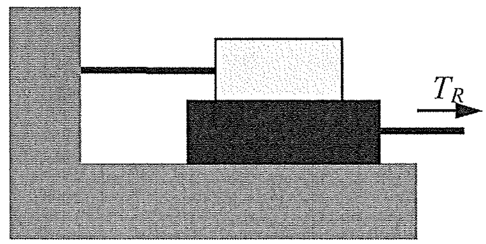
Discussion 5a : Newton's Laws of Motion and Forces

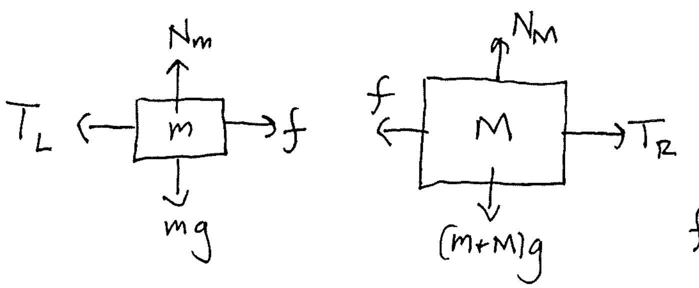
Name: Cool J. Student

Goal: To be able to apply Newton's laws of motion and to understand forces, in particular, friction and tension.

A) A 3.0 kg block sits atop a 10.0 kg block and, initially, both are at rest. There is friction at the interface **between** the two blocks and the coefficients of static and kinetic friction are 0.60 and 0.50 respectively (but no friction anywhere else). The top block is anchored to the left wall by a horizontal, massless & inflexible rope. There is a tension force, T_R, (to the right) applied by another horizontal rope attached to the bottom block. Gravity, with g = 10 m/s^2, acts in the vertical direction.



1) If the tension in the right rope is 10 N, what is the tension in the left rope?



Note: N_m + f are internal forces, so 3rd Law (Equal + opposite)

Is this moving? Test static friction

$f_s^{Max} = \mu_s N_m = 0.6 \cdot 3 \cdot 10 = 18N$

$T_R < 18N$ so Not moving

so $f = T_R = T_L$

2) With respect to question 1, what is the friction force by the top block on the bottom block?

$f = f_s = T_R = \boxed{10N}$

3) What tension in the right rope would the bottom block move?

The max ~~static~~ static fiction show the threshold so $T_R \geq 18N$

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4) Now the tension in the right rope is increased to 20 N. What is the tension in the left rope?

With new tension $T_R = 20N$, $T_R > f_s^{Max}$ so block moves, so go to kinetic friction regime

$f_K = \mu_K N_m = 0.5 \cdot 3 \cdot 10 = 15N$

From our FBD, the $F_L = f_k$ because the top block is anchored to the wall so

$\boxed{F_L = 15N}$

5) With respect to question 3 above, what is the friction force by the top block on the bottom block?

$\boxed{f_K = 15N}$

6) What is the resulting acceleration of the bottom block?

Reading off our FBD with a to the right:

$T_L - f_K = Ma$

$20 - 15 = 10a$

$5 = 10a$

$\boxed{a = 0.5 \, m/s^2}$

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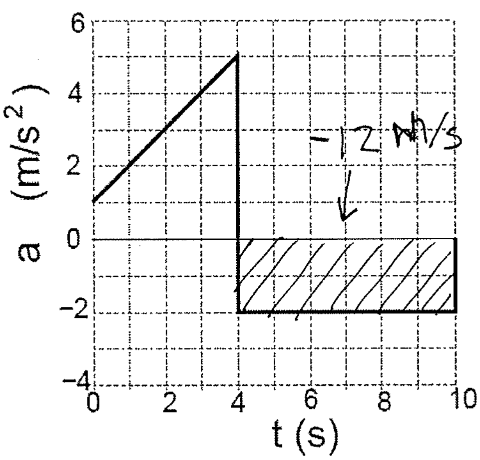
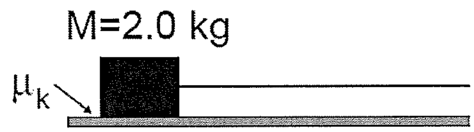
B) You have a 2.0 kg block that moves on a linear path on a horizontal surface. The block is initially pulled to the right. The coefficient of kinetic friction between the block and the path is μ_k. Attached to the block is a horizontally mounted massless string as shown in the figure below. The block includes an accelerometer which records acceleration *vs.* time. As you increase the tension in the rope the block experiences an increasingly positive acceleration. At some point in time the rope snaps and then the block slides to a stop (at a time of 10 seconds). Gravity, with g = 10. m/s^2, acts downward.



Watch out! Don't know if start from rest!



1) At what time does the string break?

From the diagram, we can see the change at

$t = 4\,s$

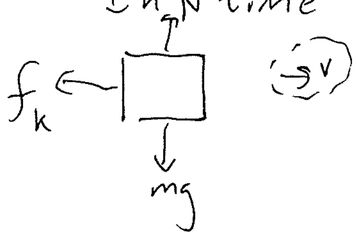
2) What speed did the block have when the string broke?

We know $\int a\,dt = \Delta v$. and the block stops at t=10s, so we integrate (take the area) of [4, 10]

$\int_4^{10} a\,dt = -12 = 0 - v_i$ or $v_i = 12\ m/s$

3) What is the value of μ_k?

