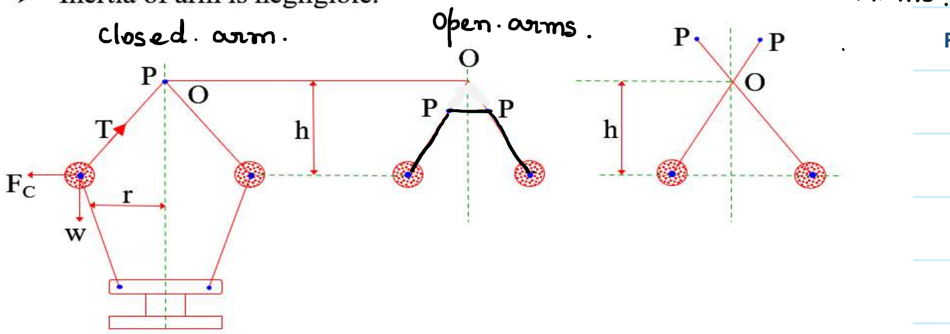
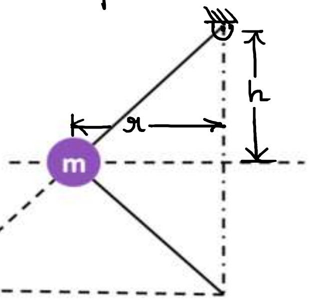
ANALYSIS OF WATT GOVERNOR:

- Sleeve of watt governor is massless.
- Inertia of arm is negligible.



HEIGHT OF GOVERNOR (h): It is the distance between the plane containing governor balls to the point where upper arms are intersecting with the governor axis either by their own or extended.

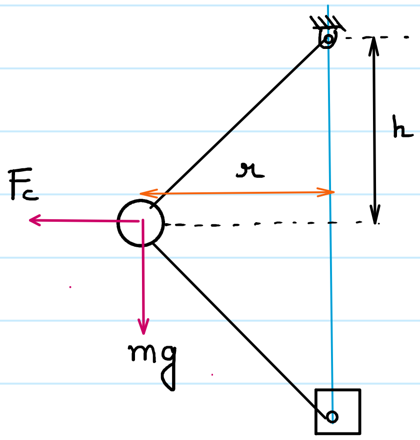
r = radius of rotation of flyballs.



Watt governor is used for low speed Prime movers.

LIMITATIONS: The variation of 'h' was appreciable for low value of 'N', for high speed the variation in 'h' is very small due to which the governor become insensitive corresponding to high speed.

- The working range of watt governor is very less.



$$\Sigma M_{Hinge} = 0$$

$$F_c \times h = mg \times r.$$

$$mr\omega^2 \times h = mg \times r.$$

$$\omega^2 = g/h.$$

$$\boxed{h = g/\omega^2}$$

$$h = \frac{9.81}{\left(\frac{2\pi}{60}\right)^2 \cdot N^2} = \frac{895}{N^2} \text{ mts.}$$

$h \propto \frac{1}{\omega^2}$. as $\omega\uparrow$ $\omega^2\uparrow\uparrow$ $h\downarrow\downarrow$.

N-speed of governor. h – height of governor

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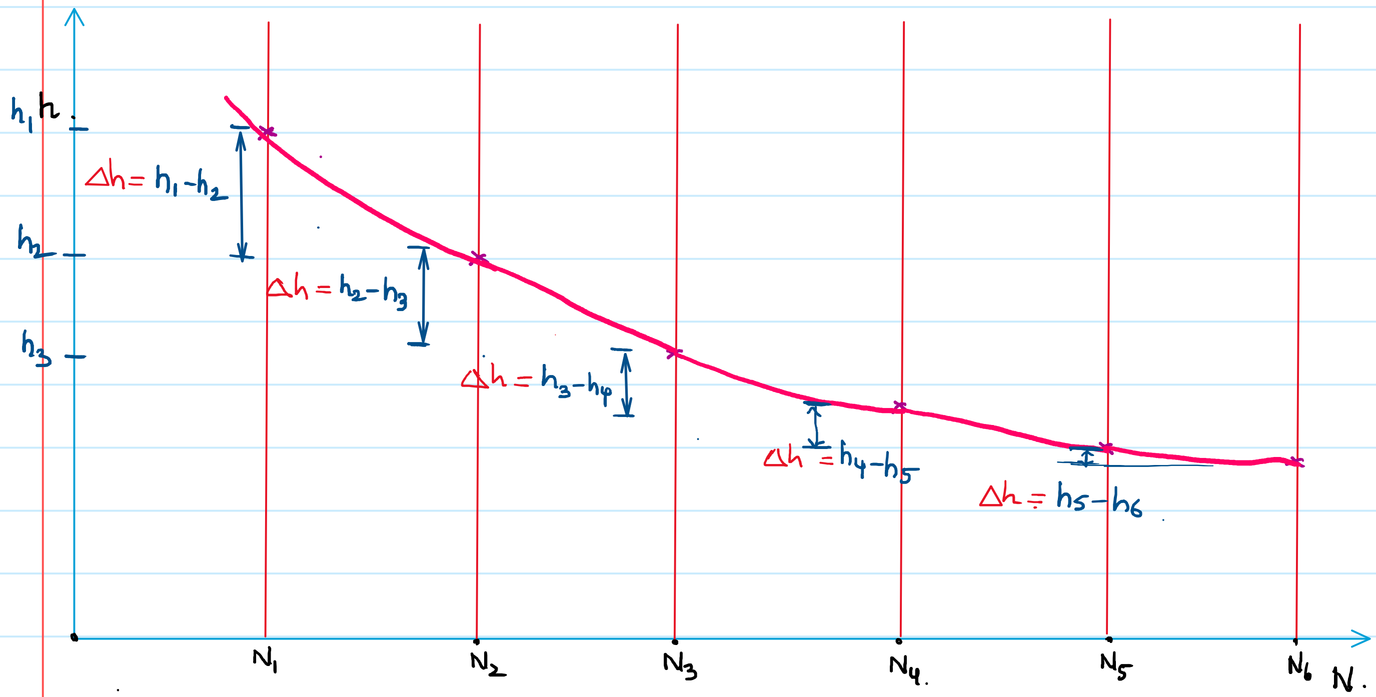


As $N\uparrow$ $\Delta h\downarrow$ for N_7 $\Delta h \to 0$ $h_6 - h_7 = 0 \Rightarrow h_6 = h_7$.

There is no sleeve displacement for speed N_7 and governor becomes insensitive at higher speeds.

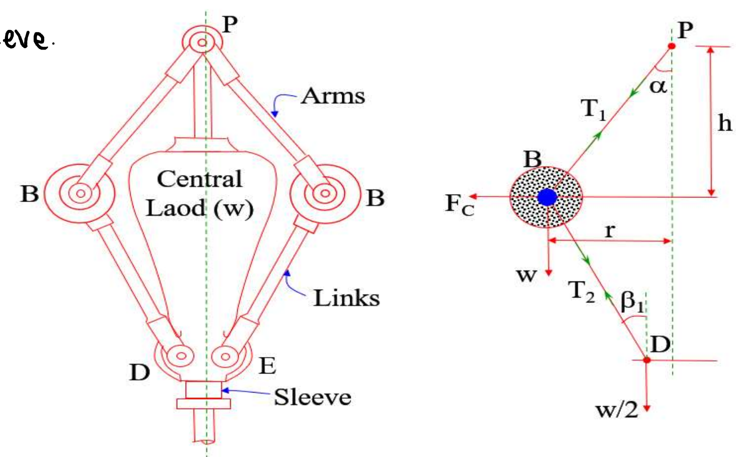
Hence Watt governor is used only for low speed prime mover.

Porter Governor → Dead wt. governor / Gravity controlled governor.

m – Mass of flyball.

M – Mass of sleeve.

