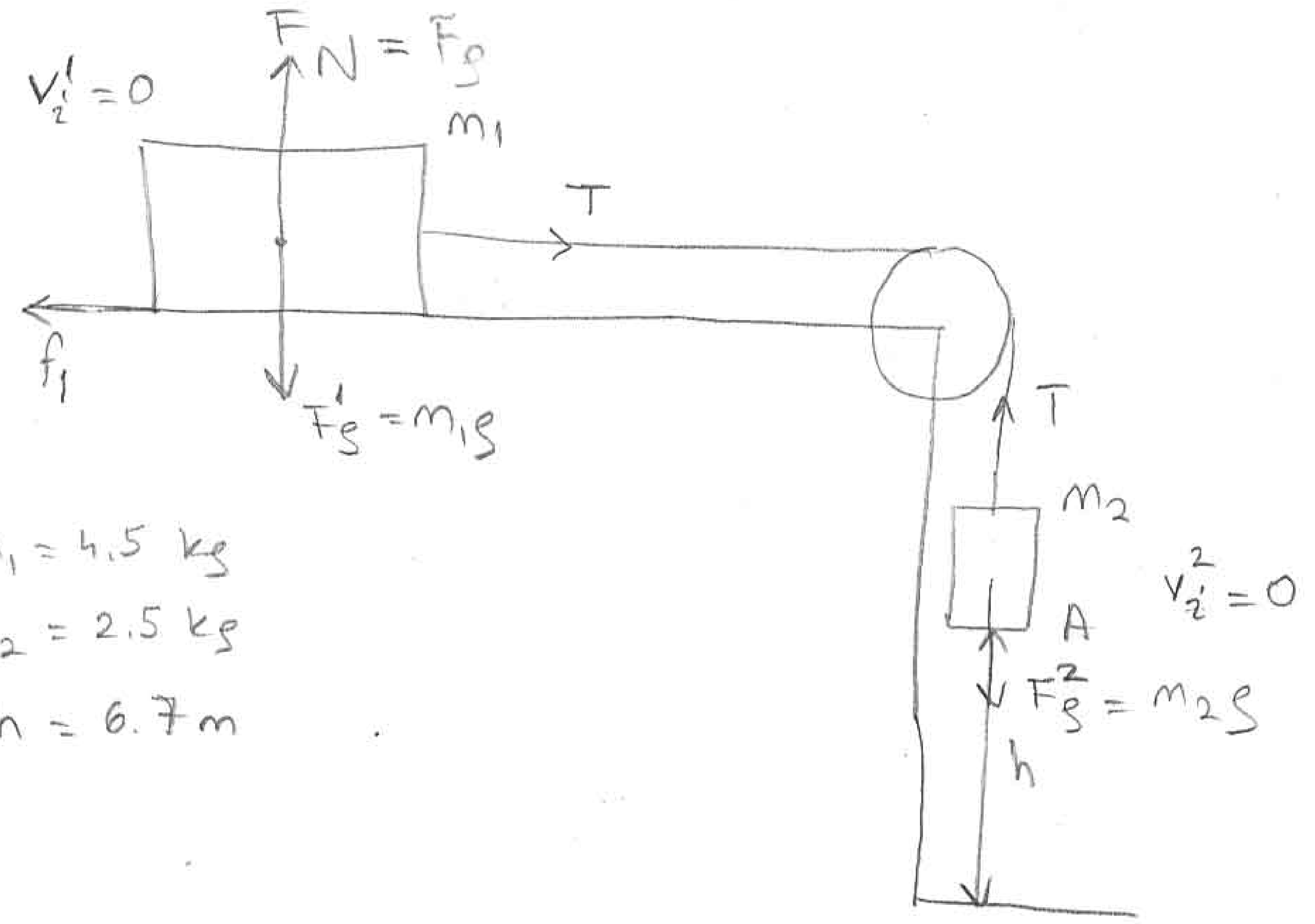
1)



$m_1 = 4.5$ kg

$m_2 = 2.5$ kg

$h = 6.7$ m

a) Since there is no friction energy is conserved:

$$m_2 g h = \frac{1}{2} m_1 (v_f^1)^2 + \frac{1}{2} m_2 (v_f^2)^2$$

Using the fact that $v_f^1 = v_f^2 = v$

$$m_2 g h = \frac{1}{2}(m_1 + m_2) v^2 \Rightarrow v = \sqrt{\frac{2 m_2 g h}{m_1 + m_2}} \Rightarrow \boxed{v = 6.8 \text{ m/s}}$$

b) Look at the figure above

c) $f_1 = \mu_k \cdot F_N = \mu_k \cdot m_1 g \Rightarrow \boxed{f_1 = 0.15 \times 10^2 \text{ N}}$

d) $W_{f_1} = -f_1 \cdot h \Rightarrow \boxed{W_f = -1.0 \times 10^2 \text{ J}}$

e) Speed v' of m_2 just before it hits the floor is equal to speed of m_1 just before m_2 hits the floor.

