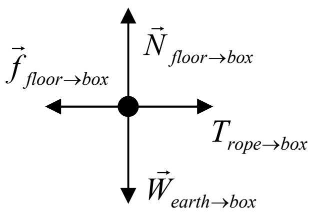
Problem 5 (20 points)

a. Need free body diagrams to see this. Since v = constant, $F^{net} = 0$ for both the rope and the crate (Newton's first law of motion). Let's assume that the magnitude of the tension in the rope is constant so that $T_{box\to rope} = T_{rope\to box} = T_{worker\to rope}$



$\vec{F}^{Net} = 0$

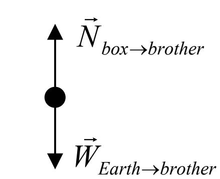
Since the net force = 0, the horizontal forces acting on the box add up to zero. Since there are only two of them, these two forces are equal in magnitude and opposite in direction. Thus, the force that the worker exerts is equal in magnitude and opposite in direction to the friction force exerted by the floor on the box. The magnitude of this friction force = $\mu N_{floor\to box}$. However, since the normal force is one of only two vertical forces acting on the box with the other force being the Weight force exerted by the Earth on the box, the two vertical forces are of equal magnitude. Therefore

$T_{worker\to rope} = f_{floor\to box} = \mu N_{floor\to box} = \mu W_{Earth\to box} = \mu mg$ and

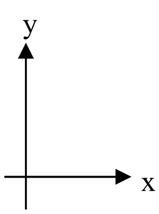
The force exerted by the worker on the rope points to the right.

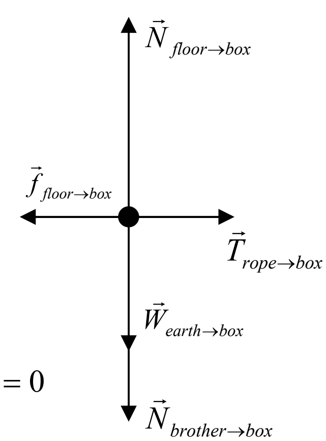
b. Yes, how hard the worker pulls does depend on whether or not her little brother is on top. As we showed above, how hard the worker pulls depends on the strength of the normal force exerted by the floor on the box. As we saw in the two-book problem in class, placing the little brother on top of the box increases the normal force the floor exerts on the box. Looking at the forces acting on the box, the net force on the box is zero since it is stationary and not moving. So the normal force of the floor on the box must be equal in magnitude to the weight force of the Earth on box plus the normal force of the little brother on the box. Since the weight force on the box has not changed, the normal force exerted by the floor on the box is larger than if the brother were removed. (See the free body diagrams in part c). This increases the frictional force exerted by the floor on the box, which means the worker must pull harder to keep the box moving with constant velocity.

c.



$\vec{F}^{Net} = 0$





$\vec{F}^{Net} = 0$

$T_{wkr\to rope} = 300$ N

Since $\vec{F}^{Net} = 0$, then $F_x^{Net} = F_y^{Net} = 0$

For little brother,

$0 = F_y^{Net} = \vec{N}_{y\ box\to brother} + \vec{W}_{y\ Earth\to brother}$

$\vec{N}_{y\ bx\to br} = -\vec{W}_{y\ E\to br} = -(-m_{br}g) = m_{br}g$

From Newton's 3rd law of motion

$\vec{N}_{y\ br\to bx} = -\vec{N}_{y\ bx\to br} = -m_{br}g$

For the box

$0 = F_y^{Net} = \vec{N}_{y\ f\to bx} + \vec{N}_{y\ br\to bx} + \vec{W}_{y\ E\to bx}$

$\vec{N}_{y\ f\to bx} = -\vec{N}_{y\ br\to bx} - \vec{W}_{y\ E\to bx}$

$\vec{N}_{y\ f\to bx} = -(-m_{br}g) - (-m_{bx}g) = (m_{br} + m_{bx})g$

$T_{wrkr\to rope} = f_{fl\to bx} = \mu\left|\vec{N}_{y\ fl\to bx}\right| = \mu(m_{br} + m_{bx})g$

$T_{wkr\to rope} = (0.4)\ [(30\text{ kg}) + (50\text{ kg})]\ (9.8\text{ m/s}^2)$