# Ch 12 Static Equilibrium

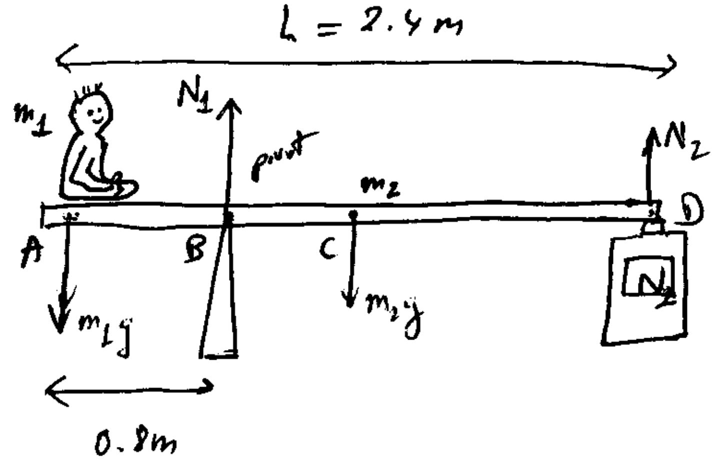
not moving

1) $\sum_i \vec{F}_i = 0$ (Net force on system is 0)

2) $\sum_i \vec{\tau}_i = 0$ (Net torque on system is also 0)

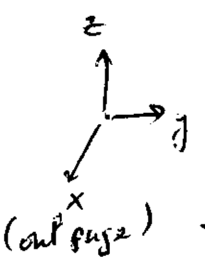
not rotating

(12.22)




What is the position of the child for a given value of N so system is in static equilibrium?

**Data:** $m_1 = 40\,kg$ ; $m_2 = 60\,kg$
$L = 2.4\,m$ ; pivot at
0.8 m from left.
$N_2 = 100\,N$ or $300\,N$.



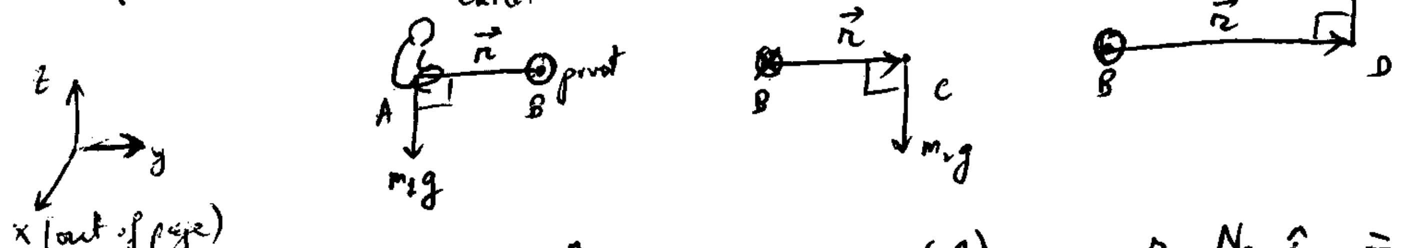

→ Beam connects everything → Focus on beam:

Static equilibrium
$$\begin{cases} \sum_i F_i = 0 \rightarrow N_1 + N_2 - m_1 g - m_2 g = 0 \\ \sum_i \vec{\tau}_i = 0 \rightarrow \vec{\tau}_1 + \vec{\tau}_2 + \vec{\tau}_{N_2} = 0 \end{cases}$$

Note: There are 4 forces but only 3 torques since $\vec{N}_1$ is applied right on the pivot point!
In general any force applying on pivot has $\vec{r} = 0$ → no torque contribution

→ A common technique in static equilibrium is to place a pivot at the application point of the force we know least about

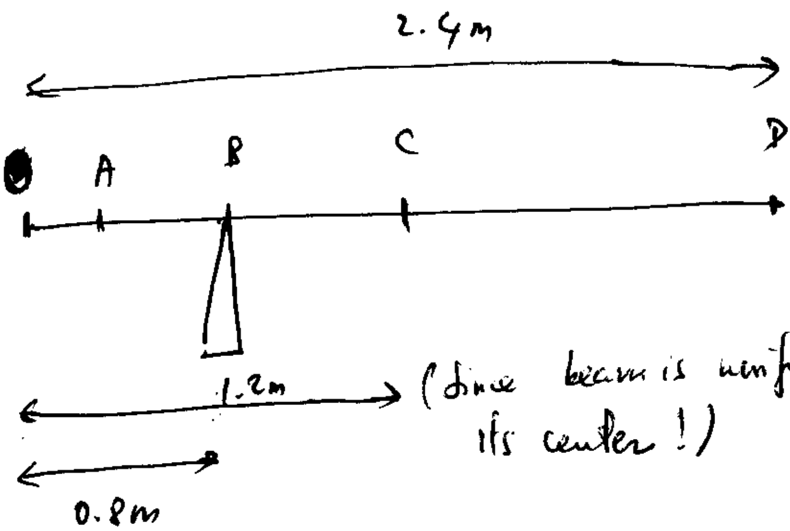
$$\sum_i \vec{\tau}_i = 0 \rightarrow \underset{\text{child}}{\vec{\tau}_1} + \underset{\text{beam}}{\vec{\tau}_2} + \vec{\tau}_{N_2} = 0$$




$$r_{BA} m_1 g\, \hat{i} + r_{BC} m_2 g\, (-\hat{i}) + r_{BD} N_2\, \hat{i} = 0$$

$$r_{BA} m_1 g + r_{BD} N_2 - r_{BC} m_2 g = 0$$

Figure out $r_{BD}$ & $r_{BC}$, then find $r_{BA}$ from this eq.




$r_{BD} = 1.6m$

$r_{BC} = 0.4m$

(since beam is uniform, its CM is at its center!)

a) $\rightarrow r_{BA} = \dfrac{r_{BC} m_2 g - r_{BD} N_2}{m_1 g} = \dfrac{0.4 \cdot 60 \cdot 9.81 - 1.6 \cdot 100}{40 \cdot 9.81} = 0.19m$

$N_2 = 100N$

From left edge of beam: child sits @ $0.8 - 0.19 = \boxed{0.61m}$

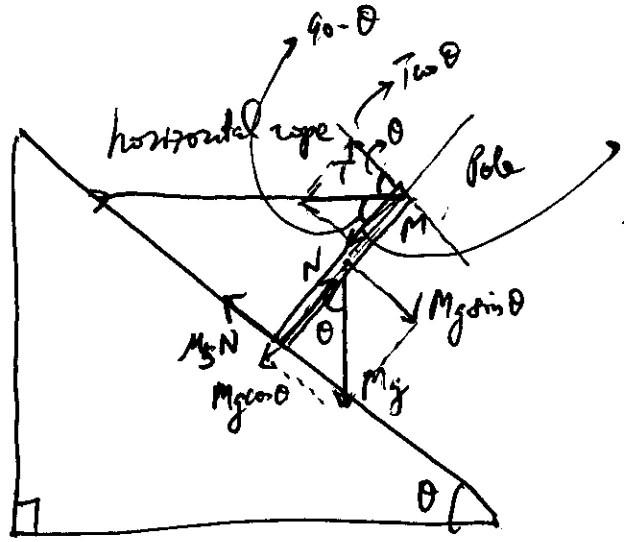
b) $N_2 = 300N$ $\quad r_{BA} = \dfrac{0.4 \cdot 60 \cdot 9.81 - 1.6 \cdot 300}{40 \cdot 9.81} = -0.62m$