The work done by net force acting on the system composed of m_1 and m_2 is equal to the change in kinetic energy of the system.

$$\frac{1}{2} m_1 v'^2 + \frac{1}{2} m_2 v'^2 = m_2 g h - f_1 h = g h (m_2 - \mu_k m_1)$$

$$v' = \sqrt{\frac{2 g h (m_2 - \mu_k m_1)}{m_1 + m_2}} \Rightarrow \boxed{v' = 4.2 \text{ m/s}}$$

f) $P = F \cdot v \Rightarrow P_{av} = F_g \cdot v_{av} = m_2 g \cdot \frac{0 + v'}{2} \Rightarrow \boxed{P_{av} = 51 \text{ W}}$

2)

a) $E = U(x=2m) + K = 0 + \frac{1}{2}mv^2 = \boxed{5.0\ J}$

b) Turning points x_t are such that $U(x_t) = E = 5.0\ J$.
Simple geometry shows that $\boxed{x_t = 1m \text{ or } 4m}$

c) Motion is allowed between turning points. So $\boxed{1m \le x \le 4m}$

d) In order to escape to infinity, objects energy E should be greater than U for all $x \geq x_0$ and/or $x \le x_0$ where x_0 is some point inside the allowed region. So $\boxed{E_{min} = 10 J}$

e) $F = -\frac{dU}{dx}$.

For $2m < x < 6m$, $U(x) = 2.5x - 5$

So $\boxed{F = -2.5\ N}$

f) $F = ma \Rightarrow a = \frac{F}{m}$ $\Rightarrow T = \frac{m(v'-v)}{F}$ $\Rightarrow \boxed{T = 0.44\ s}$

$v' = v + at \Rightarrow T = \frac{v'-v}{a}$

Here v = velocity at $x = 2m$

$v' = 0$ velocity at $x = 4m$

Since $E = U$ at turning point,

$K = 0 \Rightarrow v = 0$.

3)

a) $\Delta U = Mg\,\Delta h = Mg\,(L - L\cos\theta_{max}) = MgL(1-\cos\theta_{max}) \Rightarrow \boxed{\Delta U = 20\ J}$

b) Energy is conserved. So

$\Delta K = \Delta U \Rightarrow \frac{1}{2}Mv_p^2 = \Delta U \Rightarrow v_p = \sqrt{\frac{2\Delta U}{M}} \Rightarrow \boxed{v_p = 3.1\ m/s}$

c) Momentum is conserved:

$mv_i = mv_f + Mv_p \Rightarrow v_f = \frac{mv_i - Mv_p}{m} \Rightarrow \boxed{v_f = 2.7\times10^2\ m/s}$

d) $\Delta E = \frac{1}{2}mv_i^2 - \left(\Delta U + \frac{1}{2}mv_f^2\right) \Rightarrow \boxed{\Delta E = 4.2\times10^3\ J}$

e) $F_{av} = \frac{\Delta p}{\Delta t} = \frac{m(v_f - v_i)}{\Delta t} \Rightarrow \boxed{F_{av} = -2.6\times10^4\ N}$

4) a) From symmetry it is easy to see that, the center of mass is at the center. So $x_{cm} = 1.5a$ $y_{cm} = 3.5a$. Let's calculate explicitly:

The center of mass of each block is at its center. Denoting the mass of a single block by m_1 we have, going from up to down, left to right:

$$x_{cm} = \frac{\cancel{m_1} 0.5a + \cancel{m_1} 1.5a + \cancel{m_1} 2.5a + \cancel{m_1} 0.5a + \cancel{m_1} 2.5a + \cancel{m_1} 0.5a + \cancel{m_1} 1.5a + \cancel{m_1} 2.5a}{8\cancel{m_1}} = \frac{12a}{8}$$

$$\boxed{x_{cm} = 1.5a}$$

$$y_{cm} = \frac{\cancel{m_1} 4.5a + \cancel{m_1} 4.5a + \cancel{m_1} 4.5a + \cancel{m_1} 3.5a + \cancel{m_1} 3.5a + \cancel{m_1} 2.5a + \cancel{m_1} 2.5a + \cancel{m_1} 2.5a}{8\cancel{m_1}} = \frac{28a}{8}$$

$$\boxed{y_{cm} = 3.5a}$$

b) From symmetry, the center of mass is at the center. So $x_{cm} = 0.5a$, $y_{cm} = 1.0a$

$$x_{cm} = \frac{\cancel{m_2}\, 0.5a + \cancel{m_2}\, 0.5a}{2\cancel{m_2}} = \frac{a}{2} \Rightarrow \boxed{x_{cm} = 0.5a}$$

$$y_{cm} = \frac{\cancel{m_2}\, 0.5a + \cancel{m_2}\, 1.5a}{2\cancel{m_2}} = \frac{2a}{2} \Rightarrow \boxed{y_{cm} = 1.0a}$$

c) We can treat the objects of part a and b as point particles. Denoting the total masses of the objects by M_a and M_b we have

$$M_a = 8m_1 = 8a^2\sigma_1 \qquad M_b = 2m_2 = 2a^2\sigma_2$$

So

$$x_{cm} = \frac{M_a 1.5a + M_b 0.5a}{M_a + M_b} \Rightarrow \boxed{x_{cm} = a\frac{12\sigma_1 + \sigma_2}{2(4\sigma_1 + \sigma_2)}}$$

$$y_{cm} = \frac{M_a 3.5a + M_b 1.0a}{M_a + M_b} \Rightarrow \boxed{y_{cm} = a\frac{14\sigma_1 + \sigma_2}{4\sigma_1 + \sigma_2}}$$