ANNOUNCEMENTS

- Homework #8, due Wednesday, October 17!

  Conceptual questions: Chapter 8, #8 and #14
  Problems: Chapter 8, #62, #68

- 5-minute quiz on Chapter 8 Friday, October 19

- Finish reading Chapter 8 by Monday, October 15

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

CONSERVATIVE AND NON-CONSERVATIVE FORCES

In Potential Energy and Conservation of Energy, any transition between kinetic and potential energy conserved the total energy of the system. This was path independent, meaning that we can start and stop at any two points in the problem, and the total energy of the system—kinetic plus potential—at these points are equal to each other. This is characteristic of a **conservative force**. We dealt with conservative forces in the preceding section, such as the gravitational force and spring force. When comparing the motion of the football in Figure 8.2, the total energy of the system never changes, even though the gravitational potential energy of the football increases, as the ball rises relative to ground and falls back to the initial gravitational potential energy when the football player catches the ball. **Non-conservative forces** are dissipative forces such as friction or air resistance. These forces take energy away from the system as the system progresses, energy that you can't get back. These forces are path dependent; therefore it matters where the object starts and stops.

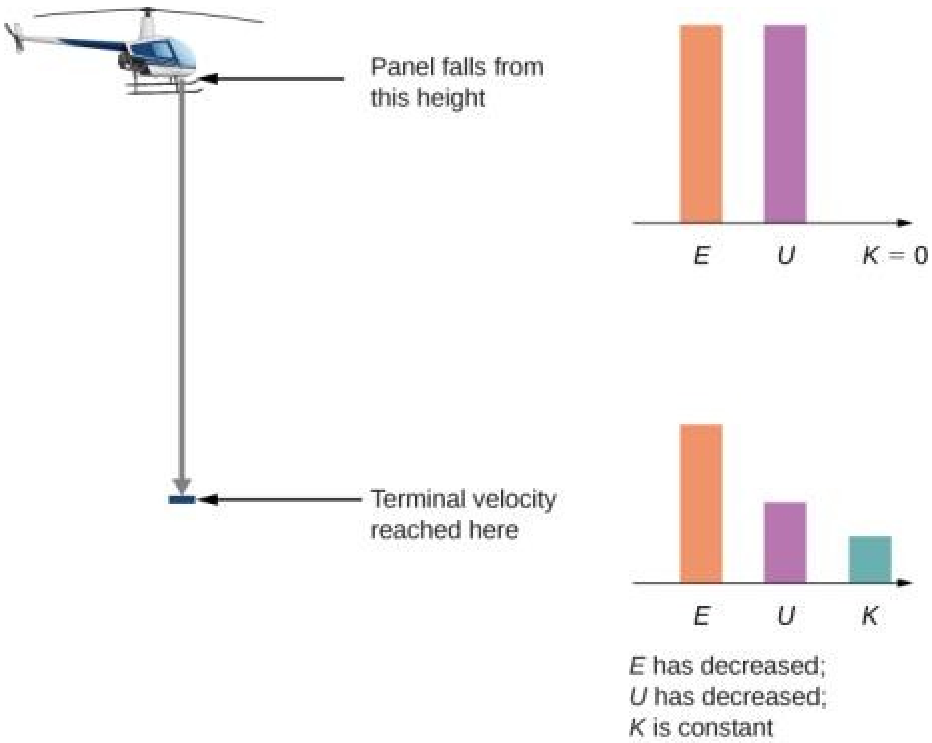
CONSERVATION OF ENERGY

The mechanical energy *E* of a particle stays constant unless forces outside the system or non-conservative forces do work on it, in which case, the change in the mechanical energy is equal to the work done by the non-conservative forces:

$$W_{\text{nc},AB} = \Delta(K+U)_{AB} = \Delta E_{AB}. \tag{8.12}$$

$$0 = W_{\text{nc},AB} = \Delta(K+U)_{AB} = \Delta E_{AB}. \tag{8.13}$$

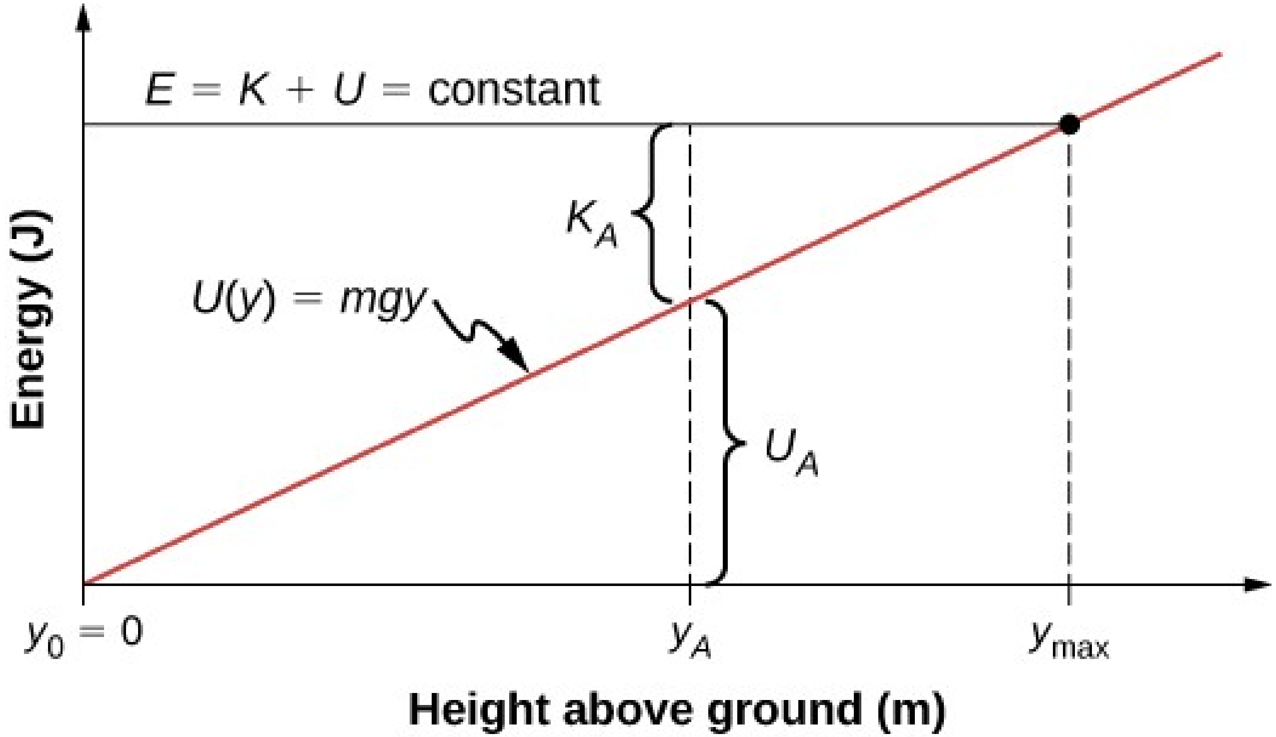
EXAMPLE



A helicopter loses a panel that falls until it reaches terminal velocity of 45 m/s. How much did air resistance contribute to the dissipation of energy in this problem?

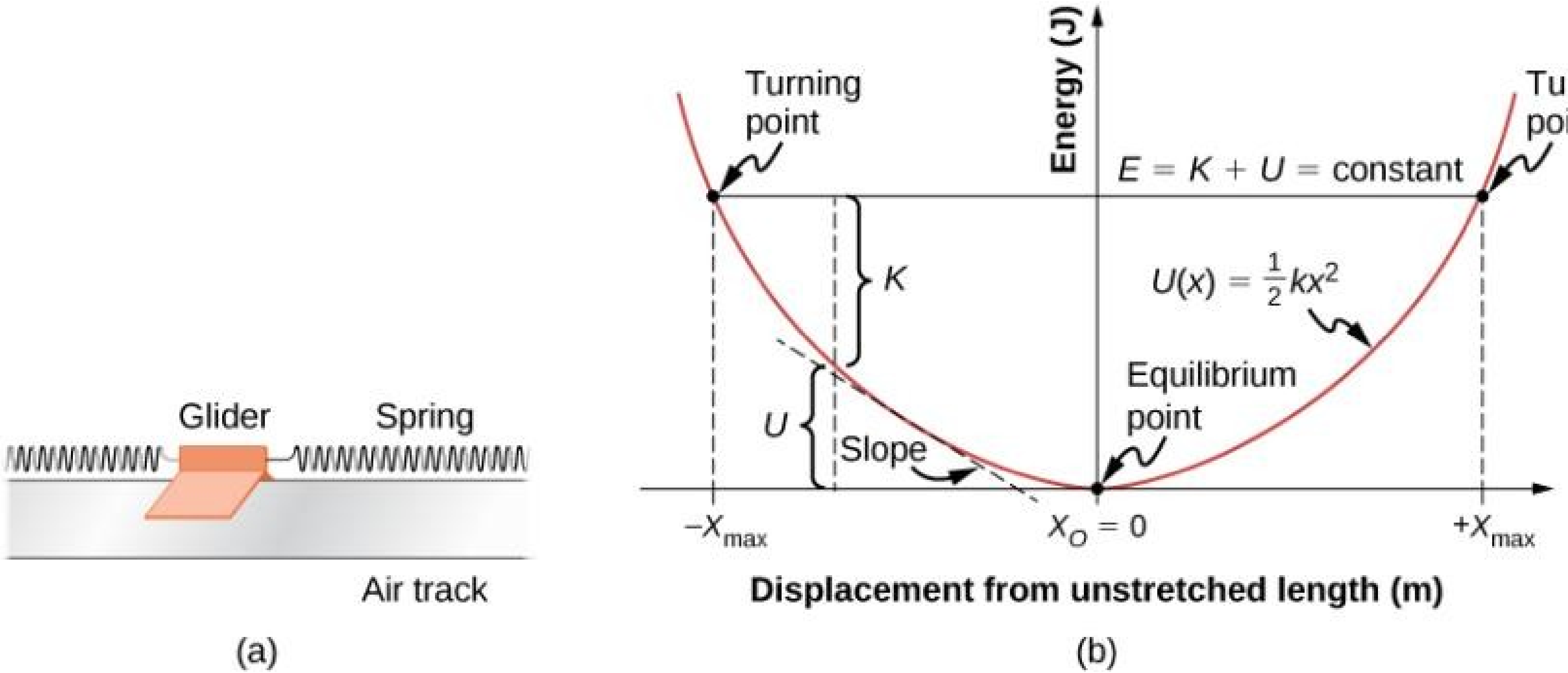
$$\begin{aligned}\Delta E_{\text{diss}} &= \left|K_{\text{f}} - K_{\text{i}} + U_{\text{f}} - U_{\text{i}}\right| \\ &= \left|\tfrac{1}{2}(15\ \text{kg})(45\ \text{m/s})^2 - 0 + 0 - (15\ \text{kg})\left(9.8\ \text{m/s}^2\right)(1000\ \text{m})\right| = 130\ \text{kJ}.\end{aligned}$$

