Example 1:
A scale is fixed to the bottom of an elevator. A 50 kg box is on the scale. What is the scale reading when

a.) the elevator is at rest?

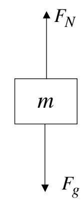
b.) the elevator accelerates upward at 2.0 m/s^2?

c.) the elevator accelerates downward at 1.5 m/s^2?

d.) the elevator moves at constant velocity?

Example 1:
A scale is fixed to the bottom of an elevator. A 50 kg box is on the scale. What is the scale reading when

a.) the elevator is at rest?



$m = 50\text{ kg} \quad a = 0$

$\sum_y F = ma = 0$

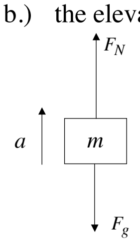
$F_N - F_g = 0$

$F_N = F_g$

$F_N = mg = (50\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{500\text{ N}}$

Example 1:
A scale is fixed to the bottom of an elevator. A 50 kg box is on the scale. What is the scale reading when

b.) the elevator accelerates upward at 2.0 m/s^2?



$m = 50\text{ kg} \quad a = 2.0\ \frac{\text{m}}{\text{s}^2} \uparrow$

$\sum_y F = ma$

$F_N - F_g = ma$

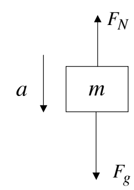
$F_N = ma + F_g$

$F_N = ma + mg$

$F_N = (50\text{ kg})\left(2\ \frac{\text{m}}{\text{s}^2}\right) + (50\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{600\text{ N}}$

Example 1:
A scale is fixed to the bottom of an elevator. A 50 kg box is on the scale. What is the scale reading when

c.) the elevator accelerates downward at 1.5 m/s^2?



$m = 50\text{ kg} \quad a = 1.5\ \frac{\text{m}}{\text{s}^2} \downarrow$

$\sum_y F = ma$

$F_g - F_N = ma$

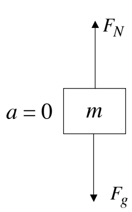
$F_N = F_g - ma$

$F_N = mg - ma$

$F_N = (50\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) - (50\text{ kg})\left(1.5\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{425\text{ N}}$

Example 1:
A scale is fixed to the bottom of an elevator. A 50 kg box is on the scale. What is the scale reading when

d.) the elevator moves at constant velocity?



$m = 50\text{ kg} \quad a = 0$

$\sum_y F = ma = 0$

$F_N - F_g = 0$

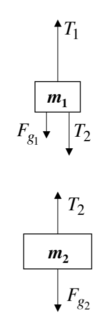
$F_N = F_g$

$F_N = mg = (50\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{500\text{ N}}$

Example 2:
Two masses are suspended using cords with negligible mass.

a.) Draw free-body diagrams for each mass.

b.) Find the tensions in the cords if m_1 = 25 kg and m_2 = 55 kg.



$T_2 = F_{g_2} = m_2 g = (55\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{550\text{ N}}$

$T_1 = F_{g_1} + F_{g_2} = m_1 g + m_2 g = (25\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) + (55\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{800\text{ N}}$

Example 3:

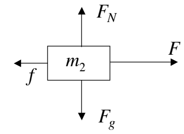
A 25 kg box is at rest on a rough horizontal surface. The coefficients of static and kinetic friction are 0.50 and 0.2 respectively.

a.) How much force is needed to just set the box in motion?

b.) How much force is needed to move the box at a constant velocity of 10 m/s?

c.) How much force is needed to move the box with an acceleration of 2 m/s^2?

Example 3: $m = 25$ kg, $\mu_s = 0.50$, and $\mu_k = 0.20$



a.) F = ? to just get the box moving

$$\sum F_y = ma = 0 \qquad \sum F_x = ma$$
$$F_N - F_g = 0 \qquad F - f_s = 0$$
$$F_N = F_g = mg \qquad F = f_s = \mu_s F_N$$
$$F = \mu_s mg = 0.50(25\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)$$
$$\boxed{F = 125\text{ N}}$$

b.) $v = 10\ \frac{\text{m}}{\text{s}}$, F = ?