Child sits 0.62m to the right of pivot (B)

From left edge of beam: child sits @ $\boxed{1.42m}$

12.57

Min $\mu_s$
so pole not slipping

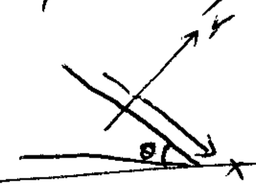



T tends to rotate pole in CCW direction → @ contact point b/w pole & incline motion tends to be downhill → Friction will be uphill!

→ Forces on pole (four):
- $Mg$ (its weight at its CM)
- $N$ (normal force by incline)
- $T$ (by rope)
- $\mu_s N$ (by friction w/ incline)

Static equilibrium:

$$\boxed{\sum_i \vec{F}_i = 0}$$

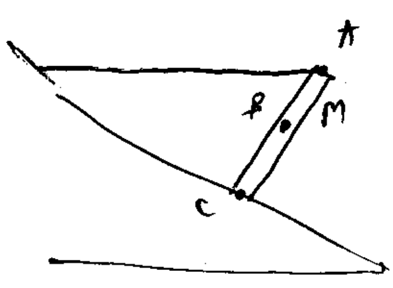



$$\boxed{\begin{aligned} x&: \quad Mg\sin\theta - T\cos\theta - \mu_s N = 0 \quad (1) \\ y&: \quad N - Mg\cos\theta - T\sin\theta = 0 \quad (2) \end{aligned}}$$

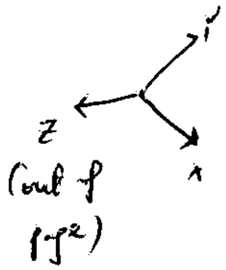
$$\boxed{\sum_i \vec{\tau}_i = 0}$$

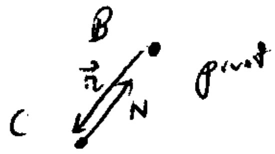
Pivot: place pivot @ application point of force we know the least about.

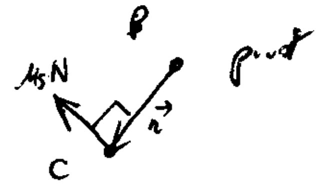
Candidates for the pivot point:
- A
- $\boxed{B}$
- C (can't since $\mu_s$ will not be in our equation!)

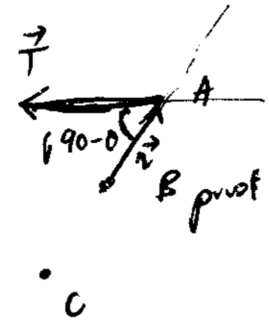


$\boxed{\text{Let's pick } B \text{ (pivot @)}:}$ → 3 torques: not from $Mg$;




$\sin 180^\circ = 0$

(No torque from N either)

$\underbrace{r_{BC}}_{\frac{L}{2}} \mu_s N (-\hat{k})$ $\boxed{\text{into page}}$

(L length of pole)

$\underbrace{r_{BA}}_{\frac{L}{2}} T \underbrace{\sin(90-\theta)}_{\cos\theta} (\hat{k})$ $\boxed{\text{out of page}}$

(L length of pole)

$$-\frac{\cancel{L}}{\cancel{2}}\mu_s N + \frac{\cancel{L}}{\cancel{2}} T\cos\theta = 0$$

$$\boxed{-\mu_s N + T\cos\theta = 0} \quad (3)$$

Eliminate tension T:
(3) Solve for T then plug it into (1):

$$T = \frac{\mu_s N}{\cos\theta}$$

$$\rightarrow \quad Mg\sin\theta - \frac{\mu_s N}{\cancel{\cos\theta}}\cancel{\cos\theta} - \mu_s N = 0$$

$$Mg\sin\theta - 2\mu_s N = 0$$

$$N = \frac{Mg\sin\theta}{2\mu_s}$$

(2) $\quad N - Mg\cos\theta - T\sin\theta = 0$

$$\frac{Mg\sin\theta}{2\mu_s} - Mg\cos\theta - \mu_s N \underbrace{\frac{\sin\theta}{\cos\theta}}_{\tan\theta} = 0$$

$$\frac{\cancel{Mg}\sin\theta}{2\mu_s} - \cancel{Mg}\cos\theta - \cancel{\mu_s}\tan\theta\,\frac{\cancel{Mg}\sin\theta}{2\cancel{\mu_s}} = 0$$

$$\frac{1}{\sin\theta}\times\left(\frac{\sin\theta}{2\mu_s} - \cos\theta - \frac{\tan\theta\sin\theta}{2} = 0\right)$$

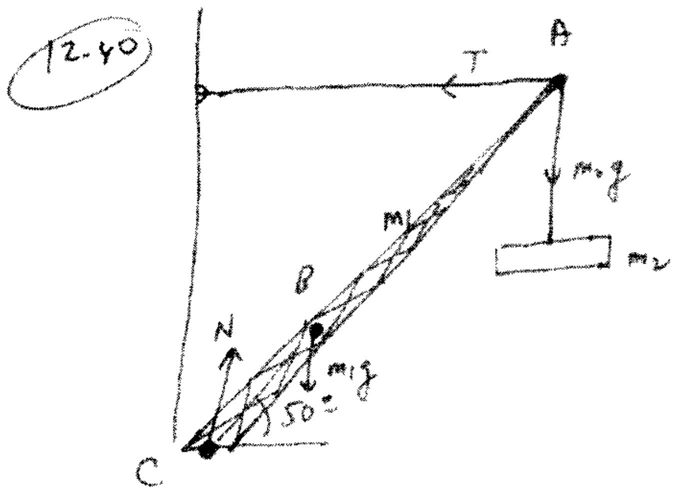
$$\frac{1}{2\mu_s} - \frac{1}{\tan\theta} - \frac{\tan\theta}{2} = 0$$

$$\frac{1}{\cancel{2}\mu_s} = \frac{1}{\tan\theta} + \frac{\tan\theta}{2} = \frac{2+\tan^2\theta}{\cancel{2}\tan\theta}$$

$$\mu_s = \frac{\tan\theta}{2+\tan^2\theta}$$ (Min to hold the pole)

$$\boxed{\mu_s \geqslant \frac{\tan\theta}{2+\tan^2\theta}}$$

12.40




Data: $CA = 15\,m$, $CB = 5\,m$

B @ CM of boom (mass $m_1$)

$m_1 = 860\,kg$.

