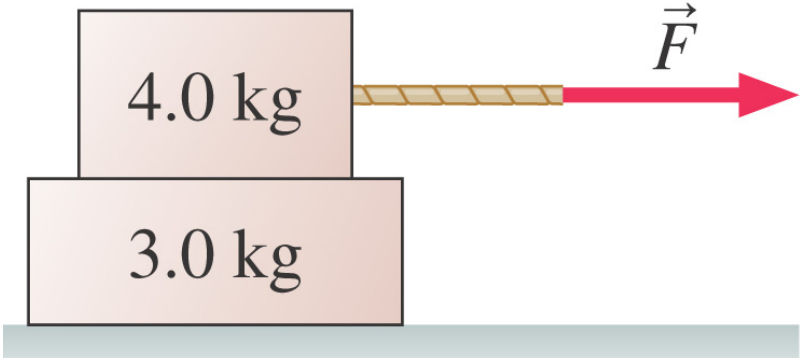
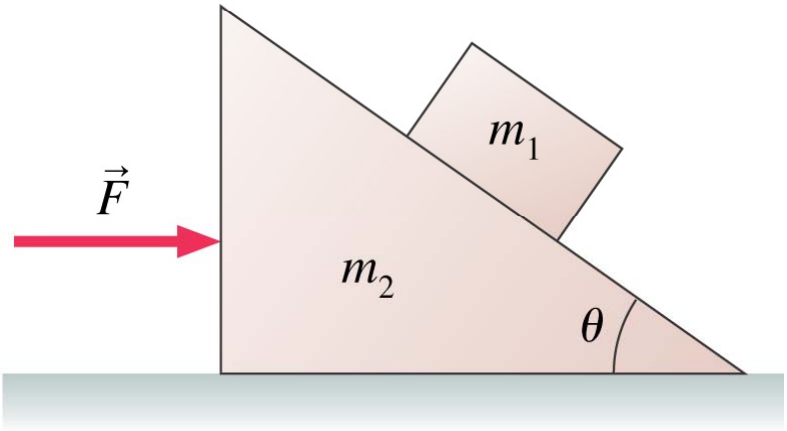
Newton's Third Law

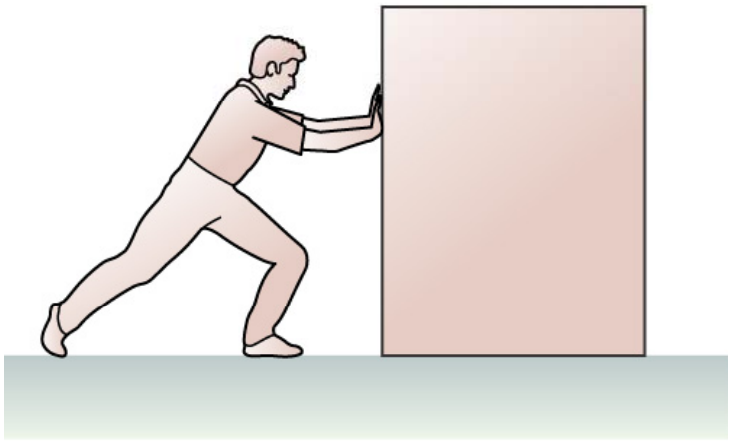
Readings: Chapter 8

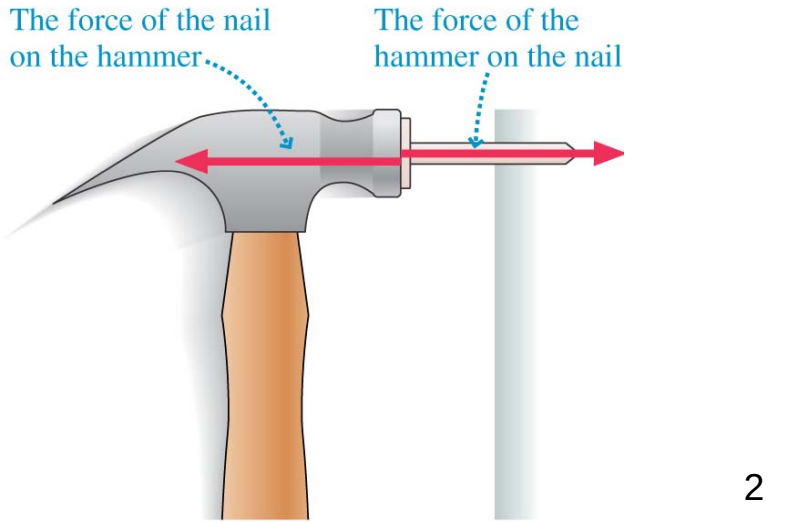
Newton's Third Law

When you have more than 1 system the Newton's Third Law can provide an additional information about the forces.





