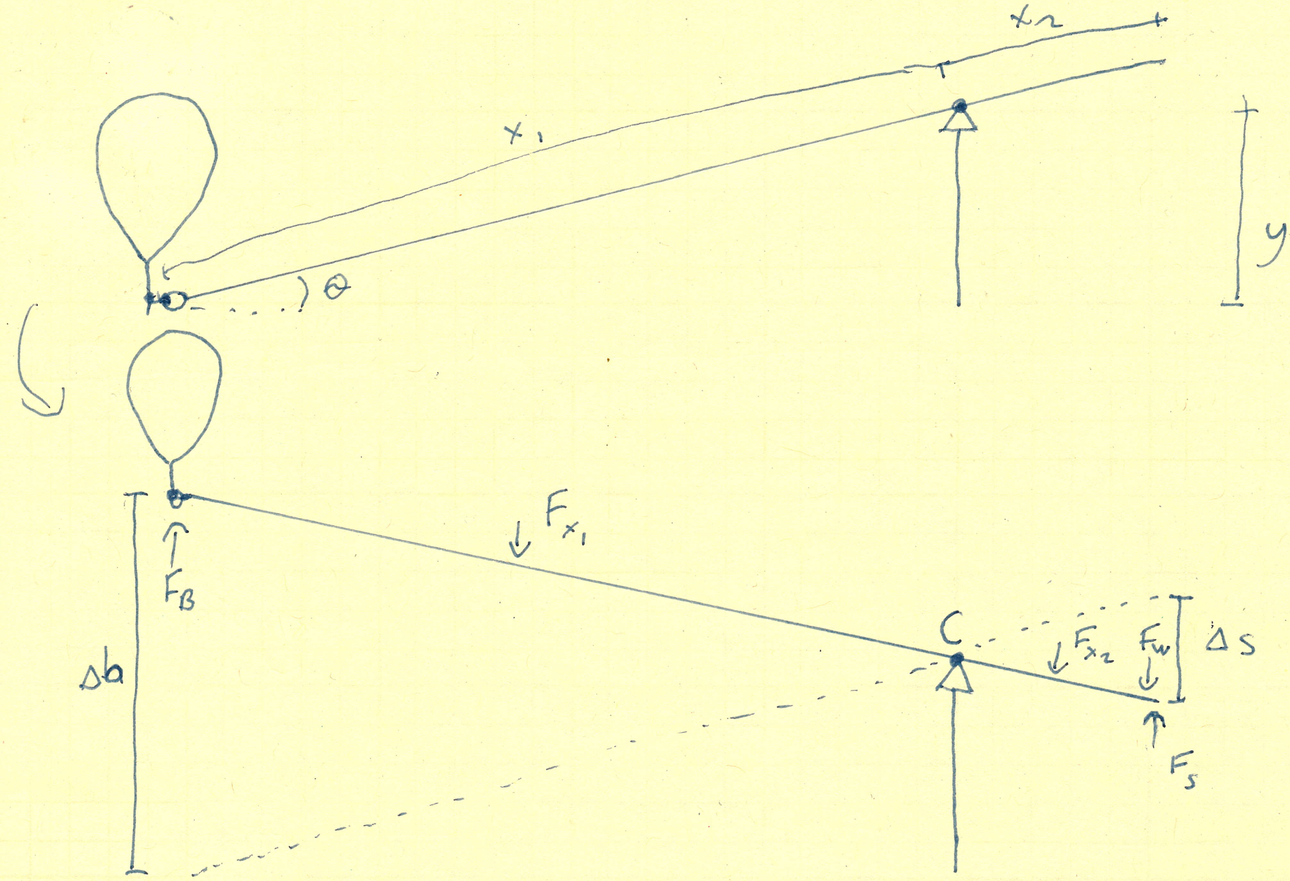
Engineering Analysis for Simplified Lever-Switch Mechanism

Goal: Find required lever length and any required counterweight / counterforce.

