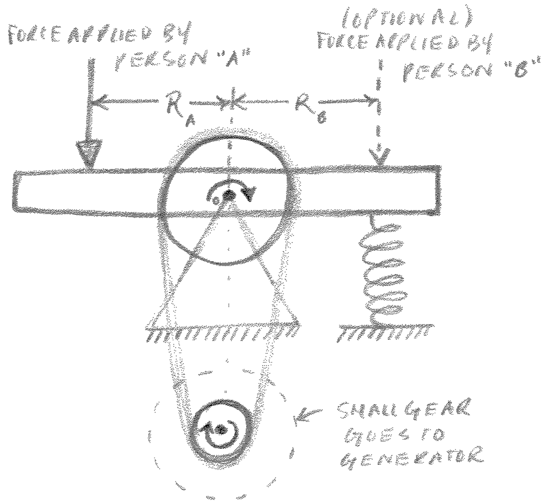
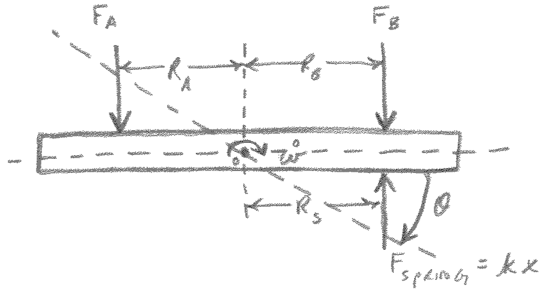
A, "SEE - SAW" IDEA





$$\Sigma M_{z_0} = F_A R_A - F_B R_B + F_S R_S = -I\alpha$$

ASSUME
$F_A = m_A g$
$F_B = m_B g$
$\alpha \neq 0$
$F_S = kx$, $x \equiv$ spring compression
RECTANGULAR CROSS SECTION

$$\Sigma M_{z_0} = F_A R_A - F_B R_B + F_S R_S = -I\alpha$$

$$m_A g R_A - m_B g R_B + kx R_S = -\frac{1}{12} b h^3 \frac{d}{dt}(\omega)$$

$x \equiv$ SPRING COMPRESSION

$$\tan(\theta) = \frac{x}{R_S} \rightarrow x = R_S \tan(\theta)$$

$$m_B g R_B - m_A g R_A - k R_S \tan(\theta) R_S = \frac{1}{12} b h^3 \frac{d}{dt}(\omega)$$

$$\Rightarrow \frac{d}{dt}(\omega) = 12 \left\{ \frac{m_B g R_B - m_A g R_A - k R_S^2 \tan(\theta)}{b h^3} \right\}$$

ASSUME F_A, F_B, F_S are all constant / θ = constant

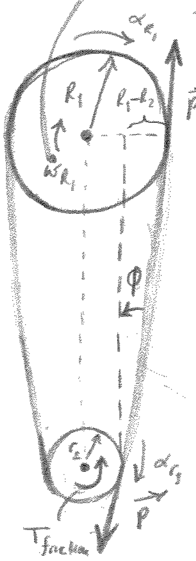
↳ INTEGRATE WITH RESPECT TO "t"

$$\boxed{\omega = \frac{12}{bh^3} \left\{ m_B g R_B - m_A g R_A - k R_S^2 \tan(\theta) \right\} \cdot t}$$

angular velocity caused purely by F_A, F_B, & F_S

NEED TO CONSIDER FRICTION INDUCED BY GENERATOR

look at small gear, r_2



$$\Sigma M_{z_{0_{r_2}}} = -P r_2 + \underbrace{T_{fric}}_{\text{PRODUCED BY GENERATOR}} = -I_{r_2} \alpha_{r_2}$$

$$-P r_2 + \frac{P_{gen}}{2\pi f_{gen}} = -\frac{1}{2} m_{r_2} r_2^2 \alpha_{r_2} \Rightarrow P = \frac{P_{gen}}{2\pi r_2 f_{gen}} + \frac{1}{2} m_{r_2} r_2 \alpha_{r_2}$$

$$\Sigma M_{z_{0_{r_1}}} = P R_1 - M_{R_1} = -I_{R_1} \alpha_{R_1}$$

SUBSTITUTE FOR P

$$\left\{ \frac{P_{gen}}{2\pi r_2 f_{gen}} + \frac{1}{2} m_{r_2} r_2 \alpha_{r_2} \right\} R_1 - \left\{ m_B g R_B - m_A g R_A - k R_S^2 \tan(\theta) \right\} = -\frac{1}{2} m_{R_1} R_1^2 \alpha_{R_1}$$

