1. The figure at right shows a hand pushing a block as it moves through a displacement $\Delta \vec{s}$.
   a) Suppose instead the force exerted by the hand were directed partially downward as shown. Both the displacement of the block and the magnitude of the force are the same as before. Would the work done by the new force be greater than, less than, or equal to the work done by the original force? (Why?)

Suppose instead that the hand were to push with a force of the same magnitude as before but do zero work. The displacement of the block is the same as before. Draw an arrow to show the direction of the hand.

2. A block is initially moving to the right on a level, frictionless surface. A hand exerts a constant horizontal force on the block that causes the block to slow down (stage 1), turn around, and then move in the opposite direction while speeding up (stage 2)
   a) Complete the table below. Draw arrows to indicate relevant direction, and take the positive $x$-direction to the right

<table>
<thead>
<tr>
<th>Displacement of block</th>
<th>Force on block by hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leftarrow$</td>
<td></td>
</tr>
</tbody>
</table>

   b) Which entries above, if any, would differ if instead the positive $x$-direction were defined to be to the left? (Why?)

   c) Consider this (incorrect) statement: “The force is always to the left. So if left is negative, then the work done is negative in both stages. If we change the coordinate system and make left positive, then the work is positive in both cases”. What is wrong with the argument?
3. A block is moving to the left on a frictionless, horizontal table. A hand exerts a constant horizontal force on the block

   a) Suppose the work done on the block by the hand is positive. Draw arrows at right showing the direction of the displacement of the block, and the direction of the force on the block.

   Explain briefly how you chose the direction of the force on the block by the hand.

   Is the block speeding up, slowing down or moving with constant speed? Why?

   [Table: Displacement of block | Force on block by hand]

   [Diagram: Arrows showing displacement and force directions]

   b) A hand again exerts a constant horizontal force on the left-moving block, but this time the work done on the block by the hand is negative. Draw arrows showing both the direction of the displacement of the block, and the direction of the force on the block.

   Again explain briefly how you chose the direction of the force on the block by the hand.

   Is the block speeding up, slowing down or moving with constant speed? Why?
4. Consider the same block in a separate experiment. The table is still frictionless and horizontal. Now, two hands push horizontally on the block at the same time. Hand 1 does positive work ($W_1 > 0$) and hand 2 does negative work ($W_2 < 0$), but the direction each hand is pushing may change for the different cases.

For each of the following cases, draw a free-body diagram for the block that shows all horizontal and vertical forces exerted on the block. (Label the force from hand 1 "$F_1$" and the force from hand 2 "$F_2$".)

Also, in each case below, decide whether the sum $W_1 + W_2$ is positive, negative or zero.

a) The block moves to the right and speeds up.

Is $W_1 + W_2$ in this situation positive, negative or zero?

b) The block moves to the left and speeds up.

Is $W_1 + W_2$ in this situation positive, negative or zero?

c) The block moves to the right and slows down.

Is $W_1 + W_2$ in this situation positive, negative or zero?

d) The block moves to the left with constant speed.

Is $W_1 + W_2$ in this situation positive, negative or zero?

In all cases on this page, remember! We want $W_1 > 0$, and $W_2 < 0$.
5. In the free-body diagrams to part 2, there are forces besides $F_1$ and $F_2$. How much work is done by each of these forces? Explain. (Hint: it is the same in all cases.)

6. The sum of the works done by all forces on an object is called the *net work*, $W_{\text{net}}$. Generalize from your results to part 2 to describe how the *speed* of an object changes (speeds up, slows down, or remains the same) if the net work is
   
   a) positive,
   
   b) negative,
   
   c) zero.

The “Work-Energy theorem” says that the net work on an object equals the CHANGE in kinetic energy of the object, $W_{\text{net}} = \Delta KE = KE_{\text{final}} - KE_{\text{initial}}$, where kinetic energy (KE) is defined to be

$$KE = \frac{1}{2}mv^2.$$  Look at your answers above and discuss how they are consistent with this theorem!
7. Consider a new set-up: glider A is pulled by a string across a level, frictionless table. The string exerts a *constant* horizontal force

a) How does the net work done on glider A in moving through a distance $d$ compare with the net work done on the glider in moving through a distance $4d$?

b) Assume that the glider starts from rest. Find the ratio of the speed after the glider has moved a distance $4d$ to the speed of the glider after moving a distance $d$. Explain the relationship between net work done on the glider and change in speed of the glider (For example, how does speed change if net work is doubled?)

c) A string pulls a second glider, glider B, across the table with the same force as is applied to glider A. The mass of glider B is greater than the mass of glider A ($m_B > m_A$). Both gliders start from rest. After each glider has been pulled a distance $d$, is the kinetic energy of glider A *greater than, less than or equal to* the kinetic energy of glider B?

How does the velocity of glider A compare to that of B? Explain. (does your answer make good physical sense to you? Why?)
8. The diagrams show two identical gliders that move to the right without friction. The hands exert identical, horizontal forces on the gliders. But, the second glider experiences an additional (smaller) force from a massless string held as shown.

Suppose the gliders both move through identical displacements.

a) Is the work done on glider 1 by the hand greater than, less than, or equal to the work done on glider 2 by the hand? Explain...

b) Is the change in kinetic energy of glider 1 greater than, less than, or equal to the change in kinetic energy of glider 2? Base your answer on your knowledge of the net work done on each object.

Thinking just about Newton’s 2nd law, does your answer to the previous question make sense?