ANNOUNCEMENTS

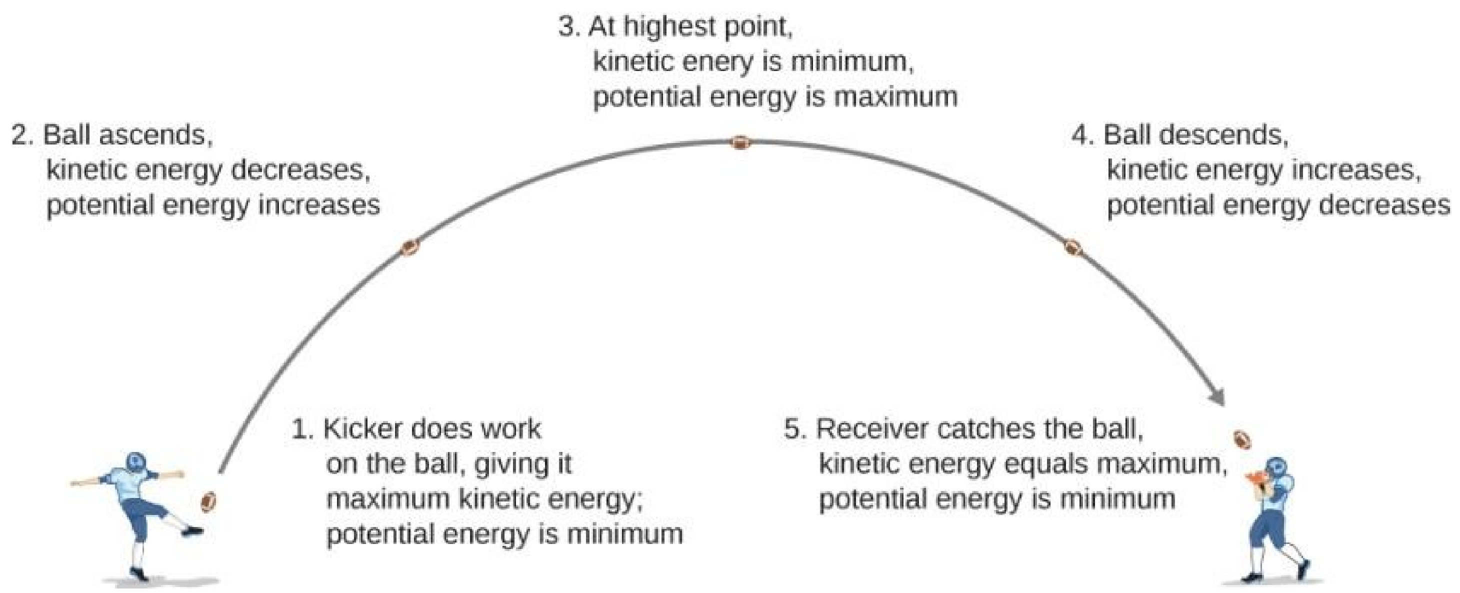
- Homework #7, due Today!

  Conceptual questions: Chapter 7, #4 and #8
  Problems: Chapter 7, #26, #28

- 5-minute quiz on Chapter 7: Friday, October 12

- Read Section 8.1, 8.3 and 8.4 by Monday, October 15

POTENTIAL ENERGY



As a football starts its descent toward the wide receiver, gravitational potential energy is converted back into kinetic energy.

$$\Delta U_{AB} = U_B - U_A = -W_{AB}. \quad (8.1)$$

$$\Delta K_{AB} = \Delta U_{AB}.$$

GRAVITATIONAL POTENTIAL ENERGY

In Work, the work done on a body by Earth's uniform gravitational force, near its surface, depended on the mass of the body, the acceleration due to gravity, and the difference in height the body traversed, as given by Equation 7.4. By definition, this work is the negative of the difference in the gravitational potential energy, so that difference is

