AP Physics C Review
Chapter 8: Potential Energy & Conservation of Energy

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Background / Summary: In this unit, we explore conservation of energy and how we can use energy analysis and potential energy to answer problems in mechanics.

Important Formulas:

$$U_g = mgh\,,\, U_s = \frac{1}{2}kx^2\;,\; K = \frac{1}{2}mv^2\; W_{done\ by\ a\ force} = -\Delta U = \int_{x_i}^{x_f} F_{conservative\ force} \cdot dx = \Delta K,$$

$$\Sigma E_{initial} = \Sigma E_{final}\;,\; E_{mechanical} = K + U\;,\; F = -\frac{dU}{dx}$$

Problems in this Unit and the Formulas Needed to Solve:

In this chapter there are a few different types of problems that a physics student will encounter. For problems that involve solving for one energy or measured aspect of that energy (*h* or *m* for U, as an example), any of the formulas that include various types of energy on each side of the equation or the aspects of that energy will be helpful for substituting and solving algebraically. For problems that involve a conservative force, using the integral expression for potential energy is ideal. Lastly, for problems with potential energy diagrams, using the derivative of potential energy over displacement as force is helpful for solving problems that ask for specific points from a function or slopes of the graphs.

Key Terms:

conservative force:
force that does work independent of path
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
mechanical energy:
sum of the kinetic and potential energies
non-conservative force:
force that does work that depends on path
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

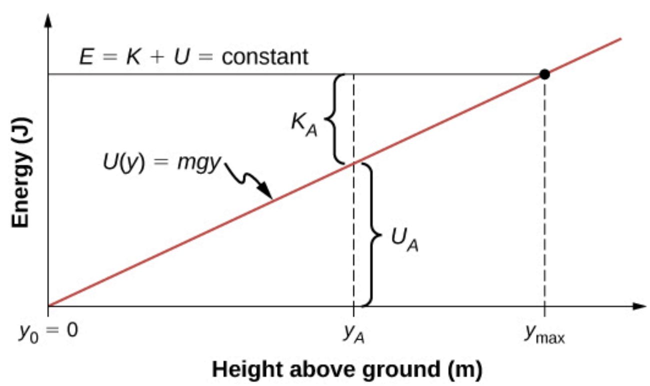


Figure 8.10 The potential energy graph for an object in vertical free fall, with various quantities indicated.

Chapter Concepts and Objectives

8.1 Potential Energy

- Relate the difference of potential energy to work done on a particle for a system without friction or air drag
- Explain the meaning of the zero of the potential energy function for a system
- Calculate and apply the gravitational potential energy for an object near Earth's surface and the elastic potential energy of a mass-spring system

8.2 Conservative and Non-Conservative Forces

- Characterize a conservative force in several different ways
- Specify mathematical conditions that must be satisfied by a conservative force and its components
- Relate the conservative force between particles of a system to the potential energy of the system
- Calculate the components of a conservative force in various cases

8.3 Conservation of Energy

- Formulate the principle of conservation of mechanical energy, with or without the presence of non-conservative forces
- Use the conservation of mechanical energy to calculate various properties of simple systems

8.4 Potential Energy Diagrams and Stability

- Create and interpret graphs of potential energy
- Explain the connection between stability and potential energy

Problems

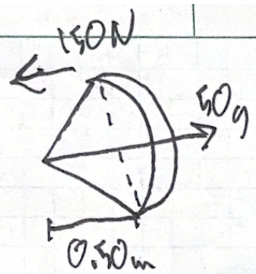
37. Assume that the force of a bow on an arrow behaves like the spring force. In aiming the arrow, an archer pulls the bow back 50 cm and holds it in position with a force of $150\ \text{N}$. If the mass of the arrow is $50\ \text{g}$ and the "spring" is massless, what is the speed of the arrow immediately after it leaves the bow?

41. A baseball of mass 0.25 kg is hit at home plate with a speed of 40 m/s. When it lands in a seat in the left-field bleachers a horizontal distance 120 m from home plate, it is moving at 30 m/s. If the ball lands 20 m above the spot where it was hit, how much work is done on it by air resistance?

29. A particle of mass $2.0\ \text{kg}$ moves under the influence of the force $F(x) = \left(-5x^2 + 7x\right)\ \text{N}$. If its speed at $x = -4.0\ \text{m}$ is $v = 20.0\ \text{m/s}$, what is its speed at $x = 4.0\ \text{m}$?

Answer Key

37.



Hooke's Law: $F_{spring} = kx$

$150N = k(0.50m)$

$300 N/m = k$

Solve for Spring constant k

Solve for Spring potential energy

$U_s = \frac{1}{2}kx^2$

$U_s = \frac{1}{2}(300 N/m)(0.50m)^2$

$U_s = 37.5 J$

Use conservation of E to get v

$\Sigma E_i = \Sigma E_f \rightarrow U_i + \cancel{K_i}^{0} = \cancel{U_f}^{0} + K_f$

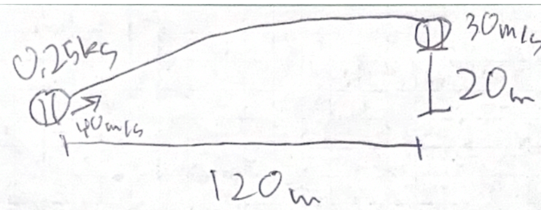
$K = \frac{1}{2}mv^2$

$U_s = K_f$

$37.5J = \frac{1}{2}(0.050kg)(v)^2$

$\boxed{38.7 m/s = v}$

41.



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

$U_g = mgh$

$\Sigma E_i = \Sigma E_f$

Work done by air friction

$K_i + \cancel{U_i}^{0} = K_f + U_f + \Delta E_{int}$

$\frac{1}{2}(0.25kg)(40m/s)^2 = \frac{1}{2}(0.25kg)(30m/s)^2 + (0.25kg)(9.8m/s^2)(20m) + \Delta E_{int}$

$38.5J = \Delta E_{int}$

Work is in the opposite direction of motion when something is slowed down, so Work by air resistance $= -38.5J$

24.

$$\Delta K = \int_{x_i}^{x_f} f(x)\, dx$$

Solve for change in KE

$$\Delta K = \int_{-4.0}^{4.0} (-5x^2 + 7x)\, dx$$

$$\Delta K = -\frac{5}{3}x^3 + \frac{7}{2}x^2 \Big|_{-4.0}^{4.0}$$

$$\Delta K = -213.33\,J$$

$$K_i + \Delta K = K_f$$

$$\frac{1}{2}mv_i^2 + \Delta K = \frac{1}{2}mv_f^2$$

$$\frac{1}{2}(2.0\,kg)(20\,m/s)^2 - 213.33\,J = \frac{1}{2}(2.0\,kg)(v_f)^2$$

Use kinetic energy to solve for v

$$13.7\,m/s = v_f$$