"Equilibrium" $\sum \vec{F} = 0$

Static (not moving)
Dynamic (moving w/ constant $\vec{v}$)

Falling object

$\vec{F}_{drag} \propto v$ or v^2

$\vec{F}_g$

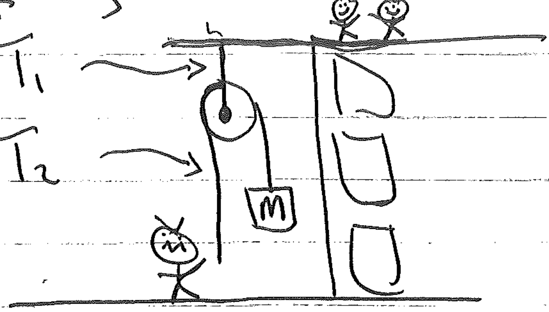
"Terminal Velocity

From last class:

Ex] 1000 kg piano to be lifted @ constant velocity. Find tension in the ropes.

T_1

T_2



ASIDE:
- One rope, one tension
- Pulleys...

Assume already moving.

for piano $+\hat{j}$

$\vec{T}_2 = +T_2\hat{j}$

$\vec{F}_g = -mg\hat{j}$

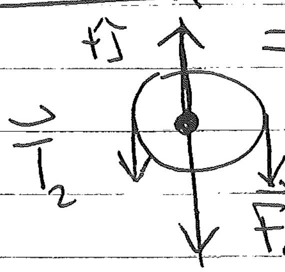
2nd $\sum \vec{F} = m\vec{a}$

$\boxed{\hat{j}}$ $\sum F_y = m\cancel{a_y} \rightarrow 0$

$T_2 - mg = 0$

$T_2 = mg = 1000(9.8) = \underline{\underline{9800\ N}}$

for pulley (massless?) *



$+\hat{j}$ $\quad \vec{T}_1 = +T_1\hat{j}$

$\vec{T}_2 \quad \vec{T}_2$

$\vec{F}_g = -\cancel{m_{pulley}}\, g\,\hat{j}$ * YIKES!!!

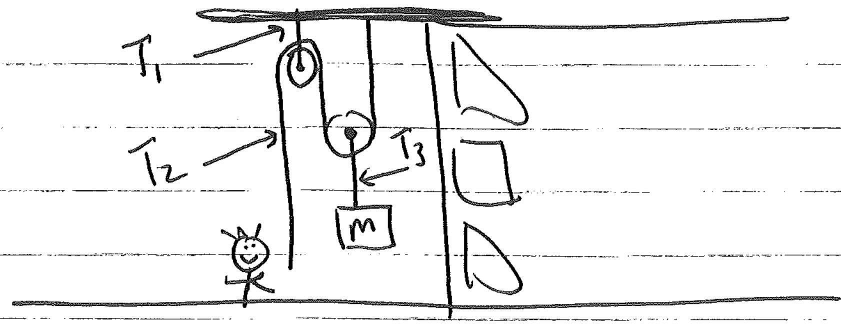
$\rightarrow 0$ Massless!

2nd $\boxed{\hat{j}}$ $\sum F_y = M_{pulley}\cancel{a_y} \rightarrow \underline{\underline{0}}$ Equilibrium

(?)

$-T_2 - T_2 + T_1 = 0$

$T_1 = 2T_2 = \underline{\underline{19600 \text{ newtons}}}$



for Piano

$+\hat{j}$

$\vec{T}_3 = +T_3\hat{j}$

$\vec{F}_g = -mg\hat{j}$

2^{nd} $[\hat{j}]$ $\Sigma F_y = m\underbrace{a_y}_{\to 0}$

$T_3 = mg = \underline{9800\ N}$

for lower pulley (massless)

