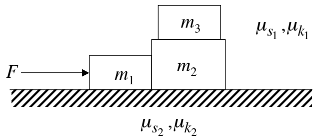
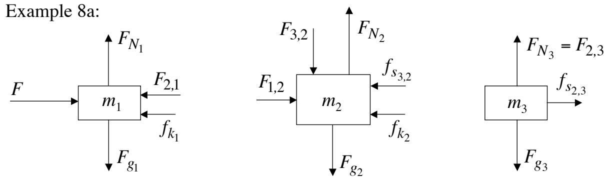


Example 8:

A force F is applied to m_1 causing all blocks to accelerate to the right. Assume that block m_3 moves without slipping.

a.) Draw free-body diagrams for all three masses.
b.) Find an expression for the acceleration a.
c.) What is the frictional force acting on m_3?
d.) What is the force between blocks m_1 and m_2?

Example 8a:



Example 8b: (a = ?)

$\sum F_y = ma$

$(m_1)\ F_{N_1} - F_{g_1} = 0$ $\quad (m_2)\ F_{N_2} - F_{g_2} - F_{3,2} = 0$ $\quad (m_3)\ F_{N_3} - F_{g_3} = 0$

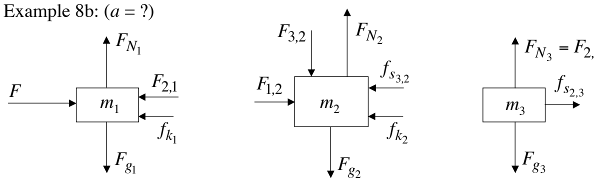
$F_{N_1} = F_{g_1} = m_1 g$ $\quad F_{N_2} = F_{g_2} + F_{3,2}$ $\quad F_{N_3} = F_{g_3} = m_3 g$

$F_{N_1} = m_1 g$ $\quad F_{N_2} = m_2 g + F_{3,2}$ $\quad F_{N_3} = F_{2,3} = m_3 g$

$F_{N_2} = m_2 g + m_3 g \ \left(F_{3,2} = F_{2,3}\right)$

$F_{N_2} = \left(m_2 + m_3\right) g$

Example 8b: (a = ?)



$\sum F_x = ma$

$(m_1)\ F - F_{2,1} - f_{k_1} = m_1 a$ $\quad (m_2)\ F_{1,2} - f_{k_2} - f_{s_{3,2}} = m_2 a$ $\quad (m_3)\ f_{s_{2,3}} = m_3 a$

$(1)\ F - F_{2,1} - \mu_{k_2} F_{N_1} = m_1 a$ $\quad (2)\ F_{1,2} - \mu_{k_2} F_{N_2} - f_{s_{3,2}} = m_2 a$ $\quad (3)\ f_{s_{2,3}} = m_3 a$

$(1+2+3)\ F - \mu_{k_2} F_{N_1} - \mu_{k_2} F_{N_2} = \left(m_1 + m_2 + m_3\right) a \ \left(\text{since } F_{2,1} = F_{1,2} \text{ and } f_{s_{3,2}} = f_{s_{2,3}}\right)$

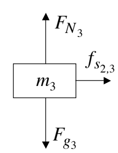
$$a = \frac{F - \mu_{k_2} F_{N_1} - \mu_{k_2} F_{N_2}}{m_1 + m_2 + m_3}$$

Example 8b : $(a = ?)$

$$a = \frac{F - \mu_{k_2} F_{N_1} - \mu_{k_2} F_{N_2}}{m_1 + m_2 + m_3}$$

$$a = \frac{F - \mu_{k_2} m_1 g - \mu_{k_2} \left(m_2 + m_3\right) g}{m_1 + m_2 + m_3} = \boxed{\frac{F - \mu_{k_2}\left(m_1 + m_2 + m_3\right) g}{m_1 + m_2 + m_3}}$$