ENERGY DIAGRAMS



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

ENERGY DIAGRAMS

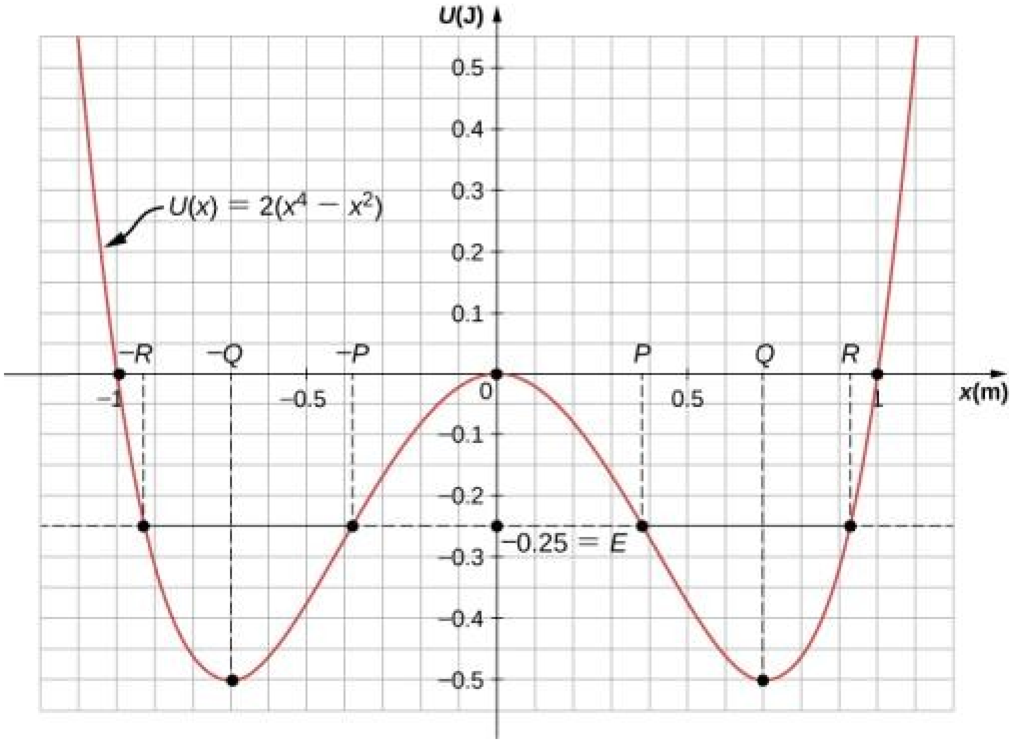


(a) A glider between springs on an air track is an example of a horizontal mass-spring system.

(b) The potential energy diagram for this system, with various quantities indicated.