$+\hat{j}$

$+T_2\hat{j} = \vec{T}_2$ $\quad \vec{T}_2 = +T_2\hat{j}$

$\vec{T}_3 = -T_3\hat{j}$

2^{nd} $[\hat{j}]$ $\Sigma F_y = 0$ ☺ $\boxed{a_y = 0}$

$T_2 + T_2 - T_3 = 0$

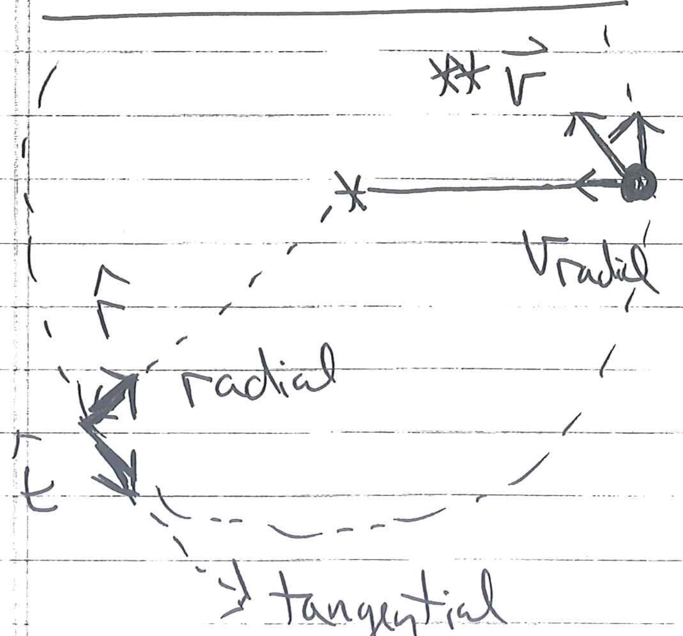
"Mechanical Advantage" $T_2 = \frac{T_3}{2} = \underline{4900\ N}$ ☺

for upper pulley ☺ ... $T_1 = 2T_2$

Circular Motion

*NOTE: I have defined an accelerated frame of reference. That is why it looks a bit odd.

Beyond what we will do ☺



Rock on a rope swinging in a circle.

$|\vec{V}_{tan}| = $ Constant ✡

Q] If moving @ constant speed, is there an acceleration?

YES. Accelerations change velocities.
Direction is changing!!

Imagine this coordinate system:

tangential axis $\Rightarrow \hat{t}$
radial axis $\Rightarrow \hat{r}$

$$** \quad \vec{V} = V_{tan.}\hat{t} + \cancel{V_{radial}\hat{r}} \rightarrow 0 \quad *$$

$$\vec{a} = \underbrace{\cancel{a_{tan.}}}_{\rightarrow 0 \text{ ✡}}\hat{t} + a_{rad.}\hat{r} \quad *$$

changing direction

Geometrical Proof shows

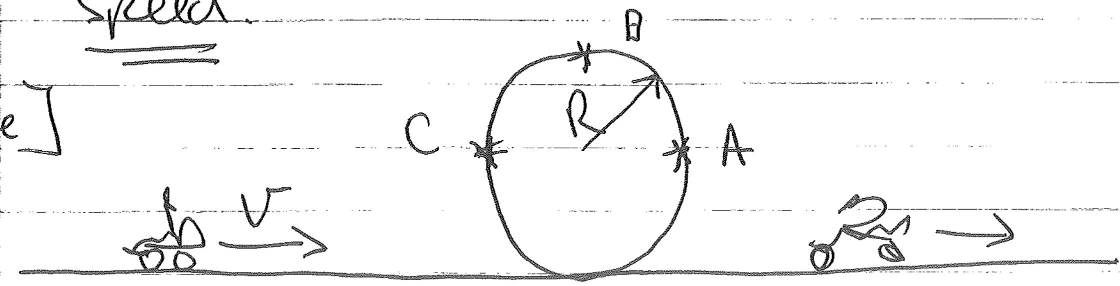
that for circular Motion

$$a_{radial} = \frac{V_{tangential}^2}{R}$$

R ← radius of circle.

