Chapter C10: Thermal Energy

C10.1: Disappearing Energy

We can't concoct a potential energy function for the frictional part of a contact interaction.

C10.2: Caloric is Energy

This section mostly gives some historical background on what scientists thought about heat in the 1700's and early 1800's. I think the main thing to take from this section is that it's not obvious (or at least it wasn't then) that heat and energy are directly related.

C10.3: Thermal Energy

A substance's temperature is related to average kinetic energy of its molecules:

$$K_{\text{ave}} = \frac{3}{2} k_B T \; . \tag{1}$$

We won't use this equation much, if at all. It's important, though, because it sets up the connection between temperature and average energy. One could (more or less) think of this relationship as defining temperature.

One can also think of k_B as forming a bridge between microscopic (molecular) and macroscopic energy.

C10.4: Friction and Thermal Energy

C10.5: Heat and Work

- Heat: Energy transfer from one object to another across a well defined boundary, and which is directly due to a difference in temperature between the two objects.
- Work: Work is any other kind of energy flowing across the boundary between two systems.
- Internal Energy: Energy (kinetic and otherwise) "hidden" inside an object. Unlike heat, internal energy is a property of an object.

C10.6: Specific "Heat"

The specific "heat" c is defined via:

$$dU^{\text{th}} = mcdT \tag{2}$$

This relates internal energy changes to temperature changes.

C10.8: Keeping Track of Internal Energies

Using Eq. (2) we can apply conservation of energy as we did in earlier chapters, but now we can keep track of thermal energy as well. One has to think hard about minus signs, though.

Examples:

Two kilograms of copper pennies in a bag are dropped from a height of 100 meters. Assume (somewhat unrealistically) that upon impact the pennies get all of their kinetic energy converted to thermal energy. If the temperature of the pennies was initially 30 degrees Celsius, what is their temperature after they hit the ground?

An example from the previous chapter:

A 5 kg sphere with radius 0.2 meters rolls without slipping down a hill that is 20 meters high. If the sphere starts at rest at the top of the hill, what is the speed of its center of mass at the bottom?

Practice

1. A cylindrical hoop with mass M and radius R rolls without slipping down a ramp that is 3 meters tall. What is the speed of the hoop's center of mass at the bottom?

2. A solid sphere with mass M and radius R rolls without slipping down a ramp that is 3 meters tall. What is the speed of the hoop's center of mass at the bottom?

3. Two hundred grams of aluminum are heated to 100 degrees Celsius. The aluminum is then placed in 300 grams of water in a well insulated container. What is the final temperature of the water and aluminum? The temperature of the water was 30 before the hot metal was added.

4. Suppose you drop a 2 kg brick off a 50 m building. The brick hits the ground, bounces a few times, and comes to rest.

   (a) How much energy has the brick lost?

   (b) Suppose this energy could be used to heat 1 kg of water. If the water started at 30 C, how hot would it end up?