محاضرة

CH-5 :

* Governors

محكمات (منظمات السرعه)

Production : مقدمه

وظيفة المنظم هي ان ينظم حركه متوسطه للماكنه اوتوماتيكيا عندما تكون هناك تغير في الحمل.

The function of a governor is to regulate the mean speed of the engine, when there are variation in the Load automa--tially.

or when the Load increas $L\uparrow$, the Speed decrease $n\downarrow$, then automatically the fuel increase $F\nearrow$ untill get mean Speed $\rightarrow n_{mean}$; and apposite.

* Types of Governors :

I) Centrifugal Governors. محكمات الطرد المركزي

II) Inertia Governors. محكمات القصور الذاتي

Types of Centrifugal governors :

Centrifugal governors

- 1) Pendulum type — النوع البندولي
  - Watt g-r — محكم واط
- 2) Loaded type. — النوع ذات الحمل
  - a) dead weight g-rs — ذات الحمل الميت
    - 1) Porter g-r
    - 2) Proell g-r
  - b- Spring Controlled g-rs. — ذات السيطره بالنابض
    - 1) Hartnell g-r
    - 2) Hartung g-r
    - 3) Wilson hartnell g-r
    - 4- Pickering g-r

I) Centrifugal G-rs

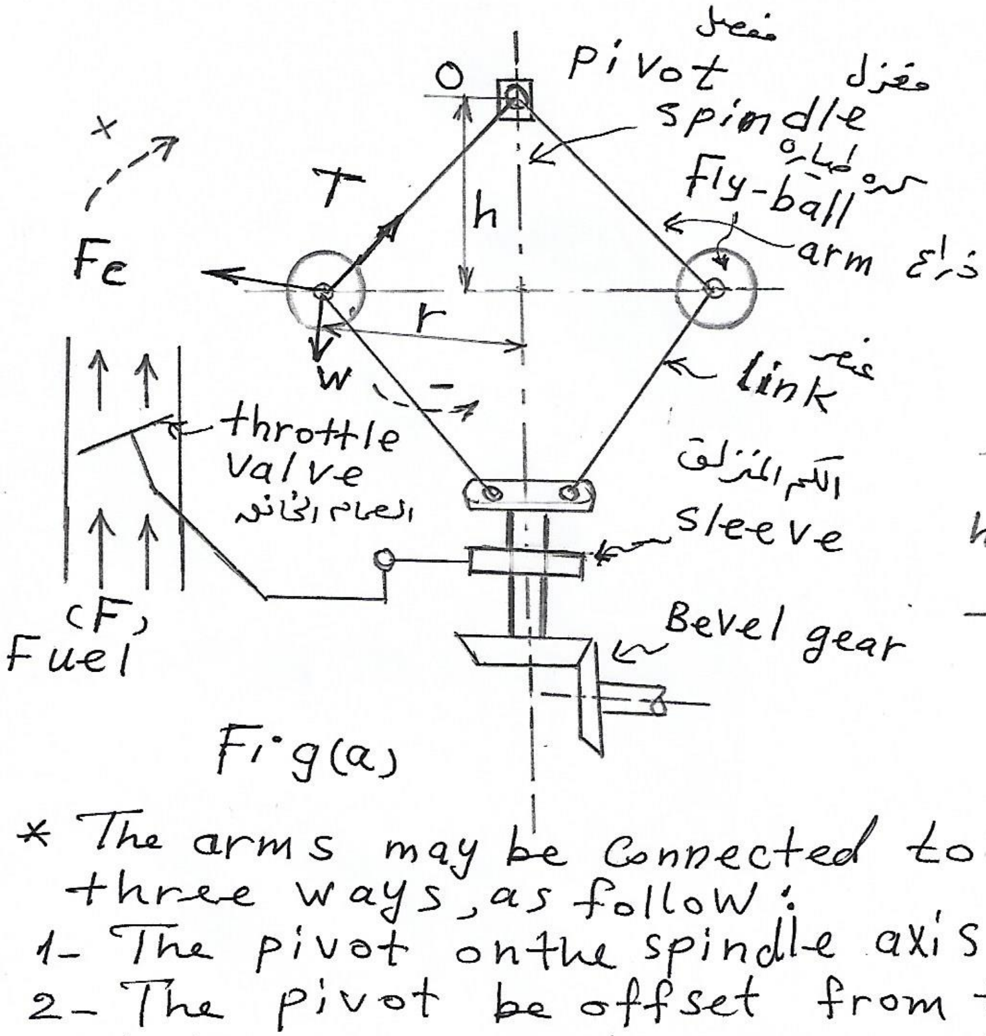
There work is bassed on the balancing of Centrifugal force of the rotating balls by an eqnal and opposite radial force, known as controlling force.

$$\boxed{F_b = F_c}$$

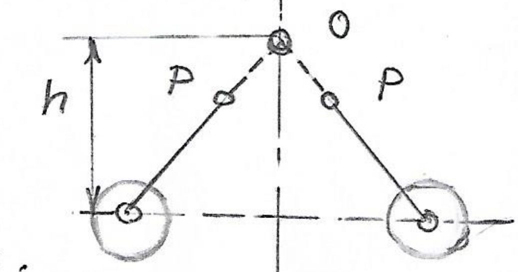
* For example: -

1) Watt Governor: منظم واط

It is the Simplest form of G-rs, as shown in fig (a) all the parts.