Example 8c : $\left(f_{s_{2,3}} = ?\right)$



$$(3)\ f_{s_{2,3}} = m_3 a = \boxed{\frac{m_3\left(F - \mu_{k_2}\left(m_1 + m_2 + m_3\right) g\right)}{m_1 + m_2 + m_3}}$$

Example 8d : $\left(F_{1,2} = F_{2,1} = ?\right)$

$(1)\ F - F_{2,1} - \mu_{k_2} F_{N_1} = m_1 a$ $\quad (2)\ F_{1,2} - \mu_{k_2} F_{N_2} - f_{s_{3,2}} = m_2 a$

using (1) $F_{2,1} = F - \mu_{k_2} F_{N_1} - m_1 a$

$$F_{2,1} = F - \mu_{k_2} m_1 g - m_1 \left(\frac{F - \mu_{k_2}\left(m_1 + m_2 + m_3\right) g}{m_1 + m_2 + m_3}\right)$$

this simplifies to : $\boxed{F_{2,1} = \dfrac{F\left(m_2 + m_3\right)}{m_1 + m_2 + m_3}}$

Example 8d : $\left(F_{1,2} = F_{2,1} = ?\right)$

$(1)\ F - F_{2,1} - \mu_{k_2} F_{N_1} = m_1 a$ $\quad (2)\ F_{1,2} - \mu_{k_2} F_{N_2} - f_{s_{3,2}} = m_2 a$

using (2) $\quad F_{1,2} = \mu_{k_2} F_{N_2} + f_{s_{3,2}} + m_2 a$

$$F_{1,2} = \mu_{k_2}\left(m_1 + m_2\right) g + \frac{m_3\left(F - \mu_{k_2}\left(m_1 + m_2 + m_3\right) g\right)}{m_1 + m_2 + m_3} + m_2 \left(\frac{F - \mu_{k_2}\left(m_1 + m_2 + m_3\right) g}{m_1 + m_2 + m_3}\right)$$

this also simplifies to : $\boxed{F_{2,1} = \dfrac{F\left(m_2 + m_3\right)}{m_1 + m_2 + m_3}}$

Example 8d : $(F_{1,2} = F_{2,1} = ?)$

(1) $F - F_{2,1} - \mu_{k_2} F_{N_1} = m_1 a$ (2) $F_{1,2} - \mu_{k_2} F_{N_2} - f_{s_{3,2}} = m_2 a$

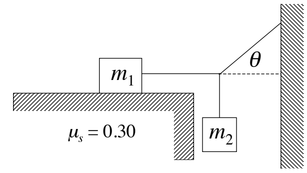
using (2) $F_{1,2} = \mu_{k_2} F_{N_2} + f_{s_{3,2}} + m_2 a$

$$F_{1,2} = \mu_{k_2}(m_2 + m_3)g + \frac{m_3\left(F - \mu_{k_2}(m_1 + m_2 + m_3)g\right)}{m_1 + m_2 + m_3} + m_2\left(\frac{F - \mu_{k_2}(m_1 + m_2 + m_3)g}{m_1 + m_2 + m_3}\right)$$

$$F_{1,2} = \mu_{k_2}(m_2 + m_3)g + (m_2 + m_3)\left(\frac{F - \mu_{k_2}(m_1 + m_2 + m_3)g}{m_1 + m_2 + m_3}\right)$$

$$F_{1,2} = (m_2 + m_3)\left(\mu_{k_2} g + \frac{F}{m_1 + m_2 + m_3} - \mu_{k_2} g\right)$$

$$F_{2,1} = \frac{F(m_2 + m_3)}{m_1 + m_2 + m_3}$$

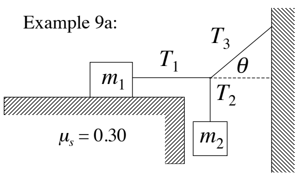


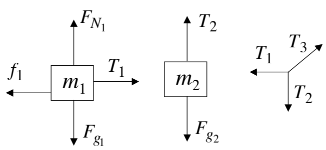
Example 9:

a.) Block 1 has a mass of 9 kg and the coefficient of static friction between the block and the surface on which it rests is 0.30. Block 2 has a mass of 1.5 kg, and the system is in static equilibrium. Find the friction force exerted on block 1 if the slanted cord has an angle $\theta = 53.13°$ with respect to the horizontal.

b.) Find the maximum value of m_2 for which the system will remain in equilibrium.

