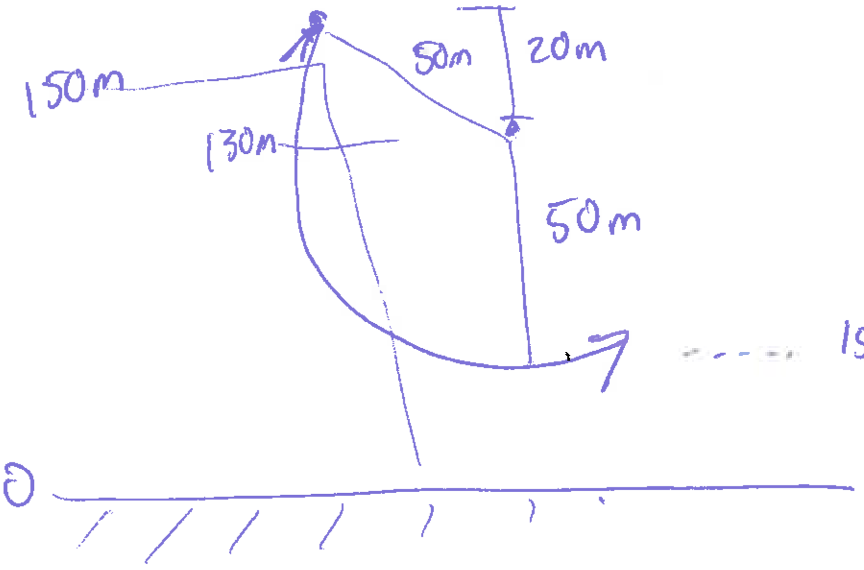
# ① Spider-man Swings!



150-20-50= 80m

Tension ⊥ to motion. ⇒ no work.

$$K_1 + U_1 = K_2 + U_2$$

define $U_1 = 0$ - it's all relative & makes math easier.

$$K_1 = U_1 = 0 = \frac{1}{2}\cancel{m}V^2 + \cancel{m}\underset{10m/s^2}{g}\underset{-70m.}{h}$$

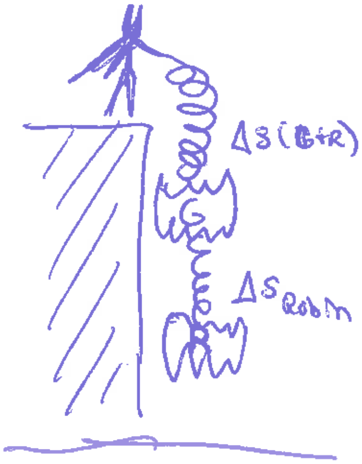
$$70\,m \cdot g = \frac{1}{2}v^2$$

$$1400\,m^2/s^2 = v^2$$

$$\boxed{V = 37\,m/s}$$

~82 mph!

②



$K = 5\,N/mm = 5000\,N/m$

ΔS in each spring?

$$|F| = K\cdot S$$

**Robin:**

$$F = T = \overset{50\,kg}{m}\overset{10\,m/s^2}{g} = K\cdot \Delta S_{Robin}$$

$$\Delta S_{Robin} = \frac{mg}{K} = \frac{50\cdot 10}{5000}\,m = \boxed{0{,}1\,m}$$

**Robin + Batgirl:**

$$W = (\underbrace{m_R + m_{BG}}_{110\,kg})\underset{10\,m/s^2}{g}$$

$$\Delta S_{R+G} = \frac{110\,kg \cdot 10\,m/s^2}{5000\,N/m} = \boxed{0{,}22\,m}$$

③. Black Widow's Guns

$$p_i = m\underset{\underset{0}{\parallel}}{V} = 0 \qquad p_{final} = 0$$

by conservation of momentum.

$$p_{final} = \underset{\underset{615g}{\parallel}}{m_g}\,\underset{\underset{\text{Recoil Velocity}}{\parallel}}{V_g} + \underset{\underset{7.5g}{\parallel}}{m_B}\,\underset{\underset{370\,ms}{\parallel}}{V_B} = 0$$

Velocities in opposite directions.