Fig(a)



Fig(b)

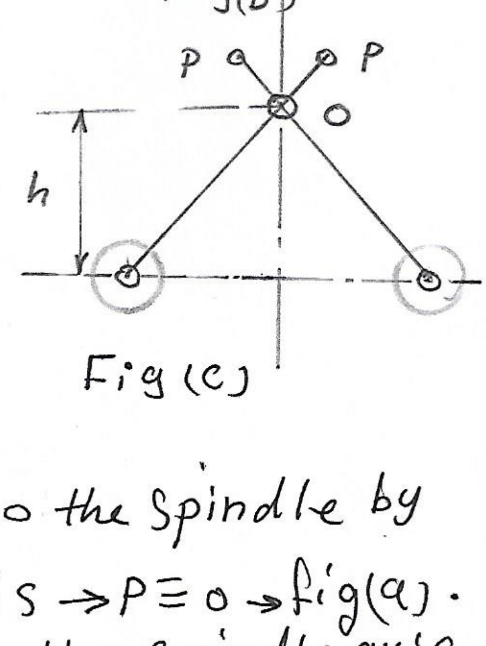


Fig (c)

* The arms may be connected to the spindle by three ways, as follow:

1- The pivot on the spindle axis → $P \equiv O$ → fig(a).
2- The pivot be offset from the spindle axis, but the arms intersect at O → fig(b),
3- The pivot be offset, but the arms crosses at O → fig(c).

* In order to find the relation between the height of the G-r and the speed of the arms and balls about the spindle axis.
* We take the moment about the pivot point (O), and by neglecting the weights of the arms, links and sleeve (by assuming these weights are very small w.r.t the weight of the balls).

$\therefore \sum M_o = 0$

$$F_c * h - W * r + T * 0 = 0$$

$\therefore F_c * h = W * r$

but $F_c = m r \omega^2 = \frac{W}{g} r \omega^2$, $\omega = \frac{2\pi n}{60}$ rad/s

$\therefore \frac{\cancel{W}}{g} \omega^2 \cancel{r} * h = \cancel{W} * \cancel{r}$

$$\therefore h = \frac{g}{\omega^2} = \frac{9.81}{\left(\frac{2\pi n}{60}\right)^2} = \frac{895}{n^2} \; m$$

$$\therefore \boxed{h = \frac{895}{n^2} , m} \quad --- (1)$$

Where :

W - weight of ball, N

T - tension in the arm, N

ω - angular velocity of arm and ball, rad/s

r - radius of the bath of rotation of ball, m

F_c = Centrifugal force acting on the ball, N

h - height of the governor, m

$\Delta h = h_1 - h_2$, change in height , m

II- Porter governor

منظم بورتر

It is a modification of watt's g-r with a central load to the sleeve, as shown in fig(a)

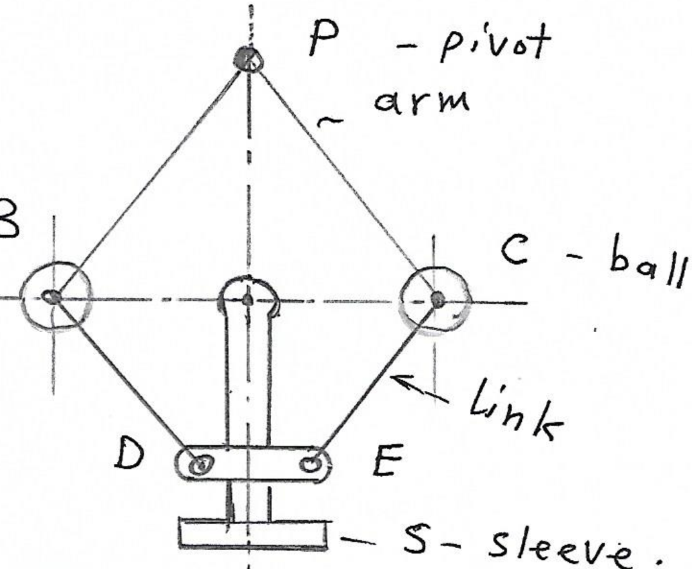


Fig (a)

* In order to determine the relation between h and n, we use two methods.

* I, <u>Method of resolution of forces, as follow:</u>

a) By resolving forces vertically at Point (D), and take equilibrium of them at point (D). fig (1)

