8.20: Potential Energy and Conservation of Energy (Summary)

Key Terms

conservative force	force that does work independent of path
conserved quantity	one that cannot be created or destroyed, but may be transformed between different forms of itself
energy conservation	total energy of an isolated system is constant
equilibrium point	position where the assumed conservative, net force on a particle, given by the slope of its potential energy curve, is zero
exact differential	is the total differential of a function and requires the use of partial derivatives if the function involves more than one dimension
mechanical energy	sum of the kinetic and potential energies
non-conservative force	force that does work that depends on path
non-renewable	energy source that is not renewable, but is depleted by human consumption
potential energy	function of position, energy possessed by an object relative to the system considered
potential energy diagram	graph of a particle's potential energy as a function of position
potential energy difference	negative of the work done acting between two points in space
renewable	energy source that is replenished by natural processes, over human time scales
turning point	position where the velocity of a particle, in one-dimensional motion, changes sign

Key Equations

Difference of potential energy	$$\Delta U_{AB} = U_B - U_A = -W_{AB} \tag{8.20.1}$$
Potential energy with respect to zero of potential energy at $\vec{r}$	$$\vec{r}_0 \Delta U = U(\vec{r}) - U(\vec{r}_0) \tag{8.20.2}$$
Gravitational potential energy near Earth's surface	$$U(y) = mgy + const. \tag{8.20.3}$$
Potential energy for an ideal spring	$$U(x) = \frac{1}{2}kx^2 + const. \tag{8.20.4}$$
Work done by conservative force over a closed path	$$W_{closed\ path} = \oint \vec{E}_{cons} \cdot d\vec{r} = 0 \tag{8.20.5}$$
Condition for conservative force in two dimensions	$$\left(\frac{dF_x}{dy}\right) = \left(\frac{dF_y}{dx}\right) \tag{8.20.6}$$
Conservative force is the negative derivative of potential energy	$$F_l = -\frac{dU}{dl} \tag{8.20.7}$$
Conservation of energy with no non-conservative forces	$$0 = W_{nc,\ AB} = \Delta(K+U)_{AB} = \Delta E_{AB}. \tag{8.20.8}$$

Summary

8.1 Potential Energy of a System

- For a single-particle system, the difference of potential energy is the opposite of the work done by the forces acting on the particle as it moves from one position to another.
- Since only differences of potential energy are physically meaningful, the zero of the potential energy function can be chosen at a convenient location.
- The potential energies for Earth's constant gravity, near its surface, and for a Hooke's law force are linear and quadratic functions of position, respectively.

8.2 Conservative and Non-Conservative Forces

- A conservative force is one for which the work done is independent of path. Equivalently, a force is conservative if the work done over any closed path is zero.
- A non-conservative force is one for which the work done depends on the path.
- For a conservative force, the infinitesimal work is an exact differential. This implies conditions on the derivatives of the force's components.
- The component of a conservative force, in a particular direction, equals the negative of the derivative of the potential energy for that force, with respect to a displacement in that direction.

8.3 Conservation of Energy

- A conserved quantity is a physical property that stays constant regardless of the path taken.
- A form of the work-energy theorem says that the change in the mechanical energy of a particle equals the work done on it by non-conservative forces.
- If non-conservative forces do no work and there are no external forces, the mechanical energy of a particle stays constant. This is a statement of the conservation of mechanical energy and there is no change in the total mechanical energy.
- For one-dimensional particle motion, in which the mechanical energy is constant and the potential energy is known, the particle's position, as a function of time, can be found by evaluating an integral that is derived from the conservation of mechanical energy.

8.4 Potential Energy Diagrams and Stability

- Interpreting a one-dimensional potential energy diagram allows you to obtain qualitative, and some quantitative, information about the motion of a particle.
- At a turning point, the potential energy equals the mechanical energy and the kinetic energy is zero, indicating that the direction of the velocity reverses there.
- The negative of the slope of the potential energy curve, for a particle, equals the one-dimensional component of the conservative force on the particle. At an equilibrium point, the slope is zero and is a stable (unstable) equilibrium for a potential energy minimum (maximum).

8.5 Sources of Energy

- Energy can be transferred from one system to another and transformed or converted from one type into another. Some of the basic types of energy are kinetic, potential, thermal, and electromagnetic.
- Renewable energy sources are those that are replenished by ongoing natural processes, over human time scales. Examples are wind, water, geothermal, and solar power.
- Non-renewable energy sources are those that are depleted by consumption, over human time scales. Examples are fossil fuel and nuclear power.

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