Example 9a:





$m_1 = 9$ kg, $\mu_s = 0.30$, $m_2 = 1.5$ kg, $\theta = 53.13°$, $f_1 = ?$

The system is in static equilibrium and all forces balance.

$\sum F_x = ma$

$T_1 - f_1 = 0$

(1) $f_1 = T_1$

$T_{3_x} - T_1 = 0$

$T_1 = T_{3_x} = T_3\cos\theta$

(2) $T_1 = T_3\cos\theta$

$\sum F_y = ma$

$F_{N_1} - F_{g_1} = 0$

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

$F_{g_2} - T_2 = 0$

(3) $T_2 = F_{g_2} = m_2 g$

$T_{3_y} - T_2 = 0$

$T_2 = T_{3_y} = T_3\sin\theta$

(4) $T_2 = T_3\sin\theta$

(from 3) $T_2 = m_2 g = (1.5\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = 15$ N

(from 4) $T_3 = \frac{T_2}{\sin\theta} = \frac{15\text{ N}}{\sin 53.13°} = 18.75$ N

Example 9a: $m_1 = 9$ kg, $\mu_s = 0.30$, $m_2 = 1.5$ kg, $\theta = 53.13°$, $f_1 = ?$

$\sum F_x = ma$

$T_1 - f_1 = 0$

(1) $f_1 = T_1$

$T_{3_x} - T_1 = 0$

$T_1 = T_{3_x} = T_3\cos\theta$

(2) $T_1 = T_3\cos\theta$

$\sum F_y = ma$

$F_{N_1} - F_{g_1} = 0$

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

$F_{g_2} - T_2 = 0$

(3) $T_2 = F_{g_2} = m_2 g$

$T_{3_y} - T_2 = 0$

$T_2 = T_{3_y} = T_3\sin\theta$

(4) $T_2 = T_3\sin\theta$

(from 3) $T_2 = m_2 g = (1.5\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = 15$ N

(from 4) $T_3 = \frac{T_2}{\sin\theta} = \frac{15\text{ N}}{\sin 53.13°} = 18.75$ N

(from 2) $T_1 = T_3\cos\theta = (18.75\text{ N})\cos 53.13° = 11.25$ N

(so from 1) $f_1 = T_1 = \boxed{11.25\text{ N}}$

Example 9b: $m_1 = 9$ kg, $\mu_s = 0.30$, $m_2 = 1.5$ kg, $\theta = 53.13°$, $f_1 = ?$

$\sum F_x = ma$

$T_1 - f_1 = 0$

(1) $f_1 = T_1$

$T_{3_x} - T_1 = 0$

$T_1 = T_{3_x} = T_3\cos\theta$

(2) $T_1 = T_3\cos\theta$

$\sum F_y = ma$

$F_{N_1} - F_{g_1} = 0$

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

$F_{g_2} - T_2 = 0$

(3) $T_2 = F_{g_2} = m_2 g$

$T_{3_y} - T_2 = 0$

$T_2 = T_{3_y} = T_3\sin\theta$

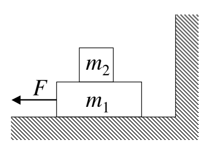
(4) $T_2 = T_3\sin\theta$

static limit is when $T_1 = f_{s_1} = \mu_s F_{N_1} = \mu_s m_1 g = 0.30(9\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = 27$ N

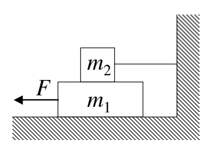
(from 2) $T_3 = \frac{T_1}{\cos\theta} = \frac{(27\text{ N})}{\cos 53.13°} = 45$ N

