× cross product of vectors

$\underline{r}$ = position where force is applied

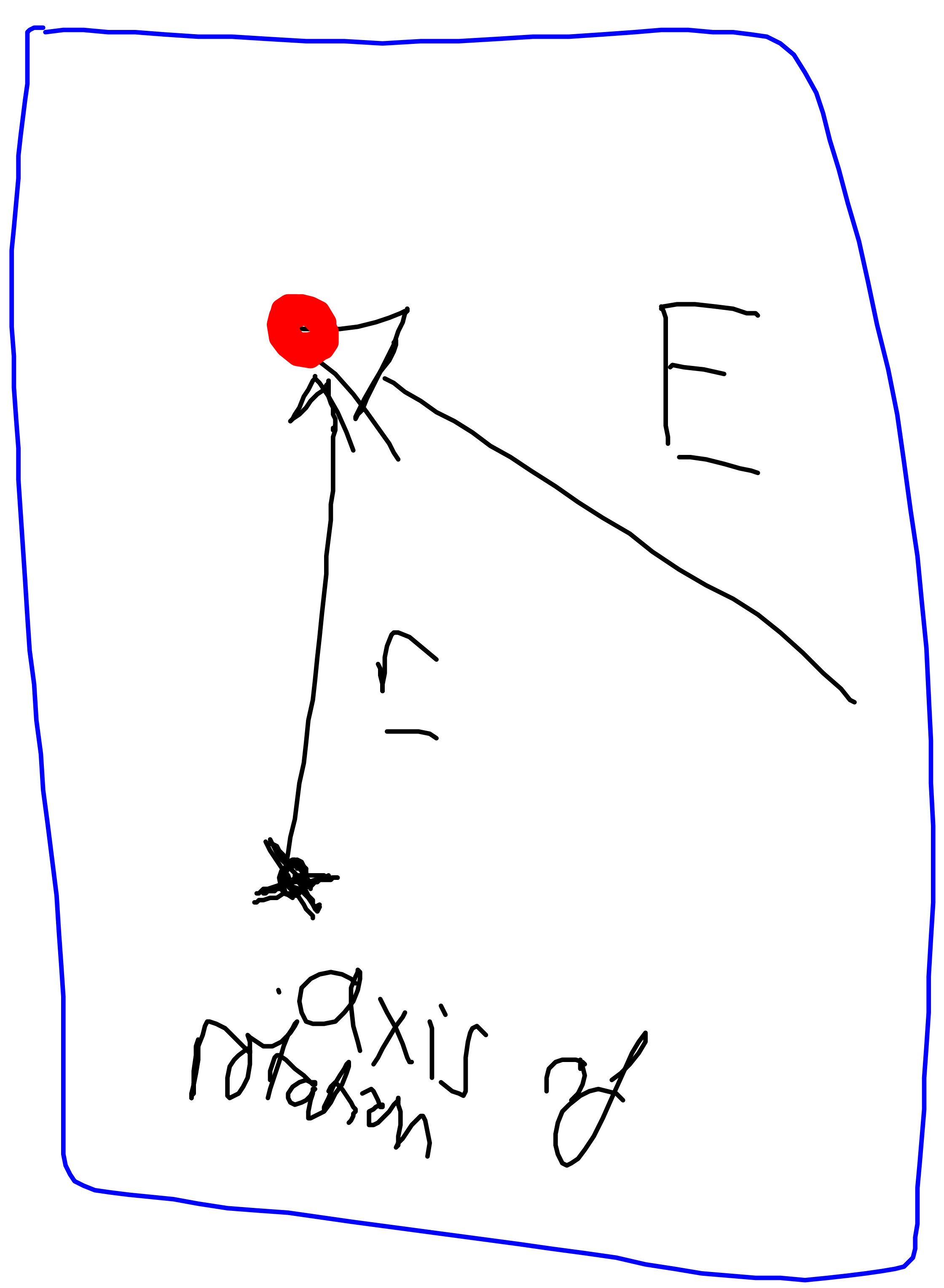
$$\underline{\tau} = \underline{r} \times \underline{F}$$