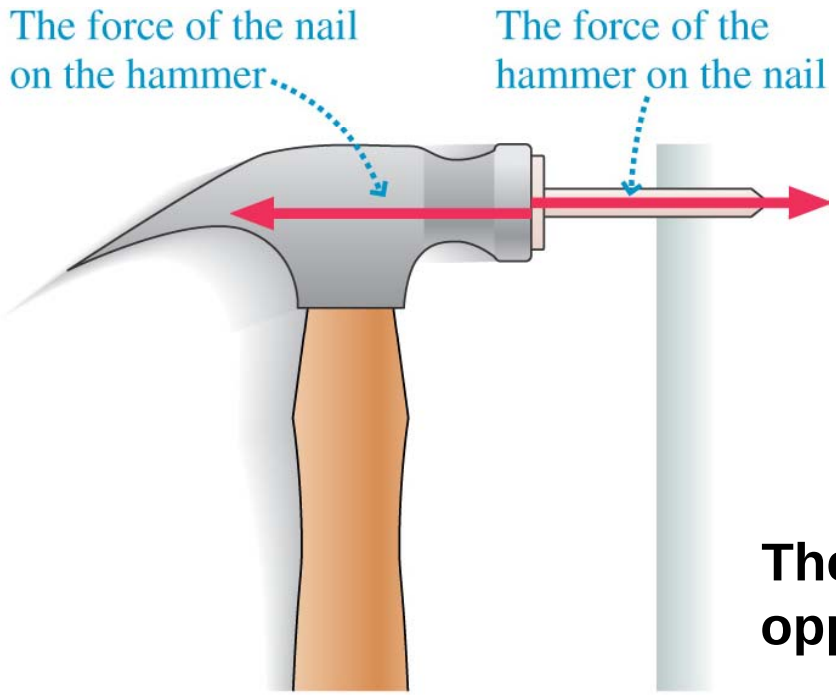




Newton's Third Law

The force of the nail on the hammer $\vec{F}_{nail-hammer}$

The force of the hammer on the nail $\vec{F}_{hammer-nail}$



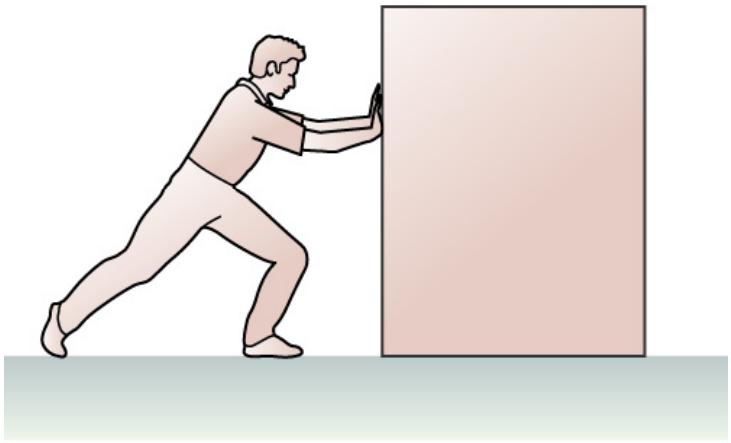
The Newton's Third Law:

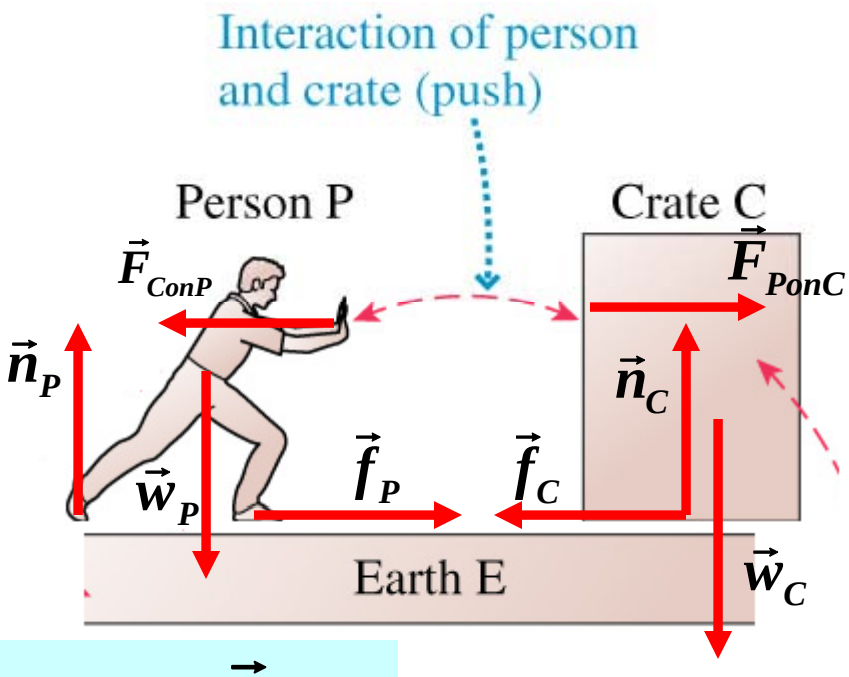
$$\vec{F}_{hammer-nail} = -\vec{F}_{nail-hammer}$$