$$\frac{P_{gen}}{2\pi f_{gen}} \left(\frac{R_1}{r_2} \right) + \frac{1}{2} m_{r_2} R_1 r_2 \alpha_{r_2} - m_B g R_B + m_A g R_A + k R_S^2 \tan(\theta) = -\frac{1}{2} m_{R_1} R_1^2 \alpha_{R_1}$$

$$\left.\begin{matrix} \frac{d}{dt}(\theta_1 R_1 = \theta_2 r_2) \\ \downarrow \\ \omega_1 R_1 = \omega_2 r_2 \\ \downarrow \end{matrix}\right\} \therefore \alpha_2 = \left(\frac{R_1}{r_2} \right) \alpha_1 = (GR)\alpha_1, \quad GR = \frac{R_1}{r_2}$$

A, "SEE-SAW" IDEA

$$\frac{P_{gen}}{2\pi f_{gen}}\left(\frac{R_1}{r_2}\right) + \frac{1}{2} m_{r_2} R_1 r_2 \alpha_{r_2} - m_B g R_B + m_A g R_A + k R_s^2 \tan(\theta) = -\frac{1}{2} m_{R_1} R_1^2 \alpha_{R_1}$$

SUBSTITUTE $\alpha_2 = \left(\frac{R_1}{r_2}\right)\alpha_1$

$$-\frac{P_{gen}}{2\pi f_{gen}}\left(\frac{R_1}{r_2}\right) - \frac{1}{2} m_{r_2} R_1 \cancel{r_2}\left(\frac{R_1}{\cancel{r_2}}\right)\alpha_{R_1} + m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta) = \frac{1}{2} m_{R_1} R_1^2 \alpha_{R_1}$$

$$-\frac{P_{gen}}{2\pi f_{gen}}\left(\frac{R_1}{r_2}\right) - \frac{1}{2} m_{r_2} R_1^2 \alpha_{R_1} + m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta) = \frac{1}{2} m_{R_1} R_1^2 \alpha_{R_1}$$

$$-\frac{P_{gen}}{\cancel{2}\pi f_{gen}} \cdot \frac{\cancel{R_1}}{r_2} \cdot \frac{\cancel{2}}{m_{R_1} R_1^{\cancel{2}}} - \cancel{\frac{1}{2}} m_{r_2} \cancel{R_1^2} \alpha_{r_1} \cdot \frac{\cancel{2}}{m_{R_1} \cancel{R_1^2}} + m_B g R_B \cdot \frac{2}{m_{R_1} R_1^2} - m_A g R_A \cdot \frac{2}{m_{R_1} R_1^2} - k R_s^2 \tan(\theta) \cdot \frac{2}{m_{R_1} R_1^2} = \alpha_{R_1}$$

$$\frac{-P_{gen}}{R_1 \pi m_{R_1} r_2 f_{gen}} - \frac{m_{r_2}\alpha_{r_1}}{m_{R_1}} + \frac{2}{m_{R_1} R_1^2}\left\{ m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta)\right\} = \alpha_{R_1}$$

$$\frac{-P_{gen}}{R_1 \pi m_{R_1} r_2 f_{gen}} + \frac{2}{m_{R_1} R_1^2}\left\{ m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta)\right\} = \left\{1 + \frac{m_{r_2}}{m_{R_1}}\right\}\alpha_1$$

$$\Downarrow$$

$$\frac{m_{R_1} + m_{r_2}}{m_{R_1}}$$

$$-\frac{\cancel{m_{R_1}}}{m_{R_1} + m_{r_2}} \cdot \frac{P_{gen}}{R_1 \pi \cancel{m_{R_1}} r_2 f_{gen}} + \frac{\cancel{m_{R_1}}}{m_{R_1} + m_{r_2}} \cdot \frac{2}{\cancel{m_{R_1}} R_1^2}\left\{ m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta)\right\} = \alpha_1$$

$$\boxed{-\frac{P_{gen}}{R_1 \pi r_2 f_{gen}(m_{R_1} + m_{r_2})} + \frac{2}{R_1^2(m_{R_1} + m_{r_2})}\left\{ m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta)\right\} = \alpha_1}$$