ANALYSIS OF PORTER GOVERNOR:



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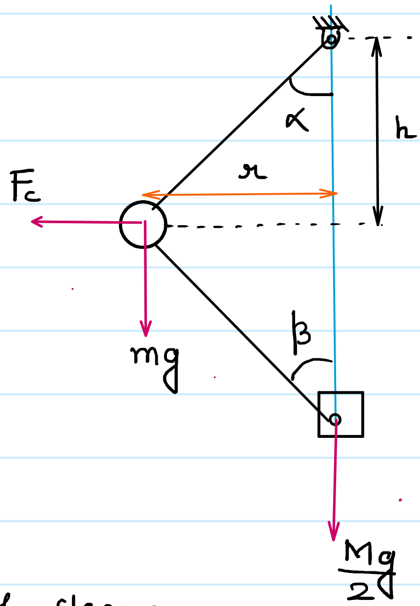
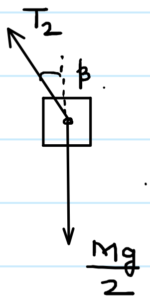


$$\boxed{\tan\alpha = \frac{r}{h}}$$

F.B.D. of sleeve.

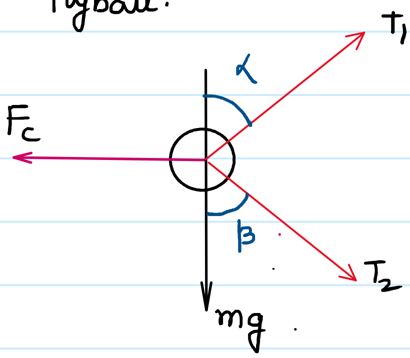


T_2 – Tension in lower arm.

$\Sigma F_y = 0$

$$T_2 \cdot \cos\beta = \frac{Mg}{2} \Rightarrow T_2 = \frac{Mg}{2\cos\beta}.$$

F.B.D. of flyball.



$\Sigma F_x = 0$

$$T_1 \sin\alpha + T_2 \sin\beta = F_c.$$

$$T_1 \sin\alpha = F_c - T_2 \cdot \sin\beta.$$

$$T_1 \sin\alpha = F_c - \frac{Mg}{2} \cdot \tan\beta. \rightarrow (A)$$

$\Sigma F_y = 0$

$$T_1 \cos\alpha = mg + T_2 \cdot \cos\beta.$$

$$T_1 \cos\alpha = mg + \frac{Mg}{2} \rightarrow (B)$$

$$\frac{A}{B} = \tan\alpha = \frac{F_c - \frac{Mg}{2}\tan\beta}{mg + \frac{Mg}{2}}$$

$$mg \cdot \tan\alpha + \frac{Mg}{2} \cdot \tan\alpha = mr\omega^2 - \frac{Mg}{2} \cdot \tan\beta.$$

$$mr\omega^2 = \tan\alpha \cdot \left[mg + \frac{Mg}{2} \cdot \left(1 + \frac{\tan\beta}{\tan\alpha}\right)\right]$$

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

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Considering friction at sleeve.

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

$f = 0$ when the sleeve is not moving. $\omega =$ constant.
$f = -ve$ when the sleeve is moving downwards ω decreases.
$f = +ve$ when the sleeve is moving upwards. ω increases.

$f = 0$, upper and lower arms are of equal lenght. $\alpha = \beta$, $q = 1$

$$h = \frac{mg + Mg}{m \cdot \omega^2} \Rightarrow h = \left(\frac{m+M}{m}\right) \cdot \frac{g}{\omega^2}$$

$$\omega^2 = \left(\frac{m+M}{m}\right) \cdot g/h.$$

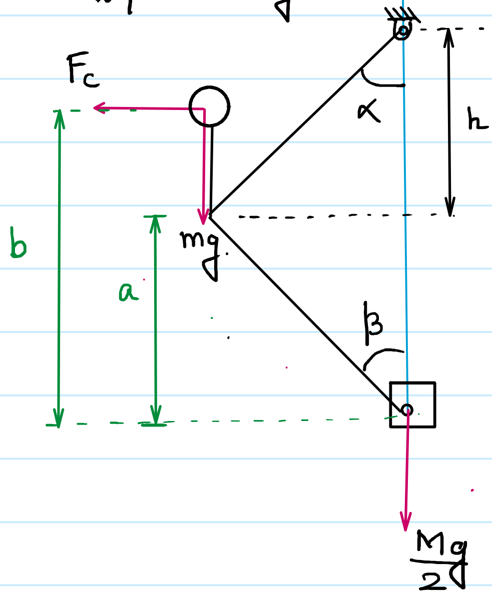
$$\omega^2_{porter} = \left(\frac{m+M}{m}\right) \cdot \omega^2_{watt}$$

$$\frac{\omega^2_{porter}}{\omega^2_{watt}} = \left(\frac{m+M}{m}\right) > 1.$$

$(M > m)$

Porter governor can be used for high speed Prime movers.

Proell governor – Dead wt / Gravity Controlled governor.



$$h = \left(\frac{a}{b}\right)\left[\frac{mg + \frac{(Mg \pm f)}{2}(1+q)}{m\omega^2}\right]$$

HARTNELL GOVERNOR/ Spring load Governor.

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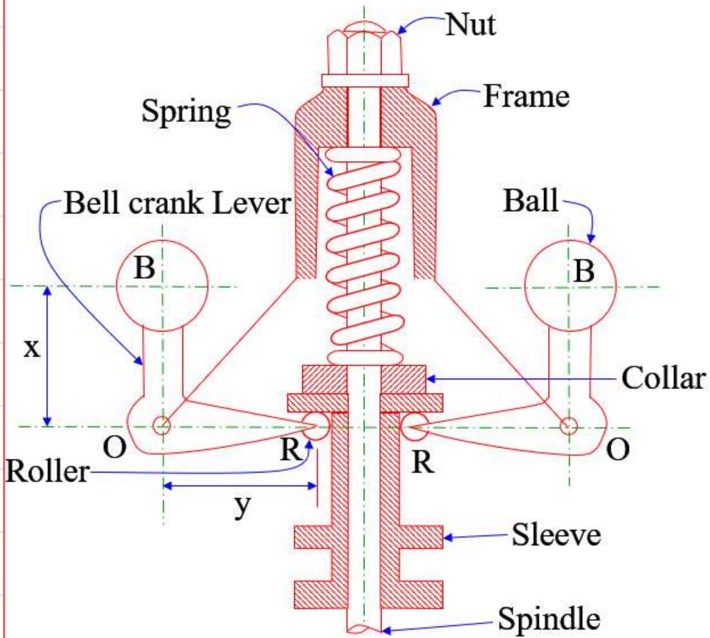


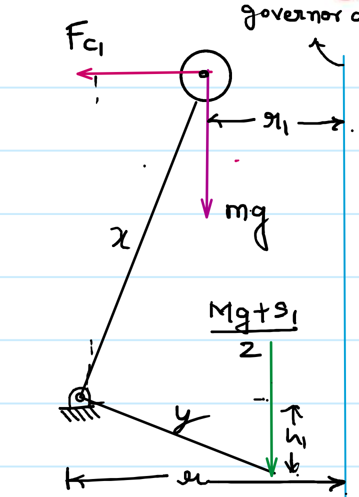
r_1, r_2 radii of rotation for $\omega_{min}, \omega_{max}$

S_1, S, S_2 – Spring forces @ min pos'n, mean pos'n, max. pos'n.

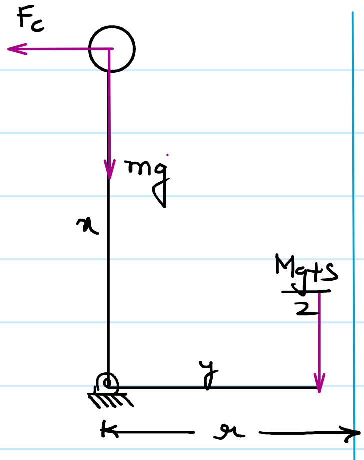
x – lenght of ball arm.

y – lenght of sleeve arm.

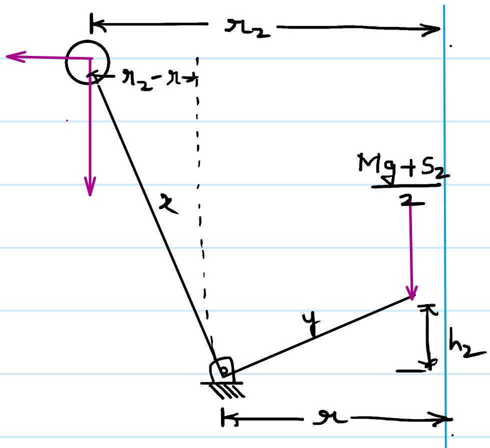
m, M – masses of flyball. & sleeve.



Min position.



Mean pos'n.



