Today: Chapter 4 (Newton's Laws)

Forces cause acceleration.

Newton's 1st law: without forces acting on an object (or if the forces cancel out), then the objects acceleration is $\vec{0}$, so it moves with constant speed & direction. (If at rest, it stays at rest.)

"net Force"

$\sum \vec{F}$ = sum of forces acting on an object

If $\sum \vec{F} = \vec{0}$, then $\vec{a} = \vec{0}$.

If an object has mass m,
then $\sum \vec{F} = m\vec{a}$. (Newton's 2nd law) Force = mass × acceleration

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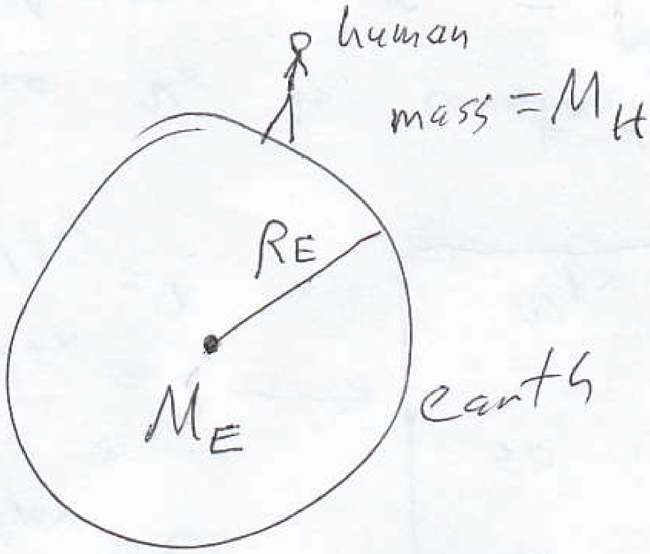
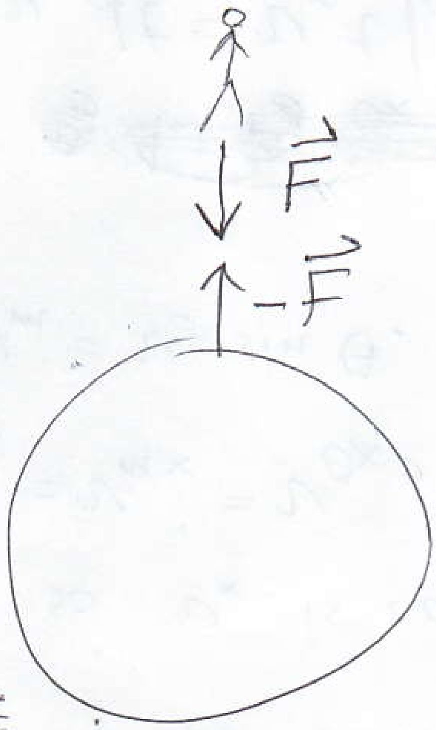
Newton's 3rd Law:

Forces come in symmetrical pairs. Specifically, if object A exerts force $\vec{F}$ on object B, then object B exerts force $-\vec{F}$ on A. "For every action, there is an equal (in magnitude) and opposite (in direction) reaction."

The 3rd law holds because these pairs of forces are interactions between objects.

All forces come from interactions between objects.