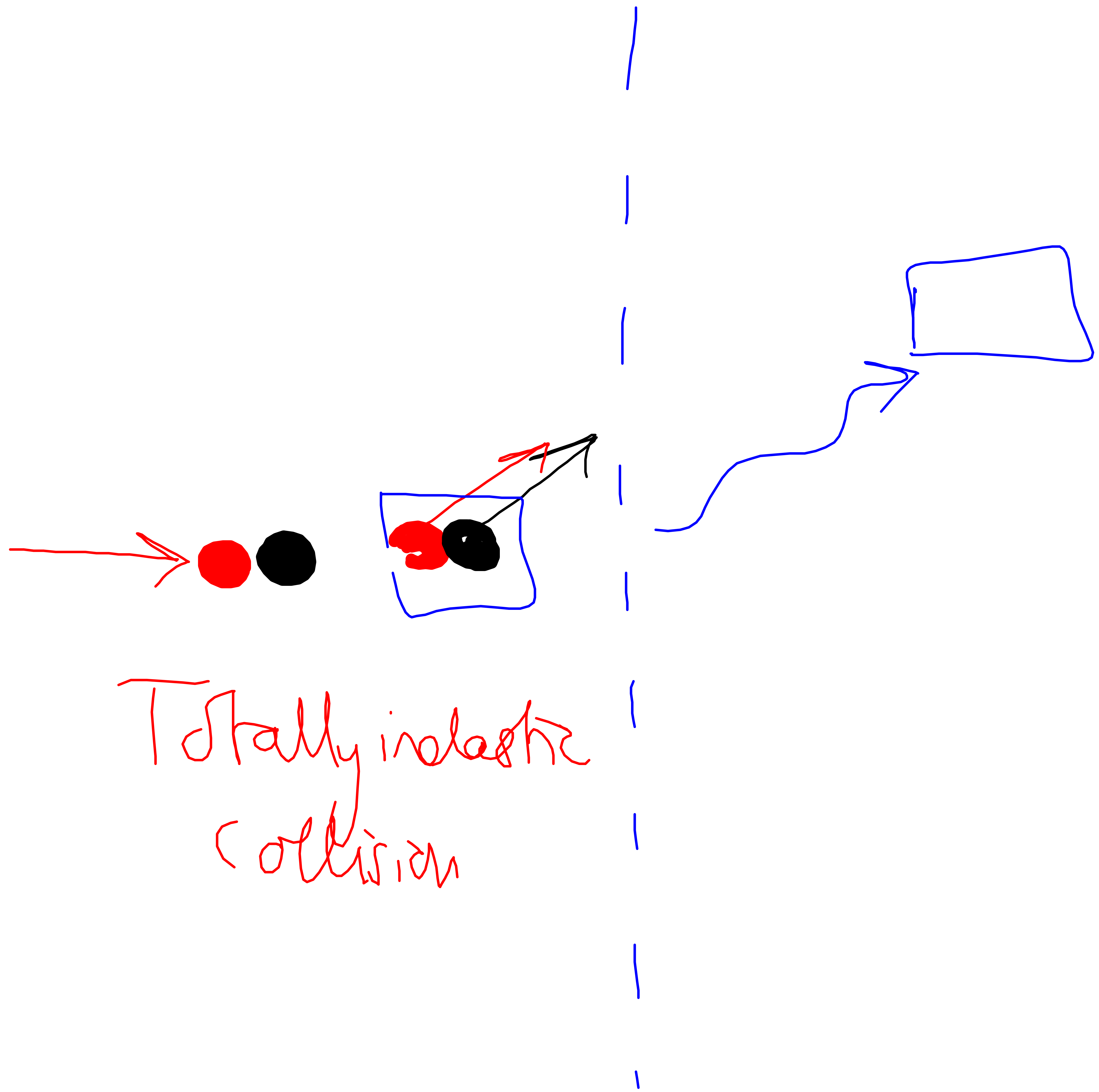
$$= rF\sin\phi\ \hat{\underline{n}}$$

defined as

unit vector in direction of Right Hand Rule for $\underline{\tau}$ twist

angle between $\underline{r}$ and $\underline{F}$





Totally inelastic
collision

$$\sum \underline{F} = M \underline{a}_{CM} = 0 \quad \text{if}$$

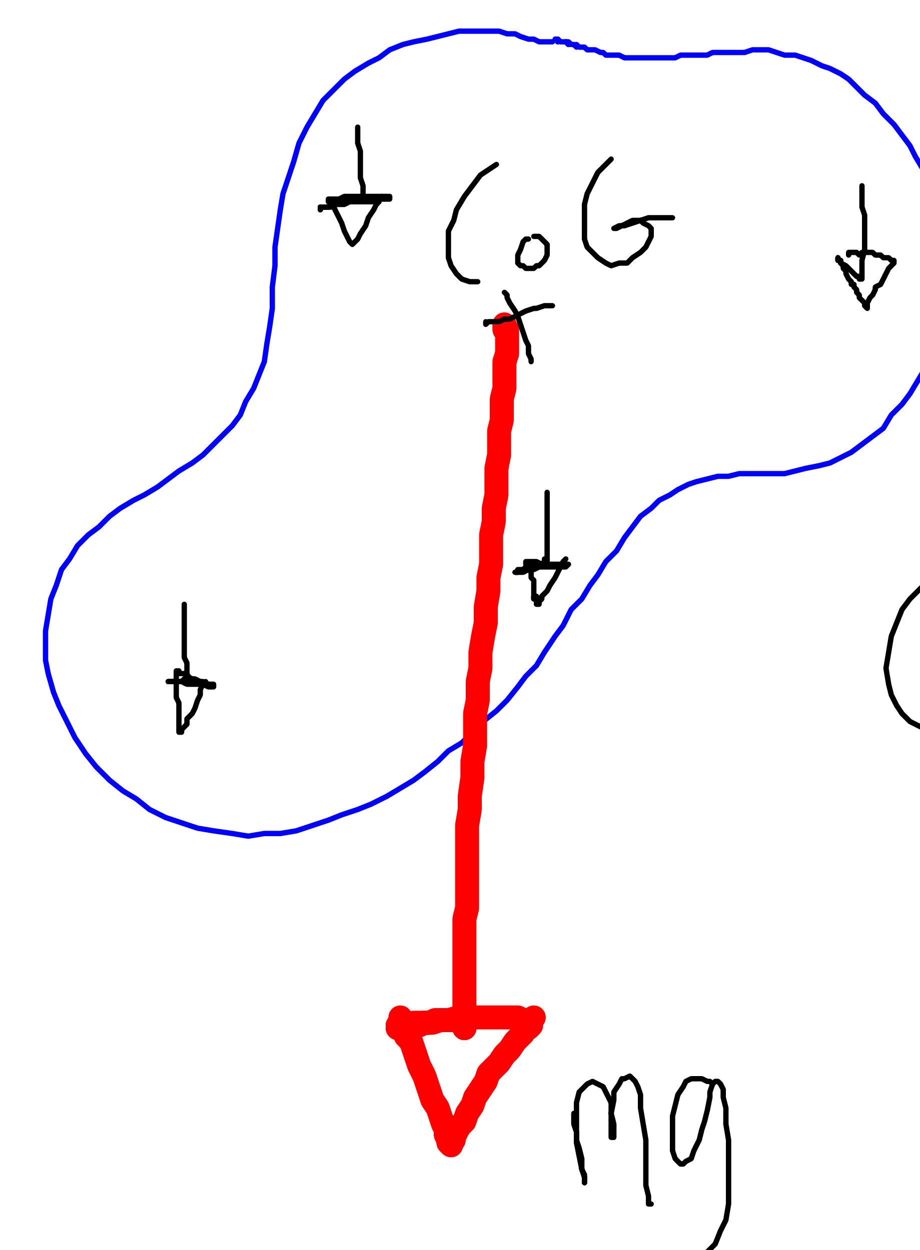
$$\sum \underline{\tau} = I \underline{\alpha} = 0$$

