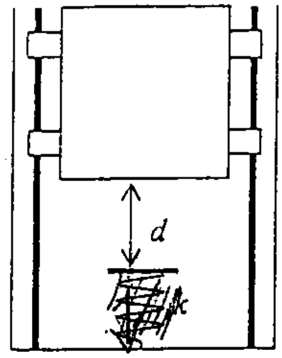
1. The cable of the 1800-kg elevator cab in the figure snaps when the cab is at rest at the first floor, where the cab bottom is a distance $d = 3.7$ m above a spring of spring constant k = 0.15 MN/m. A safety device clamps the cab against guide rails so that a frictional force of 4.4 kN opposes the cab motion. Find the speed of the cab just before it hits the ~~spring~~. ground.




Work - Energy Theorem:

$$-F_R d = \left(\frac{1}{2}mv^2 - 0\right) + (0 - mgd)$$

$$\therefore \frac{1}{2}mv^2 = (mg - F_R)d$$

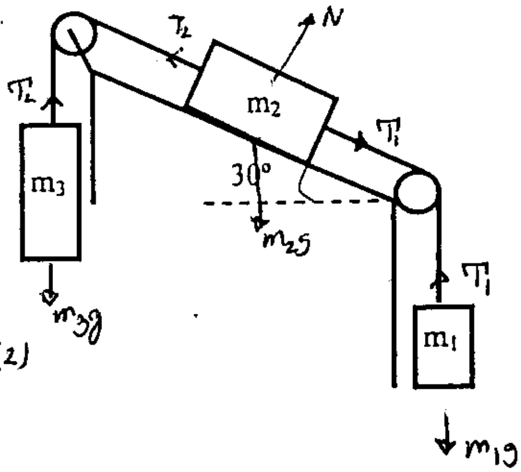
$$\therefore v = \sqrt{2\left(g - \frac{F_R}{m}\right)d} = \sqrt{2\left(9.8 - \frac{4.4\times10^3}{18\times10^2}\right)3.7}$$

$$= \sqrt{2\,(9.8 - 2.44)\times3.7}$$

$$\boxed{v = 7.33\ m/s}$$

2. The three blocks in the figure below are connected by massless cords and pulleys. Data: $m_1 = 8$ kg, $m_2 = 2$ kg, $m_3 = 1$ kg. The coefficient of kinetic friction between $m_2$ and the incline is 0.2.

   (a) Show the free body force diagram.
   (b) Calculate the acceleration of $m_1$, $m_2$, $m_3$.
   (c) Calculate the tensions on the cords.
   (d) Calculate the normal force acting on $m_2$.




$$m_1 g - T_1 = m_1 a \quad (1)$$

$$T_1 + m_2 g \sin\theta - T_2 - \mu m_2 g \cos\theta = m_2 a \quad (2)$$

$$T_2 - m_3 g = m_3 a \quad (3)$$

Adding (1), (2), (3)

$$m_1 g + m_2 g \sin\theta - \mu m_2 g \cos\theta - m_3 g = (m_1 + m_2 + m_3) a$$

$$a = \frac{(m_1 + m_2 \sin\theta - \mu m_2 \cos\theta - m_3) g}{m_1 + m_2 + m_3} = \frac{\{8 + 2 \times \sin 30° - (0.2)(2)\cos 30° - 1}{11}$$

$$= 9.8(8 - \cancel{(2)(2)}\ 0.346)/11 = 6.82\ m/s^2$$

from (1)

$$T_1 = m_1 (g - a) = 23.84\ N$$

from (3)

$$T_2 = m_3 (g + a) = 1(9.8 + 6.82) = 16.62\ N$$

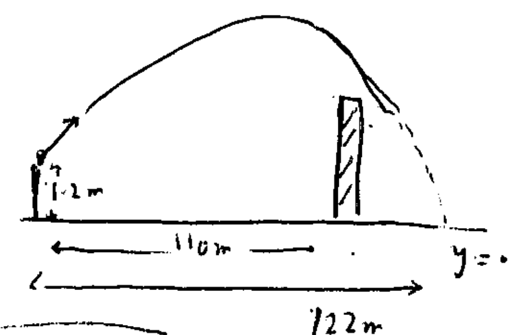
$$N = m_2 g \cos 30° = 2 \times 9.8 \times \cos 30° = 16.97\ N$$

| | | | |
|---|---|---|---|
| (b) a= 6.82 $m/s^2$ | (c) $T_1$= 23.84N | $T_2$= 16.62N | (d) N= 16.97N |

