Holt Physics

Problem 6A

MOMENTUM

PROBLEM

The world's most massive train ran in South Africa in 1989. Over 7 km long, the train traveled 861.0 km in 22.67 h. Imagine that the distance was traveled in a straight line north. If the train's average momentum was 7.32×10^8 kg•m/s to the north, what was its mass?

SOLUTION

Given: $\Delta \mathbf{x} = 861.0$ km to the north

$\Delta t = 22.67$ h

$\mathbf{p_{avg}} = 7.32 \times 10^8 \frac{\text{kg m}}{\text{s}}$ to the north

Unknown: $\mathbf{v_{avg}} = ?$ $m = ?$

Use the definition of average velocity to calculate $\mathbf{v_{avg}}$, and then substitute this value for velocity in the definition of momentum to solve for mass.

$$\mathbf{v_{avg}} = \frac{\Delta \mathbf{x}}{\Delta t} = \frac{(861.0 \times 10^3 \text{ m})}{(22.67 \text{ h})(3600 \text{ s/h})} = 10.55 \frac{\text{m}}{\text{s}} \text{ to the north}$$

$$\mathbf{p_{avg}} = m\mathbf{v_{avg}}$$

$$m = \frac{\mathbf{p_{avg}}}{\mathbf{v_{avg}}} = \frac{\left(7.32 \times 10^8 \frac{\text{kg m}}{\text{s}}\right)}{\left(10.55 \frac{\text{m}}{\text{s}}\right)} = \boxed{6.94 \times 10^7 \text{ kg}}$$

ADDITIONAL PRACTICE

1. In 1987, Marisa Canofoglia, of Italy, roller-skated at a record-setting speed of 40.3 km/h. If the magnitude of Canofoglia's momentum was 6.60×10^2 kg m/s, what was her mass?
2. In 1976, a 53 kg helicopter was built in Denmark. Suppose this helicopter flew east with a speed of 60.0 m/s and the total momentum of the helicopter and pilot was 7.20×10^3 kg m/s to the east. What was the mass of the pilot?
3. One of the smallest planes ever flown was the *Bumble Bee II,* which had a mass of 1.80×10^2 kg. If the pilot's mass was 7.0×10^1 kg, what was the velocity of both plane and pilot if their momentum was 2.08×10^4 kg m/s to the west?
4. The first human-made satellite, *Sputnik I,* had a mass of 83.6 kg and a momentum with a magnitude of 6.63×10^5 kg m/s. What was the satellite's speed?

5. Among the largest passenger ships currently in use, the *Norway* has been in service the longest. The *Norway* is more than 300 m long, has a mass of 6.9×10^7 kg, and can reach a top cruising speed of 33 km/h. Calculate the magnitude of the ship's momentum.

6. In 1994, a tower 22.13 m tall was built of Lego® blocks. Suppose a block with a mass of 2.00 g is dropped from the top of this tower. Neglecting air resistance, calculate the block's momentum at the instant the block hits the ground.

Holt Physics

Problem 6B

FORCE AND MOMENTUM

PROBLEM

In 1993, a generator with a mass of 1.24×10^5 kg was flown from Germany to a power plant in India on a Ukrainian-built plane. This constituted the heaviest single piece of cargo ever carried by a plane. Suppose the plane took off with a speed of 101 m/s toward the southeast and then accelerated to a final cruising speed of 197 m/s. During this acceleration, a force of 4.00×10^5 N in the southeast direction was exerted on the generator. For how much time did the force act on the generator?

SOLUTION

Given: $m = 1.24 \times 10^5$ kg

$\mathbf{v_i} = 101$ m/s to the southeast

$\mathbf{v_f} = 197$ m/s to the southeast

$\mathbf{F} = 4.00 \times 10^5$ N to the southeast

Unknown: $\Delta t = ?$

Use the impulse-momentum theorem to determine the time the force acts on the generator.

$$\mathbf{F}\,\Delta t = \Delta \mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i}$$

$$\Delta t = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\mathbf{F}}$$

$$\Delta t = \frac{(1.24 \times 10^5 \text{ kg})(197 \text{ m/s}) - (1.24 \times 10^5 \text{ kg})(101 \text{ m/s})}{4.00 \times 10^5 \text{ N}}$$

$$\Delta t = \frac{2.44 \times 10^7 \text{ kg}\bullet\text{m/s} - 1.25 \times 10^7 \text{ kg}\bullet\text{m/s}}{4.00 \times 10^5 \text{ N}}$$

$$\Delta t = \frac{1.19 \times 10^7 \text{ kg}\bullet\text{m/s}}{4.00 \times 10^5 \text{ N}}$$

$$\Delta t = \boxed{29.8 \text{ s}}$$

ADDITIONAL PRACTICE

1. In 1991, a Swedish company, Kalmar LMV, constructed a forklift truck capable of raising 9.0×10^4 kg to a height of about 2 m. Suppose a mass this size is lifted with an upward velocity of 12 cm/s. The mass is initially at rest and reaches its upward speed because of a net force of 6.0×10^3 N exerted upward. For how long is this force applied?