ENERGY DIAGRAMS

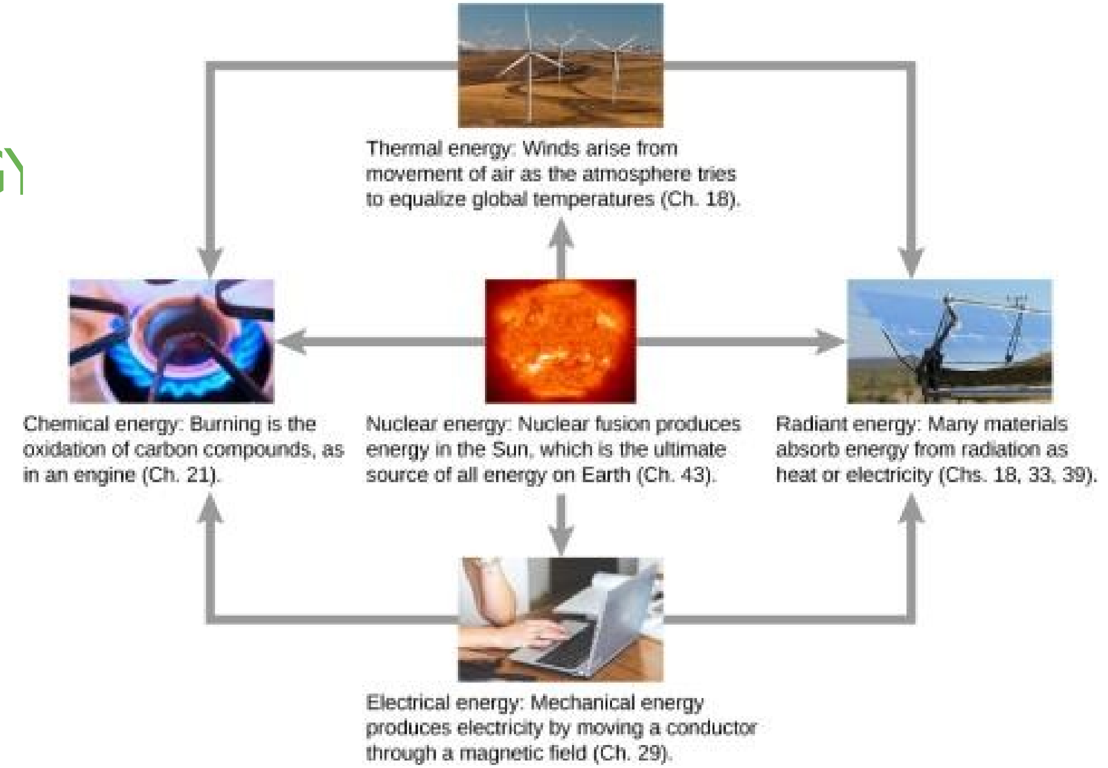
$$F_l = -\frac{dU}{dl}.$$



Quartic and Quadratic Potential Energy Diagram

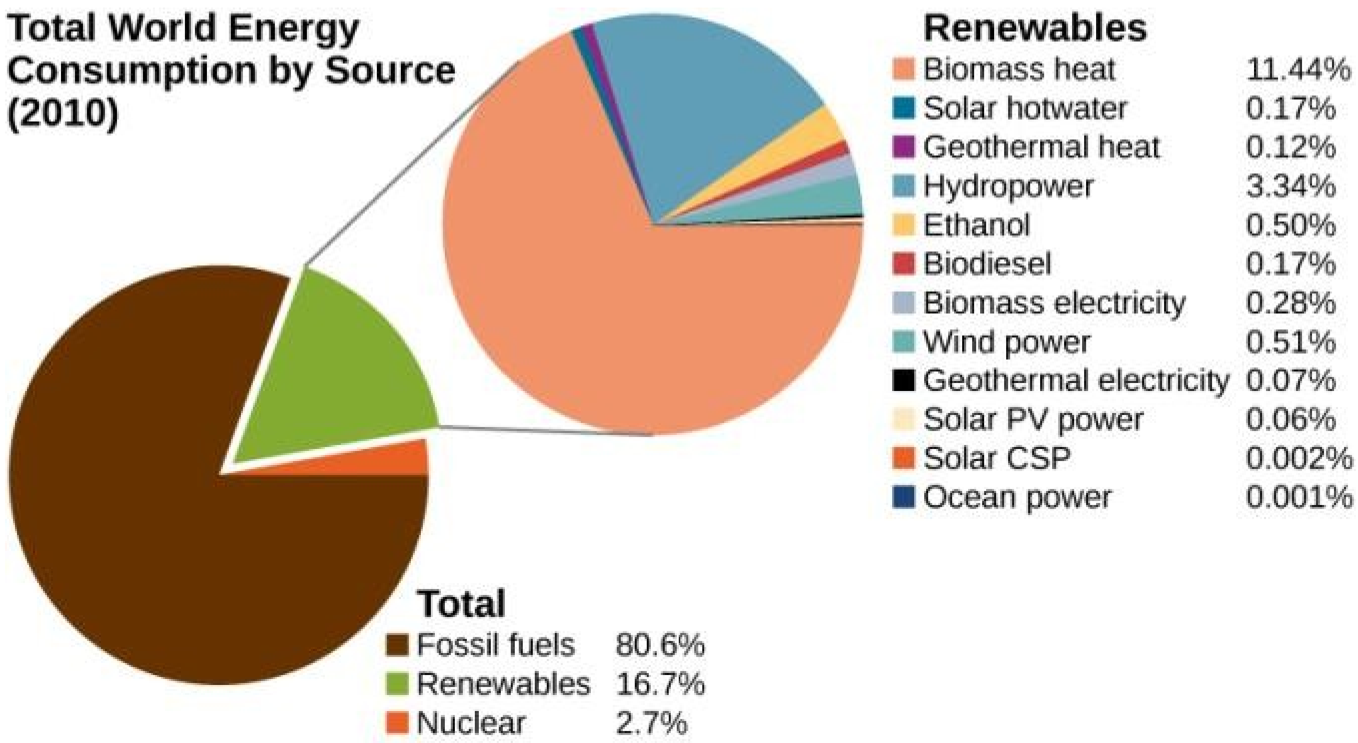
The potential energy for a particle undergoing one-dimensional motion along the *x*-axis is $U(x) = 2(x^4 - x^2)$, where *U* is in joules and *x* is in meters. The particle is not subject to any non-conservative forces and its mechanical energy is constant at $E = -0.25$ J. (a) Is the motion of the particle confined to any regions on the *x*-axis, and if so, what are they? (b) Are there any equilibrium points, and if so, where are they and are they stable or unstable?

FORMS OF ENERGY



- Atoms and molecules inside all objects are in random motion. The internal kinetic energy from these random motions is called *thermal energy*, because it is related to the temperature of the object. Note that thermal energy can also be transferred from one place to another, not transformed or converted, by the familiar processes of conduction, convection, and radiation. In this case, the energy is known as *heat energy*.
- *Electrical energy* is a common form that is converted to many other forms and does work in a wide range of practical situations.
- Fuels, such as gasoline and food, have *chemical energy*, which is potential energy arising from their molecular structure. Chemical energy can be converted into thermal energy by reactions like oxidation. Chemical reactions can also produce electrical energy, such as in batteries. Electrical energy can, in turn, produce thermal energy and light, such as in an electric heater or a light bulb.
- Light is just one kind of electromagnetic radiation, or *radiant energy*, which also includes radio, infrared, ultraviolet, X-rays, and gamma rays. All bodies with thermal energy can radiate energy in electromagnetic waves.
- *Nuclear energy* comes from reactions and processes that convert measurable amounts of mass into energy. Nuclear energy is transformed into radiant energy in the Sun, into thermal energy in the boilers of nuclear power plants, and then into electrical energy in the generators of power plants. These and all other forms of energy can be transformed into one another and, to a certain degree, can be converted into mechanical work.

