Improvement Test – Nov. 2017

Sub:	Dynamics of Machinery	**Code:**	15ME52
Date: 20/ 11 / 2017	**Duration:** 90 mins	**Max Marks:** 50	**Sem:** V
		Branch:	MECH

Note: Answer any **five** questions.

		Marks	OBE CO	RBT
1	State the conditions for the equilibrium of following systems: i. Two force member ii) Three force member iii) Member with two force and torque	**10**	CO1	L2
2	In a four-link mechanism shown in fig (a), torque T_3 and T_4 have magnitudes of 30 N-m and 20 N-m respectively. The link lengths are AD = 800 mm, AB = 300 mm, BC = 700 mm and CD = 400 mm. For the static equilibrium of the mechanism, determine the required input torque T_2	**10**	CO1	L4

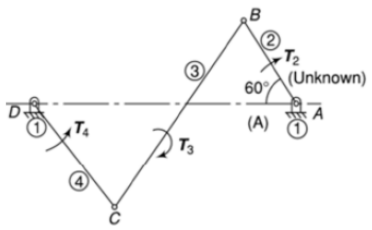
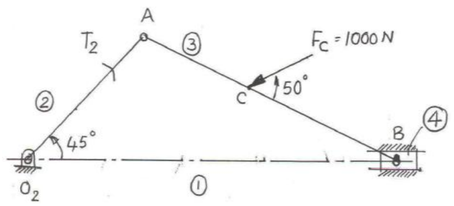


fig (a)

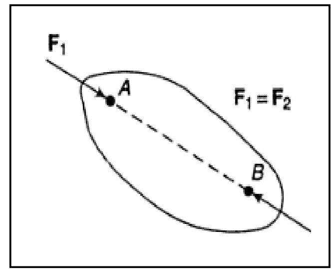


AC=70mm,
AB=150mm,
O_2A= 40mm

fig (b)

		Marks	CO	RBT
3	Determine torque T_2 to keep the mechanism in equilibrium shown in fig (b).	**10**	CO1	L3
4	a. With usual notations and diagrams, derive an expression for the gyroscopic couple produced by a rotating disc.	5	CO3	L2
	b. A disc of 5 kg mass with radius of gyration 70 mm is mounted at span on a horizontal shaft spins at 720 rpm in clockwise direction when viewed from the right hand bearing. If the shaft precesses about the vertical axis at 30 rpm in clockwise direction when viewed from the top, determine the gyroscopic couple.	**5**	CO3	L2
5	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**	CO3	L3
6	The turbine rotor of a ship has a mass of 3500 kg. It has a radius of gyration of 0.45 m and a speed of 3000 r.p.m, clockwise when looking from stern. Determine the gyroscopic couple and its effect upon the ship: i. When the ship is steering to the left on a curve of 100 m radius at a speed of 36 km/h. ii. When the ship is pitching in a simple harmonic motion, the bow falling with its maximum velocity. The period of pitching is 40 seconds and the total angular displacement between the two extreme positions of pitching is 12 degrees.	**10**	CO3	L4

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).*

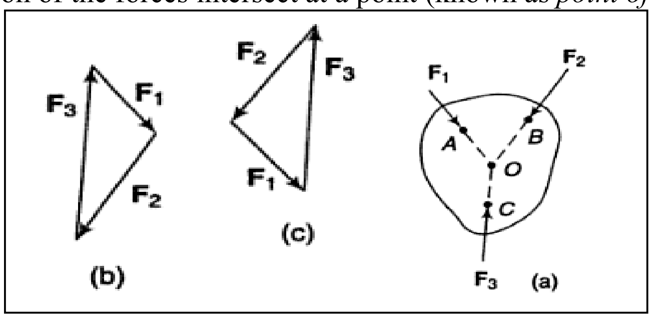


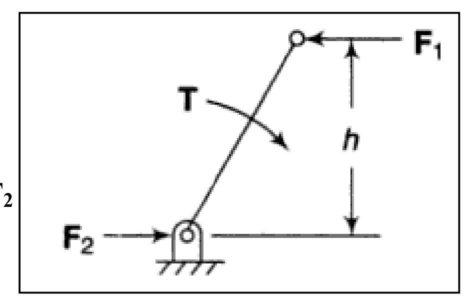
Figure (a) indicates an example for the three force member and (b) and (c) indicates the force polygon to check for the static equilibrium.

