Internal Assessment Test IV – Feb 2022

Sub:	Dynamics of Machinery	**Code:**	18ME53
Date: 03/ 02 / 2022	Duration: 90 mins Max Marks: 50 **Sem:** V	**Branch:**	MECH

Note: Answer **all** questions.

		Marks	OBE CO	OBE RBT
1	Define the following i)Sensitiveness (ii) Isochronism (iii)Hunting of governor (iv)Effort of governor.	**4**	CO3	L1
2	Derive an expression for equilibrium speed of governor.	**10**	CO3	L2
3	In a porter governor, the upper and lower arms are 200 mm and 250 mm respectively and pivoted on the axis of rotation. The mass of central load is 15 kg, the mass of each ball is 2 kg and friction of the sleeve together with the resistance of the operating gear is equal to a load of 24 N at the sleeve. If the limiting inclinations of the upper arms to the verticals are 30° and 40°. Find the range of speed taking friction in to account.	**16**	CO3	L3
4	Determine i) Critical damping coefficient ii) damping factor (iii) natural frequency of damped vibration (iv) logarithmic decrement (v) ratio of two consecutive amplitudes which consists of mass of 25 kg, a spring of stiffness 15kN/m and a damper. The damping provided is only 15% of critical value.	**10**	CO5	L3
5	With neat sketches, enumerate on the effect of gyroscopic couple on an aeroplane	**10**	CO4	L2

Solution for Internal Assessment Test IV - Jan 2022

1. a

SENSITIVENESS

It is defined as the ratio of the difference between the maximum & minimum equilibrium speeds to the mean equilibrium Speed.

Mean Speed $N = \frac{N_1 + N_2}{2}$

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

$$= \frac{2(\omega_2 - \omega_1)}{\omega_1 + \omega_2}$$

ISOCHRONOUS GOVERNOR

A governor is said to be isochronous when the equilibrium Speed is constant (i.e range of Speed is zero) for all radii of rotation of the balls within the working range, neglecting friction.

HUNTING

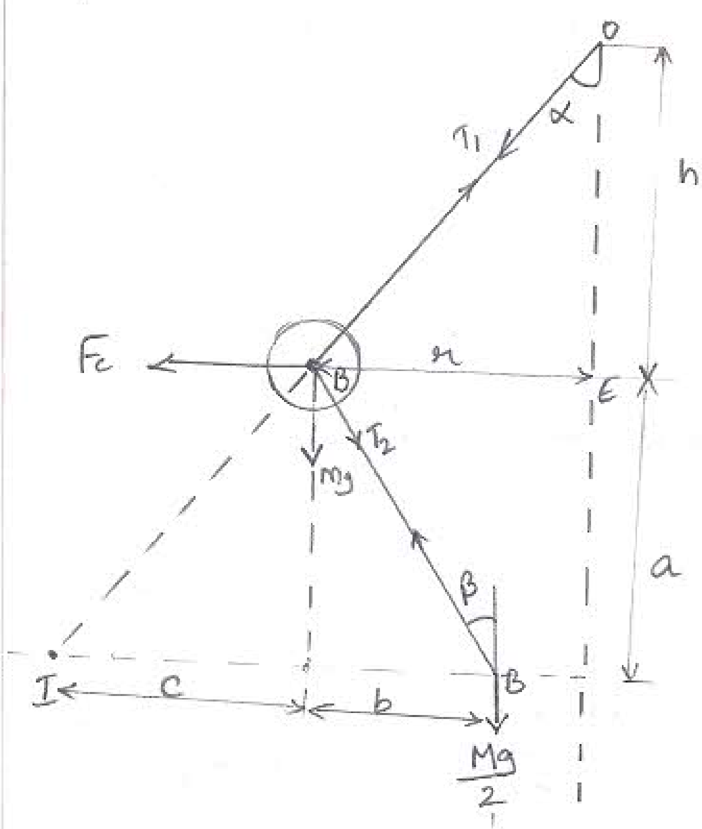
A governor is said to be hunt if the speed of the engine fluctuates continuously above & below the mean speed. This is caused by a sensitive governor. In actual practice hunting is impossible in an isochronous governor because of friction of mechanism.