FIGURE 8.15



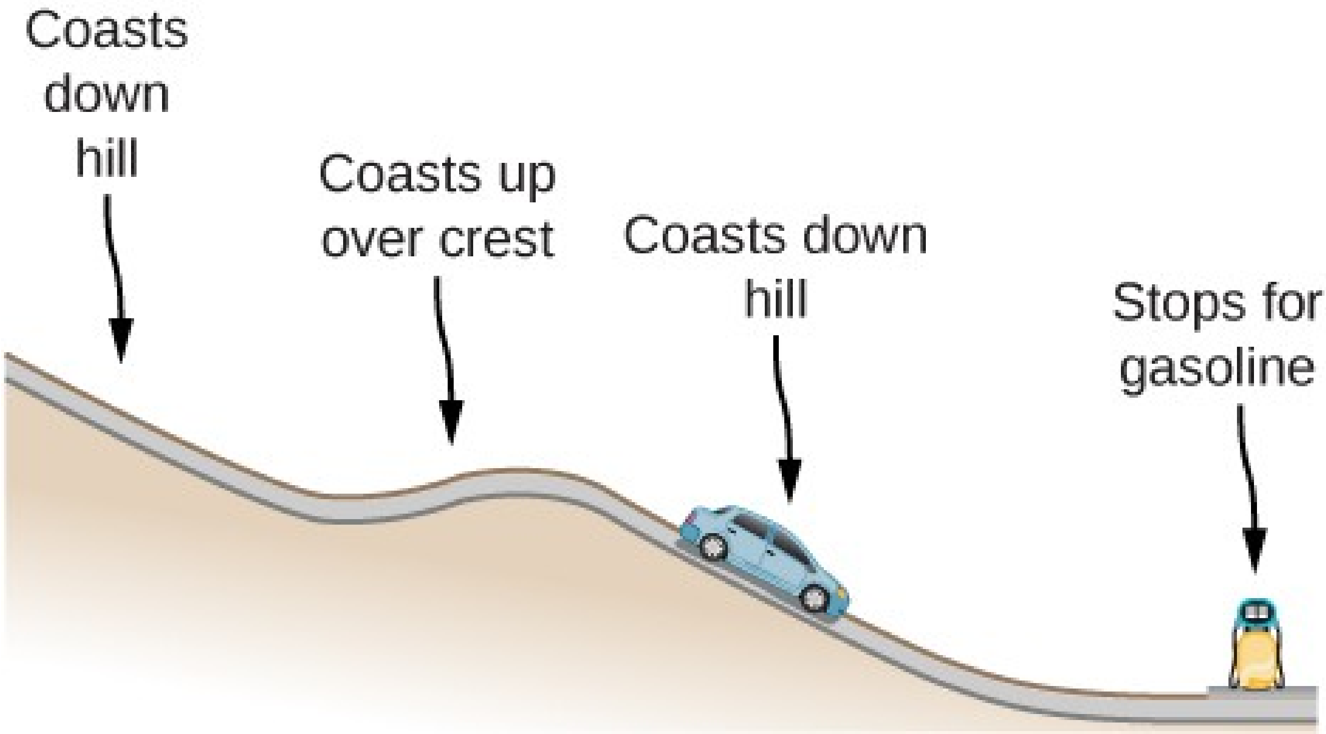
World energy consumption by source; the percentage of renewables is increasing, accounting for 19% in 2012.

FIGURE 8.16

Solar cell arrays found in a sunny area converting the solar energy into stored electrical energy. (credit: Sarah Swenty)

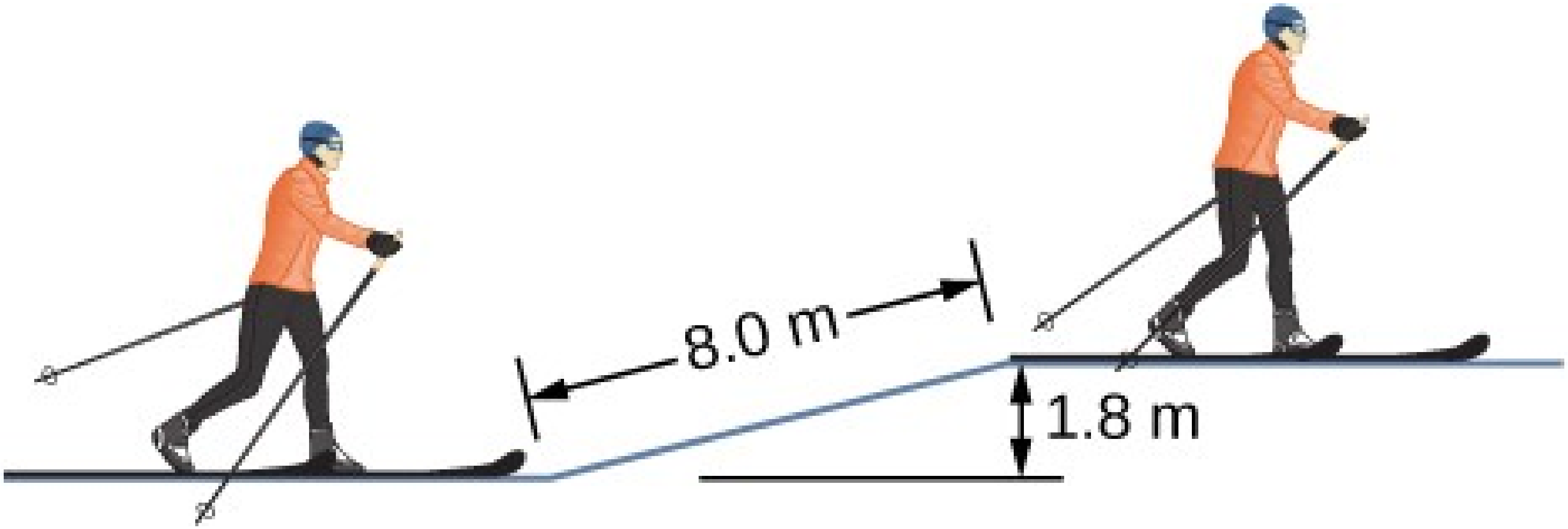
EXERCISE 11

Consider the following scenario. A car for which friction is *not* negligible accelerates from rest down a hill, running out of gasoline after a short distance (see below). The driver lets the car coast farther down the hill, then up and over a small crest. He then coasts down that hill into a gas station, where he brakes to a stop and fills the tank with gasoline. Identify the forms of energy the car has, and how they are changed and transferred in this series of events.



