)^2}$$

$$\theta_R = \tan^{-1}\left(\frac{\Sigma F_V}{\Sigma F_H}\right)$$

Step 4: Find magnitude and direction of balancing mass.

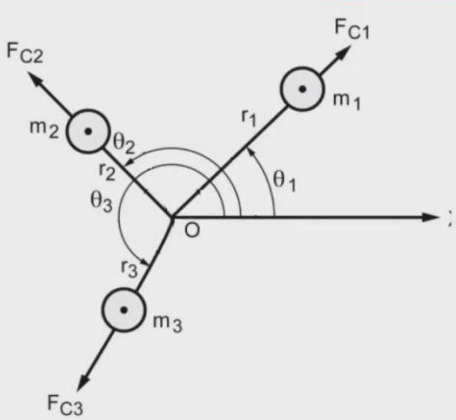
$$F_{CR} = m_B r_B$$

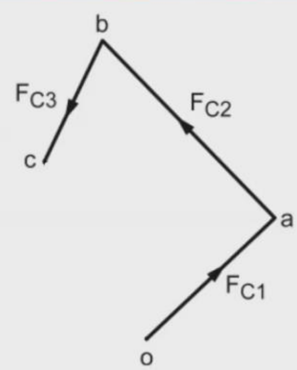
$$\theta_B = \theta_R + 180°$$

Balancing Force = Resultant Force & in Opposite Direction

Balancing of Several Masses Revolving in the Same Plane

METHOD 2: GRAPHICAL METHOD





Force polygon

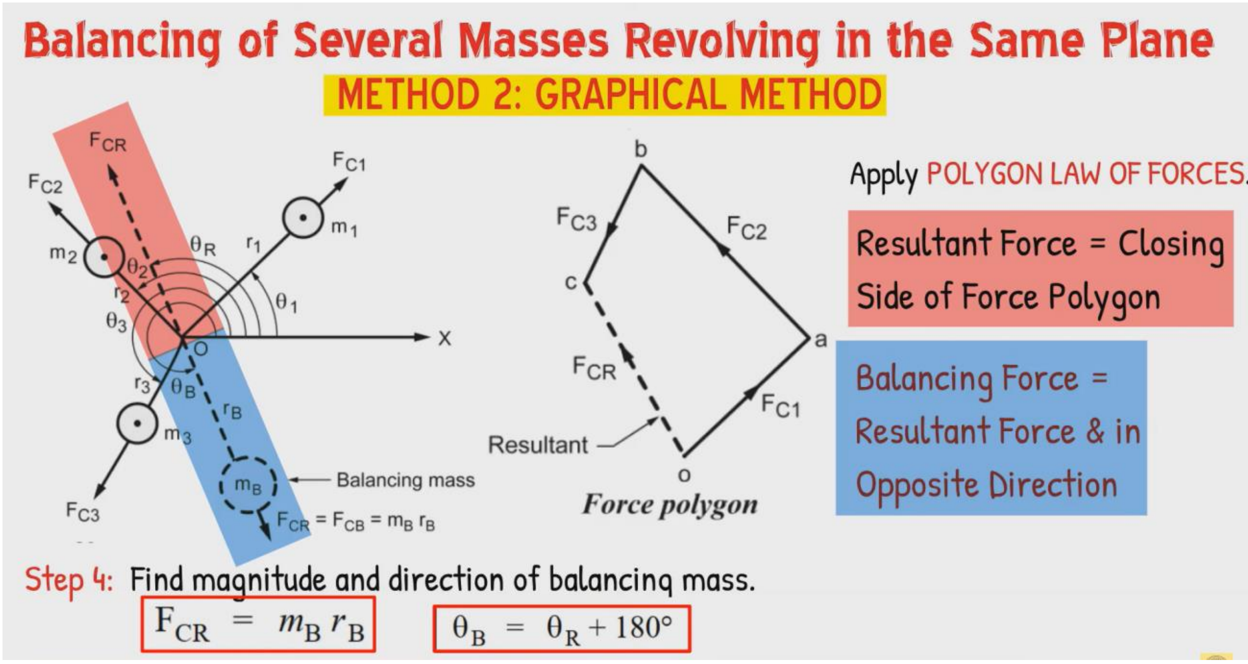
Step 1: Draw the space diagram with position of masses.

Step 2: Find centrifugal forces exerted by each rotating mass. Fc1 = m1.r1; Fc2 = m2.r2; Fc3 = m3.r3.

Step 3: Draw force polygon.

If Force Polygon is Closed ➡ Resultant = 0 ➡ No out-of-balance forces in the system

If Force Polygon is Open ➡ Resultant is not zero ➡ We have OUT-OF-BALANCE FORCE



Governors

- The function of a governor is to regulate the mean speed of an engine, when there are variations in the load *e.g.* when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid.
- On the other hand, when the load on the engine decreases, its speed increases and thus less working fluid is required.
- The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.