$$F = |\vec{F}| = |-\vec{F}| = \frac{G M_H M_E}{R_E^2}$$

$$|\vec{a}_H| = \frac{F}{M_H} = \frac{G M_E}{R_E^2} = g = \boxed{9.80\,m/s^2}$$

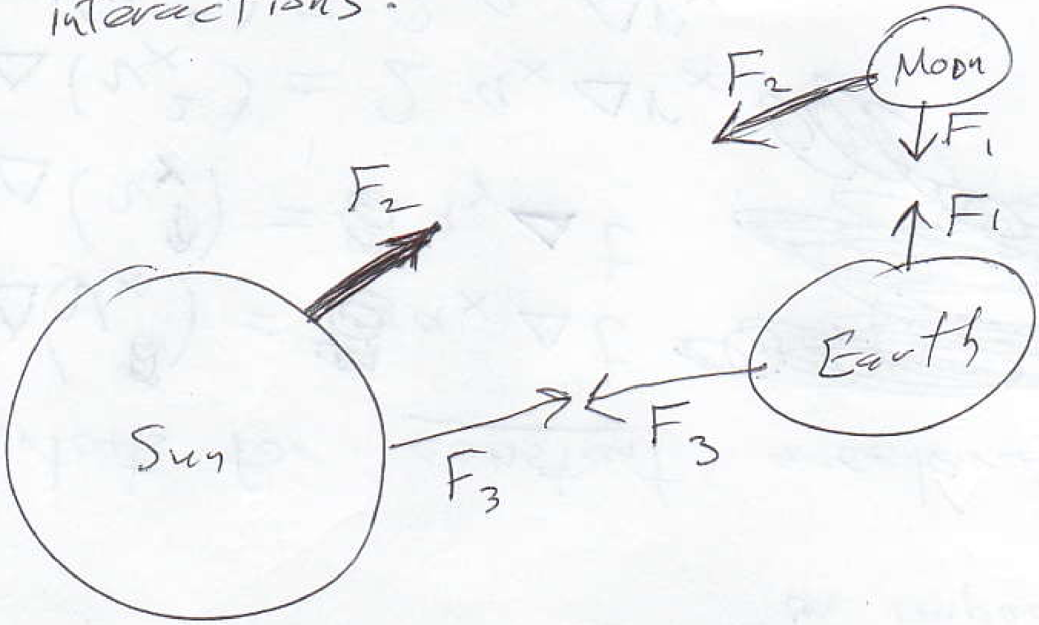
$$|\vec{a}_E| = \frac{F}{M_E} = \frac{G M_H}{R_E^2} = \boxed{1.3 \times 10^{-22}\,m/s^2}$$

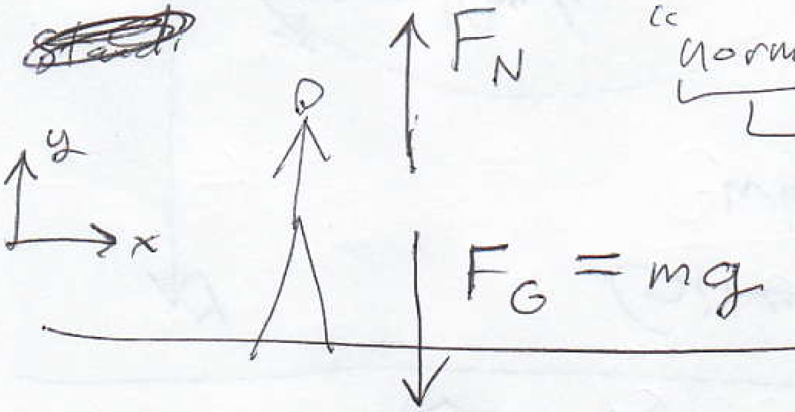
$$G = 6.67 \times 10^{-11}\,\frac{m^3}{kg \cdot s^2}$$

$M_H = 82\,kg$ $R_E = 6.38 \times 10^6\,m$

$M_E = 5.97 \times 10^{24}\,kg$

3 interactions:





"normal force"
normal → perpendicular (to floor)

$F_N = F_G$ because $a_y = 0$

If $\vec{a} \uparrow$, then $F_N > F_G$.

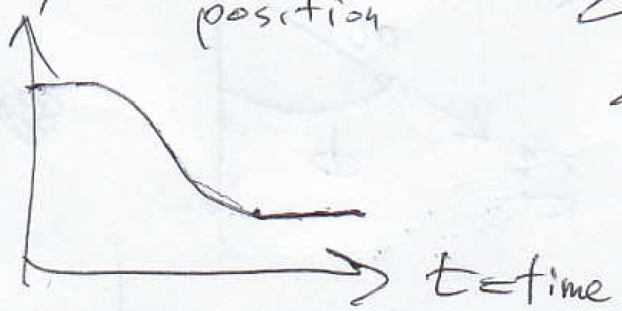
If $\vec{a} \downarrow$, then $F_N < F_G$.