EQUILIBRIUM

Note: Static equilibrium

$\Rightarrow \underline{V}_{CM} = 0$

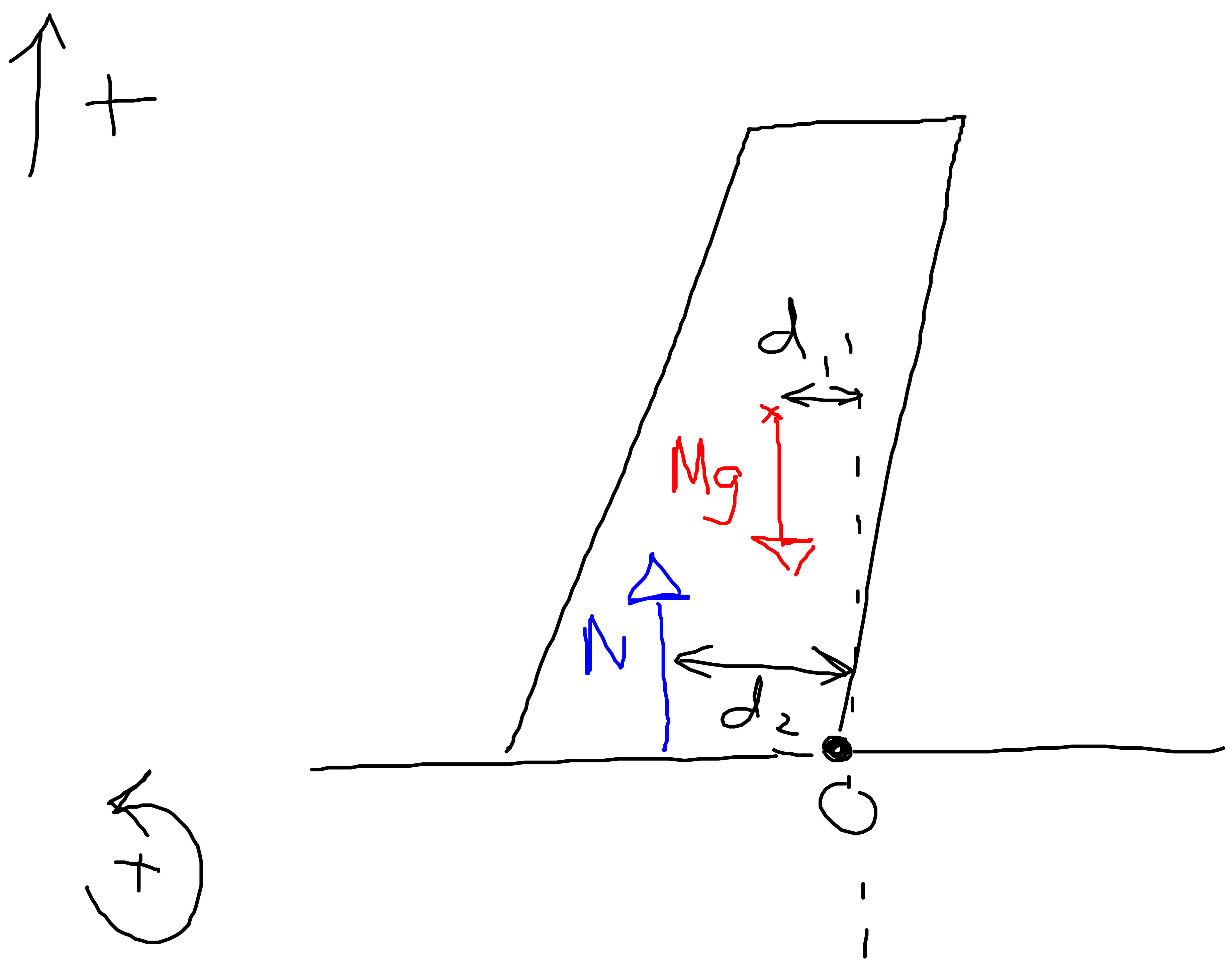
$\underline{\omega} = 0$

