MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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Review C: Work and Kinetic Energy

Work and Kinetic Energy

C.1 Energy

C.1.1 The Concept of Energy

The concept of energy helps us describe many processes in the world around us.

- Falling water releases stored "gravitational potential energy" turning into a "kinetic energy" of motion. This "mechanical energy" can be used to spin turbines and alternators doing "work" to generate electrical energy. It's sent to you along power lines. When you use any electrical device such as a refrigerator, the electrical energy turns into mechanical energy to make the refrigerant flow to remove 'heat' (the kinetic motion of atoms), from the inside to the outside.

- "Human beings transform the stored chemical energy of food into various forms necessary for the maintenance of the functions of the various organ system, tissues and cells in the body."[1] This "catabolic energy" is used by the human to do work on the surroundings (for example pedaling a bicycle) and release heat.

- Burning gasoline in car engines converts "chemical energy" stored in the atomic bonds of the constituent atoms of gasoline into heat that then drives a piston. With gearing and road friction, this motion is converted into the movement of the automobile.

- Stretching or compressing a spring stores 'elastic potential energy' that can be released as kinetic energy.

- The process of vision begins with stored "atomic energy" released as electromagnetic radiation (light) that is detected by exciting atoms in the eye, creating chemical energy.

- When a proton fuses with deuterium, (deuterium is a hydrogen atom that has an extra neutron along with the proton in the nucleus), helium three is formed (two protons and one neutron) along with radiant energy in the form of photons. The mass of the proton and deuterium are greater than the mass of the helium. This "mass energy" is carried away by the photon.

These energy transformations are going on all the time in the manmade world and the natural world involving different forms of energy: kinetic energy, gravitational energy, heat energy, elastic energy, electrical energy, chemical energy, electromagnetic energy,

[1] George B. Benedik and Felix M.H. Villars, *Physics with Illustrative Examples from Medicine and Biology Volume 1 Mechanics,* Addison-Wesley, Reading, 1973, p. 5-116.

nuclear energy, or mass energy. Energy is always conserved in these processes although it may be converted from one form into another.

Any physical process can be characterized by an "initial state" that transforms into a "final state". Each form of energy E_i undergoes a change during this transformation,

$$\Delta E_i = E_{\text{final},i} - E_{\text{initial},i} \quad \text{(C.1.1)}$$

Conservation of energy means that the sum of these changes is zero,

$$\Delta E_1 + \Delta E_2 + \cdots = \sum_{i=1}^{N} \Delta E_i = 0 \quad \text{(C.1.2)}$$

Two critical points emerge. The first is that only change in energy has meaning. The initial or final energy is actually a meaningless concept. What we need to count is the change of energy and so we search for physical laws that determine how each form of energy changes. The second point is that we must account for all the ways energy can change. If we observe a process, and the changes in energy do not add up to zero, then the laws for energy transformations are either wrong or there is a new type of change of energy that we had not previously discovered. Some quantity is conserved in all processes and we call that *energy*. If we can quantify the changes of forms of energies then we have a very powerful tool to understand nature.

We will begin our analysis of conservation of energy by considering processes involving only a few forms of changing energy. We will make assumptions such as "ignore the effects of friction". This means that from the outset we assume that the change in heat energy is zero.

Energy is always conserved but sometimes we prefer to restrict our attention to a set of objects that we define to be our system. The rest of the universe acts as the surroundings. Our conservation of energy then becomes

$$\Delta E_{\text{system}} + \Delta E_{\text{surroundings}} = 0 \quad \text{(C.1.3)}$$

C.1.2 Kinetic Energy

Our first form of energy that we will study is the *kinetic energy* K, an energy associated with the motion of an object with mass m. Let's consider a car moving along a straight road (call this road the x-axis) with velocity $\vec{\mathbf{v}} = v_x \hat{\mathbf{i}}$. The speed v of the car is the magnitude of the velocity. The kinetic energy of the car is defined to be the positive scalar quantity

$$K = \frac{1}{2} m v^2 \quad \text{(C.1.4)}$$