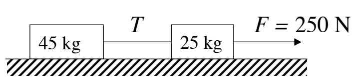
$$\sum F_x = ma$$
$$F - f_k = 0$$
$$F = f_k = \mu_k F_N = \mu_k mg$$
$$F = 0.20(25\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)$$
$$\boxed{F = 50\text{ N}}$$

c.) $a = 2\ \frac{\text{m}}{\text{s}^2}$, F = ?

$$\sum F_x = ma$$
$$F - f_k = ma \qquad F = ma + \mu_k F_N$$
$$F = ma + f_k \qquad F = ma + \mu_k mg$$
$$F = (25\text{ kg})\left(2\ \frac{\text{m}}{\text{s}^2}\right) + 0.20(25\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)$$
$$\boxed{F = 100\text{ N}}$$

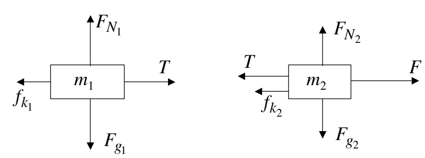
Example 4:

Two boxes are connected by a cord with negligible mass, as shown in the figure below. A force of 250 N is applied horizontally to the 25 kg box causing the boxes to accelerate to the right. The coefficient of kinetic friction between the boxes and the surface is 0.20. Find the magnitude of the acceleration of the boxes and the tension in the cord that connects them.



Example 4:

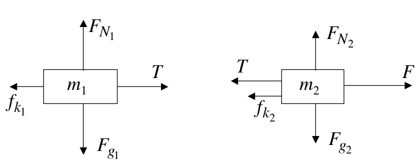
$m_1 = 45$ kg, $m_2 = 25$ kg, $F = 250$ N, and $\mu_k = 0.20$ kg



$$\sum F_y = ma = 0 \qquad (1)\ F_{N_1} - F_{g_1} = 0 \qquad (2)\ F_{N_2} - F_{g_2} = 0$$
$$F_{N_1} = F_{g_1} = m_1 g \qquad F_{N_2} = F_{g_2} = m_2 g$$
$$\sum F_x = ma \qquad (3)\ T - f_{k_1} = m_1 a \qquad (4)\ F - T - f_{k_2} = m_2 a$$
$$(3)+(4)\ \ F - f_{k_1} - f_{k_2} = (m_1 + m_2)a$$
$$a = \frac{F - f_{k_1} - f_{k_2}}{m_1 + m_2} = \frac{F - \mu_{k_1} m_1 g - \mu_{k_2} m_2 g}{m_1 + m_2}\ \boxed{= 1.57\ \frac{\text{m}}{\text{s}^2}}\ \left(g = 10\ \frac{\text{m}}{\text{s}^2}\right)$$

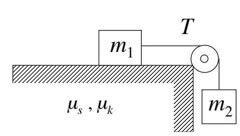
Example 4:

$m_1 = 45$ kg, $m_2 = 25$ kg, $F = 250$ N, and $\mu_k = 0.20$ kg



$$\sum F_y = ma = 0 \qquad (1)\ F_{N_1} - F_{g_1} = 0 \qquad (2)\ F_{N_2} - F_{g_2} = 0$$
$$F_{N_1} = F_{g_1} = m_1 g \qquad F_{N_2} = F_{g_2} = m_2 g$$
$$\sum F_x = ma \qquad (3)\ T - f_{k_1} = m_1 a \qquad (4)\ F - T - f_{k_2} = m_2 a$$

from (3) $T = m_1 a + f_{k_1} = m_1 a + \mu_{k_1} m_1 g \boxed{= 161\text{ N}}$



Example 5:

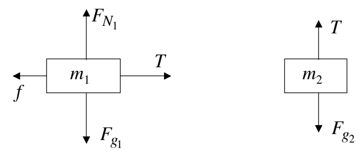
Two masses are connected by a cord of negligible mass. Assume that the pulley is frictionless and of negligible mass. The boxes are initially held at rest and m_2 is then released. Assuming that the system moves:

a.) Draw free-body diagrams for m_1 and m_2.

b.) Find expressions for the acceleration a and the tension T in the cord.

Suppose that the system does not move when m_2 is released and repeat parts (a) and (b).

