Work and Energy

Chapter 7.1-7.3

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Conservative Forces

- A force is conservative if the work done by it on a particle is independent of the path taken
- Examples of conservative forces:
  - Gravitational force
  - Elastic force (springs)
  - Electrostatic force
- Work done by conservative forces:
  - Can be recovered
  - Depends only on initial and final positions
  - Path-independent

Potential Energy

- Potential energy: energy stored due to position or configuration
- For conservative forces:

$$\Delta PE = -W_{\text{cons}}$$

where:

  - ΔPE is change in potential energy
  - W_{cons} is work done by conservative force
- Types:
  - Gravitational potential energy
  - Elastic potential energy

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Conservation of Mechanical Energy

- Mechanical energy = Kinetic energy + Potential energy

$$E = K + PE$$

- When only conservative forces act:

$$E_{\text{initial}} = E_{\text{final}}$$

- Or:

$$K_i + PE_i = K_f + PE_f$$

- This principle helps solve many physics problems!

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Nonconservative Forces

- Work depends on path taken
- Examples:
  - Friction
  - Air resistance
  - Tension in a rope
- With nonconservative forces:

$$\Delta E = W_{\text{nc}}$$

where W_{nc} is work done by nonconservative forces

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I Do: Roller Coaster Problem

A roller coaster car (mass 500 kg) starts from rest at height 40 m. What is its speed at height 15 m?

Solution

Using conservation of mechanical energy:

$$E_i = E_f$$

$$mgh_i + \frac{1}{2}mv_i^2 = mgh_f + \frac{1}{2}mv_f^2$$

$$(500)(9.8)(40) + 0 = (500)(9.8)(15) + \frac{1}{2}(500)v_f^2$$

$$196000 = 73500 + 250v_f^2$$

$$v_f = 22.6 \text{ m/s}$$

We Do: Spring Problem

Let's solve together: A 2 kg mass is attached to a spring ($k = 100$ N/m) and compressed 0.3 m. What height will it reach when released?

Step-by-Step

1. Initial energy (compressed spring):

$$\frac{1}{2}kx^2 = \frac{1}{2}(100)(0.3)^2 = 4.5 \text{ J}$$

2. At maximum height:

$$mgh = 4.5 \text{ J}$$

3. Solve for h:

$$h = \frac{4.5}{(2)(9.8)} = 0.23 \text{ m}$$

You Do: Practice Problem

Now try this one:

Problem

A 0.5 kg ball is thrown upward with initial velocity 15 m/s. Calculate:

- Maximum height reached
- Velocity when it returns to half the maximum height

Use conservation of energy principles!

You Do: Practice Problem

Now try this one:

Problem

A 0.5 kg ball is thrown upward with initial velocity 15 m/s. Calculate:

- Maximum height reached
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Use conservation of energy principles!

Hint

Start with:

$$\frac{1}{2}mv_i^2 = mgh_{\text{max}}$$

Then use conservation of energy again for the second part.

Key Takeaways

- Conservative forces:
  - Path-independent work
  - Enable potential energy definition
- Conservation of mechanical energy:
  - Powerful problem-solving tool
  - Only valid for conservative forces
- Nonconservative forces:
  - Change total mechanical energy
  - Require additional work calculations