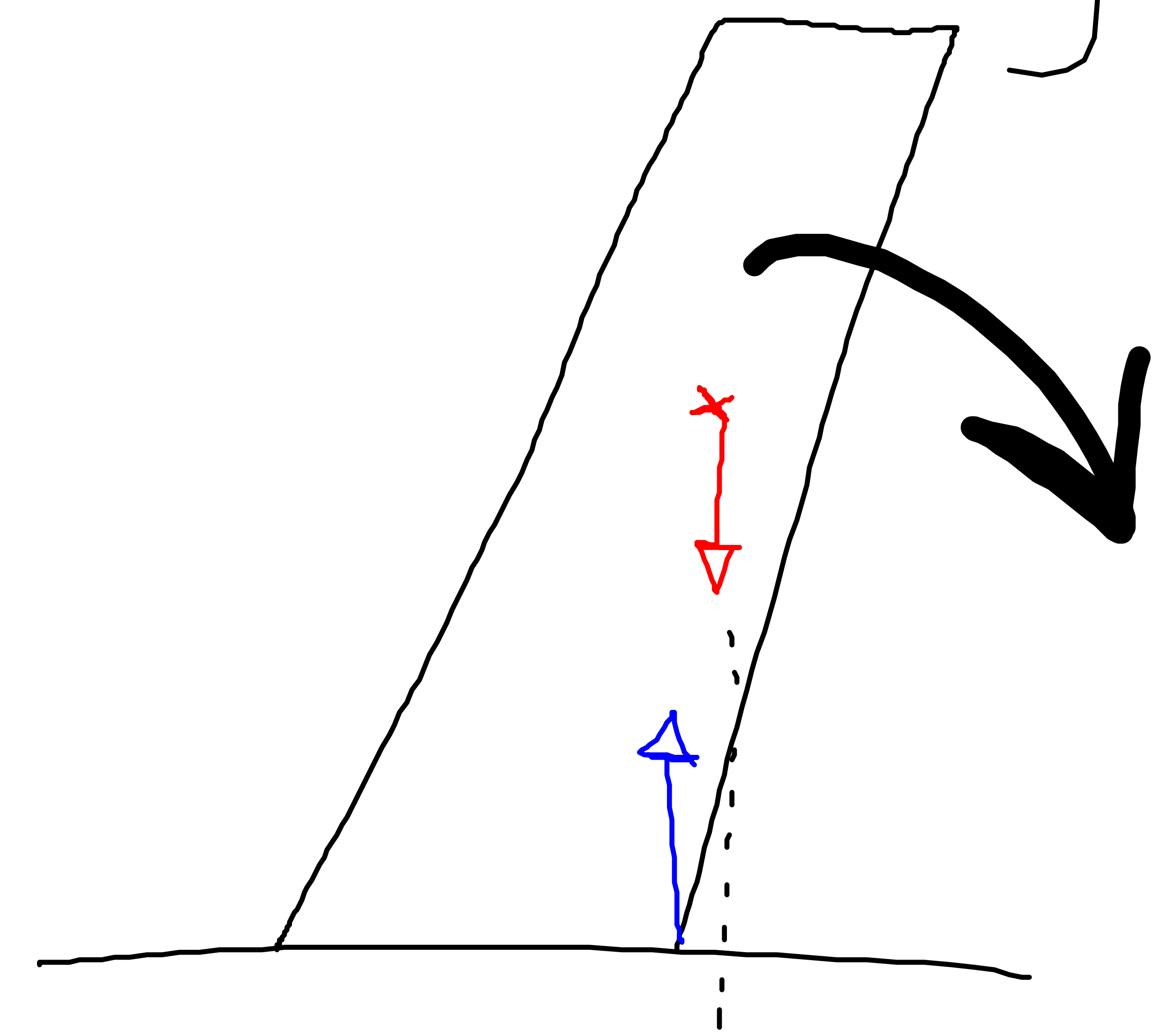


CoG = CM

(g constant)

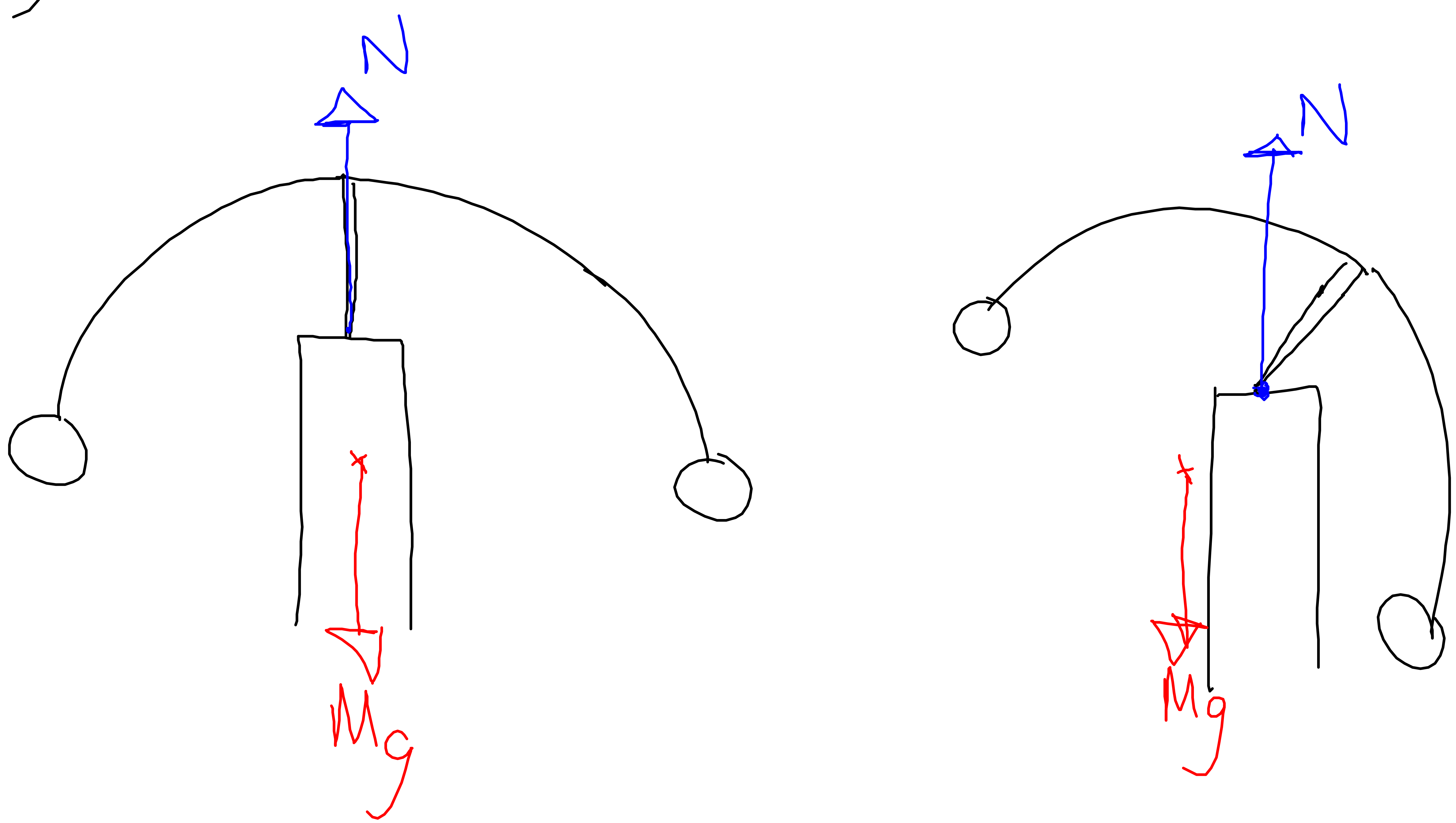
$$\sum F = 0 = N - Mg \Rightarrow N = Mg$$