Max. pos'n.

Min position:

$\Sigma M_{Hinge} = 0$

$F_{c_1} \times x - mg(\underbrace{r - r_1}_{0}) = \frac{Mg+S_1}{2} \cdot y$

$F_{c_1} \cdot x = \frac{Mg+S_1}{2} \cdot y$

$M = 0 \Rightarrow F_{c_1} \cdot x = \frac{S_1}{2} \cdot y \rightarrow (A)$

Mean pos'n:

$\Sigma M_{Hinge} = 0$

$F_c x = \frac{Mg+S}{2} \cdot y$

$M = 0$

$F_c \cdot x = \frac{S}{2} \cdot y$

Max pos'n:

$\Sigma M_{Hinge} = 0.$

$F_{c_2} \cdot x + mg(r_2 - r) = \left(\frac{Mg+S_2}{2}\right) y$

$F_{c_2} \cdot x = \frac{S_2}{2} \cdot y \rightarrow (B)$

$$(B-A) = (F_{c_2} - F_{c_1}) x = \left(\frac{S_2 - S_1}{2}\right) \cdot y$$

Neglecting the effect of obliquity of arms., Neglecting the effect of moment due to revolving mass.

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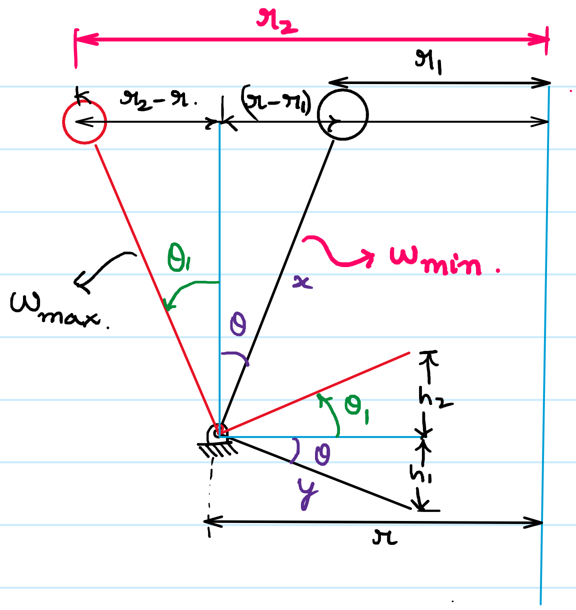

sleeve displacement $= h_1 + h_2$

$$\frac{h_1}{y} = \frac{(r - r_1)}{x}$$

$$h_1 = (r - r_1) \cdot \frac{y}{x}$$

$$\frac{h_2}{y} = \frac{(r_2 - r)}{x} \Rightarrow h_2 = (r_2 - r) \cdot \frac{y}{x}$$

sleeve displacement $h = h_1 + h_2 = \frac{y}{x}(r - r_1) + \frac{y}{x}(r_2 - r)$

$$h = \frac{y}{x} \cdot (r_2 - r_1)$$

Spring force $= S_1 = k h_1$

Spring force $= S_2 = k \cdot h_2$

$$(F_{c_2} - F_{c_1}) x = \frac{(S_2 - S_1)}{2} \cdot y$$

$$(F_{c_2} - F_{c_1}) x = \frac{k}{2} \cdot (h_2 - (-h_1)) y \Rightarrow (F_{c_2} - F_{c_1}) x = \frac{k}{2} \cdot (h_1 + h_2) \cdot y$$

$$(F_{c_2} - F_{c_1}) \cdot x = \frac{k}{2} \cdot \frac{y}{x} \cdot (r_2 - r_1) \cdot y$$

$$k = \frac{2(F_{c_2} - F_{c_1})}{(r_2 - r_1)} \cdot \left(\frac{x}{y}\right)^2$$

$x, y =$ constant.

$k =$ const.

$$\boxed{\frac{F_{c_2} - F_{c_1}}{r_2 - r_1} = \frac{F_c - F_{c_1}}{r - r_1}}$$

Terminology of Governors

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Centrifugal Force - The force which has tendency to move the flyballs away from the governor axis is called centrifugal force.

$F_c = mr\omega^2$

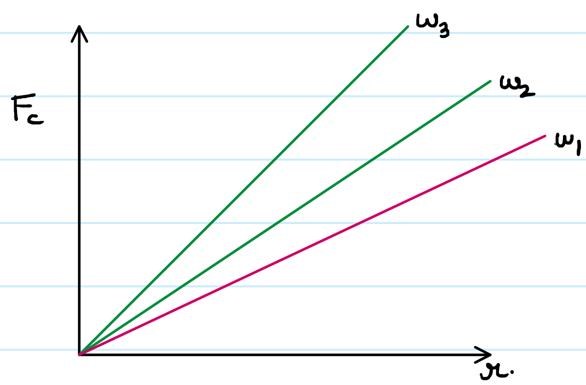
$\hookrightarrow F_c \propto r^1$

$\frac{F_c}{r} = m\omega^2$

$m = const.$

$\frac{F_c}{r} = \tan\theta = m\omega^2$

$\tan\theta \propto \omega^2$

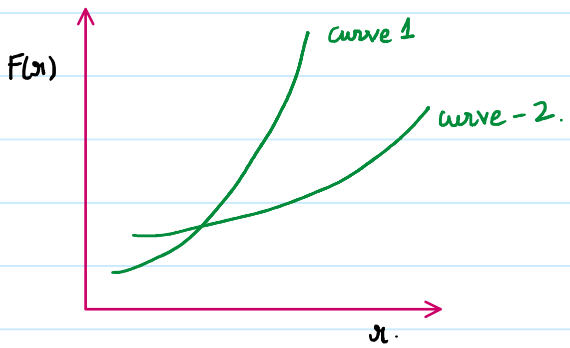


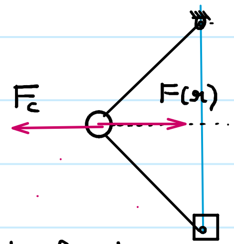
$\omega_3 > \omega_2 > \omega_1$

Controlling Force - The force which has the tendency to move the flyballs towards the governor axis is called as Controlling force.

Controlling Force in case of dead weight governor is the resultant of Weight of flyball, sleeve, friction at sleeve. **Major Component of Controlling force is from the Weight of the sleeve only.**

Controlling Force curve for Dead weight governor (Porter & Proell)



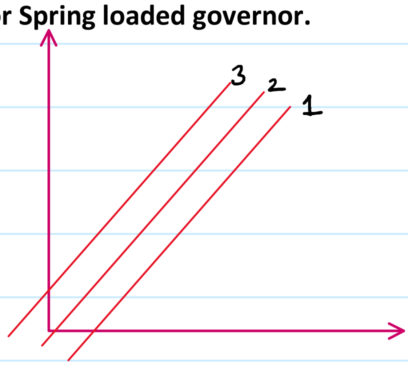


F_c – centrifugal force

F(r) – controlling force.

Controlling force in case of spring controlled governor is the resultant of Weight of flyball, sleeve, Spring and Friction at sleeve. **The major component of controlling force is coming from spring only.**

Controlling Force curve for Spring loaded governor.



$C.F_1 = ar - b$

$CF_2 = ar.$

$CF_3 = ar + b$

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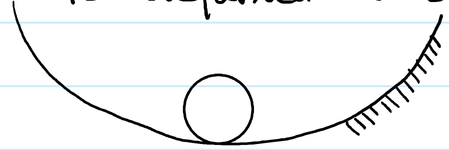
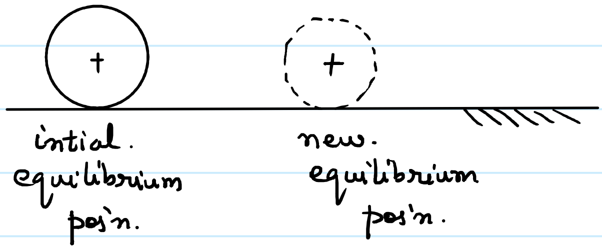
1. Stable equilibrium. – system will come back to intial equilibrium position after distrubing.
No external work is required to bring back to intial equilibrium pos'n.



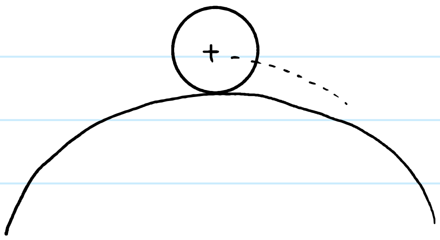
2. Neutral Equilibrium – System will move to new equilibrium., pos'n. when it is distrubed.

