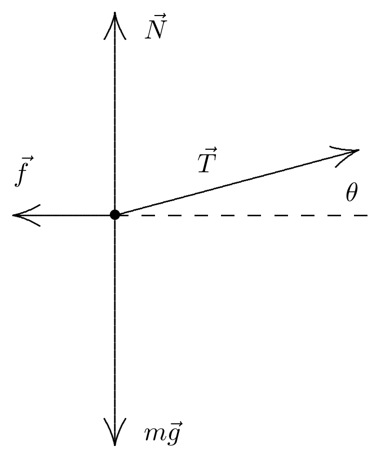
13. (a) The free-body diagram for the crate is shown below. $\vec{T}$ is the tension force of the rope on the crate, $\vec{N}$ is the normal force of the floor on the crate, $m\vec{g}$ is the force of gravity, and $\vec{f}$ is the force of friction. We take the $+x$ direction to be horizontal to the right and the $+y$ direction to be up. We assume the crate is motionless. The x component of Newton's second law leads to $T\cos\theta - f = 0$ and the y component becomes $T\sin\theta + N - mg = 0$, where $\theta = 15°$ is the angle between the rope and the horizontal.

The first equation gives $f = T\cos\theta$ and the second gives $N = mg - T\sin\theta$. If the crate is to remain at rest, f must be less than $\mu_s N$, or $T\cos\theta < \mu_s(mg - T\sin\theta)$. When the tension force is sufficient to just start the crate moving, we must have $T\cos\theta = \mu_s(mg - T\sin\theta)$. We solve for the tension:

$$\begin{aligned} T &= \frac{\mu_s mg}{\cos\theta + \mu_s \sin\theta} \\ &= \frac{(0.50)(68)(9.8)}{\cos 15° + 0.50\sin 15°} \\ &= 304 \approx 300 \text{ N} . \end{aligned}$$



(b) The second law equations for the moving crate are $T\cos\theta - f = ma$ and $N + T\sin\theta - mg = 0$. Now $f = \mu_k N$. The second equation gives $N = mg - T\sin\theta$, as before, so $f = \mu_k(mg - T\sin\theta)$. This expression is substituted for f in the first equation to obtain $T\cos\theta - \mu_k(mg - T\sin\theta) = ma$, so the acceleration is

$$a = \frac{T(\cos\theta + \mu_k \sin\theta)}{m} - \mu_k g$$

which we evaluate:

$$a = \frac{(304\,\text{N})(\cos 15° + 0.35\sin 15°)}{68\,\text{kg}} - (0.35)(9.8\,\text{m/s}^2) = 1.3\,\text{m/s}^2 .$$