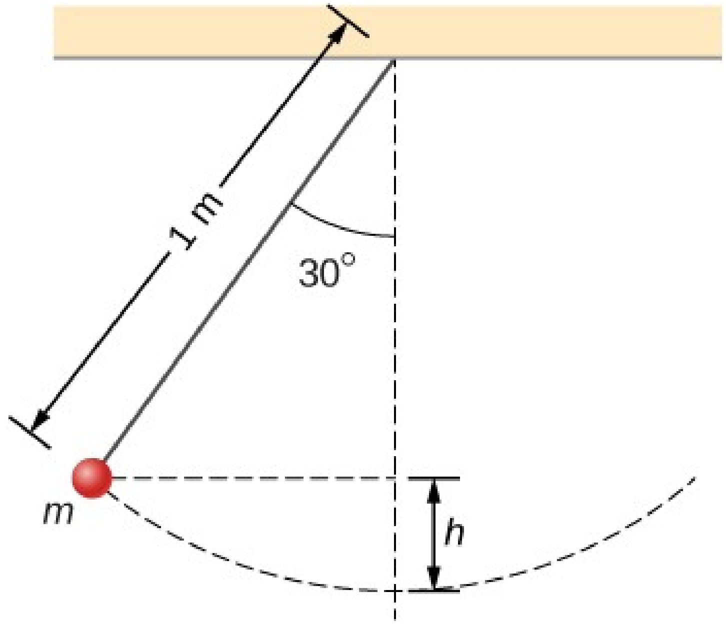
$$\Delta U_{\text{grav}} = -W_{\text{grav},AB} = mg\left(y_B - y_A\right). \tag{8.4}$$

You can see from this that the gravitational potential energy function, near Earth's surface, is

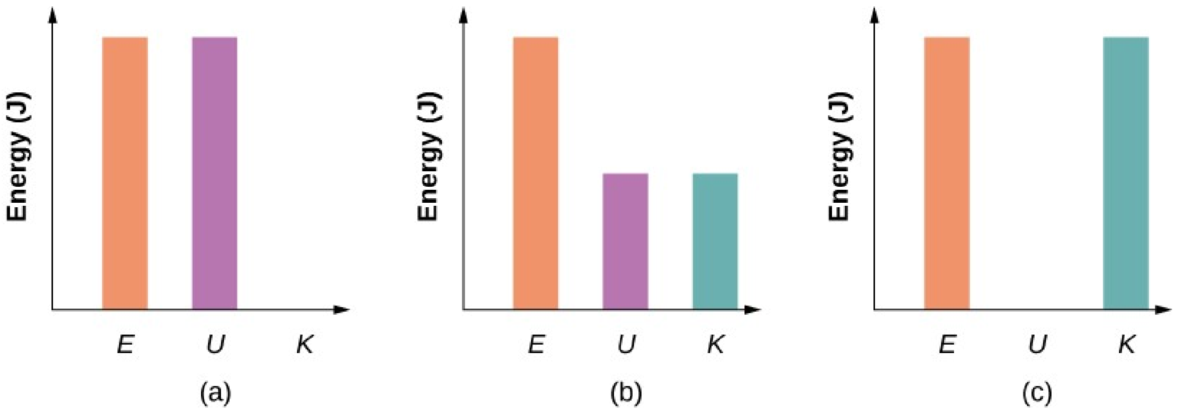
$$U\left(y\right) = mgy + \text{const.} \tag{8.5}$$