(from 4) $T_2 = T_3\sin\theta = (45\text{ N})\sin 53.13° = 36$ N

(so from 3) $m_2 = \frac{T_2}{g} = \frac{36\text{ N}}{10\ \frac{\text{m}}{\text{s}^2}} = \boxed{3.6\text{ kg}}$



(a)



(b)

Example 10:

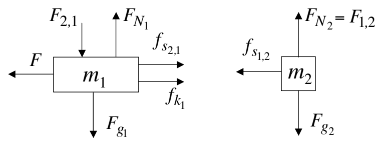
Block m_1 has a mass of 5.4 kg and block m_2 has a mass of 2.7 kg. The coefficient of kinetic friction between all surfaces is 0.25. Find the magnitude of the horizontal force $\boldsymbol{F}$ necessary to drag block m_1 to the left at constant speed

a.) if m_2 rests on m_1 and moves with it (a)

b.) if m_2 is held at rest (b).

Example 10a: $m_1 = 5.4\text{ kg},\ m_2 = 2.7\text{ kg},\ \mu_k = 0.25$
moving with constant speed $(a = 0)$, $F = ?$

a.) if m_2 rests on m_1 and moves with it (a)



$\sum F_x = ma$ (1) $F - f_{k_1} - f_{s_{2,1}} = 0$ (2) $f_{s_{1,2}} = 0$

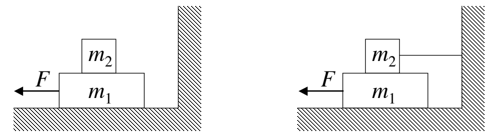
$\sum F_y = ma$ $F_{N_1} - F_{2,1} - F_{g_1} = 0$ $F_{N_2} - F_{g_2} = 0$

$F_{N_1} = F_{2,1} + F_{g_1}$ $F_{N_2} = F_{g_2} = m_2 g$

$F_{N_1} = m_1 g + m_2 g$ $F_{1,2} = F_{N_2} = m_2 g$

(3) $F_{N_1} = (m_1 + m_2) g$

$(1+2)$ $F - f_{k_1} = 0$ so $F = f_{k_1} = \mu_k F_{N_1} = \mu_k (m_1 + m_2) g =$ **20.25 N**



(a) (b)

Example 10:

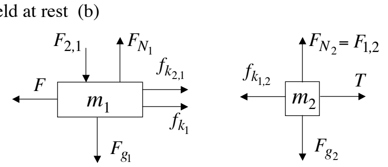
Block m_1 has a mass of 5.4 kg and block m_2 has a mass of 2.7 kg. The coefficient of kinetic friction between all surfaces is 0.25. Find the magnitude of the horizontal force $\boldsymbol{F}$ necessary to drag block m_1 to the left at constant speed

a.) if m_2 rests on m_1 and moves with it (a)

b.) if m_2 is held at rest (b).

Example 10b: $m_1 = 5.4\text{ kg},\ m_2 = 2.7\text{ kg},\ \mu_k = 0.25$
moving with constant speed $(a = 0)$, $F = ?$

b.) if m_2 is held at rest (b)



$\sum F_x = ma$ (1) $F - f_{k_1} - f_{k_{2,1}} = 0$ (2) $f_{k_{1,2}} - T = 0$

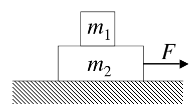
$\sum F_y = ma$ $F_{N_1} - F_{2,1} - F_{g_1} = 0$ $F_{N_2} - F_{g_2} = 0$

$F_{N_1} = F_{2,1} + F_{g_1}$ $F_{N_2} = F_{g_2} = m_2 g$

$F_{N_1} = m_1 g + m_2 g$ $F_{1,2} = F_{N_2} = m_2 g$

(3) $F_{N_1} = (m_1 + m_2) g$ $\left(f_{k_{2,1}} = f_{k_{1,2}}\right)$

(using 1) $F = f_{k_1} + f_{k_{2,1}} = \mu_k F_{N_1} + \mu_k F_{N_2} = \mu_k (m_1 + m_2) g + \mu_k m_2 g =$ **27 N**



Example 11:

A 2.0 kg block is placed on top of a 5.0 kg block as shown above. The coefficient of kinetic friction between the 5.0 kg block and the surface is 0.20. A horizontal force F is applied to the 5.0 kg block.