ANGULAR ACCELERATION OF INPUT SHAFT / GEAR 1

$\frac{d\omega}{dt} = \alpha \therefore$

assume θ = constant

$$\boxed{\omega_1 = \left\{\frac{2}{R_1^2(m_{R_1} + m_{r_2})}\left\{ m_B g R_B - m_A g R_A - k R_s^2 \tan(\theta)\right\} - \frac{P_{gen}}{\pi R_1 r_2 f_{gen}(m_{r_1} + m_{r_2})}\right\} t}$$

ANGULAR VELOCITY OF INPUT SHAFT / GEAR 1

ASSUME $R_A = R_B = R \rightarrow$ SOLVE FOR R

$$\omega_1 = \frac{2}{R_1^2(m_{R_1} + m_{r_2})} R(m_B g - m_A g)t - \frac{2}{R_1^2(m_{R_1} + m_{r_2})} k R_s^2 \tan(\theta) t - \frac{P_{gen}}{R_1 \pi r_2 f_{gen}(m_{R_1} + m_{r_2})} t$$

$$\frac{2}{R_1^2(m_{R_1} + m_{r_2})}(m_B g - m_A g) t \cdot R = \omega_1 + \frac{2}{R_1^2(m_{R_1} + m_{r_2})} k R_s^2 \tan(\theta) t + \frac{P_{gen}}{R_1 \pi r_2 f_{gen}(m_{R_1} + m_{r_2})} t$$

$$R = \frac{R_1^2(m_{R_1} + m_{r_2})}{2(m_B g - m_A g)t} \cdot \omega_1 + \frac{\cancel{R_1^2(m_{R_1} + m_{r_2})}}{\cancel{2}(m_B g - m_A g)\cancel{t}} \cdot \frac{\cancel{2}}{\cancel{R_1^2(m_{R_1} + m_{r_2})}} k R_s^2 \underbrace{\tan(\theta)}_{\frac{x}{R_s}} \cancel{t} + \frac{R_1^{\cancel{2}}\cancel{(m_{R_1} + m_{r_2})}}{2(m_B g - m_A g)\cancel{t}} \cdot \frac{P_{gen}}{\cancel{R_1}\pi r_2 f_{gen}\cancel{(m_{R_1} + m_{r_2})}} \cancel{t}$$

$$\boxed{R = \frac{R_1^2(m_{R_1} + m_{r_2})}{2(m_B g - m_A g)} \cdot \frac{\omega_1}{t} + \frac{k R_s x}{(m_B g - m_A g)} + \frac{R_1 P_{gen}}{2(m_B g - m_A g)\pi r_2 f_{gen}}}$$

CHECK UNITS: $m^2 \cdot kg \cdot rad/s = m^2 \cdot kg \cdot \frac{1}{\ldots} \cdot \frac{m^2 \cdot kg \cdot \cancel{s^2}}{\ldots} \cdot \frac{1}{\ldots}$ ✓ $\frac{\cancel{N}}{\cancel{m}} \cdot m^{\cancel{2}} = m$ ✓ $\frac{m \cdot \frac{Nm}{s}}{N \cdot m \ldots} = \frac{\cancel{Nm^2}}{s} \cdot \frac{s}{\cancel{Nm}} = m$ ✓

A, "SEE-SAW" IDEA

USE AN ITERATIVE METHOD TO DETERMINE RADIUS, R

ASSUME THE FOLLOWING VALUES

$m_{R_1} \equiv$ mass of large gear $= 10\,lb / 32.2\,ft/s^2 = 0.31055$ slug

$m_{r_2} \equiv$ mass of little gear $= 1\,lb / 32.2\,ft/s^2 = .0310559$ slug

$R_1 \equiv$ radius of large gear $= 1\,ft$

$r_2 \equiv$ radius of little gear $= 0.1\,ft$

} 1:10 Gear Ratio

$k \equiv$ spring constant $= 240\,lb/ft$

$R_s \equiv$ Radius to spring $= 1\,ft$

$m_A g \equiv$ Weight of person "A" $= 50\,lb$

$m_B g \equiv$ Weight of person "B" $= 90\,lb$

} assume a 40 lb force differential applied by users

$\omega_1 \equiv$ angular velocity of large gear $= 2\pi(5Hz) = 31.4159\,\frac{1}{s}$

