Rajasthan Institute of Engineering & Technology,Jaipur.

Department of Mechanical Engineering

I Mid Term examination
Session: 2018-19
VSemester & ME
Dynamics of Machines 5ME2A

Time: 2hrs. Set-I M.M.:20

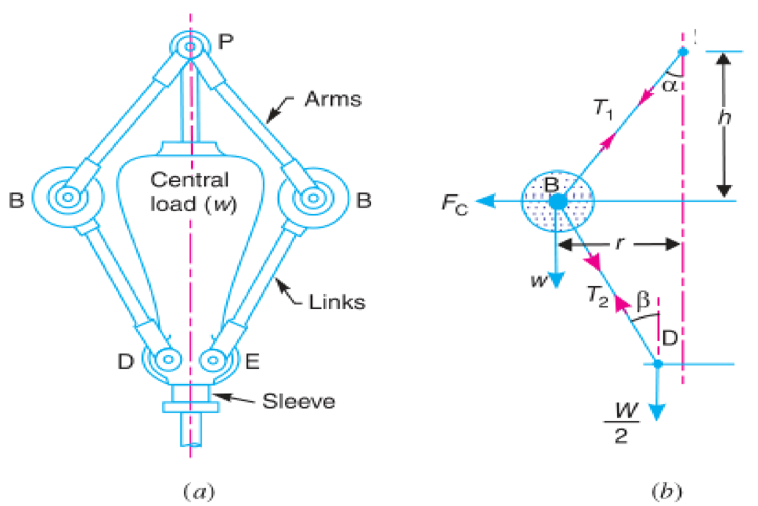
Instruction for students:
1. No provision for supplementary answer book.

Q.1 What do you understand by Governors? Derive the equation of lift of sleeve for Porter Governor.

Ans.1The 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. A little consideration will show, that when the load increases, the configuration of the governor changes and a valve is moved to increase the supply of the working fluid ; conversely, when the load decreases, the engine speed increases and the governor decreases the supply of working fluid.

Porter Governor

Consider the forces acting on one-half of the governor as shown in



Porter governor.

Let m = Mass of each ball in kg,
w = Weight of each ball in newtons = $m.g$,
M = Mass of the central load in kg,
W = Weight of the central load in newtons = $M.g$,
r = Radius of rotation in metres,

h = Height of governor in metres ,

N = Speed of the balls in r.p.m .,

ω = Angular speed of the balls in rad/s = $2\pi N/60$ rad/s,

F_C = Centrifugal force acting on the ball in newtons = $m.\omega^2.r$,

T_1 = Force in the arm in newtons,

T_2 = Force in the link in newtons,

α = Angle of inclination of the arm (or upper link) to the vertical, and

β = Angle of inclination of the link

2. Instantaneous centre method

In this method, equilibrium of the forces acting on the link BD are considered. The instantaneous centre I lies at the point of intersection of PB produced and a line through D perpendicular to the spindle axis, as shown in Fig. 18.4. Taking moments about the point I,

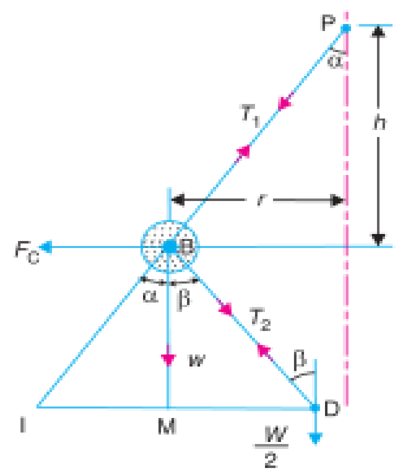


Fig. 18.4. Instantaneous centre method.

$$F_C \times BM = w \times IM + \frac{W}{2} \times ID$$

$$= m.g \times IM + \frac{M.g}{2} \times ID$$

$$\therefore \quad F_C = m.g \times \frac{IM}{BM} + \frac{M.g}{2} \times \frac{ID}{BM}$$

$$= m.g \times \frac{IM}{BM} + \frac{M.g}{2}\left(\frac{IM + MD}{BM}\right)$$

$$= m.g \times \frac{IM}{BM} + \frac{M.g}{2}\left(\frac{IM}{BM} + \frac{MD}{BM}\right)$$

$$= m.g \tan\alpha + \frac{M.g}{2}(\tan\alpha + \tan\beta)$$

$$\ldots\left(\because \frac{IM}{BM} = \tan\alpha, \text{ and } \frac{MD}{BM} = \tan\beta\right)$$

Dividing throughout by $\tan\alpha$,

$$\frac{F_C}{\tan\alpha} = m.g + \frac{M.g}{2}\left(1 + \frac{\tan\beta}{\tan\alpha}\right) = m.g + \frac{M.g}{2}(1+q) \qquad \ldots\left(\because q = \frac{\tan\beta}{\tan\alpha}\right)$$

We know that $F_C = m.\omega^2.r$, and $\tan\alpha = \frac{r}{h}$

$$\therefore \quad m.\omega^2.r \times \frac{h}{r} = m.g + \frac{M.g}{2}(1+q)$$

or

$$h = \frac{m.g + \frac{M.g}{2}(1+q)}{m} \times \frac{1}{\omega^2} = \frac{m + \frac{M}{2}(1+q)}{m} \times \frac{g}{\omega^2}$$

. . . (Same as before)

When $\tan\alpha = \tan\beta$ or $q = 1$, then

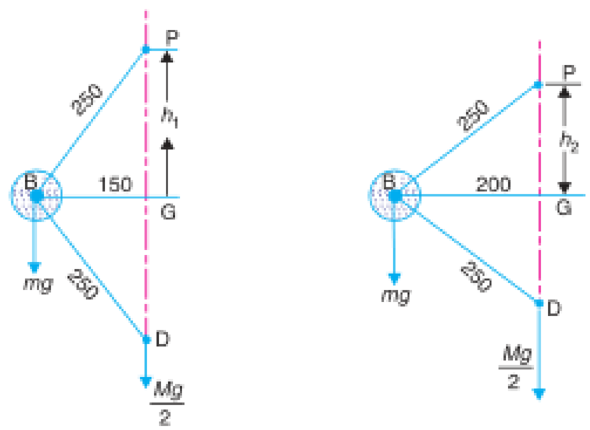
$$h = \frac{m + M}{m} \times \frac{g}{\omega^2}$$

Or

Q.1 A porter governor has equal arms each 250 mm long & pivoted on the axis of rotation Each ball has a mass of 5 kg and the mass of central load on the sleeve is 25 kg. The radius of rotation of the ball is 150 mm when the governor begins to lift & 200 mm when the governor is at maximum speed .Find the minimum & maximum speeds & range of speed of the governor.