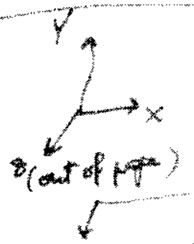
$m_2 = 2500\,kg$

$\sum_i \vec{F}_i = 0 \rightarrow$ net force on boom is zero

Static equilibrium for $m_1$ :

$\boxed{\sum_i \vec{\tau}_i = 0} \rightarrow$ pivot: A B C

we don't know N & its angle




$\vec{\tau}_{m_1 g} + \vec{\tau}_{m_2 g} + \vec{\tau}_T = 0$

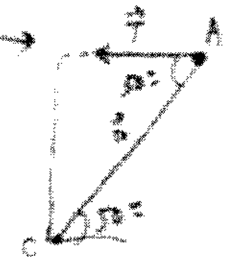

$\alpha + 50 + 90 = 180$

$\alpha = 40°$

$\vec{\tau}_{m_1 g} = \underbrace{r_{CB}}_{5m} m_1 g \sin 40° \,(-\hat{k})$


$\alpha = 40°$

$\vec{\tau}_{m_2 g} = \underbrace{r_{CA}}_{15m} m_2 g \sin 40° \,(-\hat{k})$



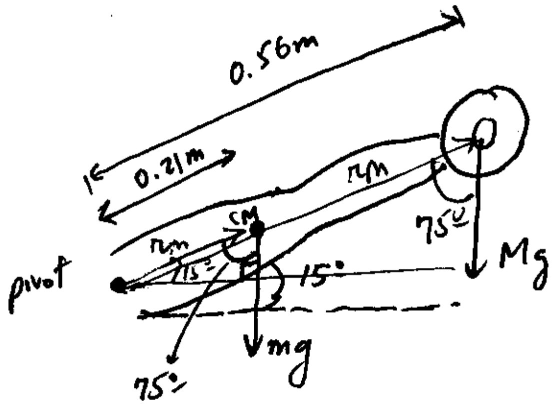

$\vec{\tau}_T = \underbrace{r_{CA}}_{15m} T \sin 50° \,(\hat{k})$

$-5 \times 860 \times 9.81 \sin 40° - 15 \times 2500 \times 9.81 \sin 40° + 15\, T \sin 50° = 0$

$$T = \frac{5 \times 860 \times 9.81 \sin 40° + 15 \times 2500 \times 9.81 \sin 40°}{15 \sin 50°}\ N$$

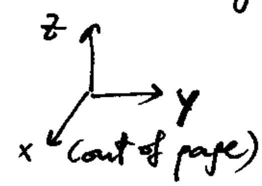
$T = 22900\ N$

12-28




$m = 4.2\,kg$

$M = 6\,kg$




(a) Torque about shoulder (pivot) : $\vec{\tau} = \vec{\tau}_m + \vec{\tau}_M$

$\vec{\tau} = \vec{r} \times \vec{F}$

↳ From pivot to application point $\vec{F}$

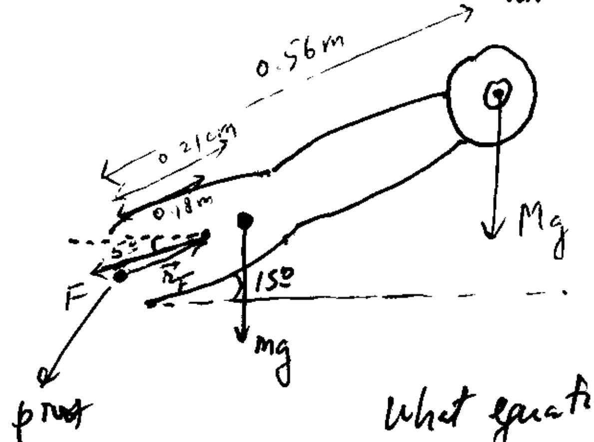
$\vec{\tau} = r_m mg \sin 75^\circ (-\hat{\imath}) + r_M Mg \sin 75^\circ (-\hat{\imath})$

$= (0.21 \cdot 4.2 + 0.56 \cdot 6)\, 9.81 \sin 75^\circ \; (-\hat{\imath})$ Nm

$= 40.2$ Nm $(-\hat{\imath})$

↓ into the page.

(b)



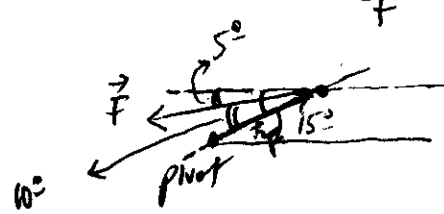

F: force exerted by deltoid muscle 5° below horizontal @ 0.18m from pivot.

What equation can we use to find F?

→ Static equilibrium : $\left\{ \begin{array}{l} \sum_i \vec{F}_i = 0 \\ \boxed{\sum_i \vec{\tau}_i = 0} \end{array} \right.$

Since we have $\vec{\tau}$ by m (arm) & M (weight) → Let's calculate $\vec{\tau}_F$,

$\vec{\tau}_F = r_F F \sin 10^\circ (\hat{\imath}) = 0.18 F \sin 10^\circ \; (\hat{\imath})$




$\sum_i \vec{\tau}_i = 0 \Rightarrow 0.18 F \sin 10^\circ - 40.2 = 0$

$F = \dfrac{40.2}{0.18 \cdot \sin 10^\circ} = 1280\,N$

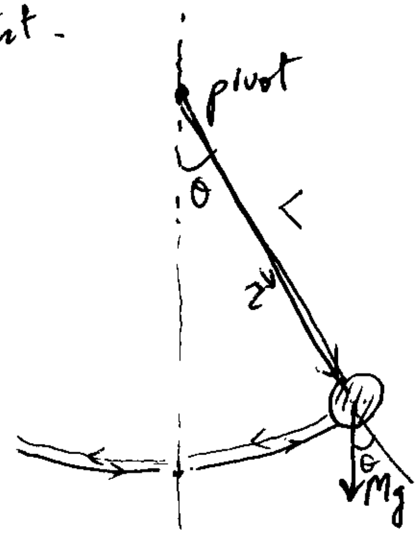
$= 1.28\,kN$

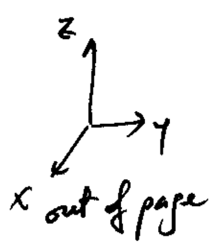
# Ch 13 Oscillatory Motion

→ A different type of motion: not linear, not exactly rotational

Examples:

1) Pendulum: bob attached to a string (having negligible mass compared to the bob), attached to a fixed point which is the center of rotation or pivot point.