$x \equiv$ spring compression length $= 4\,in = 0.3333\,ft$

$f_{gen} \equiv$ frequency of the generator $= 50\,Hz$

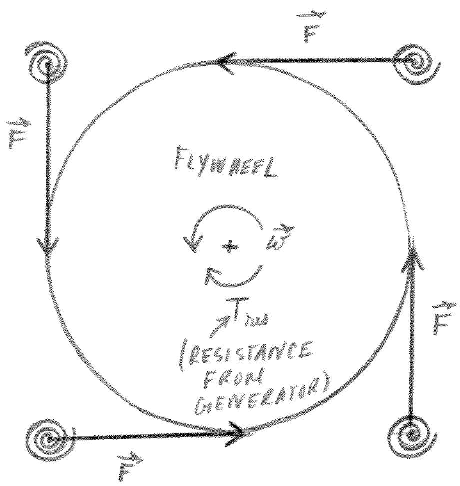
$P_{gen} \equiv$ power output of the generator $= 17\,W = 12.5386\,\frac{lb \cdot ft}{s}$

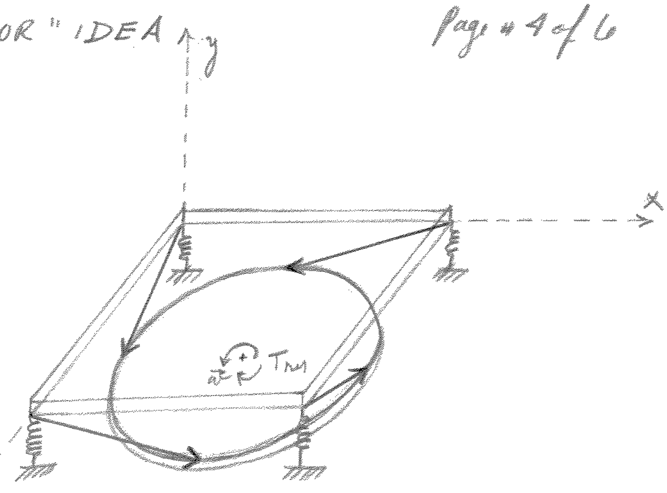
$t \equiv$ time to reach $\omega_1 = 10\,s$

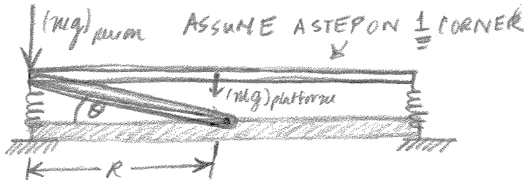
$$R = \underbrace{\frac{(1ft)^2(0.31055\,slug + .031055\,slug)(31.4159\frac{1}{s})}{2(90lb - 50lb)(10s)}}_{.013415ft} + \overbrace{\frac{(240\,lb/ft)(1ft)(0.333ft)}{(90lb - 50lb)}}^{1.9998ft} + \underbrace{\frac{(1ft)(12.5386\,lb\cdot ft/s)}{2(90lb - 50lb)\pi(0.1ft)(50\frac{1}{s})}}_{.009978ft} = 2.02319ft$$

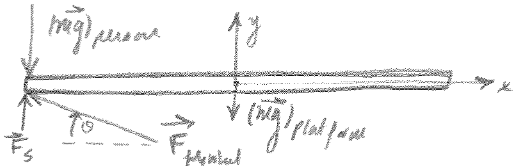
$\boxed{R = 2.0\,ft}$ ∴ PLATFORM LENGTH $= \underline{\underline{4ft}}$

B, "SPRING-FLOOR" IDEA

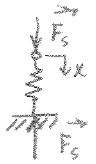


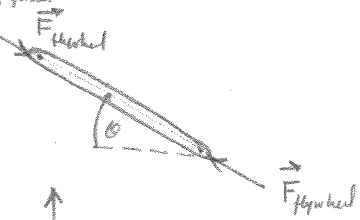






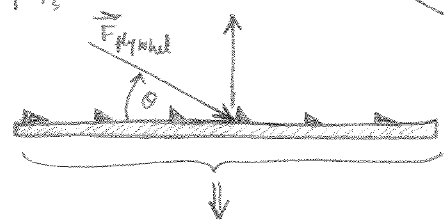
$$\left\{\begin{array}{l} F_{fly_y} = -F_{fly}\sin(\theta) \\ F_{fly_x} = -F_{fly}\cos(\theta) \end{array}\right.$$