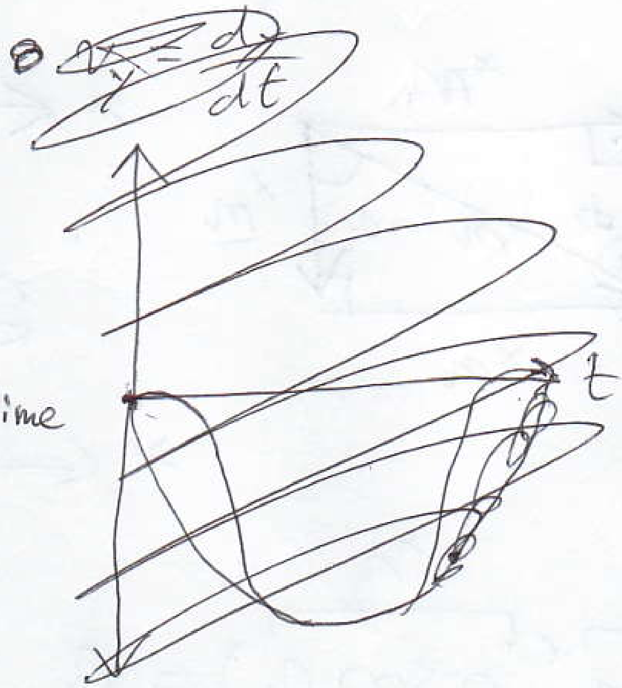
$$\sum \vec{F} = \vec{F}_N + \vec{F}_G = m\vec{a}$$

$$\sum F_y = F_N - F_G = m a_y$$

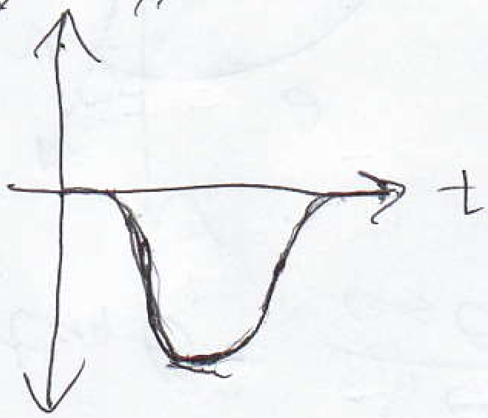
Crouching:

y = vertical position

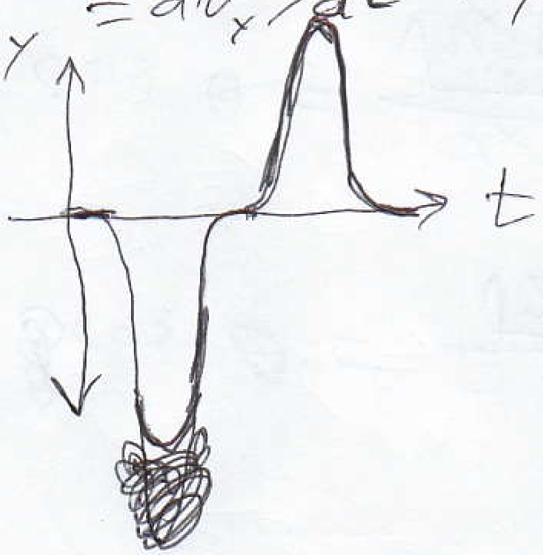




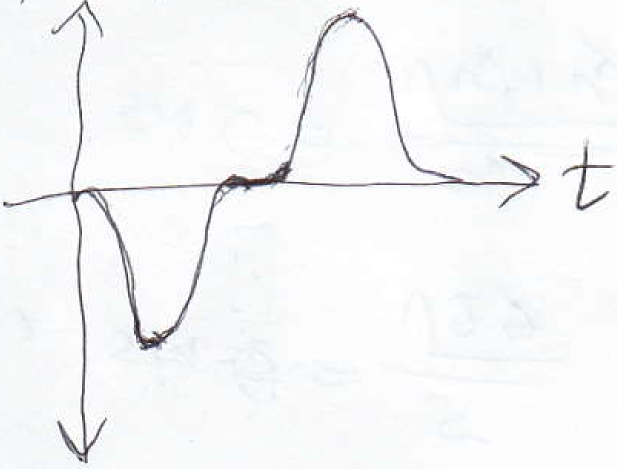
$v_y = dy/dt$



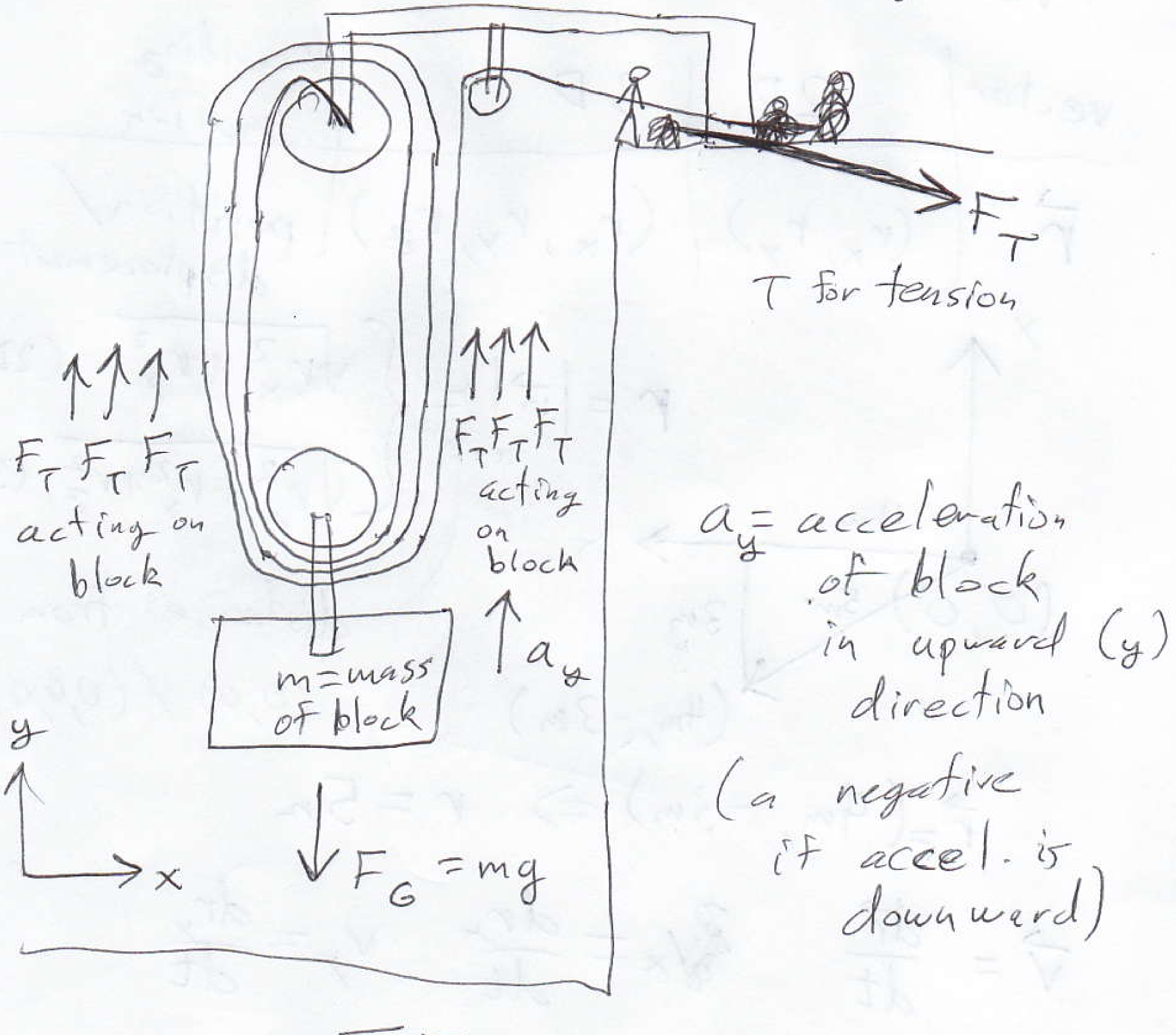
$a_y = dv_y/dt$



$ma_y = \sum F_y = F_N - F_G$



Pulley with mechanical advantage 6:

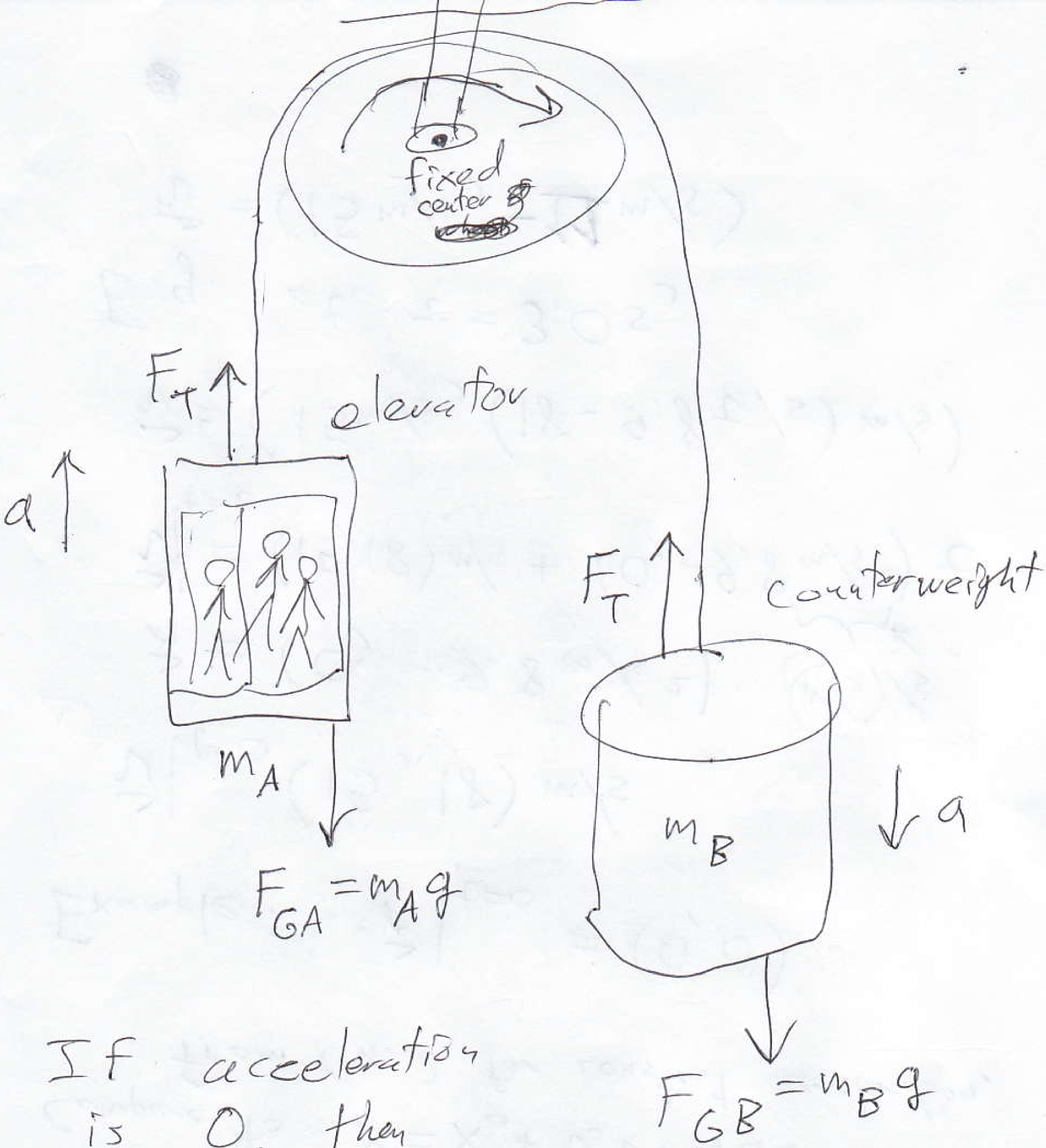


$$ma_y = \sum F_y = 6F_T - \underbrace{mg}$$

← weight of block

If lifting block at constant speed, then $a_y = 0$, so $0 = 6F_T - mg$,

so $F_T = \frac{1}{6} mg = \frac{1}{6}$ weight.



