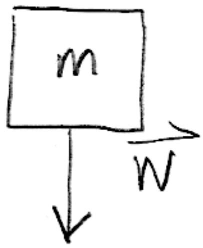
Mass and Weight



m = mass

$\simeq N_{atoms} \times \left(M_{atom} - \frac{BE_1}{c^2}\right)$ (pure material)

$\simeq N_{atoms} \cdot \left(Z \cdot (m_p + m_e) + N \cdot m_n - \frac{\text{Binding Energy}}{c^2}\right)$

Z = atomic #

N = # neutrons

$-\frac{BE_1}{c^2}$

$\vec{W}$ = force of gravity

on earth, $|\vec{W}| = W \propto m$

$= mg$

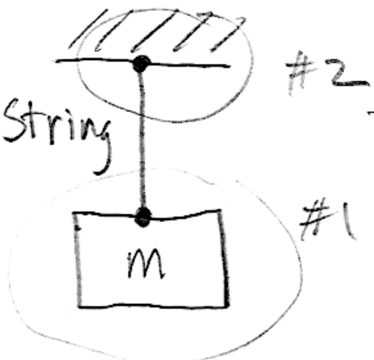
$g \cong 9.8\ m/s^2$, $\simeq$ independent of position

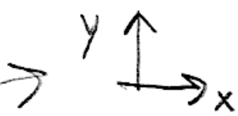
direction: downward,

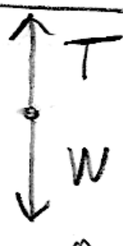
$\simeq$ toward center of earth.

Can be influenced by:

- earth not exactly a sphere.
- large lumps of matter (mountains)



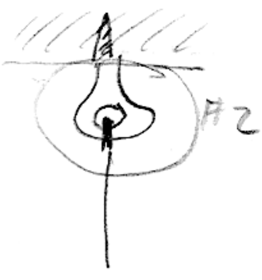




y: $T - W = 0$, $T = W$

$T = mg$

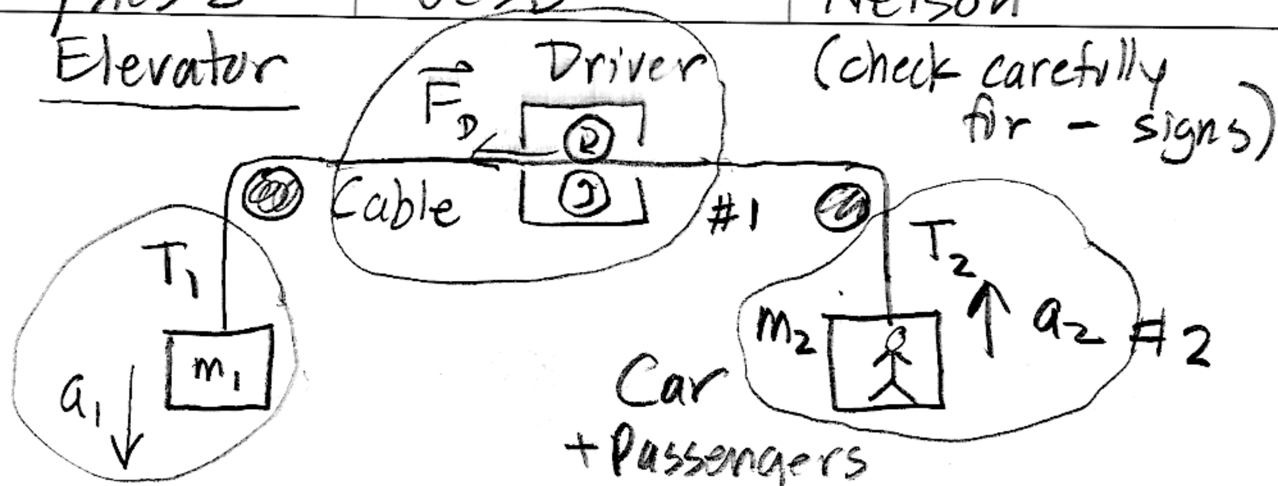
- Tension same throughout string
- <u>or</u> spring



$C - T = 0$

$C = T$

Elevator (check carefully for − signs)



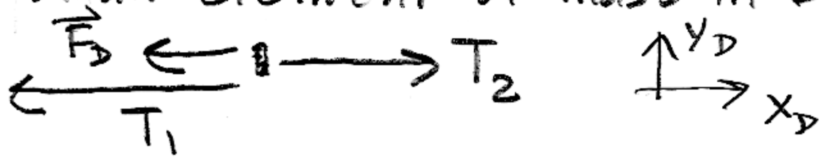
Cable is fixed length ... a constraint; most of Kleppner's hard problems involve a challenging constraint.

