Chapter 8

1

Conservation of energy

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Lecture 02

2

Non-Conservative Systems

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Changes in Mechanical Energy for Non-Conservative Forces

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When work is done by non-conservative forces (W_{nc}) and conservative forces (W_c), then; the work done by all non-conservative forces equals the change in the total mechanical energy of the system.

$$W_{nc} = \Delta E$$

Situations Involving Kinetic Friction

4

Friction is a non-conservative force. So, if friction is present, we have:

$$W_{nc} = \Delta E$$

$$-f_k d = \Delta E$$

Spring - Block and applied force

Saturday, 30 January, 2021 15:19

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.

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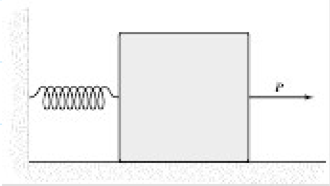
A $10\ kg$ block on a horizontal frictionless surface is attached to a light spring $\kappa = 0.8\ kN/m$. The block is initially at rest at its equilibrium position when a force $P = 80\ N$ acting parallel to the surface is applied to the block. What is the speed of the block when it is $13\ cm$ from its equilibrium position?



Solution:

The mechanical energy isn't conserved:

$$W_P = \Delta E \ \Rightarrow\ W_P = \left(K_f + U_{sf}\right) - \left(K_i + U_{si}\right)$$

$$\Rightarrow\ Pd\cos 0 = \left(\frac{1}{2}mv_f^2 + \frac{1}{2}\kappa x_f^2\right) - \left(\frac{1}{2}mv_i^2 + \frac{1}{2}\kappa x_i^2\right)$$

$$Where: \{x_i = 0\ m\ ;\ d = x_f = 0.13\ m\ ;\ v_i = 0\ m/s\}$$

$$\Rightarrow\ 80 \times 0.13 \times 1 = \left[\left(0.5 \times 10 \times v_f^2\right) + \left(0.5 \times 800 \times 0.13^2\right)\right] - (0 + 0)\ \Rightarrow\ v_f = 0.85\ m/s$$

Work Done by a Constant Force

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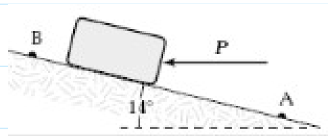
A $1.4\ kg$ block is pushed up a frictionless 14° incline from point A to point B by a force $P = 6\ N$. Points A and B are $1.2\ m$ apart. If the kinetic energies of the block at A and B are $3\ J$ and $4\ J$, respectively, how much work is done on the block by the force P between A and B?



Solution:

The mechanical energy isn't conserved:

$W_P = \Delta E \Rightarrow W_P = (K_B + U_B) - (K_A + U_A)$

$\Rightarrow W_P = (K_B + mgh_B) - (K_A + mgh_A)$

Where: $\{h_A = 0\ \mathrm{m}\ ;\ h_B = 1.2 \sin 14 = 0.3\ \mathrm{m}\ ;\ K_A = 3\ \mathrm{J}\ ;\ K_B = 4\ \mathrm{J}\}$

$\Rightarrow W_P = [4 + (1.4 \times 10 \times 0.3)] - [3 + 0] = 5.2\ \mathrm{J}$

Crate Sliding Down a Ramp

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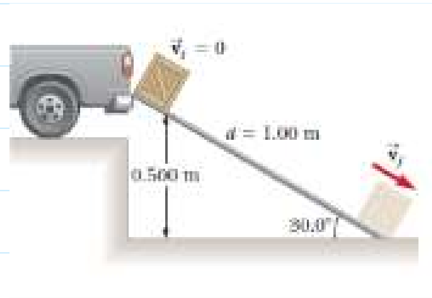
A $3\,kg$ crate slides down a ramp. The ramp is $1\,m$ in length and inclined at an angle of $\theta = 30^{\circ}$. The crate starts from rest at the top, experiences a constant friction force of magnitude $5\,N$, and continues to move a short distance on the horizontal floor after it leaves the ramp.

- Determine the speed of the crate at the bottom of the ramp.
- How far does the crate slide on the horizontal floor if it continues to experience a friction force of magnitude $5\,N$?



SOLUTION

Because$v_i = 0$, the initial kinetic energy of the system when the crate is at the top of the ramp is zero. If the y coordinate is measured from the bottom of the ramp (the final position of the crate, for which we choose the gravitational potential energy of the system to be zero) with the upward direction being positive, then $y_i = 0.500m.$

Write the expression for the total mechanical energy of the system when the crate is at the top:

$$E_i = K_i + U_i = 0 + U_i = mgy_i$$

Write an expression for the final mechanical energy:

$$E_f = K_f + U_f = \frac{1}{2}mv_f^2 + 0$$

Apply Equation 8.16:

$$\Delta E_{mech} = E_f - E_i = \frac{1}{2}mv_f^2 - mgy_i = -f_k d$$

Solve for v_f :

$$v_f = \sqrt{\frac{2}{m}mgy_i - f_k d}$$

Substitute numerical values:

$$v_f = \sqrt{\frac{2}{3.00kg}[3.00kg\ 9.80m/s^2\ 0.500m - 5.00N\ 1.00m]} = 2.54m/s$$

SOLUTION

This part of the problem is handled in exactly the same way as part (A), but in this case we can consider the mechanical energy of the system to consist only of kinetic energy because the potential energy of the system remains fixed.