$$|V_g| = \frac{m_B|V_B|}{m_g} = \frac{7.5g(370\,m/s)}{615g}$$

$$\boxed{V_g = 4.5\,m/s}$$

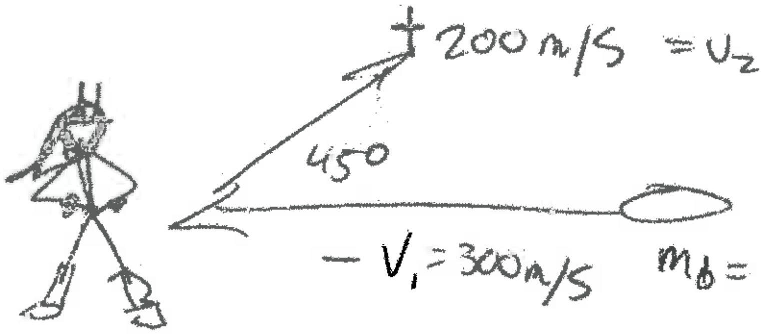
Kinetic Energy Ratio:

$$\frac{K_B}{K_G} = \frac{\cancel{\tfrac{1}{2}}\,m_B V_B^2}{\cancel{\tfrac{1}{2}}\,m_G V_G^2} = \frac{7.5(370)^2}{615(4.5)^2}$$

$$= \boxed{82}$$

④

## Wonder Woman deflects bullets



$m_b = 5\,g = 0.005$ kg

$\Delta t = 0.0010$ sec

Impulse?

$J_x = \Delta p_x$

$J_y = \Delta p_y$

$V_{1x} = 300$ m/s $\quad V_{1y} = 0$

$V_{2x} = (+200 \text{ m/s}) \underset{0.707}{\cos 45°} = 141$ m/s

$V_{2y} = (+200 \text{ m/s}) \sin 45° = 141$ m/s

$J_x = mV_{2x} - mV_{1x} = 0.005 \text{ kg} (+141 \text{ m/s} + 300 \text{ m/s})$

$= 2.2$ kg·m/s

$J_y = mV_{2y} - mV_{1y} = 0.005 \text{ kg} (141 \text{ m/s}) = 0.70$ kg·

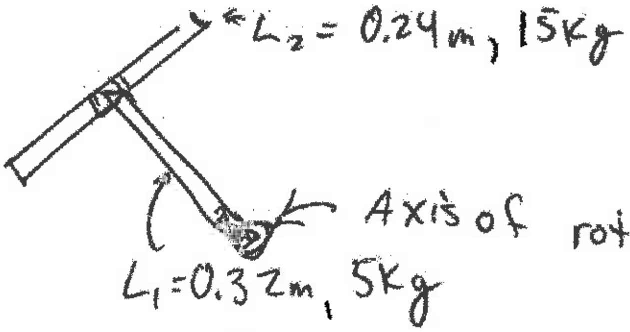
$|J| = \sqrt{J_x^2 + J_y^2} = \sqrt{0.5 + 4.8} = \sqrt{5.3} = \boxed{2.3 \text{ kg·m/s}}$

$\theta = \arctan \frac{J_y}{J_x} = \boxed{0.3 \text{ rad}} = (18°)$

$F_{AVE} = \frac{J}{\Delta t}$, same angle but × 1000 ⇒ N

$\sqrt{}\,2300$ N

## ⑤ Thor's Hammer



Axis of rotation out of page.

$$I_{tot} = I_{head} + I_{handle}$$

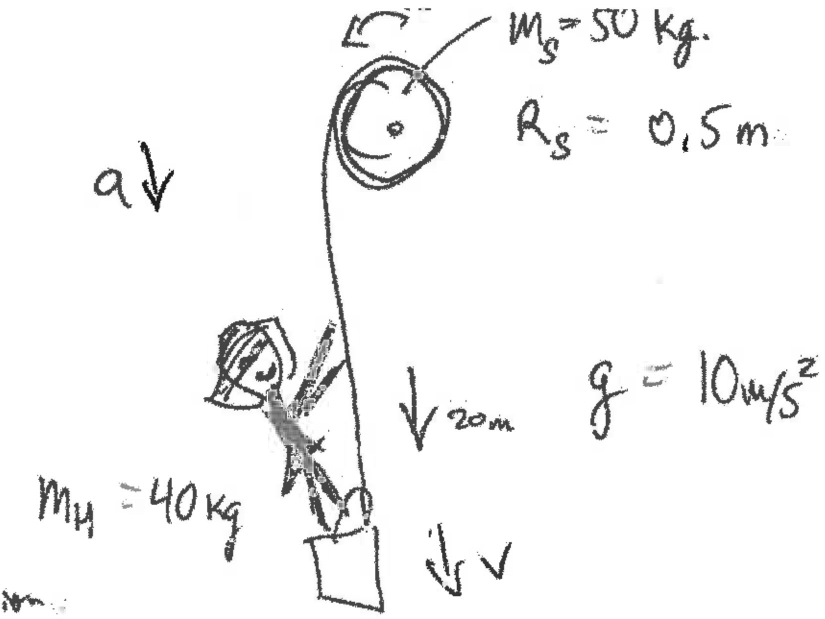
$$I_{handle} = \frac{1}{3} M_1 L_1^2 \quad (\text{Fig. b})$$