If acceleration is 0, then what is the tension F_T?

$$\begin{cases} 0 = F_T - m_A g \\ 0 = F_T - m_B g \end{cases}$$

$$m_A g = F_T = m_B g \Rightarrow m_A = m_B$$

If $m_A \neq m_B$, then accel. $\neq 0$.
(Unless we apply brakes or a motor.)

$$\begin{cases} \text{elevator: } & m_A a = F_T - m_A g \\ \text{counterweight: } & -m_B a = F_T - m_B g \end{cases}$$

$a = ?$ $F_T = ?$

$$m_A a + m_B a = -m_A g + m_B g$$

(1st =) − (2nd =)

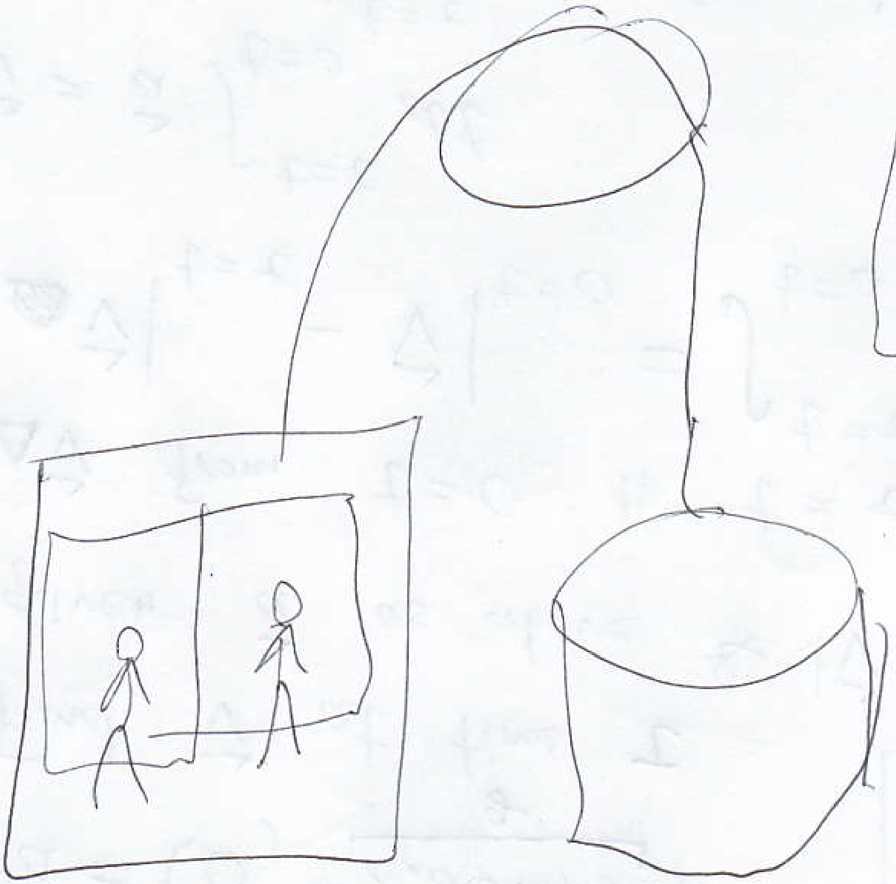
$$(m_A + m_B) a = (m_B - m_A) g$$

$$a = \frac{m_B - m_A}{m_B + m_A} g$$

1st = : $m_A \left(\frac{m_B - m_A}{m_B + m_A} \right) g = F_T - m_A g$

$$F_T = m_A \left(\frac{m_B - m_A}{m_B + m_A} \right) g + m_A g$$

$$F_T = m_A g \left(\frac{m_B - m_A}{m_B + m_A} + 1 \right) = m_A g \frac{2 m_B}{m_B + m_A}$$



1 pound force $= 4.45\ kg \cdot m/s^2$

$m_A = 500 kg$ $m_B = 1000 kg$

$$a = \frac{m_B - m_A}{m_B + m_A} g = \frac{500 kg}{1500 kg} g = \frac{1}{3} g$$

Try $m_B = 600 kg$:

$$a = \frac{100 kg}{1100 kg} g = \frac{1}{11} g$$

≈ 1000 lbs

$$F_T = \frac{2 m_A m_B g}{m_A + m_B} = 5000 \underbrace{kg \cdot m/s^2}_{N}$$

"newton"