Unit 3- Momentum & Energy

Short Answer

1. Define momentum qualitatively and quantitatively.
   Momentum, a vector, is the product of an objects mass and velocity.(mass in motion)
   $$\vec{p} = m\vec{v}$$

2. State the impulse-momentum theorem and give one example of its use.
   The impulse-momentum theorem states that the impulse is a change in momentum
   $$\vec{F}\Delta t = m\overrightarrow{v_f} - m\overrightarrow{v_i}$$

3. If you throw a ball against a wall, which of the three impulses is the greatest: throw, bounce, or catch?
   The greatest impulse would occur when the ball hits the wall because there would be a change in direction creating a greater velocity change, therefore a greater impulse.

4. How is it possible for an object to obtain a larger impulse from a smaller force than from a larger force?
   $\vec{J} = \vec{F}\Delta t$, the force would just have to act for a grater time interval.

5. You drop a dish from the table. Explain whether the impulse will be less if the dish lands on a carpet instead of a bare floor.
   The impulse will be the same assuming that the dish is brought to a stop. The carpet increases the impact time, decreasing the impact force on the dish so that the dish does not break. If the dish hits the bare floor, the impact time is small, but the force is large enough to cause the dish to break.

6. After pushing against a brick wall for a long time, you are feeling extremely tired, but you have not done any work on the wall. Explain.
   In order for work to be done the force needs to cause the displacement. If there is no displacement no work is done.

7. By what factor does the kinetic energy of an object change if its speed is doubled?
   $E_k = \frac{1}{2}mv^2$
   $E_k = \frac{1}{2}m(2v)^2$ E_k will increase by a factor of 4
   $E_k = \frac{1}{2}m4v^2$
   $E_k = 4\left(\frac{1}{2}mv^2\right)$

8. A baseball and a car can have the same kinetic energy. If this is true, what must be different about them? In this situation, how would the motion of each object compare?
   In order for two objects with different masses to have the same kinetic energy they must have different velocities. The object with a smaller mass must have a larger velocity.

Problems

1. What is the mass of a car that is travelling with a velocity of 28 m/s[W] and a momentum of 4.2×10^4 kgm/s[W]? [Ans:1500kg]

   $v = 28\ m/s[w]$
   $p = 4.2 \times 10^4\ \frac{kgm}{s}$ [w]
   $m =?$

   $\vec{p} = m\vec{v}$
   $m = \frac{p}{v}$
   $m = \frac{4.2 \times 10^4}{28}$
   $m = 1500\ kg$

2. The momentum of a 55.0 kg in-line skater is 66.0 kgm/s [S]. What is his velocity? [Ans:1.20 m/s [S]]

$p = 66.0\frac{kgm}{s}$ [S]
$m = 55.0\ kg$
$v =?$

$\vec{p} = m\vec{v}$
$\vec{v} = \frac{\vec{p}}{m}$
$\vec{v} = \frac{66.0}{55}$
$\vec{v} = 1.20\frac{m}{s}\ [S]$

3. How fast would a 5.0 x 10^{-3}kg golf ball have to travel to have the same momentum as a 5.0 kg bowling ball that is rolling at 6.0 m/s? [Ans:6000 m/s]

$m_1 = 5.0 \times 10^{-3} kg$
$m_2 = 5.0\ kg$
$v_2 = 6.0\frac{m}{s}$
$v_1 =?$

$\vec{p} = m\vec{v}$
$m_1\vec{v}_1 = m_2\vec{v}_2$
$(5.0 \times 10^{-3})(\vec{v}_1) = (5.0)(6.0)$
$\vec{v}_1 = 6000$ m/s forward

4. Calculate the impulse for the following interactions.
   a. A person knocks at the door with an average force of 9.1 N [E] over a time interval of 2.5 x 10^{-3}s. [Ans:0.023 N s [E]]

$F = 9.1\ N[E]$
$t = 2.5 \times 10^{-3} s$
$\vec{J} =$

$\vec{J} = \vec{F}\Delta t$
$\vec{J} = (9.1)(2.5 \times 10^{-3})$
$\vec{J} = 0.023\ Ns\ [E]$

   b. A wooden mallet strikes a large iron gong with an average force of 4.2 N[S] over a time interval of 8.6 x 10^{-3}s. [Ans:0.036 N s[S]]

$F = 4.2\ N[S]$
$t = 8.6 \times 10^{-3} s$
$\vec{J} =?$

$\vec{J} = \vec{F}\Delta t$
$\vec{J} = (4.2)(8.6 \times 10^{-3})$
$\vec{J} = 0.036\ Ns\ [S]$

5. A volleyball player spikes the ball with an impulse of 8.8 Ns over a duration of 2.3 x 10^{-3}s. What is the average applied force? [Ans:3800N]

$t = 2.3 \times 10^{-3} s$
$\vec{J} = 8.8\ Ns$
$F =?$

$\frac{\vec{J}}{\Delta t} = \vec{F}$
$\vec{F} = \frac{8.8}{2.3 \times 10^{-3}}$
$\vec{F} = 3800\ N$