Ans.1

Solution. Given : $BP = BD = 250$ mm $= 0.25$ m ; $m = 5$ kg ; $M = 15$ kg ; $r_1 = 150$ mm $= 0.15$m; $r_2 = 200$ mm $= 0.2$ m



(*a*) Minimum position. (*b*) Maximum position.

Fig. 18.5

The minimum and maximum positions of the governor are shown in Fig. 18.5 (*a*) and (*b*) respectively.

Minimum speed when $r_1 = BG = 0.15$ m

Let N_1 = Minimum speed.

From Fig. 18.5 (*a*), we find that height of the governor,

$$h_1 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(0.25)^2 - (0.15)^2} = 0.2 \text{ m}$$

We know that

$$(N_1)^2 = \frac{m + M}{m} \times \frac{895}{h_1} = \frac{5 + 15}{5} \times \frac{895}{0.2} = 17\,900$$

$\therefore$ $N_1 = 133.8$ r.p.m. **Ans.**

Maximum speed when $r_2 = BG = 0.2$ m

Let N_2 = Maximum speed.

From Fig. 18.5 (*b*), we find that height of the governor,

$$h_2 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(0.25)^2 - (0.2)^2} = 0.15 \text{ m}$$

We know that

$$(N_2)^2 = \frac{m+M}{m} \times \frac{895}{h_2} = \frac{5+15}{5} \times \frac{895}{0.15} = 23\,867$$

$\therefore$ $N_2 = 154.5$ r.p.m. **Ans.**

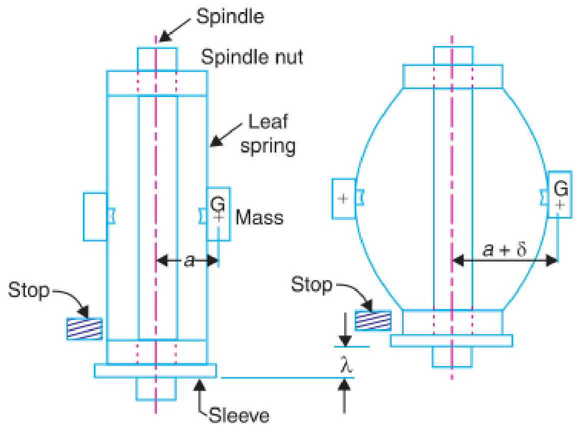
Range of speed

We know that range of speed

$$= N_2 - N_1 = 154.4 - 133.8 = 20.7 \text{ r.p.m. } \textbf{Ans.}$$

Q.2 Explain the working of Pickering Governor & write their formulas of deflection.

Ans.2A Pickering governor is mostly used for driving gramophone. It consists of three straight leaf springs arranged at equal angular intervals round the spindle. Each spring carries a weight at the centre. The weights move outwards and the springs bend as they rotate about the spindle axis with increasing speed. The upper end of the spring is attached by ascrew to hexagonal nut fixed to the governor spindle. The lower end of the spring is attached to a sleeve which is free to slide on the spindle. The spindle runs in a bearing at each end and is driven through gearing by the motor. The sleeve can rise until it reaches a stop, whose position is adjustable.



Let m = Mass attached at the centre of the leaf spring,

a = Distance from the spindle axis to the centre of gravity of the mass, when the governor is at rest,

ω = Angular speed of the governor spindle,

δ = Deflection of the centre of the leaf spring at angular speed ω,

a + δ = Distance from the spindle axis to the centre of gravity of the mass, when the governor is rotating, and

λ = Lift of the sleeve corresponding to the deflection δ.

We know that the maximum deflection of a leaf spring with both ends fixed and carrying a load (W) at the centre is,

We know that the maximum deflection of a leaf spring with both ends fixed and carrying a load (W) at the centre is,

$$\delta = \frac{W.l^3}{192\,EI} \qquad \ldots (i)$$

where l = Distance between the fixed ends of the spring,

E = Young's modulus of the material of the spring, and

I = Moment of inertia of its cross-section about the neutral axis $= \frac{b.t^3}{12}$

(where b and t are width and thickness of spring).

Or

Q.2 A Hartnell Governor having a sleeve spring & two right angled bell crank levers moves between 290rpm & 310rpm for a sleeve lift of 15mm The sleeve arms & the ball arms are 80mm & 120mm respectively. The lavers are pivoted at 120mm from the governor axis & mass of each ball is 2.5 kg The ball arms parallel to the governor axis at the lowest equilibrium speed .Determine loads on the spring at the lowest & highest equilibrium speed.

Ans.2

Solution. Given : $N_1 = 290$ r.p.m. or $\omega_1 = 2\pi \times 290/60 = 30.4$ rad/s ; $N_2 = 310$ r.p.m. or $\omega_2 = 2\pi \times 310/60 = 32.5$ rad/s ; $h = 15$ mm $= 0.015$ m ; $y = 80$ mm $= 0.08$ m ; $x = 120$ mm $= 0.12$ m ; $r = 120$ mm $= 0.12$ m ; $m = 2.5$ kg

1. Loads on the spring at the lowest and highest equilibrium speeds

Let S = Spring load at lowest equilibrium speed, and

S_2 = Spring load at highest equilibrium speed.

Since the ball arms are parallel to governor axis at the lowest equilibrium speed (*i.e.* at $N_1 = 290$ r.p.m.), as shown in Fig. 18.20 (*a*), therefore

$$r = r_1 = 120 \text{ mm} = 0.12 \text{ m}$$

We know that centrifugal force at the minimum speed,

$$F_{C1} = m\,(\omega_1)^2\, r_1 = 2.5\,(30.4)^2\ 0.12 = 277 \text{ N}$$

Now let us find the radius of rotation at the highest equilibrium speed, *i.e.* at $N_2 = 310$ r.p.m. The position of ball arm and sleeve arm at the highest equilibrium speed is shown in Fig. 18.20 (*b*).