Example 5:



$\sum F_y = ma$ (1) $F_{N_1} - F_{g_1} = 0$ (2) $F_{g_2} - T = m_2 a$

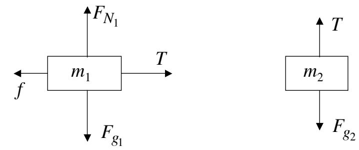
$F_{N_1} = F_{g_1} = m_1 g$

$\sum F_x = ma$ (3) $T - f_{k_1} = m_1 a$ no x - forces

$(2)+(3)\quad F_{g_2} - f_{k_1} = (m_1 + m_2)a$

$$a = \frac{F_{g_2} - f_{k_1}}{m_1 + m_2} = \boxed{\frac{m_2 g - \mu_{k_1} m_1 g}{m_1 + m_2}}$$

Example 5:



$\sum F_y = ma$ (1) $F_{N_1} - F_{g_1} = 0$ (2) $F_{g_2} - T = m_2 a$

$F_{N_1} = F_{g_1} = m_1 g$

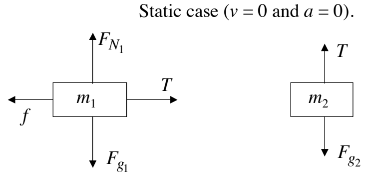
$\sum F_x = ma$ (3) $T - f_{k_1} = m_1 a$ no x - forces

from (3) $T = m_1 a + f_{k_1} = m_1\left(\frac{m_2 g - \mu_{k_1} m_1 g}{m_1 + m_2}\right) + \mu_{k_1} m_1 g$

$$\boxed{T = \frac{m_1 m_2 g\left(1 + \mu_{k_1}\right)}{m_1 + m_2}}$$

Example 5:

Static case ($v = 0$ and $a = 0$).



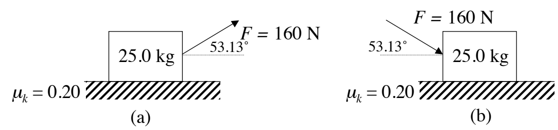
$\sum F_y = ma = 0$ (1) $F_{N_1} - F_{g_1} = 0$ (2) $F_{g_2} - T = 0$

$F_{N_1} = F_{g_1} = m_1 g$

$\sum F_x = ma = 0$ (3) $T - f = 0$ no x - forces

(2) $F_{g_2} - T = 0$ so $\boxed{T = F_{g_2} = m_2 g}$

(3) $T - f = 0$ so $\boxed{f = T = m_2 g}$



Example 6:

A 25 kg box is being pulled by a force that makes a 53.13° angle above the horizontal as shown in figure (a).

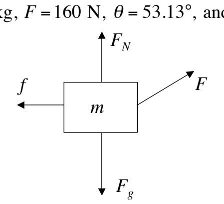
i.) Find the normal force acting on the box.

ii.) Find the acceleration of the box.

Repeat part (i) and (ii) if the force is applied below the horizontal as shown in figure (b).

Example 6a:

$m = 25$ kg, $F = 160$ N, $\theta = 53.13°$, and $\mu_k = 0.20$



i.) $F_N = ?$

$\sum F_y = ma$ (1) $F_N + F_y - F_g = 0$

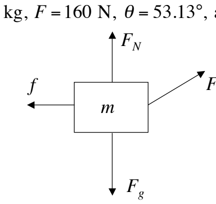
$F_N = F_g - F_y$

$F_N = mg - F\sin\theta$

$F_N = (25 \text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) - (160 \text{ N})\sin 53.13° = \boxed{122 \text{ N}}$

Example 6a:

$m = 25$ kg, $F = 160$ N, $\theta = 53.13°$, and $\mu_k = 0.20$



ii.) $a = ?$

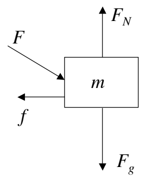
$\sum F_x = ma$ (2) $F_x - f_k = ma$

$$a = \frac{F_x - f_k}{m} = \frac{F\cos\theta - \mu_k F_N}{m}$$

$$a = \frac{(160 \text{ N})\cos 53.13° - 0.20(122 \text{ N})}{25 \text{ kg}} = \boxed{2.86\ \frac{\text{m}}{\text{s}^2}}$$

Example 6b:

$m = 25\text{ kg},\ F = 160\text{ N},\ \theta = 53.13°,\text{ and } \mu_k = 0.20$



i.) $F_N = ?$

$\sum F_y = ma \qquad (1)\ F_N - F_y - F_g = 0$

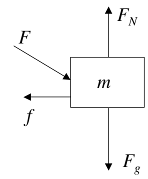
$$F_N = F_g + F_y$$

$$F_N = mg + F\sin\theta$$

$$F_N = (25\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) + (160\text{ N})\sin 53.13° = \boxed{378\text{ N}}$$

Example 6b:

$m = 25\text{ kg},\ F = 160\text{ N},\ \theta = 53.13°,\text{ and } \mu_k = 0.20$