$$\sum \tau_O = 0 = +Mg\,d_1 - N\,d_2 \Rightarrow d_1 = d_2$$

$N = Mg$

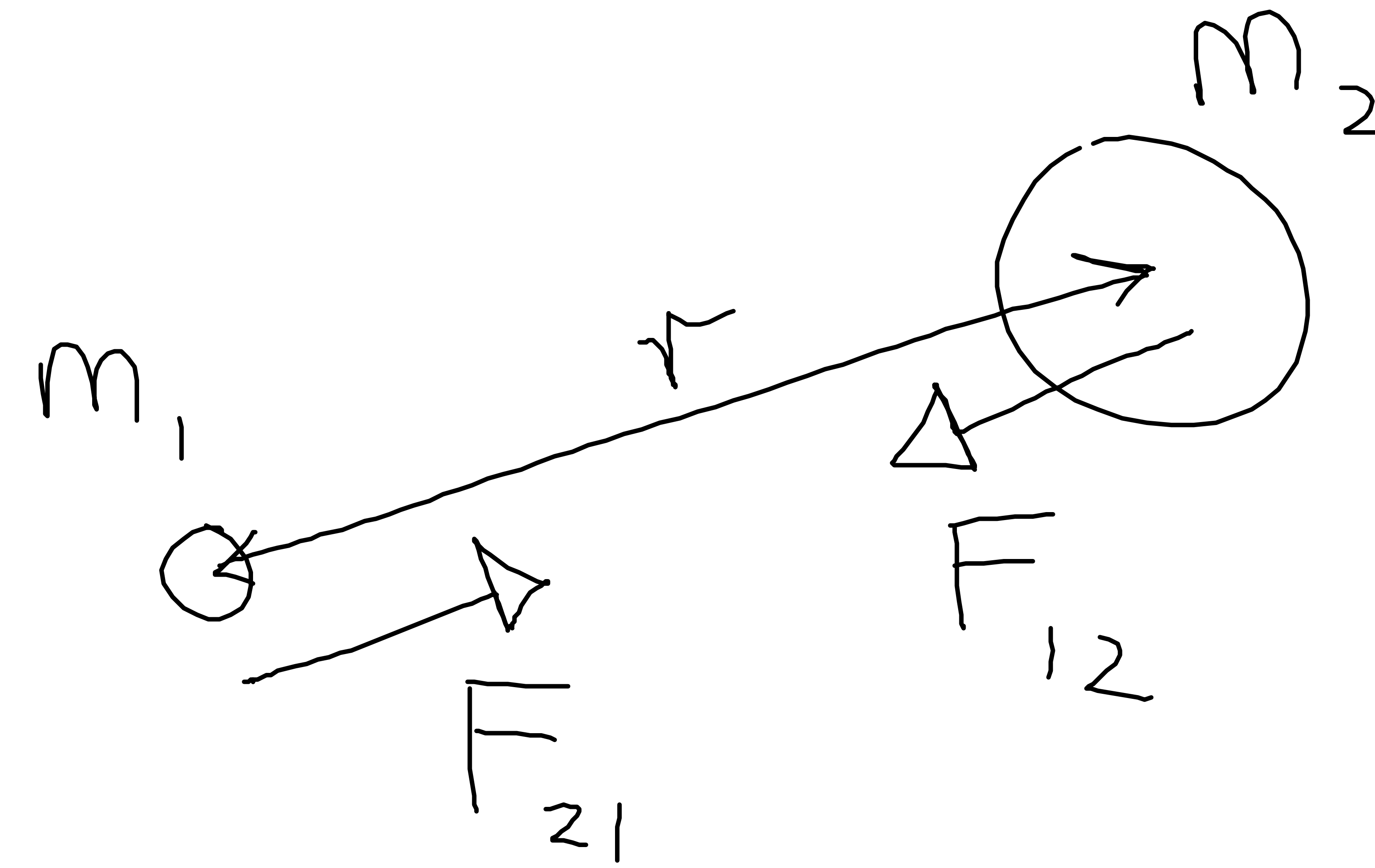


GRAVITY

$g = 9.80\,m/s^2$

approximate near Earth's surface

action-at-a-distance



(no overlap)

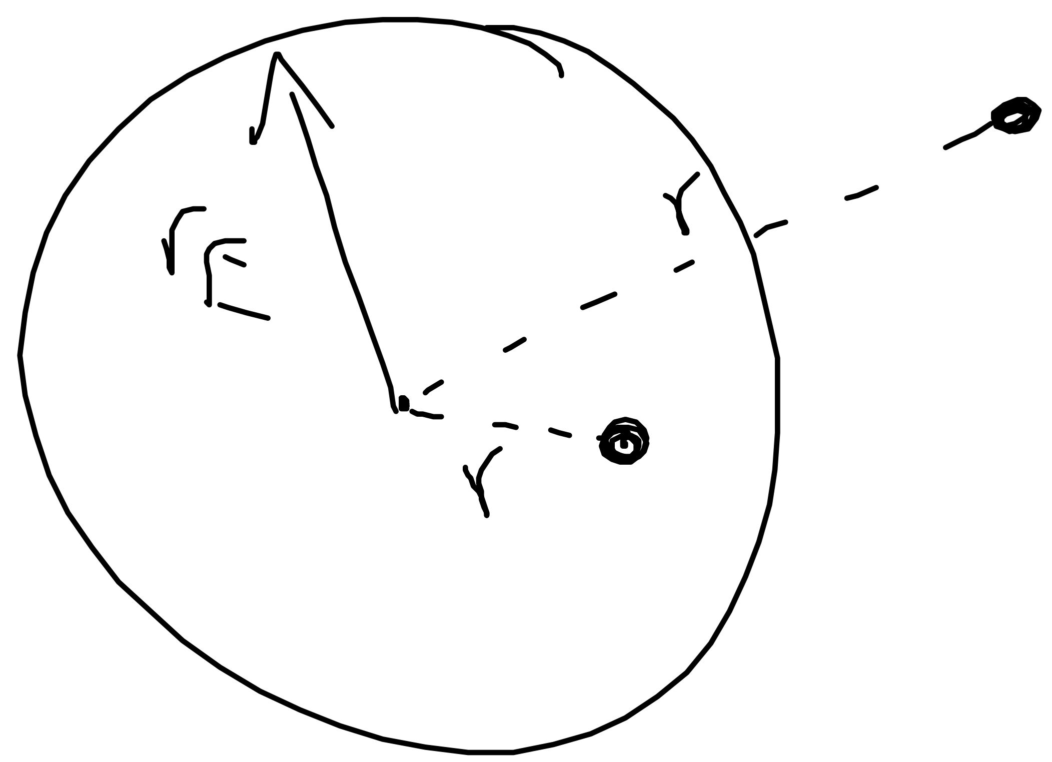
$$F_{12} = F_{21} = \frac{m_1 m_2 G}{r^2}$$