As the bob is released, θ decreases to 0 (vertical), then increases again to the same value (if friction & air resistance are ignored) and then returning to the original position, and repeating → oscillations

Almost a rotational motion:

$$\tau = I\alpha \quad \text{or} \quad \alpha = \frac{\tau}{I}$$

(angular acceleration of pendulum is the torque by gravity divided by the moment of inertia of the bob wrt the pivot point: $ML^2$)

$$\vec{\tau} = \vec{r} \times \vec{F} = \underbrace{LMg\sin\theta}_{\tau}\,(-\hat{i})$$

$$\rightarrow \alpha = \frac{\tau}{I} = -\frac{\cancel{L}\cancel{M}g\sin\theta}{\cancel{M}L^{\cancel{2}}} = -\frac{g}{L}\sin\theta$$

$$\boxed{\frac{d^2\theta}{dt^2} = -\frac{g}{L}\sin\theta}$$

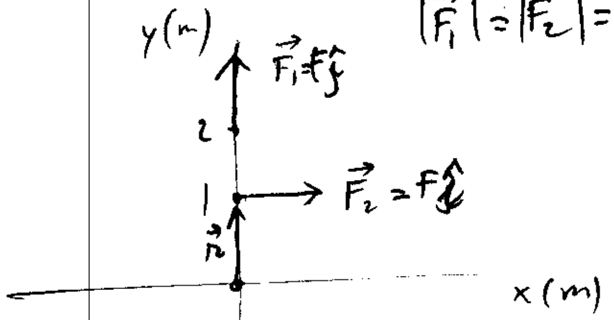
approximation: $\sin\theta \approx \theta$ → This happens when θ is small → "Small Angle Approx."

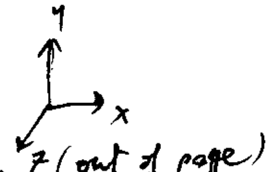
12.16

(a)

$|\vec{F}_1| = |\vec{F}_2| = F$ Can we add $\vec{F}_3$ so the three

$$\begin{cases} \sum_{i=1}^{3} \vec{F}_i = 0 & (1) \\ \sum_{i=1}^{3} \vec{\tau}_i = 0 & (2) \end{cases}$$



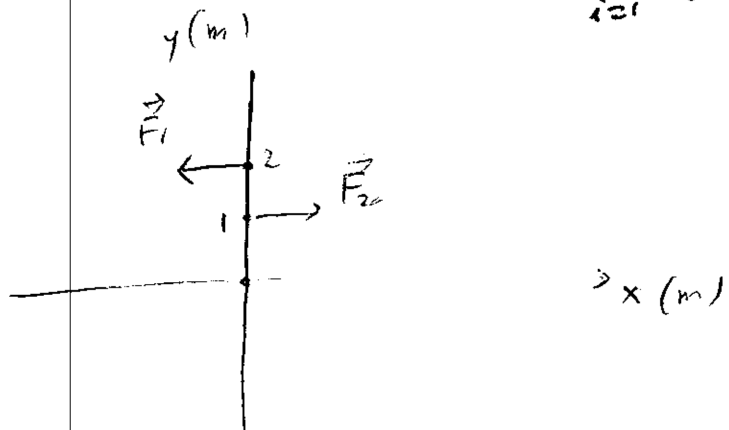




(1) Yes $\boxed{\vec{F}_3 = -F\hat{i} - F\hat{j}}$ $\rightarrow \sum_{i=1}^{3} \vec{F}_i = 0$

(2) Yes : $\vec{r} \times \vec{F}$ Let's pick, for example origin as the pivot point. Torque by $\vec{F}_2$ is $1 \cdot F(-\hat{k})$. Torque by $\vec{F}_3$ is torque by $-F\hat{j}$, which is zero, plus torque by $-F\hat{i}$, which is equal and opposite to torque by $\vec{F}_2$.

$\rightarrow \sum_{i=1}^{3} \vec{\tau}_i = 0$

(b)




(1) $\sum_{i=1}^{3} \vec{F}_i = 0$ No

(2) $\sum_{i=1}^{3} \vec{\tau}_i = 0$ Yes. $\left( \vec{F}_3 = -F\hat{i} \text{ or } \vec{F}_3 = F\hat{j} \text{ — } \right)$

Small Angle Approximation. $\sin\theta \simeq \theta$

$$\rightarrow \boxed{\frac{d^2\theta}{dt^2} = -\frac{g}{L}\theta}$$

2nd order linear differential equation.

$$\theta = \theta_M \cos\omega t$$

$\theta_M$ = amplitude of oscillation
$\omega$ : angular frequency

$\omega$ : # angular oscillations per second :

$$\frac{d\theta}{dt} = -\omega\theta_M \sin\omega t$$

$$\frac{d^2\theta}{dt^2} = \boxed{-\omega^2 \cancel{\theta_M \cos\omega t} = -\frac{g}{L}\cancel{\theta_M \cos\omega t}}$$

$$\boxed{\omega = \sqrt{\frac{g}{L}}}$$

Ang. freq of a pendulum is determined by L (inversely) & g.

↳ { large L → lower $\omega$
lower L ⇒ higher $\omega$

For a pendulum (where we can apply the "small angle approx."), the number of oscillations per second or angular frequency depends on $g$ and $L$ (but not on $m$)

$\omega = \sqrt{\frac{g}{L}}$ { less $\omega$ for longer pendulum; more osc. per second for shorter pendulum

2) Torsional pendulum

Not a swinging motion, more of a twisting back & forth


$I$ - moment of inertia for rotation about the axis

$\tau = I\alpha$

Twisting: $\tau = -\kappa\theta$ → twisting angle

$\kappa$ "kappa": torsional constant (Analog of Hooke's Law for twisting motion)

$-\kappa\theta = I \frac{d^2\theta}{dt^2}$

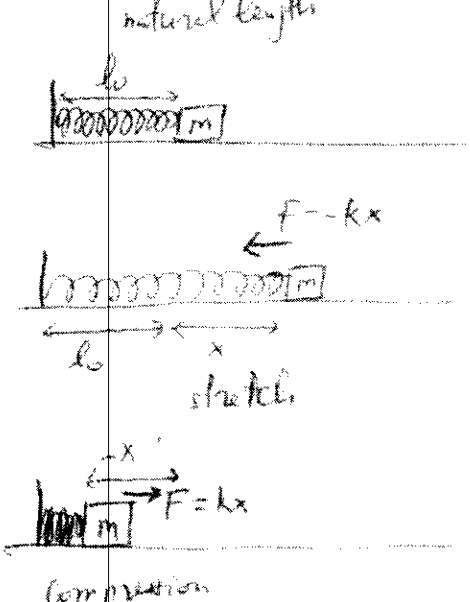
$$\boxed{\frac{d^2\theta}{dt^2} = -\frac{\kappa}{I}\theta}$$

