13. (a) The free-body diagram for the crate is shown below. $\vec{T}$ is the tension force of the rope on the crate, $\vec{F}_N$ 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 equations for the x and the y components of the force according to Newton's second law are:

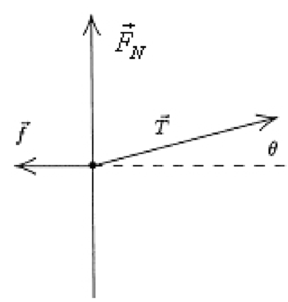
$$T\cos\theta - f = 0$$
$$T\sin\theta + F_N - mg = 0$$

where $\theta = 15°$ is the angle between the rope and the horizontal. The first equation gives $f = T\cos\theta$ and the second gives $F_N = mg - T\sin\theta$. If the crate is to remain at rest, f must be less than $\mu_s F_N$, 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:

$$T = \frac{\mu_s mg}{\cos\theta + \mu_s\sin\theta} = \frac{(0.50)(68)(9.8)}{\cos 15° + 0.50\sin 15°} = 304 \approx 3.0\times10^2\ \text{N}.$$



(b) The second law equations for the moving crate are

$$T\cos\theta - f = ma$$
$$F_N + T\sin\theta - mg = 0.$$

Now $f = \mu_k F_N$, and the second equation gives $F_N = mg - T\sin\theta$, which yields $f = \mu_k(mg - T\sin\theta)$. 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

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

Numerically, it is given by

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