VIRTUAL WORK

It is an imaginary work done by the force system due to their corresponding infinitesimal displacement.

Principal of Virtual Work

If the system is in equilibrium, then total virtual work done by the force system due to corresponding virtual displacement are always Zero.

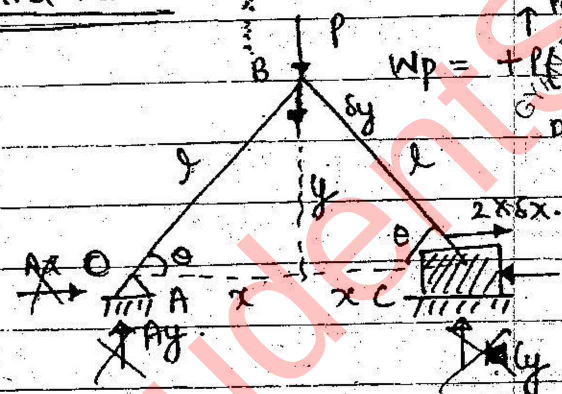
1) Frame Structure

→ Relation between external ~~force~~ - external force or external - internal force or external resistive reaction.

2) Portal Frame

External - External relation or External - Internal relation.

Find P and F



Same direction of P and δy

$W_P = +P(-\delta y)$

Decrement

$2\times\delta x$. $(W_F) = -F\times(2\delta x)$

Origin (0,0) – where the most unknown forces will be present and that are not required to be found.

→ Like reactions at A are not required.

→ Block resting on Smooth surface

$\delta y \rightarrow$ decrement in (y) ∴ $-\delta y$

$\delta x \rightarrow$ increament in (x) ∴ $+\delta x$

Work = F × distance

distance (x) :→ Horizontal force → Horizontal distance

Vertical Force → Vertical distance

If Force and displacement in same direction

W.D = ⊕ Force × displacement

opp. direction (WD) = ⊖ Force × Increament

(External – External relation)

$$\boxed{\text{Total Virtual Work Done} = 0}$$

T.V.W.D = 0

$+P(-\delta y) - F(+2\delta x) = 0$

$-P\delta y = 2F \times \delta x$

$-P(l\cos\theta\,\delta\theta) = 2F \times (-l\sin\theta)(\delta\theta)$

$$\boxed{P = 2F \times \tan\theta}$$

Imp

$\boxed{\sin\theta = \frac{y}{l}}$ $\boxed{\cos\theta = \frac{x}{l}}$

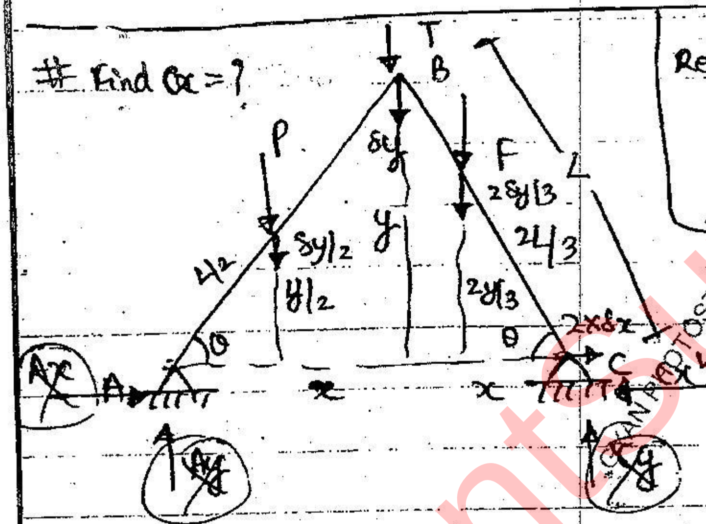
$y = l\sin\theta$

$\boxed{\delta y = l\cos\theta\,\delta\theta}$

$-\sin\theta\,\delta\theta = \frac{\delta x}{l}$

$\boxed{\delta x = -l\sin\theta\,\delta\theta}$

Find Cx = ?



Relation b/w External reaction and external forces (Cx).
(Find horizontal component at hinge support C).

T.V.W.D = 0.