2nd order linear differential equation

↳ $\theta = \theta_m \cos\omega t$ ; $\boxed{\omega = \sqrt{\frac{\kappa}{I}}}$

$\theta_m$: amplitude of oscillation

3) Spring & bob $\begin{cases} k = \text{spring constant} \\ m = \text{mass of bob} \end{cases}$




Spring always opposes the motion of m
→ m undergoes oscillatory motion

Newton's 2nd Law –

$$F = ma$$

$$-kx = m\frac{d^2x}{dt^2}$$

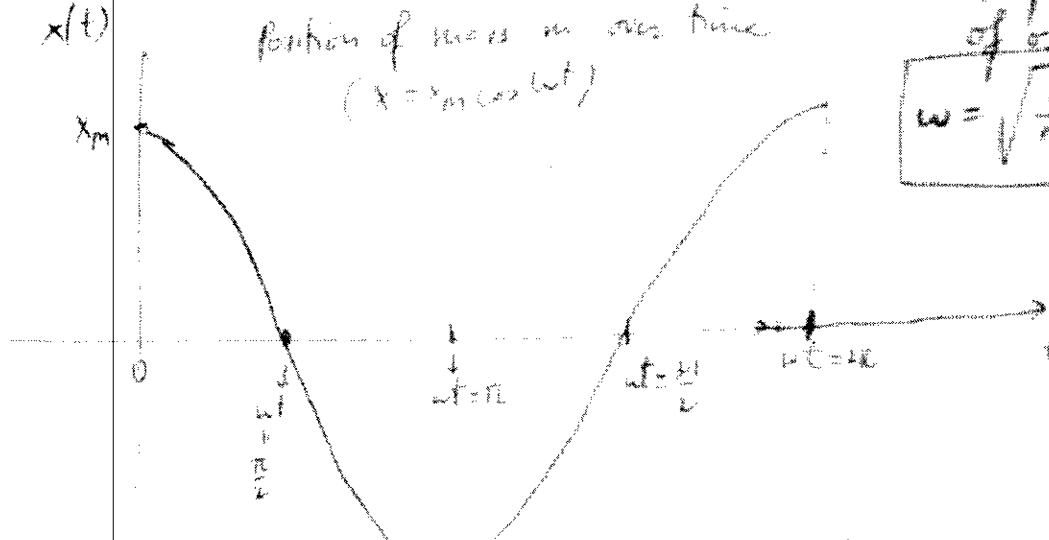
$$\boxed{\frac{d^2x}{dt^2} = -\frac{k}{m}x}$$

2nd order linear differential eq

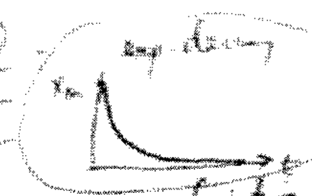
→ $x = x_m \cos(\omega t)$

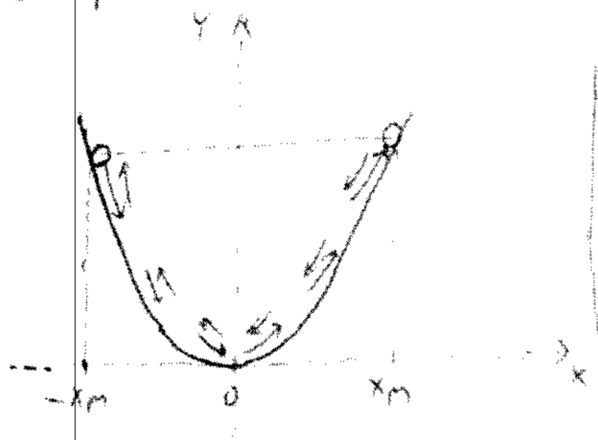
$x_m$ → amplitude of oscillation

$$\boxed{\omega = \sqrt{\frac{k}{m}}}$$



4) A particle trapped in a potential well :



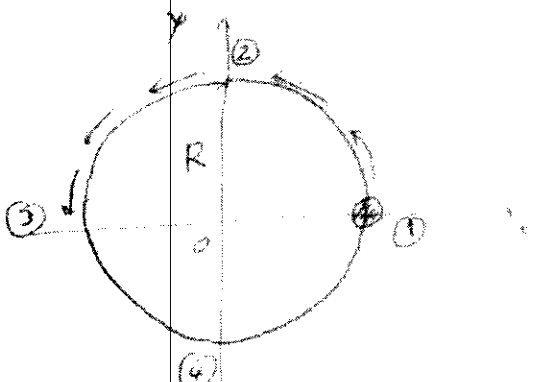

→ Assume there is no friction

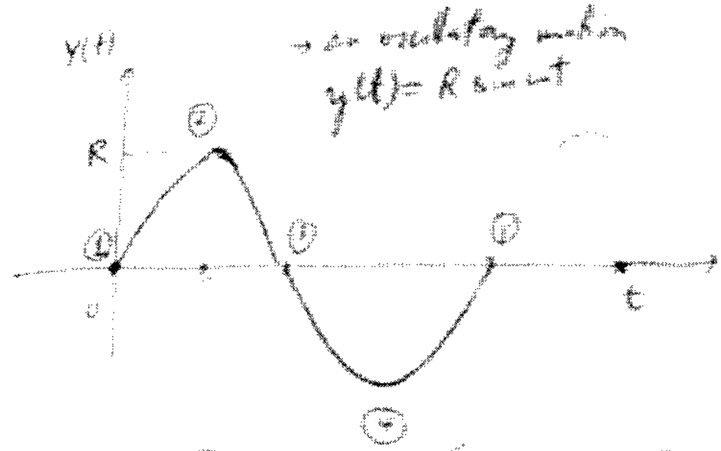
$x(t) = x_m \cos(\omega t)$ → Simple Harmonic Motion SHM

→ If there is friction : damped oscillatory motion

$$x(t) = \underbrace{x_m e^{-\frac{bt}{2m}}}_{\text{amplitude decaying exponentially}} \cos(\omega t + \overset{\text{phi}}{\phi})$$

5) Coordinate x & y of a particle undergoing a Uniform Circular Motion or UCM



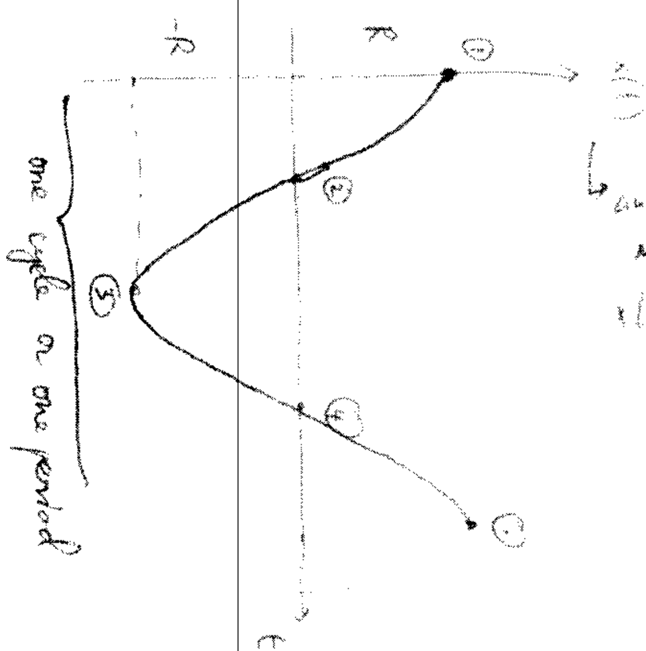




→ an oscillatory motion

$y(t) = R \sin \omega t$

one cycle or one period T

$$\boxed{T = \frac{2\pi}{\omega}}$$




↳ an oscillatory motion

$x(t) = R \cos(\omega t)$ (x & y are coords of a particle in UCM) → are shifted by a phase of 90° or $\frac{\pi}{2}$


