Momentum and Collisions

ADDITIONAL PRACTICE B

Givens	*Solutions*
1. $m = 9.0 \times 10^4$ kg $\mathbf{v_i} = 0$ m/s $\mathbf{v_f} = 12$ cm/s upward $\mathbf{F} = 6.0 \times 10^3$ N	$\Delta t = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\mathbf{F}} = \dfrac{(9.0 \times 10^4\ \text{kg})(0.12\ \text{m/s}) - (9.0 \times 10^4\ \text{kg})(0\ \text{m/s})}{6.0 \times 10^3\ \text{N}}$ $\Delta t = \dfrac{(9.0 \times 10^4\ \text{kg})(0.12\ \text{m/s})}{6.0 \times 10^3\ \text{N}} = \boxed{1.8\ \text{s}}$
2. $m = 1.00 \times 10^6$ kg $v_i = 0$ m/s $v_f = 0.20$ m/s $F = 12.5$ kN	$\Delta p = mv_f - mv_i = (1.00 \times 10^6\ \text{kg})(0.20\ \text{m/s}) - (1.00 \times 10^6\ \text{kg})(0\ \text{m/s})$ $\Delta p = \boxed{2.0 \times 10^5\ \text{kg•m/s}}$ $\Delta t = \dfrac{\Delta p}{F} = \dfrac{2.0 \times 10^5\ \text{kg•m/s}}{12.5 \times 10^3\ \text{N}} = \boxed{16\ \text{s}}$
3. $h = 12.0$ cm $\mathbf{F} = 330$ N, upward $m = 65$ kg $g = 9.81$ m/s^2	The speed of the pogo stick before and after it presses against the ground can be determined from the conservation of energy. $PE_g = KE$ $mgh = \frac{1}{2}mv^2$ $v = \pm\sqrt{2gh}$ For the pogo stick's downward motion, $v_i = -\sqrt{2gh}$ For the pogo stick's upward motion, $v_f = +\sqrt{2gh}$ $\Delta p = mv_f - mv_i = m\sqrt{2gh} - m\left(-\sqrt{2gh}\right)$ $\Delta p = 2m\sqrt{2gh}$ $\Delta t = \dfrac{\Delta p}{F} = \dfrac{2m\sqrt{2gh}}{F} = \dfrac{(2)(65\ \text{kg})\sqrt{(2)(9.81\ \text{m/s}^2)(0.120\ \text{m})}}{330\ \text{N}}$ $\Delta t = \boxed{0.60\ \text{s}}$
4. $m = 6.0 \times 10^3$ kg $\mathbf{F} = 8.0$ kN to the east $\Delta t = 8.0$ s $\mathbf{v_i} = 0$ m/s	$\mathbf{v_f} = \dfrac{\mathbf{F}\Delta t + m\mathbf{v_i}}{m} = \dfrac{(8.0 \times 10^3\ \text{N})(8.0\ \text{s}) + (6.0 \times 10^3\ \text{kg})(0\ \text{m/s})}{6.0 \times 10^3\ \text{kg}}$ $\mathbf{v_f} = \boxed{11\ \text{m/s, east}}$

Givens	*Solutions*
5. $v_i = 125.5$ km/h $m = 2.00 \times 10^2$ kg $F = -3.60 \times 10^2$ N $\Delta t = 10.0$ s	$v_f = \dfrac{F\Delta t + mv_i}{m}$ $v_f = \dfrac{(-3.60 \times 10^2 \text{ N})(10.0 \text{ s}) + (2.00 \times 10^2 \text{ kg})(125.5 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})}{2.00 \times 10^2 \text{ kg}}$ $v_f = \dfrac{-3.60 \times 10^3 \text{ N•s} + 6.97 \times 10^3 \text{ kg•m/s}}{2.00 \times 10^2 \text{ kg}} = \dfrac{3.37 \times 10^3 \text{ kg•m/s}}{2.00 \times 10^2 \text{ kg}} = \boxed{16.8 \text{ m/s}}$ or $v_f = (16.8 \times 10^{-3} \text{ km/s})(3600 \text{ s/h}) = \boxed{60.5 \text{ km/h}}$
6. $m = 45$ kg $F = 1.6 \times 10^3$ N $\Delta t = 0.68$ s $v_i = 0$ m/s	$v_f = \dfrac{F\Delta t + mv_i}{m} = \dfrac{(1.6 \times 10^3 \text{ N})(0.68 \text{ s}) + (45 \text{ kg})(0 \text{ m/s})}{45 \text{ kg}}$ $v_f = \dfrac{(1.6 \times 10^3 \text{ N})(0.68 \text{ s})}{45 \text{ kg}} = \boxed{24 \text{ m/s}}$
7. $m = 4.85 \times 10^5$ kg $\mathbf{v_i} = 20.0$ m/s northwest $\mathbf{v_f} = 25.0$ m/s northwest $\Delta t = 5.00$ s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(4.85 \times 10^5 \text{ kg})(25.0 \text{ m/s}) - (4.85 \times 10^5 \text{ kg})(20.0 \text{ m/s})}{5.00 \text{ s}}$ $\mathbf{F} = \dfrac{1.21 \times 10^7 \text{ kg•m/s} - 9.70 \times 10^6 \text{ kg•m/s}}{5.00 \text{ s}} = \dfrac{2.4 \times 10^6 \text{ kg•m/s}}{5.00 \text{ s}}$ $\mathbf{F} = \boxed{4.8 \times 10^5 \text{ N northwest}}$
8. $\mathbf{v_f} = 12.5$ m/s upward $m = 70.0$ kg $\Delta t = 4.00$ s $\mathbf{v_i} = 0$ m/s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(70.0 \text{ kg})(12.5 \text{ m/s}) - (70.0 \text{ kg})(0 \text{ m/s})}{4.00 \text{ s}} = 219 \text{ N}$ $\mathbf{F} = \boxed{219 \text{ N upward}}$
9. $m = 12.0$ kg $h = 40.0$ m $\Delta t = 0.250$ s $v_f = 0$ m/s $g = 9.81$ m/s^2	From conservation of energy, $\mathbf{v_i} = -\sqrt{2gh}$ $\Delta p = m\mathbf{v_f} - m\mathbf{v_i} = m\mathbf{v_f} - m\left(-\sqrt{2gh}\right)$ $\Delta p = (12.0 \text{ kg})(0 \text{ m/s}) + (12.0 \text{ kg})\sqrt{(2)(9.81 \text{ m/s}^2)(40.0 \text{ m})} = 336 \text{ kg•m/s}$ $\mathbf{F} = \dfrac{\Delta p}{\Delta t} = \dfrac{336 \text{ kg•m/s}}{0.250 \text{ s}} = 1340 \text{ N} = \boxed{1340 \text{ N upward}}$

Momentum and Collisions

Problem B

FORCE AND IMPULSE

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.

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

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

$$\Delta t = \frac{(1.24\times10^5 \text{ kg})(197 \text{ m/s}) - (1.24\times10^5 \text{ kg})(101 \text{ m/s})}{4.00\times10^5 \text{ N}}$$

$$\Delta t = \frac{2.44\times10^7 \text{ kg}\bullet\text{m/s} - 1.25\times10^7 \text{ kg}\bullet\text{m/s}}{4.00\times10^5 \text{ N}}$$

$$\Delta t = \frac{1.19\times10^7 \text{ kg}\bullet\text{m/s}}{4.00\times10^5 \text{ N}}$$

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

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.