1.9 Forces, Momentum, and Work:

In Chapter 1.3, we defined force as a push or pull; an interaction between two bodies where momentum is *exchanged*. Each body receives an equal *impulse* (Δp), in opposite directions, thus conserving total momentum. We further stated that when a force acts on a body, that the body's momentum changes:
$F = dp/dt$;

that the body accelerates:
$F = ma$;

and that work is done on the body:
$F = dE/dx$.

The above equation $F = dE/dx$ comes from the definition of work: $W = dE = F*dx$, the work done on an object is the object's energy change is force over distance.

Exercise 1: Prove that the units energy (*Joules*) is the same as the unit of work: N*m, consistent with $F*dx$.

Direction matters. You do work if the force and direction of movement is in the same direction, you do negative work if they are in opposite directions, and you do no work if Force is perpendicular to the change in position. Hence you can see that if a car is moving forward:

- if you push a car forward while it is moving forward, you do positive work on the car, and its kinetic energy increases;
- if you push a car backwards while it is moving forward, you do negative work on the car, and its kinetic energy decreases;
- if you push on a car to the left while it is moving forward, you do zero work on the car, and its kinetic energy doesn't change.

If you are not sure if work is positive or negative, you can ask yourself how the energy of the body changed. For instance, if you carry a 20 kg mass 100 m across a soccer field, you feel you've done lots of *work* as we use the term in English… you're tired out. However, you can see that you have not changed the energy of the mass; you have only changed its position. Directions of force and displacement? You have displaced the mass horizontally, but the force you put on it is upward, perpendicular to your change in position, so no work is done. This is very different from if you carried the mass up a hillside 100 m, increasing your elevation 30 m. Now you know you've done work because the mass has higher potential energy. If you're not sure, just drop the mass the 30 m downward and see if there is some energy transformation!

Exercise 2:
What is the force you need to put on the 20 kg mass as you carry it – so gravity didn't pull it out of your hands? Calculate the work you did in the above example. Do you use the 100 m or the 30 m? How can you be sure?