EFFORT & POWER OF A GOVERNOR

The effort of a governor is the mean force exerted at the sleeve for a given percentage change of speed.

2 Instantaneous Centre method.

In this method, equilibrium of forces acting on link AB is considered.



For equilibrium $\Sigma F = 0$; $\Sigma M = 0$

Taking moment about I.

$$F_c \cdot a = mg \cdot c + \frac{Mg}{2}\left[c + b\right] \quad \rightarrow (1)$$

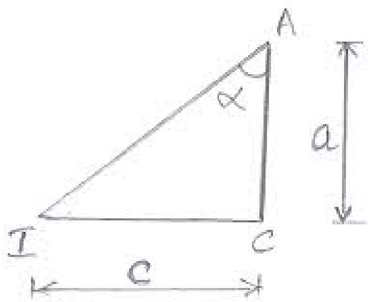
Centrifugal force $F_c = m\omega^2 r$

Substituting this in eqn (1)

$$m\omega^2 r . a = mg \cdot c + \frac{Mg}{2}\left[c + b\right]$$

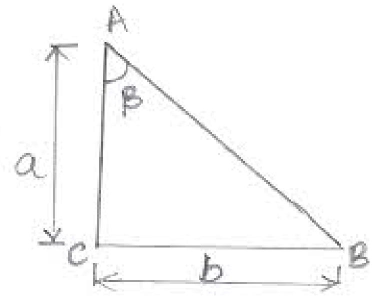
$$m\omega^2 r = mg \cdot \frac{c}{a} + \frac{Mg}{2}\left[\frac{c}{a} + \frac{b}{a}\right] \quad \rightarrow (2)$$

Consider Δ^{le} ACI



$$\tan\alpha = \frac{c}{a} \rightarrow \text{(A)}$$

Consider Δ^{le} ACB



$$\tan\beta = \frac{b}{a} \rightarrow \text{(B)}$$

Substituting (A) & (B) in eqn (2) we get

$$m\omega^2 r = mg.\tan\alpha + \frac{Mg}{2}\left[\tan\alpha + \tan\beta\right]$$

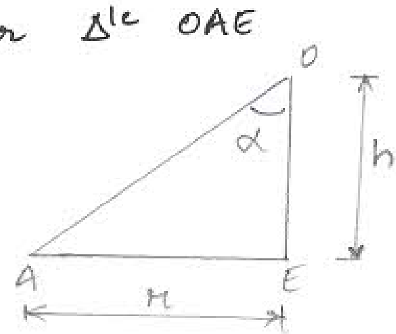
$$m\omega^2 r = \tan\alpha\left[mg + \frac{Mg}{2}\left(1 + \frac{\tan\beta}{\tan\alpha}\right)\right] \rightarrow (3)$$