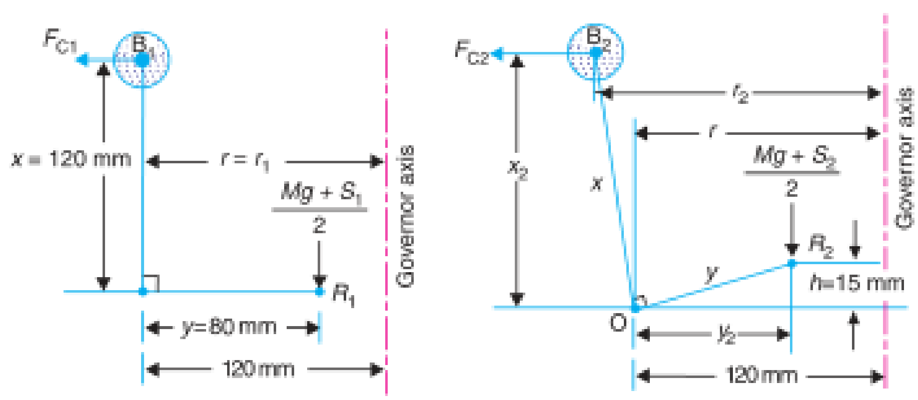
Let r_2 = Radius of rotation at $N_2 = 310$ r.p.m.

We know that $$h = (r_2 - r_1)\,\frac{y}{x}$$

or $$r_2 = r_1 + h\left(\frac{x}{y}\right) = 0.12 + 0.015\left(\frac{0.12}{0.08}\right) = 0.1425 \text{ m}$$

$\therefore$ Centrifugal force at the maximum speed,

$$F_{C2} = m\,(\omega_2)^2\, r_2 = 2.5 \times (32.5)^2 \times 0.1425 = 376 \text{ N}$$



(*a*) Lowest position. (*b*) Highest position.

Fig. 18.20

Neglecting the obliquity effect of arms and the moment due to the weight of the balls, we have for lowest position,

$$M.g + S_1 = 2F_{C1} \times \frac{x}{y} = 2 \times 277 \times \frac{0.12}{0.08} = 831 \text{ N}$$

$\therefore$ $S_2 = 831$ N **Ans.** $(\because M = 0)$

and for highest position,

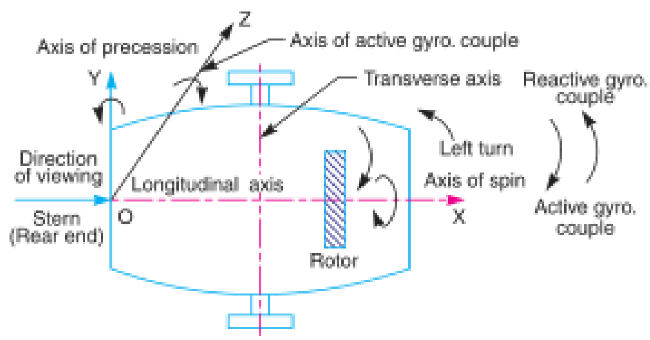
$$M.g + S_2 = 2F_{C2} \times \frac{x}{y} = 2 \times 376 \times \frac{0.12}{0.08} = 1128 \text{ N}$$

$\therefore$ $S_1 = 1128$ N **Ans.** $(\because M = 0)$

Q.3 Explain the effect of Gyroscopic Couple on a Naval ship during Steering ,Pitching and Rolling with neat sketch .

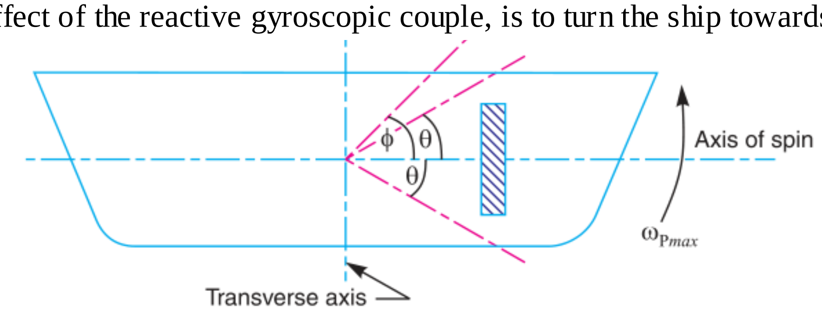
Ans.3 (1)**Effect of Gyroscopic Couple on a Naval Ship during Steering**

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 whenviewed from the stern,When the rotor of the ship rotates in the clockwise direction when viewed from the stern, it will have its angular momentum vector in the direction ox as shown. As the ship steers to the left, the active gyroscopic couple will change the angular momentum vector from ox to ox′. The vector xx′ now represents the active gyroscopic couple and is perpendicular to ox. Thus the plane of active gyroscopic couple is perpendicular to xx′ and its direction in the axis OZ for left hand turn is clockwise The reactive gyroscopic couple of the same magnitude will act in the opposite direction (i.e. in anticlockwise direction). 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 will be to raise the stern and lower the bow. When the rotor rates in the anticlockwise direction,when viewed from the stern and the ship is steering to the left, then the effect of reactive gyroscopic couple will be to lower the bow and raise the stern.



(2) 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, 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. When the pitching is upward, the effect of the reactive gyroscopic couple will try to move the ship toward star-board. On the other hand, if the pitching is downward, the effect of the reactive gyroscopic couple, is to turn the ship towards port side.



Effect of Gyroscopic Couple on a Naval Ship during Rolling

The effect of gyroscopic couple to occur, the axis of precession should always be perpendicular to the axis of spin. If, however, the axis of precession becomes parallel to the axis of spin, there will be no effect of the gyroscopic couple acting on the body of the ship.In case of rolling of a ship, the axis of precession (i.e. longitudinal axis) is always parallel to the axis of spin for all positions. Hence, there is no effect of the gyroscopic couple acting on the body of a ship.

Or

Q.3 Drive a relation for stability of a four Wheel drive moving in a Curved Path.

Ans.3 **Stability of a Four Wheel Drive Moving in a Curved Path**

Consider the four wheels A, B, C and D of an automobile locomotive taking a turn towards left as shown in Fig. 14.11. The wheels A and C are inner wheels, whereas B and D are outer wheels. The centre of gravity ($C.G.$) of the vehicle lies vertically above the road surface.

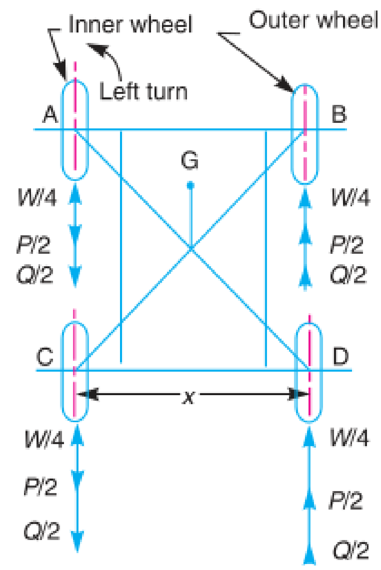


Fig. 14.11. Four wheel drive moving in a curved path.