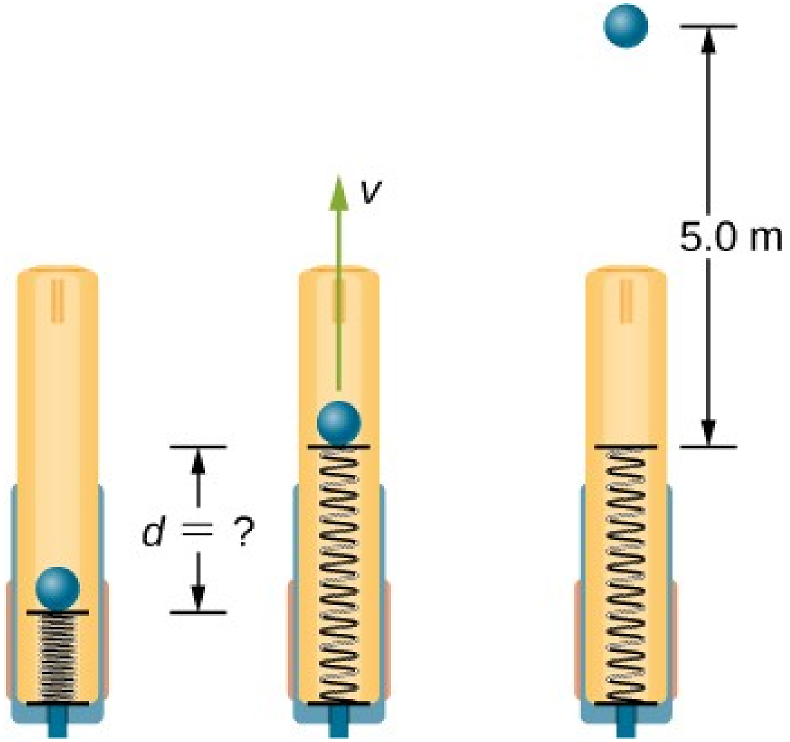
EXERCISE 38

A $100 - \mathrm{kg}$ man is skiing across level ground at a speed of $8.0\ \mathrm{m/s}$ when he comes to the small slope 1.8 m higher than ground level shown in the following figure. (a) If the skier coasts up the hill, what is his speed when he reaches the top plateau? Assume friction between the snow and skis is negligible. (b) What is his speed when he reaches the upper level if an $80 - \mathrm{N}$ frictional force acts on the skis?



EXERCISE 43

The massless spring of a spring gun has a force constant $k = 12\ \mathrm{N/cm}$. When the gun is aimed vertically, a 15-g projectile is shot to a height of 5.0 m above the end of the expanded spring. (See below.) How much was the spring compressed initially?



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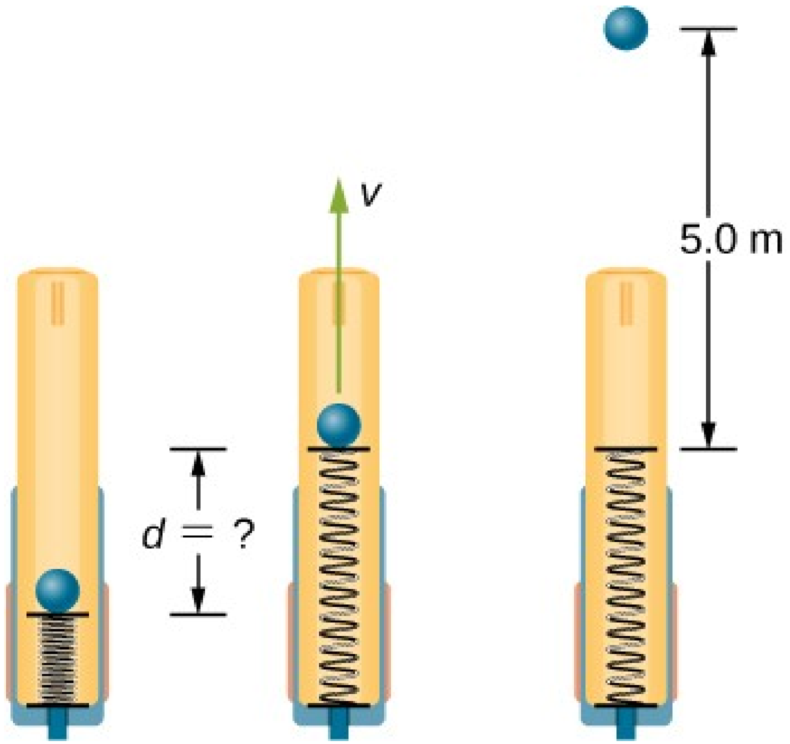
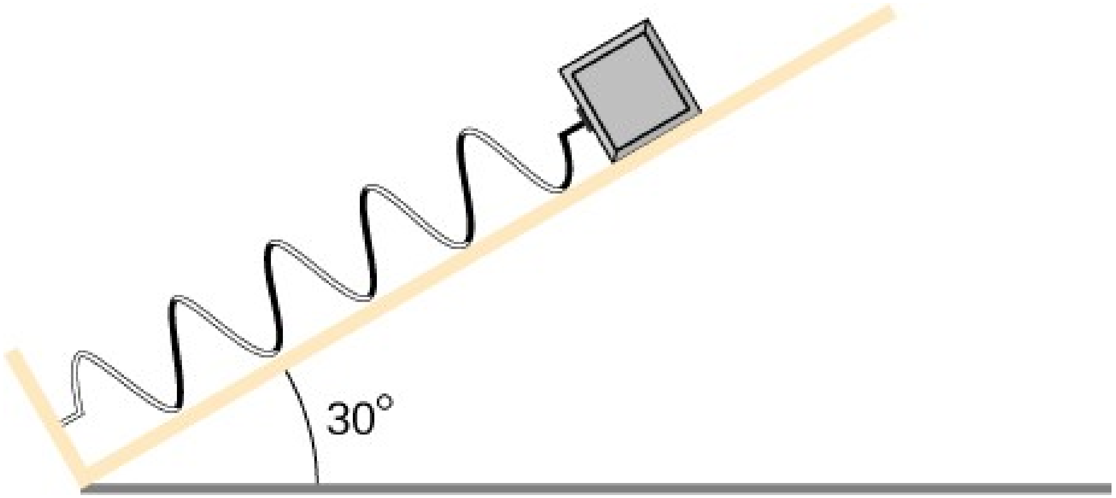