Denote $\frac{\tan\beta}{\tan\alpha} = K$

Equation (3) becomes

$$m\omega^2 r = \tan\alpha\left[mg + \frac{Mg}{2}(1+K)\right] \rightarrow (4)$$

Consider Δ^{le} OAE



$$\tan\alpha = \frac{r}{h} \rightarrow \text{(C)}$$

Substitute (C) in eqn (4) we get

$$m\omega^2 r = \frac{r}{h}\left[mg + \frac{Mg}{2}(1+K)\right]$$

$$\omega^2 = \frac{r}{mrh}\left[mg + \frac{Mg}{2}(1+K)\right]$$

$$= \frac{1}{mh}\left[mg + \frac{Mg}{2}(1+K)\right]$$

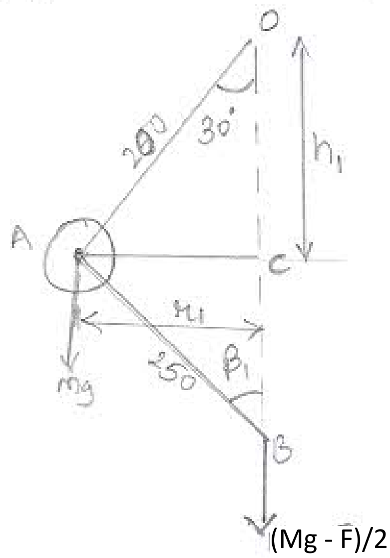
$$\left(\frac{2\pi N}{60}\right)^2 = \frac{1}{mh}\left[mg + \frac{Mg}{2}(1+K)\right]$$

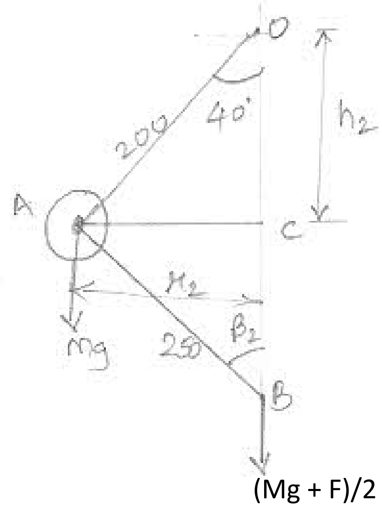
$$= \frac{g}{h}\left[\frac{m + \frac{M}{2}(1+K)}{m}\right]$$

$$\boxed{N^2 = \frac{895}{h}\left[\frac{m + \frac{M}{2}(1+K)}{m}\right]}$$

3. In an engine governor of the Porter type, the upper & lower arms are 200 mm & 250 mm respectively & pivoted on the axis of rotation. The mass of the Central load is 15 Kg, the mass of each ball is 2 kg & friction of the Sleeve together with the resistance of the operating gear is equal to a load of 24 N at the Sleeve. If the limiting inclinations of the upper arms to the vertical are 30° & 40°, find, taking friction into account, range of Speed of the governor.

Sol:





Given :- $OA = 200\ mm = 0.2 m$; $AB = 0.25 m$, $M = 15\ Kg$,

$m = 2\ Kg$; $F = 24 N$; $\alpha_1 = 30°$, $\alpha_2 = 40°$

From fig. a. $r_1 = 0.2 \sin 30° = 0.2 \times 0.5 = 0.1 m$

Height of governor,

$h_1 = 0.2 \cos 30° = 0.2 \times 0.866 = 0.1732\ m$

$BC = \sqrt{0.25^2 - 0.1^2} = 0.23 m.$

$$\tan \beta_1 = \frac{0.1}{0.23} = 0.4348$$

$$\tan \alpha_1 = \tan 30° = 0.5774.$$

$$K_1 = \frac{\tan \beta_1}{\tan \alpha_1} = \frac{0.4348}{0.5774} = 0.753$$

$$N_1^2 = \frac{895}{h_1} \cdot \left[\frac{m.g + \frac{M.g - F}{2} (1+K_1)}{mg} \right]$$

$$= \frac{895}{0.1732} \left[\frac{2 \times 9.81 + \left(\frac{15 \times 9.81 - 24}{2}\right)(1+0.753)}{2 \times 9.81} \right]$$