Let m = Mass of the vehicle in kg,

W = Weight of the vehicle in newtons = $m.g$,

r_W = Radius of the wheels in metres,

R = Radius of curvature in metres ($R > r_W$),

h = Distance of centre of gravity, vertically above the road surface in metres,

x = Width of track in metres,

I_W = Mass moment of inertia of one of the wheels in kg-m^2,

ω_W = Angular velocity of the wheels or velocity of spin in rad/s,

I_E = Mass moment of inertia of the rotating parts of the engine in kg-m^2,

ω_E = Angular velocity of the rotating parts of the engine in rad/s,

G = Gear ratio = ω_E / ω_W,

v = Linear velocity of the vehicle in m/s = $\omega_W . r_W$

A little considereation will show,that the weight of the vehicle (W) will be equally distributed over the four wheels which will act downwards. The reaction between each wheel and the road surface of the same magnitude will act upwards.Therefore Road reaction over each wheel

= W/4 = m.g /4 newtons

1. Effect of the gyroscopic couple

Since the vehicle takes a turn towards left due to the precession and other rotating parts, therefore a gyroscopic couple will act.

We know that velocity of precession,

$$\omega_P = v/R$$

∴ Gyroscopic couple due to 4 wheels,

$$C_W = 4\, I_W . \omega_W . \omega_P$$

and gyroscopic couple due to the rotating parts of the engine,

$$C_E = I_E . \omega_E . \omega_P = I_E . G . \omega_W . \omega_P \qquad \ldots (\because G = \omega_E / \omega_W)$$

∴ Net gyroscopic couple,

$$C = C_W \pm C_E = 4\, I_W . \omega_W . \omega_P \pm I_E . G . \omega_W . \omega_P$$

$$= \omega_W . \omega_P \,(4\, I_W \pm G . I_E)$$

The positive sign is used when the wheels and rotating parts of the engine rotate in the same direction. If the rotating parts of the engine revolves in opposite direction, then negative sign is used.Due to the gyroscopic couple, vertical reaction on the road surface will be produced. The reaction will be vertically upwards on the outer wheels and vertically downwards on the inner wheels.Let the magnitude of this reaction at the two outer or inner wheels be P newtons. Then

$$P \times x = C \text{ or } P = C/x$$

∴ Vertical reaction at each of the outer or inner wheels,

$$P/2 = C/2x$$

2. Effect of the centrifugal couple

Since the vehicle moves along a curved path, therefore centrifugal force will act outwardly at the centre of gravity of the vehicle. The effect of this centrifugal force is also to overturn the vehicle.

We know that centrifugal force,

$$F_C = \frac{m \times v^2}{R}$$

∴ The couple tending to overturn the vehicle or overturning couple,

$$C_O = F_C \times h = \frac{m.v^2}{R} \times h$$

This overturning couple is balanced by vertical reactions, which are vertically upwards on the outer wheels and vertically downwards on the inner wheels. Let the magnitude of this reaction at the two outer or inner wheels be Q. Then

$$Q \times x = C_O \quad \text{or} \quad Q = \frac{C_O}{x} = \frac{m.v^2.h}{R.x}$$

∴ Vertical reaction at each of the outer or inner wheels,

$$\frac{Q}{2} = \frac{m.v^2.h}{2R.x}$$

∴ Total vertical reaction at each of the outer wheel,

$$P_O = \frac{W}{4} + \frac{P}{2} + \frac{Q}{2}$$

and total vertical reaction at each of the inner wheel,

$$P_I = \frac{W}{4} - \frac{P}{2} - \frac{Q}{2}$$

A little consideration will show that when the vehicle is running at high speeds, P_I may be zero or even negative. This will cause the inner wheels to leave the ground thus tending to overturn the automobile. In order to have the contact between the inner wheels and the ground, the sum of $P/2$ and $Q/2$ must be less than $W/4$.

Q.4 Derive a relation for Energy stored in a Flywheel

Ans.4 Flywheel controls the speed variations caused by the fluctuation of the engine turning moment during each cycle of operation.

Energy Stored in a Flywheel

When a flywheel absorbs energy, its speed increases and when it gives up energy, its speed decreases.

Let m = Mass of the flywheel in kg,

k = Radius of gyration of the flywheel in metres,

I = Mass moment of inertia of the flywheel about its axis of rotation in kg-m 2 = m.k 2 ,

N 1 and N 2 = Maximum and minimum speeds during the cycle in r.p.m.,

ω 1 and ω 2 = Maximum and minimum angular speeds during the cycle in rad/s,

We know that the mean kinetic energy of the flywheel,

$$E = \frac{1}{2} \times I.\omega^2 = \frac{1}{2} \times m.k^2.\omega^2 \qquad \text{(in N-m or joules)}$$

As the speed of the flywheel changes from ω_1 to ω_2, the maximum fluctuation of energy,

$$\Delta E = \text{Maximum K.E.} - \text{Minimum K.E.}$$

$$= \frac{1}{2} \times I (\omega_1)^2 - \frac{1}{2} \times I (\omega_2)^2 = \frac{1}{2} \times I \left[(\omega_1)^2 - (\omega_2)^2 \right]$$

$$= \frac{1}{2} \times I (\omega_1 + \omega_2)(\omega_1 - \omega_2) = I.\omega(\omega_1 - \omega_2) \qquad ...(i)$$

$$... \left(\because \omega = \frac{\omega_1 + \omega_2}{2} \right)$$

$$= I.\omega^2 \left(\frac{\omega_1 - \omega_2}{\omega} \right) \qquad \text{... (Multiplying and dividing by } \omega)$$

$$= I.\omega^2.C_S = m.k^2.\omega^2.C_S \qquad ... (\because I = m.k^2) \quad ...(ii)$$

$$= 2.E.C_S \text{ (in N–m or joules)} \qquad ... \left(\because E = \frac{1}{2} \times I.\omega^2 \right) ... (iii)$$

The radius of gyration (k) may be taken equal to the mean radius of the rim (R), because the thickness of rim is very small as compared to the diameter of rim. Therefore, substituting $k = R$, in equation ***(ii)***, we have

$$\Delta E = m.R^2.\omega^2.C_S = m.v^2.C_S$$

where v = Mean linear velocity (*i.e.* at the mean radius) in m/s = $\omega.R$

Or

Q.4 Differentiate Simple & Reverted gear train with neat sketch.