$\because \Sigma F_{V D} = 0$

$\therefore + \frac{W}{2} - T_2 \cos\beta = 0 \Rightarrow$

$\therefore T_2 \cos\beta = \frac{W}{2}$

$$\boxed{\therefore T_2 = \frac{W}{2 \cos\beta}} \quad --- (1)$$

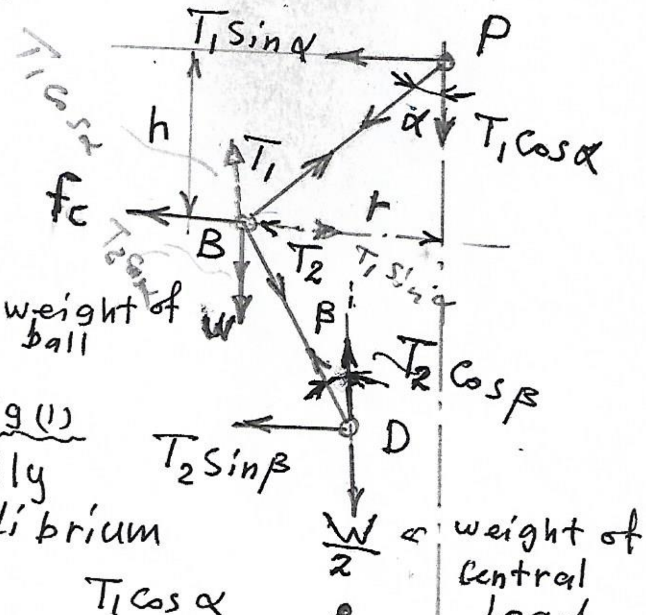


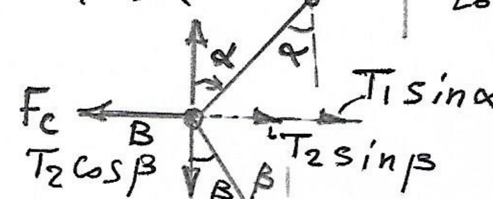
Fig (1)

b) By Resolving forces vertically at point (B), and take equilibrium at P-(B). Fig (2)

$\because \Sigma F_{V B} = 0$

$\therefore + T_1 \cos\alpha - W - T_2 \cos\beta = 0$

by sub-ing T_2 from (1)



$\therefore T_1 \cos\alpha = w + \dfrac{W}{2\cancel{\cos\beta}} \cdot \cancel{\cos\beta} = w + \dfrac{W}{2}$

$\therefore \boxed{T_1 \cos\alpha = w + \dfrac{W}{2}}$ --- (2)

C- By resolving forces horizontally acting at point (B) and take equilibrium of forces at p. (B) $\rightarrow \Sigma F B_h = 0$

$\therefore -F_c + T_1 \sin\alpha + T_2 \sin\beta = 0$

by sub T_2 from (1), we get

$T_1 \sin\alpha = F_c - \dfrac{W}{2\cos\beta} \sin\beta = F_c - \dfrac{W}{2} \tan g\beta$

$\tan\beta$

$\therefore \boxed{T_1 \sin\alpha = F_c - \dfrac{W}{2} \tan g\beta}$ --- (3)

By dividing (3) by (2) $\rightarrow$ we get

$\dfrac{\cancel{T_1} \sin\alpha}{\cancel{T_1} \cos\alpha} = \dfrac{F_c - \frac{W}{2}\tan\beta}{w + \frac{W}{2}}$ $\tan\alpha$

$\therefore (w + \dfrac{W}{2}) \tan g\alpha = F_c - \dfrac{W}{2} \tan g\beta \rightarrow$ by dividing on / tang α

$(w + \dfrac{W}{2}) = \dfrac{F_c}{\tan g\alpha} - \dfrac{W}{2} \dfrac{\tan g\beta}{\tan g\alpha}$ --- (4)

by assuming $\dfrac{\tan g\beta}{\tan g\alpha} = q$, and from $\Delta PBr \rightarrow \tan g\alpha = \dfrac{r}{h}$

$F_c = mr\omega^2$.

and by sub in (4) $\rightarrow$ we get.

$\dfrac{W}{2} + w = mr\omega^2 * \dfrac{h}{r} - \dfrac{W}{2} * q = m\cancel{r}\omega^2 \dfrac{h}{\cancel{r}} - \dfrac{W}{2} q$

عامل مشترك

$\therefore mh\omega^2 = w + \dfrac{W}{2} + \dfrac{W}{2} \cdot q = w + \dfrac{W}{2}(1+q)$

$\therefore \boxed{h = \dfrac{w + \frac{W}{2}(1+q)}{\frac{W}{g}\,\omega^2} = \dfrac{w + \frac{W}{2}(1+q)}{\frac{W}{g}\left(\frac{2\pi n}{60}\right)^2}}$ --- (5)

and $n^2 = \dfrac{w + \frac{W}{2}(1+q)}{[illegible]}$ 895

Not (1) : when the length of Link = length of arm, then the point B and point D Locate on the ⊥ line, and

$\tan\alpha = \tan\beta$, and $q = \frac{\tan\alpha}{\tan\beta} = 1$, and.

$$n^2 = \frac{w + \cancel{\frac{W}{2}(1+1)}}{w} * \frac{895}{h}$$

$$\therefore \boxed{n^2 = \frac{w+W}{w} * \frac{895}{h}} = \frac{m+M}{m} * \frac{895}{h}$$

Not (1) when the length of Link = length of arm the point B and point D Lie on one ⊥ line, and $q = 1$

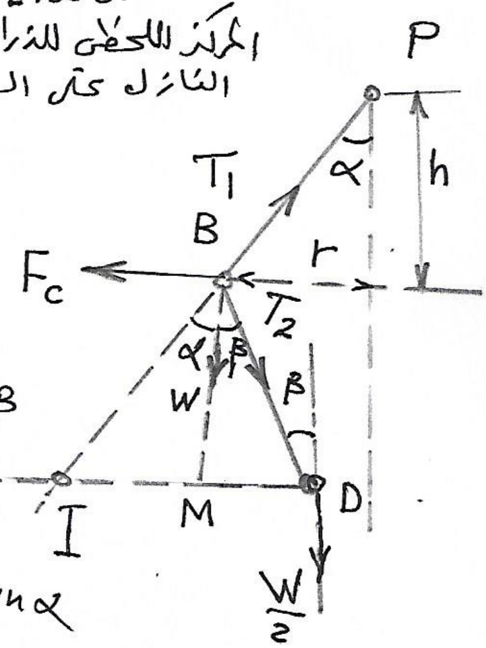
$\therefore \tan\alpha = \tan\beta$

and $n^2 = \frac{w+W}{w} * \frac{895}{h}$.