$+T(-\delta y) + F(-2\delta y/3)$
$+P(-\delta y/2) - Cx(+2\delta x) = 0.$

$-\left[\frac{P}{2} + T + \frac{2F}{3}\right] l\cos\theta\,\delta\theta$
$= 2Cx \times (-l\sin\theta\,\delta\theta)$

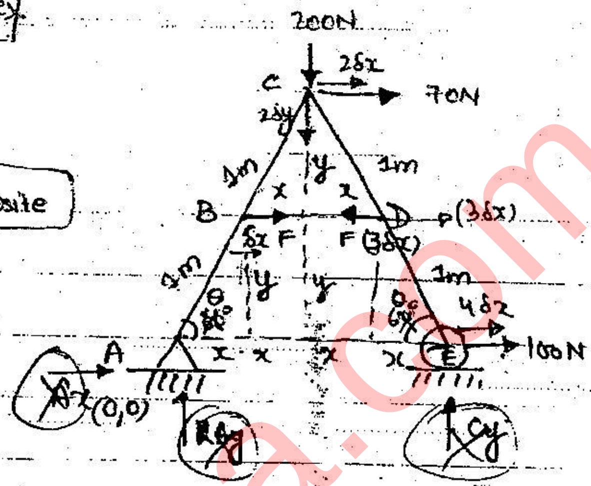
$$\boxed{Cx = \left(\frac{3P + 6T + 4F}{12}\right)\cot\theta}$$

Relation b/w external and Internal forces

Find tension in Member BD.

Soln

Replace member BD by two equal and opposite tensile forces. Let it be F.



$$\delta(W)=0.$$

$$+200(-2\delta y)+(70)(+2\delta x)+F(+\delta x)-F(+3\delta x)+100(+4\delta x)=0.$$

$$200(-2)(\cos\theta)\delta\theta+540(-\sin\theta)(\delta\theta)=2F\times(-\sin\theta)(\delta\theta).$$

$\sin\theta=\frac{y}{1}$

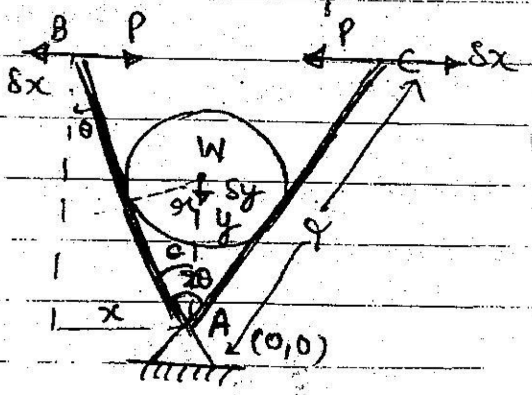
$\cos\theta\,\delta\theta=\delta y$

$\cos\theta=\frac{x}{1}$

$-\sin\theta\,\delta\theta=\delta x$

$$\boxed{F=\frac{400\cos\theta+540\sin\theta}{2\sin\theta}}$$

Find P in terms of W.



$\sin\theta=\frac{r}{y}$

$y=r\,\mathrm{cosec}\,\theta$

$\boxed{\delta y=-r\,\mathrm{cosec}\,\theta\cot\theta\,\delta\theta.}$

$\sin\theta=\frac{x}{l}$ $\quad x=l\sin\theta$

$\boxed{\delta x=l\cos\theta\,\delta\theta}$

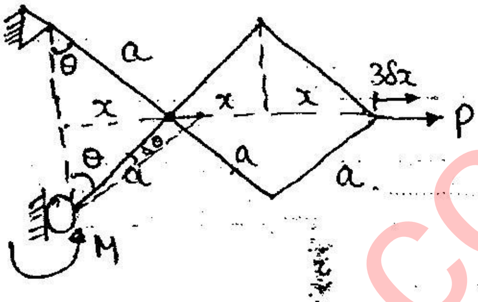
$$+W(-\delta y)-P(+\delta x)\times 2=0.$$

$$-W(-r\,\mathrm{cosec}\,\theta\cot\theta)\delta\theta=2P\times(\cos\theta)\delta\theta(l)$$

$$\boxed{P=\frac{W(r)}{2l\sin^2\theta}}$$

→ Moment gives (Angular displacement).