__Summary:__ __For a spring & bob__

SHM : $\frac{d^2x}{dt^2} = -\frac{k}{m}x$ ($x$ position of mass $m$)

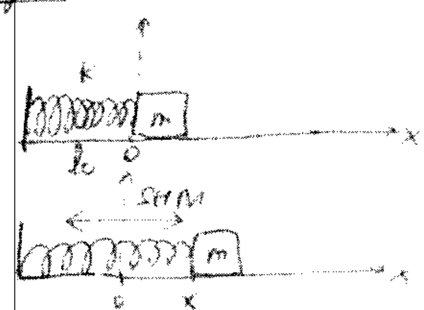
$\hookrightarrow$ solution is $x(t) = x_m \cos\omega t$ ; $\omega = \sqrt{\frac{k}{m}}$

Damped SHM : $\frac{d^2x}{dt^2} = -\frac{k}{m}x \underbrace{- \frac{b}{m}\frac{dx}{dt}}_{\text{damping term}}$

$\hookrightarrow$ solution is $x(t) = x_m e^{-\frac{bt}{2m}} \cos(\omega' t + \phi)$

---

__Energy in SHM__ : __For a spring & bob__




SHM : $x(t) = x_m \cos\omega t$
$\hookrightarrow$ displacement w.r.t. equilibrium length

$\omega = \sqrt{\frac{k}{m}}$

__Total energy__ since system lying on a horizontal surface
→ same grav potential energy at all times
→ can ignore

$\hookrightarrow E = KE + U_{elastic} = \underbrace{\frac{1}{2}mv^2}_{\text{mass } m} + \underbrace{\frac{1}{2}kx^2}_{\text{spring } k}$

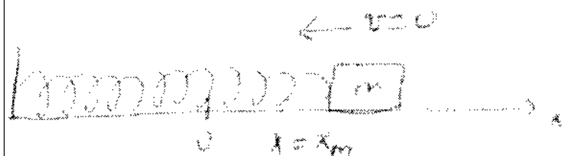
SHM : $\left\{ \begin{array}{l} x(t) = x_m \cos\omega t \\ v(t) = \frac{dx}{dt} = -x_m \omega \sin\omega t \end{array} \right\} \rightarrow E = \frac{1}{2} m x_m^2 \omega^2 \sin^2\omega t + \frac{1}{2} k x_m^2 \cos^2\omega t$

$\omega = \sqrt{\frac{k}{m}} \Rightarrow \omega^2 = \frac{k}{m}$

$$E = \frac{1}{2} m x_m^2 \frac{k}{m} \sin^2 \omega t + \frac{1}{2} k x_m^2 \cos^2 \omega t$$

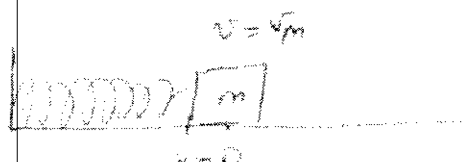
$$= \frac{1}{2} k x_m^2 \underbrace{\left[ \sin^2 \omega t + \cos^2 \omega t \right]}_{1}$$

Total energy in a mass + spring system in SHM is constant over time! equal to $\frac{1}{2} k x_m^2$




$$E = \frac{1}{2} m v^2 + \frac{1}{2} k x^2$$

$$E = \frac{1}{2} m 0^2 + \frac{1}{2} k x_m^2 = \frac{1}{2} k x_m^2$$

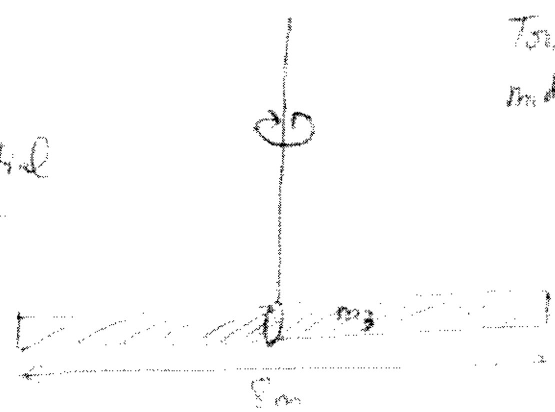



$$E = \frac{1}{2} m v_m^2 + \frac{1}{2} k 0^2 = \frac{1}{2} m x_m^2 \omega^2 = \frac{1}{2} \cancel{m} x_m^2 \frac{k}{\cancel{m}} = \frac{1}{2} k x_m^2$$

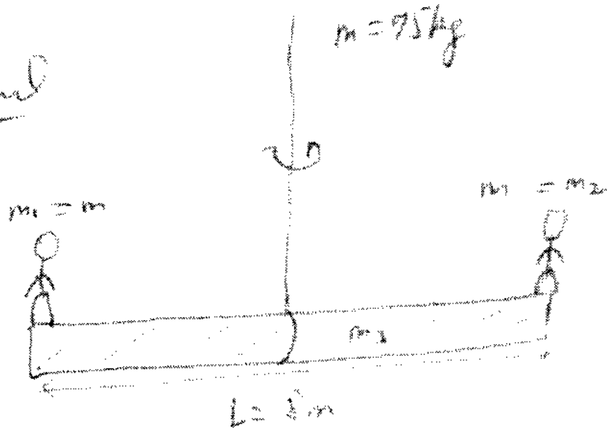
13.50

Torsional oscillations about middle axis $\Rightarrow \omega_i = \sqrt{\frac{K_t}{I_i}}$

initial



Final




$$\omega_f = \sqrt{\frac{K}{I_f}}$$

K: material of string torsional constant

$\rightarrow K_i = K_f = K$

$$I_f = I_i + 2m\left(\frac{L}{2}\right)^2$$

$I_f > I_i \rightarrow \omega_f < \omega_i$

$$\frac{\omega_f}{\omega_i} = 0.8 = \frac{\sqrt{\frac{K}{I_f}}}{\sqrt{\frac{K}{I_i}}} = \sqrt{\frac{I_i}{I_f}}$$