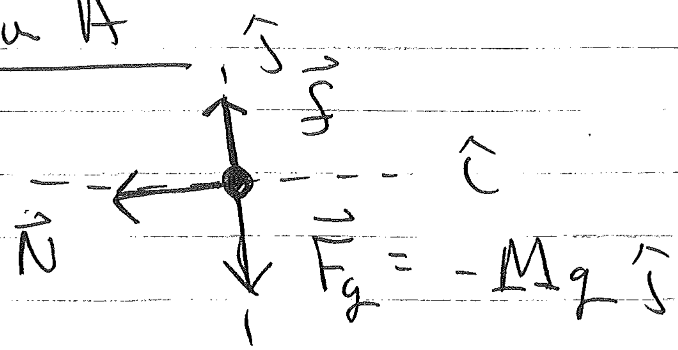
Ex.] Daredevil-Dan drives @ a constant speed.

M [Dan+bike]



Draw Free body diagram @ each location for [Dan + bike]

Location A



2^{nd} $\boxed{\hat{i}}$ $\Sigma F_x = M a_x$

a_x ← centripetal $\neq 0$

$N = M a_x$

N ← "Centripetal" Force (A LABEL for force causing circular motion)

a_x ← centripetal acceleration

My coordinates, expect a_x to be $(-\hat{i})$ direction. $\left(-\frac{V^2}{R}\right)$

$$\boxed{\hat{j}} \quad \sum F_y = M a_y, \quad a_y \rightarrow 0$$

"Constant speed"

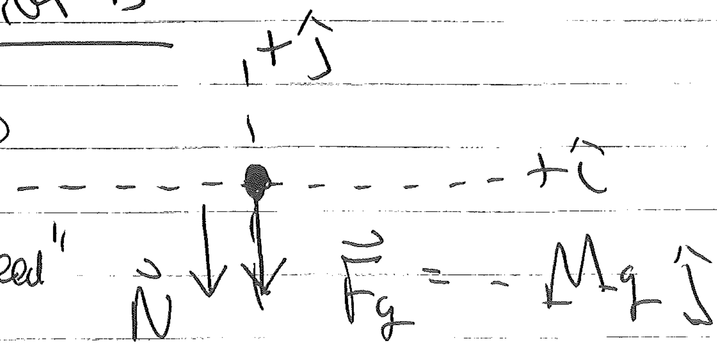
$$+f - Mg = 0$$

$$f = Mg$$

Location B

$\vec{f} = 0$

"Constant Speed"

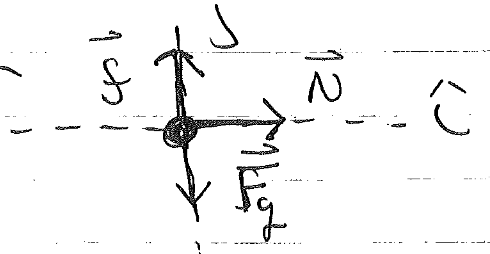


? no $\quad \boxed{\hat{i}} \quad \sum F_x = \cancel{M a_x} \rightarrow 0$

$$\boxed{\hat{j}} \quad \sum F_y = M a_y \leftarrow \left(-\frac{v^2}{R}\right)$$