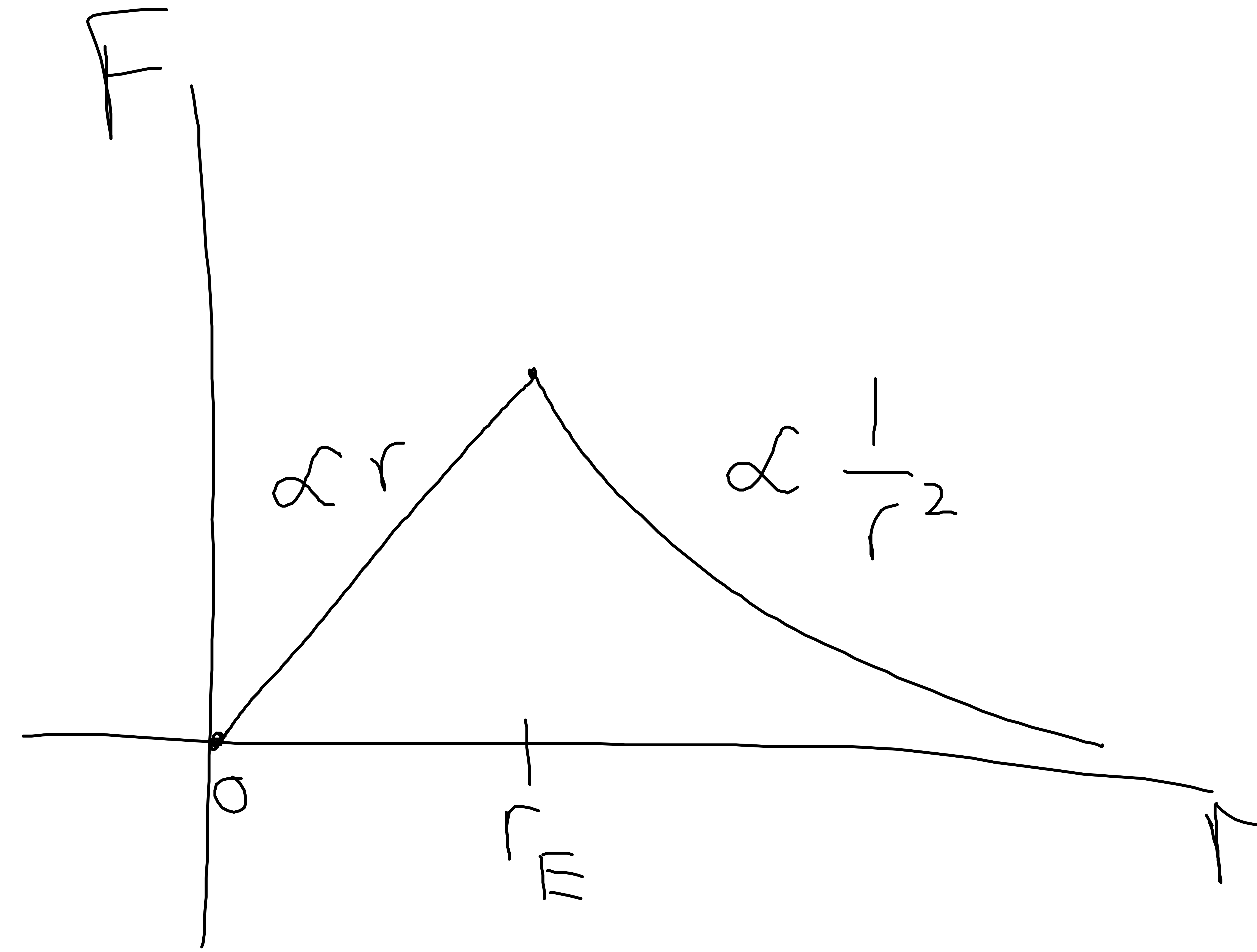
$$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$

$$F = \left(\frac{G M_E}{r_E^2}\right) m$$

$\rightarrow 9.8\,m/s^2$

Overlap





$$F = G\frac{m_1 m_2}{r^2}$$

Potential Energy

$+\uparrow$ $\quad U = mgy$

(if $F = mg$ constant)