Ans.4 **Simple Gear Train**

When there is only one gear on each shaft, it is known as simple gear train. The gears are represented by their pitch circles.When the distance between the two shafts is small,the two gears 1 and 2 are made to mesh with each other to transmit motion from one shaft to the other, as shown in Fig. 13.1 (a). Since the gear 1 drives the gear 2, therefore gear 1 is called the driver and the gear 2 is called the driven or follower. It may be noted that the motion of the driven gear is opposite to the motion of driving gear. Since the speed ratio (or velocity ratio) of gear train is the ratio of the speed of the driver to the speed of the driven or follower and ratio of speeds of any pair of gears in mesh is the inverse of their number of teeth, therefore It may be noted that ratio of the speed of the driven or follower to the speed of the driver is known as train value of the gear train.

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

$$\text{Train value} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$

Reverted Gear Train

When the axes of the first gear (i.e. first driver) and the last gear (i.e. last driven or follower) are co-axial,then the gear train is known as reverted gear train that gear 1 (i.e. first driver) drives the gear 2 (i.e. first driven or follower) in the opposite direction. Since the gears 2 and 3 are mounted on the same shaft, therefore they form a compound gear and the gear 3 will rotate in the same direction as that of gear 2. The gear 3 (which is now the second driver) drives the gear 4(i.e. the last driven or follower) in the same direction as that of gear 1. Thus we see that in a reverted gear train, the motion of the first gear and the last gear is like.

Let T_1 = Number of teeth on gear 1, r_1 = Pitch circle radius of gear 1, and

N_1 = Speed of gear 1 in r.p.m.Similarly,

T_2 , T_3 , T_4 = Number of teeth on respective gears,

r_2 , r_3 , r_4 = Pitch circle radii of respective gears, and

N_2 , N_3 , N_4 = Speed of respective gears in r.p.m.

Since the distance between the centres of the shafts of gears 1 and 2 as well as gears 3 and 4 is same, therefore

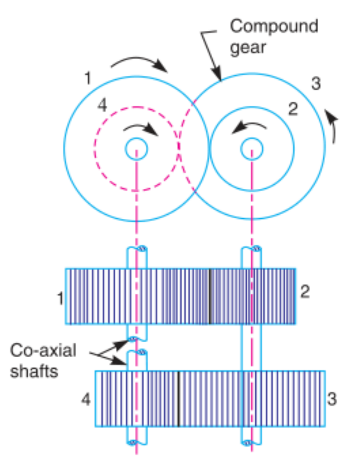
$$r_1 + r_2 = r_3 + r_4 \quad \text{...(i)}$$

Also, the circular pitch or module of all the gears is assumed to be same, therefore number of teeth on each gear is directly proportional to its circumference or radius.

$$\therefore {}^*T_1 + T_2 = T_3 + T_4$$

$$\text{Speed ratio} = \frac{\text{Product of number of teeth on drivens}}{\text{Product of number of teeth on drivers}}$$

$$\frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3}$$



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Instruction for students:

1. No provision for supplementary answer book.

Q.1 Differentiate between Governor and Flywheel? Writedown the classification of Governors.
Ans.1

Sr. No.	Flywheel	Governor
1.	Maintains constant speed but the means is different from that of Governor. Stores excess of rotational energy from the power stroke and supply back during non-power strokes of the cycle	Maintains constant speed but the means is different from that of Flywheel. Controls mean speed of the engine under full/half/varying load conditions by regulating the supply of working fluid to the engine
2.	In this, there are energy variations but runs the crankshaft at constant speed in each stroke of the cycle	When load on the engine increases, speed decreases. It increases the flow of fuel to keep the constant mean speed
3.	Flywheel controls the speed for one cycle only	Governor maintains constant mean speed over a period of time.
4.	Flywheel is not required in all the prime movers (engines)	Governor is required in all the prime movers (engines)
5.	It is a heavy machine part	It is a relatively light machine part
6.	Has large moment of inertia	Relatively small moment of inertia
7.	Rotating part	Non- Rotating part
8.	Running charges are less	Running charges are high
9.	Angular speed increases while storing energy and decreases during supply back of energy	Runs at mean speed under all loads on the engine

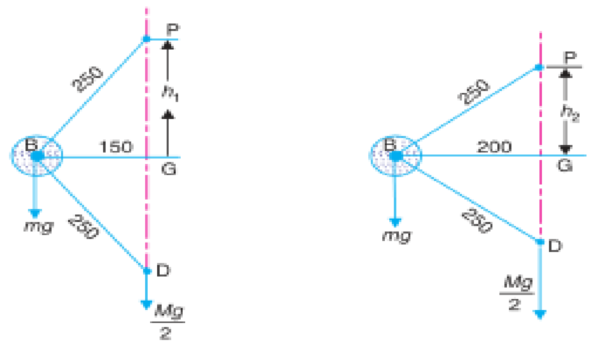
10.	Crankshaft runs at constant speed	Load increases speed decreases and vice -varsa. But it controls the MEAN speed by controlling the flow of fuel in the engine
11.	There are no valves attached with the flywheel	Valves are there and there opening is controlled by the centrifugal force on the balls attached

Or

Q.1 A porter governor has equal arms each 250 mm long & pivoted on the axis of rotation,Each ball has a mass of 5 kg & the mass of central load on the sleeve is 25 kg. The radius of rotation of the ball is 150 mm when the governor begins to lift & 200 mm when the governor is at maximum speed .Find the minimum & maximum speeds & range of speed of the governor

Ans.1

Solution. Given : $BP = BD = 250$ mm $= 0.25$ m ; $m = 5$ kg ; $M = 15$ kg ; $r_1 = 150$ mm $= 0.15$m; $r_2 = 200$ mm $= 0.2$ m



(*a*) Minimum position. (*b*) Maximum position.

Fig. 18.5

The minimum and maximum positions of the governor are shown in Fig. 18.5 (*a*) and (*b*) respectively.

Minimum speed when $r_1 = BG = 0.15$ m

Let N_1 = Minimum speed.

From Fig. 18.5 (*a*), we find that height of the governor,

$$h_1 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(0.25)^2 - (0.15)^2} = 0.2 \text{ m}$$

We know that

$$(N_1)^2 = \frac{m + M}{m} \times \frac{895}{h_1} = \frac{5 + 15}{5} \times \frac{895}{0.2} = 17\ 900$$

$\therefore$ $N_1 = 133.8$ r.p.m. **Ans.**

Maximum speed when $r_2 = BG = 0.2$ m

Let N_2 = Maximum speed.