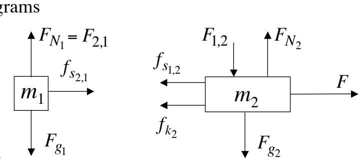
a.) Draw a free-body diagram for each block.

b.) Calculate the magnitude of the force necessary to pull both blocks to the right with an acceleration of 3.0 m/s^2.

c.) Find the minimum coefficient of static friction between the blocks such that the 2.0 kg block does not slip under the acceleration of 3.0 m/s^2.

Example 11: $m_1 = 2\text{ kg},\ m_2 = 5\text{ kg}$, between block 1 and surface $\mu_{k_2} = 0.2$

a.) Free-body diagrams



b.) $a = 3\ \dfrac{\text{m}}{\text{s}^2}$, $F = ?$

$\sum F_x = ma$ (1) $f_{s_{2,1}} = m_1 a$ (2) $F - f_{s_{1,2}} - f_{k_2} = m_2 a$

$\sum F_y = ma$ $F_{N_1} - F_{g_1} = 0$ $F_{N_2} - F_{1,2} - F_{g_2} = 0$

(3) $F_{N_1} = F_{g_1} = m_1 g$ $F_{N_2} = m_1 g + m_2 g = (m_1 + m_2) g$

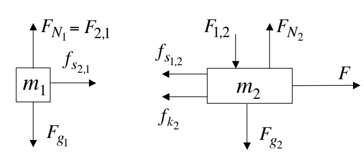
$(1+2)$ $F - f_{k_2} = (m_1 + m_2) a$ $\left(f_{s_{2,1}} = f_{s_{1,2}}\right)$

$$F = (m_1 + m_2) a + f_{k_2} = (m_1 + m_2) a + \mu_{k_2} F_{N_2} = (m_1 + m_2) a + \mu_{k_2} (m_1 + m_2) g$$

$$F = (2\text{ kg} + 5\text{ kg})\left(3\ \frac{\text{m}}{\text{s}^2}\right) + 0.2(2\text{ kg} + 5\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)$$

$$\boxed{F = 35\text{ N}}$$

Example 11: $m_1 = 2\text{ kg},\ m_2 = 5\text{ kg}$, between block 1 and surface $\mu_{k_2} = 0.2$



c.) $a = 3\ \dfrac{\text{m}}{\text{s}^2}$, $\mu_{s_{2,1}} = ?$

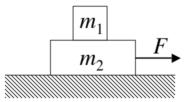
(1) $f_{s_{2,1}} = m_1 a$ (3) $F_{N_1} = F_{g_1} = m_1 g$

$$\mu_{s_{2,1}} F_{N_1} = m_1 a$$

$$\mu_{s_{2,1}} = \frac{m_1 a}{F_{N_1}} = \frac{m_1 a}{m_1 g}$$

$$\mu_{s_{2,1}} = \frac{a}{g} = \frac{3\ \frac{\text{m}}{\text{s}^2}}{10\ \frac{\text{m}}{\text{s}^2}}$$

$$\boxed{\mu_{s_{2,1}} = 0.30}$$



Example 12:

A block $m_1 = 2$ kg is placed on top of a block $m_2 = 4$ kg that is resting on a frictionless table as shown above. The coefficients of friction between the blocks are $\mu_s = 0.3$ and $\mu_k = 0.2$.

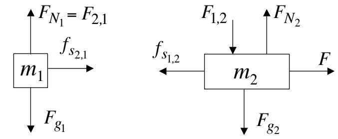
a.) What is the maximum force F that can be applied if the 2 kg block is not to slide on the 4 kg block?

b.) If F has half this value, find the acceleration of each block and the force of friction acting on each block.

c.) If F has twice the value found in (a), find the acceleration of each block.