$$K_A + U_A = K_B + U_B$$

$$\frac{1}{2}kd^2 = mgh \qquad d = \sqrt{\frac{2mgh}{k}}$$

EXERCISE 64

A block of mass 500 g is attached to a spring of spring constant 80 N/m (see the following figure). The other end of the spring is attached to a support while the mass rests on a rough surface with a coefficient of friction of 0.20 that is inclined at angle of $30°$. The block is pushed along the surface till the spring compresses by 10 cm and is then released from rest. (a) How much potential energy was stored in the block-spring-support system when the block was just released? (b) Determine the speed of the block when it crosses the point when the spring is neither compressed nor stretched. (c) Determine the position of the block where it just comes to rest on its way up the incline.



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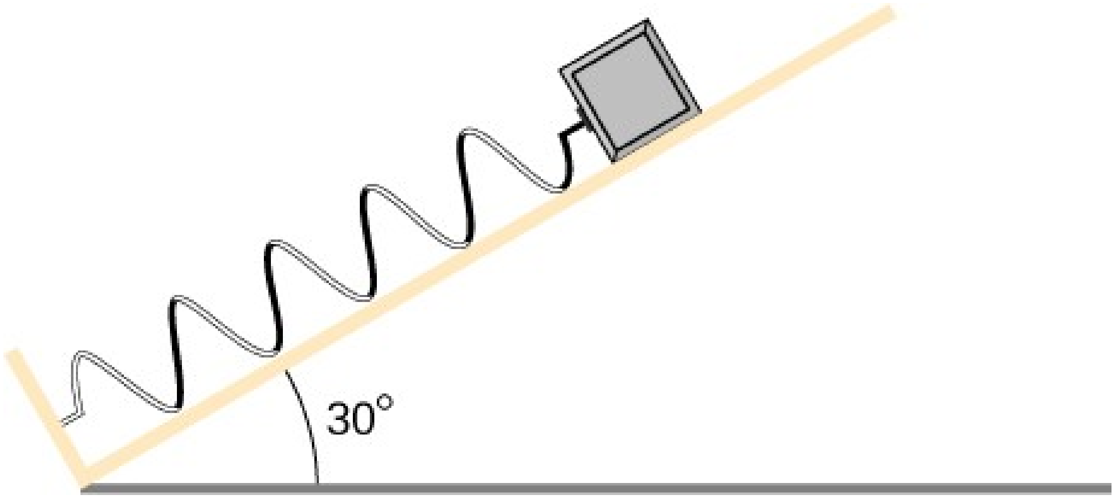

$$K_A + U_A = K_B + U_B$$

$$K_{\text{block}} = U_{\text{spring}} = \frac{1}{2}kx^2 \qquad U_{\text{block}} = 0$$

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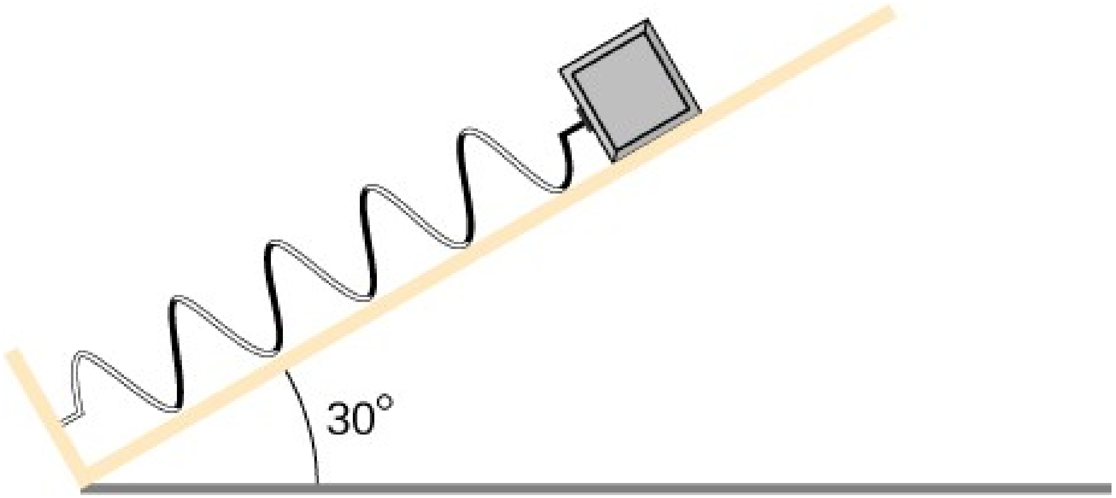

$$K_{\text{block}} = U_{\text{spring}} - mg \cdot d \sin(30°) - \mu \cdot mg \cos(30°) \cdot d$$