The forces (action-reaction pair) have opposite direction and the same magnitude

They (action-reaction pair) never occur on the same object

Newton's Third Law





Two systems: Person and Crate

The Newton's Third Law: $\vec{F}_{ConP} = -\vec{F}_{PonC}$

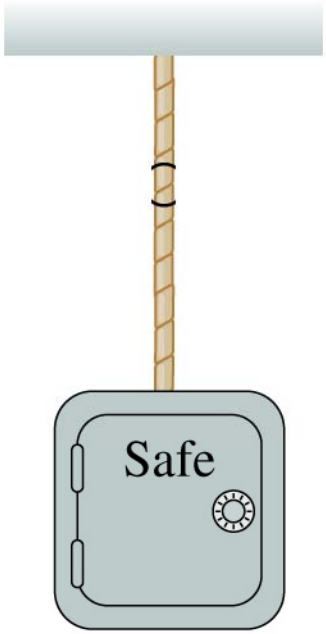
Equilibrium:

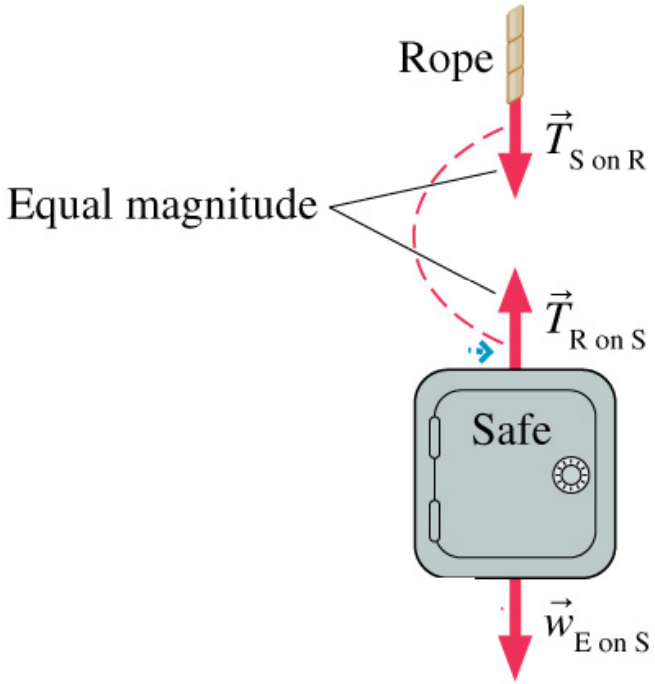
1. **System P:** $\vec{F}_{P,net} = \vec{F}_{ConP} + \vec{n}_P + \vec{w}_P + \vec{f}_P = 0$
2. **System C** $\vec{F}_{C,net} = \vec{F}_{PonC} + \vec{n}_C + \vec{w}_C + \vec{f}_C = 0$
3. **System P+C** $\vec{F}_{P+C,net} = \vec{n}_P + \vec{w}_P + \vec{f}_P + \vec{n}_C + \vec{w}_C + \vec{f}_C = 0$

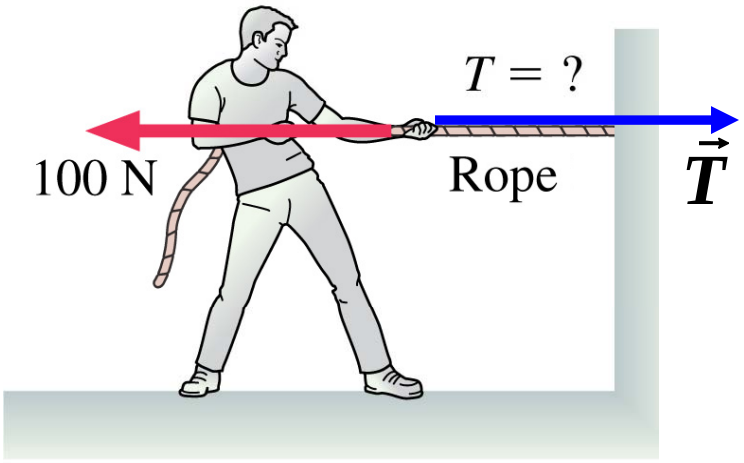
$\vec{F}_{P+C,net} = \vec{F}_{P,net} + \vec{F}_{C,net} = 0$ $\quad$ $\vec{F}_{ConP} + \vec{F}_{PonC} = 0$