Find M in terms of P.



$\sin\theta = \frac{x}{a}$ $\quad x = a\sin\theta$

$\boxed{\delta x = a\cos\theta\,\delta\theta}$

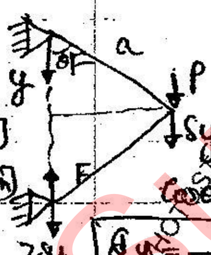
$-M(+\delta\theta) + P(+3\delta x) = 0.$

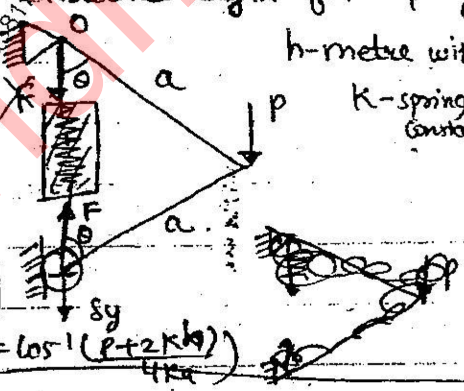
$\boxed{M = 3Pa\cos\theta}$

Find spring force and corresponding angle θ, If unstretched Length of the spring h-metre with K-spring constant

$\delta U = 0 \quad +P(+\delta y) - F(+2\delta y) = 0.$

spring force $\boxed{F = \frac{P}{2}}$





$F = K\delta = K[\text{stretched} - \text{unstretched}]$

$= K[$ ~~freelong~~ Length of String in Fig $-$ Free Length$]$

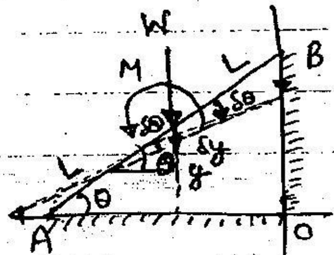
$\cos\theta = y/a$

$2\delta y \quad \boxed{\delta y = -\sin\theta\,\delta\theta}$

$F = K[2y - h]$

$\boxed{\frac{P}{2K} = (2a\cos\theta - h)} \Rightarrow \left(\theta = \cos^{-1}\left(\frac{P + 2Kh}{4Ka}\right)\right)$

Find M in terms of W.



$-M(-\delta\theta) + W(-\delta y) = 0.$

$+M\,\delta\theta = W\,\delta y$

$M\,\delta\theta = W(L\cos\theta\,\delta\theta)$

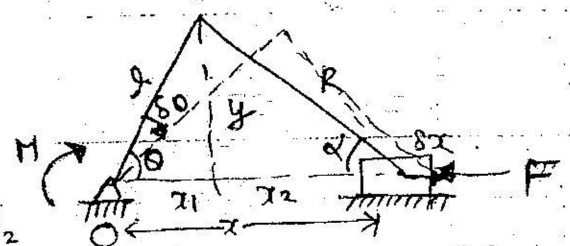
$\boxed{M = W \cdot L\cos\theta}$

δθ and θ in same direction ∴ decrement in θ. ∴ (−δθ)

$y = L\sin\theta$

$\delta y = L\cos\theta\,\delta\theta$

Find M in terms of F.



$x_2^2 + y^2 = R^2$

$x_2^2 = R^2 - y^2$

$x_2^2 = R^2 - L^2\sin^2\theta \Rightarrow x = \sqrt{R^2 - L^2\sin^2\theta}$

$x = x_2 + x_1 = l\cos\theta + \sqrt{R^2 - l^2\sin^2\theta}$

$\delta x = -l\sin\theta\,\delta\theta + \frac{1}{2}(R^2 - L^2\sin^2\theta)^{-1/2}$
$(-2L^2\sin\theta\cos\theta\,\delta\theta)]$

$y = l\sin\theta \quad x_2 = R\cos\alpha$

$x_1 = l\cos\theta$

$$\delta x = -L\left[\sin\theta + \frac{L\sin 2\theta}{2\sqrt{R^2 - L^2\sin^2\theta}}\right]\delta\theta$$