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

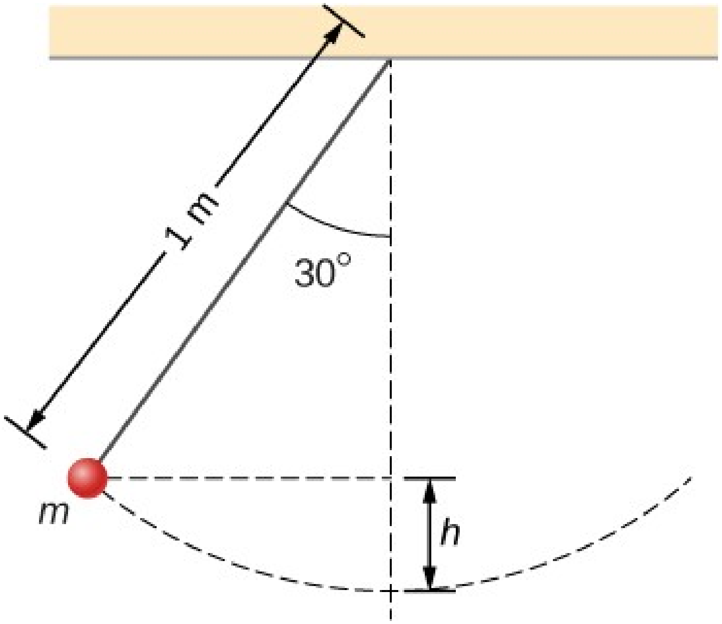
SIMPLE PENDULUM



A particle hung from a string constitutes a simple pendulum.



SIMPLE PENDULUM



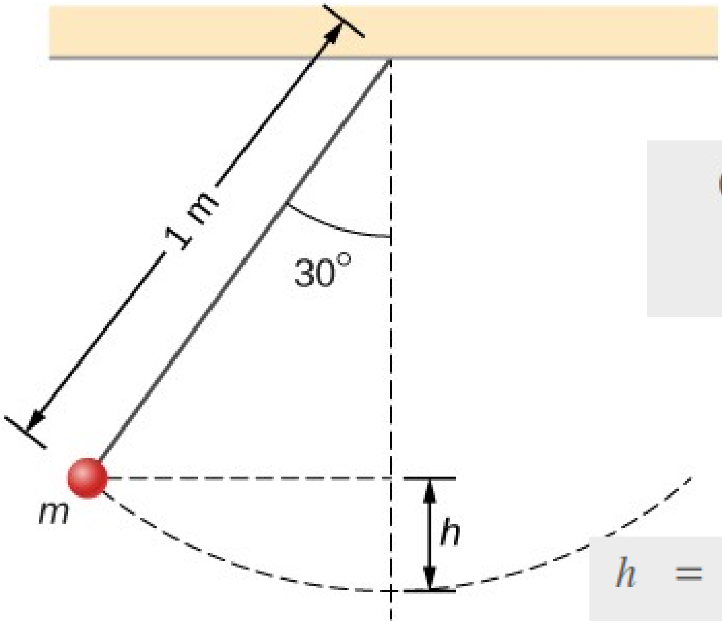
A particle hung from a string constitutes a simple pendulum.

Simple Pendulum

A particle of mass *m* is hung from the ceiling by a massless string of length 1.0 m, as shown in Figure 8.7. The particle is released from rest, when the angle between the string and the downward vertical direction is $30°$. What is its speed when it reaches the lowest point of its arc?

SIMPLE PENDULUM

$$K_i + U_i = K_f + U_f.$$



$$0 + mgh = \frac{1}{2}mv^2 + 0$$
$$v = \sqrt{2gh}.$$

$$h = L - L\cos\theta = L(1 - \cos\theta).$$

A particle hung from a string constitutes a simple pendulum.

Simple Pendulum

A particle of mass *m* is hung from the ceiling by a massless string of length 1.0 m, as shown in Figure 8.7. The particle is released from rest, when the angle between the string and the downward vertical direction is $30°$. What is its speed when it reaches the lowest point of its arc?

