Internal Assessment Test III – Jan 2022

Sub: Dynamics of Machinery | **Code:** 18ME53

Date: 27/ 01 / 2022 | **Duration:** 90 mins | **Max Marks:** 50 | **Sem:** V | **Branch:** MECH

Note: Answer any **five** questions.

	Question	Marks	OBE CO	OBE RBT
1	State the conditions for the equilibrium of following systems: i. Two force member ii) Three force member	**4**	CO1	L1
2	A four link mechanism is acted upon by forces as shown in the fig (a). Determine the torque T_2 to be applied on link 2 to keep the mechanism in equilibrium. AD=50mm, AB=40mm, BC=100mm, DC=75mm, DE= 35mm.	**16**	CO1	L3

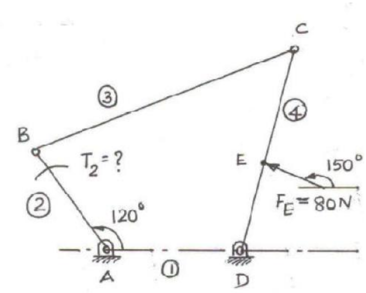


fig (a)

Internal Assessment Test III – Jan 2022

Sub: Dynamics of Machinery | **Code:** 18ME53

Date: 27/ 01 / 2022 | **Duration:** 90 mins | **Max Marks:** 50 | **Sem:** V | **Branch:** MECH

Note: Answer any **five** questions.

1 State the conditions for the equilibrium of following systems: i. Two force member ii) Three force member — 4, CO1, L1

2 A four link mechanism is acted upon by forces as shown in the fig (a). Determine the torque T_2 to be applied on link 2 to keep the mechanism in equilibrium. AD=50mm, AB=40mm, BC=100mm, DC=75mm, DE= 35mm. — 16, CO1, L3

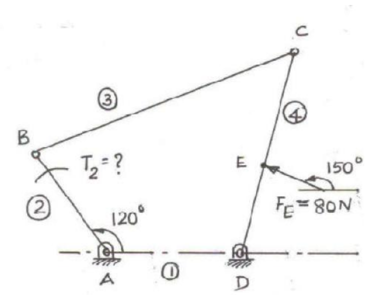


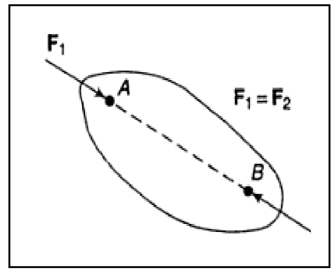
fig (a)

3.	A TV set of 25 kg mass must be isolated from a machine vibrating with amplitude of 0.1 mm at 1000 rpm. The TV set is mounted on five isolators each having a stiffness of 30,000 N/m and a damping constant of 400 N-s/m. Determine i. Amplitude of vibration of the body (i.e TV Set) ii. Dynamic load on each isolator due to vibration.	**10**	CO6	L3
4	An aeroplane flying at 240 km/hr turns towards left and completes a quarter circle of 60 m radius. The mass of the rotary engine and the propeller of the plane amounts to 450 kg, with a radius of gyration of 320 mm. The engine speed is 2000 rpm clockwise when viewed from the rear. Determine the gyroscopic couple on the aircraft and state its effect. In what way the effect is changed when the aeroplane turns towards right?	**10**	CO4	L2
5	With neat sketches, enumerate on the effect of gyroscopic couple on steering and pitching of a ship	**10**	CO4	L2

3.	A TV set of 25 kg mass must be isolated from a machine vibrating with amplitude of 0.1 mm at 1000 rpm. The TV set is mounted on five isolators each having a stiffness of 30,000 N/m and a damping constant of 400 N-s/m. Determine i. Amplitude of vibration of the body (i.e TV Set) ii. Dynamic load on each isolator due to vibration.	**10**	CO6	L3
4	An aeroplane flying at 240 km/hr turns towards left and completes a quarter circle of 60 m radius. The mass of the rotary engine and the propeller of the plane amounts to 450 kg, with a radius of gyration of 320 mm. The engine speed is 2000 rpm clockwise when viewed from the rear. Determine the gyroscopic couple on the aircraft and state its effect. In what way the effect is changed when the aeroplane turns towards right?	**10**	CO4	L2
5	With neat sketches, enumerate on the effect of gyroscopic couple on steering and pitching of a ship	**10**	CO4	L2

Equilibrium of Two Force Members

A member under the action of two forces will be in equilibrium if



- The forces are of the same magnitude,
- The forces act along the same line, and the forces are in opposite directions