$$= 33596.$$

$$N_1 = \sqrt{33596} = 183.3 \text{ rpm}$$

$$\boxed{N_1 = 183.3 \text{ rpm}}$$

From fig. b. $r_2 = 0.2 \sin 40° = 0.2 \times 0.643 = 0.1268$ m

Height of governor,

$$h_2 = 0.2 \cos 40° = 0.2 \times 0.766 = 0.1532 \text{ m}$$

$$BC = \sqrt{0.25^2 - 0.1268^2} = 0.2154 \text{ m}$$

$$\tan \beta_2 = \frac{0.1268}{0.2154} = 0.59.$$

$$\tan \alpha_2 = \tan 40° = 0.839$$

$$K_2 = \frac{\tan \beta_2}{\tan \alpha_2} = \frac{0.59}{0.839} = 0.703$$

$$N_2^2 = \frac{895}{h_2}\left[\frac{mg + \frac{Mg+F}{2}(1+k_2)}{mg}\right]$$

$$= \frac{895}{0.1532}\left[\frac{2\times 9.81 + \frac{15\times 9.81 + 24}{2}(1+0.703)}{2\times 9.81}\right]$$

$$= 49,236$$

$$N_2 = \sqrt{49236} = 222 \text{ rpm}$$

$$\boxed{N_2 = 222 \text{ rpm}}$$

Range of Speed

$$= N_2 - N_1$$

$$= 222 - 183.3$$

$$= 38.7 \text{ rpm}$$

CMR

4) $M = 25\,kg$; $K = 15\,kN/m = 15{,}000\,N/m$; $C = 0.15\,C_c$

Damping factor $\xi = \frac{c}{c_c} = \frac{0.15\,C_c}{C_c} = 0.15$

Critical damping Coeff. $C_c = 2m\omega_n = 2 \times 25 \times \sqrt{\frac{15{,}000}{25}}$

$C_c = \qquad N\text{-}s/m$

Logarithmic decrement $\delta = \frac{2\pi\xi}{\sqrt{1-\xi^2}} = \frac{2\pi(0.15)}{\sqrt{1-0.15^2}}$

$\delta = 0.9439$

Ratio of two Cons. amp'

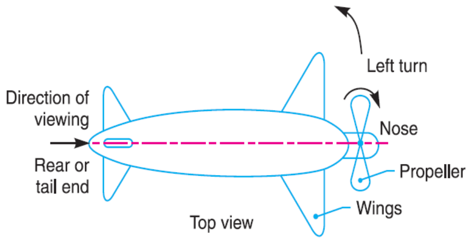
$\delta = \ln\left(\frac{x_n}{x_{n+1}}\right)$

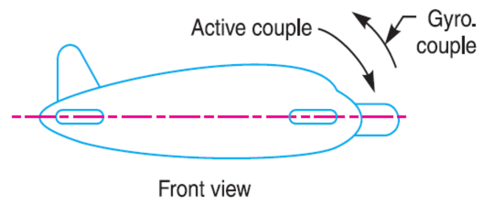
$\frac{x_n}{x_{n+1}} = e^{\delta} = e^{0.9439} = 2.57$

Effect of the Gyroscopic Couple on an Aero-plane

The top and front view of an aero-plane are shown in Fig.

Let engine or propeller rotates in the clockwise direction when seen from the rear or tail end and the aero-plane takes a turn to the left.

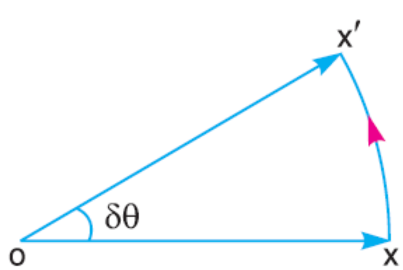




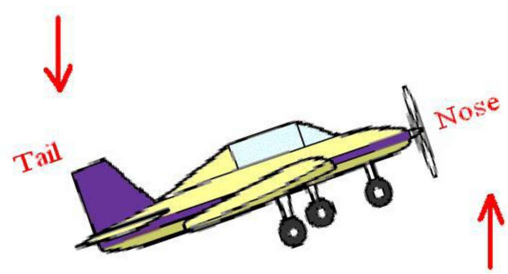
Let
ω = Angular velocity of the engine in rad/s,
m = Mass of the engine and the propeller in kg,
k = Its radius of gyration in metres,
I = Mass moment of inertia of the engine and the propeller in kg-m = $m.k^2$,
v = Linear velocity of the aeroplane in m/s, R = Radius of curvature in metres, and
ω_p = Angular velocity of precession = $\frac{v}{R} =$ rad/s

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

Before taking the left turn, the angular momentum vector is represented by ox.
•When it takes left turn, the active gyroscopic couple will change the direction of the angular momentum vector from ox to ox' as shown in Fig (a).
•The vector xx', in the limit, represents the change of angular momentum or the active gyroscopic couple and is perpendicular to ox.