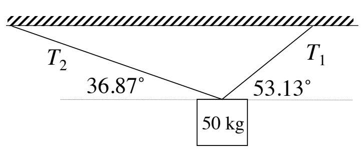


ii.) $a = ?$

$\sum F_x = ma \qquad (2)\ F_x - f_k = ma$

$$a = \frac{F_x - f_k}{m} = \frac{F\cos\theta - \mu_k F_N}{m}$$

$$a = \frac{(160\text{ N})\cos 53.13° - 0.20(378\text{ N})}{25\text{ kg}} = \boxed{0.82\ \frac{\text{m}}{\text{s}^2}}$$



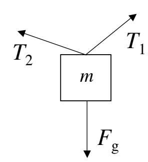
Example 7:

A 50 kg box is suspended by two cords as shown in the figure above.

a.) Find the tensions T_1 and T_2.

b.) If the maximum amount of tension each cord can sustain without breaking is 600 N, what is the largest mass that can be supported assuming that the angles do not change?

Example 7a:



$m = 50\text{ kg}$
$\theta_1 = 53.13°$
$\theta_2 = 180° - 36.87° = 143.13°$

$\sum F_x = ma \qquad T_{1_x} + T_{2_x} = 0$

$(1)\ T_1\cos\theta_1 + T_2\cos\theta_2 = 0$

$\sum F_y = ma \qquad T_{1_y} + T_{2_y} - F_g = 0$

$T_{1_y} + T_{2_y} = F_g$

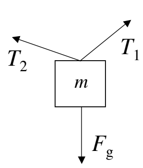
$(2)\ T_1\sin\theta_1 + T_2\sin\theta_2 = F_g$

using (1) $T_2 = \dfrac{-T_1\cos\theta_1}{\cos\theta_2}$ into (2) $T_1\sin\theta_1 + \left(\dfrac{-T_1\cos\theta_1}{\cos\theta_2}\right)\sin\theta_2 = F_g$

$$T_1(\sin\theta_1 - \cos\theta_1\tan\theta_2) = F_g$$

$$T_1 = \frac{mg}{\sin\theta_1 - \cos\theta_1\tan\theta_2} = \frac{(50\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)}{\sin(53.13°) - \cos(53.13°)\tan(143.13°)} = \boxed{400\text{ N}}$$

Example 7a:



$m = 50\text{ kg}$
$\theta_1 = 53.13°$
$\theta_2 = 180° - 36.87° = 143.13°$

$\sum F_x = ma \qquad T_{1_x} + T_{2_x} = 0$

$(1)\ T_1\cos\theta_1 + T_2\cos\theta_2 = 0$

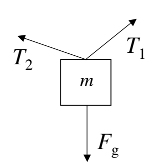
$\sum F_y = ma \qquad T_{1_y} + T_{2_y} - F_g = 0$

$T_{1_y} + T_{2_y} = F_g$

$(2)\ T_1\sin\theta_1 + T_2\sin\theta_2 = F_g$

using (1) $T_2 = \dfrac{-T_1\cos\theta_1}{\cos\theta_2} = \dfrac{-(400\text{ N})\cos 53.13°}{\cos 143.13°} = \boxed{300\text{ N}}$

Example 7b:



$m = 50\text{ kg}$
$\theta_1 = 53.13°$
$\theta_2 = 180° - 36.87° = 143.13°$
$T_{max} = 600\text{ N},\ m = ?$

$\sum F_x = ma \qquad T_{1_x} + T_{2_x} = 0$

$(1)\ T_1\cos\theta_1 + T_2\cos\theta_2 = 0$

$\sum F_y = ma \qquad T_{1_y} + T_{2_y} - F_g = 0$

$T_{1_y} + T_{2_y} = F_g$

$(2)\ T_1\sin\theta_1 + T_2\sin\theta_2 = F_g$

using (1) $T_2 = \dfrac{-T_1\cos\theta_1}{\cos\theta_2} = \dfrac{-T_1\cos 53.13°}{\cos 143.13°} = 0.75\ T_1 \quad (\text{so } T_1 > T_2)$

set $T_1 = 600\text{ N}$ and $T_2 = 0.75(600\text{ N}) = 450\text{ N}$

from (2) $T_1\sin\theta_1 + T_2\sin\theta_2 = mg$ and $m = \dfrac{T_1\sin\theta_1 + T_2\sin\theta_2}{g}$

and $m = \dfrac{(600\text{ N})\sin 53.13° + (450\text{ N})\sin 143.13°}{10\ \frac{\text{m}}{\text{s}^2}} = \boxed{75\text{ kg}}$