Problem diagram:



Key constraints:

$\Delta s = 4$ mm to bottom out a Cherry Red switch

$F_B = 0.05$ N (about half the expected net buoyancy of a 12-in balloon)

$\Delta b \geq 50$ mm (to allow visible movement and reduce risk of accidentally triggering mechanism)

$F_s = 0.5$ N

$$\Sigma \overset{\curvearrowleft}{M}_c < 0$$

$$-F_B x_1 \cancel{\cos\theta} + F_{x_1}\frac{x_1}{2}\cancel{\cos\theta} - F_{x_2}\frac{x_2}{2}\cancel{\cos\theta} - F_w x_2 \cancel{\cos\theta} + F_s x_2 \cancel{\cos\theta} = 0$$

$$x_1\left(\frac{F_{x_1}}{2} - F_B\right) + x_2\left(F_s - F_w - \frac{F_{x_2}}{2}\right) = 0$$

$$F_{x_1} = \rho g v_1 = \rho g A x_1 \qquad F_{x_2} = \rho g A x_2$$

Let $k = \rho g A$ linear mass density of lever is ~ constant

$$x_1\left(\frac{k x_1}{2} - F_B\right) + x_2\left(F_s - F_w - \frac{k x_2}{2}\right) = 0$$

$\Delta b = 50mm$ $\Delta s = 4mm$

Similar triangles: $\frac{\Delta b}{x_1} = \frac{\Delta s}{x_2}$ $x_2 = x_1 \frac{\Delta s}{\Delta b} = 0.08 x_1$

$$x_1\left(\frac{k x_1}{2} - F_B\right) + 0.08 x_1\left(F_s - F_w - \frac{k \cdot 0.08 x_1}{2}\right) = 0$$

$$\frac{k x_1^2}{2} - \frac{k \cdot 0.0064 x_1^2}{2} + 0.08 x_1 (\overset{F_s\downarrow}{0.5}) - 0.08 x_1 F_w - x_1 (\overset{F_B\downarrow}{0.05}) = 0$$

$$0.4968\, k x_1^2 - 0.01 x_1 - 0.08 x_1 F_w = 0$$

$$x_1 = 0 \quad \text{or} \quad 0.4968k x_1 - 0.01 - 0.08F_w = 0$$

$$0.4968\, k x_1 = 0.08 F_w + 0.01$$

$$x_1 = \frac{0.1610 F_w + 0.02013}{k}$$

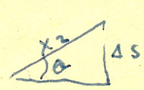
Assume the lever is a 1/4" square aluminum bar

$\rho = 2.7\ g/cm^3$ $g = 981\ cm/s^2$ $A = (0.635cm)^2 = 0.4032\ cm^2$

$k = 2.7 \times 981 \times 0.4032 = 1068.\ g/s^2 = 1.068\ kg/s^2$

$x_1 = 0.1507 F_w + 0.01885$

We should constrain $\theta < 30°$ to keep the lever end force pointing mostly down



$\frac{\Delta s}{x_2} = \sin\theta$ $x_2 = \Delta s / \sin\theta = 4mm/\tfrac{1}{2} = 8mm$

$x_1 = \frac{8mm}{0.08} = 100mm = 0.1m$

$0.1 = 0.1507 F_w + 0.01885$

$F_w = 0.5385\ N$ that's a lot... like a 1" solid steel ball

At this length, plastic is probably fine

Try a 6mm ABS square tube with 1mm walls

$A = (0.6\,cm)^2 - (0.5)^2 cm^2 = 0.11\,cm^2$

$\rho = 1.1\ g/cm^3$

$k = 1.1 \times 981 \times 0.11 = 118.7\ g/s^2 = 0.1187\ kg/s^2$

$x_1 = 1.356\,F_w + 0.1696$

$0.1 = 1.356\,F_w + 0.1696$ $\quad$ $F_w < 0$ nope

Try a solid ABS bar, 6mm

$k = 1.1 \times 981 \times 0.36 = 388\ g/s^2 = 0.388\ kg/s^2$

$0.1 = 0.4149 F_w + 0.0519$

$F_w = 0.1160\ N$ $\quad$ this works for me

Final values:

x_1 : 100mm

x_2 : 8mm

F_w : 0.1160 N $\rightarrow$ 11.8 g $\quad$ includes any linkage, adapter, pressure plate

Δs : 4mm

Δb : 50mm

Material: ABS plastic, solid square extrusion, 6mm × 6mm