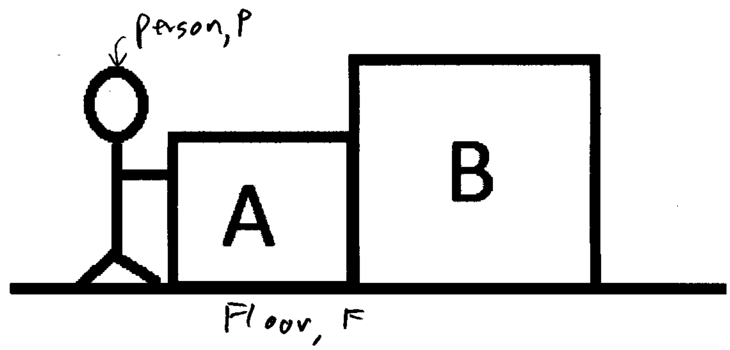
Quiz: Standard Problems 4. Newton's Second Law: Multiple Objects, No Vector Components

Name: Solution Lab section (circle one): 9am 11am

Useful Equations:

$F_{net} = ma$ $f_s \leq \mu_s n$ $f_k = \mu_k n$ $f_r = \mu_r n$ $w = mg$

The worker pushes the two blocks as shown to the right. Block A is made of very slippery ice, which has negligible friction with all surfaces. Block B is made of wood, and has a coefficient of kinetic friction of 0.50 with the floor. The mass of block A is 4.0 kg and the mass of block B is 6.0 kg.

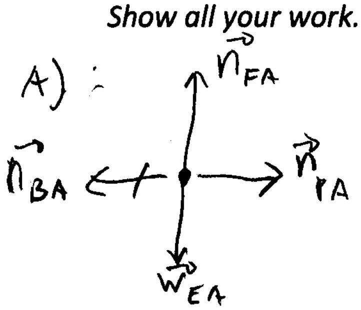


a) If the worker pushes with a force of 50 N, what is the acceleration of the blocks?

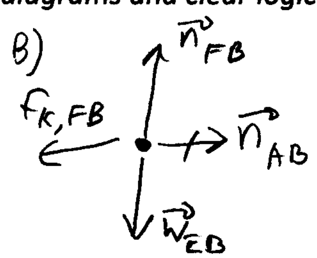
b) What are the magnitudes of the normal forces between the blocks when the worker pushes with a force of 50 N?

Show all your work. Free body diagrams and clear logic are required.

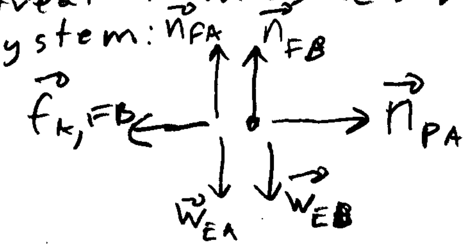
a) A):



B)



Both will move together, so it's also useful to treat them as a single system:



Looking at the system's FBD, all we need is to find $f_{K,FB}$. This appears in the FBD for B. We know $f_{K,FB} = \mu_K n_{FB}$.

In B, $F_{net,y} = n_{FB} - W_{EB} = m a_{By} = 0$ because B will not go up or down

So $n_{FB} = W_{EB} = m_B g$. So $f_{K,FB} = \mu_K m_B g$.

Now looking at the system, $n_{PA} - f_{KFB} = m_{A+B} a_x$

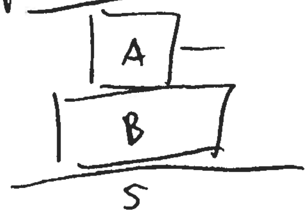
$$\Rightarrow a_x = \frac{n_{PA} - \mu_K m_B g}{m_A + m_B} = \frac{50N - (0.5)(6\,kg)(9.8\,m/s^2)}{4\,kg + 6\,kg} = 2.06\ m/s^2$$

b) Now look at A: $F_{net,x} = n_{PA} - n_{BA} = m_A a_x$

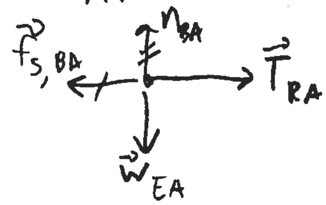
$\Rightarrow n_{BA} = n_{PA} - m_A a_x = 50N - (4\,kg)(2.06\,m/s^2) = 41.76\,N$

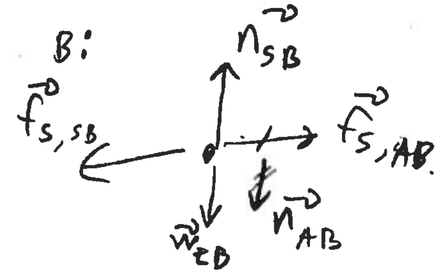
which is the mag. of n_{AB} as well b/c of the 3rd law.

2. $\boxed{\text{O and P}}$

a) 

If they are not moving

A: 

B: 

The movement will start either when block A slides alone or when block B starts sliding on the lower surface. We need to find which surface will slip first

$\boxed{\text{Solve}}$ From the FBDs we can see that sliding between A and B will occur when $T_{RA} \geq f_{s,BA,max}$

$f_{s,BA,max} = \mu_s n_{BA}$; and since A does not accelerate up or down $n_{BA} - W_{EA} = 0 \Rightarrow n_{BA} = W_{EA} = m_A g$.

So ~~the blocks with~~ block A alone will slide if

$T_{RA} \geq \mu_s m_A g = 19.6N$

but will the surface between B and S slide first?