6. a. What is the impulse of a 0.300 kg hockey puck slap shot that strikes the goal post at a velocity of 44 m/s [N] and rebounds straight back with a velocity of 9.2 m/s [S]? [Ans:16 N s]

$m = 0.300kg$
$v_i = 44\frac{m}{s}[N]$
$v_f = 9.2\frac{m}{s}[S]$

$\vec{J} = \Delta\vec{p}$
$\vec{J} = m\vec{v}_f - m\vec{v}_i$
$\vec{J} = (0.300)(-9.2) - (0.300)(44)$
$\vec{J} = -15.96\ Ns = 16\ Ns\ [S]$

b. If the average force of the interaction was -2.5 x 10^3N, what was the duration of the interaction? [Ans:0.0064 s]

$F = -2.5 \times 10^3 N$
$t =?$
$\vec{J} = \Delta\vec{p}$
$\vec{F}\Delta t = \Delta\vec{p}$

$\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$
$\vec{F} = \frac{-15.96}{-2.5 \times 10^3}$
$\vec{F} = 0.006384s = 0.0064\ s$

7. A 2.5 kg curling stone is moving down the ice at 3.5 m/s [W]. What force would be needed to stop the stone in a time of 3.5 x 10^{-4}s? [Ans:25000 N[E]]

$m = 2.5\ kg$

$v_i = 3.5\frac{m}{s}[W]$

$\Delta t = 3.5 \times 10^{-4} s$

$v_f = 0\frac{m}{s}$

$\vec{F} = ?$

$\vec{F}\Delta t = m\vec{v}_f - m\vec{v}_i$

$\vec{F} = \frac{m\vec{v}_f - m\vec{v}_i}{\Delta t}$

$\vec{F} = \frac{(2.5)(0) - (2.5)(3.5)}{3.5 \times 10^{-4}}$

$\vec{F} = 25000\ N\ [E]$

8. A 48.0 kg skateboarder kicks his 7.0 kg board ahead with a velocity of 2.6 m/s [E]. If he runs with a velocity of 3.2 m/s [E] and jumps onto the skateboard, what is the velocity of the skateboard and the skateboarder immediately after he jumps on the board? [Ans:3.1 m/s [E]]

$m_s = 48.0\ kg$

$m_b = 7.0\ kg$

$v_{bi} = 2.6\frac{m}{s}[E]$

$v_{si} = 3.2\frac{m}{s}[E]$

$v_f = ?$

$m_s v_{si} + m_b v_{bi} = v_f(m_s + m_b)$

$(48.0)(3.2) + (7.0)(2.6) = v_f(48.0 + 7.0)$

$\frac{(48.0)(3.2) + (7.0)(2.6)}{55} = \frac{v_f(55)}{55}$

$v_f = 3.12\frac{m}{s} = 3.1\frac{m}{s}$

9. Astrid, who has a mass of 37.0 kg, steps off a stationary 8.0 kg toboggan onto the snow. If her forward velocity is 0.50 m/s, what is the recoil velocity of the toboggan?(assume that friction is negligible.) [Ans:-2.31 m/s]

$m_a = 37.0\ kg$

$m_t = 8.0\ kg$

$v_{ai} = 0\frac{m}{s}$

$v_{ti} = 0\frac{m}{s}$

$v_{af} = 0.5\frac{m}{s}$

$v_{tf} = ?$

$v_i(m_a + m_t) = m_a v_{af} + m_t v_{tf}$

$0(37.0 + 8.0) = (37.0)(0.5) + (8.0)(v_{tf})$

$0 = 18.5 + 8.0 v_{tf}$

$\frac{-18.5}{8.0} = \frac{8.0 v_{tf}}{8.0}$

$v_{tf} = -2.31\frac{m}{s}$

10. A 60.0 t (1 t = 1000 kg)submarine, initially travelling forward at 1.5 m/s, fires a 5.30 x 10^2 kg torpedo straight ahead with a velocity of 21 m/s in relation to the submarine. What is the velocity of the submarine immediately after it fires the torpedo? [Ans:1.3 m/s]

$m_s = 60.0\ t = 60\ 000 kg$

$m_t = 5.0 \times 10^2\ kg$

$v_{si} = 1.5\frac{m}{s}$

$v_{ti} = 1.5\frac{m}{s}$

$v_{tf} = 21 + 1.5\frac{m}{s} = 22.5\frac{m}{s}$

$v_{sf} = ?$

$v_i(m_s + m_t) = m_s v_{sf} + m_t v_{tf}$

$1.5(60\ 000 + 500) = (60\ 000)(v_{sf}) + (500)(22.5)$

$90750 = (60\ 000)(v_{sf}) + 11250$

$\frac{90750 - 11250}{60\ 000} = \frac{60\ 000 v_{sf}}{60\ 000}$

$v_{sf} = 1.325\frac{m}{s} = 1.3\frac{m}{s}$

11. Suppose that a 75.0 kg goalkeeper catches a 0.40kg ball that is moving at 32 m/s. With what forward velocity must the goalkeeper jump when she catches the ball so that the goalkeeper and the ball have a horizontal velocity of zero? [Ans:0.17m/s]