طريقة المركز اللحظي

II) Instantaneous Center Method

المركز اللحظي للذراع BD هو (I) الناتج من امتداد الذراع PB وتقاطعه مع العمود النازل على المبدل (المنزلق) في نقطة (D).



$\therefore$ By taking moment about (I),

$\therefore \sum M_I = 0$

تقسيم المعادلة على BM

$$+F_c * BM - w * IM - \frac{W}{2} * ID = 0 \text{ by } \div BM$$

$$\therefore F_c = w \overset{\tan\alpha}{\frac{IM}{BM}} + \frac{W}{2} * \frac{ID \Rightarrow IM + MD}{BM} \quad \to \tan\beta \quad \to \tan\alpha$$

$$\therefore F_c = w \tan\alpha + \frac{W}{2}(\tan\alpha + \tan\beta) \Rightarrow \div \tan\alpha$$

$$\therefore \frac{F_c \leftarrow \frac{w}{g} r\omega^2}{\tan\alpha \to \frac{r}{h}} = w + \frac{W}{2}\left(1 + \frac{\tan\beta}{\tan\alpha} \to = q\right)$$

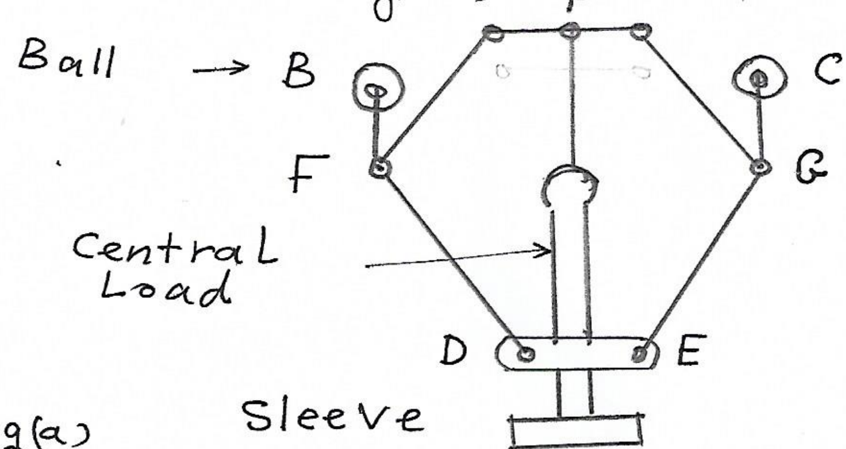
$$\therefore \frac{\frac{w}{g} r\omega^2}{\frac{r}{h}} = w + \frac{W}{2}(1+q)$$

$$\therefore \boxed{h = \frac{w + \frac{W}{2}(1+q)}{\frac{w}{g}\,\omega^2}} \quad \text{--- (6)}, \text{ when } q = 1$$

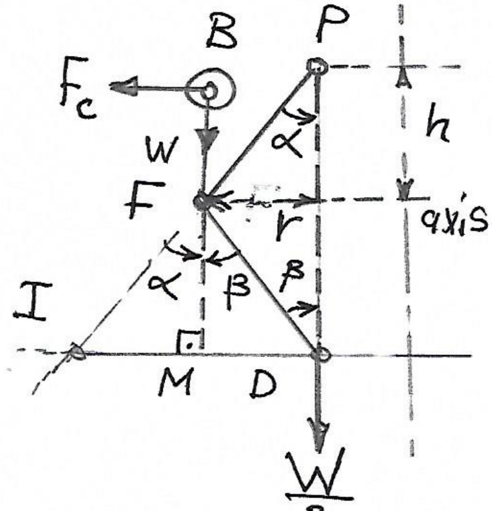
$$w + W \quad \text{--- (7)}$$

III) Proell G-r :

It has a ball at B and C to the ext-
-ension of the links DF and EG, as
shown in fig (a)



Fig(a)



In order to determine the relation bet-
- ween n and h we take equilibrium
of the forces of one half of the G-r,
by using I-center Method of FD at the
intersect of PF with ⊥ to axis at
point D, then we take the ⊥ on ID from
B, and by taking moment about I

$\therefore \sum M_I = 0$

by div-ing on

$$\therefore F_c \cdot BM = W * IM + \frac{W}{2} * ID \quad \text{—(1)} \quad \% \, BM$$

$$\therefore f_c = W * \frac{IM}{BM} * \frac{W}{2} * \frac{ID}{BM} =$$

$$= W * \frac{IM}{BM} + \frac{W}{2}\left(\frac{IM + MD}{BM}\right) \rightarrow X \; \frac{FM}{FM}$$

by mutiby-ing with

$$\therefore F_c = \frac{FM}{BM}\left[W * \underbrace{\frac{IM}{FM}}_{\tan\alpha} + \frac{W}{2}\left(\underbrace{\frac{IM}{FM}}_{\tan\alpha} + \underbrace{\frac{MD}{FM}}_{\tan\beta}\right)\right]$$

$$= \frac{FM}{BM}\left[W * \tan\alpha + \frac{W}{2}\left(\tan\alpha + \tan\beta\right)\right] \rightarrow \%$$

