Chapters 6–7

Terms

Be able to define or discuss the following terms and ideas, with their SI units if appropriate.

1. system
2. surroundings
3. particle
4. particle energy
5. gamma
6. kinetic energy
7. rest energy
8. work
9. meaning of positive work and negative work
10. conservation of energy
11. dot product
12. electron volt (eV)
13. multiparticle system
14. potential energy
15. gravitational potential energy
16. coulomb (or electric) potential energy
17. energy diagram
18. escape speed
19. conservative force
20. spring potential energy (for an ideal spring)

Equations

Understand the meaning and know the SI units of all symbols in these equations; know how to perform each mathematical operation, such as trig functions; know how to solve for any unknown quantity; understand how changing one quantity affects another quantity (if all other quantities remain constant); be able to apply one or more equations to solve a problem.

- Total energy of a particle.

$$E = \gamma mc^2$$

where

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

- Rest energy

$$E_{rest} = mc^2$$

- Total energy of a particle can be written as the sum of its rest energy and kinetic energy.

$$E = E_{rest} + K$$

- For an object moving with a speed much less than the speed of light:

$$K \approx \frac{1}{2}mv^2$$

- Work done by a constant force $\vec{F}$ acting through a straight-line displacement $\Delta\vec{r}$:

$$\begin{aligned} W &= \vec{F}\cdot\Delta\vec{r} \\ &= F_x\Delta x + F_y\Delta y + F_z\Delta z \\ &= |\vec{F}||\Delta\vec{r}|\cos\theta \end{aligned}$$

- Work done by a non-constant force along a path from point i to point f:

$$W = \int_i^f \vec{F}\cdot d\vec{r}$$

The above integral is calculated along the path through which the force acts. Thus, it is called a path integral.

- Work done by the gravitational force by Earth on a particle of mass m near Earth:

$$W = -mg\Delta y = -mg(y_f - y_i)$$

where $+y$ is defined to be away from Earth and perpendicular to Earth's surface.

- For a 1-dimensional conservative force:

$$F_x = -\frac{dU}{dx}$$

- Gravitational potential energy of a two-body system:

$$U_{grav} = -\frac{Gm_1m_2}{r}$$

- Gravitational potential of an object-Earth system near the surface of Earth:

$$U_{grav} = mgy$$

- Electric (or Coulomb) potential energy of two charged particles:

$$U_{coul} = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r}$$

- Spring potential energy (for an ideal spring).

$$U_{spring} = \frac{1}{2}ks^2$$

Skills

1. Calculate the total work done on a particle if given the forces on the particle and the displacements through which they act.
2. Apply Conservation of Energy (i.e. The Energy Principle) to a single particle and solve for an unknown.
3. Apply Conservation of Energy to a multiparticle system that includes a two-body gravitational interaction and solve for an unknown.
4. Apply Conservation of Energy to a multiparticle system that includes charged particles.
5. Apply Conservation of Energy to a multiparticle system that includes a change in rest energy, such as nuclear fission, nuclear fusion, and matter-antimatter annihilation.
6. Apply conservation of energy to a system that includes a spring.
7. Interpret an energy diagram and use it to determine total energy, potential energy, and kinetic energy for a multiparticle system.
8. Know that for a gravitational or coulomb (i.e. electric) interaction, a negative total energy means that it is bound and positive total energy means that it is unbound.
9. Calculate the energy needed to separate a multiparticle system with gravitational or electric interactions.

Lab Skills

1. Calculate total energy, rest energy, and kinetic energy for a particle. Identify the maximum possible speed from a graph of K vs v for a particle.

2. Apply Conservation of Energy to a system such as a roller coaster to calculate the speed of the object at any point along its path.

3. Apply Conservation of Energy to a system such as a roller coaster and calculate the loss of mechanical energy (due to friction).

4. Convert energy units from joules to electron volts.

5. Apply conservation of energy to a harmonic oscillator; graph the total energy, potential energy, and kinetic energy of a harmonic oscillator.

6. Graph total energy as a function of amplitude for a harmonic oscillator.