External Work is required.



3. Unstable equilibrium. – System continues to undergo the change in. state after its is distrubed from the. equilibrium.

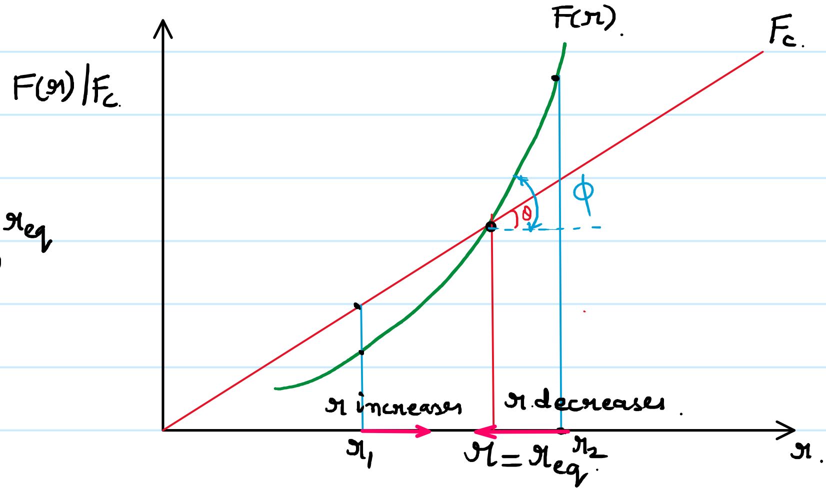
External Work is required.



$$(W.D)_{\text{unstable equilibrium}} > (W.D)_{\text{Neutral equilibrium}}$$

Stability Analysis of Dead wt. governor.

@ $r = r_{eq}$
$\phi > \theta$



@ $r = r_{eq}$ $F_c = F(r)$.

@ $r = r_1$ $F_c > F(r)$.

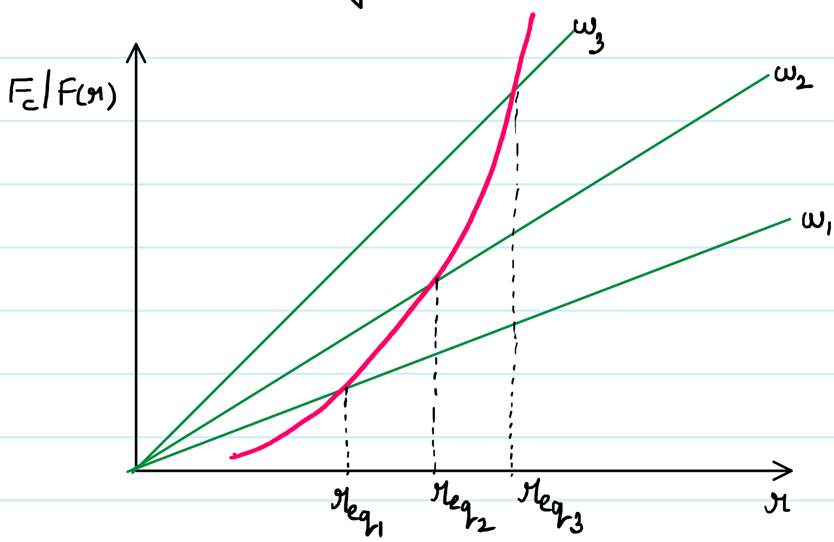
F_c increases r.

@ $r = r_2$ $F(r) > F_c$.

$F(r)$ decreases r.

F_c, $F(r)$ will push the governor to $r = r_{eq}$. Hence the given governor is stable.

ϕ – Slope of controlling curve, θ – slope of F_c vs r graph.

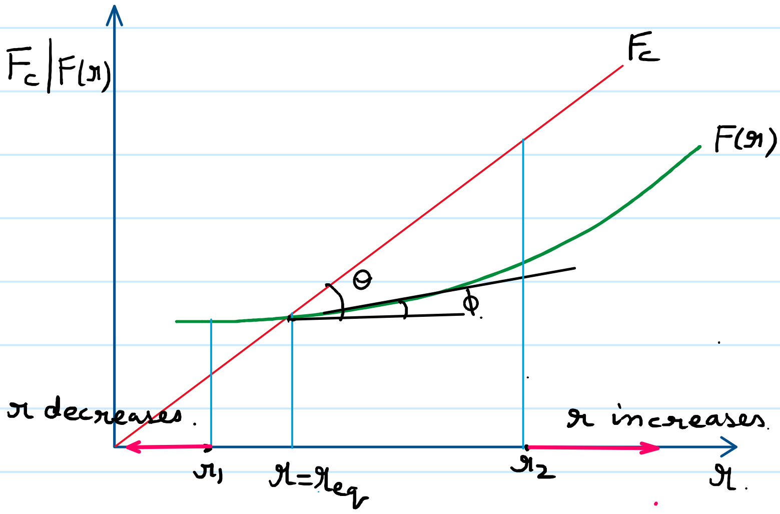


r_{eq} – equilibrium radius.

As $r_{eq} \uparrow$ $\omega \uparrow$ sleeve will move upward, opening of throttle valve will decrease., Fuel supply decreases.

As $r_{eq} \downarrow$ $\omega \downarrow$ sleeve will move downward, opening of throttle valve will. increase., Fuel supply increases.

Hence the governor is said to be stable.



@ $r = r_{eq}$ $F_c = F(r)$

$\theta > \phi$

@ $r = r_1$ $F(r) > F_c$

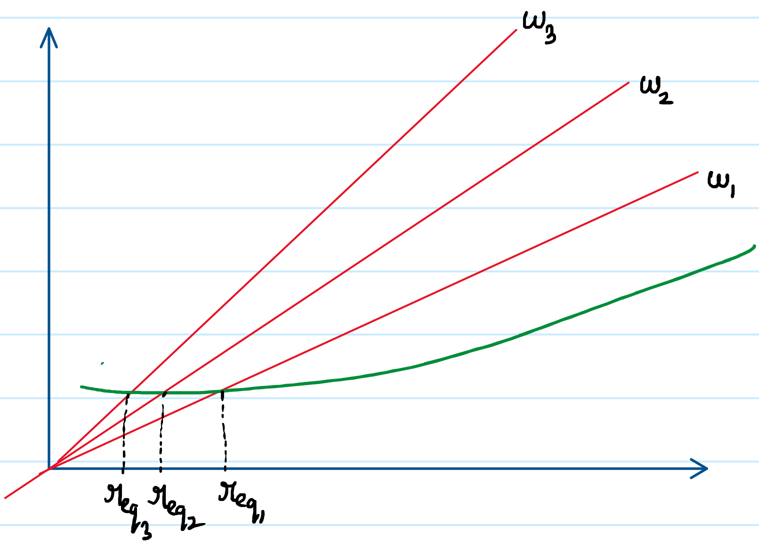
$F(r)$ decreases r.

@ $r = r_2$ $F_c > F(r)$

F_c increases r.

F_c, $F(r)$ will deviate the governor from $r = r_{eq}$.

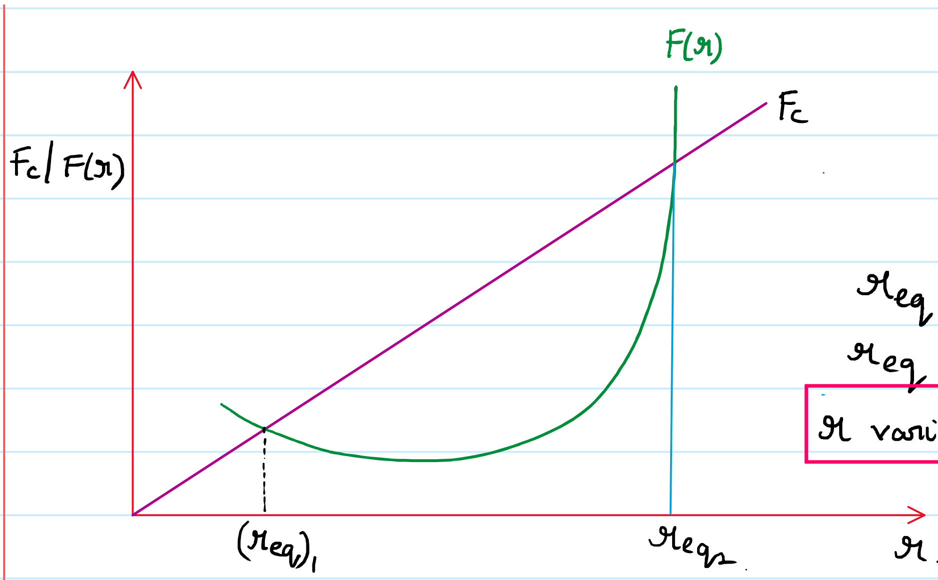
Hence the governor is unstable.