$$v = \sqrt{\frac{2K_{\text{block}}}{m}}$$

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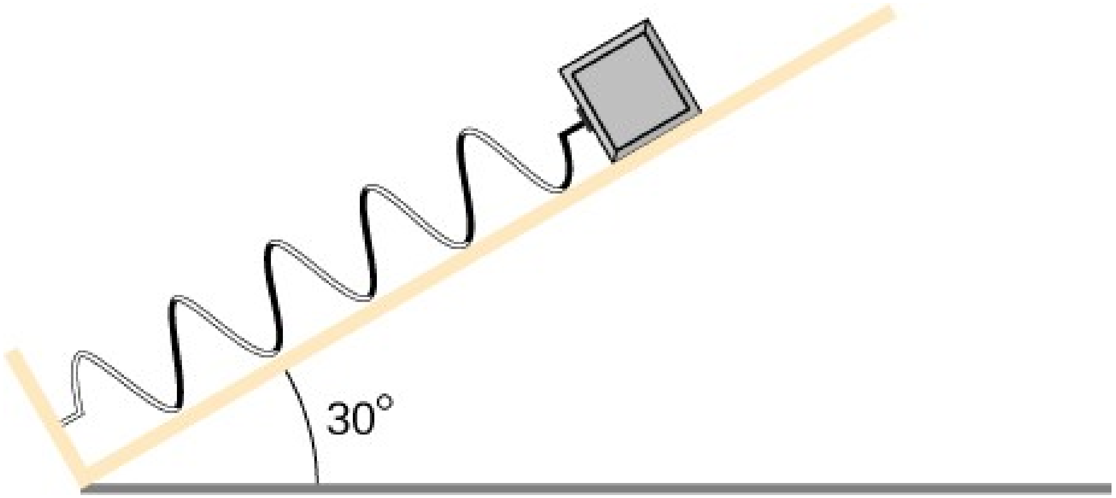
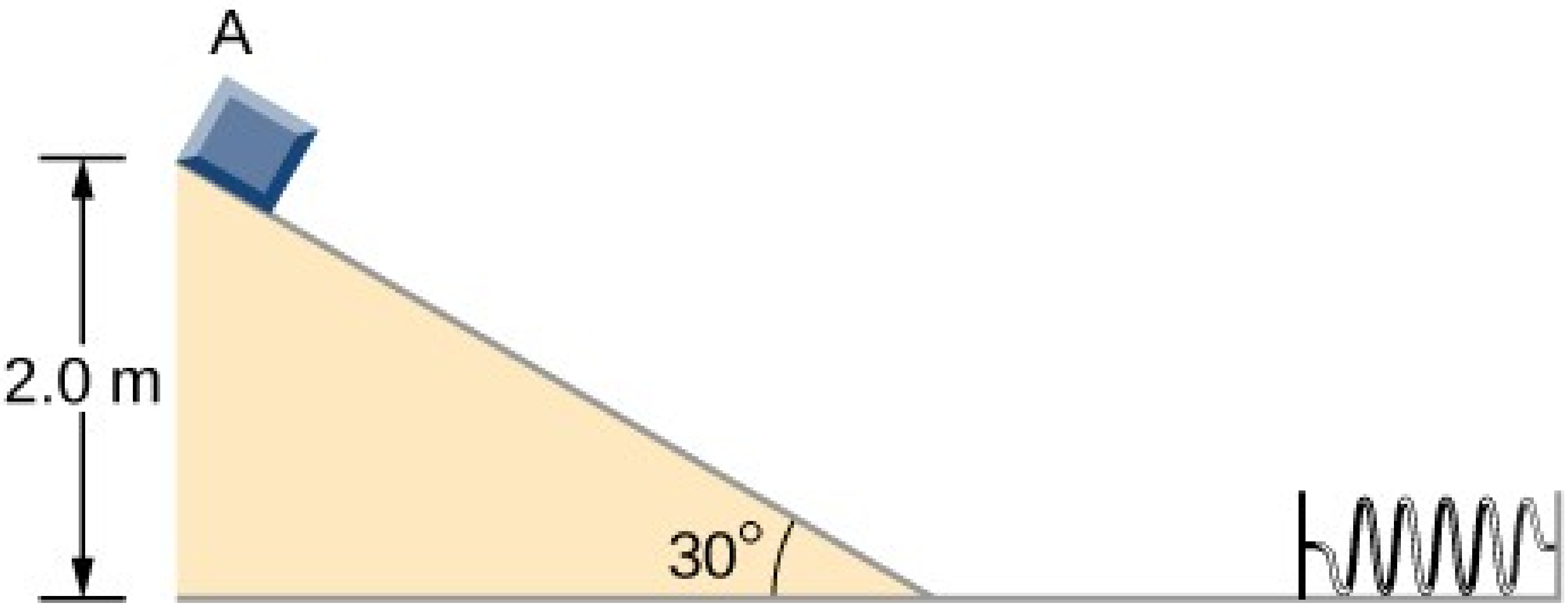


$$\frac{1}{2}kx^2 = mg \cdot d\sin(30°) + \mu \cdot mg\cos(30°) \cdot d$$

$$d = \frac{kx^2}{2mg[\sin(30°) + \mu\cos(30°)]}$$

EXERCISE 74

An object of mass 10 kg is released at point *A*, slides to the bottom of the $30°$ incline, then collides with a horizontal massless spring, compressing it a maximum distance of 0.75 m. (See below.) The spring constant is 500 M/m, the height of the incline is 2.0 m, and the horizontal surface is frictionless. (a) What is the speed of the object at the bottom of the incline? (b) What is the work of friction on the object while it is on the incline? (c) The spring recoils and sends the object back toward the incline. What is the speed of the object when it reaches the base of the incline? (d) What vertical distance does it move back up the incline?



EXERCISE 83