Physics 1501

Fall 2008

Mechanics, Thermodynamics, Waves, Fluids

Lecture 15: Conservation of Energy II

Recap: conservative forces

- Examples of conservative forces include
  - Gravity
  - The static electric force
  - The force of an ideal spring
- Nonconservative forces include
  - Friction

Recap: potential energy

- The “stored work” associated with a conservative force is called **potential energy.**
  - Potential energy is stored energy that can be released as kinetic energy.
- The change in potential energy is defined as the negative of the work done by a conservative force acting over any path between two points:

$$\Delta U_{AB} = -\int_A^B \vec{F} \cdot d\vec{r}$$

  - Potential energy change is independent of path.
  - Only *changes* in potential energy matter.
  - We’re free to set the zero of potential energy at any convenient point.

Recap: conservation of mechanical energy

- By the work-energy theorem, the change in an object's kinetic energy equals the net work done *on* the object: $\Delta K = W_{net}$
- When only conservative forces act, the net work is the negative of the potential-energy change: $W_{net} = -\Delta U$
- Therefore when only conservative forces act, any change in potential energy is compensated by an opposite change in kinetic energy:

$$\Delta K + \Delta U = 0$$

- Equivalently,

$$K + U = \text{constant} = K_0 + U_0$$

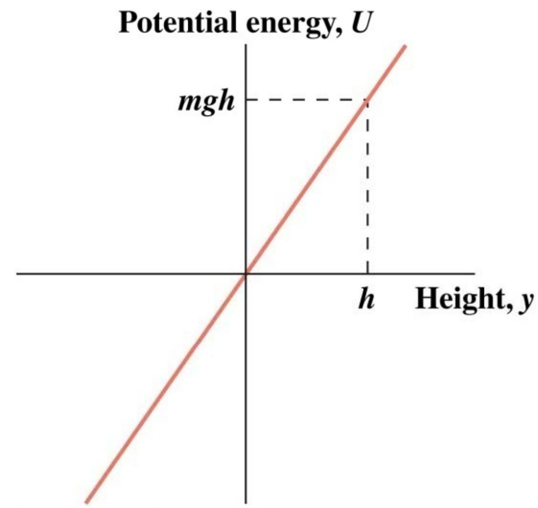
- Both these equations are statements of the law of **conservation of mechanical energy.**

Two common forms of potential energy

- **Gravitational potential energy** stores the work done against gravity:

$$\Delta U = mg\,\Delta y$$

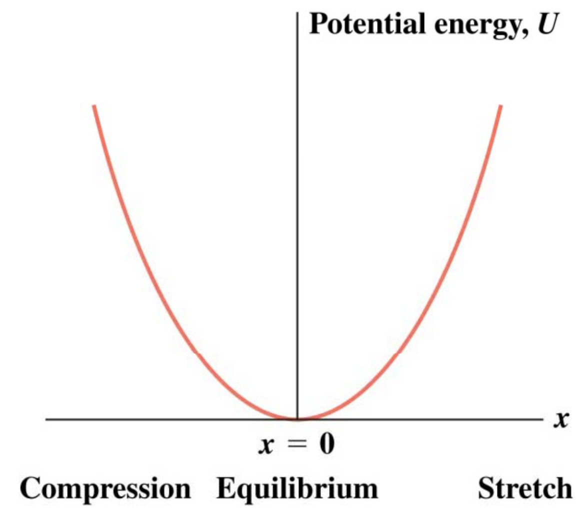
  - Gravitational potential energy increases linearly with height *y*.
  - This reflects the *constant* gravitational force near Earth's surface.



- **Elastic potential energy** stores the work done in stretching or compressing springs or spring-like systems:

$$U = \tfrac{1}{2}kx^2$$

  - Elastic potential energy increases *quadratically* with stretch or compression *x*.
  - This reflects the *linearly increasing* spring force.
  - Here the zero of potential energy is taken in the spring's equilibrium configuration.