Spring Potential Energy

A system contains a perfectly elastic spring, with an unstretched length of 20 cm and a spring constant of 4 N/cm. (a) How much elastic potential energy does the spring contribute when its length is 23 cm? (b) How much more potential energy does it contribute if its length increases to 26 cm?

$$\Delta U = -W_{AB} = \frac{1}{2}k(x_B^2 - x_A^2), \quad (8.6)$$

where the object travels from point *A* to point *B*. The potential energy function corresponding to this difference is

$$U(x) = \frac{1}{2}kx^2 + \text{const.} \quad (8.7)$$

$$K_A + U_A = K_C + U_C$$

$$0 = 0 + mgy_C + \left(\tfrac{1}{2}ky_C\right)^2$$

$$y_C = \frac{-2mg}{k}$$

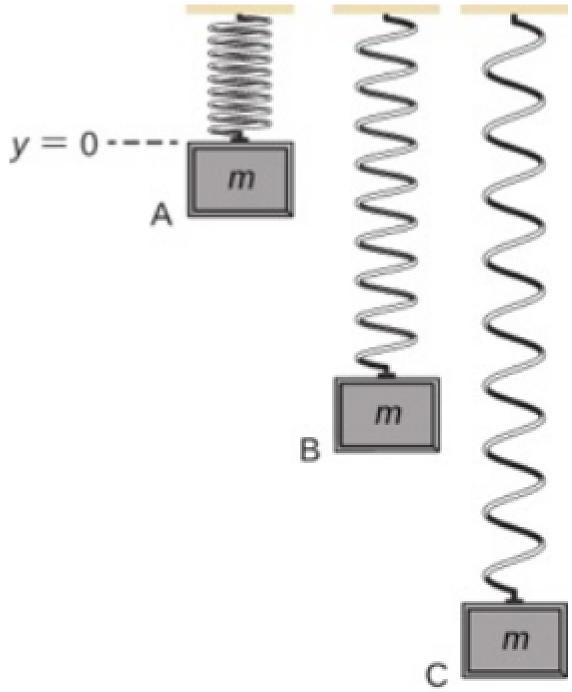
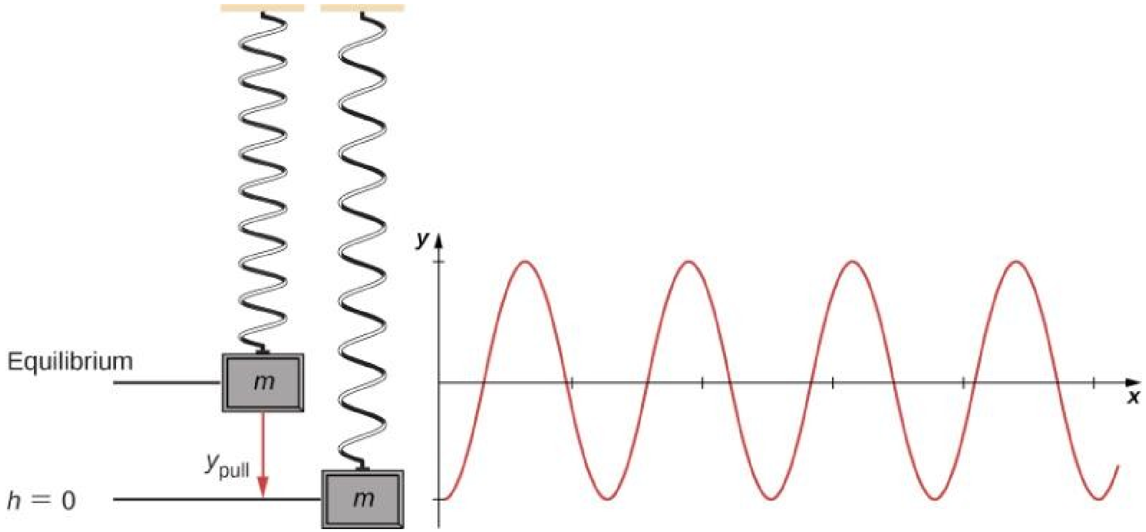


Figure 8.4 A vertical mass-spring system, with the y-axis pointing downward. The mass is initially at an unstretched spring length, point A. Then it is released, expanding past point B to point C, where it comes to a stop.



A vertical mass-spring system, with the *y*-axis pointing upwards. The mass is initially at an equilibrium position and pulled downward to y_{pull}. An oscillation begins, centered at the equilibrium position.

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.