$m_g = 75.0\ kg$
$m_b = 0.40kg$
$v_{bi} = -32\frac{m}{s}$
$v_{gi} = ?$
$v_f = 0$

$m_g v_{gi} + m_b v_{bi} = v_f(m_g + m_b)$
$(75.0)(v_{gi}) + (0.40)(-32) = 0$
$\frac{(75.0)(v_{gi})}{75.0} = \frac{12.8}{75.0}$
$v_{gi} = 0.171\frac{m}{s} = 0.17\frac{m}{s} forward$

12. A toddler pushes a chair at a constant speed with a force of 25.0 N for a distance of 2.5 m. How much work is the child doing on the chair?[Ans:63J]

$F_p = 25.0\ N$
$d = 2.5\ m$

$w = Fdcos\ \theta$
$w = (25)(2.5)(1)$
$w = 63J$

13. A businesswoman is applying a force of 12.0 N [upwards] to carry her briefcase for a horizontal distance of 200.0 m. How much work is she doing on the briefcase? [Ans: 0.00N]

No work is done. A vertical force cannot cause a horizontal displacement.

14. 4050 J of work was done on a pile of snow to move it 3.4 m. What force must have been applied by the snow plow to do this work? [Ans: 1200N]

$w = 4050\ J$
$d = 3.4\ m$
$F = ?$

$w = Fdcos\ \theta$
$\frac{4050}{3.4} = \frac{F(3.4)(1)}{3.4}$
$F = 1191.176\ N = 1200\ N$

15. A women pushes a shopping cart with a force of 75 N at a constant speed ot 0.75 m/s for an hour around the grocery store. How much work does she do on the cart? [Ans: 200 000 J]

$F = 75\ N$
$v = 0.75\frac{m}{s}$
$t = 1h = 3600s$

$v = \frac{d}{t}$
$d = vt$
$d = (0.75)(3600)$

$d = 2700m$
$w = Fdcos\ \theta$
$w = (75)(2700)(1)$
$w = 200\ 000J$

16. The school caretaker is applying a 200 N force 45° to the horizontal to push a lawn mower a horizontal distance of 20.0 m. How much work does he do on the lawn mower, assuming no friction? [Ans:3000J]

$F_p = 200\ N$
$\theta = 45°$
$d = 20.0\ m$

$w = Fdcos\ \theta$
$w = (200)(20)(\cos 45°)$
$w = 2828.43\ J = 3000J$

17. If a hair dryer does 3000.0 J of work to heat the air every 2 seconds, what is its power? [Ans: 2000 W]

$w = 3\,000.0\,J$
$t = 2s$
$P =?$

$$P = \frac{W}{t}$$
$$P = \frac{3\,000}{2}$$
$$P = 1500\,W = 2\,000W$$

18. How long would it take a 1.00 kW electric motor on a conveyor belt to do 750 J of work? [Ans: 0.75 s]

$P = 1.00kW = 1\,000W$
$w = 750\,J$
$t =?$
$P = \frac{W}{t}$

$$t = \frac{W}{P}$$
$$t = \frac{750}{1000}$$
$$t = 0.75\,s$$

19. What is the kinetic energy of a 60.0 g tennis ball that is travelling at

a. 10.0 m/s? [Ans:3.00J]

$m = 60.0\,g = 0.06kg$
$v = 10.0\frac{m}{s}$
$E_k =?$
$E_k = \frac{1}{2}mv^2$
$E_k = \frac{1}{2}(0.06)(10.0)^2$
$E_k = 3.00\,J$

b. 25.0 m/s? [Ans:18.8J]

$m = 60.0\,g = 0.06kg$
$v = 25.0\frac{m}{s}$
$E_k =?$
$E_k = \frac{1}{2}mv^2$
$E_k = \frac{1}{2}(0.06)(25.0)^2$
$E_k = 18.8\,J$

20. What is the mass of an object that is travelling at 10.0 m/s with kinetic energy of 370 J? [Ans: 7.4kg]

$m =?$
$v = 10.0\frac{m}{s}$
$E_k = 370\,J$

$$E_k = \frac{1}{2}mv^2$$
$$370 = \frac{1}{2}m(10.0)^2$$
$$\frac{(370)(2)}{100} = m$$
$$m = 7.4\,kg$$

21. How much work is done by an Olympic tri-athlete who accelerates herself on her bicycle (a combined mass of 105 kg) from 5.0 m/s to 10.0 m/s. Assume she is biking on a level road? [Ans:3900J]

$m = 105\,kg$
$v_i = 5.0\frac{m}{s}$
$v_f = 10.0\frac{m}{s}$

$w = \Delta E_k + \Delta E_p$
$No\ change\ in\ heigh\ \therefore no\ E_p$
$w = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$w = \frac{1}{2}(105)(10.0)^2 - \frac{1}{2}(105)(5.0)^2$
$w = 3937.5\,J = 3900\,J$