Newton's Third Law

Two systems: Rope and Safe



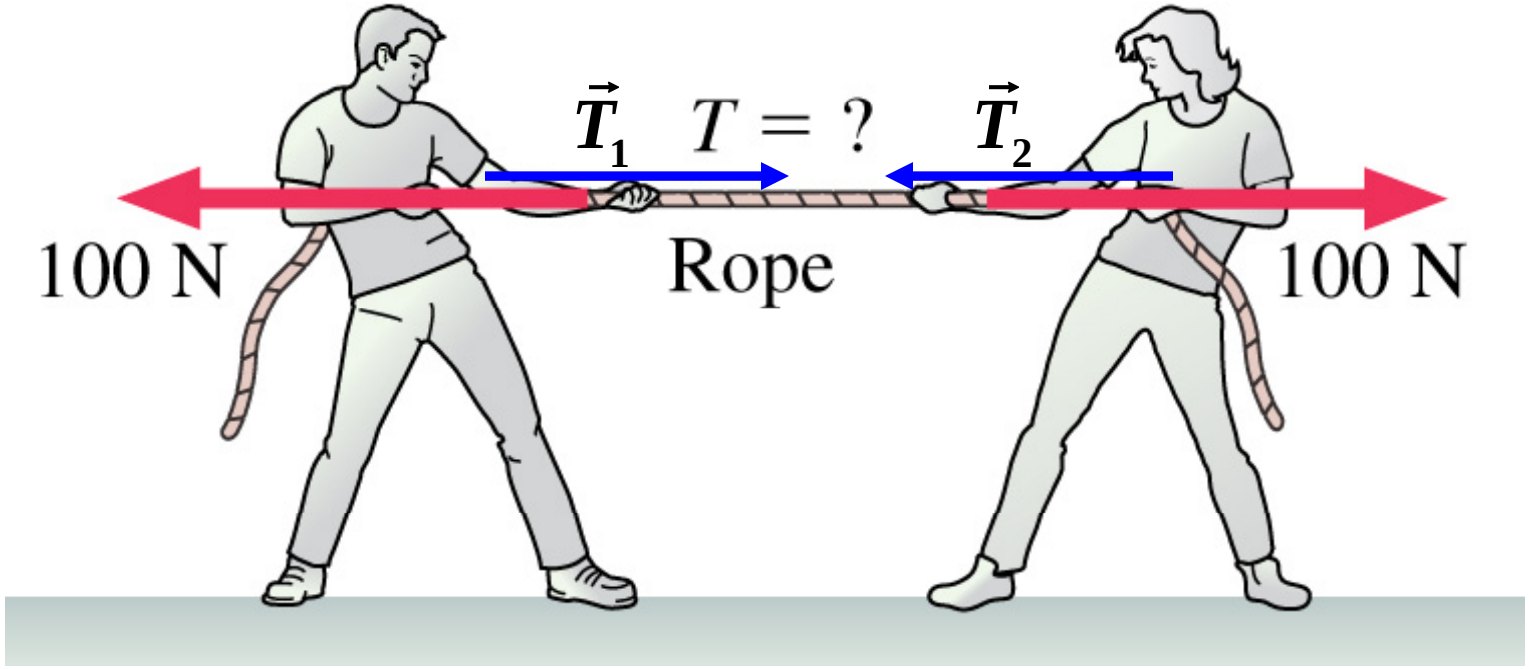




Newton's Third Law:

$$T = 100\,N$$

$$T_1 = T_2 = 100\,N$$



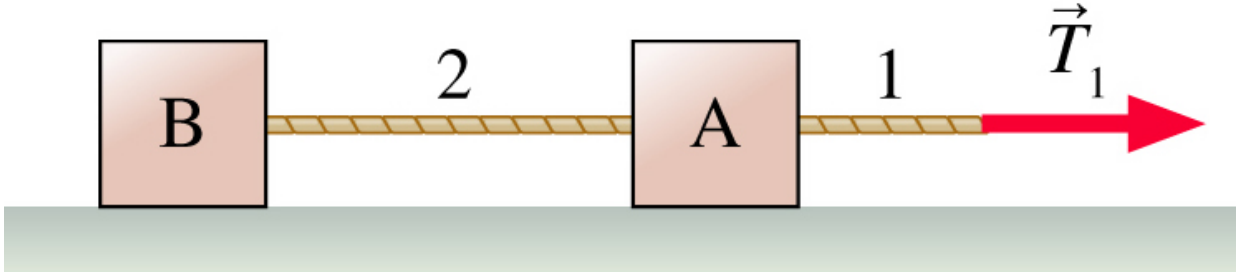
Find tension of rope 2 $T_2 = ?$

$T_1 = 100N$

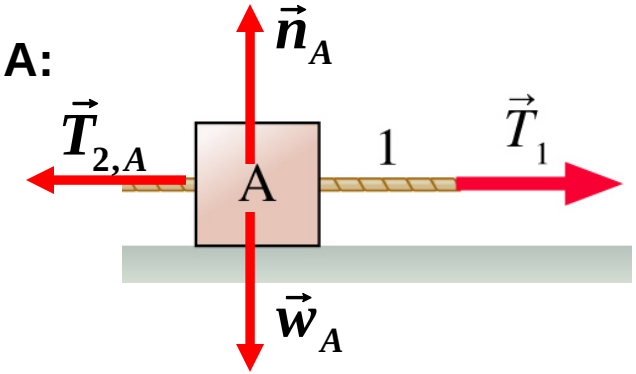
$m_A = 1kg$

$m_B = 4kg$

No friction



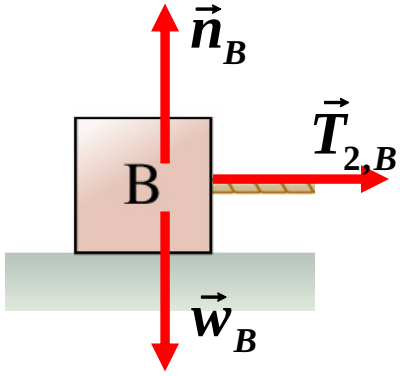
System A:



$$\vec{F}_{A,net} = \vec{T}_{2,A} + \vec{n}_A + \vec{w}_A + \vec{T}_1 = m_A\vec{a}$$

$$T_1 - T_{2,A} = m_A a$$

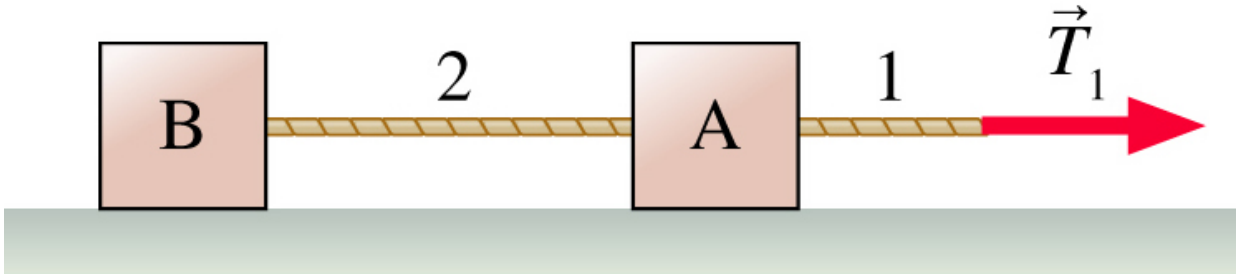
System B:



$$\vec{F}_{B,net} = \vec{T}_{2,B} + \vec{n}_B + \vec{w}_B = m_B\vec{a}$$

$$T_{2,B} = m_B a$$

Find tension of rope 2 $T_2 = ?$



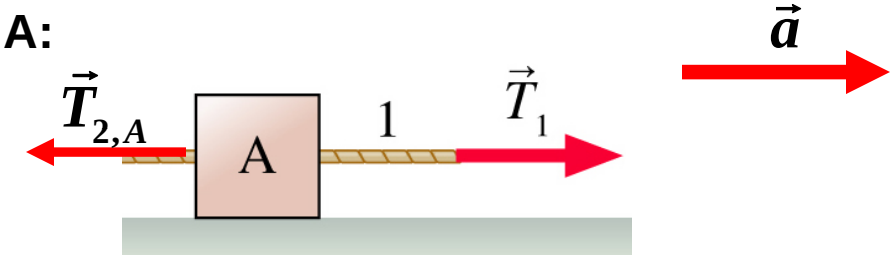
$T_1 = 100N$

$m_A = 1kg$

$m_B = 4kg$

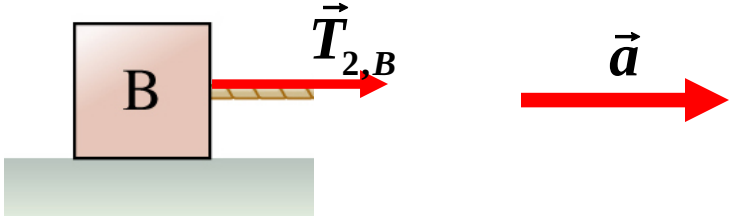
No friction

System A:



$T_1 - T_{2,A} = m_A a$

System B:



$T_{2,B} = m_B a$

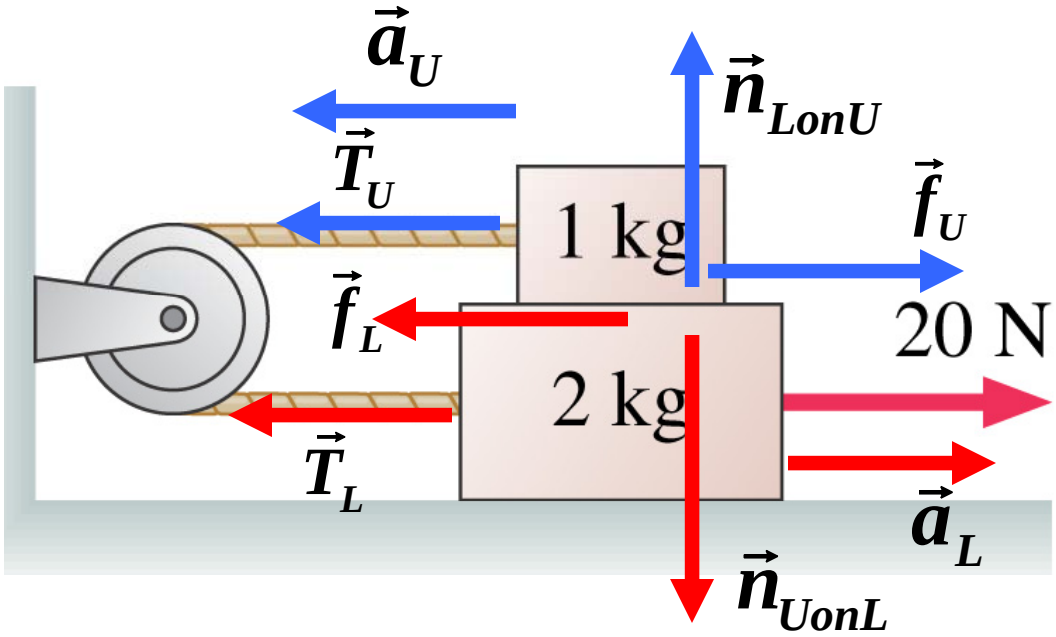
Newton's Third Law: $T_{2,B} = T_{2,A} = T_2$