2. A bronze statue of Buddha was completed in Tokyo in 1993. The statue is 35 m tall and has a mass of 1.00×10^6 kg. Suppose this statue were to be moved to a different location. What is the magnitude of the impulse that must act on the statue in order for the speed to increase from 0 m/s

to 0.20 m/s? If the magnitude of the net force acting on the statue is 12.5 kN, how long will it take for the final speed to be reached?

3. In 1990, Gary Stewart of California made 177 737 jumps on a pogo stick. Suppose that the pogo stick reaches a height of 12.0 cm with each jump and that the average net force acting on the pogo stick during the contact with the ground is 330 N upward. What is the time of contact with the ground between the jumps? Assume the total mass of Stewart and the pogo stick is 65 kg. (Hint: The difference between the initial and final velocities is one of direction rather than magnitude.)

4. The specially designed armored car that was built for Leonid Brezhnev when he was head of the Soviet Union had a mass of about 6.0×10^3 kg. Suppose this car is accelerated from rest by a force of 8.0 kN to the east. What is the car's velocity after 8.0 s?

5. In 1992, Dan Bozich of the United States drove a gasoline-powered go-cart at a speed of 125.5 km/h. Suppose Bozich applies the brakes upon reaching this speed. If the combined mass of the go-cart and driver is 2.00×10^2 kg, the decelerating force is 3.60×10^2 N opposite the cart's motion, and the time during which the deceleration takes place is 10.0 s. What is the final speed of Bozich and the go-cart?

6. The "human cannonball" has long been a popular—and extremely dangerous—circus stunt. In order for a 45 kg person to leave the cannon with the fastest speed yet achieved by a human cannonball, a 1.6×10^3 N force must be exerted on that person for 0.68 s. What is the record speed at which a person has been shot from a circus cannon?

7. The largest steam-powered locomotive was built in the United States in 1943. It is still operational and is used for entertainment purposes. The locomotive's mass is 4.85×10^5 kg. Suppose this locomotive is traveling northwest along a straight track at a speed of 20.0 m/s. What force must the locomotive exert to increase its velocity to 25.0 m/s to the northwest in 5.00 s?

8. With upward speeds of 12.5 m/s, the elevators in the Yokohama Landmark Tower in Yokohama, Japan, are among the fastest elevators in the world. Suppose a passenger with a mass of 70.0 kg enters one of these elevators. The elevator then goes up, reaching full speed in 4.00 s. Calculate the net force that is applied to the passenger during the elevator's acceleration.

9. Certain earthworms living in South Africa have lengths as great as 6.0 m and masses as great as 12.0 kg. Suppose an eagle picks up an earthworm of this size, only to drop it after both have reached a height of 40.0 m above the ground. By skillfully using its muscles, the earthworm manages to extend the time during which it collides with the ground to 0.250 s. What is the net force that acts on the earthworm during its collision with the ground? Assume the earthworm's vertical speed when it is initially dropped to be 0 m/s.

Holt Physics

Problem 6C

STOPPING DISTANCE

PROBLEM

The largest nuts (and, presumably, the largest bolts) are manufactured in England. The nuts have a mass of 4.74 × 10^3 kg each, which is greater than any passenger car currently in production. Suppose one of these nuts slides along a rough horizontal surface with an initial velocity of 2.40 m/s to the right. If the force of friction acting on the nut is 6.8 × 10^3 N to the left, what is the change in the nut's momentum after 1.1 s? How far does the nut travel during its change in momentum?