☆ UNLIKE IN CLASS: take $a_1 > 0$, $a_2 > 0$, put in − sign in for components BY ~~HAND~~

Then constraint is: $a_1 = a_2$

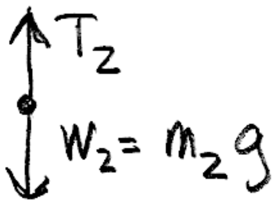
Given: m_1, m_2, a_2 Find: T_1, T_2, F_D, a_1

$\boxed{\text{System \#1}}$: a small element of cable mass in Driver



$$*\ T_2 - T_1 - F_D = 0$$

$\boxed{\text{System \#2}}$: mass m_2:

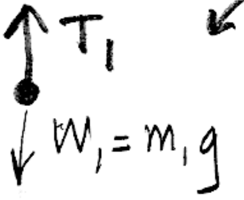


$$T_2 - m_2 g = +m_2 a_2$$

$$\boxed{T_2 = m_2 (g + a_2)}$$

all given on RHS got T_2!

$\boxed{\text{System \#3}}$ mass m_1



$$T_1 - m_1 g = -m_1 a_1 = -m_1 a_2$$

$$\boxed{T_1 = m_1 (g - a_2)}$$

all given on RHS got T_1!

<u>Last Unknown</u> $F_D = T_2 - T_1 \quad (*)$

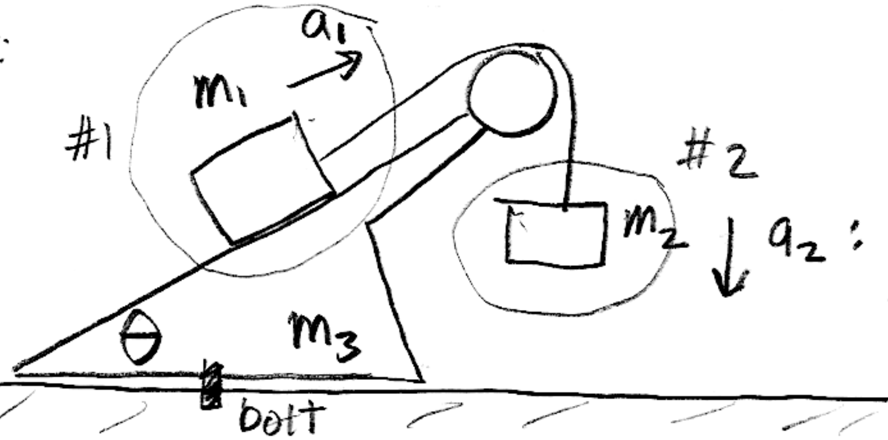
$$= m_2(g+a_2) - m_1(g-a_2)$$

$$\boxed{F_D = (m_2 - m_1)g + (m_1+m_2)a_1}$$

"Balance" term vanishes when $m_1 = m_2$

"Push" Term right from Newton II

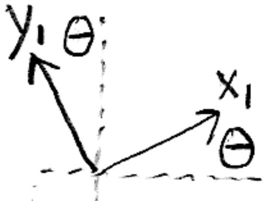
Constraint:
$a_1 = a_2$
(string fixed length)



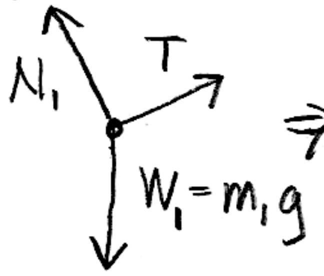
a_2: $a_2 > 0$ component by hand later

<u>Given</u>: m_1, m_2, θ <u>Find</u>: $a_1 = a_2, T$, Normal Forces

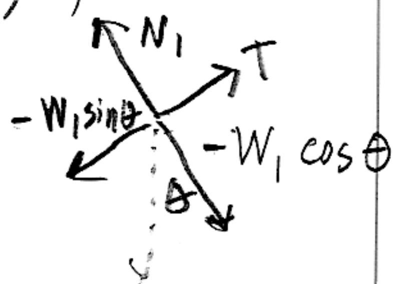
(1)



mass m_1



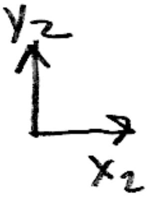
$\Rightarrow$ resolve W_1 on (x_1, y_1) $\Rightarrow$