Equilibrium of Three Force Members

A member under the action of three forces will be in equilibrium if

- The resultant of the forces is zero, and
- The lines of action of the forces intersect at a point (known as *point of concurrency).*

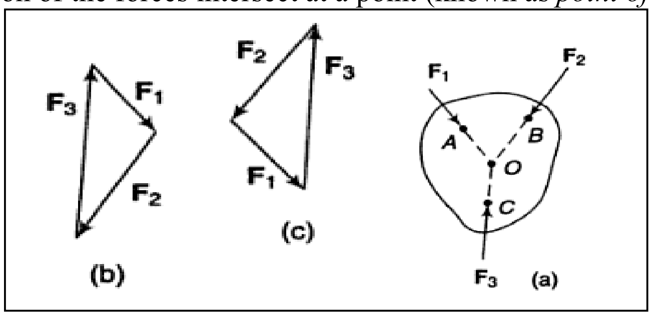


Figure (a) indicates an example for the three force member and (b) and (c) indicates the force polygon to check for the static equilibrium.

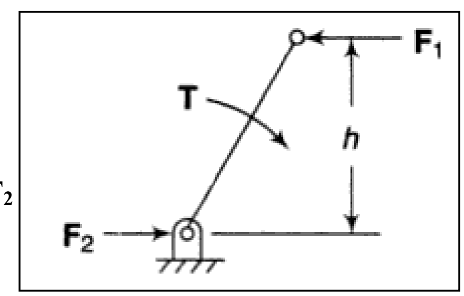
Member with two forces and a torque

A member under the action of two forces and an applied torque will be in equilibrium if

- The forces are equal in magnitude, parallel in direction and opposite in sense and
- The forces form a couple which is equal and opposite to the applied torque.

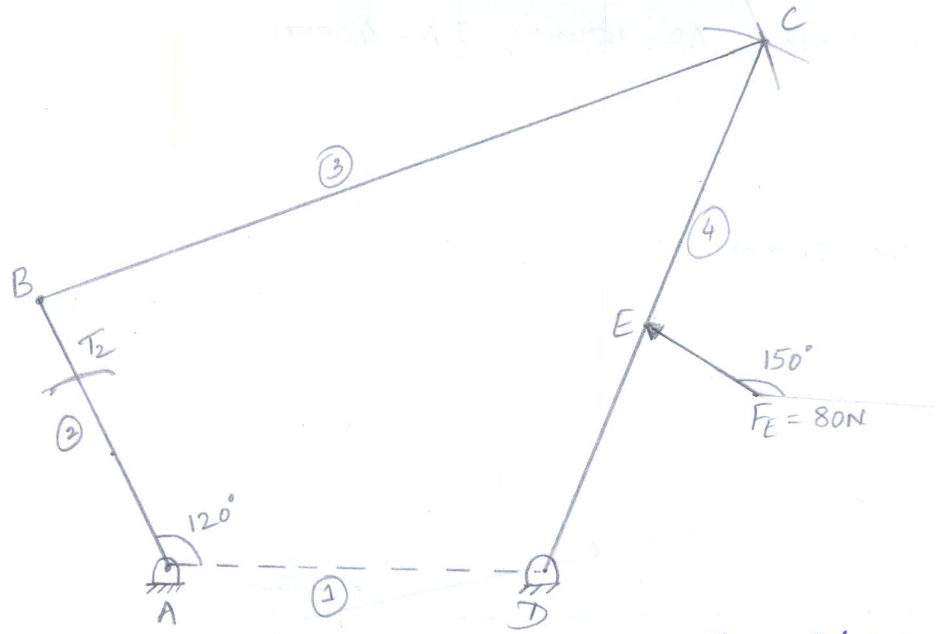
Figure shows a member acted upon by two equal forces $\mathbf{F_1}$, and $\mathbf{F_2}$ and an applied torque $\mathbf{T}$ for equilibrium,