$\tan\alpha$

$$= \frac{F_M}{B_M} * \tan\alpha \left[w + \frac{W}{2}\left(1 + \frac{\tan\beta}{\tan\alpha}\right)\right]$$

But $F_c = \frac{W}{g}\omega^2 r$, $\tan\alpha = \frac{r}{h}$, $q = \frac{\tan\beta}{\tan\alpha}$

$$\therefore \frac{W}{g}\omega^2 r = \frac{F_M}{B_M} * \frac{r}{h}\left[w + \frac{W}{2}(1+q)\right] \quad \text{--- (2)}$$

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

$$\therefore N^2 = \frac{F_M}{B_M}\left[\frac{w + \frac{W}{2}(1+q)}{W}\right] * \frac{895}{h} \quad \text{--- (3)}$$

when $\alpha = \beta \rightarrow q = 1$

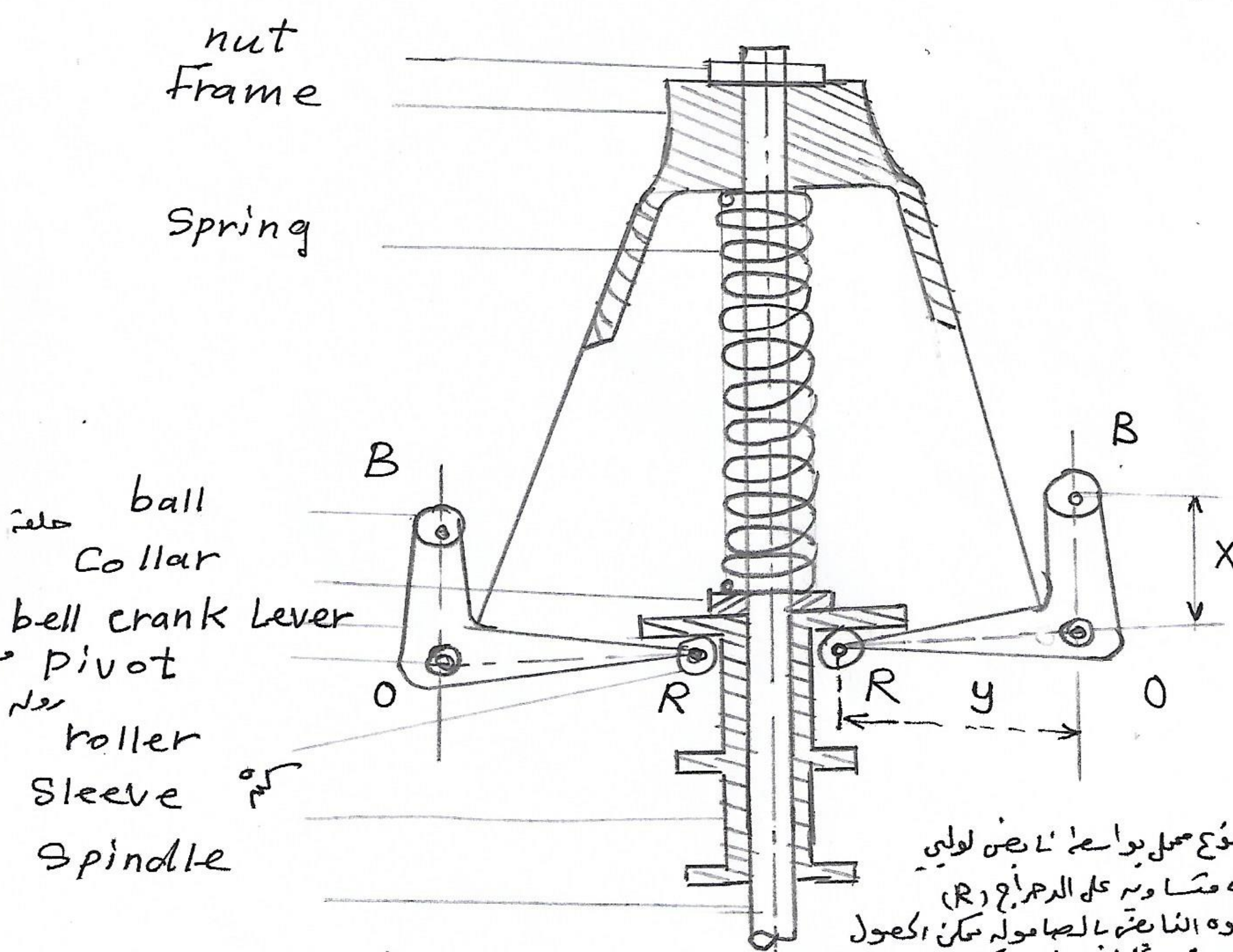
$$\therefore \boxed{N^2 = \frac{F_M}{B_M}\left(\frac{w+W}{W}\right) * \frac{895}{h}} \quad \text{--- (4)}$$

in metres

when $g = 9{,}81 \ m/s^2$

III) Hartnell G-r

It is a Spring Loaded g-r as shown in fig(a)



هذا النوع يعمل بواسطة نابض لولبي
يسلط قوة متساوية على الدحرج (R)
يتم تنظيم قوة النابض بالصامولة يمكن الحصول

* Examples on G-rs :

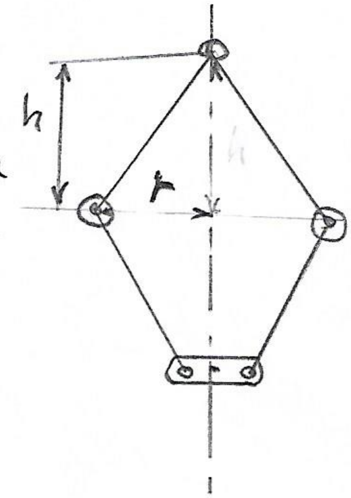
* example (1) :

Calculate the vertical height of a watt Governor, when it rotates at (60 r.p.m), also find the change in vertical height when it's speed inerease to (61 r.p.m).