Rotating M, we get:-

$$+M(-\delta\theta) - F(+\delta x) = 0.$$

$$-M\,\delta\theta = F\,\delta x.$$

$$-M(\cancel{\delta\theta}) = -L\left[\sin\theta + \frac{L\sin 2\theta}{2\sqrt{R^2 - L^2\sin^2\theta}}\right]\cancel{\delta\theta}$$

$$\boxed{M = L\left[\sin\theta + \frac{L\sin 2\theta}{2\sqrt{R^2 - L^2\sin^2\theta}}\right]}$$

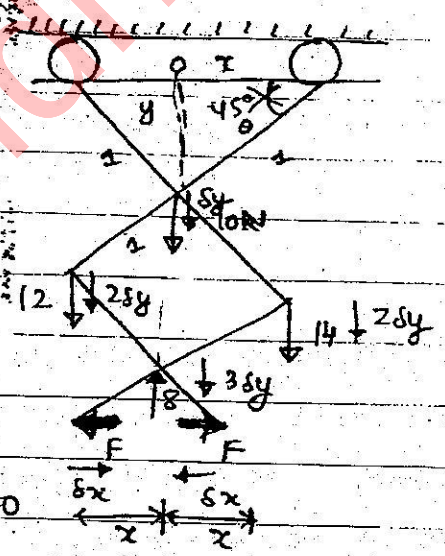
Find Force F.

$x = l\cos\theta$

$\delta x = l(-\sin\theta)\delta\theta$

$y = l\sin\theta$

$\delta y = l\cos\theta\,\delta\theta$



$+10(+\delta y) + 12(+2\delta y) + 14(+2\delta y) - 8(3\delta y)$

$-F(-\delta x)\times 2 = 0.$

$(+10 + \cancel{24} + 28 - \cancel{24})\delta y + F(\delta x)2 = 0.$

~~$8\delta y + 2F\delta x = 0$~~ $\quad 38\,\delta y + F(2\delta x) = 0$

~~$F\delta x = 43\delta y$~~ $\quad F = \frac{38}{2}$

$F = 43\frac{\delta y}{\delta x}$ $\quad \boxed{F = 19N}$

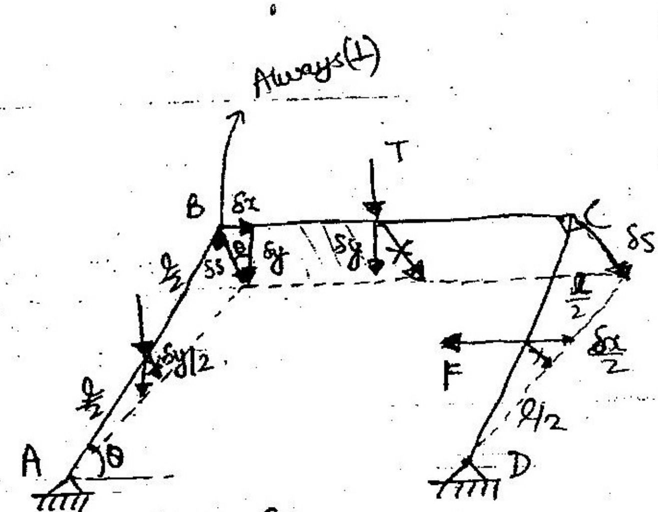
~~$F = 43(l\cos\theta)\delta\theta$~~
$-l\sin\theta\,\delta\theta$

$\boxed{\cancel{F = -43\cot\theta}}$

Here it was tough to know origin, so we can take the centre of two rolls to be origin and then distances to be calc.

PORTAL FRAME

\# Find relation between P, T and F.



$$+T(\delta y) + P(\delta y/2) - F\left(\frac{\delta x}{2}\right) = 0$$

$$\left(T+\frac{P}{2}\right)\delta y = F\left(\frac{\delta x}{2}\right)$$

$$\boxed{(2T+P)\cot\theta = F}$$

$$\sin\theta = \frac{\delta x}{\delta s}$$

$$\boxed{\delta x = \delta s \sin\theta}$$

$$\cos\theta = \frac{\delta y}{\delta s}$$

$$\boxed{\delta y = \delta s \cos\theta}$$

(No increment or decrement to be taken here. as y is not decreasing or ... at point.