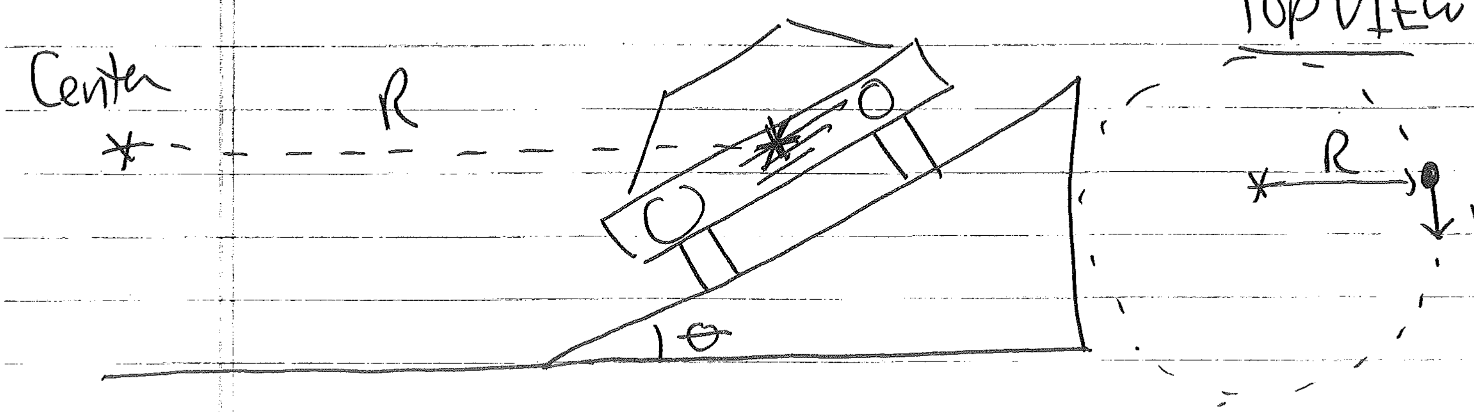
$$\underbrace{-N - Mg}_{\text{"Centripetal Force"}} = M\left(-\frac{v^2}{R}\right)$$

Location C

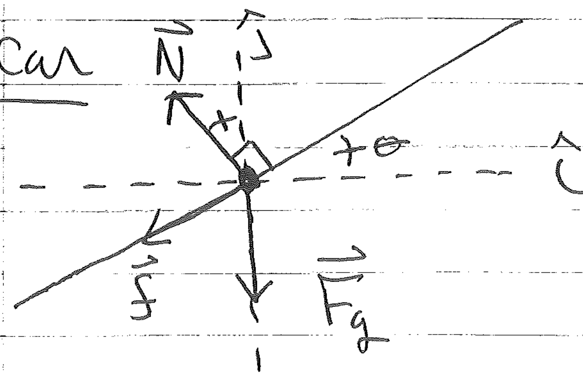


HW Hint

Car on a banked curve.



for car



$\vec{f}$ is preventing car from sliding up ramp.

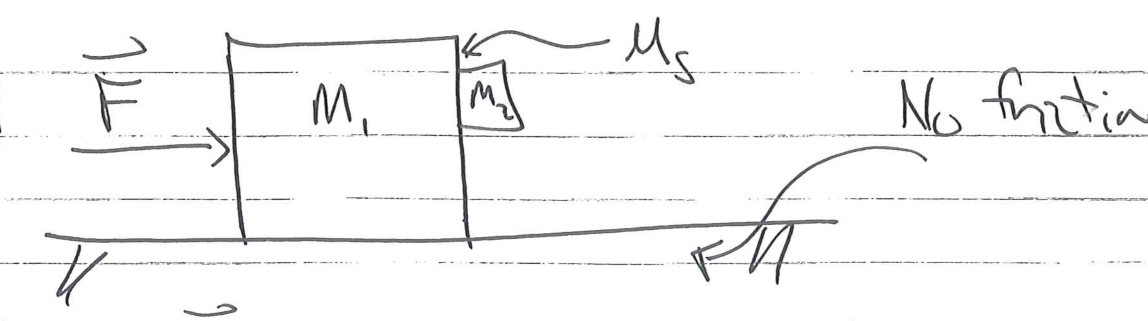
2^{nd} $\sum \vec{F} = m\vec{a}$

$\boxed{\hat{j}}$ $\sum F_y = m\cancel{a_y}^{\,0}$

$\boxed{\hat{i}}$ $\sum F_x = m\underbrace{a_x}_{\left(-\frac{v^2}{R}\right)}$ ← Centripetal !!