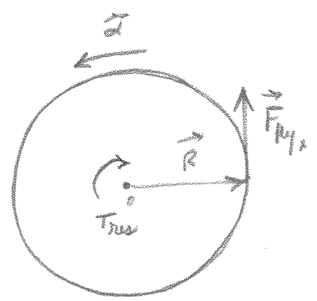
$$\Sigma F_y = -m_{per} g - m_{plat} + F_s + F_{fly}\sin(\theta) = 0$$

$$F_{fly} = \frac{m_{per} g + m_{plat} g - kx}{\sin(\theta)} = \frac{m_{TOT} g - kx}{\sin(\theta)}$$



$$\therefore F_{fly_x} = -\frac{m_{TOT} g - kx}{\tan(\theta)}$$ } DRIVING FORCE ON FLYWHEEL

$$\Longrightarrow F_{fly_x} = \frac{-m_{TOT} g + kx}{\frac{(l_u - x)}{R}} = \frac{(-m_{TOT} g + kx)R}{(l_u - x)}$$



$$\Sigma M_o = R F_{fly_x} - T_{res} = I\alpha$$

$$\frac{R\cdot(-m_{TOT} g + kx)R}{(l_u - x)} - \frac{P_{gen}}{2\pi f_{gen}} = \frac{1}{2} m_{fly} R^2 \alpha$$

$$\frac{(-m_{TOT} g + kx)}{(l_u - x)} R^2 - \frac{P_{gen}}{2\pi f_{gen}} = \frac{1}{2} m_{fly} R^2 \alpha$$

$$\boxed{\frac{2(-m_{TOT} g + kx)}{(l_u - x) m_{fly}} - \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}} = \alpha}$$

ANGULAR ACCELERATION OF FLYWHEEL

$$dw = \left(\frac{2(-m_{TOT} g + kx)}{(l_u - x) m_{fly}} - \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}}\right) dt$$

} assume P_{gen}, f_{gen}, m_{TOT}, m_{fly}, R, + x are all constants

$$\boxed{w = \left(\frac{2(-m_{TOT} g + kx)}{(l_u - x) m_{fly}} - \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}}\right) t}$$

ANGULAR VELOCITY OF FLYWHEEL

B, "SPRING - FLOOR" IDEA

$$\omega_{fly} = \frac{2(-m_{TOT}\, g + kx)}{m_{fly}(l_n - x)}\, t \;-\; \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}}\, t$$

SOLVE FOR $\underline{\underline{k}}$

$$\omega_{fly} = -\frac{2\, m_{TOT}\, g}{m_{fly}(l_n - x)}\, t + \frac{2kx}{m_{fly}(l_n - x)}\, t - \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}}\, t$$

$$\frac{2kx}{m_{fly}(l_n - x)}\, t = \omega_{fly} + \frac{2\, m_{TOT}\, g}{m_{fly}(l_n - x)}\, t + \frac{P_{gen}}{\pi m_{fly} R^2 f_{gen}}\, t$$

$$k = \frac{m_{fly}(l_n - x)}{2xt}\,\omega_{fly} + \frac{\cancel{m_{fly}}\cancel{(l_n - x)}}{\cancel{2}x\cancel{t}} \cdot \frac{\cancel{2}\, m_{TOT}\, g\, \cancel{t}}{\cancel{m_{fly}}\cancel{(l_n - x)}} + \frac{\cancel{m_{fly}}(l_n - x)}{2x\cancel{t}} \cdot \frac{P_{gen}\, \cancel{t}}{\pi \cancel{m_{fly}} R^2 f_{gen}}$$

$$\boxed{k = \left(\frac{l_n - x}{x}\right)\frac{m_{fly}\,\omega_{fly}}{2t} + \frac{m_{TOT}\, g}{x} + \left(\frac{l_n - x}{x}\right)\frac{P_{gen}}{2\pi R^2 f_{gen}}}$$