SOLUTION

Given: $m = 4.74 \times 10^3$ kg

$\mathbf{v_i} = 2.40$ m/s to the right $= +2.40$ m/s

$\mathbf{F} = 6.8 \times 10^3$ N to the left $= -6.8 \times 10^3$ N

$\Delta t = 1.1$ s

Unknown: $\Delta \mathbf{p} = ?$ $\quad \Delta \mathbf{x} = ?$

Use the impulse-momentum theorem to calculate the change in momentum. Use the definition of momentum to find $\mathbf{v_f}$, and then use the equation for stopping distance to solve for $\Delta \mathbf{x}$.

$$\Delta \mathbf{p} = \mathbf{F}\Delta \mathbf{t} = (-6.8 \times 10^3 \text{ N})(1.1 \text{ s})$$

$$\Delta \mathbf{p} = \boxed{-7.5 \times 10^3 \text{ kg m/s to the right, or } 7.5 \times 10^3 \text{ kg m/s to the left}}$$

$$\Delta \mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i}$$

$$\mathbf{v_f} = \frac{\Delta \mathbf{p} + m\mathbf{v_i}}{m}$$

$$\mathbf{v_f} = \frac{-7.5 \times 10^3 \text{ kg m/s} + (4.74 \times 10^3 \text{ kg})(2.40 \text{ m/s})}{4.74 \times 10^3 \text{ kg}}$$

$$\mathbf{v_f} = \frac{-7.5 \times 10^3 \text{ kg m/s} + 1.14 \times 10^4 \text{ kg m/s}}{4.74 \times 10^3 \text{ kg}} = \frac{3900 \text{ kg m/s}}{4.74 \times 10^3 \text{ kg}}$$

$$\mathbf{v_f} = \boxed{0.82 \text{ m/s to the right}}$$

$$\Delta \mathbf{x} = \tfrac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \tfrac{1}{2}(2.40 \text{ m/s} + 0.82 \text{ m/s})(1.1 \text{ s}) = \tfrac{1}{2}(3.22 \text{ m/s})(1.1 \text{ s})$$

$$\Delta \mathbf{x} = \boxed{1.8 \text{ m/s to the right}}$$

ADDITIONAL PRACTICE

1. The most powerful tugboats in the world are built in Finland. These boats exert a force with a magnitude of 2.85 × 10^6 N. Suppose one of these tugboats is trying to slow a huge barge that has a mass of 2.0 × 10^7 kg and is moving with a speed of 3.0 m/s. If the tugboat exerts its maximum force for 21 s in the direction opposite to that in which the barge is moving, what will be the change in the barge's momentum? How far will the barge travel before it is brought to a stop?

2. In 1920, a 6.5×10^4 kg meteorite was found in Africa. Suppose a meteorite with this mass enters Earth's atmosphere with a speed of 1.0 km/s. What is the change in the meteorite's momentum if an average constant force of -1.7×10^6 N acts on the meteorite for 30.0 s? How far does the meteorite travel during this time?

3. The longest canoe in the world was constructed in New Zealand. The combined mass of the canoe and its crew of more than 70 people was 2.03×10^4 kg. Suppose the canoe is rowed from rest to a velocity of 5.00 m/s to the east, at which point the crew takes a break for 20.3 s. If a constant average retarding force of 1.20×10^3 N to the west acts on the canoe, what is the change in the momentum of the canoe and crew? How far does the canoe travel during the time the crew is not rowing?

4. The record for the smallest dog in the world belongs to a terrier who had a mass of only 113 g. Suppose this dog runs to the right with a speed of 2.00 m/s when it suddenly sees a mouse. The dog becomes scared and uses its paws to bring itself to rest in 0.80 s. What is the force required to stop the dog? What is the dog's stopping distance?

5. In 1992, an ice palace estimated to be 4.90×10^6 kg was built in Minnesota. Despite this sizable mass, this structure could be moved at a constant velocity because of the small force of friction between the ice blocks of its base and the ice of the lake upon which it was constructed. Imagine moving the entire palace with a speed of 0.200 m/s on this very smooth, icy surface. Once the palace is no longer being pushed, it coasts to a stop in 10.0 s. What is the average force of kinetic friction acting on the palace? What is the palace's stopping distance?

6. *Steel Phantom* is a roller coaster in Pennsylvania that, like the *Desperado* in Nevada, has a vertical drop of 68.6 m. Suppose a roller-coaster car with a mass of 1.00×10^3 kg travels from the top of that drop without friction. The car then decelerates along a horizontal stretch of track until it comes to a stop. How long does it take the car to decelerate if the constant force acting on it is -2.24×10^4 N? How far does the car travel along the horizontal track before stopping? Assume the car's speed at the peak of the drop is zero.

7. Two Japanese islands are connected by a long rail tunnel that extends horizontally underwater. Imagine a communication system in which a small rail car with a mass of 100.0 kg is launched by a type of cannon in order to transport messages between the two islands. Assume a rail car from one end of the tunnel has a speed of 4.50×10^2 m/s, which is just large enough for a constant frictional force of -188 N to cause the car to stop at the other end of the tunnel. How long does it take for the car to travel the length of the tunnel? What is the length of the tunnel?