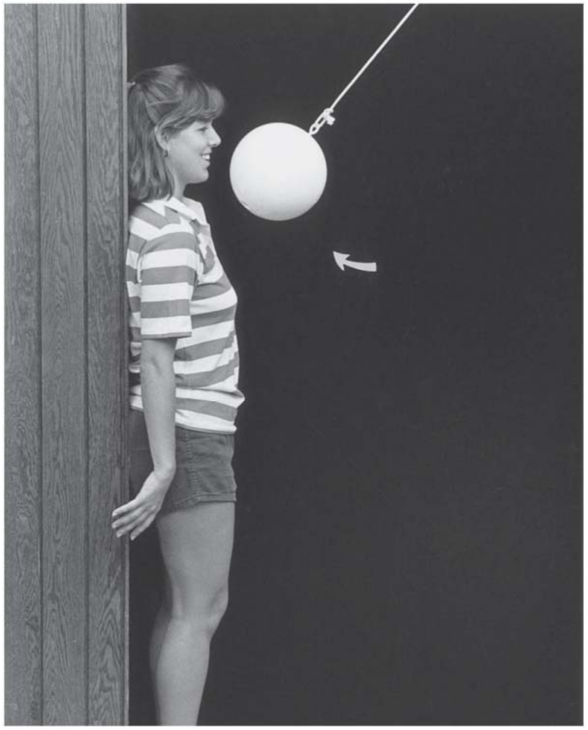


Clicker question

A bowling ball is tied to the end of a long rope and suspended from the ceiling. A student stands at one side of the room, holds the ball to her nose, and then releases it from rest. Should she duck as it swings back?

A. She should duck!

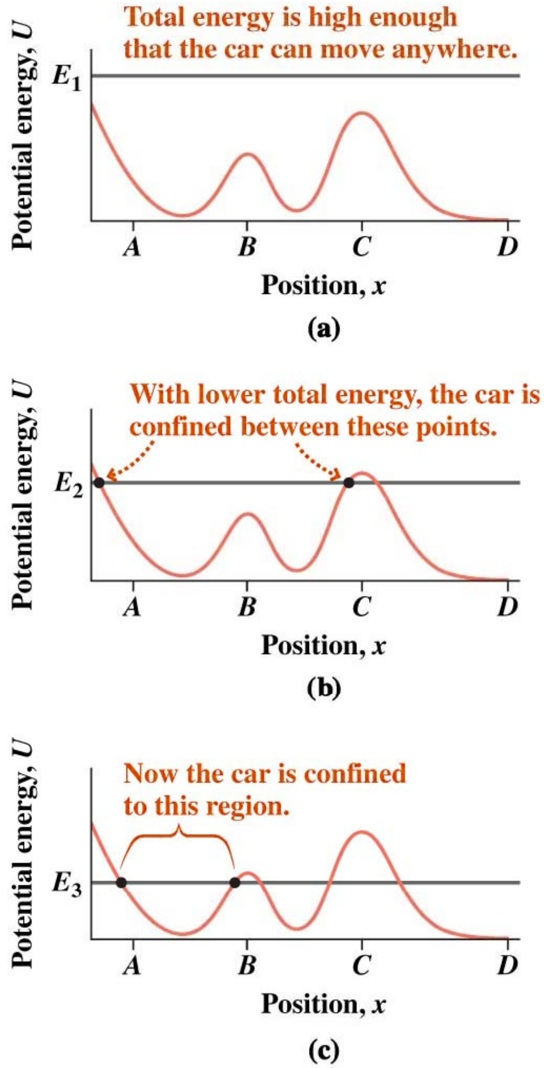
B. She does not need to duck.



Potential-energy curves

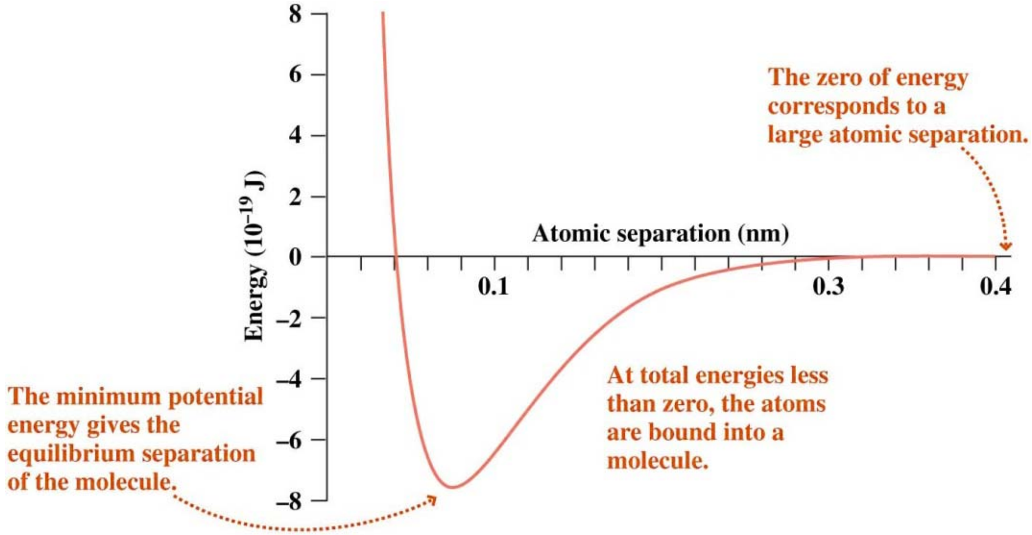
- Potential-energy curves depict a system's potential energy as a function of position or other quantities representing the system's configuration.
- An object with a given total energy can be "trapped" in a "potential well" established by points where its total energy equals its potential energy.
- These points are **turning points**, beyond which the object cannot move given its fixed total energy.