In time $t \in [4, 10]$ our forces are



so $f_k = ma = \mu N = mg\mu_k$ or

$\mu_k = \frac{a}{g} = \frac{+2}{10} = 0.2$

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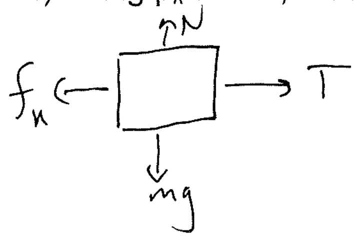
4) Using μ_k above, what was the tension in the string at t = 2.0 seconds?

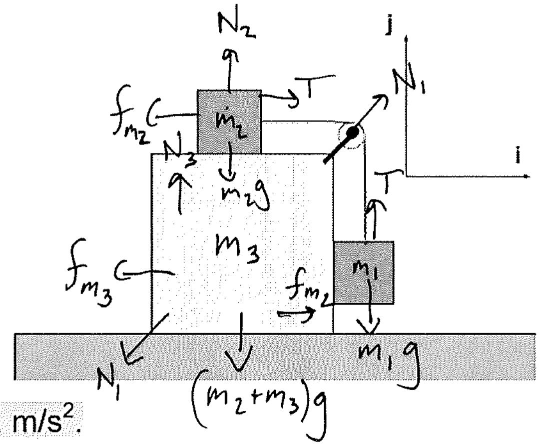


$T - f_k = ma \Rightarrow f_k = \mu_k mg$

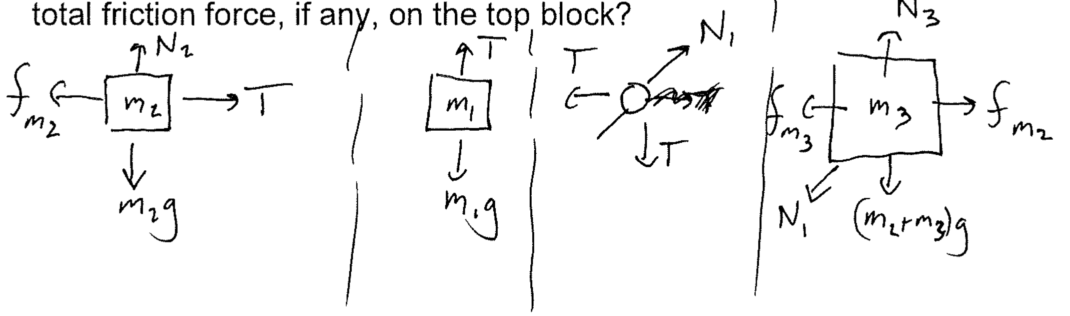
$T = ma + \mu mg = m(a + \mu g)$

$T = 2(3 + 0.2 \cdot 10) = 2(3 + 2) = \boxed{10\,N}$

C) Three masses are arranged in a fashion as depicted in the figure. A 6.0 kg mass sits atop a larger 9.0 kg mass which itself sits on a horizontal table top. A third, 3.0 kg mass hangs vertically just barely touching the right face of the large mass. A massless inflexible string connects the hanging mass to the top mass passing over a frictionless pulley (P). All horizontal surfaces have coefficients of static and kinetic friction of 0.80 and 0.40 respectively. All vertical surfaces are frictionless. Let g=10. m/s².



1) At first all the blocks are stationary. What is the magnitude and direction of the total friction force, if any, on the top block?



$f_{m_2} = T$ and

$T = m_1 g = 3 \cdot 10 = 30N$

$\boxed{f_{m_2} = 30N}$

2) What is the magnitude and direction of the total friction force on the large mass, if any, at the interface between the table top (ground or "G") and this mass?

So asking about $f_{m_3} = f_{m_2} - N_1 \sin 45^\circ$ but

$N_1 \sin(45^\circ) = T = 30N$ so $\boxed{f_{m_3} = 30 - 30 = 0\,N}$

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There is a little tap directly down on the hanging mass, just enough to cause this block to slide. Assume this motion applies to questions 3, 4 and 5 below.

3) The 9.0 kg mass does not move. What is the acceleration of m_2; tension now in the string?

acceleration of m_1 + m_2 are the same so reading off FBD

$$a = \frac{3 \cdot 10 - 0.4 \cdot 6 \cdot 10}{3+6} = \frac{30-24}{9} = \boxed{0.667\ m/s^2}$$

$$m_1 g - T = m_1 a$$

$$+ \quad -f_K + T = m_2 a$$

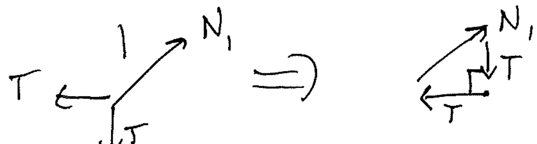
$$m_1 g - \mu_K m_2 g = (m_1 + m_2) a$$

$$T = m_1 g - m_1 a = 3(10 - 0.667) = \boxed{28\ N}$$

4) What is the magnitude of the net **horizontal** force on the pulley? What is the magnitude of net force on the support rod (S) by the pulley?

Since the pulley doesn't move, the net is $\boxed{0\ N}$

The F_{net} of support rod by the pulley is what is labelled N_1



or $N_1 = \sqrt{T^2 + T^2} = \sqrt{2} \cdot T = \sqrt{2} \cdot 28$ $\boxed{= 39.6\ N}$

5) What is the magnitude and direction of the total friction force on the large mass, if any, at the interface between the table top and this mass?

Again

$$f_{m_3} = f_{m_2} - N_1 \sin 45°$$

but $N_1 \sin 45° = T = 28N$

$f_{m_2} = \mu_K N_2$ since moving

$$f_{m_3} = 24 - 28 = -4N$$

So actually $\boxed{4N}$ to the right!

(negative means opposite direction of where arrow drawn)