$\omega_f$ diminishes by 20% $\quad \omega_f = \omega_i - 0.2\,\omega_i = 0.8\,\omega_i$

When there is a square root → square up both side

$$0.8^2 = \frac{I_i}{I_f} = \frac{I_i}{I_i + m\frac{L^2}{2}}$$

$$0.8^2 I_i + mL^2\frac{0.8^2}{2} = I_i$$

$$\boxed{I_i = \frac{mL^2\frac{0.8^2}{2}}{1-0.8^2}}$$

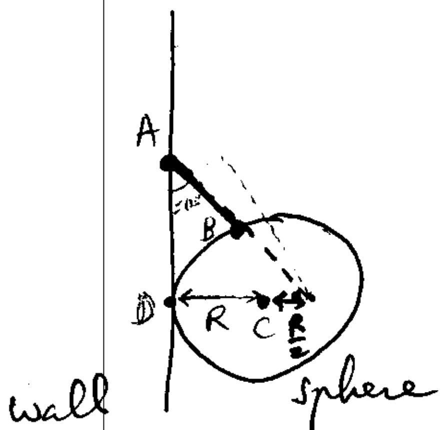
Also: $I_i$ = moment of inertia of a beam ($L, m_3$) w.r.t. center axis $\quad I_i = \frac{1}{12} m_3 L^2$

$$\rightarrow \frac{1}{12} m_3 \cancel{L^2} = m\frac{\cancel{L^2}}{2}\,\frac{0.8^2}{1-0.8^2}$$

$$m_3 = 6m\,\frac{0.8^2}{1-0.8^2} = 450\,\frac{0.8^2}{1-0.8^2}$$

$$\boxed{m_3 = 800\,kg}$$

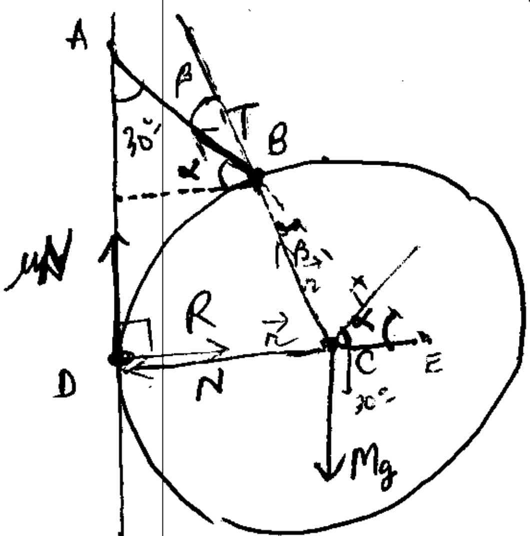
12.29




→ Smallest coef of friction $\boxed{\mu_s}$ b/w sphere & wall

Static Equilibrium
$$\sum_i \vec{F}_i = 0 \begin{cases} y: & N - T\cos 60^\circ = 0 \quad (1) \\ z: & T\sin 60^\circ + \mu N - Mg = 0 \quad (2) \end{cases}$$

$$\sum_i \vec{\tau}_i = 0 \rightarrow \underline{\underline{\text{Pivot}}}: \ C \ (\text{no information on } M \text{ !})$$




z
y
x (out of page)

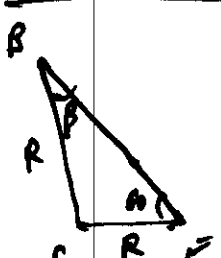
$$\underset{\substack{\parallel \\ 0}}{\vec{\tau}_N} + \vec{\tau}_{\mu N} + \vec{\tau}_T = 0$$

$$\cancel{R}\cdot\mu N\cdot(-\hat{i}) + \cancel{R}T\sin 25.6^\circ(\hat{i}) = 0$$

$$\boxed{-\mu N + T\sin 25.6^\circ = 0 \quad (3)}$$

$\alpha = 90 - 30^\circ = 60^\circ$

Law of sins:




$$\frac{\sin 60}{R} = \frac{\sin\beta}{\frac{R}{2}} \rightarrow 2\sin\beta = \sin 60 \rightarrow \beta = \sin^{-1}\left(\frac{\sin 60}{2}\right) = 25.6^\circ$$

Use (1) in (3) : (1) → $N = T\cos 60^\circ$

→ (3) $-\mu\cancel{T}\cos 60^\circ + \cancel{T}\sin 25.6^\circ = 0$

$$\boxed{\mu \geq \frac{\sin 25.6^\circ}{\cos 60^\circ} \qquad \mu \geq 0.86}$$

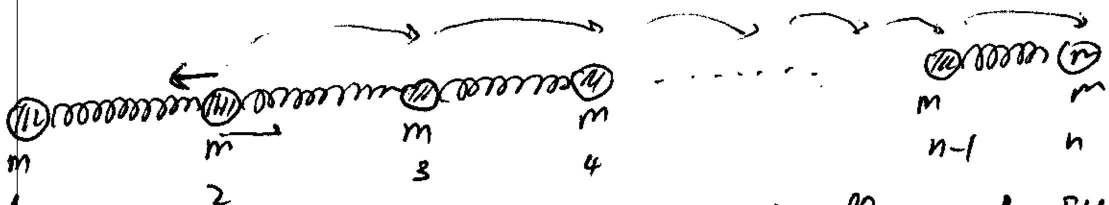
# Ch 14 Wave Motion:

<u>Oscillatory motion</u>: periodic (regularly repeating in $\boxed{\text{time}}$) variation of a position or angle:

<u>Wave motion</u>: the oscillation/periodic variation/perturbation is propagated in $\boxed{\text{space}}$

1) <u>Propagation</u>: Propagation of a perturbation is such that the objects involved (spring & mass for example) are local while the perturbation reaches as far as ~~the~~ possible.

An example of a longitudinal wave →

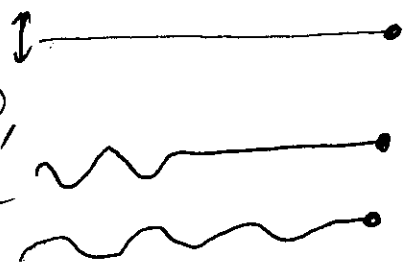



If a perturbation is applied on $m_2$ → it will go into SHM being still local. However $m_3$ will start to do same thing, $m_4$ ... $m_n$ : the perturbation is <u>propagated</u> while the objects involved are still local

2) <u>Waves</u> involve both $\boxed{\text{time \& space}}$ variation!

3) <u>Two types</u>:
- Transverse waves: perturbation is perpendicular to direction of propagation.
- Longitudinal waves: perturbation is parallel to direction of propagation

Transverse wave:
. Pieces of string stay local, perturbation propagate to the right



string attached to a fixed point. then starts vertical oscillations on the left end.