SPRING CONSTANT NECCESSARY FOR $\alpha \neq 0$ and <u>GEARING</u>

$\omega_{fly} \neq \omega_{gen}$

check UNITS:

$$\left[\frac{N}{m}\right] = \left[\frac{m}{m} \cdot \frac{kg \cdot rad/s}{s}\right] + \left[\frac{N}{m}\right] + \left[\frac{m}{m} \cdot \frac{W}{m^2 \cdot 1/s}\right]$$

$$= \left[\frac{kg \cdot rad}{s^2}\right] + \left[\frac{N}{m}\right] + \left[\frac{N \cdot \cancel{m}}{\cancel{s}} \cdot \frac{\cancel{s}}{m^{\cancel{2}}}\right]$$

$$= \left[\frac{N \cdot \cancel{s^2}}{m} \cdot rad \cdot \frac{1}{\cancel{s^2}}\right] + \left[\frac{N}{m}\right] + \left[\frac{N}{m}\right]$$

$$= \left[\frac{N}{m}\right] ✓$$

USE AN ITERATIVE METHOD TO DETERMINE REALISTIC K-VALUES

ASSUME THE FOLLOWING VALUES:

$l_n \equiv$ natural length $= 4\,in = 0.333\bar{3}\,ft$

$x \equiv$ compression length $= 1\,in = .0833\bar{3}\,ft$

$R \equiv$ Radius of Flywheel $= 1.5\,ft$

$m_{fly} \equiv$ mass of flywheel $= 20\,lb / 32.2\,ft/s^2 = 0.621118\,slug$

$m_{TOT}\, g \equiv$ mass of person + platform $= 150\,lb$

$P_{gen} \equiv$ Power of Generator $= 17\,W = 12.5386\,\frac{lb \cdot ft}{s}$

$f_{gen} \equiv$ Frequency of the Generator $= 50\,Hz$

$\omega_{fly} \equiv$ angular velocity of the flywheel $= 2\pi(5\,Hz) = 31.41592\,\frac{rad}{s}$ } 1:10 GEARING

$t \equiv$ time to reach $\omega_{fly} = 5\,sec$

$$k = \underbrace{\left(\frac{.3333\,ft}{.08333\,ft} - 1\right)\frac{(0.6142\,slugs)(31.41592\,\frac{rad}{s})}{2(5\,s)}}_{5.13562\,\frac{lb}{ft}} + \underbrace{\frac{150\,lb}{.08333\,ft}}_{1800\,\frac{lb}{ft}} + \underbrace{\left(\frac{.3333\,ft}{.08333\,ft} - 1\right)\frac{12.5386\,\frac{lb \cdot ft}{s}}{2\pi(1.5\,ft)^2(50\,\frac{1}{s})}}_{.053215\,\frac{lb}{ft}} \cong 1805\,\frac{lb}{ft}$$

$\underline{\underline{k = 150\,\frac{lb}{in}}}$ | TRUE SINCE INPUT $m_{TOT}\, g = 150\,lb$, $x = 1\,in$ ✓

∴ <u>DESIGN IS POSSIBLE</u>

COST ANALYSIS (PRELIMINARY)

IDEA A "SEE-SAW" IDEA pages 1-3

IDEA B "SPRING-FLOOR" IDEA pages 4-5

IDEA C HAND CRANK + FLYWHEEL w/ COLOR LEDs

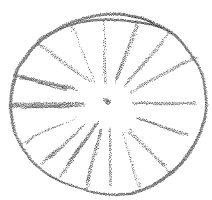
↳ this is the most afforable idea, which is just an enhancement to the current design to reduce physical activity.

NOTE: ADD COLOR LED'S to FLYWHEEL, SO THAT COLORS ARE LIT WHILE USING THE HAND CRANK — COLORS WILL "SPIN"

IDEA "A" SEE-SAW IDEA		IDEA "B" SPRING FLOOR IDEA		IDEA "C" ENHANCED HANDCRANK	
SPRING	\$50	SPRINGS	\$10/8	FLYWHEEL	NEED EST
SPROCKET + CHAIN	\$20	GEARS/SPROCKET & CHAIN	\$20	LEDs (7)	\$160/400
2x4 TREATED	\$6	PLYWOOD	\$6		
BALLBEARING	\$5	2x4 TREATED	\$6		
		MOTION ARMS	\$12		
		BALL BEARING	\$5		
		FLYWHEEL w/ GROOVE	NEED EST.		
TOTAL	\$81	TOTAL	\$50.25 + EST	TOTAL	\$1.60 + EST

WE NEED AN ESTIMATE FOR A FLYWHEEL w/ GROOVE PATTERN "BEVELED GEAR" CONCEPT ON TOP SURFACE.

NEED AN ESTIMATE ON HOLLOW PLASTIC FLYWHEEL (fill w/ sand & dirt upon installation)



D ≈ 1.5ft