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 **T** for equilibrium,

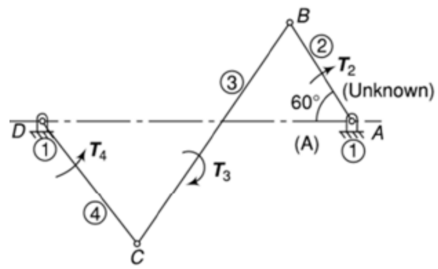


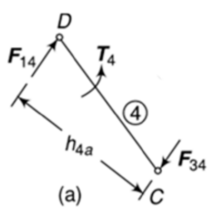
$$T = F_1 h = F_2 h$$

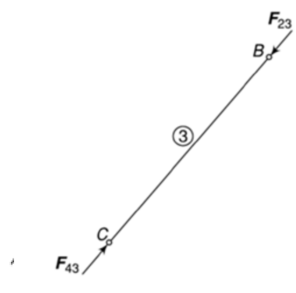
Where *T, F_1 and F_2 are the magnitudes of **T**, $\mathbf{F_1}$ and* $\mathbf{F_2}$ respectively.

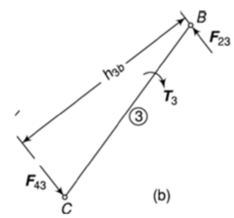
T is clockwise whereas the couple formed by $\mathbf{F_1}$, and $\mathbf{F_2}$ is counter-clockwise.

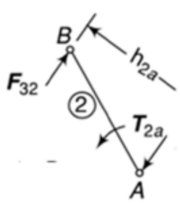
In a four-link mechanism shown in Fig., torque T_3 and T_4 have magnitudes of 30 N-m and 20 N-m respectively. The link lengths are AD = 800 mm, AB = 300 mm, BC = 700 mm and CD = 400 mm. For the static equilibrium of the mechanism, determine the required input torque T_2

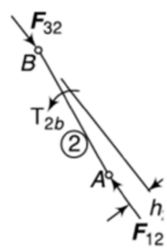












<u>Neglecting torque T_3</u>

Torque T_4 on the link 4 is balanced by a couple having two equal, parallel and opposite forces at C and *D*. As the link 3 is a two-force member, F_{43} and therefore, F_{34} and F_{14} will be parallel to *BC*.

$$F_{34} = F_{14} = \frac{T_4}{h_{4a}} = \frac{20}{0.383} = 52.2 \text{ N}$$

and $F_{34} = F_{43} = F_{23} = F_{32} = F_{12} = 52.2$ N

$T_{2a} = F_{32} \times h_{2a} = 52.2 \times 0.274 = 14.3$ N.m counter-clockwise.

<u>Neglecting torque T_4</u>

F_{43} is along CD. The diagram is self-explanatory.