- **Potential-energy curves for a roller-coaster car with three different total energies:**



Potential-energy curve for a molecule

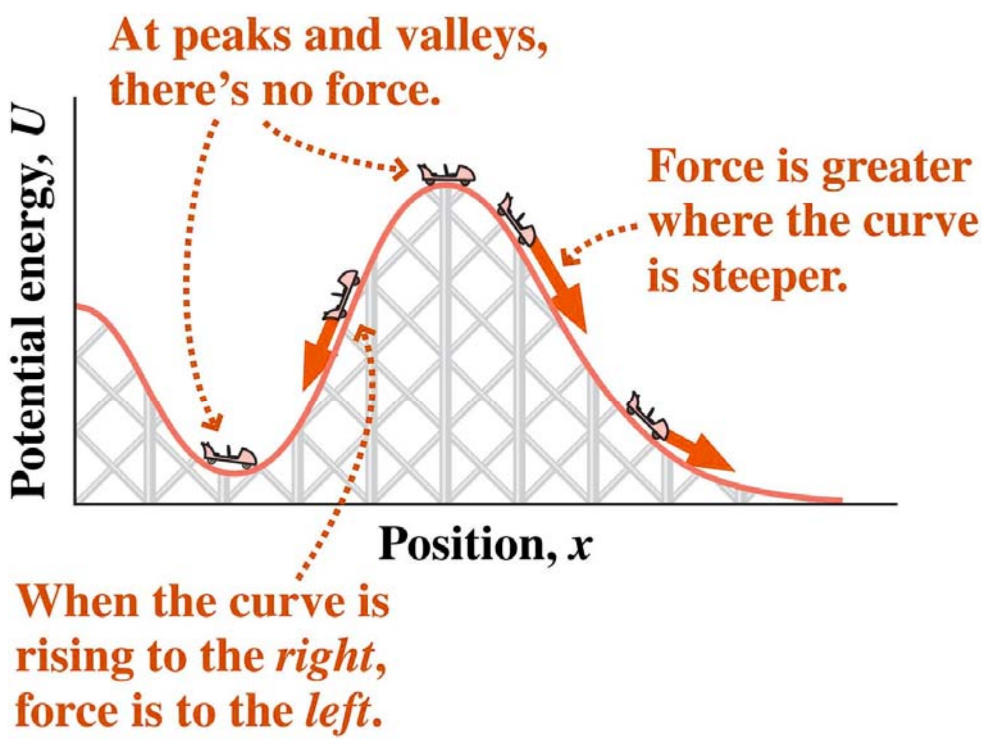
- Potential-energy curves help determine the structure of systems, from molecules to engineered systems to stars.
- The potential-energy curve for a pair of hydrogen atoms shows potential energy as a function of atomic separation.
  - **The minimum in the graph shows the equilibrium separation of the H_2 molecule.**
  - **It's convenient to take the zero of potential energy at infinite separation.**
  - **Then negative energies represent bound states of the hydrogen molecule.**
  - **Positive states represent separated hydrogen atoms.**



Force and potential energy

- Force is greatest where potential energy increases most rapidly.
- Mathematically, the component of force in a given direction is the negative derivative of the potential energy with respect to position in that direction:

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



Clicker question

This figure shows the potential energy for an electron in a microelectronic device. From among the labeled points, find the point **where the force on the electron is greatest**.