3. A baseball leaves the bat at a height of 1.2 m above the ground, traveling at an initial angle of 45° with the horizontal, and with a velocity such that the horizontal range would be 122 m. At a horizontal distance of 110 m from the bat is a fence 9.1 m high.
Calculate whether the ball will hit the fence or will be a home run.
[Notice: horizontal range R = $(v_0^2/g)\sin 2\theta_0$ ].

$$R = \frac{v_0^2}{g}\sin 2\theta_0$$

$$\therefore \boxed{v_0 = 34.6\ m/s}$$




Find y ~~to~~ at the fence:

$$110\,m = v_0 \cos 45^\circ t \qquad \therefore \boxed{t = 4.49\,s}$$

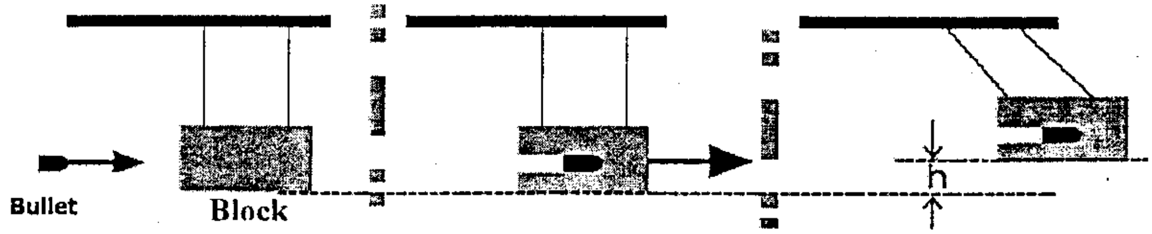
$$y = y_0 + v_0 \sin\theta_0 t - \frac{1}{2}gt^2$$

$$= 1.2 + (34.6)(\sin 45^\circ)(4.49) - \frac{1}{2}(9.8)(4.49)^2$$

$$\boxed{y = 12.2\ m}$$

$\therefore$ The ball will not strike the fence

4. **Forensic scientists can measure the muzzle velocity of a gun by firing a bullet horizontally into a large hanging block that absorbs the bullet and swings upward (as shown in the figure). In one such test, a 5.00 g bullet is fired at a 3.00 kg block which absorbs the bullet and swings upward. If the resulting change in elevation of the block h is 7.00 cm. What was the original speed of the bullet?**




$v$ = speed of bullet

$V$ = " " bullet + block after collision

P conservation: $m_b v = (m_b + M) V$ (1)

E conservation: $\frac{1}{2}(m_b + M)V^2 = (m_b + M) g h$ (2)