$$T = F_1 h = F_2 h$$

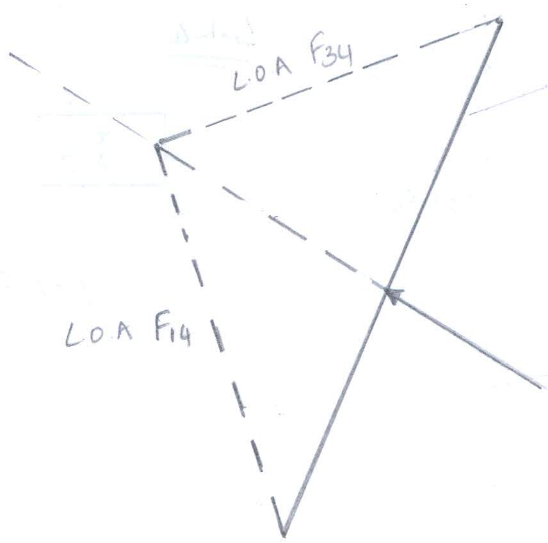


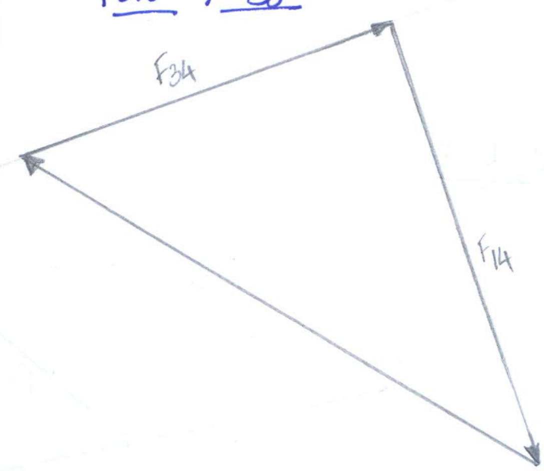
Where *T, F_1 and F_2 are the magnitudes of* $\mathbf{T}$*,* $\mathbf{F_1}$ *and* $\mathbf{F_2}$ respectively.

$\mathbf{T}$ is clockwise whereas the couple formed by $\mathbf{F_1}$, and $\mathbf{F_2}$ is counter-clockwise.



Force Polygon





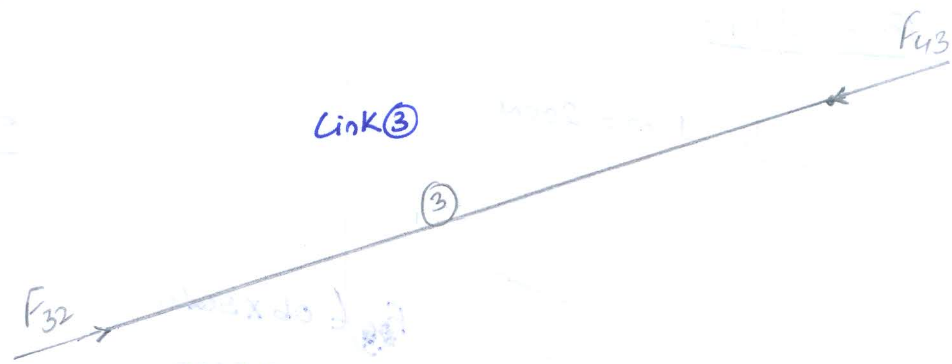
$F_{34} = 50N$

$F_{14} = 61N$

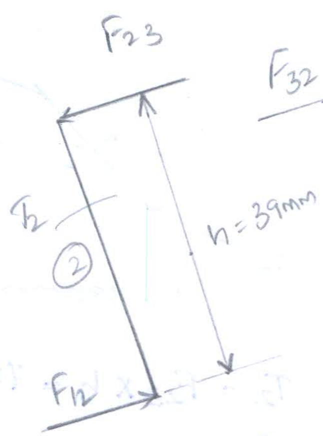
$F_{34} = -F_{43}$

$-F_{32} = +F_{23}$

Link 3



Link 2



$$T_2 = F_{23} \times h$$

$$= 50 \times 39$$

$$T_2 = 1.9 \text{ N-m}$$

Given $K = 30{,}000\ N/m$; $N = 1000\ rpm$

$m = 25\ kg$; $C = 400\ N\text{-}s/m$

$Y = 0.1\ mm$; No of isolators $= 5$

Equivalent Stiffness

$$K_e = 5 \times 30{,}000 = 15 \times 10^4\ N/m$$

Equivalent damping Coeff.

$$C = 5 \times 400 = 2000\ N\text{-}s/m$$

Circular freq. $\omega = \frac{2\pi N}{60} = \frac{2\pi(1000)}{60}$

$$\omega = 104.72\ r/s$$

Circular freq. of undamped Vib.

$$\omega_n = \sqrt{\frac{K_e}{m}} = \sqrt{\frac{15 \times 10^4}{25}} = 77.46\ r/s$$

