14.8 Dissipative Forces: Friction

Suppose we consider an object moving on a rough surface. As the object slides it slows down and stops. While the sliding occurs both the object and the surface increase in temperature. The increase in temperature is due to the molecules inside the materials increasing their kinetic energy. This random kinetic energy is called *thermal energy*. Kinetic energy associated with the coherent motion of the molecules of the object has been dissipated into kinetic energy associated with random motion of the molecules composing the object and surface.

If we define the system to be just the object, then the friction force acts as an external force on the system and results in the dissipation of energy into both the block and the surface. Without knowing further properties of the material we cannot determine the exact changes in the energy of the system.

Friction introduces a problem in that the point of contact is not well defined because the surface of contact is constantly deforming as the object moves along the surface. If we considered the object and the surface as the system, then the friction force is an internal force, and the decrease in the kinetic energy of the moving object ends up as an increase in the internal random kinetic energy of the constituent parts of the system. When there is dissipation at the boundary of the system, we need an additional model (thermal equation of state) for how the dissipated energy distributes itself among the constituent parts of the system.

14.8.1 Source Energy

Consider a person walking. The frictional force between the person and the ground does no work because the point of contact between the person's foot and the ground undergoes no displacement as the person applies a force against the ground, (there may be some slippage but that would be opposite the direction of motion of the person). However the kinetic energy of the object increases. Have we disproved the work-energy theorem? The answer is no! The chemical energy stored in the body tissue is converted to kinetic energy and thermal energy. Because the person-air-ground can be treated as a closed system, we have that

$$0 = \Delta E_{\text{sys}} = \Delta E_{\text{chemical}} + \Delta E_{\text{thermal}} + \Delta E_{\text{mechanical}}, \quad (\text{closed system}). \qquad (14.7.1)$$

If we assume that there is no change in the potential energy of the system, then $\Delta E_{\text{mechanical}} = \Delta K$. Therefore some of the internal chemical energy has been transformed into thermal energy and the rest has changed into the kinetic energy of the system,

$$-\Delta E_{\text{chemical}} = \Delta E_{\text{thermal}} + \Delta K\ . \qquad (14.7.2)$$