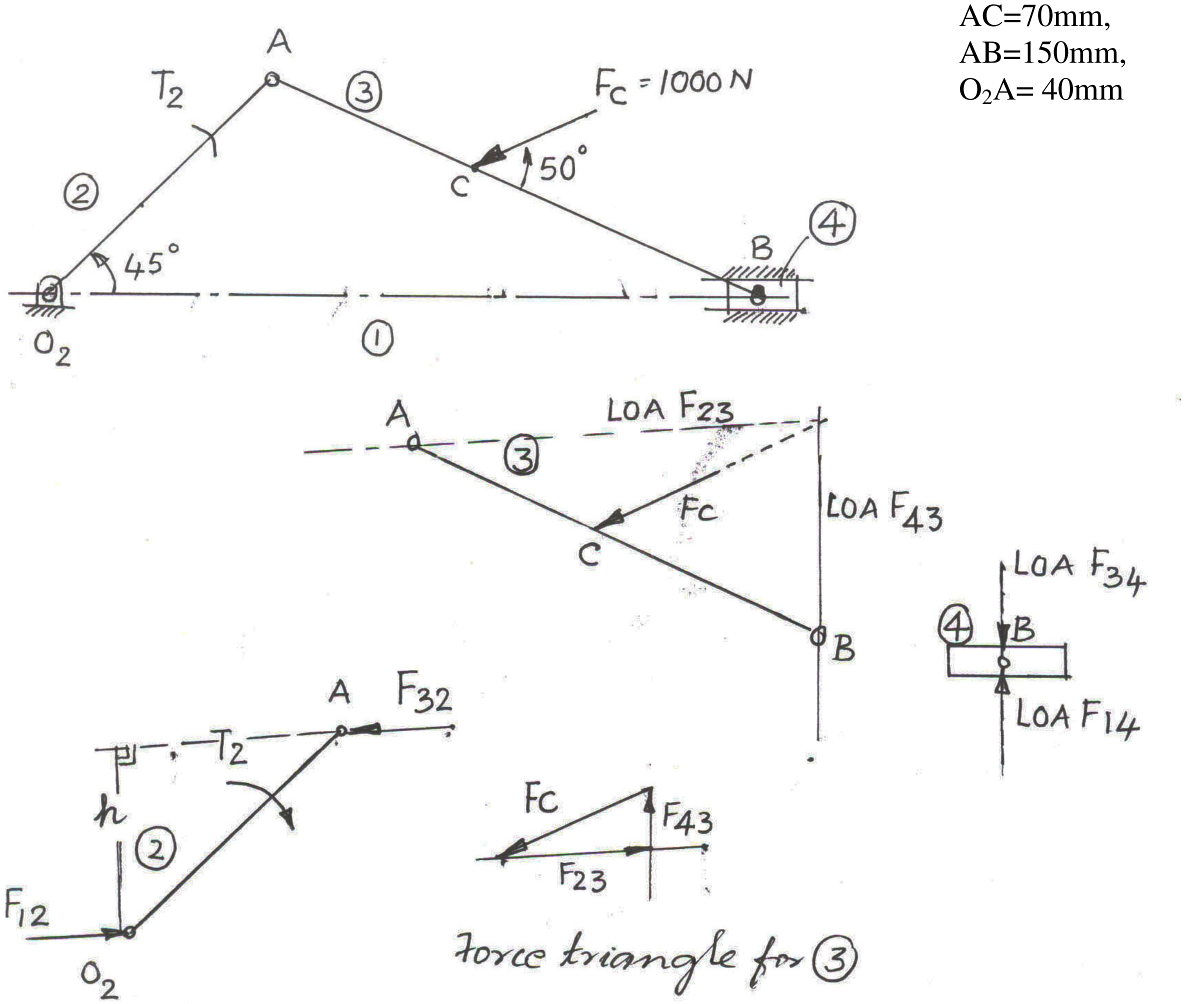
$$F_{43} = F_{23} = \frac{T_3}{h_{3b}} = \frac{30}{0.67} = 44.8 \text{ N} \quad ; \quad F_{23} = F_{32} = F_{12} = 44.8 \text{ N}$$

$T_2 = T_{2a} + T_{2b}$ = 14.3 + 1.88 = <u>16.18N</u> Counter clockwise

3

Determine T_2 to keep the mechanism in equilibrium

AC=70mm,
AB=150mm,
O_2A= 40mm



$$T_2 = F_{32} \times h = F_{12} \times h$$

F_{32} and F_{12} form a CCW couple and hence T_2 acts clock wise.

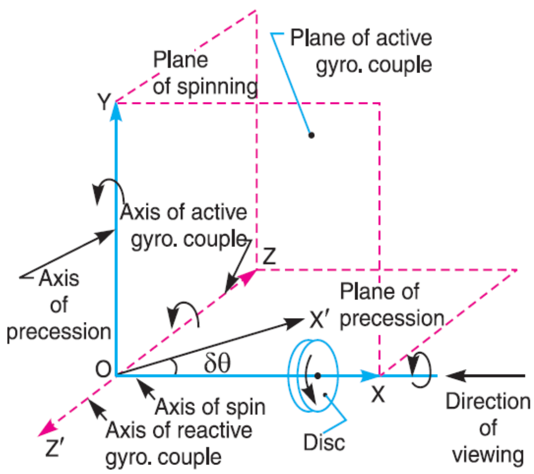
F_{23} = 840 N; F_{43} = 540 N; T_2 = 27.72 N-m

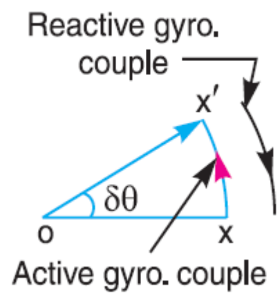
4.a

Gyroscopic Couple

•Consider a disc spinning with an angular velocity ω rad/s about the axis of spin OX, in anticlockwise direction when seen from the front, as shown in Fig.