$$T_1 - T_2 = m_A a$$
$$T_2 = m_B a$$

$$a = \frac{T_1}{m_A + m_B}$$

$$T_2 = \frac{m_B T_1}{m_A + m_B} = \frac{4 \cdot 100}{5} = 80N$$

Example: Find acceleration of the lower block. The coefficient of kinetic friction between the lower block and the surface is 0.3. The coefficient of kinetic friction between the lower block and the upper block is 0.3.

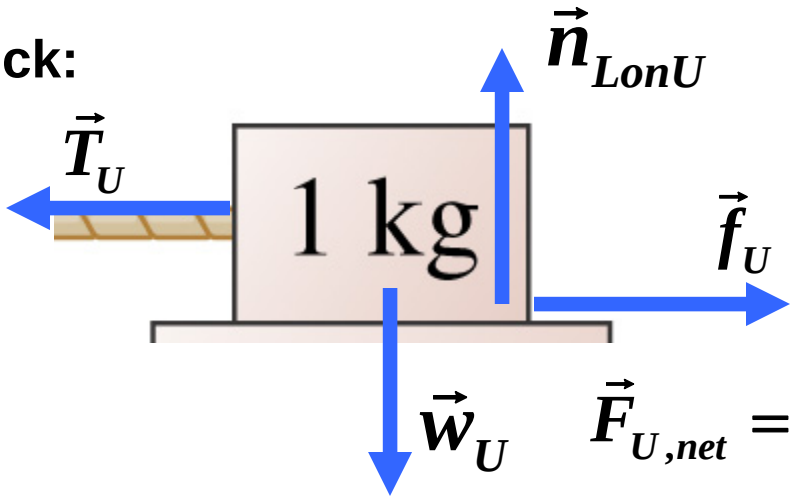


$$a_L = a_U$$

Newton's Third Law: $\vec{f}_L = -\vec{f}_U$ $\qquad T_L = T_U$

$$\vec{n}_{LonU} = -\vec{n}_{UonL}$$

Upper block:

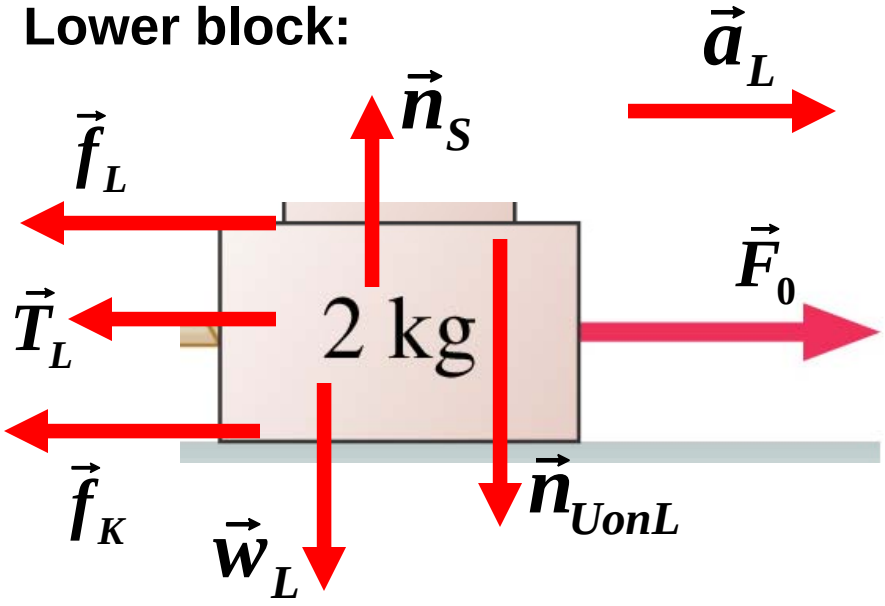


$$\vec{F}_{U,net} = \vec{f}_U + \vec{n}_{LonU} + \vec{w}_U + \vec{T}_U = m_U \vec{a}_U$$

$$n_{LonU} - w_U = 0$$

$$-f_U + T_U = m_U a_U$$

Lower block:



$$\vec{F}_{L,net} = \vec{f}_L + \vec{n}_{UonL} + \vec{n}_S + \vec{w}_L + \vec{T}_L + \vec{f}_K + \vec{F}_0 = m_L \vec{a}_L$$