Holt Physics

Problem 6D

CONSERVATION OF MOMENTUM

PROBLEM

Kangaroos are good runners that can sustain a speed of 56 km/h (15.5 m/s). Suppose a kangaroo is sitting on a log that is floating in a lake. When the kangaroo gets scared, she jumps off the log with a velocity of 15 m/s toward the bank. The log moves with a velocity of 3.8 m/s away from the bank. If the mass of the log is 250 kg, what is the mass of the kangaroo?

SOLUTION

1. DEFINE

Given:

$\mathbf{v_{k,i}}$ = initial velocity of kangaroo = 0 m/s

$\mathbf{v_{l,i}}$ = initial velocity of log = 0 m/s

$\mathbf{v_{k,f}}$ = final velocity of kangaroo = 15 m/s toward bank = +15 m/s

$\mathbf{v_{l,f}}$ = final velocity of log = 3.8 m/s away from bank = –3.8 m/s

m_l = mass of log = 250 kg

Unknown: m_k = mass of kangaroo = ?

2. PLAN

Choose the equation(s) or situation: Because the momentum of the kangaroo-log system is conserved and therefore remains constant, the total initial momentum of the kangaroo and log will equal the total final momentum of the kangaroo and log.

$$m_k\mathbf{v_{k,i}} + m_l\mathbf{v_{l,i}} = m_k\mathbf{v_{k,f}} + m_l\mathbf{v_{l,f}}$$

The initial velocities of the kangaroo and log are zero, and therefore the initial momentum for each of them is zero. It thus follows that the total final momentum for the kangaroo and log must also equal zero. The momentum-conservation equation reduces to the following:

$$m_k\mathbf{v_{k,f}} + m_l\mathbf{v_{l,f}} = 0$$

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

$$m_k = \frac{-m_l\mathbf{v_{l,f}}}{\mathbf{v_{k,f}}}$$

3. CALCULATE

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

$$m_k = \frac{-(250\ \text{kg})(-3.8\ \text{m/s})}{15\ \text{m/s}}$$

$$m_k = \boxed{63\ \text{kg}}$$

4. EVALUATE

Because the log is about four times as massive as the kangaroo, its velocity is about one-fourth as large as the kangaroo's velocity.

NAME ______________________ DATE ____________ CLASS ______________

ADDITIONAL PRACTICE

1. The largest single publication in the world is the 1112-volume set of *British Parliamentary Papers* for 1968 through 1972. The complete set has a mass of 3.3×10^3 kg. Suppose the entire publication is placed on a cart that can move without friction. The cart is at rest, and a librarian is sitting on top of it, just having loaded the last volume. The librarian jumps off the cart with a horizontal velocity relative to the floor of 2.5 m/s to the right. The cart begins to roll to the left at a speed of 0.05 m/s. Assuming the cart's mass is negligible, what is the librarian's mass?

2. The largest grand piano in the world is *really* grand. Built in London, it has a mass of 1.25×10^3 kg. Suppose a pianist finishes playing this piano and pushes herself from the piano so that she rolls backwards with a speed of 1.4 m/s. Meanwhile, the piano rolls forward so that in 4.0 s it travels 24 cm at constant velocity. Assuming the stool that the pianist is sitting on has a negligible mass, what is the pianist's mass?

3. With a mass of 114 kg, *Baby Bird* is the smallest monoplane ever flown. Suppose the *Baby Bird* and pilot are coasting along the runway when the pilot jumps horizontally to the runway behind the plane. The pilot's velocity upon leaving the plane is 5.32 m/s backward. After the pilot jumps from the plane, the plane coasts forward with a speed of 3.40 m/s. If the pilot's mass equals 60.0 kg, what is the velocity of the plane and pilot before the pilot jumps?

4. The September 14, 1987, issue of the *New York Times* had a mass of 5.4 kg. Suppose a skateboarder picks up a copy of this issue to have a look at the comic pages while rolling backward on the skateboard. Upon realizing that the *New York Times* doesn't have a "funnies" section, the skateboarder promptly throws the entire issue in a recycling container. The newspaper is thrown forward with a speed of 7.4 m/s. When the skater throws the newspaper away, he rolls backward at a speed of 1.4 m/s. If the combined mass of the skateboarder and skateboard is assumed to be 50.0 kg, what is the initial velocity of the skateboarder and newspaper?

5. The longest bicycle in the world was built in New Zealand in 1988. It is more than 20 m in length, has a mass of 3.4×10^2 kg, and can be ridden by four people at a time. Suppose four people are riding the bike southeast when they realize that the street turns and that the bike won't make it around the corner. All four riders jump off the bike at the same time and with the same velocity (9.0 km/h to the northwest, as measured relative to Earth). The bicycle continues to travel forward with a velocity of 28 km/h to the southeast. If the combined mass of the riders is 2.6×10^2 kg, what is the velocity of the bicycle and riders immediately before the riders' escape?