Before there is any movement, $f_{s,BA} = T_{RA} = f_{s,AB}$

If $f_{s,AB}$ exceeds $f_{s,SB}$, then ~~the~~ block B will start to slide $f_{s,SB,max} = \mu_s n_{SB}$ From the FBD,

$n_{SB} - W_{EB} - n_{AB} = m_B a_y = 0$. $n_{AB} = W_{EA}$, from above,

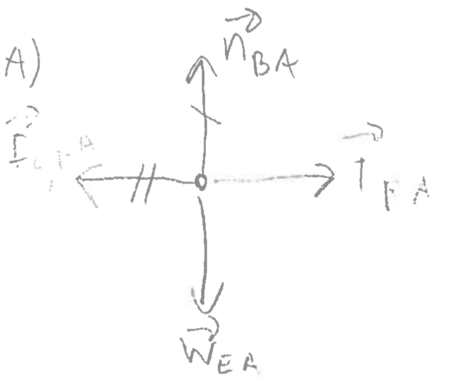
so $n_{SB} = W_{EB} + W_{EA} = (m_A + m_B) g = 68.6N$

so $f_{s,SB,max} = \mu_s n_{SB} = 13.72 N$

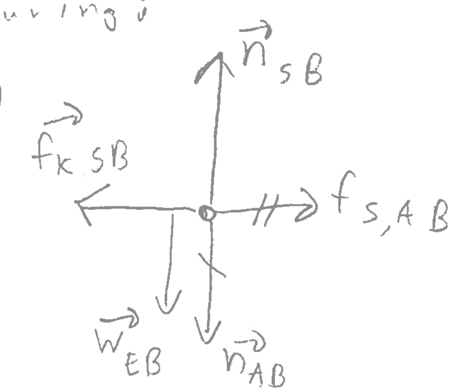
So this surface will start sliding first, as soon as the applied force reaches 13.72N.

b) $\boxed{10\ pt}$ Now that we have established that both blocks mutually slide together, draw FBDs for when this is occuring:

A)



B)



as T_{RA} increases, the accel of the whole system increases. ~~Eventually~~ As that happens, $f_{S,AB}$ will have to increase (to keep upping the accel of block B). ~~$f_{s,BA}$ must also increase~~ At some point they will reach the maximum possible static friction force, so exceeding this force will cause A to slide relative to B. Let's analyze B to find the acceleration at which $f_{S,AB}$ is maximum, then use that accel. to find the corresponding tension.

$\boxed{\text{Solve}}$ Looking at B:

$$F_{net,x} = f_{S,AB} - f_{KSB} = m_B a_{Bx}$$

$$F_{net,y} = n_{SB} - W_{EB} - n_{AB} = m_B a_{By} = 0$$

Now if $f_{S,AB}$ is maxed out, $f_{S,AB} = \mu_{S(AB)} n_{AB}$

From part a we still have $n_{AB} = m_A g$

and $n_{SB} = (m_A + m_B) g$. So, using also $f_{K,SB} = \mu_{KSB} n_{SB}$ and subbing in to the x-Newton's law eqn gives

$$\mu_{SAB} m_A g - \mu_{KSB} (m_A + m_B) g = m_B a_{Bx,max}$$

b. continued

so $a_{B,x,max} = \dfrac{\mu_{sAB}\, m_A g - \mu_{kSB}(m_A + m_B) g}{m_B}$

$= \dfrac{0.5 \cdot 4\,kg \cdot 9.8\,m/s^2 - 0.1\,(7\,kg)(9.8\,m/s^2)}{3\,kg}$

$a_{B,x,max} = 4.25\ m/s^2$.

This is the max accel the static friction can provide. Analyzing block A at this juncture gives $T_{RA} - f_{sBA} = m_A a_{Ax}$

since $f_{sBA} = f_{sAB}$ and up till this point $a_{Ax} = a_{Bx}$,

$T_{RA} - f_{sAB,max} = m_A a_{B,x,max}$

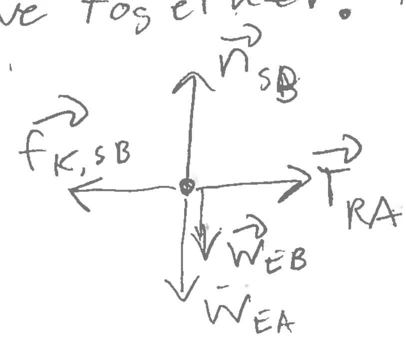
$T_{RA} = m_A a_{B,x,max} + f_{sAB,max}$

$= (4\,kg)(4.24\,m/s^2) + \cancel{0.3}\ 0.5 \cdot 4\,kg \cdot 9.8\,m/s^2$

$= \cancel{28.7\,N}$. 36.6 N

c) O+P

From above, we know that at ZON, ~~those~~ both blocks move together. Treat them as one system: (the internal forces don't show up on the FBD).



Solve N's 2nd gives

$F_{net,x} = T_{RA} - f_{kSB} = (m_A + m_B)\, a_x$

$F_{net,y} = n_{SB} - W_{EA} - W_{EB} = (m_A + m_B)\, a_y = 0$

so $n_{SB} = W_{EA} + W_{EB}$

$n_{SB} = (m_A + m_B) g$

and

$f_{kSB} = \mu_k (m_A + m_B) g$

so $F_{net,x} = T_{RA} - f_{K,SB} = (M_{A+B})a_x$

$$\Rightarrow a_x = \frac{20N - 6.86N}{7kg} = 1.88 \ m/s^2$$

$\boxed{\text{Reflect}}$ We had to consider two different possibilities in part a. In part b, we had to consider very carefully when the two blocks would slide relative to each other even as they were accelerating.