Introduction to Physical Science

Potential Energy

Presented by Robert Wagner

Work Against Gravity

- Doing work against gravity
  - Potential Energy - stored energy
  - Force needs to lift an object is equal to its weight: mg
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- The gravitational potential energy depends only on relative position of object
  - Zero point often defined to be Earth’s surface
  - Can define it differently depending on the problem
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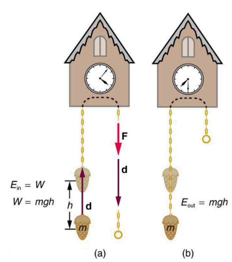
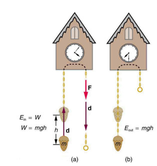
Example

- What is the change in potential energy when a 0.500 kg mass hung from a cuckoo clock is raised by 1.00 m.
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve



Example



- What is the change in potential energy when a 0.500 kg mass hung from a cuckoo clock is raised by 1.00 m.
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$m = 0.500\,kg$; $h = 1.00\,m$; $g = 9.80 m/s^2$

$$\Delta PE_g = mgh$$

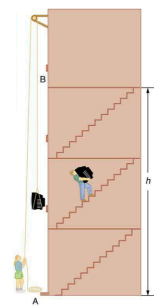
$$\Delta PE_g = (0.500\,kg)(9.80\,m/s^2)(1.00\,m)$$

$$\Delta PE_g = 4.90\,kg \cdot m^2/s^2$$

$$\Delta PE_g = 4.90\,Joules$$

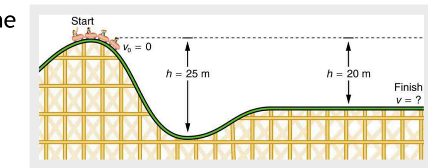
Potential Energy Calculations

- The change in potential energy depends on the change in height
  - The path does not matter
  - Simplifies calculations
- For both (A) and (B) in the diagram, the change in potential energy is the same
  - The work done is the same in both cases

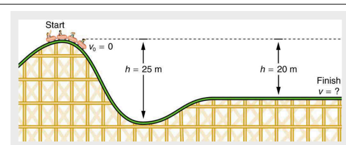


Example

- What is the final speed of the roller coaster shown. It starts from rest at the top of a 20.0 m hill. (Neglect friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve



Example



- What is the final speed of the roller coaster shown? It starts from rest at the top of a 20.0 m hill. (Neglect friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve

$$v_o = 0\ ;\ h = 20.0\,m$$

$$\Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2$$

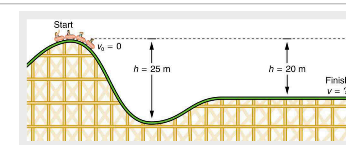
$$\Delta PE = \Delta KE$$

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

$$v = \sqrt{2gh} = \sqrt{2(9.80m/s^2)(20.0\,m)}$$

$$v = 19.8\,m/s$$

Example



- What is the final speed of the roller coaster shown if the initial speed is 5.00 m/s. (Neglect friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve

$$v_o = 5.0\,m/s\ ;\ h = 20.0\,m$$

$$\Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2$$

$$\Delta PE = \Delta KE$$

$$mgh = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2$$

$$v = \sqrt{2gh + v_o^2} = \sqrt{2(9.80m/s^2)(20.0\,m) + (5.00\,m/s)^2}$$

$$v = 20.4\,m/s$$

Conservative Forces

- A conservative force is one where the work done depends only on the starting and ending points, but not the path taken
- Examples - gravitational force (previously discussed) ; spring
  - Winding a spring stores energy that can later be released
- Potential Energy - Energy of a system due to position, shape or configuration
  - It is stored energy that can be recovered

Potential Energy of a Spring

- Hooke's Law: ; k = force constant
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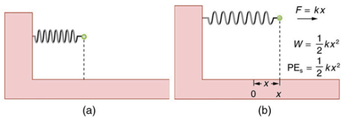
- The displacement from the undisturbed position is given by x



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Conservation of Mechanical Energy

- When only conservative forces were involved:
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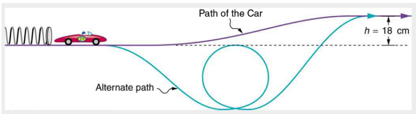
  -
  -
- Energy changes form
  - Changes between kinetic energy and potential energy
  - Total energy remains constant

Example

- A 0.100 kg toy car is propelled by a spring. The track rises by 0.180 m above the starting point. The spring is compressed 4.00cm and has a force constant 250.0 N/m. (Neglect Friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve



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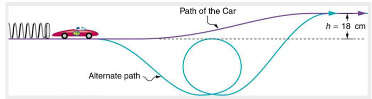
Example



- A 0.100 kg toy car is propelled by a spring. The track rises by 0.180 m above the starting point. The spring is compressed 4.00cm and has a force constant 250.0 N/m. What is the speed of the car before it starts up the slope? (Neglect Friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve

$m = 0.100\,kg\ ;\ h = 18\,cm\ ;\ k = 250.0\,N/m$

$$KE_i + PE_i = KE_f + PE_f$$

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

$$\frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{k}{m}}x_i = \sqrt{\frac{250.0\,N/m}{0.100\,kg}}(0.0400\,m)$$

$$v_f = 2.00\,m/s$$

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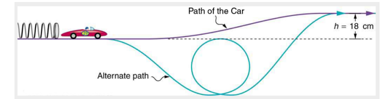
Example



- A 0.100 kg toy car is propelled by a spring. The track rises by 0.180 m above the starting point. The spring is compressed 4.00cm and has a force constant 250.0 N/m. What is the speed of the car at the top of the slope? (Neglect Friction)
  - Draw a sketch
  - List known values ; identify unknown
  - Determine equation to use
  - Plug in known values and solve

$m = 0.100\,kg\ ;\ h = 18\,cm\ ;\ k = 250.0\,N/m$

$$KE_i + PE_i = KE_f + PE_f$$

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

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

$$v_f = \sqrt{\frac{kx_i^2}{m} - 2gh_f} = \sqrt{\frac{250.0\,N/m}{0.100\,kg}(0.0400\,m)^2 - 2(9.80m/s^2)(0.180\,m}$$

$$v_f = 0.687\,m/s$$

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Summary

- Potential energy is energy that is stored - examples can be gravity or stored energy in a spring
- The zero point for gravitational potential energy can be selected depending on the specific problem
- Conservative forces are forces that only depend on the initial and final positions, not the path taken between them