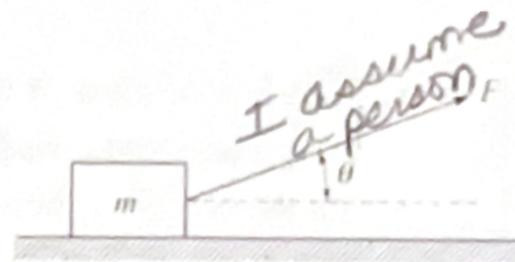


3. A sofa of mass  $m$  is pulled across a rough horizontal surface at constant speed by a force of magnitude  $F$ , which acts at an angle of  $\theta$  to the horizontal, as shown. Derive a symbolic expression for the coefficient of kinetic friction between the sofa and the surface in terms of the given variables and fundamental constants.



$\mu_k$

$$\Sigma F_{msx} = 0 \text{ and } \Sigma F_{ansy} = 0$$

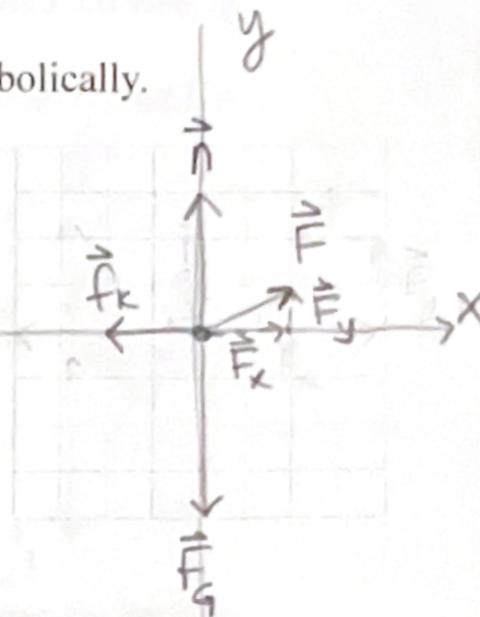
$$a_{sx} = 0 \text{ and } a_{sy} = 0$$

$$\Delta \vec{v} = 0$$

a. Sort the cards

b. Draw a motion diagram. Draw a force diagram and complete the organizer symbolically.

$\vec{F}$	by ___ on ___	$F_x$	$F_y$
$\vec{F}_G$	Earth on sofa	$F_{Gx} = 0$	$F_{Gy} = -m_s g$
$\vec{n}$	surface on sofa	$n_x = 0$	$n_y = +n$
$\vec{F}$	person on sofa	$F_x = +F \cos \theta$	$F_y = +F \sin \theta$
$\vec{f}_k$	surface on sofa	$f_{kx} = -f_k = -\mu_k n$	$f_{ky} = 0$



c. Represent mathematically and derive the symbolic expression.

$$a_{sx} = \frac{\Sigma F_{onsx}}{m_s}$$

$$0 = \frac{0 + 0 + F \cos \theta - \mu_k n}{m_s}$$

$$0 = F \cos \theta - \mu_k n$$

$$\mu_k = \frac{F \cos \theta}{n} \quad \text{--- (1)}$$

$\rightarrow$   $n$  is not a given variable, so I need an expression for  $n$ . I can get this using the  $y$ -direction of Newton's second law:

$$a_{sy} = \frac{\Sigma F_{onsy}}{m_s}$$

$$0 = \frac{-m_s g + n + F \sin \theta + 0}{m_s}$$

$$n = m_s g - F \sin \theta$$

Substitute this into (1), getting:

$$\mu_k = \frac{F \cos \theta}{m_s g - F \sin \theta}$$

d. Calculate the coefficient of kinetic friction if the sofa weighs 300 lbs (1334 N), and the force is 729 N at an angle of  $38^\circ$ .

$$\mu_k = \frac{F \cos \theta}{m_s g - F \sin \theta}$$

$$= \frac{(729 \text{ N}) \cos 38^\circ}{(1334 \text{ N}) - (729 \text{ N}) \sin 38^\circ} = \frac{574.46 \text{ N}}{1334 \text{ N} - 448.82 \text{ N}} = \boxed{0.65}$$

sofa: 1334 N is its weight, this is  $F_G$ . So this is equal to  $m_s g$ .

e. Suppose the magnitude of the force  $F$  is increased, but the angle  $\theta$ , mass, and surfaces remain the same. Once you have made your decisions, come explain your reasoning to me.

- Does this cause the normal force to increase, decrease, or stay the same?

$\vec{n}$  decreases

- Does this change cause the kinetic friction force to increase, decrease, or stay the same?

$f_k$  decreases

- Does this change cause the sofa's motion to be constant velocity or constant acceleration?

constant acceleration ( $\vec{a} \neq 0$ )