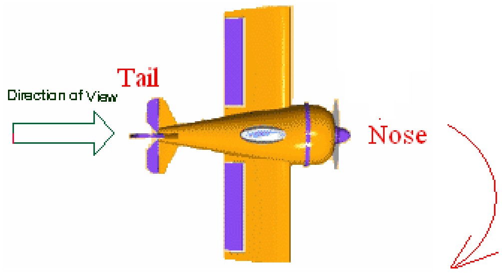


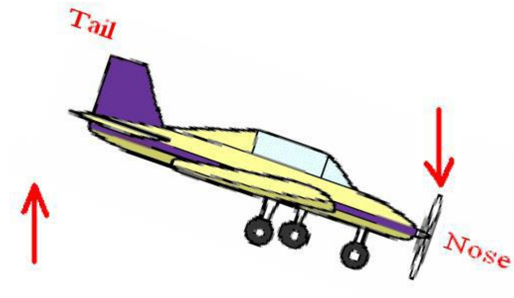
(*a*) Aeroplane taking left turn.



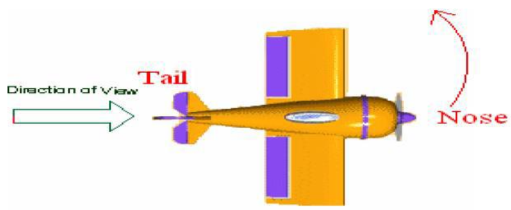
Effect of this couple is, to **raise the nose** and **dip the tail** of the aeroplane.

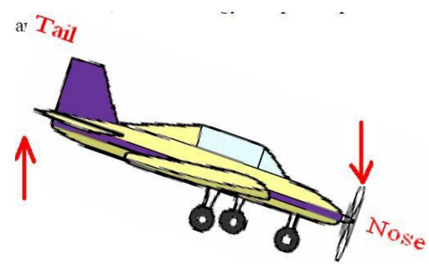
1. When the engine or propeller rotates in **clockwise** direction when viewed from the **rear** or tail end and the aeroplane takes a **right** turn, the effect of the reactive gyroscopic couple will be to **dip the nose** and **raise the tail** of the aeroplane.



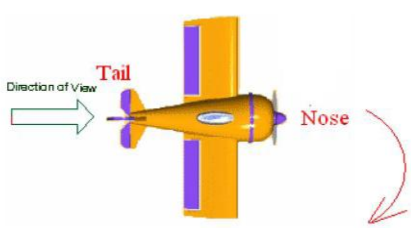


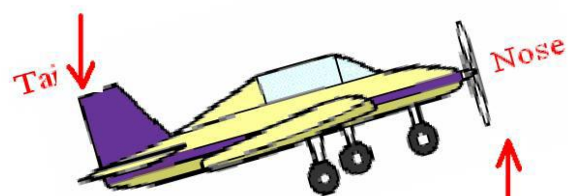
2.When the engine or propeller rotates in **anticlockwise** direction when viewed from the **rear** or tail end and the aeroplane takes a **left** turn, then the effect of reactive gyroscopic couple will be to **dip the nose** and **raise the tail** of the aeroplane.





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





4. When the engine or propeller rotates in **clockwise** direction when viewed from the **front** and the aeroplane takes a **left** turn, then the effect of reactive gyroscopic couple will be to **raise the tail** and **dip the nose** of the aeroplane.