•Since the plane in which the disc is rotating is parallel to the plane YOZ therefore it is called plane of spinning.





Let I = Mass moment of inertia of the disc about OX, and

ω = Angular velocity of the disc.

Angular momentum of the disc = $I\omega$

∴ Change in angular momentum

$$= \vec{ox'} - \vec{ox} = \vec{xx'} = \vec{ox}.\delta\theta \qquad \text{...(in the direction of } \vec{xx'}\text{)}$$

$$= I.\ \omega.\delta\theta$$

and rate of change of angular momentum

$$= I.\omega \times \frac{\delta\theta}{dt}$$

Since the rate of change of angular momentum will result by the application of a couple to the disc, therefore the couple applied to the disc causing precession,

$$C = \underset{\delta t \to 0}{\mathrm{Lt}}\ I.\omega \times \frac{\delta\theta}{\delta t} = I.\omega \times \frac{d\theta}{dt} = I.\omega.\omega_P \qquad \text{...}\left(\because \frac{d\theta}{dt} = \omega_P\right)$$

4. b

Angular velocity:

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 720}{60}$$

$$= 75.4 \text{ rad/s}$$

Angular velocity of precession: $\omega_p = \frac{2\pi N_p}{60}$

$$= \frac{2\pi \times 30}{60} = 3.14 \text{ rad/s}$$

Moment of inertia: $I = mk^2$

$$= 5 \times 0.07^2 = 0.0245 \text{ kg m}^2$$

Gyroscopic couple: $C = I\,\omega\omega_p$

$$= 0.0245 \times 75.4 \times 3.14$$

$$= 5.8 \text{ Nm}$$

5.

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

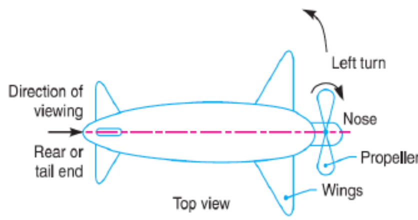
Mass moment of inertia of the rotor, $I = m k^2$ = 450 $(0.32)^2$ = 46.08 kg-m^2

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.

6.

Given: m = 3500 kg ; k = *045* m;

N = 3000 r.p.m. or ω = *2Π* x 3000/60 = 314.2 rad/s

i. *When the ship is steering to the left*

Given: R = 100 m; v = km/h = 10 m/s

Mass moment of inertia of the rotor, $I = m k^2$ = 3500 $(0.45)^2$ = 708.75 kg-m^2

Angular velocity of precession, $\omega_p = \frac{v}{R} = \frac{10}{100}$ = 0.1 rad/s .

Gyroscopic couple, C = $I \omega \omega_p$ = 708.75 x 314.2 x 0.1 = 22 270 N-m = 22.27 kN-m.

ii. When the ship is pitching with the bow falling

Given: t_p = 40 s

Total angular displacement between the two extreme positions of pitching is 12 *(i.e* 2ϕ = 12°), therefore amplitude of swing,

ϕ = 12/2= 6° ; $6^{\circ} = \frac{6\times\pi}{180} = 0.105$ rad

Angular velocity of the simple harmonic motion,

$$\omega_1 = \frac{2\pi}{t_p} = \frac{2\pi}{40} = 0.157\ r/s$$

Maximum angular velocity of precession,

$$\omega_p = \emptyset\omega_1 = 0.105 \times 0.157 = 0.0165\ rad/s$$

Gyroscopic couple, C = $I\ \omega \omega_p$

= 708.75 x 3142 x 0.0165 = 3675 N-m = 3.675 kN-m.

When the bow is falling *(i.e. when the pitching is downward)*, the effect of the reactive gyroscopic couple is to **move the ship towards port side.**