As $r_{eq} \uparrow$ $\omega \downarrow$ sleeve will move upwards, throttle valve opening decrease, Fuel supply decreases.

As $r_{eq} \downarrow$ $\omega \uparrow$ sleeve will move downward, throttle valve opening increases, Fuel supply increases.

Governor is said to be unstable.



$r_{eq} \uparrow \quad \omega = \text{constant}.$

$r_{eq} \downarrow \quad \omega = \text{constant}.$

$\boxed{r \text{ varies} \quad \omega = \text{constant}}$

↳ Isochronism.

@ $r = r_{eq_1}$ $\quad F_c = F(r)$ sleeve is closer to B.D.C., opening of throttle more, Fuel supply increases.

@ $r = r_{eq_2}$ $\quad F_c = F(r)$, sleeve is closer to T.D.C, opening of throttle less, Fuel supply decreases.

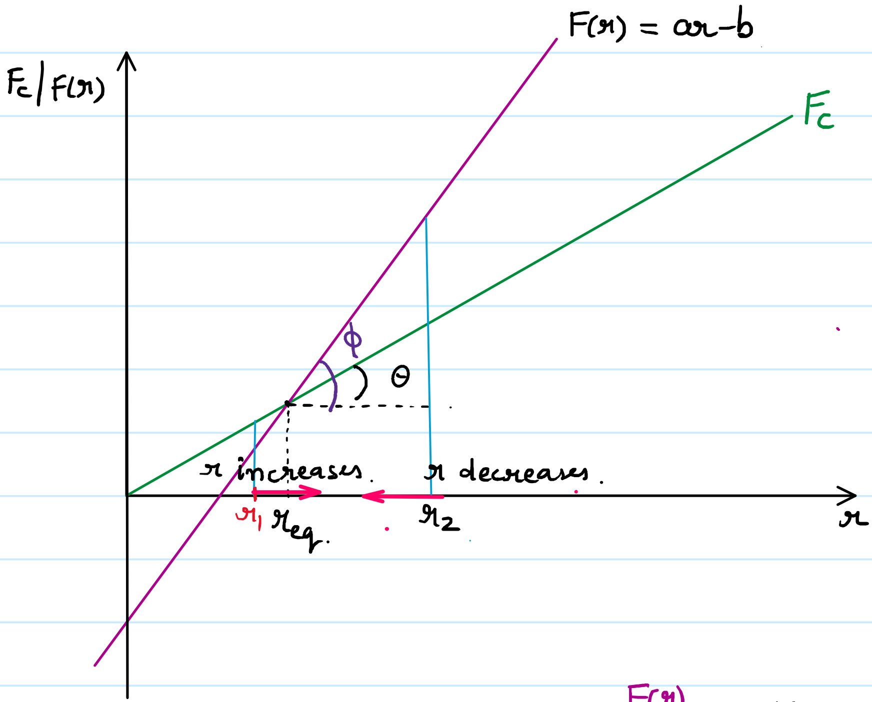
ω = constant

$$\omega^2 = \left[\frac{mg + \frac{Mg}{2}(1+q)}{mh}\right] \qquad m, M, g \longrightarrow \text{constant}.$$

$$\tan\alpha = \frac{r}{h} \Rightarrow h \propto r. \qquad \omega^2 \propto \frac{1}{h}, \; h \propto r. \Rightarrow \boxed{\omega^2 \propto \frac{1}{r}}$$

Isochronism is not possible in case of Dead Wt. Governor.

For a stable governor there must be unique value of speed for a given radius of rotation of flyballs.



@ $r = r_{eq}$ $F_c = F(r)$

$\phi > \theta$

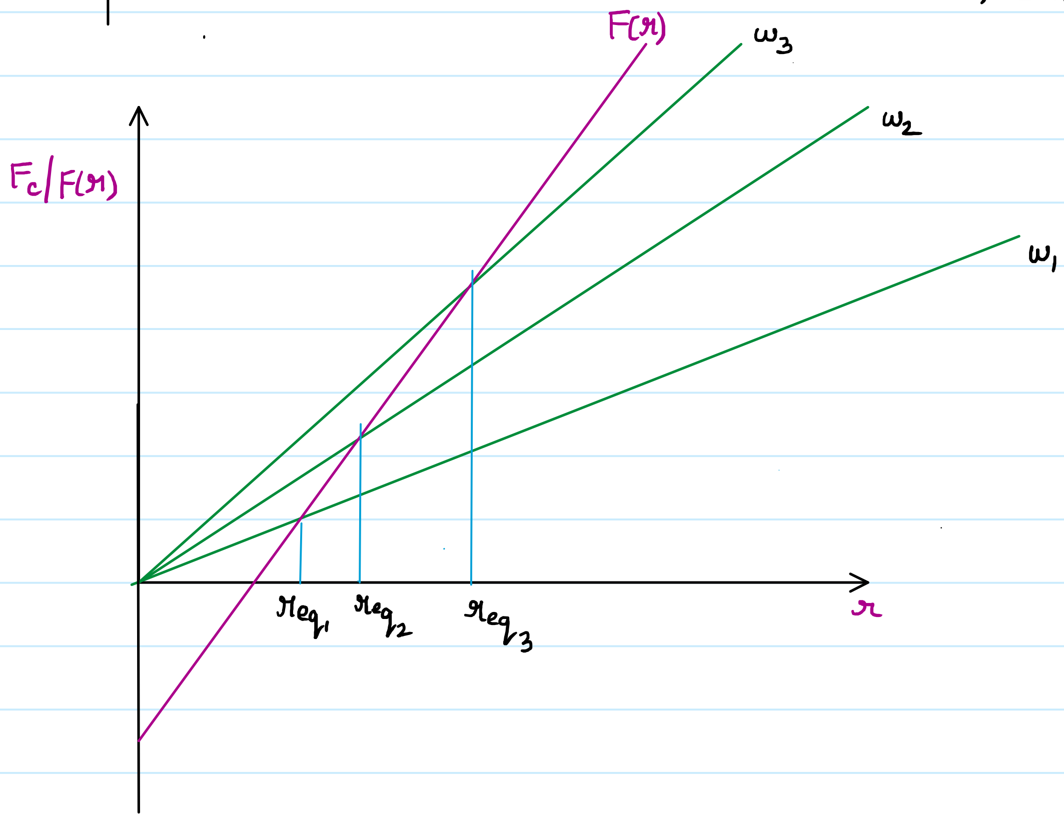
@ $r = r_1$ $F_c > F(r)$

F_c increases r.

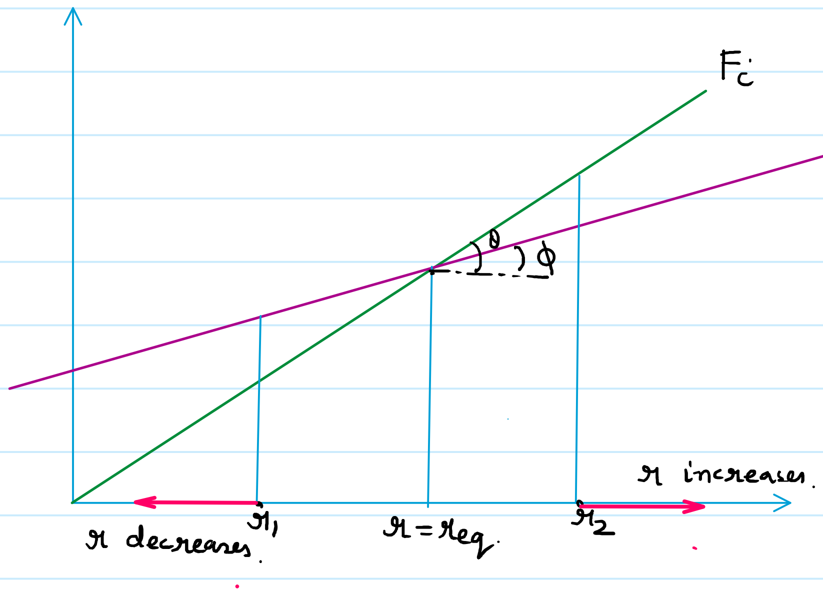
@ $r = r_2$ $F(r) > F_c$

$F(r)$. decreases r.

