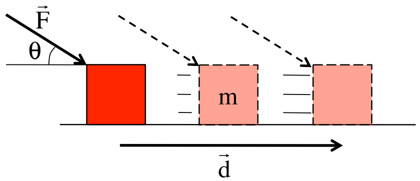
Problem 7.1

A 2.50 kg block is accelerated over a 2.20 meter distance by a force of 16.0 newtons at an angle of 25.0°, as shown.

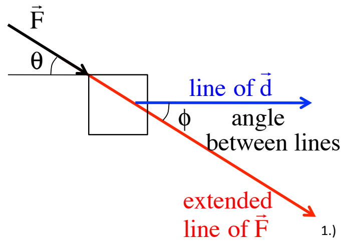


a.) How much work does "F" do during the motion?

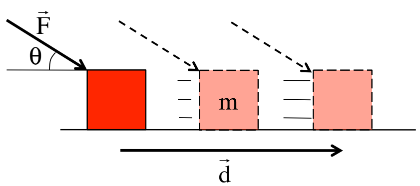
You can do work calculation, which is just a dot product, any one of three ways. The first I'll show I call the *definition approach*. We know that:

$$W_F = \vec{F} \bullet \vec{d}$$
$$= |\vec{F}||\vec{d}|\cos\phi$$

where $|\vec{F}|$ is the magnitude of the force, $|\vec{d}|$ is the magnitude of the displacement and ϕ is the angle between *the line of the force vector* and *the line of the displacement vector*. (To be clear about the angle in this case, I've extended the line of $\vec{F}$ and the line of $\vec{d}$ in the sketch to the right.)



Executing the operation, we can write:



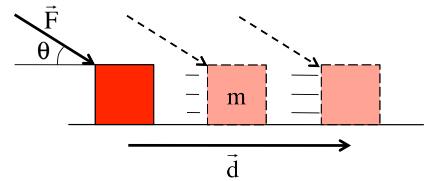
$$W_F = |\vec{F}||\vec{d}|\cos\phi$$
$$= (16.0\text{ N})(2.20\text{ m})\cos 25^\circ$$
$$= 31.9\text{ N}\bullet\text{m} \qquad \text{(where a N}\bullet\text{m is called a joule and has the symbol "J")}$$

The second approach can be seen by noting that a work calculation is designed to give you a feel for how big a velocity change an object might experience as a consequence of the force acting on the object over its displacement. The only force component that will change an object's velocity magnitude is the component *along the line of the displacement*. That means, apparently, that:

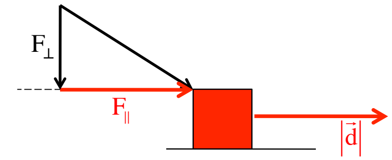
$$W_F = \vec{F} \bullet \vec{d}$$
$$= F_{\parallel}|\vec{d}|$$

where the symbol $F_{\parallel}$ is meant to denote the component of $\vec{F}$ that is PARALLEL to the line of $\vec{d}$.

Noting that the force component parallel to the displacement is just its horizontal component in this case, we can write:



$$F_{\parallel} = |\vec{F}|\cos\phi$$
$$= (16.0\text{ N})\cos 25^\circ$$
$$= 14.5\text{ N}$$

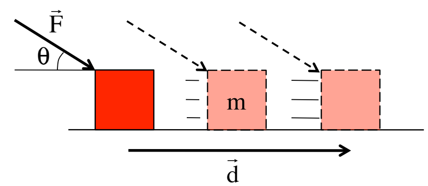


We can use this *F-parallel* approach to write:

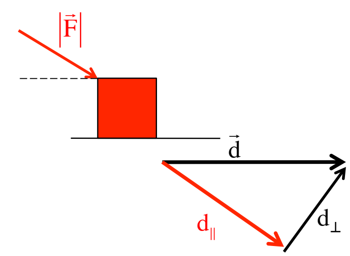
$$W_F = F_{\parallel}|\vec{d}|$$
$$= (14.5\text{ N})(2.20\text{ m})$$
$$= 31.9\text{ N}\bullet\text{m}$$

Not surprising, this is the same value we got using the *definition approach*.

The third approach is the mirror image of the *F-parallel* approach. That is:



$$W_F = \vec{F} \bullet \vec{d}$$
$$= d_{\parallel}|\vec{F}|$$

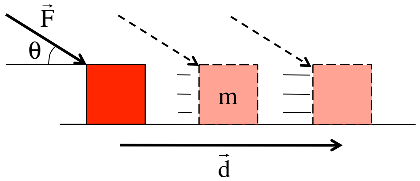


where the symbol $d_{\parallel}$ is meant to denote the component of $\vec{d}$ that is PARALLEL to the line of $\vec{F}$. In this case, the sketch shows that quantity. Mathematically, we get:

$$d_{\parallel} = |\vec{d}|\cos\phi$$
$$= (2.20\text{ m})\cos 25^\circ$$
$$= 1.99\text{ m}$$

Executing the operation, we can write:

$$
\begin{aligned}
W_F &= \vec{F} \bullet \vec{d} \\
&= d_{\parallel} |\vec{F}| \\
&= (1.99 \text{ m})(16.0 \text{ N}) \\
&= 31.9 \text{ J} \qquad \text{(as before and as expected)}
\end{aligned}
$$

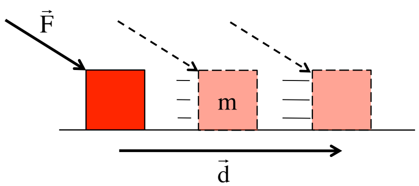


b.) Determine the work done by the normal force acting on the box:

By definition, a normal forces are always perpendicular to the surface that provides them. In SLIDING situations, that means they are ALWAYS perpendicular to the motion and NEVER motivate the body to speed up or slow down . . . hence they do NO WORK.

Note: This is not to say that there are no non-sliding situation in which a normal force does work. Think about standing in an elevator and having the normal force between your and the floor accelerate you upward. In that case, a normal force is doing work. For SLIDING situations, though, they never do!

c.) How much work does gravity do



In this case, gravity does zero work on several counts. Conceptually, gravity is at right angles to the displacement, so it won't make the body accelerate and, hence, will do no work. OR, mathematically, the angle between gravity and the displacement is ninety degrees, and the cosine of ninety degrees is zero so the dot product (and work) will be zero.

d.) Determine the total work done by the forces acting on the box.

The easiest way to do this is to simply sum up all the work done by all the forces. For this problem, the only work done was due to "F," so the total work is $W_{net} = 31.9$ J.

Note: Another way to get the total work would have been to do a vector summation of all the forces to get the *net* force acting in the system, then determine:

$$W_{net} = \vec{F}_{net} \bullet \vec{d}.$$