* Solution :

1) initial height . الارتفاع الابتدائي

$$h_1 = \frac{895}{N_1^2} = \frac{895}{(60)^2} = 0{,}248\ m$$



2) and for final height الارتفاع النهائي

$$h_2 = \frac{895}{(N_2)^2} = \frac{895}{(61)^2} = 0{,}24\ m$$

3) Change in height

$$\Delta h = h_1 - h_2 = 0{,}248 - 0{,}24 = 0{,}008\ m$$

* example (2) :

A porter G-r has equal arms each (250 mm) Long and pivoted on the axis of rotation. each ball has a mass of (5 kg) and the mass of the central Load on the sleeve is (15 kg). The radius of rotation of the ball is (150 mm), when the g-r begins to lift ~~and~~ (200 mm) when the g-r is at max-m speed. find the minimum and max-m speeds and range of speed of the g-r, and range of heights.

* Solution :

Solution :

1) Draw max-m and min-m position of the g-r with a following dates, as in fig(a), fig(b)

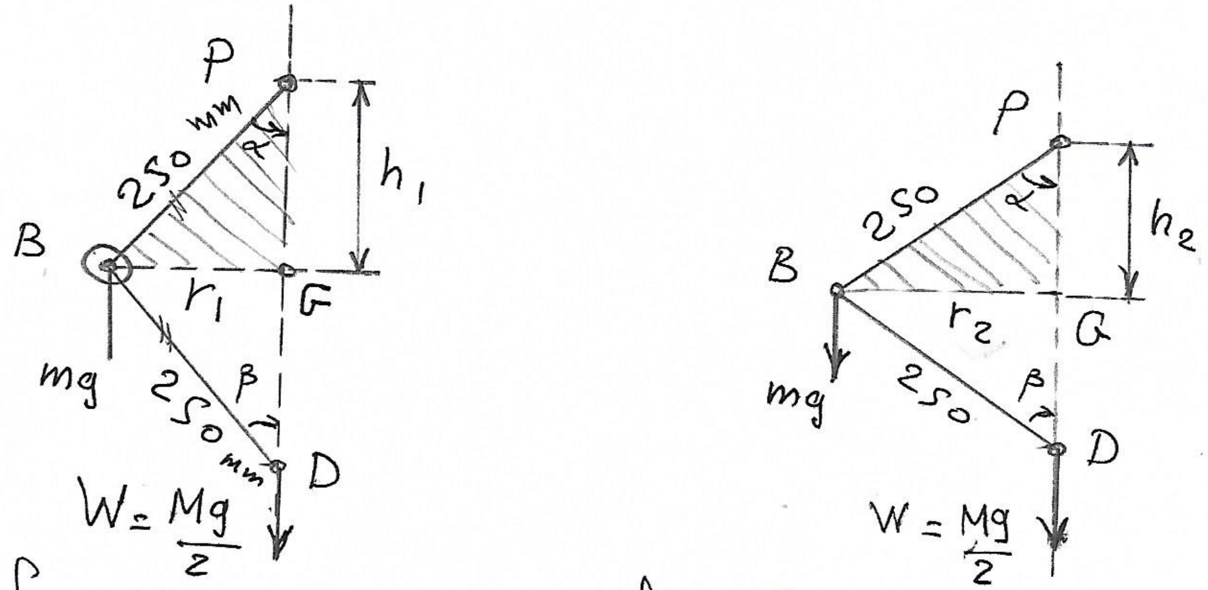


fig (a) for Min-M p-n fig (b) for Max-m p-n

By using Method of resolution of forces.

2) for min-m p-n with r_1, n_1, the height (h_1) be

From right triangle $\Delta PBG \rightarrow PB^2 = BG^2 + PG^2$

$\therefore h_1 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(0,25)^2 - (0,15)^2} = 0,2\,m$

and $N_1^2 = \frac{m + \frac{M}{2}(1+q)}{m} * \frac{895}{h_1}$

when arm are equal, But arm $BP = BD = 250\,mm$

$\therefore N_1^2 = \frac{m + \frac{M}{2}(1+1) = 2}{m} * \frac{895}{h_1} = \frac{m + M}{m} * \frac{895}{h_1}$, $\tan\alpha = \tan\beta$, $\rightarrow q = \frac{\tan\beta}{\tan\beta} = 1$

$\therefore N_1^2 = \frac{5+15}{5} * \frac{895}{0,2} = 17900 \rightarrow N_1 = \sqrt{17900}$