Write an expression for the mechanical energy of the system when the crate leaves the bottom of the ramp:

$$E_i = K_i = \frac{1}{2}mv_i^2$$

Apply Equation 8.16 with$E_f = 0$:

$$E_f - E_i = 0 - \frac{1}{2}mv^2 = -f_k d \rightarrow \frac{1}{2}mv^2 = f_k d$$

Solve for the distance d and substitute numerical values:

$$d = \frac{mv^2}{2f_k} = \frac{3.00kg\ 2.54m/s^2}{2\ 5.00\text{N}} = 1.94m$$

A Block–Spring System - n.c.

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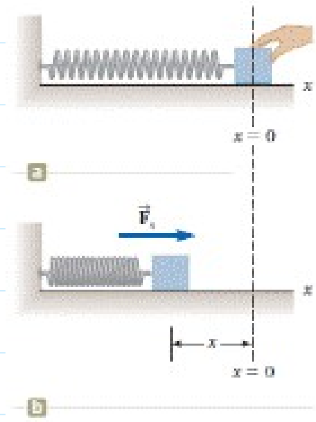
A block of mass $1.6\ kg$ is attached to a horizontal spring that has a force constant of $\kappa = 1000\ \ N/m$. The spring is compressed $2\ cm$ and is then released from rest. Calculate the speed of the block as it passes through the equilibrium position $(x = 0)$ if a constant friction force of $4\ N$ retards its motion from the moment it is released.



SOLUTION

Write

$$K_f = K_i - f_k d + W_s$$

Substitute numerical values:

$$K_f = 0 - 4.0N 0.020m + \frac{1}{2} 1000N/m\ 0.020m^2 = 0.12J$$

Write the definition of kinetic energy:

$$K_f = \frac{1}{2} m v_f^2$$

Solve for $v_f$and substitute numerical values:

$$v_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2\ 0.12J}{1.6kg}} = 0.39m/s$$

What if the friction force were increased to 10.0 N? What is the block's speed at $x = 0$?

Answer In this case, the value of $f_k d$as the block moves to $x = 0$is

$$f_k d = (10.0N)(0.020m) = 0.20J$$

which is equal in magnitude to the kinetic energy at $x = 0$for the frictionless case. (Verify it!). Therefore, all the kinetic energy has been transformed to internal energy by friction when the block arrives at $x = 0$, and its speed at this point is $v = 0$.

Block–Spring Collision - n.c.

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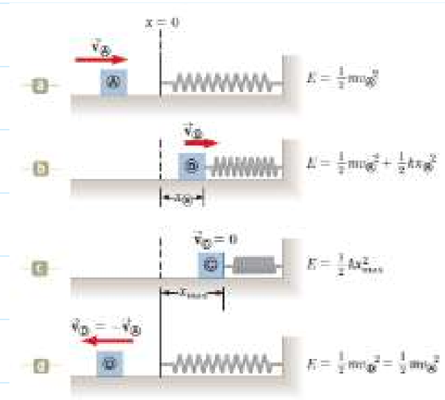
A block having a mass of $0.8\,kg$ is given an initial velocity $v_A = 1.2\ m/s$ to the right and collides with a spring whose mass is negligible and whose force constant is $\kappa = 50\ N/m$. Suppose a constant force of kinetic friction acts between the block and the surface, with $\mu_k = 0.5$. If the speed of the block at the moment it collides with the spring is $v_A = 1.2\ m/s$, what is the maximum compression x_C in the spring?



SOLUTION

in the vertical direction, we see that $n = mg$

Evaluate the magnitude of the friction force: $f_k = \mu_k n = \mu_k mg$

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Write the change in the mechanical energy of the system due to friction as the block is displaced from $x = 0$ to x_C:
$\Delta E_{mech} = -f_h x_C$

Substitute the initial and final energies:

$$\Delta E_{mech} = E_f - E_i = 0 + \frac{1}{2}kx_C^2 - \frac{1}{2}mv_A^2 + 0 = -f_h x_C$$

$$\frac{1}{2}kx_C^2 - \frac{1}{2}mv_A^2 = -\mu_k mgx_C$$

Substitute numerical values:

$$\frac{1}{2}\ 50x_C^2 - \frac{1}{2}0.80\ 1.2^2 = -0.50\ 0.80kg\ 9.80kg\ 9.80\mathrm{m/s^2}\ x_C$$

$$25x_C^2 + 3.9x_C - 0.58 = 0$$

Solving the quadratic equation for $x_C$gives $x_C = 0.093m$and $x_C = -0.25m$. The physically meaningful root is $x_C = 0.093m$.