6. The largest frog ever found was discovered in Cameroon in 1989. The frog's mass was nearly 3.6 kg. Suppose this frog is placed on a skateboard with a mass of 3.0 kg. The frog jumps horizontally off the skateboard to the right, and the skateboard rolls freely in the opposite direction with a speed of 2.0 m/s relative to the ground. If the frog and skateboard are initially at rest, what is the initial horizontal velocity of the frog?

7. In 1994, a pumpkin with a mass of 449 kg was grown in Canada. Suppose you want to push a pumpkin with this mass along a smooth, horizontal ramp. You give the pumpkin a good push, only to find yourself sliding backwards at a speed of 4.0 m/s. How far will the pumpkin slide 3.0 s after the push? Assume your mass to be 60.0 kg.

Holt Physics

Problem 6E

PERFECTLY INELASTIC COLLISIONS

PROBLEM

The Chinese giant salamander is one of the largest of salamanders. Suppose a Chinese giant salamander chases a 5.00 kg carp with a velocity of 3.60 m/s to the right and the carp moves with a velocity of 2.20 m/s in the same direction (away from the salamander). If the speed of the salamander and carp immediately after the salamander catches the carp is 3.50 m/s to the right, what is the salamander's mass?

SOLUTION

Given: m_c = mass of carp = 5.00 kg

$\mathbf{v_{s,i}}$ = initial velocity of salamander = 3.60 m/s to the right

$\mathbf{v_{c,i}}$ = initial velocity of carp = 2.20 m/s to the right

$\mathbf{v_f}$ = final velocity = 3.50 m/s to the right

Unknown: m_s = mass of salamander = ?

Use the equation for a perfectly inelastic collision and rearrange it to solve for m_s.

$$m_s\mathbf{v_{s,i}} + m_c\mathbf{v_{c,i}} = (m_s + m_c)\mathbf{v_f}$$

$$m_s = \frac{m_c\mathbf{v_f} - m_c\mathbf{v_{c,i}}}{\mathbf{v_{s,i}} - \mathbf{v_f}}$$

$$m_s = \frac{(5.00 \text{ kg})(3.50 \text{ m/s}) - (5.00 \text{ kg})(2.20 \text{ m/s})}{3.60 \text{ m/s} - 3.50 \text{ m/s}}$$

$$m_s = \frac{17.5 \text{ kg m/s} - 11.0 \text{ kg m/s}}{0.10 \text{ m/s}}$$

$$m_s = \frac{6.5 \text{ kg m/s}}{0.10 \text{ m/s}}$$

$$m_s = \boxed{65 \text{ kg}}$$

ADDITIONAL PRACTICE

1. Zorba, an English mastiff with a mass of 155 kg, jumps forward horizontally at a speed of 6.0 m/s into a boat that is floating at rest. After the jump, the boat and Zorba move with a velocity of 2.2 m/s forward. Calculate the boat's mass.

2. Yvonne van Gennip of the Netherlands ice skated 10.0 km with an average speed of 10.8 m/s. Suppose van Gennip crosses the finish line at her average speed and takes a huge bouquet of flowers handed to her by a fan. As a result, her speed drops to 10.01 m/s. If van Gennip's mass is 63.0 kg, what is the mass of the bouquet?

3. The world's largest guitar was built by a group of high school students in Indiana. Suppose that this guitar is placed on a light cart. The cart and guitar are then pushed with a velocity of 4.48 m/s to the right. One of the students tries to slow the cart by stepping on it as it passes by her. The new velocity of the cart, guitar, and student is 4.00 m/s to the right. If the student's mass is 54 kg, what is the mass of the guitar? Assume the mass of the cart is negligible.

4. The longest passenger buses in the world operate in Zaire. These buses are more than 30 m long, have two trailers, and have a total mass of 28×10^3 kg. Imagine a safety test involving one of these buses and a truck with a mass of 12×10^3 kg. The truck with an unknown velocity hits a bus that is at rest so that the two vehicles move forward together with a speed of 3.0 m/s. Calculate the truck's velocity prior to the collision.

5. Sumo wrestlers must be very heavy to be successful in their sport, which involves pushing the rival out of the ring. One of the greatest sumo champions, Akebono, had a mass of 227 kg. The heaviest sumo wrestler ever, Konishiki, at one point had a mass of 267 kg. Suppose these two wrestlers are opponents in a match. Akebono moves left with a speed of 4.0 m/s, while Konishiki moves toward Akebono with an unknown speed. After the wrestlers undergo an inelastic collision, both have a velocity of zero. From this information, calculate Konishiki's velocity before colliding with Akebono.