From Fig. 18.5 (*b*), we find that height of the governor,

$$h_2 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(0.25)^2 - (0.2)^2} = 0.15 \text{ m}$$

We know that

$$(N_2)^2 = \frac{m+M}{m} \times \frac{895}{h_2} = \frac{5+15}{5} \times \frac{895}{0.15} = 23\ 867$$

$\therefore$ $N_2 = 154.5$ r.p.m. **Ans.**

Range of speed

We know that range of speed

$$= N_2 - N_1 = 154.4 - 133.8 = 20.7 \text{ r.p.m. } \textbf{Ans.}$$

Q.2 In a Proell governor has equal arms of length 300 mm,The upper & lower arms are pivoted on the axis of governor.The extension arm of lower link each 80 mm long & parallel to to the axis of when the radious of rotation of balls is 150 mm and 200 mmm.The mass of each ball 10 kg & mass of the central load 100 kg.determine the range of governor

Ans.2

Solution. Given : $PF = DF = 300$ mm ; $BF = 80$ mm ; $m = 10$ kg ; $M = 100$ kg ; $r_1 = 150$ mm; $r_2 = 200$ mm

First of all, let us find the minimum and maximum speed of the governor. The minimum and maximum position of the governor is shown in Fig. 18.13.

Let N_1 = Minimum speed when radius of rotation, $r_1 = FG = 150$ mm ; and

N_2 = Maximum speed when radius of rotation , $r_2 = FG = 200$ mm.

From Fig. 18.13 (*a*), we find that height of the governor,

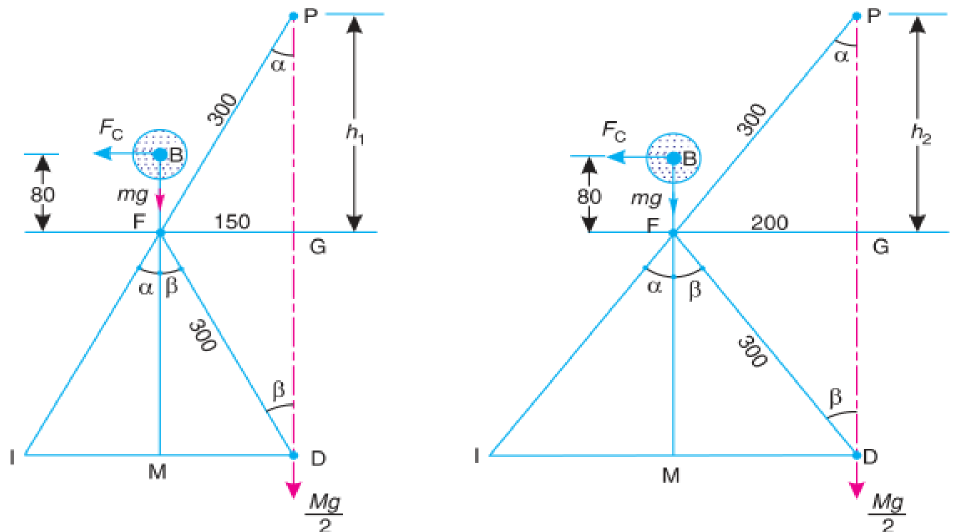
$$h_1 = PG = \sqrt{(PF)^2 - (FG)^2} = \sqrt{(300)^2 - (150)^2} = 260 \text{ mm} = 0.26 \text{ m}$$

and $FM = GD = PG = 260$ mm $= 0.26$ m

$\therefore$ $BM = BF + FM = 80 + 260 = 340$ mm $= 0.34$ m

We know that $$(N_1)^2 = \frac{FM}{BM}\left(\frac{m+M}{m}\right)\frac{895}{h_1} \quad \ldots (\because \alpha = \beta \text{ or } q = 1)$$

$$= \frac{0.26}{0.34}\left(\frac{10+100}{10}\right)\frac{895}{0.26} = 28\,956 \quad \text{or} \quad N_1 = 170 \text{ r.p.m.}$$



All dimensions in mm.

Now from Fig. 18.13 (*b*), we find that height of the governor,

$$h_2 = PG = \sqrt{(PF)^2 - (FG)^2} = \sqrt{(300)^2 - (200)^2} = 224 \text{ mm} = 0.224 \text{ m}$$

and $FM = GD = PG = 224$ mm $= 0.224$ m

$\therefore$ $BM = BF + FM = 80 + 224 = 304$ mm $= 0.304$ m

We know that $$(N_2)^2 = \frac{FM}{BM}\left(\frac{m+M}{m}\right)\frac{895}{h_2} \quad \ldots (\because \alpha = \beta \text{ or } q = 1)$$

$$= \frac{0.224}{0.304}\left(\frac{10+100}{10}\right)\frac{895}{0.224} = 32\,385 \quad \text{or} \quad N_2 = 180 \text{ r.p.m.}$$

We know that range of speed

$= N_2 - N_1 = 180 - 170 = 10$ r.p.m. **Ans.**

Or

Q.2. Write short notes:-Any two

(a) Isochronous Governor (b) Sensitiveness of governor (c) Governor Hunting

Ans.2 **(a) 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. The isochronism is the stage of infinite sensitivity. Let us consider the case of a Porter governor running at speeds N 1 and N 2 r.p.m.

$$(N_1)^2 = \frac{m + \frac{M}{2}(1+q)}{m} \times \frac{895}{h_1} \qquad \ldots (i)$$

and

$$(N_2)^2 = \frac{m + \frac{M}{2}(1+q)}{m} \times \frac{895}{h_2} \qquad \ldots (ii)$$

For isochronism, range of speed should be zero *i.e.* $N_2 - N_1 = 0$ or $N_2 = N_1$. Therefore from equations (*i*) and (*ii*), $h_1 = h_2$, which is impossible in case of a Porter governor. Hence a ***Porter governor cannot be isochronous.***

(b) Sensitiveness of governor

The sensitiveness is defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed.

Let N 1 = Minimum equilibrium speed,

N 2 = Maximum equilibrium speed,

Let N_1 = Minimum equilibrium speed,

N_2 = Maximum equilibrium speed, and

N = Mean equilibrium speed $= \frac{N_1 + N_2}{2}$.

