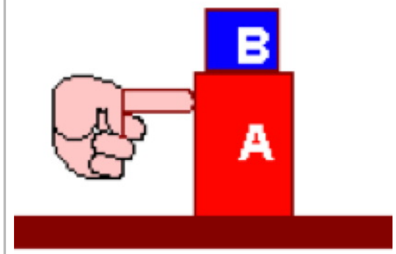
# Pushing a block on a block – qualitative

4.1.2.P18

A heavy block, labeled "A", is sitting on a table. On top of that block is a lighter block, labeled "B" as shown in the figure at the right. For the first parts of this problem you are asked to identify the direction of forces in this system under various circumstances. The labels in the subscripts indicate: A = block A, B = block B, F = finger, T = table. Specify the direction in your answers using the following notation:

- R means points to the right
- L means points to the left
- U means point up
- D means points down
- 0 indicates there is no such force at the instant specified.




1. You start pushing on block A as shown, but it is too heavy and does not move. While you are pushing on block A but while it is not moving, specify the direction of the following normal (N) and frictional (f) forces between the various objects indicated.

(a) $N_{A\to B}$
(b) $f_{T\to A}$
(c) $f_{A\to B}$
(d) $N_{F\to A}$
(e) $f_{B\to A}$
(f) $N_{B\to A}$

2. Now you push a little harder and the block begins to move. Block B moves with it without slipping. While the blocks are speeding up specify the direction of the following forces between the various objects indicated.

(a) $N_{A\to B}$
(b) $f_{T\to A}$
(c) $f_{A\to B}$
(d) $N_{F\to A}$
(e) $f_{B\to A}$
(f) $N_{B\to A}$

3. Now you push so that the blocks move at a constant velocity. Block B moves with A without slipping. While the blocks are moving at a constant speed specify the direction of the following forces between the various objects indicated.

(a) $N_{A\to B}$
(b) $f_{T\to A}$
(c) $f_{A\to B}$
(d) $N_{F\to A}$
(e) $f_{B\to A}$
(f) $N_{B\to A}$

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# Pushing a block on a block - symbols

4.1.2.P19

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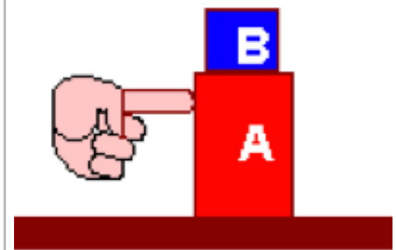
|---|---|
| A heavy block, labeled "A", is sitting on a table. On top of that block is a lighter block, labeled "B" as shown in the figure at the right. For the first parts of this problem you are asked to identify the direction of forces in this system under various circumstances. In this problem, we will be looking at the relationships between the various forces in the problem under various circumstances. In order to simplify the equations we write, we will not use our full "who is acting on whom" force notation, but will use the following simplifications. (Note that we have taken for granted that you understood and could use Newton's 3rd law.) |  |



- $N_{F\to A} = F$ (force of the finger pushing block A)
- $N_{A\to B} = N_{B\to A} = N$ (the normal forces acting between the blocks)
- $N_{T\to A} = N_T$ (the normal force of the table acting on block A)
- $f_{T\to A} = f_T$ (the friction force between block A and the table)
- $f_{A\to B} = f_{B\to A} = f$ (the friction force between the two blocks)
- $W_{E\to A} = W_A$ (weight of block A)
- $W_{E\to B} = W_B$ (weight of block B)

We then have the seven symbols representing all the forces in the problem: F, $N_T$, N, $f_T$, f, $W_A$, and $W_B$.

(A) If the finger is pushing but not hard enough, neither block will move. By Newton's 2nd law, for any object that is not accelerating, the forces in each direction must balance.

1. Write the equations for the balance of the forces in the horizontal and vertical directions for block A and for block B (four equations).
2. Three of the quantities are in principle straightforward to measure (using, say, a spring scale): F, $W_A$, and $W_B$. The other four, $f_T$, f, $N_T$, and N, are "invisible" -- that is, a little bit harder to measure directly. (Though you might be able to think of a way!) If you knew the three easily measurable quantities, could you find the other four (invisible) ones? If so, write equations to express each invisible one in terms of the three measurable ones. If not, explain what else you would need.

(B) If the finger is pushing hard enough, the two blocks will start to speed up. Assume they speed up together without slipping. By Newton's 2nd law, for any object that is accelerating, ma in each direction must equal the net forces in that direction.

1. Write the equations for ma in the horizontal and vertical directions for block A and for block B (four equations).
2. In addition to the three quantities that are in principle straightforward to measure (F, $W_A$, and $W_B$), the accelerations $a_A$ and $a_B$ can be easily measured (say using a video capture program). If you knew the accelerations and the three easily measurable quantities, could you find the other four (invisible) ones? If so, write equations to express each invisible one in terms of the three known quantities. If not, explain what else you would need.
3. Compared to part (A), we have new quantities, but the same number of equations. How is this possible? What changes between the two situations?

(C) Once the blocks have sped up, the finger still has to push on it to keep it going at a constant velocity, even though N2 tells us that at a constant velocity, all forces must balance. Assume that both blocks move with the same speed and don't slide.

1. Write the equations that express the balance of forces for each block and each direction.
2. Suppose we assume that the finger is pushing harder on the blocks in part (C) than it did in part (A) but not as hard as it was in part (B). Which of the other 6 forces have to change compared to what they were in part (B)? If they do change, do they each get bigger? small? go to zero?

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# Pushing a block on a block - quantitative

4.2.2.P6

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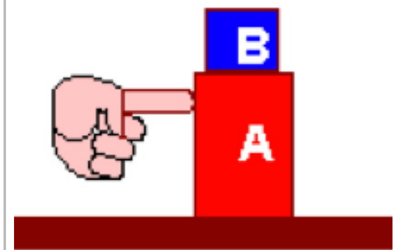
| A heavy block, labeled "A", is sitting on a table. On top of that block is a lighter block, labeled "B" as shown in the figure at the right. Consider three cases.<br><br>(A) The finger is pushing but not hard enough. Neither block moves.<br>(B) The finger is pushing hard enough that the two blocks are speeding up.<br>(C) The blocks have sped up, and are now moving at a constant speed. The finger still has to push to keep them going at a constant velocity.<br><br>In all cases where the blocks are moving, they are moving together. (Block B is not sliding on block A.) |  |

Block A has a mass of 0.6 kg; block B has a mass of 0.1 kg. the coefficient of friction between the block and the table is 0.3 and the coefficient of friction between the two blocks is 0.2. (You may use g = 10 N/kg and you may treat kinetic and static friction as the same.)

1. For case (A), what is the maximum force the finger can exert without the blocks beginning to move?

2. For case (B), while the blocks are speeding up, the finger is pushing with a force of 3.5 N. Can you find the acceleration of block A? If so, find it and show your work. If not, explain why not.

3. Find the time $\Delta t$ needed for this force to bring the block from rest to a speed of 10 cm/s.

3. For case (B), we are assuming that the blocks are moving together. This means that block B is speeding up. But the finger is not touching block B. What force is responsible for the acceleration of block B? Find its magnitude and direction. Is our assumption correct? Will block B indeed be able to speed up with block A without slipping? Explain.

4. Suppose the bottom block has a mass of 0.4 kg and the top block has a mass of 0.1 kg What force do you need to exert to keep the blocks moving at a constant speed of 10 cm/s?

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