$\therefore N_1 = 133$ r.p.m

3) for max-m p-n with r_2, $n_2 \rightarrow h_2$

$h_2 = PG = \sqrt{(PB)^2 - (BG^2)} = \sqrt{(0,25)^2 - (0,2)^2} = 0,15\,m$

and $N_2^2 = \frac{m + M}{m} * \frac{895}{h_2} = \frac{5 + 15}{5} * \frac{895}{0,15} = \sqrt{23867}$

$\therefore N_2 = 154,5$ r.p.m

4) $\therefore$ The rang of speed

$\Delta N = N_2 - N_1 = 154,4 - 133,8 = 20,7$ r.p.m

5) rang of height

$\Delta h = h_1 - h_2 = 0,2 - 0,15 = 0,05\,m$

Example (3) :

The arms of a porter g-r are each (250 mm) long and pivoted on the g-r axis. The mass of each ball is (5 kg) and mass of the central sleeve is (30 kg). The radius of rotation of the balls is (150 mm) when the sleeve begins to rise and reaches a value of (200 mm) for max-m speed. Determine the speed range of the g-r, If the friction at the sleeve is equivalent of (20 N) of Load at the sleeve. determine how the speed range is modified.

Solution:

1) Draw min-m and max-m position of the G-r with a following dates ⇒ fig (a), fig (b).

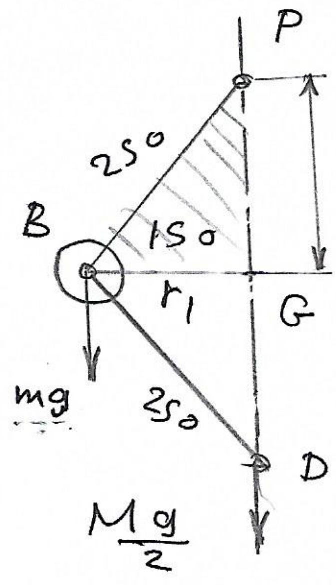


fig (a) Min-m p-n

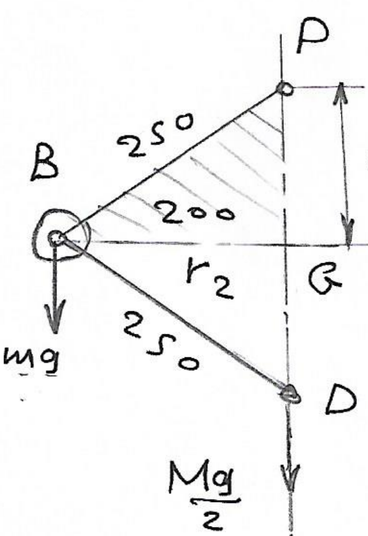


fig (b) Max-m p-n

2) for the Min-m p-n with (r_1), the height.

$$h_1 = PG = \sqrt{(PB)^2 + (BG)^2} = \sqrt{(250)^2 - (150)^2} = 200\ mm = 0.2\ m$$

∴ the speed N_1

$$(N_1)^2 = \frac{m+M}{m} * \frac{895}{h_1} = \frac{5+30}{5} * \frac{895}{0.2} = 31325$$

3 - For the max-m ~~p-n~~ with r_2, the height

$$h_2 = PG = \sqrt{(PB)^2 - (BG)^2} = \sqrt{(250)^2 - (200)^2} = 150\,mm = 0,15\,m$$

and the speed N_2

$$(N_2^2) = \frac{\cancel{g}(m+M)}{\cancel{g}\,m} * \frac{895}{h_2} = \frac{5+30}{5} * \frac{895}{0,15} = 41767$$

$\therefore N_2 = 204,4$ r.p.m

and the range of speed

$$\Delta N = N_2 - N_1 = 204,4 - 177 = 27.4 \text{ r.p.m}$$

4- The act of friction is opposite the movment of the sleeve ملاحظة: الاحتكاك عادة يكون للاعلى

$\therefore$ for ↓ dawnwards of the sleeve (min-m p-n)

$$(N_1)^2 = \frac{mg + \left(\frac{Mg - f}{2}\right)(1+q)}{mg} * \frac{895}{h_1} \rightarrow \text{For min} \downarrow -f \uparrow$$

$$= \frac{5*9,81 + (30*9,81 - 20)}{5*9,81} * \frac{895}{0,2} = 29500$$

$\therefore N_1 = 172$ r.p.m

and fo the upwards of the sleeve (max-m p-n) → max↑ +f↑

$$(N_2)^2 = \frac{mg + \left(\frac{Mg + f}{2}\right)(1+q)}{mg} * \frac{895}{h_2}$$