$$I_{head} = \underset{(\text{Fig. a})}{\frac{1}{12} M_2 L_2^2} + M_2 \underset{L_1}{\underset{\shortparallel}{d}}{}^2 \quad (\text{parallel-axis Th})$$

Plug in #s; use kg, m.

$$\boxed{I_{tot} = 1{,}77\ kg \cdot m^2}$$

## ④ Hit Girl



$y_0 = 20m = h$

Use energy conservation.

No Net work.

$K_1 = 0 \qquad U_1 = \overset{40kg}{m} g \overset{20m}{h} =$

$U_2 = 0$

$K_2 = \frac{1}{2} m_H V^2 + \frac{1}{2} \underset{\frac{1}{2} M_s R_s^2}{I} \omega^2 \qquad V_f = R\omega$

$K_1 + U_1 = K_2 + U_2$

$m_H g h = \frac{1}{2} m_H v^2 + \frac{1}{2}\left(\frac{1}{2} M_s R_s^{\cancel{2}}\right)\left(\frac{V_f}{\cancel{R_s}}\right)^2 + 0$

$- V_f = \sqrt{\frac{2gh}{1 + M_s/2m_H}} = \sqrt{\frac{400}{1 + 50/80}}$

$- V_f = 15.7 m/s = \overset{=0}{V_0} + at$

$x = 0 = 20m + \underset{=0}{V_0} t + \frac{1}{2} a t^2$

$at \overset{-}{=} 15.7 m/s$ so:. $-20m \overset{-}{=} \left(\frac{1}{2} t\right)(15.7 m/s)$

$\boxed{t = 2.55 \text{ sec.}}$

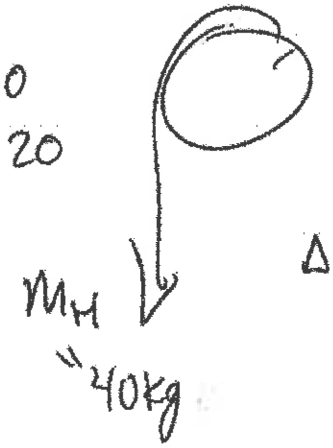
# ⑥ Hit Girl Alternative

$m_s$ 50k

$R_s$ 0.5.

$V_0 = 0$

$X_0 = 20$



$\Delta y = 20m$

$$\Sigma F_y = m_H g + (-T) = m_H a_y$$

$$\Sigma \tau = TR = I\alpha = \frac{1}{2} m_s R_s^2 \alpha$$

$$a = R_s \alpha$$

$$T\cancel{R_s} = \frac{1}{2} m_s \cancel{R_s} a$$

$$T = m_H g - m_H a = (g-a) m_H$$

$$(g-a) m_H = \frac{1}{2} m_s a$$

$$g_{m_H} = \frac{1}{2} m_s a + a m_H$$

$$g_{m_H} = \left(\frac{1}{2} m_s + m_H\right) a$$

$$a = \left(\frac{1}{2} \underset{50}{\underset{\shortparallel}{m_s}} + \underset{40}{\underset{\shortparallel}{m_H}}\right)^{-1} \overset{10}{\overset{\shortparallel}{g}} m_H$$

$$a = \left(\frac{10}{65} m/s^2\right) 40$$

$$a = 6.15 \, m/s^2$$

$$x = X_0 - \frac{1}{2} a t^2$$

$$0 = 20 - \frac{1}{2} a t^2 \Rightarrow \frac{40}{6.15} = t^2$$

$$t = (6.5 \, sec^2)^{1/2}$$

$$\boxed{t = 2.55 \text{ sec.}}$$