$g = 9.80$

$W = -\Delta U$ for $F = \dfrac{Gm_1m_2}{r^2}$

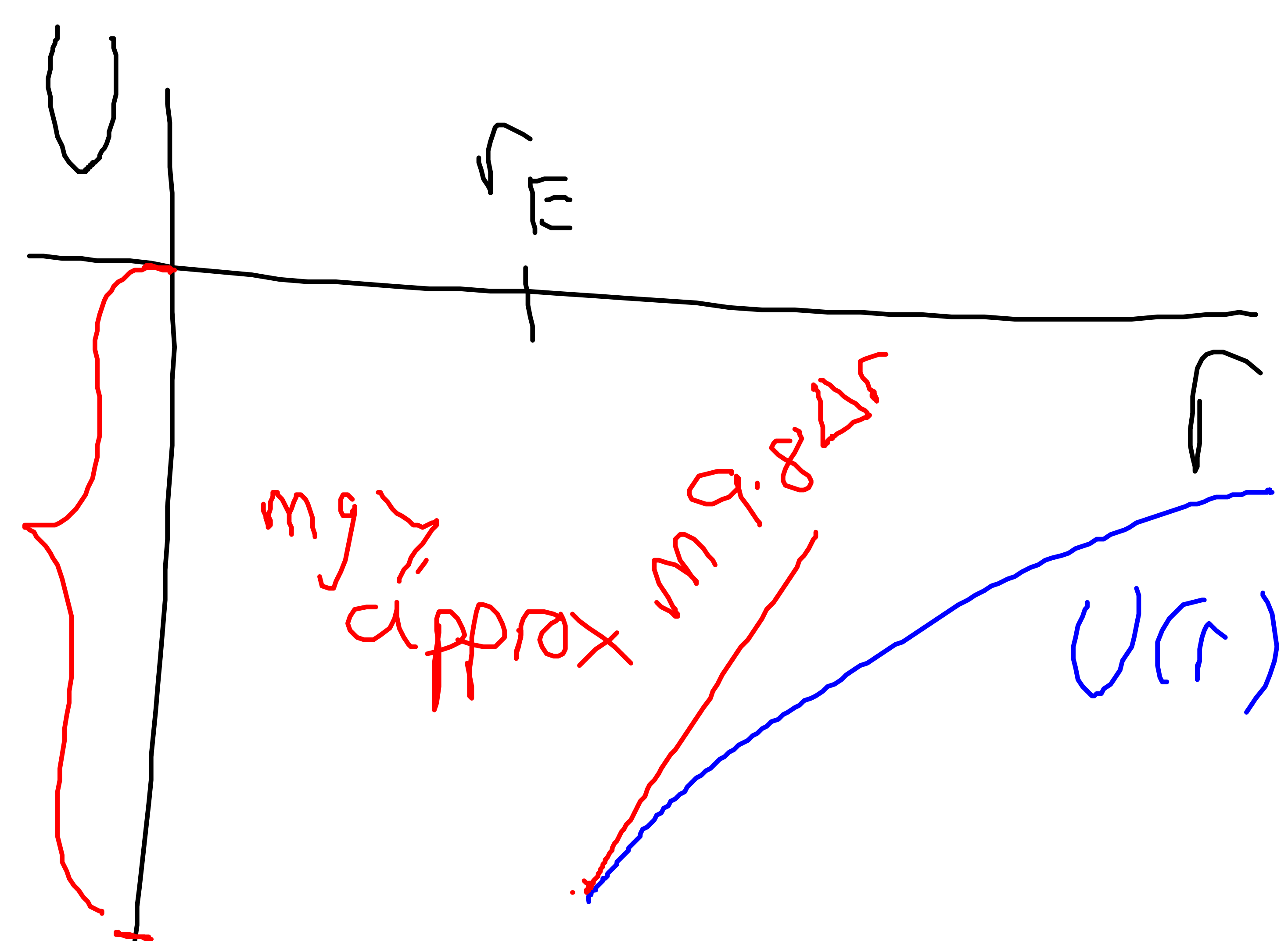
$\Rightarrow U(r) = -\dfrac{Gm_1m_2}{r}$

$U(\infty) = 0$ convention

$U(r) < 0$

energy to escape surface of Earth to ∞

E_{sc}: energy



$$E = K + U$$

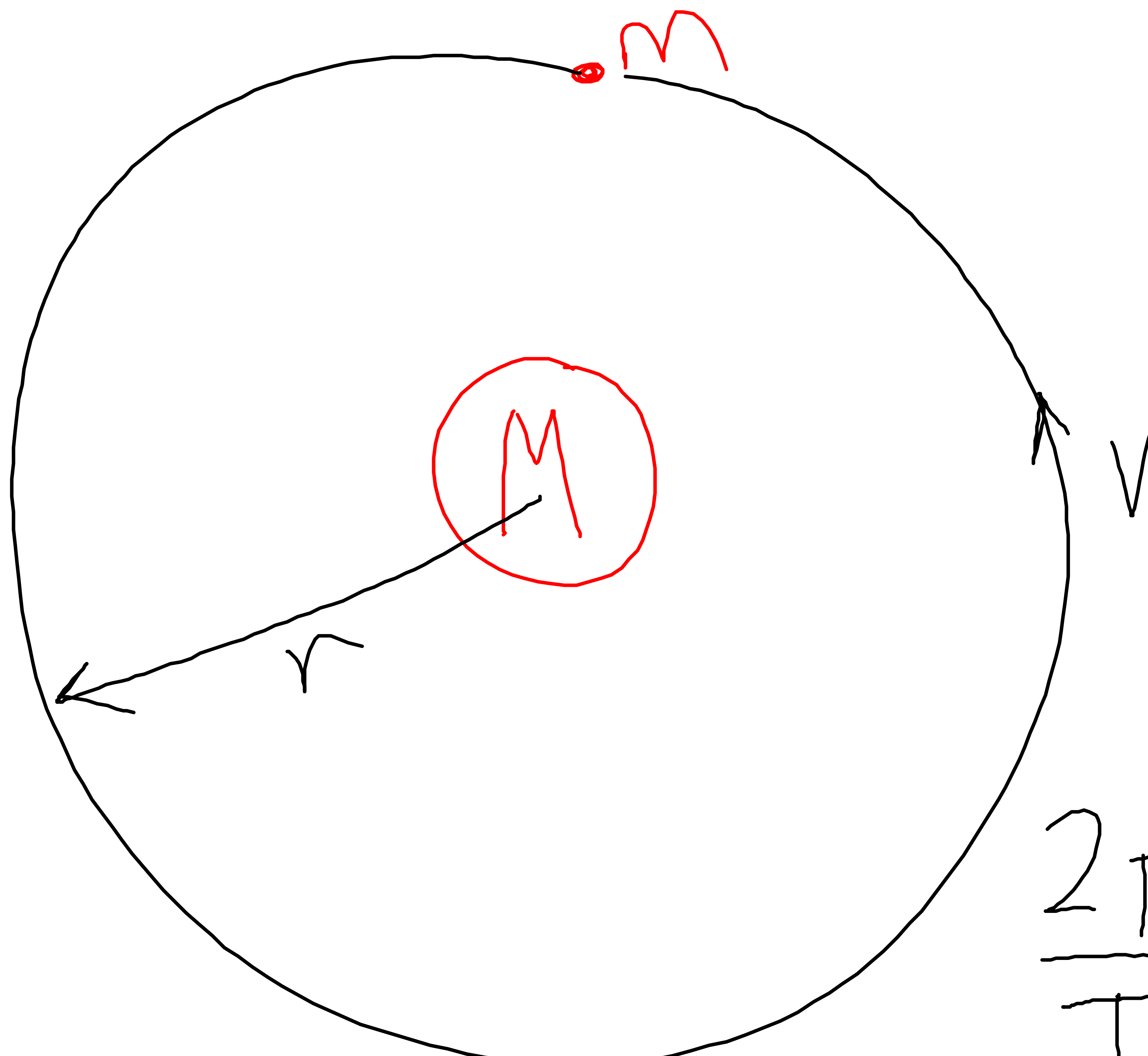
$\Delta E = 0$ if no non-conservative forces

