PB 5-2C

Work and Energy

Problem C

WORK-KINETIC ENERGY THEOREM

PROBLEM

A forward force of 11.0 N is applied to a loaded cart over a distance of 15.0 m. If the cart, which is initially at rest, has a final speed of 1.98 m/s, what is the combined mass of the cart and its contents?

SOLUTION

1. DEFINE

Given:

$F_{applied} = 11.0$ N

$d = 15.0$ m

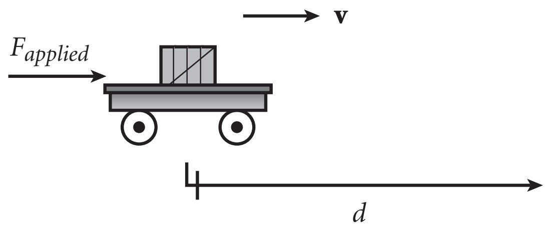
$\theta = 0°$

$v_i = 0$ m/s

$v_f = 1.98$ m/s

Unknown: $m = ?$

Diagram:



2. PLAN

Choose the equation (s) or situation: The net work done on the cart can be expressed by using the definition of work in terms of net force. Because the force is in the same direction as the cart's displacement ($\theta = 0°$), the net work is simply the product of the net force and the distance the cart is pushed. The net work can also be explained in terms of changing kinetic energy by using the work-kinetic energy theorem.

$$W_{net} = F_{net}d(\cos\theta) = F_{net}d$$

$$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

The net force on the cart is equal to the applied force. By inserting $F_{applied}$ into the equation for W_{net} and using the work-kinetic energy equivalence, the following equation is obtained.

$$F_{applied}d = \frac{1}{2}m(v_f^2 - v_i^2)$$

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

$$m = \frac{2F_{applied}d}{v_f^2 - v_i^2}$$

3. CALCULATE

Substitute the values into the equation(s) and solve:

$$m = \frac{(2)(11.0\text{ N})(15.0\text{ m})}{(1.98\text{ m/s})^2 - (0\text{ m/s})^2}$$

$$m = \frac{(2)(11.0\text{ N})(15.0\text{ m})}{(1.98\text{ m/s})^2}$$

$$m = \boxed{84.2\text{ kg}}$$

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4. EVALUATE Note that the form of the equation is equivalent to Newton's second law, with acceleration given by the kinematic equation.

$$a = \frac{v_f^2 - v_i^2}{2d}$$

ADDITIONAL PRACTICE

1. A hockey puck with an initial speed of 8.0 m/s coasts 45 m to a stop across the ice. If the force of friction on the puck has a magnitude of 0.12 N, what is the puck's mass?

2. A meteoroid is a small fragment of rock that orbits a planet or the sun. When a meteoroid enters a planet's atmosphere, it most likely will burn up entirely, glowing brilliantly as it does so. It is then referred to as a meteor. Consider a meteoroid that has an initial speed of 15.00 km/s when it enters the thin upper region of Earth's atmosphere. Suppose this meteoroid encounters a force of resistance with a magnitude of 9.00×10^{-2} N, so that after it travels 500.0 km parallel to Earth's surface the meteoroid's speed is 14.97 km/s. Assume that the meteoroid does not lose any mass as its temperature increases, and that the change in the gravitational potential energy is negligible. What is the mass of the meteoroid?

3. A car moving at a speed of 48.0 km/h accelerates 100.0 m up a steep hill, so that at the top of the hill its speed is 59.0 km/h. If the car's mass is 1100 kg, what is the magnitude of the net force acting on it?

4. A 450 kg compressor slides down a loading ramp that is 7.0 m long. Initially at rest, the compressor's speed at the bottom of the ramp is 1.1 m/s. What is the magnitude of the net force acting on the compressor?

5. The force that stops a fighter jet as it lands on the flight deck of an aircraft carrier is provided by a series of arresting cables. These cables are attached to large springs that stretch enough to keep the plane from slowing down too suddenly. Suppose a Hornet jet traveling with an initial speed of 2.40×10^2 km/h lands on the flight deck, where it is brought to rest by a net acceleration of magnitude 30.8 m/s^2. If the jet's mass is 1.30×10^4 kg, how far does the jet travel during its deceleration?

6. A 50.0 kg parachutist falls at a speed of 47.00 m/s when the parachute opens. The parachutist's speed upon landing is 5.00 m/s. How much work is done by the air to reduce the parachutist's speed?

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7. The giant sequoia redwood trees of the Sierra Nevada in California are said never to die from old age. Instead, an old tree dies when its shallow roots become loosened and the tree falls over. Removing a dead mature redwood from a forest is no easy feat, as the tree can have a mass of nearly 2.0×10^6 kg. Suppose a redwood with this mass is lifted 7.5 m with a net upward acceleration of 7.5×10^{-2} m/s^2. If the tree's initial kinetic energy is zero, what is the final kinetic energy?

8. An applied force of 92 N is exerted horizontally on an 18 kg box of books. The coefficient of kinetic friction between the floor and the box is 0.35. If the box is initially at rest with zero kinetic energy, what is the final kinetic energy after it has been moved 7.6 m across the floor?

9. A 2.00×10^2 kg iceboat is propelled across the horizontal surface of a frozen lake by the wind. The wind exerts a constant force of 4.00×10^2 N while the boat moves 0.90 km. Assume that frictional forces are negligible and that the boat starts from rest. What is the boat's final speed?

10. A certain firework is made of a small cardboard tube with a mass of about 20.0 g. When lit, the tube slides 2.5 m across a smooth surface. If the forward force on the tube is 7.3×10^{-2} N and the coefficient of friction between the tube and the ground is 0.20, what is the tube's final speed? Assume the tube is initially at rest.