Example 12: $m_1 = 2$ kg, $m_2 = 4$ kg, between blocks $\mu_s = 0.3$ and $\mu_k = 0.2$ frictionless table

a.) What is the maximum force F that can be applied if the 2 kg block is not to slide on the 4 kg block?



$\sum F_x = ma$ (1) $f_{s_{2,1}} = m_1 a$ (2) $F - f_{s_{1,2}} = m_2 a$

$\sum F_y = ma$ $F_{N_1} - F_{g_1} = 0$ $F_{N_2} - F_{1,2} - F_{g_2} = 0$

(3) $F_{N_1} = F_{g_1} = m_1 g$ $F_{N_2} = m_1 g + m_2 g$

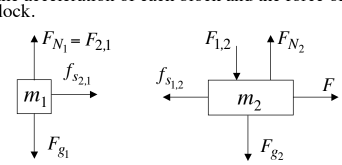
(at the static limit) $f_{s_{2,1}} = \mu_s F_{N_1} = \mu_s m_1 g = (0.3)(2\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right) = 6\text{ N}$

(using 1) $a = \frac{f_{s_{2,1}}}{m_1} = \frac{6\text{ N}}{2\text{ kg}} = 3\ \frac{\text{m}}{\text{s}^2}$ (using 2) $F = m_2 a + f_{s_{1,2}}$

$F = (4\text{ kg})\left(3\ \frac{\text{m}}{\text{s}^2}\right) + 6\text{ N} = \boxed{18\text{ N}}$

Example 12: $m_1 = 2$ kg, $m_2 = 4$ kg, between blocks $\mu_s = 0.3$ and $\mu_k = 0.2$ frictionless table

b.) If $F = 9$ N, find the acceleration of each block and the force of friction acting on each block.



$\sum F_x = ma$ (1) $f_{s_{2,1}} = m_1 a$ (2) $F - f_{s_{1,2}} = m_2 a$

$\sum F_y = ma$ $F_{N_1} - F_{g_1} = 0$ $F_{N_2} - F_{1,2} - F_{g_2} = 0$

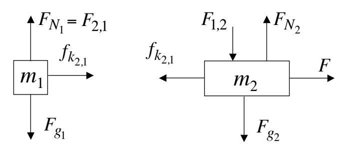
(3) $F_{N_1} = F_{g_1} = m_1 g$ $F_{N_2} = m_1 g + m_2 g$

(1+2) $F = (m_1 + m_2)a$ so $a = \frac{F}{m_1 + m_2} = \frac{9\text{ N}}{2\text{ kg} + 4\text{ kg}} = \boxed{1.5\ \frac{\text{m}}{\text{s}^2}}$

(using 1) $f_{s_{2,1}} = m_1 a = (2\text{ kg})\left(1.5\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{3\text{ N}}$

Example 12: $m_1 = 2$ kg, $m_2 = 4$ kg, between blocks $\mu_s = 0.3$ and $\mu_k = 0.2$ frictionless table

c.) If $F = 36$ N, find the acceleration of each block.



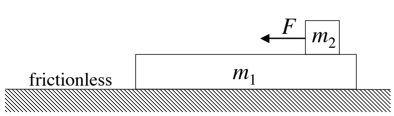
$\sum F_x = ma$ (1) $f_{k_{2,1}} = m_1 a_1$ (2) $F - f_{k_{1,2}} = m_2 a_2$

$\sum F_y = ma$ $F_{N_1} - F_{g_1} = 0$ $F_{N_2} - F_{1,2} - F_{g_2} = 0$

(3) $F_{N_1} = F_{g_1} = m_1 g$ $F_{N_2} = m_1 g + m_2 g$

(using 1) $a_1 = \frac{f_{k_{2,1}}}{m_1} = \frac{\mu_k F_{N_1}}{m_1} = \frac{\mu_k m_1 g}{m_1} = \mu_k g = (0.2)\left(10\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{2\ \frac{\text{m}}{\text{s}^2}}$