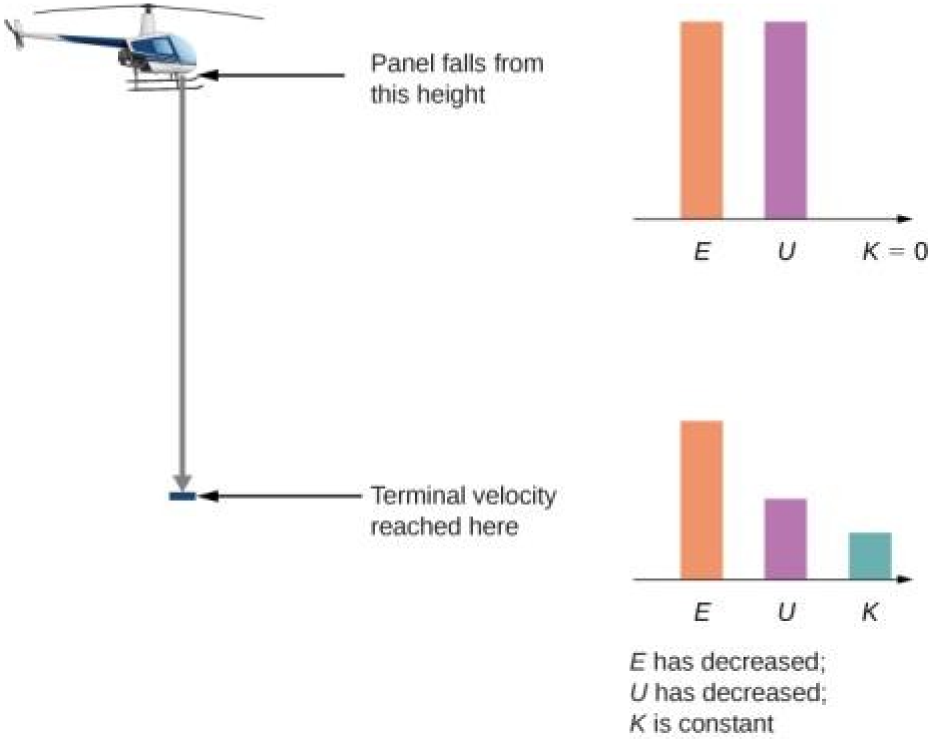
CONSERVATION OF ENERGY

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:

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

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

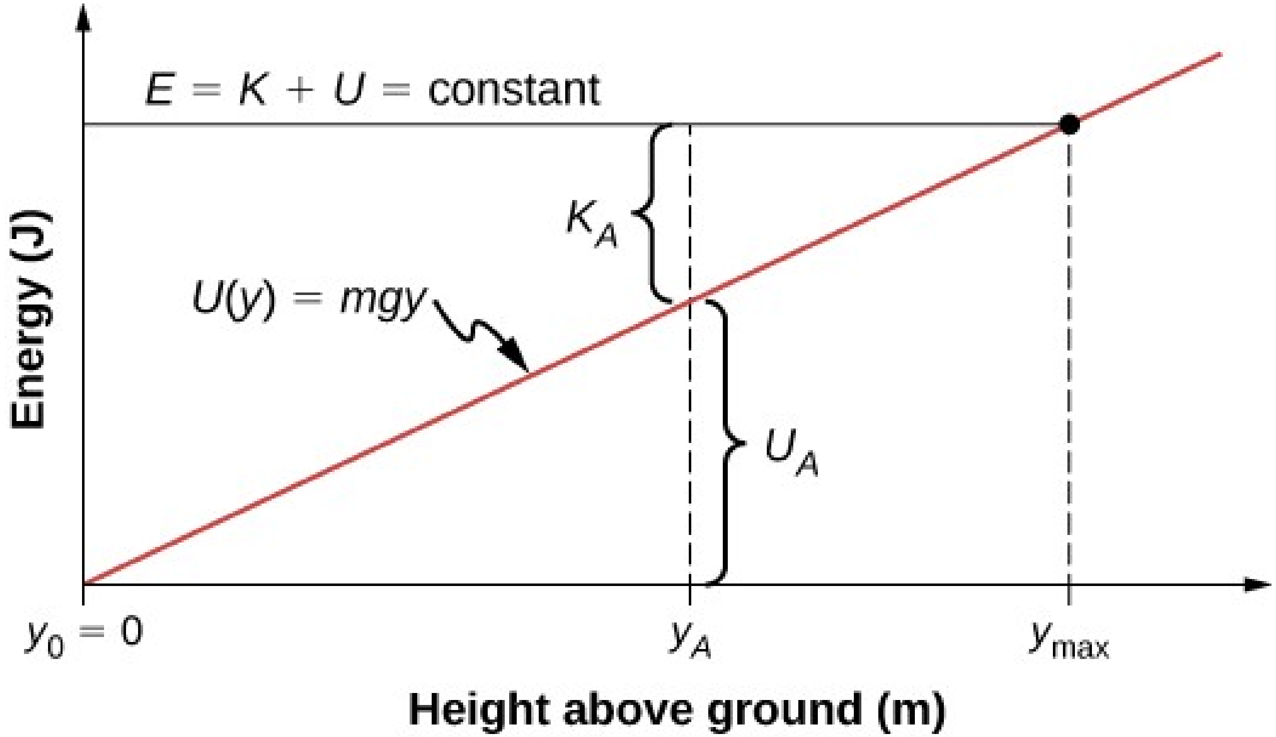
EXAMPLE



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?

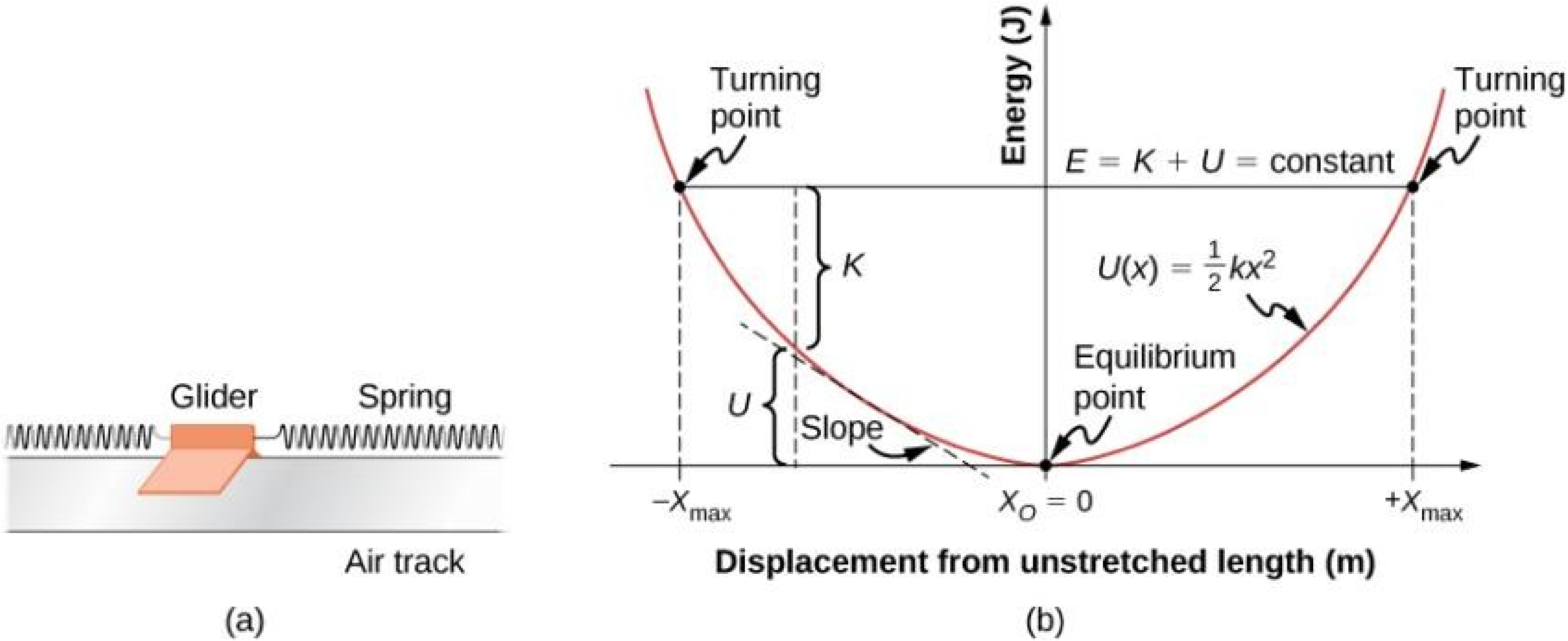
$$\begin{aligned}\Delta E_{\text{diss}} &= |K_{\text{f}} - K_{\text{i}} + U_{\text{f}} - U_{\text{i}}| \\ &= \left|\tfrac{1}{2}(15\text{ kg})(45\text{ m/s})^2 - 0 + 0 - (15\text{ kg})\left(9.8\text{ m/s}^2\right)(1000\text{ m})\right| = 130\text{ kJ.}\end{aligned}$$