Conserved $E = \frac{1}{2}mv^2 - \frac{GmM_E}{r}$

$$\frac{1}{2}\cancel{m}v^2 = \frac{G\cancel{m}M_E}{r}$$

Kepler's Laws

Orbit



$$\sum \underline{F} = m\underline{a}$$

$$\sum F_r = m a_r$$

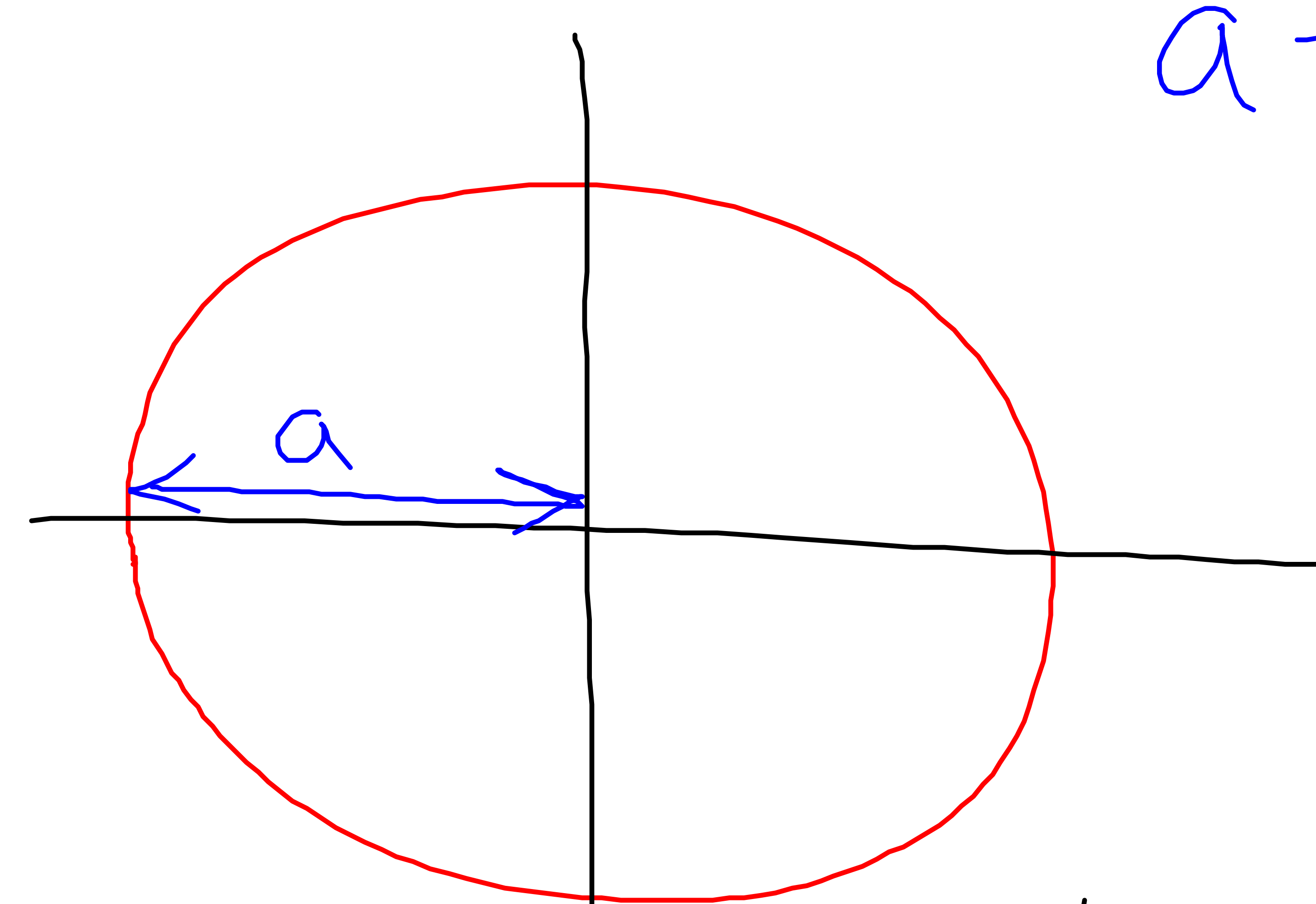
$$+\frac{GMm}{r^2} = +\frac{mv^2}{r}$$

$$\frac{2\pi r}{T} = v = \sqrt{\frac{GM}{r}}$$ (orbit equation)

T period

$$\frac{2\pi}{T} = \frac{\sqrt{GM}}{r^{3/2}}$$

Kepler's Laws



a = semi-major axis

1st - Ellipse

2nd - equal area in equal time.

because gravity no torque $\Rightarrow$ conserved angular momentum

Force toward Sun (axis of rotation)

3rd - $T^2 \propto a^3$

if circle $a = r$

$v = \frac{2\pi r}{T} \Rightarrow r \propto \frac{1}{v^2}$ (orbit equation)

$$F = \frac{G m_1 m_2}{r^2}$$