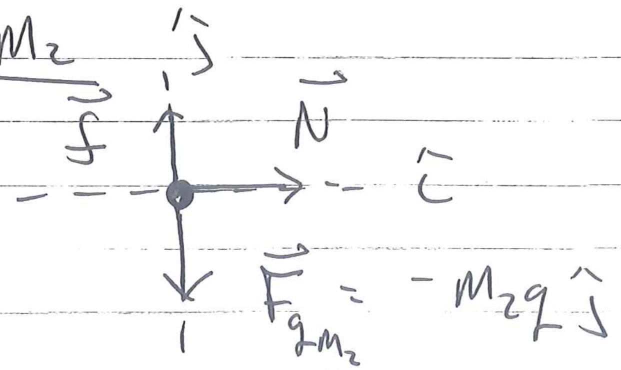
Then choose $\vec{f}$ in other direction ⇒ Prevents car from sliding down ramp.

EX



Find $\vec{F}$ such that m_2 does not slide * down the face of m_1.

for m_2



$\vec{N} = +N\hat{i}$

$\vec{f} = +\mu_s N \hat{j}$

2nd : $\sum \vec{F} = m_2 \vec{a}$

$\boxed{\hat{i}}$ . . . $\boxed{N = m_2 a_x}$

$\boxed{\hat{j}}$ . . . $\boxed{\mu_s N = m_2 g}$

A proper finish :

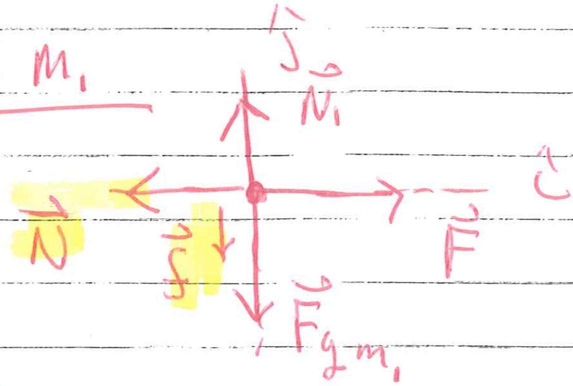
$\boxed{\hat{i}}$ $\sum F_x = m_2 a_x$

$\boxed{N = m_2 a_x}$ $\boxed{1}$

$\boxed{\hat{j}}$ $\sum F_y = m_2 \cancel{a_y} \to 0$ *

$\boxed{+\mu_s N - m_2 g = 0}$ $\boxed{2}$

For m_1



NOTE: Choice of coord. system is consistent w/ other free body diagram

$\vec{N}_1 = N_1 \hat{j}$
$\vec{F}_{gm_1} = -m_1 g \hat{j}$
$\vec{F} = F \hat{i}$
$\vec{N} = -N \hat{i}$
$\vec{f} = -\mu_s N \hat{j}$

2nd $\boxed{\hat{j}}$ $\sum F_y = m_1 \underbrace{a_y}_{0}$

$\boxed{3}$ $\boxed{N_1 - m_1 g - \mu_s N = 0}$

$\boxed{\hat{i}}$ $\sum F_x = m_1 a_x$

$\boxed{4}$ $\boxed{-N + F = m_1 a_x}$

We now have FOUR eqns. Our "knowns" are m_1, m_2, and μ_s. We need to find F in terms of these quantities.

Substitute $\boxed{1}$ into $\boxed{4}$ to get:

$\boxed{A}$ $\boxed{4} \Rightarrow F = m_1 a_x + N = m_1 a_x + m_2 a_x = a_x(m_1 + m_2)$

Substitute $\boxed{1}$ into $\boxed{2}$ to get:

$\boxed{2} \Rightarrow \mu_s m_2 a_x - m_2 g = 0$

$\therefore a_x = g/\mu_s$

use this in $\boxed{A}$ above

$\boxed{1A} \Rightarrow \quad F = a_x(m_1+m_2) = \dfrac{g(m_1+m_2)}{\mu_s}$

Would this work if $\mu_s = 0$?

NO WAY!