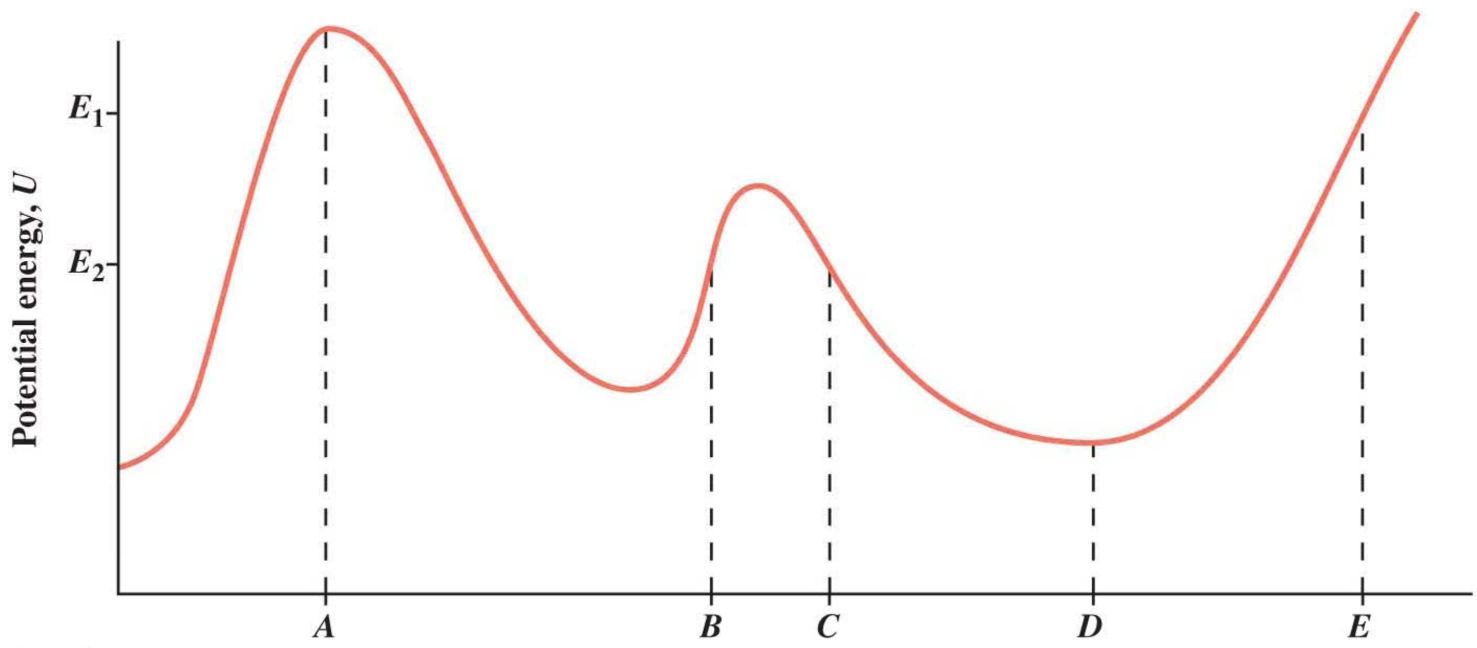
A. Point *A*

B. Point *B*

C. Point C

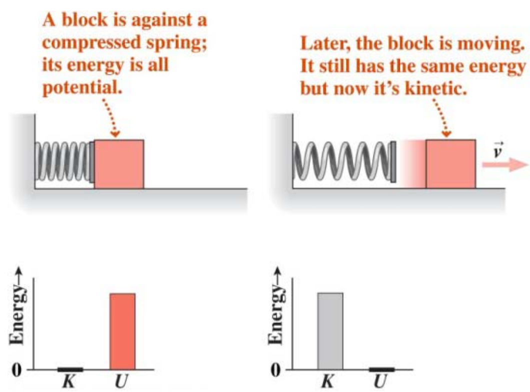
D. Point *D*

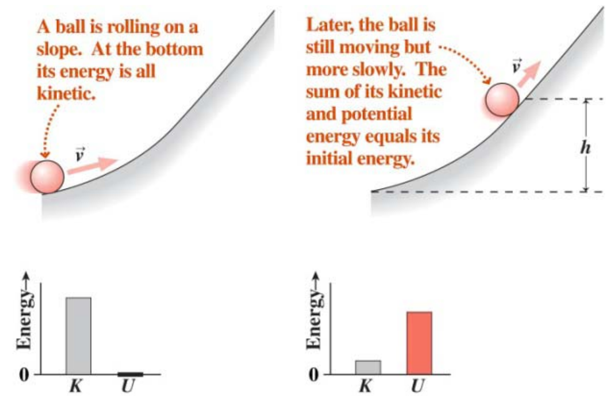
E. Point *E*



Summary

- **Potential energy** is stored energy that can be converted to kinetic energy.
- The change in potential energy is the negative of the work done by a conservative force as an object is moved on any path between two points: $\Delta U = -\int_A^B \vec{F} \cdot d\vec{r}$.
- When only conservative forces act, the total mechanical energy $K + U$ is conserved:





- **Potential-energy curves** describe potential energy as a function of position or configuration.
- **Force** is the negative derivative of potential energy: $F_x = -dU/dx$.