∴ Sensitiveness of the governor

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

$$= \frac{2(\omega_2 - \omega_1)}{\omega_1 + \omega_2} \qquad \ldots \text{(In terms of angular speeds)}$$

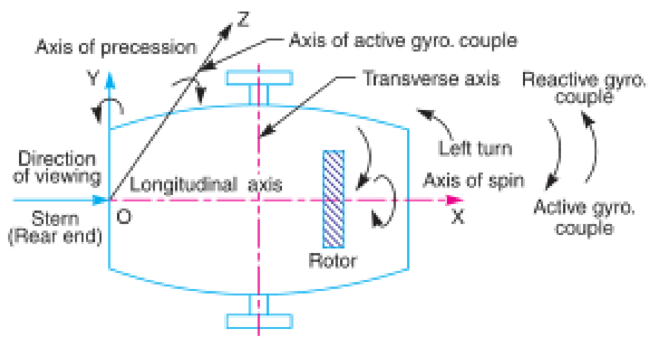
(c) Governor Hunting

A governor is said to be hunt if the speed of the engine fluctuates continuously above and below the mean speed. This is caused by a too sensitive governor which changes the fuel supply by a large amount when a small change in the speed of rotation takes place. For example, when the load on the engine increases, the engine speed decreases and, if the governor is very sensitive, the governor sleeve immediately falls to its lowest position. This will result in the opening of the control valve wide which will supply the fuel to the engine in excess of its requirement so that the engine speed rapidly increases again and the governor sleeve rises to its highest position. Due to this movement of the sleeve, the control valve will cut off the fuel supply to the engine and thus the engine speed begins to fall once again. This cycle is repeated indefinitely.Such a governor may admit either the maximum or the minimum amount of fuel. The effect of this will be to cause wide fluctuations in the engine speed or in other words, the engine will hunt.

Q.3 Explain the effect of Gyroscopic Couple on a Naval ship during Steering ,Pitching and Rolling with neat sketch.

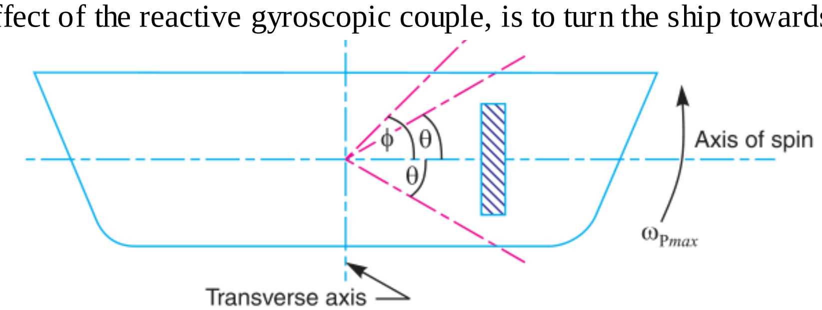
Ans.3 (1)**Effect of Gyroscopic Couple on a Naval Ship during Steering**

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 whenviewed from the stern,When the rotor of the ship rotates in the clockwise direction when viewed from the stern, it will have its angular momentum vector in the direction ox as shown. As the ship steers to the left, the active gyroscopic couple will change the angular momentum vector from ox to ox′. The vector xx′ now represents the active gyroscopic couple and is perpendicular to ox. Thus the plane of active gyroscopic couple is perpendicular to xx′ and its direction in the axis OZ for left hand turn is clockwise The reactive gyroscopic couple of the same magnitude will act in the opposite direction (i.e. in anticlockwise direction). 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 will be to raise the stern and lower the bow. When the rotor rates in the anticlockwise direction,when viewed from the stern and the ship is steering to the left, then the effect of reactive gyroscopic couple will be to lower the bow and raise the stern.



(2) 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, 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. When the pitching is upward, the effect of the reactive gyroscopic couple will try to move the ship toward star-board. On the other hand, if the pitching is downward, the effect of the reactive gyroscopic couple, is to turn the ship towards port side.



Effect of Gyroscopic Couple on a Naval Ship during Rolling

The effect of gyroscopic couple to occur, the axis of precession should always be perpendicular to the axis of spin. If, however, the axis of precession becomes parallel to the axis of spin, there will be no effect of the gyroscopic couple acting on the body of the ship.In case of rolling of a ship, the axis of precession (i.e. longitudinal axis) is always parallel to the axis of spin for all positions. Hence, there is no effect of the gyroscopic couple acting on the body of a ship.

Or

Q.3The Controlling force F_c in Newton & Radius of rotation(r) in meter for Spring controlled governor is expressed by- **F_c = 2800r-76**

The Mass of ball is 5 kg & extreme radius of rotation of balls is 100 mm & 175 mm .Find the Maximum & Minimum speeds of equilibrium.

Ans.3

Solution. Given : $m = 5$ kg ; $r_1 = 100$ mm $= 0.1$ m ; $r_2 = 175$ mm $= 0.175$ m

Maximum and minimum speeds of equilibrium

Let N_2 and N_1 = Maximum and minimum speeds of equilibrium respectively.

The controlling force is given by the expression,

$$F_C = 2800\,r - 76$$

$\therefore$ Controlling force at the minimum radius of rotation (*i.e.* at $r_1 = 0.1$ m),

$$F_{C1} = 2800 \times 0.1 - 76 = 204 \text{ N}$$

and controlling force at the maximum radius of rotation (*i.e.* at $r_2 = 0.175$ m),

$$F_{C2} = 2800 \times 0.175 - 76 = 414 \text{ N}$$

We know that $$F_{C1} = m\,(\omega_1)^2\, r_1 = m\left(\frac{2\pi N_1}{60}\right)^2 r_1$$

or $$204 = 5\left(\frac{2\pi N_1}{60}\right)^2 0.1 = 0.0055\,(N_1)^2$$

$\therefore$ $(N_1)^2 = 204 / 0.0055 = 37\,091$ or $N_1 = 192.6$ r.p.m. **Ans.**

Similarly $$F_{C2} = m\,(\omega_2)^2\, r_2 = m\left(\frac{2\pi N_2}{60}\right)^2 r_2$$

