Work and Energy

Additional Practice D

Givens	*Solutions*
1. $x = 5.00$ cm $KE_{car} = 1.09 \times 10^{-4}$ J	Assuming all of the kinetic energy becomes stored elastic potential energy, $KE_{car} = PE_{elastic} = \frac{1}{2}kx^2$ $k = \frac{2\,PE_{elastic}}{x^2} = \frac{(2)(1.09 \times 10^4\ \text{J})}{(5.00 \times 10^{-2}\ \text{m})^2}$ $k = \boxed{8.72 \times 10^6\ \text{N/m}}$
2. $PE_{elastic} = 5.78 \times 10^7$ J $x = 102$ m for each spring	$PE_{elastic} = 2\left(\frac{1}{2}kx^2\right)$ $PE_{elastic} = kx^2$ $k = \frac{PE_{elastic}}{x^2} = \frac{5.78 \times 10^7\ \text{J}}{(102\ \text{m})^2}$ $k = \boxed{5.56 \times 10^3\ \text{N/m}}$
3. $m = 0.76$ kg $x = 2.3$ cm $g = 9.81\ \text{m/s}^2$	elastic potential energy stored = decrease in gravitational potential energy $PE_{elastic} = mgx$ $PE_{elastic} = \frac{1}{2}kx^2 = mgx$ $k = \frac{2\,mgx}{x^2} = \frac{2\,mg}{x} = \frac{(2)(0.76\ \text{kg})(9.81\ \text{m/s}^2)}{2.3 \times 10^{-2}\ \text{m}}$ $k = \boxed{6.5 \times 10^2\ \text{N/m}}$
4. $m = 5.0$ kg $\theta = 25.0°$ $PE_g = 2.4 \times 10^2$ J	$PE_g = mgh = mgd(\sin\theta)$ $d = \frac{PE_g}{mg\,(\sin\theta)} = \frac{2.4 \times 10^2\ \text{J}}{(5.0\ \text{kg})(9.81\ \text{m/s}^2)(\sin 25.0°)}$ $d = \boxed{12\ \text{m}}$
5. $k = 1.5 \times 10^4$ N/m $PE_{elastic} = 120$ J	$PE_{elastic} = \frac{1}{2}kx^2$ $x = \pm\sqrt{\frac{2\,PE_{elastic}}{k}} = \pm\sqrt{\frac{(2)(120\ \text{J})}{1.5 \times 10^4\ \text{N/m}}}$ Spring is compressed, so negative root is selected. $x = \boxed{-0.13\ \text{m} = -13\ \text{cm}}$
6. $m = 1750$ kg $PE_g = 1.69 \times 10^{10}$ J $g = 6.44\ \text{m/s}^2$	$PE_g = mgh$ $h = \frac{PE_g}{mg} = \frac{1.69 \times 10^{10}\ \text{J}}{(1750\ \text{kg})(6.44\ \text{m/s}^2)}$ $h = \boxed{1.50 \times 10^6\ \text{m} = 1.50 \times 10^3\ \text{km}}$
7. $h = 7.0$ m $PE_g = 6.6 \times 10^4$ J $g = 9.81\ \text{m/s}^2$	$PE_g = mgh$ $m = \frac{PE_g}{gh} = \frac{6.6 \times 10^4\ \text{J}}{(9.81\ \text{m/s}^2)(7.0\ \text{m})}$ $m = \boxed{9.6 \times 10^2\ \text{kg}}$

© Houghton Mifflin Harcourt Publishing Company

Givens	*Solutions*
8. $PE_g = 3.36 \times 10^9$ J $h = 1.45$ km	$PE_g = mgh$ $m = \frac{PE_g}{gh} = \frac{3.36 \times 10^9 \text{ J}}{(9.81 \text{ m/s}^2)(1.45 \times 10^3 \text{ m})}$ $m = \boxed{2.36 \times 10^5 \text{ kg}}$
9. $k = 550$ N/m $x = -1.2$ cm	$PE_{elastic} = \frac{1}{2}kx^2 = \frac{1}{2}(550 \text{ N/m})(-1.2 \times 10^{-2} \text{ m})^2 = \boxed{4.0 \times 10^{-2} \text{ J}}$
10. $h = 5334$ m $m = 64.0$ kg $g = 9.81$ m/s^2	$PE_g = mgh = (64.0 \text{ kg})(9.81 \text{ m/s}^2)(5334 \text{ m}) = \boxed{3.35 \times 10^6 \text{ J}}$

© Houghton Mifflin Harcourt Publishing Company

Work and Energy

Problem D

POTENTIAL ENERGY

PROBLEM

A 70.0 kg stuntman jumps from a bridge that is 50.0 m above the water. Fortunately, a bungee cord with an unstretched length of 15.0 m is attached to the stuntman, so that he breaks his fall 12.0 m above the water's surface. If the total potential energy associated with the stuntman and cord is 3.43×10^4 J, what is the force constant of the cord?