6. Louis Borsi, of London, built a drivable car that had a mass of 9.50 kg and could move as fast as 24.0 km/h. Suppose the inventor falls out of this car and the car proceeds driverless to the north at its maximum speed. The inventor's young daughter, who has a mass of 32.0 kg, "catches" the car by jumping northward from a nearby stairway. The velocity of the car and girl is 11.0 km/h to the north. What was the velocity of Borsi's daughter as she jumped in the car?

7. In 1990, Roger Hickey of California attained a speed of 89 km/h while standing on a skateboard. Suppose Hickey is riding horizontally at his stand-up speed when he catches up to another skateboarder, who is moving at 69 km/h in the same direction. If the second skateboarder steps sideways onto Hickey's skateboard, the two riders move forward with a new speed. Calculate this speed, assuming that both skateboarders have equal, but unknown, masses and that the mass of the skateboard is negligible.

8. The white shark is the largest carnivorous fish in the world. The mass of a white shark can be as great as 3.0×10^3 kg. In spite of (or perhaps because of) the mass and ferocity of the shark, it is prized by commercial and sports fishers alike. Suppose Joe, who is one of these fishers, goes to a cliff that overlooks the ocean. To see if the sharks are biting, Joe drops a 2.5×10^2 kg fish as bait into the ocean below. As it so happens, a 3.0×10^3 kg white shark is prowling the ocean floor just below the cliff. The shark sees the bait, which is sinking straight down at a speed of 3.0 m/s. The shark swims upward with a speed of 1.0 m/s to swallow the bait. What is the velocity of the shark right after it has swallowed the bait?

9. The heaviest cow on record had a mass of 2.267×10^3 kg and lived in Maine at the beginning of the twentieth century. Imagine that during an agricultural exhibition, the cow's owner puts the cow on a railed cart that has a mass of 5.00×10^2 kg and pushes the cow and cart left to the stage with a speed of 2.00 m/s. Another farmer puts his cow, which has a mass of 1.800×10^3 kg, on an identical cart and pushes it toward the stage from the opposite direction with a speed of 1.40 m/s. The carts collide and stick together. What is the velocity of the cows after the collision?

Holt Physics

Problem 6F

KINETIC ENERGY IN PERFECTLY INELASTIC COLLISIONS

PROBLEM

Alaskan moose can be as massive as 8.00×10^2 kg. Suppose two feuding moose, both of which have a mass of 8.00×10^2 kg, back away and then run toward each other. If one of them runs to the right with a speed of 8.0 m/s and the other runs to the left with a speed of 6.0 m/s, what amount of kinetic energy will be dissipated after their inelastic collision?

SOLUTION

Given: m_1 = mass of first moose = 8.00×10^2 kg

m_2 = mass of second moose = 8.00×10^2 kg

$\mathbf{v_{1,i}}$ = initial velocity of first moose = 8.0 m/s to the right

$\mathbf{v_{2,i}}$ = initial velocity of second moose = 6.0 m/s to the left = −6.0 m/s to the right

Unknown: $\Delta KE = ?$

Use the equation for a perfectly inelastic collision.

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = (m_1 + m_2)\mathbf{v_f}$$

$$(8.00 \times 10^2 \text{ kg})(8.0 \text{ m/s}) + (8.00 \times 10^2 \text{ kg})(-6.0 \text{ m/s}) = (2)(8.00 \times 10^2 \text{ kg})\mathbf{v_f}$$

$$6.4 \times 10^3 \text{ kg m/s} - 4.8 \times 10^3 \text{ kg m/s} = (16.0 \times 10^2 \text{ kg})\mathbf{v_f}$$

$$\mathbf{v_f} = \frac{1.6 \times 10^3 \text{ kg m/s}}{16.0 \times 10^2 \text{ kg}} = 1.0 \text{ m/s to the right}$$

Use the equation for kinetic energy to calculate the kinetic energy of each moose before the collision and the final kinetic energy of the two moose combined.