ENERGY DIAGRAMS



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

ENERGY DIAGRAMS

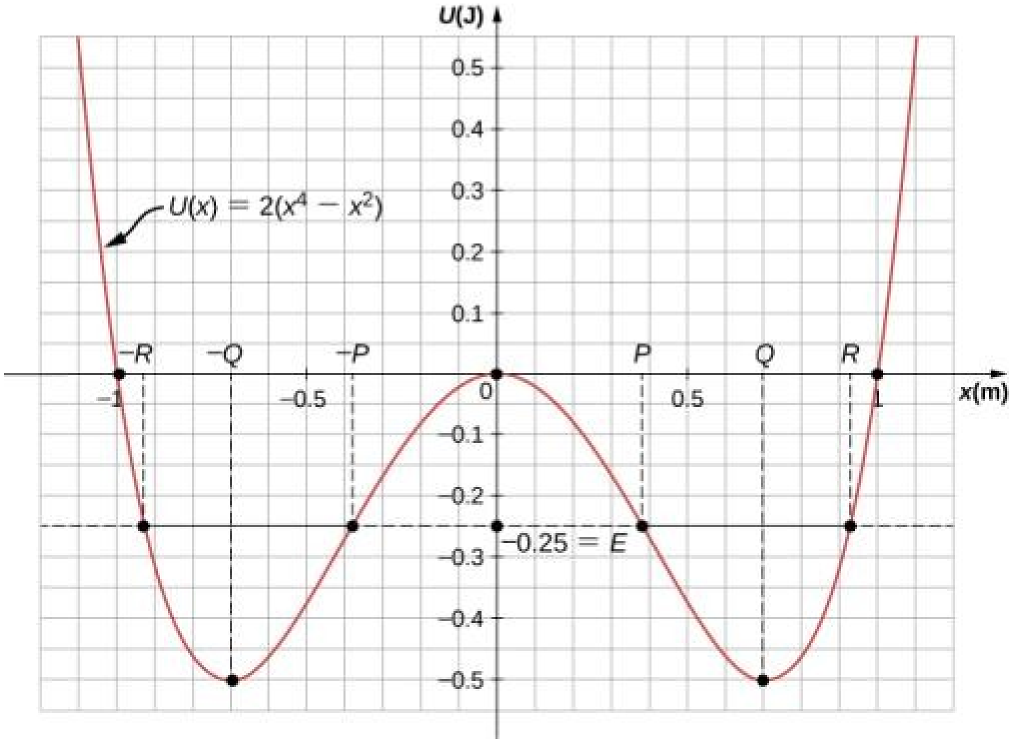


(a) A glider between springs on an air track is an example of a horizontal mass-spring system.

(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?