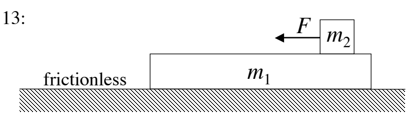
(using 2) $a_2 = \frac{F - f_{k_{2,1}}}{m_2} = \frac{F - \mu_k m_1 g}{m_2} = \frac{36\text{ N} - (0.2)(2\text{ kg})\left(10\ \frac{\text{m}}{\text{s}^2}\right)}{4\text{ kg}} = \boxed{8\ \frac{\text{m}}{\text{s}^2}}$



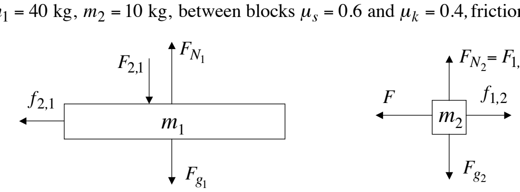
Example 13:

A 40 kg slab rests on a frictionless floor. A 10 kg block rests on top of the slab as shown above. The coefficient of static friction between the block and the slab is 0.60, whereas the kinetic coefficient is 0.40. The 10 kg block is pulled by a horizontal force with a magnitude of 100 N. What are the resulting accelerations of the block and the slab? Repeat if the force has a magnitude of 40 N.

Example 13:



$m_1 = 40$ kg, $m_2 = 10$ kg, between blocks $\mu_s = 0.6$ and $\mu_k = 0.4$, frictionless table



$\sum F_x = ma$ (1) $f_{2,1} = m_1 a_1$ (2) $F - f_{1,2} = m_2 a_2$

$\sum F_y = ma$ $F_{N_1} - F_{g_1} - F_{2,1} = 0$ $F_{N_2} - F_{g_2} = 0$

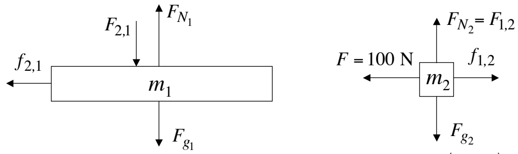
$F_{N_1} = F_{g_1} + F_{2,1}$ (3) $F_{N_2} = F_{g_2} = m_2 g$

$F_{N_1} = F_{g_1} + F_{g_2}$

$F_{N_1} = (m_1 + m_2)g$

Example 13:

$m_1 = 40$ kg, $m_2 = 10$ kg, between blocks $\mu_s = 0.6$ and $\mu_k = 0.4$, frictionless table



(find the static limit) $f_{s_{1,2}} = \mu_s F_{N_2} = \mu_s m_2 g = (0.6)(10 \text{ kg})\left(10 \ \frac{\text{m}}{\text{s}^2}\right) = 60$ N

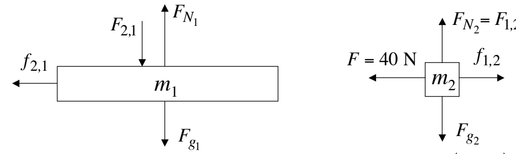
when $F = 100$ N the static limit is exceeded and block m_2 moves relative to slab m_1 therefore, the value of the friction between the blocks is the kinetic value and $f_{1,2} = f_{k_{1,2}}$

$$f_{1,2} = f_{k_{1,2}} = \mu_k F_{N_2} = \mu_k m_2 g = (0.4)(10 \text{ kg})\left(10 \ \frac{\text{m}}{\text{s}^2}\right) = 40 \text{ N}$$

$$(1) \quad a_1 = \frac{f_{2,1}}{m_1} = \frac{40 \text{ N}}{40 \text{ kg}} = \boxed{1 \ \frac{\text{m}}{\text{s}^2}} \qquad (2) \quad a_2 = \frac{F - f_{1,2}}{m_2} = \frac{100 \text{ N} - 40 \text{ N}}{10 \text{ kg}} = \boxed{6 \ \frac{\text{m}}{\text{s}^2}}$$