Initial kinetic energy:

$$KE_i = KE_{1,i} + KE_{2,i} = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2$$

$$KE_i = \tfrac{1}{2}(8.00 \times 10^2 \text{ kg})(8.0 \text{ m/s})^2 + \tfrac{1}{2}(8.00 \times 10^2 \text{ kg})(-6.0 \text{ m/s})^2$$

$$KE_i = 2.6 \times 10^4 \text{ J} + 1.4 \times 10^4 \text{ J} = 4.0 \times 10^4 \text{ J}$$

Final kinetic energy:

$$KE_f = KE_{1,f} + KE_{2,f} = \tfrac{1}{2}(m_1 + m_2)v_f^2$$

$$KE_f = \frac{(2)(8.00 \times 10^2 \text{ kg})(1.0 \text{ m/s})^2}{2}$$

$$KE_f = 8.0 \times 10^2 \text{ J}$$

Change in kinetic energy:

$$\Delta KE = KE_f - KE_i = 8.0 \times 10^2 \text{ J} - 4.0 \times 10^4 \text{ J} = \boxed{-3.9 \times 10^4 \text{ J}}$$

By expressing ΔKE as a negative number, we indicate that the energy has left the system to take a form other than mechanical energy.

1. The hog-nosed bat is the smallest mammal on Earth: it is about the same size as a bumblebee and has an average mass of 2.0 g. Suppose a hog-nosed bat with this mass flies at 2.0 m/s when it detects a bug with a mass of 0.20 g flying directly toward it at 8.0 m/s. What fraction of the total kinetic energy is dissipated when it swallows the bug?

2. The heaviest wild lion ever measured had a mass of 313 kg. Suppose this lion is walking by a lake when it sees an empty boat floating at rest near the shore. The curious lion jumps into the boat with a speed of 6.00 m/s, causing the boat with the lion in it to move away from the shore with a speed of 2.50 m/s. How much kinetic energy is dissipated in this inelastic collision.

3. The cheapest car ever commercially produced was the *Red Bug Backboard*, which sold in 1922 in the United States for about $250. The car's mass was only 111 kg. Suppose two of these cars are used in a stunt crash for an action film. If one car's initial velocity is 9.00 m/s to the right and the other car's velocity is 5.00 m/s to the left, how much kinetic energy is dissipated in the crash?

4. In 1986, four high school students built an electric car that could reach a speed of 106.0 km/h. The mass of the car was just 60.0 kg. Imagine two of these cars used in a stunt show. One car travels east with a speed of 106.0 km/h, and the other car travels west with a speed of 75.0 km/h. If each car's driver has a mass of 50.0 kg, how much kinetic energy is dissipated in the perfectly inelastic head-on collision?

5. The Arctic Snow Train, built for the U.S. Army, has a mass of 4.00×10^5 kg and a top speed of 32.0 km/h. Suppose such a train moving at its top speed is hit from behind by another snow train with a mass of 1.60×10^5 kg and a speed of 45.0 km/h in the same direction. What is the change in kinetic energy after the trains' perfect inelastic collision?

6. There was a domestic cat in Australia with a mass of 21.3 kg. Suppose this cat is sitting on a skateboard that is not moving. A 1.80×10^{-1} kg treat is thrown to the cat. When the cat catches the treat, the cat and skateboard move with a speed of 6.00×10^{-2} m/s. How much kinetic energy is dissipated in the process? Assume one-dimensional motion.

7. In 1985, a spider with a mass of 122 g was caught in Surinam, South America. (Recall that the smallest dog in the world had a smaller mass.) Suppose a spider with this mass runs at a certain unknown speed when it collides inelastically with another spider, which has a mass of 96.0 g and is at rest. Find the fraction of the kinetic energy that is dissipated in the perfect inelastic collision. Assume that the resting spider is on a low-friction surface. Do you need to know the first spider's velocity to calculate the fraction of the dissipated kinetic energy?

NAME ______________________ DATE ____________ CLASS ______________

Holt Physics

Problem 6G

ELASTIC COLLISIONS

PROBLEM

American juggler Bruce Sarafian juggled 11 identical balls at one time in 1992. Each ball had a mass of 0.20 kg. Suppose two balls have an elastic head-on collision during the act. The first ball moves away from the collision with a velocity of 3.0 m/s to the right, and the second ball moves away with a velocity of 4.0 m/s to the left. If the first ball's velocity before the collision is 4.0 m/s to the left, what is the velocity of the second ball before the collision?

SOLUTION

1. DEFINE

Given: $m_1 = m_2 = 0.20$ kg

$\mathbf{v_{1,i}}$ = initial velocity of ball 1 = 4.0 m/s to the left = −4.0 m/s to the right

$\mathbf{v_{1,f}}$ = final velocity of ball 1 = 3.0 m/s to the right

$\mathbf{v_{2,f}}$ = final velocity of ball 2 = 4.0 m/s to the left = −4.0 m/s to the right

Unknown: $\mathbf{v_{2,i}}$ = initial velocity of ball 2 = ?

2. PLAN

Choose the equation(s) or situation: Use the equation for the conservation of momentum to determine the initial velocity of ball 2. Because both balls have identical masses, the mass terms cancel.