$F(r) = ar - b$



As r_{eq} increases ω increases. Sleeve upward fuel supply ↓.



@ $r = r_{eq}$. $F_c = F$.

$\theta > \phi$.

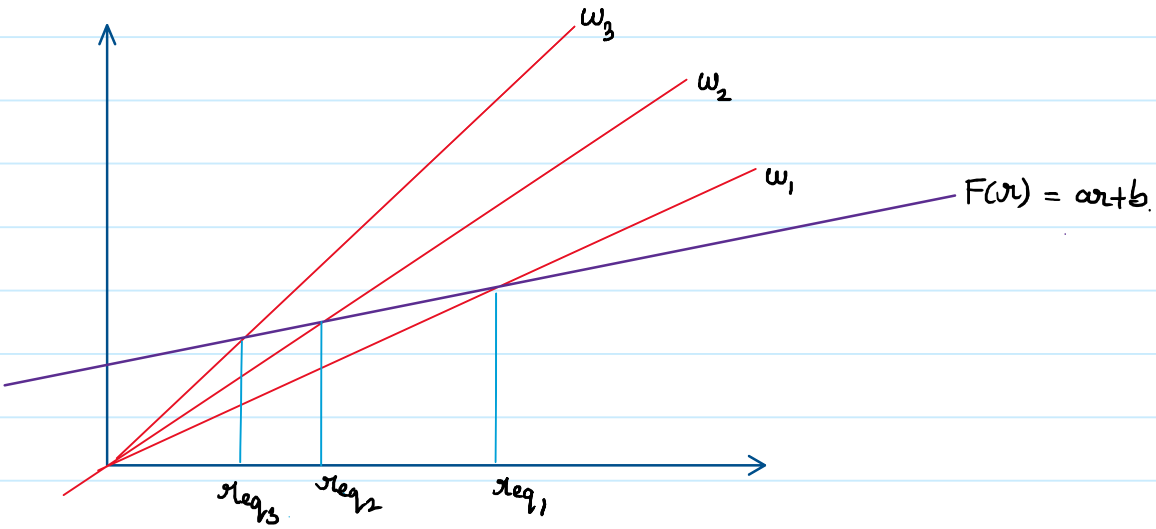
@ $r = r_1$ $F(r) > F_c$

F(r) decreases. r

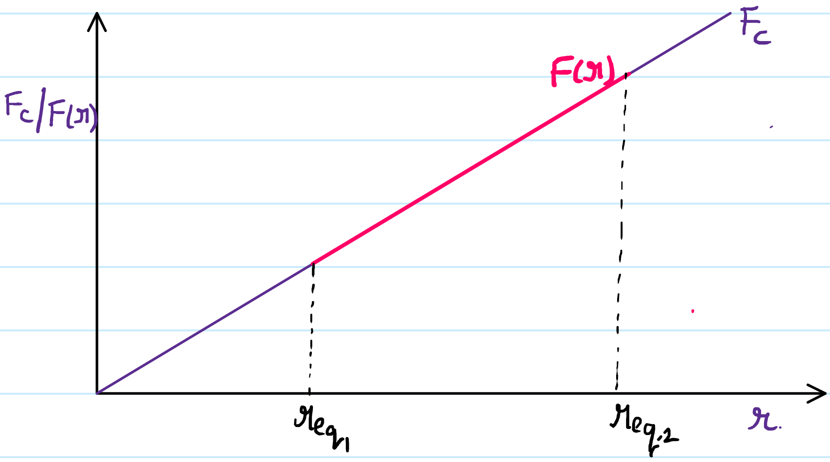
@ $r = r_2$ $F_c > F(r)$

F_c increases r

Governor is unstable.



As $r_{eq} \uparrow$ $\omega \downarrow$, $r_{eq} \downarrow$. $\omega \uparrow$. Hence the governor is unstable.



Isochronous governor.

@ $r = r_{eq_1}, r_{eq_2}$

$F_c = F(r) \quad \theta = \phi$

$\omega = \text{constant}$

$F(r) = ar$.

For Hartnell governor.

$$F_{c_1} \times x = \frac{Mg + S_1}{2} \cdot y$$

$$F_{c_2} \times x = \frac{Mg + S_2}{2} \, y$$

$$\frac{\cancel{m} \cdot r_1 \cdot \cancel{\omega_1^2} \cdot \cancel{x}}{\cancel{m} \cdot r_2 \cdot \cancel{\omega_2^2} \cdot \cancel{x}} = \frac{\frac{Mg+S_1}{\cancel{2}} \cdot \cancel{y}}{\frac{Mg+S_2}{\cancel{2}} \cdot \cancel{y}} \Rightarrow \frac{r_1}{r_2} = \frac{Mg+S_1}{Mg+S_2}$$

Condition for isochronism for Hartnell governor $\rightarrow$ $\boxed{\frac{r_1}{r_2} = \frac{S_1}{S_2}}$

Sensitivity of the Governor - It the ability of the governor to sense the change in given load and alter the fuel supply accordingly.

$$\boxed{\text{Sensitivity} = \frac{N_{max} - N_{min}}{\left(\frac{N_{max} + N_{min}}{2}\right)}}$$

$\rightarrow$ Governor coupled to Prime mover.

$$\boxed{\text{Sensitivity} = \frac{\left(\frac{N_{max} + N_{min}}{2}\right)}{(N_{max} - N_{min})}}$$

$\rightarrow$ Governor is considered as individual mechanism.

Effort of the Governor - It is the average force exerted on the sleeve for The percentage change in speed.

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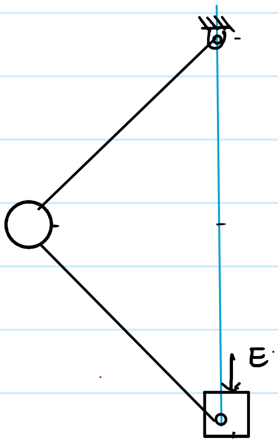

$$\omega^2 = \frac{mg + \frac{Mg}{2}(1+q)}{mh} \longrightarrow (1) \qquad \omega'^2 = \left[\frac{mg + \frac{Mg}{2}(1+q)}{mh'}\right]$$

$$\omega' = \omega(1+c) \qquad c \rightarrow \text{\% change in the speed.}$$

$$\omega'^2 = \left[\frac{mg + \left(\frac{Mg+E}{2}\right)(1+q)}{mh}\right] \longrightarrow (2)$$

$$\frac{1}{2} = \frac{\cancel{\omega^2}}{(1+c)^2 \cdot \cancel{\omega^2}} = \frac{\left[mg + \frac{Mg}{2}(1+q)\right] \times \cancel{\frac{1}{mh}}}{\left[mg + \frac{Mg+E}{2}(1+q)\right] \times \cancel{\frac{1}{mh}}}$$

$$\frac{1}{(1+c)^2} = \frac{2mg + Mg(1+q)}{2mg + (Mg+E)(1+q)} \qquad 1 + \cancel{c^2} + 2c \approx 1 + 2c \quad (c^2 \to 0)$$

$$2mg + Mg(1+q) + E.(1+q) = (1+2c) \cdot \left[2mg + Mg.(1+q)\right]$$

$$\cancel{2mg} + \cancel{Mg(1+q)} + E.(1+q) = \left[\cancel{2mg} + \cancel{Mg(1+q)}\right] + 2c\left[2mg + Mg.(1+q)\right]$$

Effort $\longrightarrow \quad \frac{E}{2} = \frac{2c.\left[2mg + Mg.(1+q)\right]}{2.(1+q)} \Rightarrow \frac{E}{2} = \frac{c.\left[2mg + Mg(1+q)\right]}{(1+q)}$