SOLUTION

1. **DEFINE**

Given: $m = 70.0$ kg $\quad h = 12.0$ m

$x = 50.0\text{ m} - 12.0\text{ m} - 15.0\text{ m} = 23.0\text{ m}$

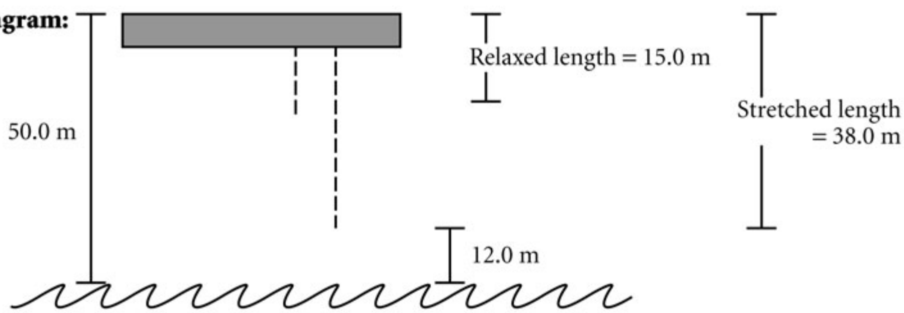
$PE_g = 0$ J at river level

$PE_{tot} = 3.43 \times 10^4$ J

$g = 9.81\text{ m/s}^2$

Unknown: $k = ?$

Diagram:



2. **PLAN** **Choose the equation(s) or situation:** The zero level for gravitational potential energy is chosen to be at the water's surface. The total potential energy is the sum of the gravitational and elastic potential energies.

$$PE_{tot} = PE_g + PE_{elastic} = mgh + \tfrac{1}{2}kx^2$$

Rearrange the equation(s) to isolate the unknown(s):

$$\tfrac{1}{2}kx^2 = PE_{tot} - mgh$$

$$k = \frac{2(PE_{tot} - mgh)]}{x^2}$$

© Houghton Mifflin Harcourt Publishing Company

3. **CALCULATE Substitute the values into the equation(s) and solve:**

$$k = \frac{(2)[3.43 \times 10^4\ \text{J} - (70.0\ \text{kg})(9.81\ \text{m/s}^2)(12.0\ \text{m})]}{(23.0\ \text{m})^2}$$

$$k = \frac{(2)(3.43 \times 10^4\ \text{J} - 8.24 \times 10^3\ \text{J})}{(23.0\ \text{m})^2} = \frac{(2)(2.61 \times 10^4\ \text{J})}{(23.0\ \text{m})^2}$$

$$k = \boxed{98.7\ \text{N/m}}$$

4. **EVALUATE** The situation in this problem is basically the same as that in Sample Problem 5D in the textbook. In order for the stuntman to have a greater height above the water, the bungee cord must store more elastic potential energy with less stretching. This occurs when the spring constant is larger (98.7 N/m > 71.8 N/m).

ADDITIONAL PRACTICE

1. A highway guardrail is designed so that it can be distorted as much as 5.00 cm when struck by an automobile. What is the minimum force constant of the guardrail if it is to withstand the impact of a car with 1.09×10^4 J of energy?
2. An arresting cable helps to slow jet planes as they land on an aircraft carrier. This is accomplished by two springs, each of which is attached to one end of the cable. Suppose the elastic potential energy stored in the springs while a jet is landing is 5.78×10^7 J. If each spring is stretched 102 m, what is the force constant of each spring?
3. A produce scale at a supermarket uses a stretched spring to indicate the weight of fruits and vegetables. If five oranges with a total mass of 0.76 kg are placed in the scale, the spring will be stretched 2.3 cm. What is the force constant of the spring?
4. A 5.0 kg stone is slid up a frictionless ramp that has an incline of 25.0° How long is the ramp if the gravitational potential energy associated with the stone is 2.4×10^2 J?
5. A pogo stick contains a spring with a force constant of 1.5×10^4 N/m. Suppose the elastic potential energy stored in the spring as the pogo stick is pushed downward is 120 J. How far is the spring compressed?
6. A 1750 kg weather satellite moves in a circular orbit with a gravitational potential energy of 1.69×10^{10} J. At the satellite's altitude above Earth's surface, the free-fall acceleration is only 6.44 m/s^2. How high above Earth's surface is the satellite?
7. An automobile to be transported by ship is raised 7.0 m above the dock. If its gravitational potential energy is 6.6×10^4 J, what is the automobile's mass?

© Houghton Mifflin Harcourt Publishing Company

8. One of the largest planes ever to fly, and the largest to fly frequently, is the Ukrainian-built Antonov An–124 *Ruslan*. Its wingspan is 73.2 m and its length is 69.2 m. The gravitational potential energy associated with the plane at an altitude of 1.45 km is 3.36×10^9 J. What is the airplane's mass?
9. The force constant of the spring in a child's toy car is 550 N/m. How much elastic potential energy is stored in the spring if the spring is compressed a distance of 1.2 cm?
10. With an elevation of 5334 m above sea level, the village of Aucanquilca, Chile, is the highest inhabited town in the world. What would be the gravitational potential energy associated with a 64.0 kg person in Aucanquilca? Assume that the free-fall acceleration at Aucanquilca is equal to that at sea level.

© Houghton Mifflin Harcourt Publishing Company