$$F_0 - f_L - T_L - f_K = m_L a_L$$

$$n_{UonL} + w_L - n_S = 0$$

Upper block:

$$n_{LonU} - w_U = 0$$

$$-f_U + T_U = m_U a_U$$

Lower block:

$$F_0 - f_L - T_L - f_K = m_L a_L$$

$$n_{UonL} + w_L - n_S = 0$$

$$a_L = a_U = a$$

$$n_{LonU} = n_{UonL} = n$$

$$f_L = f_U = 0.3n$$

$$T_L = T_U = T$$

$$f_K = 0.3n_S$$

$$n - w_U = 0$$

$$-0.3n + T = m_U a$$

$$F_0 - 0.3n - T - 0.3n_S = m_L a$$

$$n + w_L - n_S = 0$$

Unknown: n, n_S, T, a

$$n - w_U = 0$$

$$-0.3n + T = m_U a$$

$$F_0 - 0.3n - T - 0.3n_S = m_L a$$

$$n + w_L - n_S = 0$$

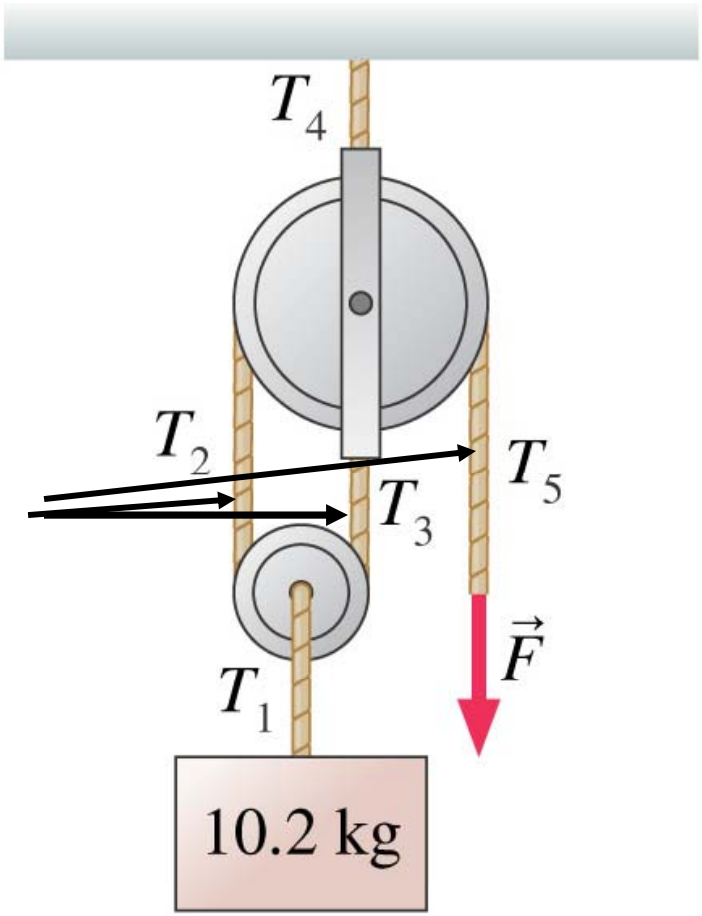
$$n - w_U = 0 \qquad n_S = n + w_L = w_U + w_L$$

$$T = m_U a + 0.3n = m_U a + 0.3w_U$$

$$F_0 - 0.3w_U - (m_U a + 0.3w_U) - 0.3(w_U + w_L) = m_L a$$

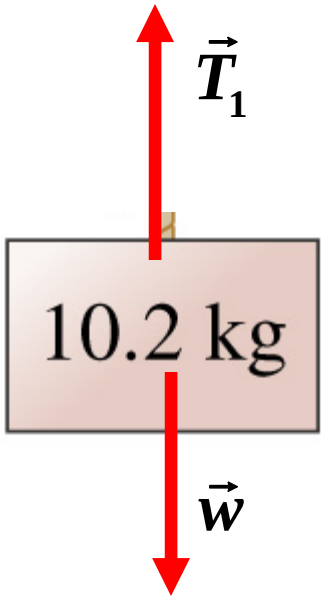
$$a = \frac{F_0 - 0.9w_U - 0.3w_L}{m_L + m_U} = \frac{20 - 0.9 \cdot 10 - 0.3 \cdot 2 \cdot 10}{3} \approx 1.7 \frac{m}{s^2}$$

Example: The 10.2 kg block is held in place by the massless rope passing over two massless, frictionless pulleys. Find the tensions T_1 to T_5 and the magnitude of force F.