$q = 1 \qquad E/2 = c.[m+M]g.$

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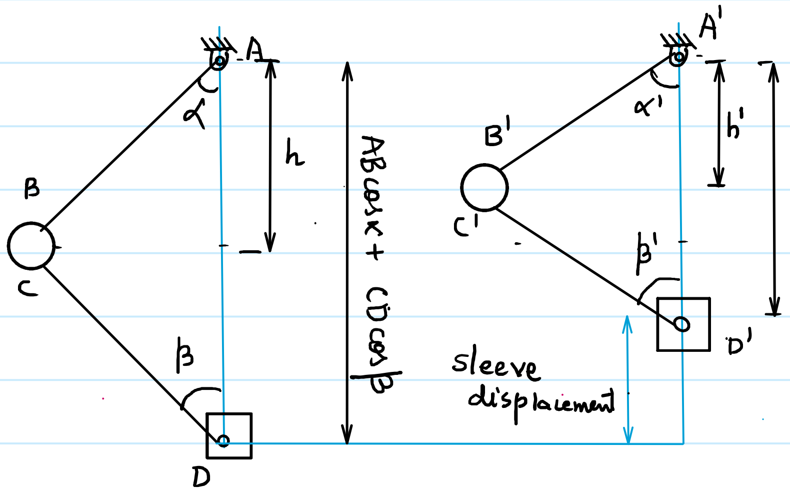
Sleeve Displacement - It is the change in the position of sleeve for a percentage change in speed.



$AB = A'B'$

$CD = C'D'$

$\alpha = \beta \Rightarrow AB = CD = A'B' = C'D'$

$$\text{Sleeve displacement} = (AB\cos\alpha + CD.\cos\beta) - (A'B'\cos\alpha' + C'D'\cos\beta')$$
$$= 2h - 2h' = 2\cdot(h-h')$$

$$h = \frac{g}{\omega^2} \qquad h' = \frac{g}{\omega'^2} \Rightarrow h' = \frac{g}{\omega^2(1+c)^2}$$

$$\text{sleeve displacement} = 2h\cdot\left[1 - \frac{h'}{h}\right] = 2h\cdot\left[1 - \frac{g/\omega^2(1+c)^2}{g/\omega^2}\right]$$

$$\text{sleeve displacement} = 2h\cdot\left[1 - \frac{1}{(1+c)^2}\right] = 2h\left[1 - \frac{1}{1+2c}\right]$$

$c^2 \approx 0$

$$= \frac{4hc}{(1+2c)}$$

Power of the Governor - It is the work done on the sleeve for a percentage change in speed.

$$\text{Work done} = \text{Effort} \times \text{sleeve displacement}$$

$$\text{Work done} = \frac{E}{2} \times 2\cdot(h-h') = c\frac{[2mg + Mg(1+q)]}{(1+q)} \times \frac{4hc}{1+2c}$$

$q = 1 \qquad \text{Work done} = [m+M]\,g\cdot h\cdot\left(\frac{4hc^2}{1+2c}\right)$

for Watt governor $M = 0$.

Hunting - A highly sensitive governor produces large sleeve displacement
For a small change in speed. Due to the variation in load there will be changes in speed this causes the rapid displacement of sleeve.
This phenomenon is called as Hunting. Upper & lower arms , sleeve experiences violent oscillations.

At Hunting governor is at resonance.
If the frequency of fluctuation in speed coincides with the natural frequency of the governor then resonance will occur.

Coefficient of Detention/Coefficient of Insensitiveness - Due to the presence friction the governor becomes insensitive over a range of speed. In order to overcome the friction the governor is required to undergo additional change in speed.

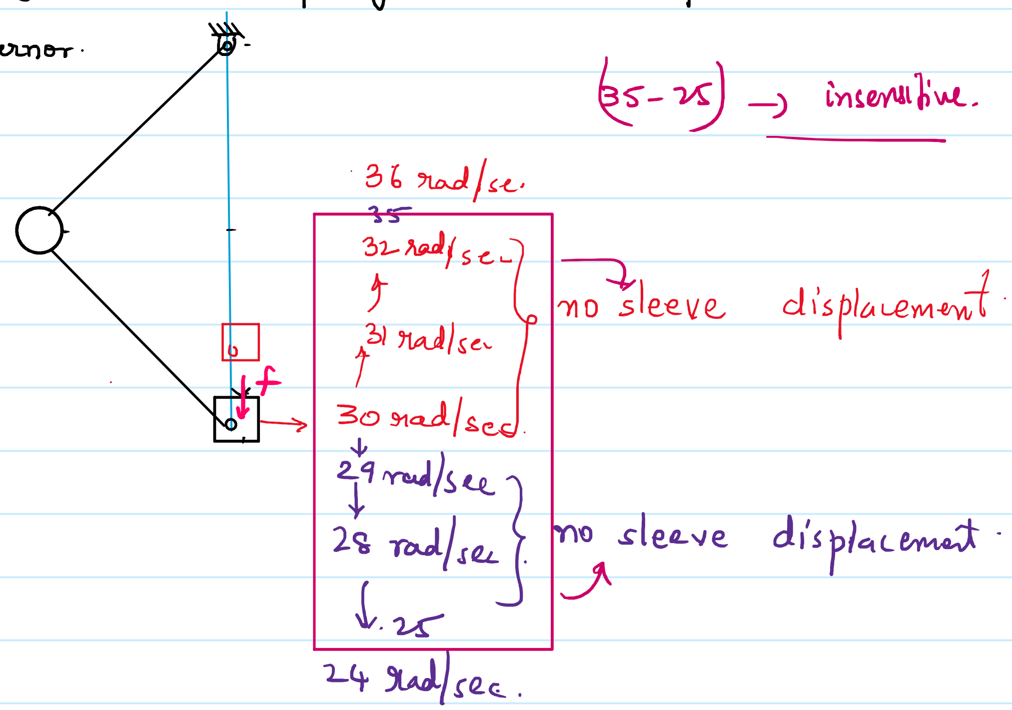
$$\text{Coefficient of Dententiion} = \frac{\omega' - \omega''}{\left(\frac{\omega' + \omega''}{2}\right)} = \frac{2f}{(m+M)g}$$

ω' – Speed of governor for which there is no sleeve displace-ment.

ω'' – Speed of governor for which there is no sleeve displacement.

f – friction force , m – mass of flyball M – Mass of sleeve.

$M = 0$ for Watt governor.



01. For a governor running at constant speed, what is the value of the force acting on the sleeve ?
(a) Zero
(b) Variable depending upon the load
(c) Maximum
(d) Minimum

$\omega = \text{constant} \Rightarrow C = 0.$

Effort = ?

$C = 0 \rightarrow \text{Effort} = 0.$

02. When a porter governor is running at equilibrium speed the friction at the sleeve will be
(a) in the upward directions
(b) in the downward directions
(c) perpendicular to the spindle
(d) zero

equilibrium speed. → $\omega = \text{constant}$

↳ sleeve is neither moving up or downward.

friction = 0.

03. In a porter governor all the links are connected on the axis of the spindle and are of same length, and are inclined to the axis by the same angle. The radius of rotation is $\sqrt{3}$ times the height of the governor which is 20 cm, sleeve mass is 10 kg and the ball mass is 2 kg each, the equilibrium speed is
(a) 17.15 rad/sec
(b) 7.67 rad/sec
(c) 12.05 rad/sec
(d) 14.15 rad/sec

$\alpha = \beta \Rightarrow q = 1.$

$r = \sqrt{3} \cdot h.$

$h = 20\text{cm}.$

$M = 10\text{ kg}$

$m = 2\text{kg}$

$\omega^2 = \left(\frac{m+M}{m}\right) \cdot g/h.$

$\omega^2 = \left(\frac{10+2}{2}\right) \times \frac{9.81}{0.2}$

$\omega = 17.15 \text{ rad/s.}$

04. In a Hartnell governor the ball arm and sleeve arm are of equal length. The sleeve mass is negligible and the ball mass is 1kg. At a ball radius of 25cm. The ball arm is vertical and the equilibrium speed is 20 rad/sec. If the spring stiffness is 200 N/cm the initial compression in the spring at this position is
(a) 1 cm
(b) 0.5 cm
(c) 2 cm
(d) 0.25 cm

$x = y$

$m = 1\text{kg}$

$r = 25\text{cm}.$

$\omega = 20\text{rad/s}.$

$K = 200\text{N/cm}$

$\delta_{\text{intial}} = ?.$

For Hartnell. Governor.