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$$

$$\mathbf{v_{1,i}} + \mathbf{v_{2,i}} = \mathbf{v_{1,f}} + \mathbf{v_{2,f}}$$

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

$$\mathbf{v_{2,i}} = \mathbf{v_{1,f}} + \mathbf{v_{2,f}} - \mathbf{v_{1,i}}$$

3. CALCULATE

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

$$\mathbf{v_{2,i}} = 3.0 \text{ m/s} - 4.0 \text{ m/s} - (-4.0 \text{ m/s})$$

$$\mathbf{v_{2,i}} = \boxed{3.0 \text{ m/s to the right}}$$

4. EVALUATE

Confirm your answer by making sure that kinetic energy is also conserved.

$$\tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}m_2v_{2,f}^2$$

$$v_{1,i}^2 + v_{2,i}^2 = v_{1,f}^2 + v_{2,f}^2$$

$$(-4.0 \text{ m/s})^2 + (3.0 \text{ m/s})^2 = (3.0 \text{ m/s})^2 + (-4.0 \text{ m/s})^2$$

$$16 \text{ m}^2/\text{s}^2 + 9.0 \text{ m}^2/\text{s}^2 = 9.0 \text{ m}^2/\text{s}^2 + 16 \text{ m}^2/\text{s}^2$$

$$25 \text{ m}^2/\text{s}^2 = 25 \text{ m}^2/\text{s}^2$$

ADDITIONAL PRACTICE

1. The moon's orbital speed around Earth is 3.680×10^3 km/h. Suppose the moon suffers a perfectly elastic collision with a comet whose mass is 50.0 percent that of the moon. (A partially inelastic collision would be a much more realistic event.) After the collision, the moon moves with a speed of -4.40×10^2 km/h, while the comet moves away from the moon at 5.740 $\times 10^3$ km/h. What is the comet's speed before the collision?

2. The largest beet root on record had a mass of 18.40 kg. The largest cabbage on record had a mass of 56.20 kg. Imagine these two vegetables traveling in opposite directions. The cabbage, which travels 5.000 m/s to the left, collides with the beet root. After the collision, the cabbage has a velocity of 6.600×10^{-2} m/s to the left, and the beet root has a velocity of 10.07 m/s to the left. What is the beet root's velocity before the perfectly elastic collision?

3. The first astronaut to walk in outer space without being tethered to a spaceship was Capt. Bruce McCandless. In 1984, he used a jet backpack, which cost about $15 million to design, to move freely about the exterior of the space shuttle *Challenger*. Imagine two astronauts working in outer space. Suppose they have equal masses and accidentally run into each other. The first astronaut moves 5.0 m/s to the right before the collision and 2.0 m/s to the left afterwards. If the second astronaut moves 5.0 m/s to the right after the perfectly elastic collision, what was the second astronaut's initial velocity?

4. Speeds as high as 273 km/h have been recorded for golf balls. Suppose a golf ball whose mass is 45.0 g is moving to the right at 273 km/h and strikes another ball that is at rest. If after the perfectly elastic collision the golf ball moves 91 km/h to the left and the other ball moves 182 km/h to the right, what is the mass of the second ball?

5. Jana Novotna of what is now the Czech Republic has the strongest serve among her fellow tennis players. In 1993, she sent the ball flying with a speed of 185 km/h. Suppose a tennis ball moving to the right at this speed hits a moveable target of unknown mass. After the one-dimensional, perfectly elastic collision, the tennis ball bounces to the left with a speed of 80.0 km/h. If the tennis ball's mass is 5.70×10^{-2} kg, what is the target's mass? (Hint: Use the conservation of kinetic energy to solve for the second unknown quantity.)

6. Recall the two colliding snow trains in item 6 of the previous section. Suppose now that the collision between the two trains is perfectly elastic instead of inelastic. The train with a 4.00×10^5 kg and a velocity of 32.0 km/h to the right is struck from behind by a second train with a mass of 1.60×10^5 kg and a velocity of 36.0 km/h to the right. If the first train's velocity increases to 35.5 km/h to the right, what is the final velocity of the second train after the collision?

7. A dump truck used in Canada has a mass of 5.50×10^5 kg when loaded and 2.30×10^5 kg when empty. Suppose two such trucks, one loaded and one empty, crash into each other at a monster truck show. The trucks are supplied with special bumpers that make a collision almost perfectly elastic. If the trucks hit each other at equal speeds of 5.00 m/s and the less massive truck recoils to the right with a speed of 9.10 m/s, what is the velocity of the full truck after the collision?