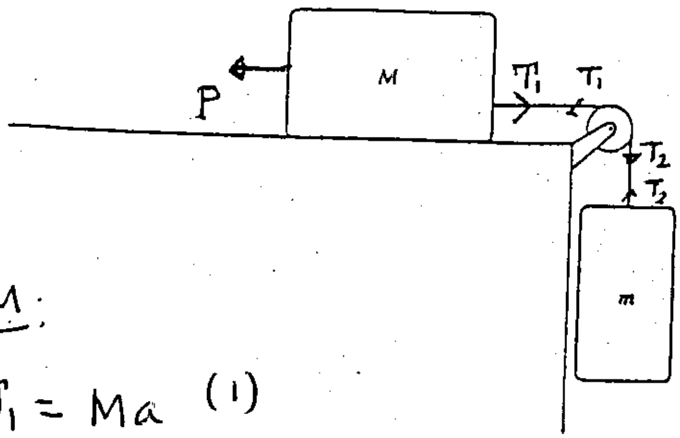
$\therefore V = \sqrt{2gh}$

$\therefore m_b v = (m_b + M)\sqrt{2gh}$

$\therefore v = \frac{(m_b + M)}{m_b}\sqrt{2gh} = 704 \text{ m/s}$

$\boxed{v = 704 \text{ m/s}}$

5. Two masses, M and m are connected by a pulley of radius R= 0.12m and rotational inertia I=0.09 Kg m$^2$. M= 6 Kg and m= 4 Kg. A force of magnitude P= 50N is applied to M. The pulley has no friction. Calculate the acceleration of the masses and the angular acceleration of the pulley.




Motion of M:

$P - T_1 = Ma \quad (1)$

Motion of m:

$T_2 - mg = ma \quad (2)$

Motion of Pulley:

$(T_1 - T_2) R = I\alpha \quad (3) \quad \therefore T_1 - T_2 = \frac{I}{R}\frac{a}{R} = \frac{I}{R^2} a \quad (4)$

Adding 1, 2, 4:

$P - mg = \left(M + m + \frac{I}{R^2}\right) a \quad \therefore \boxed{a = 0.66 \ m/s^2}$

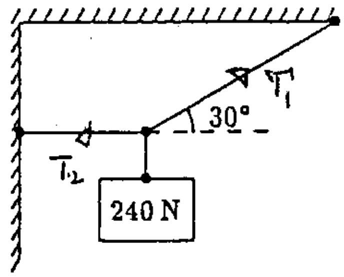
$a = R\alpha$

$\therefore \alpha = \frac{a}{R} = \frac{0.66}{0.12} = 5.3 \ rad/s^2$

$\boxed{\alpha = 5.5 \ rad/s^2}$

$a = 0.66 \ m/s^2 \quad \alpha = 5.5 \ rad/s^2$

6. A 240 N weight is hung from two ropes as shown. Find the tension force in the horizontal rope.




The Knot is in equilibrium.

$$T_1 \sin 30^\circ = 240 \qquad (1)$$

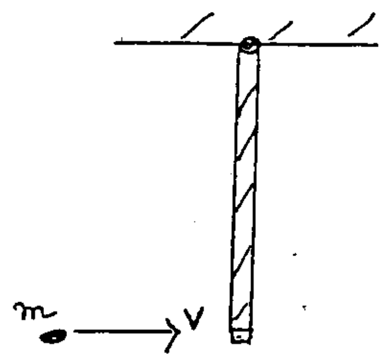
$$T_2 = T_1 \cos 30^\circ \qquad (2)$$

From (1) $$T_1 = \frac{240}{\sin 30^\circ} = 480\ N$$

$$T_2 = 480 \times \cos 30^\circ = 415.69$$

$$\boxed{T_2 = 415.69\ N}$$

7. A uniform rod of mass M and length L is hinged at the ceiling and is capable of rotating in the vertical plane. A bullet of mass m is shot to hit the rod with speed v at right angles to the rod and strike its edge. The bullet gets embedded in the rod. (i) Determine the angular momentum of the bullet just before it hits the rod. (ii) Calculate the angular speed of the rod right after the collision.
M= 1 Kg, L= 10m, v= 100 m/s, m = 0.01 Kg




(i) $L_{initial} = |\vec{r} \times \vec{p}| = Lmv = 10 \times 0.01 \times 100 \ Kg\, m^2/s$

$= 10 \ kg\, m^2/s$

(ii) $L_{after} = I\omega = \left(\frac{1}{3}ML^2 + mL^2\right)\omega$

Conservation of L ; $L_i = L_f$

$\omega = \dfrac{10}{\left(\frac{1}{3}M + m\right)L^2} = \dfrac{10}{\left(\frac{1}{3} + .01\right)(10^2)} = \dfrac{1}{3.43} = 0.29$

$\boxed{\omega = 0.29 \ rad/s}$