$$= \frac{5*9.81 + (30*9.81 + 20)}{5*9,81} * \frac{895}{0,15} = 44200$$

$\therefore N_2 = 210$ r.p.m

and the range of speed

$$\Delta N = N_2 - N_1 = 210 - 172 = 28 \text{ r.p.m.}$$

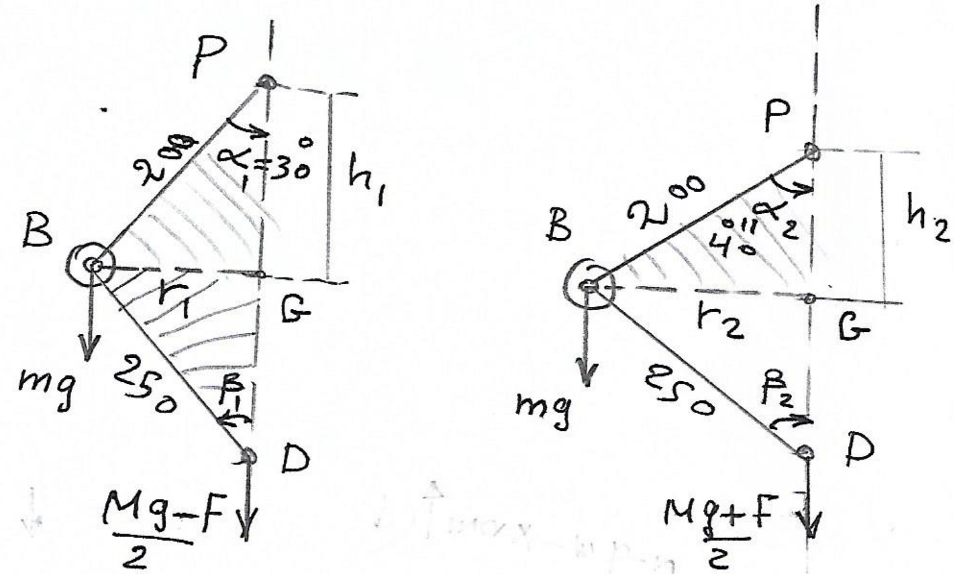
$$\frac{\cancel{g}(m+M)}{\cancel{g}\,m} = \frac{mg + Mg}{mg}$$

ملاحظة: في حالة تساوي الاذرع نختصر الثقيل كعامل مشترك وفي حالة حساب الاحتكاك نبقيها

* example(4) :

In an engine g-r of the Porter type, the upper and lower arms are (200 mm) and (250 mm) respectively and pivoted on the axis of rotation. The mass of the central load is (15 kg). the mass of each ball is (2 kg) and friction of the sleeve together with the resistance of operating gear is equal to a load of (25 N) at the sleeve. If the limiting inclinations of the upper arms to the vertical are (30°) and (40°) taking friction into account, and find the range of speed.

Solution:



Fig(a) for min-m p-n ↓ -f (downward) Fig(b) for max-m p-n ↑ +f (upward)

1) for min-m position, when sleeve moves downward. (from ΔBGP)

$\sin\alpha_1 = \frac{BG}{BP} \Rightarrow r_1 = BP \sin 30° = 0,2 * 0,5 = 0,1 m$

$\cos\alpha_1 = \frac{PG}{BP} \Rightarrow h_1 = BP \cos 30° = 0,2 * 0,866 = 0,173 m$

From Δ right triangle $BGD \Rightarrow BD^2 = BG^2 + GD^2$

$\therefore GD = \sqrt{BD^2 - BG^2} = \sqrt{(0,25)^2 - (0,1)^2} = 0,23 m$

$\tan\beta_1 = \frac{BG}{GD} = \frac{0,1}{0,23} = 0,4348$

$\therefore \tan\alpha_1 = \tan 30^\circ = 0{,}5774$

$\therefore q_1 = \dfrac{\tan\beta_1}{\tan\alpha_1} = \dfrac{0{,}4348}{0{,}5774} = 0{,}753 \quad = 1{,}3$

$\therefore (N_1)^2 = \dfrac{m.g + \left(\dfrac{M.g - F}{2}\right)(1 + q_1)}{m.g} * \dfrac{895}{h_1}$

$= \dfrac{2 * 9.81 + \left(\dfrac{15 * 9.81 - 24}{2}\right)(1 + 0{,}753)}{2 * 9.81} * \dfrac{895}{0{,}1732} =$

37,629

$= 33596 \quad 37629{,}9$

$\therefore N_1 = 183.3 \text{ r.p.m}$

193,9

2) For max-m p-n with sleev upwards ↑

$r_2 = BG = Bp \sin 40^\circ = 0{,}20 * 0{,}643 = 0{,}1268 \text{ m}$

and $h_2 = PG = Bp \cos 40^\circ = 0{,}2 * 0{,}766 = 0{,}1532 \text{ m}$

and $DG = \sqrt{(BD^2) - (BG^2)} = \sqrt{(0{,}25)^2 - (0{,}1268)^2} = 0{,}2154 \text{ m}$

and $\tan\beta_2 = \dfrac{BG}{DG} = \dfrac{0{,}1268}{0{,}2154} = 0{,}59$

$\tan\alpha_2 = \tan 40^\circ = 0{,}839$

and $q_2 = \dfrac{\tan\beta_2}{\tan\alpha_2} = \dfrac{0{,}59}{0{,}839} = 0{,}703$

and $(N_2)^2 = \dfrac{mg + \left(\dfrac{Mg + F}{2}\right)(1 + q_2)}{mg} * \dfrac{895}{h_2}$

$= \dfrac{2 \times 9.81 + \left(\dfrac{15 * 9{,}81 + 24}{2}\right)(1 + 0{,}703)}{2 \times 9{,}81} * \dfrac{895}{0{,}1532} =$

$= 49236 \quad 75670$

$N_2 \therefore 222 \text{ r.p.m} \quad 227$

$\therefore$ range of speed

92

$\Delta N = N_2 - N_1 = 222 - 183{,}3 = 38.7 \text{ r.p.m}$

$\Delta h = h_1 - h_2$

0,51

ملاحظة ؛ في حالة عدم تساوي الاذرع لا يمكن اختصار العامل (q) فتبقى