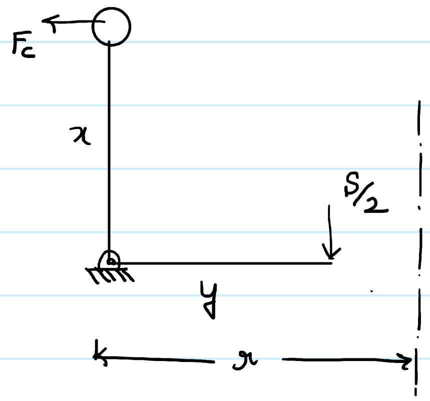
$F_c \times x = \frac{S}{2} \times y.$

$S = 2F_c.$

$K \cdot \delta_{\text{intial}} = 2 \times m r \omega^2$

$200 \times \delta_{\text{intial}} = 2 \times 1 \times 0.25 \times (20)^2$

$\delta_{\text{intial}} = 1\text{cm}.$



05. In a Hartnell governor the sleeve arm and ball arm are equal and half the radius of rotation in the mean position. The mean speed is 20 rad/sec, and the fulcrum is at a distance of 40 cm from the axis of rotation. The sleeve mass is negligible. If the ball mass is 1 kg each. The spring force at the mean position is
(a) 320 N
(b) 160 N
(c) 640 N
(d) None of the above

$x = y \quad \omega = 20 \text{ rad/s}.$
$r = 40\text{cm}. , m = 1\text{kg}$
$\Sigma M_{Hinge} = 0$
$F_c \times x = \frac{S}{2} \times y.$
$S = 2F_c \Rightarrow S = 2mr\omega^2 = 2 \times 1 \times 0.4 \times 20^2$
$S = 320\text{N}.$

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06. The sensitiveness of the governor is equal to
(a) $\frac{N_1 + N_2}{2N_1N_2}$ (b) $\frac{N_1 - N_2}{2N_1N_2}$
(c) $\frac{2(N_1 - N_2)}{N_1 + N_2}$ (d) $\frac{2(N_1 + N_2)}{N_1 - N_2}$

Where, N_1 = Maximum equilibrium speed
N_2 = Minimum equilibrium speed and
$\frac{N_1 + N_2}{2}$ = Mean equilibrium speed

$\text{Sensitivity} = \frac{\text{Range of Speed}}{\text{Mean Speed}} = \frac{N_{max} - N_{min}}{\left(\frac{N_{max} + N_{min}}{2}\right)}$

Sensitivity of isochronous governor is infinite.

07. A governor is sensitive and stable, supplied by a reliable vendor. But when connected to a steam engine it has became insensitive. The possible reason could be.
(a) steam engine requires isochronous governor
(b) the power of the governor could be too low to actuate the throttle linkage
(c) due to hunting it might have lost sensitivity
(d) either (a) or (c)

→ no sleeve displacement.
→ ω = const. for all radii
→ Highly sensitive governor.

08. The control force curve for a spring-loaded governor is a straight line. At a radius of 50cm the control force is 600N and at 60cm it is 700N. Assuming that the ball arm and sleeve arm are of equal length, identify the nature of the governor and also indicate how it can be made isochronous.
(a) Unstable, reduce the initial compression of the spring by 100 N
(b) Stable, reduce the initial compression of the spring by100 N
(c) Unstable, increase the initial compression of the spring by 100 N
(d) Stable, increase the initial compression of the spring by 100 N

$F(r) = ar + b$
@ $r = 50\text{cm}. \; F(r) = 600\text{N}.$
@ $r = 60\text{cm} \; F(r) = 700\text{N}.$

$600 = a\cdot(0.5) + b.$
$700 = a\cdot(0.6) + b$
$a = 100/0.1 = 1000r.$
$b = 100.$

$F(r) = 1000r + 100. \longrightarrow$ Unstable governor.
$F(r) = 1000r \longrightarrow$ Isochronous governor.

09. By increasing the dead weight in a Porter Governor the following does not happen
(a) It will become less sensitive
(b) The equilibrium speed will increase
(c) The stability will increase
(d) None of the above

$\omega^2 = \left[mg + \frac{Mg}{2}(1+q)\right] \cdot \frac{1}{mh}.$

a, b, c → all happens.

$\omega^2 \propto M.$

$M \uparrow$ stability $\uparrow$ sensitivity $\downarrow$

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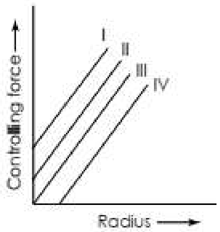
10. The plots of controlling force versus radii of rotation of the balls of spring controlled governors are shown in the given diagram. A stable governor is characterized by the curve labeled.



(a) I (b) II
(c) III $\boxed{\text{(d) IV}}$

I, II — $ar+b$. unstable governor
III → ar. → Isochronous governor.
IV → $ar-b$. → stable governor.

12. A spring controlled governor is found unstable. It can be made stable by
(a) increasing the spring stiffness ✗
(b) decreasing the spring stiffness ✓
(c) increasing the ball weight
(d) decreasing the ball weight

$F(r) = ar+b$ unstable
↓ decreasing spring stiffness
$F(r) = ar-b$ stable.

13. For a given fractional change of speed, if the displacement of the sleeve is high, then the governor is said to be
$\boxed{\text{(a) Hunting}}$
(b) Isochronous
(c) Sensitive
(d) Stable

14. Effect of friction at the sleeve of a centrifugal governor is to make it
(a) More sensitive
(b) More stable
$\boxed{\text{(c) Insensitive over a small range of speed}}$
(d) Unstable

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15. In a centrifugal governor, the controlling force is observed to be 14 N when the radius of rotation is 2 cm and 38 N when the radius of rotation is 6 cm, the governor:
(a) is a stable governor
(b) is an unstable governor
(c) is an isochronous governor
(d) cannot be said of what type with the given data

$F(r) = 14N \quad r = 2cm.$
$F(r) = 38N \quad r = 6cm.$

$F(r) = ar + b. \quad = \boxed{600r + 2}$

$14 = a(0.02) + b.$
$38 = a(0.06) + b$

$a = 600$
$b = 2$

unstable governor.

16. The controlling force in a spring controlled governor is 1500 N when the radius of rotation of the balls is 200 mm and 887.5 N when it is 130 mm. The mass of each ball is 8 kg. If the controlling force curve is a straight line, determine the controlling force and the speed of rotation when the radius of rotation is 150 mm. Also find the increase in the initial tension so that the governor is isochronous. What will be the isochronous speed?

$F(r) = 1500N. \quad r = 200mm. \quad m = 8kg$
$F(r) = 887.5 \quad r = 130mm.$

$r = 150mm. \quad F(r) = ?. \quad \omega = ?.$

intial tension. for isochronous governor = ?.

$\omega_{isochronous} = ?.$

MSQ

17. Consider the following statements in case of a governor and which of them is/are CORRECT ?
(a) A governor is said to be unstable if the radius of rotation falls as the speed increases. $\boxed{r_{eq} \uparrow \omega \downarrow}$ unstable
(b) Spring controlled governors never become isochronous.
(c) By increasing the initial compression of the spring the mean speed can be reduced.
(d) Isochronisms for a centrifugal governor can be achieved only at the expense of its stability.

$F(r) = ar - b \rightarrow ar.$

Gravity controlled governor never becomes isochronous.

(c). $F_c \times r = \frac{S \times y}{2}$

$mr\omega^2 = K.\delta_{intial}.$

$\omega^2 \propto \delta_{intial}.$

$F(r) = ar + b.$

$1500 = a(0.2) + b \qquad a = 8750$
$887.5 = a.(0.13) + b. \qquad b = -250.$

$F(r) = 8750r - 250.$

@ $r = 150mm.$

$F(r) = 8750(0.15) - 250$
$= 1062.5 \quad = mr\omega^2$
$= 1062.5 = 8 \times 0.15 \times \omega^2$

$\omega = \sqrt{\frac{1062.5}{1.2}} = 29.756 \text{ rad/s}.$

$F(r) = 8750r - 250$

↳ if intial tension is increase by 250N it becomes isochronous.

$F(r) = 8750\cancel{r} = m\cancel{r}.\omega^2_{isochronous}$

$\omega_{isochronous} = \sqrt{\frac{8750}{8}}$
$= 33.07 \text{ rad/s}.$

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