Example 13:

$m_1 = 40$ kg, $m_2 = 10$ kg, between blocks $\mu_s = 0.6$ and $\mu_k = 0.4$, frictionless table



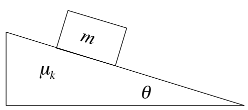
(find the static limit) $f_{s_{1,2}} = \mu_s F_{N_2} = \mu_s m_2 g = (0.6)(10 \text{ kg})\left(10 \ \frac{\text{m}}{\text{s}^2}\right) = 60$ N

$F = 40$ N is below the static limit so blocks m_2 and m_1 move together and $a_1 = a_2 = a$.

$$\sum F_x = ma \qquad (1) \quad f_{2,1} = m_1 a \qquad (2) \quad F - f_{1,2} = m_2 a$$

$$(1+2) \quad F = (m_1 + m_2)a \quad \text{so} \quad a = \frac{F}{m_1 + m_2} = \frac{40 \text{ N}}{(40 \text{ kg} + 10 \text{ kg})} = \boxed{0.8 \ \frac{\text{m}}{\text{s}^2}}$$

using (1) $f_{2,1} = m_1 a = (40 \text{ kg})\left(0.8 \ \frac{\text{m}}{\text{s}^2}\right) = 32$ N which is less than the static limit



Example 14:

A box is held at rest on an incline as shown above.

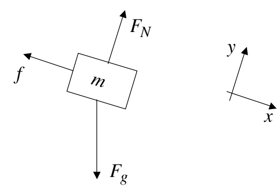
a.) Find the acceleration of the box if it is allowed to slide down the incline.

b.) What force (parallel to the incline) should be applied to the box if the box is to slide down the incline at a constant velocity?

c.) What force (parallel to the incline) should be applied to the box if the box is to move up the incline with an acceleration of a?

Example 14a:

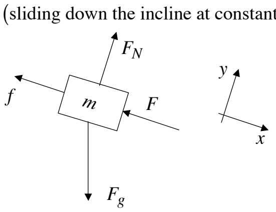
Sliding down the incline $a = ?$



$$\sum F_x = ma$$
$$F_{//} - f_k = ma$$
$$F_g \sin\theta - \mu_k F_N = ma$$
$$mg\sin\theta - \mu_k mg\cos\theta = ma$$
$$\boxed{a = g\sin\theta - \mu_k g\cos\theta}$$

$$\sum F_y = ma$$
$$F_N - F_\perp = 0$$
$$F_N = F_\perp = F_g\cos\theta$$
$$F_N = mg\cos\theta$$

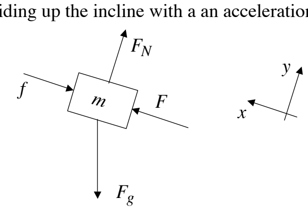
Example 14b: $a = 0$ (sliding down the incline at constant velocity $F = ?$)



$$\sum F_x = ma$$
$$F_{//} - F - f_k = 0$$
$$F_g \sin\theta - F - \mu_k F_N = 0$$
$$F = F_g \sin\theta - \mu_k F_N$$
$$\boxed{F = mg\sin\theta - \mu_k mg\cos\theta}$$

$$\sum F_y = ma$$
$$F_N - F_\perp = 0$$
$$F_N = F_\perp = F_g\cos\theta$$
$$F_N = mg\cos\theta$$

Example 14c: (sliding up the incline with a an acceleration a, $F = ?$)



$$\sum F_x = ma$$
$$F - F_{//} - f_k = ma$$
$$F - F_g \sin\theta - \mu_k F_N = ma$$
$$F = ma + F_g \sin\theta + \mu_k F_N$$
$$\boxed{F = ma + mg\sin\theta + \mu_k mg\cos\theta}$$

$$\sum F_y = ma$$
$$F_N - F_\perp = 0$$
$$F_N = F_\perp = F_g\cos\theta$$
$$F_N = mg\cos\theta$$