## Math description of a transverse wave:


$$\boxed{y(x,t) = A \sin(kx - \omega t)}$$

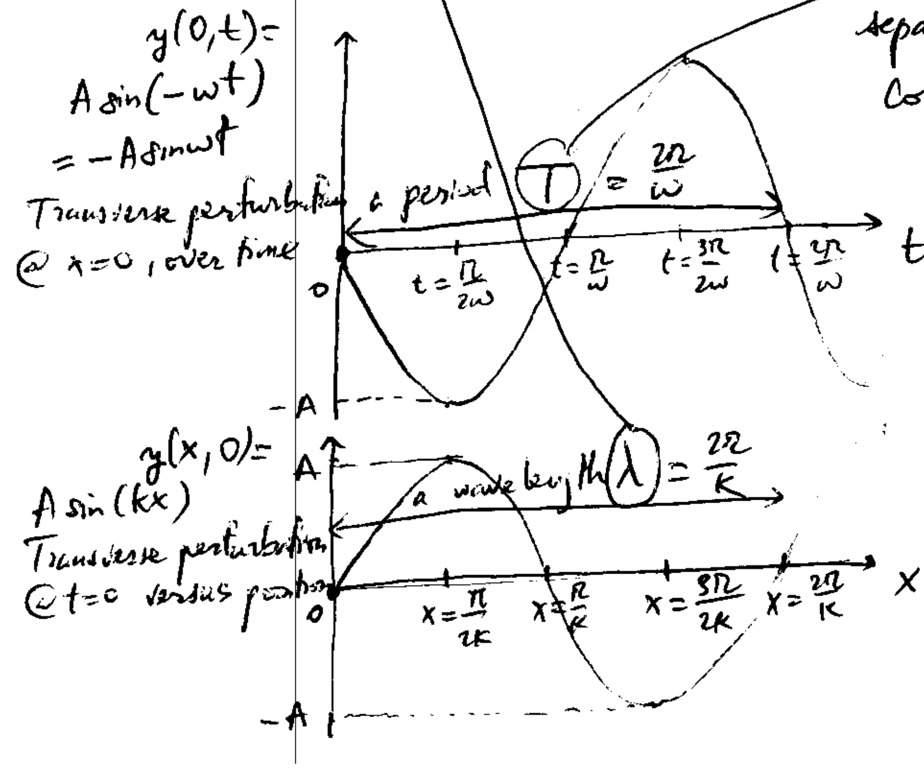
- Wave w/ time & space variation
- Perturbation along $\boxed{y}$
- Propagation is along $\boxed{x}$

A : amplitude of the wave & of the perturbation or oscillation

k : wave number $= \dfrac{2\pi}{\lambda}$ $(m^{-1})$

$\lambda$ = wave length (separation in space b/w 2 consecutive peaks) $(m)$

$\omega$ = angular frequency = by plotting $\cos \omega t$ we found $\omega = \dfrac{2\pi}{T}$ (T: period or the separation in time b/w 2 consecutive peaks) $(s^{-1})$



14.54 Wave in a wire: $y = 1.5 \sin(0.1x - 560t)$

$y \downarrow$ cm, $0.1x \downarrow$ cm, $560t \downarrow$ s

$A$? $\lambda$? $T$? $v$? $\bar{P}$?

Wire tension is 28 N

Math expression for a transverse wave, $y(x,t) = A \sin(kx - \omega t)$

1) Amplitude: $A = 1.5$ cm

2) Wave number $k = 0.1 \rightarrow \lambda = \frac{2\pi}{k} = \frac{2\pi}{0.1} = 20\pi = 62.8$ cm

3) Period $T = \frac{2\pi}{\omega} = \frac{2\pi}{560} = 11.2 \times 10^{-3}\,s = 11.2$ ms (miliseconds)

4) $\boxed{\text{Wave speed: } v = \frac{\lambda}{T}} = \frac{62.8 \times 10^{-2}\ m}{11.2 \times 10^{-3}\ s} = 56\ \frac{m}{s}$

(car speed: $100\ \frac{km}{h} \cdot \frac{1h}{3600s} \cdot \frac{1000m}{1km} = \frac{100}{3.6} = 27.8\ \frac{m}{s}$)

5) Power carried by a wave:

$\bar{P} = \frac{1}{2}\mu\omega^2 A^2 v$ (average)

$\mu$ = linear density of wire
$\omega$ = angular freq. of wave
$A$ = amplitude of wave
$v$ = speed of wave

To find the linear density of wire $\mu$ = we need to use the tension $T = 28N$

$$v = \sqrt{\frac{T\,(\text{tension})}{\mu}} \rightarrow \mu = \frac{T}{v^2} = \frac{28}{56^2}\ \frac{kg}{m}$$

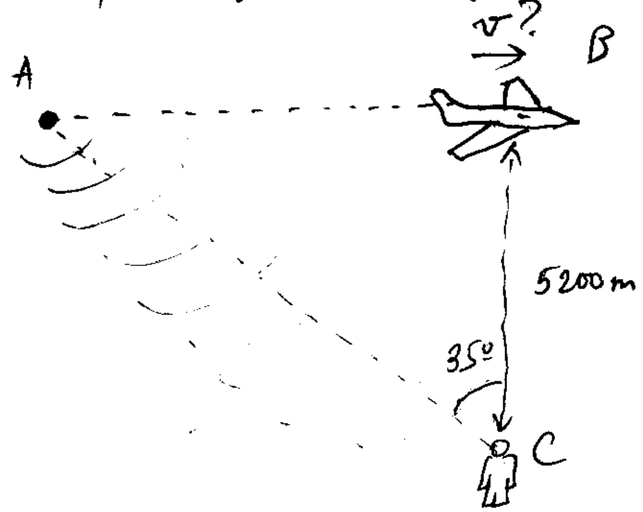
$$\bar{P} = \frac{1}{2}\frac{T}{v^{\cancel{2}}}\omega^2 A^2 \cancel{v} = \frac{1}{2}\frac{28}{56}\,560^2 \cdot 0.015^2\ W = 17.4\ W$$

14.61

Sound wave speed $v_{sound} = 330\ m/s$

(Curiosity : light wave speed $v_{light} = c = 300000000\ \frac{m}{s}$)

July 4th Fireworks!




When you see the fighter jet @ B (light wave reached your eyes) the sound from B did not reach your ears yet. Sound from A reached your ears when light from B reached your eyes.

$$v = \frac{d_{AB}}{t_{soundAC}} = \frac{d_{AB}}{\frac{d_{AC}}{v_{sound}}} = v_{sound}\frac{d_{AB}}{d_{AC}} = v_{sound} \cdot \sin 35^\circ$$

$$= 330 \cdot \sin 35^\circ = 189\ \frac{m}{s}$$

time it takes the sound to travel AC

(Curiosity : $v_{aircraft} = 189 \cdot 3.6 = 680\ \frac{km}{h}$ )