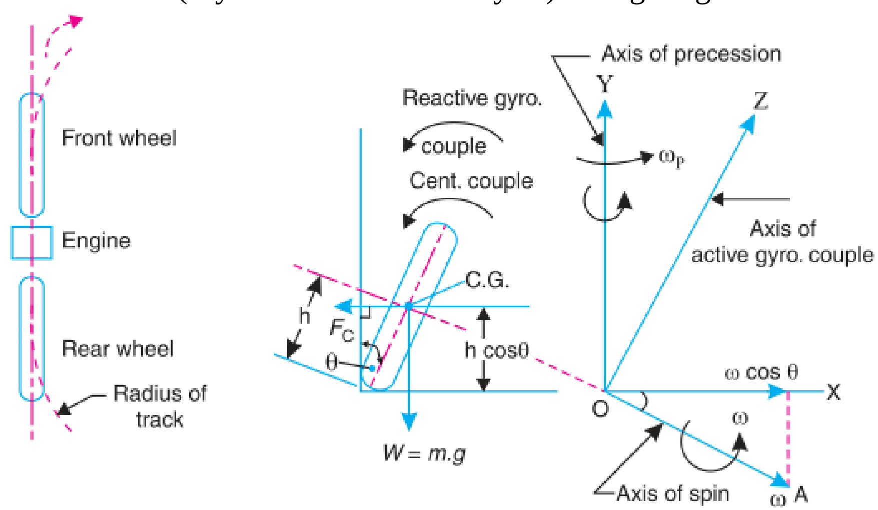
or $$414 = 5\left(\frac{2\pi N_2}{60}\right)^2 0.175 = 0.0096\,(N_2)^2$$

$\therefore$ $(N_2)^2 = 414 / 0.0096 = 43\,125$ or $N_2 = 207.6$ r.p.m. **Ans.**

Q.4 Established a relation for stability of a Two wheeler motorcycle moving in a Curved Path

Ans.4 **Stability of a Two wheeler motorcycle moving in a Curved Path**

Consider a two wheel vehicle (say a scooter or motor cycle) taking a right turn



Let m = Mass of the vehicle and its rider in kg,
W = Weight of the vehicle and its rider in newtons = m.g,
h = Height of the centre of gravity of the vehicle and rider,
r_W = Radius of the wheels, R = Radius of track or curvature,
I_W = Mass moment of inertia of each wheel,
I_E = Mass moment of inertia of the rotating parts of the engine,
ω_W = Angular velocity of the wheels,
ω_E = Angular velocity of the engine,
G = Gear ratio = ω_E / ω_W,
v = Linear velocity of the vehicle = $\omega_W \times r_W$,
θ = Angle of heel. It is inclination of the vehicle to the vertical for equilibrium.
Let us now consider the effect of the gyroscopic couple and centrifugal couple on the vehicle, as discussed below.

1. Effect of gyroscopic couple

We know that $v = \omega_W \times r_W$ or $\omega_W = v / r_W$

and
$$\omega_E = G.\omega_W = G \times \frac{v}{r_W}$$

∴ Total
$$(I \times \omega) = 2\, I_W \times \omega_W \pm I_E \times \omega_E$$
$$= 2\, I_W \times \frac{v}{r_W} \pm I_E \times G \times \frac{v}{r_W} = \frac{v}{r_W}\,(2\, I_W \pm G.I_E)$$

and velocity of precession, $\omega_P = v / R$

A little consideration will show that when the wheels move over the curved path, the vehicle is always inclined at an angle θ with the vertical plane This angle is known as angle of heel. In other words, the axis of spin is inclined to the horizontal at an angle θ, Thus the angular momentum vector Iω due to spin is represented by OA inclined to OX at an angle θ. But the precession axis is vertical. Therefore the spin vector is resolved along OX.

∴ Gyroscopic couple,

$$C_1 = I.\omega \cos\theta \times \omega_P = \frac{v}{r_W}\,(2\, I_W \pm G.I_E)\cos\theta \times \frac{v}{R}$$
$$= \frac{v^2}{R.r_W}\,(2\, I_W \pm G.I_E)\cos\theta$$

2. Effect of centrifugal couple

We know that centrifugal force,

$$F_C = \frac{m.v^2}{R}$$

This force acts horizontally through the centre of gravity (*C.G.*) along the outward direction.

∴ Centrifugal couple,

$$C_2 = F_C \times h \cos\theta = \left(\frac{m.v^2}{R}\right) h \cos\theta$$

Since the centrifugal couple has a tendency to overturn the vehicle, therefore

Total overturning couple,

$$C_O = \text{Gyroscopic couple} + \text{Centrifugal couple}$$

$$= \frac{v^2}{R.r_W}(2\,I_W + G.I_E)\cos\theta + \frac{m.v^2}{R} \times h\cos\theta$$

$$= \frac{v^2}{R}\left[\frac{2\,I_W + G.I_E}{r_W} + m.h\right]\cos\theta$$

We know that balancing couple = $m.g.h \sin\theta$

The balancing couple acts in clockwise direction when seen from the front of the vehicle. Therefore for stability, the overturning couple must be equal to the balancing couple, *i.e.*

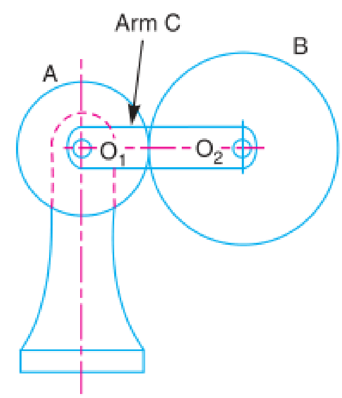
$$\frac{v^2}{R}\left(\frac{2\,I_W + G.I_E}{r_W} + m.h\right)\cos\theta = m.g.h\sin\theta$$

Or

Q.4 Construct a table for calculating the Speed ration of Simle Epicyclic gear train with neat sketch.

Ans.4 **Simle Epicyclic gear train**

A simple epicyclic gear train is where a gear A and the arm C have a common axis at O 1 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at O 2 , about which the gear B can rotate. If the arm is fixed, the gear train is simple and gear A can drive gear B or vice- versa, but if gear A is fixed and the arm is rotated about the axis of gear A (i.e. O 1), then the gear B is forced to rotate upon and around gear A. Such a motion is called epicyclic and the gear trains arranged in such a manner that one or more of their members move upon and around another member are known as epicyclic gear trains (epi. means upon and cyclic means around). The epicyclic gear trains may be simple or compound.



Step No.	Conditions of motion	Revolutions of elements		
		Arm C	Gear A	Gear B
1.	Arm fixed-gear *A* rotates through + 1 revolution *i.e.* 1 rev. anticlockwise	0	+ 1	$-\frac{T_A}{T_B}$
2.	Arm fixed-gear *A* rotates through + *x* revolutions	0	+ *x*	$-x \times \frac{T_A}{T_B}$
3.	Add + *y* revolutions to all elements	+ *y*	+ *y*	+ *y*
4.	Total motion	+ *y*	*x* + *y*	$y - x \times \frac{T_A}{T_B}$