P11. Two Blocks, Tension Forces, Difficulty: Medium, Exam class question: Yes.

Note: This is problem 5-2 from RWB In-Class Notes for Physics 121

Problem 5-2 Two blocks with masses as shown and on a frictionless horizontal surface are connected by a light rope. Assume the force magnitudes $F_1$, $F_2$ and masses $m_1$, $m_2$ are known, along with the directions of the forces as shown.

a) Before you start, what would you guess the tension $T$ would be if $F_1 = F_2$? Don’t calculate, just guess. You will get full credit for any honest guess. You can check this below when you’re done calculating.

Now consider any two of the following three systems: the whole system, the isolated system $m_1$, or the isolated system $m_2$.

b) Draw FBD’s for the two systems you consider. Remember, each FBD involves ONLY those forces DIRECTLY on the considered body.

We take this opportunity to remind you that you don’t have to know which force arrows are longer. We haven’t told you yet who is bigger – $F_1$ or $F_2$.

c) Derive two equations from a consideration of the horizontal forces in your FBD’s using the convention that the common acceleration $a$ is defined to the right.* If the system turns out to be accelerating to the left, a will be negative.

d) Solve your two equations for $a$ and $T$ in terms of $F_1$, $F_2$, $m_1$, and $m_2$. Check your formula for $a$: $a$ must be positive if $F_1 < F_2$ (the system would accelerate to the right) and $a$ must be negative if $F_1 > F_2$ (acceleration is to the left).

e) Now assume $F_1 = F_2$ in your answer in (d) and see if your guess in (a) was right. If it was wrong, try hard to analyze why, so your physics intuition can be strengthened.

Guessing is always a good self-disciplinary step. We have our own pre-conceptions and, if they fail to match up with the world around us, we need to work really hard to reshape them. (Of course, if your own private world is really much nicer than the one described in these notes, frankly, you might like to keep it just as it is.)

f) Finally, independent of whether $F_1 = F_2$, what is the net force on any part of the in-between rope with tension $T$ in it? This answer should also help you in building an intuition about the meaning of tension and questions like (a)!

Solution by RWB on Next Page...
Solution to Problem P11: (by RWB)

a) Whatever we guess, it better leave $F_{\text{net}} = 0$ for either mass!
The answer is not $2F_1$.

Let do all three systems to check ourselves

overall $F_1 \rightarrow m_1 \rightarrow F_2 \Rightarrow F_2 - F_1 = (m_1 + m_2) a \Rightarrow a = \frac{F_2 - F_1}{m_1 + m_2}$

$m_1 \rightarrow \frac{m_1}{m_1 + m_2} \rightarrow T \Rightarrow T - F_1 = m_1 a \Rightarrow T = F_1 + F_2 - F_1 = m_1 a \Rightarrow T = \frac{m_1 F_2 - F_1}{m_1 + m_2} = \frac{m_2 F_1 + m_1 F_2}{m_1 + m_2}$

$m_2 \rightarrow \frac{m_2}{m_1 + m_2} \rightarrow F_2 = F_2 - T = m_2 a \Rightarrow T = F_2 - m_2 a = \text{same}$

Notice if you add second third equation.

If you add left side, you must get same when you add right sides.

NOTICE SYMMETRY WITH PROBLEM 5-1

Mathematically let $F = F_2 - F_1 = F_1$, $m_1 \rightarrow m_2$,

$F_{1 \rightarrow 2} = F_{2 \rightarrow 1} \rightarrow T$

e) $F_1 = F_2 \Rightarrow T = \frac{m_1 + m_2}{m_1 + m_2} F = F$

$a = 0$ (Yes, must balance $F_{\text{net}} = 0$ for each $m_1, m_2$)

can double answer will help understand especially

$f) F_{\text{net}}$ (piece of rope) $= T - T = 0$

$T = T$