The same rope:

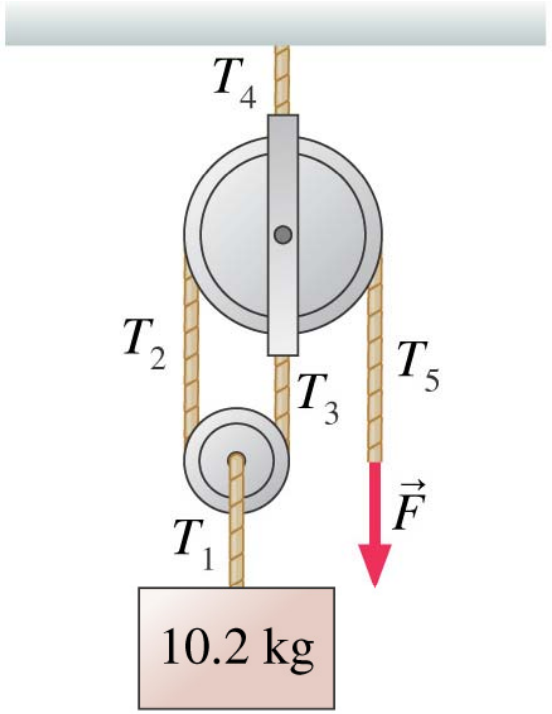
$$T_2 = T_3 = T_5$$

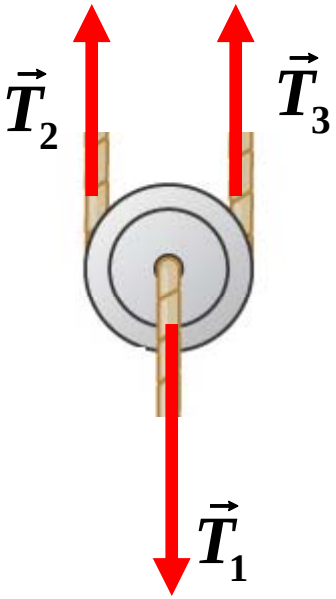


$$T_2 = T_3 = T_5$$

Equilibrium:

$$T_1 = w \approx 10.2 \bullet 10 = 102N$$

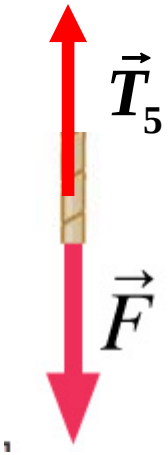




Equilibrium:

$$T_1 = T_3 + T_2 = 2T_2$$

$$T_2 = \frac{T_1}{2} = 51N = T_3 = T_5$$



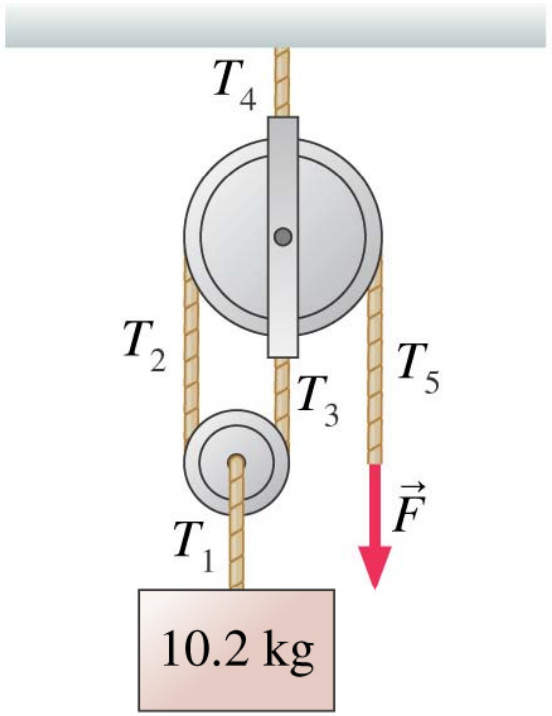
Equilibrium:

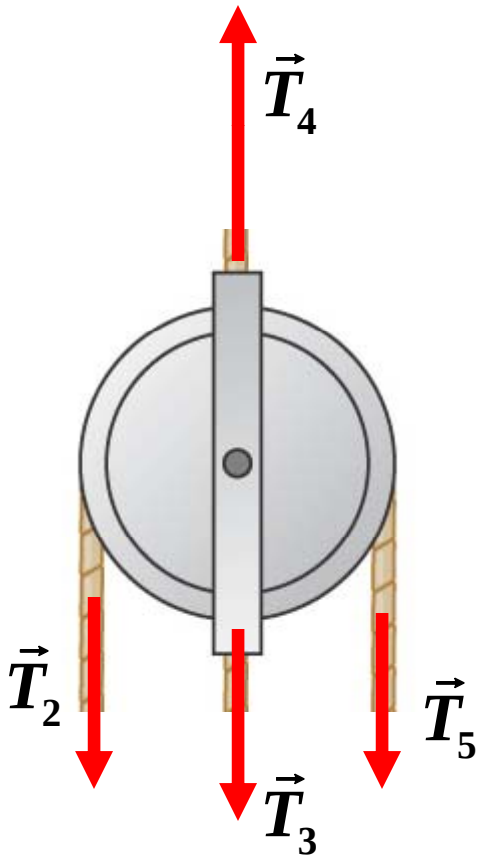
$$F = T_5 = 51N$$

$$T_2 = T_3 = T_5 = 51N$$

$$T_1 = 102N$$

$$F = 51N$$





Equilibrium:

$$T_4 = T_2 + T_3 + T_5 = 153N$$