$\underline{x_1}$: $T - W_1 \sin\theta = m_1 a_1 \quad (*)$

$\underline{y_1}$: $N_1 - W_1 \cos\theta = 0 \Rightarrow \boxed{N_1 = m_1 g\cos\theta}$

(2)



$T - W_2 = -m_2 a_2 = -m_2 a_1 \quad (\star)$

combine $\star$ with $*$, have TWO equations in 2 unknowns (T and a_1)

$$T - W_1 \sin\theta = m_1 a_1$$
$$T - W_2 = -m_2 a_1$$

$$-W_1 \sin\theta + W_2 = (m_1 + m_2)\, a_1$$

$$\boxed{a_1 = \frac{-W_1 \sin\theta + W_2}{m_1 + m_2} \qquad W_1 = m_1 g \quad W_2 = m_2 g \qquad a_1 = \left(\frac{-m_1 \sin\theta + m_2}{m_1 + m_2}\right) g}$$

- check dimensions
- $\sin\theta = 1$ resembles elevator
- $m_2 = m_1 \sin\theta$ gives $a_1 = 0$

$$T = W_2 - m_2 a_1 = m_2 g - m_2 \left(\frac{-m_1 \sin\theta + m_2}{m_1 + m_2}\right) g$$
$$= \left(\frac{m_2(m_1 + \cancel{m_2})}{m_1 + m_2} + \frac{+m_1 m_2 \sin\theta - \cancel{m_2^2}}{m_1 + m_2}\right) g$$

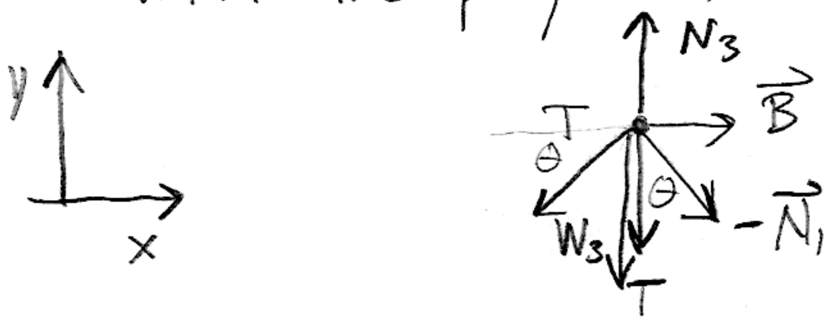
$$\boxed{T = \frac{m_1 m_2}{m_1 + m_2} \times (1 + \sin\theta)\, g}$$

known as "reduced mass" μ

$$\mu \equiv \frac{m_1 m_2}{m_1 + m_2} = \frac{1}{\frac{1}{m_1 \cdot m_2}(m_1 + m_2)} = \frac{1}{\frac{1}{m_1} + \frac{1}{m_2}}$$

or $\left.\frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2}\right\}$ smaller dominates

(3) Now think about the big piece with the pully on it.



bolt. N_3, B unknown

y: $N_3 - T - T\sin\theta - N_1\cos\theta - W_3 = 0$

$- W_1\cos^2\theta$

$$\boxed{\begin{aligned} N_3 &= T(1+\sin\theta) + W_1\cos^2\theta + W_3 \\ &= \left[\frac{m_1 m_2}{m_1+m_2}(1+\sin\theta)^2 + m_1\cos^2\theta + m_3\right]g \end{aligned}}$$

x: $-T\cos\theta + B + N_1\sin\theta = 0$

$$-\left(\frac{m_1 m_2}{m_1+m_2}\right)(1+\sin\theta)g\cdot\cos\theta + B + m_1 g\cos\theta\sin\theta = 0$$

$$B + \left(\frac{-m_1m_2 - \cancel{m_1m_2\sin\theta} + (m_1+\cancel{m_2})m_1\sin\theta}{m_1+m_2}\right)g\cos\theta = 0$$

$$B + \frac{m_1}{m_1+m_2}\left(-m_2 + m_1\sin\theta\right)g\cos\theta = 0$$

$$\boxed{B = m_1\left(\frac{-m_1\sin\theta + m_2}{m_1+m_2}\right)g\cos\theta}$$

note: when $a_1 = 0$, $B = 0$... Complicated

IMAGINE BOLT REMOVED...