Freq. ratio

$$\frac{\omega}{\omega_n} = \frac{104.72}{77.46} = 1.35$$

Damping ratio $\xi = \frac{C}{C_c} = \frac{2000}{2 \times 25 \times 77.46}$ $\because C_c = 2m\omega_n$

$$\xi = 0.52$$

i) <u>Amplitude of Vibration</u>

$$\frac{X}{Y} = \sqrt{\frac{1+\left(2\xi\frac{\omega}{\omega_n}\right)^2}{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

$$\frac{X}{0.1} = \sqrt{\frac{1+(2\times 0.52\times 1.35)^2}{(1-1.35^2)^2 + (2\times 0.52\times 1.35)^2}}$$

$$X = 0.1059\,mm$$

ii) <u>Dynamic load on isolator</u> (F_D)

$$F_D = Z\sqrt{K_e^2 + (C_e\omega)^2}$$

$$\frac{Z}{Y} = \frac{(\omega/\omega_n)^2}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

$$\frac{Z}{0.1} = \frac{(1.35)^2}{\sqrt{(1-1.35^2)^2 + (2\times 0.52\times 1.35)^2}}$$

$$Z = 0.112\,mm$$

$$F_D = 0.112\times 10^{-3}\sqrt{(15\times 10^4)^2 + (2000\times 104.72)^2}$$

$$F_D = 29\,N$$

Dynamic load on each isolator $= \frac{29}{5} = 5.8\,N$

Given : R = 60 m ; v = 240 km/hr = $\frac{240 \times 1000}{3600}$ = 66.67 m/s ; m = 450 kg ; k = 0.32 m

N = 2000 r.p.m. or ω = $2\pi N/60$ = 2π x 2000/60 = 209.43 rad/s

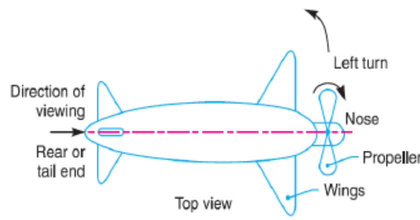
Mass moment of inertia of the rotor, $I = m\,k^2$ = 450 $(0.32)^2$ = 46.08 kg-m^2

Angular velocity of precession, $\omega_p = \frac{v}{R} = \frac{66.67}{60}$ = 1.11 rad/s

Gyroscopic couple, C = $I\,\omega\,\omega_p$ = 46.08 x 209.43x 1.11 = 10712.09 N-m

Effect

When the aero-plane turns towards left, the effect of the gyroscopic couple is to lift the nose upwards and tail downwards.



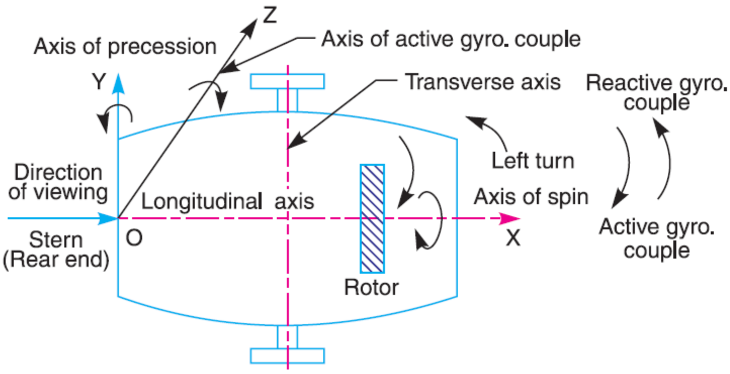
When the engine or propeller rotates in clockwise direction when viewed from the rear or tail end and the aeroplane takes a right turn, the effect of the reactive gyroscopic couple will be to dip the nose and raise the tail of the aeroplane.

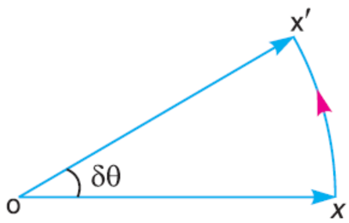
Effect of Gyroscopic Couple on a Naval Ship during Steering

•Steering is the turning of a complete ship in a curve towards left or right, while it moves forward.

•Consider the ship taking a left turn, and rotor rotates in the clockwise direction when viewed from the stern, as shown in Fig.

•The effect of gyroscopic couple on a naval ship during steering taking left or right turn may be obtained in the similar way as for an aeroplane.





(*a*) Streeing to the left

The effect of this reactive gyroscopic couple is to ***raise the bow*** *and* ***lower the stern****.*

When the ship steers to the right under similar conditions as discussed above, the effect of the reactive gyroscopic couple, *the effect of this reactive gyroscopic couple is to* ***raise the stern and lower the bow.***

Effect of Gyroscopic Couple on a Naval Ship during Pitching

•Pitching is the movement of a complete ship up and down in a vertical plane about transverse axis, as shown in Fig.

•In this case, the transverse axis is the axis of precession. The pitching of the ship is assumed to take place with simple harmonic motion i.e. the motion of the axis of spin about transverse axis is simple harmonic.