MOMENTUM WORKSHEET

1. Which has more momentum, a 1000 kg car moving 1 m/s or a 70 kg person sprinting at 8 m/s?

$1000(1) = 1000\ kg\cdot m/s$ $\quad 70kg(8m/s) = 560\ kg\cdot m/s$

Car

2. An official major league baseball has a mass of 0.14 kg. A pitcher throws a 40 m/s fastball which is hit by the batter straight back up the middle at a speed of 46 m/s.
a) What is the change in momentum of the ball during the collision with the bat?
b) If this collision occurs during a time of 0.012 seconds, what is the average force exerted by the bat on the ball?

a) $\Delta p = m(v_f - v_i) = .14(-46 - 46)$
$= -12\ kg\cdot m/s$

b) $\Delta p = Ft$
$-12 = F(.012)$
$F = -1000\ N$

3. A tennis ball may leave a top player's racket on the serve with a speed of 65.0 m/s. If the ball's mass is 0.0600 kg and it is in contact with the racket for 0.0300 s, what is the average force exerted on the ball? Would this force be enough to lift a person off the ground?

$\Delta p = m(v_f - v_i) = Ft$
$.06(65 - 0) = F(.03)$
$F = 130\ N$

4. How much force is required to stop a 60 kg person traveling at 30 m/s during a time of a) 5.0 seconds
b) 0.50 seconds
c) 0.05 seconds

a) $\Delta p = m(v_f - v_i) = Ft$
$60(0 - 30) = F(.5)$
$F = -3600\ N$

b) $60(0-30) = F(.05)$
$F = -36000\ N$

5. A 30 kg child running at 7 m/s jumps onto a 10 kg sled which was initially at rest. What will be the velocity of the child+sled immediately after the child jumps on the sled?

$p_i = p_f$
$30(7) + 0 = (30+10)v_f$
$v_f = 5.25\ m/s$

6. A 1500 kg car traveling at 15 m/s collides with a 500 kg moose which is at rest. If the moose is knocked backward at 20 m/s, what happens to the car?

$1500(15) + 0 = 500(20) + 1500v_f$
$v_f = 8.3\ m/s$

7. A 1500 kg car traveling 5.0 m/s collides head on with a 3000 kg truck traveling 7.0 m/s in the opposite direction. If the bumpers lock (the collision is inelastic),
a) what is the velocity of the two vehicles together immediately following the collision?
b) what is the magnitude of the change in velocity experienced by the driver of each car during the collision?

a) $1500(5) + 3000(-7) = (1500+3000)v_f$
$v_f = -3\ m/s$

b) i) $\Delta v_i = v_f - v_i = -3 - 5$
$= -8\ m/s$

ii) $\Delta v = -3 - (-7) = +4\ m/s$

8. A 70 kg astronaut floating in an orbiting space station throws a 1.0 kg water bottle across the room at a speed of 8.0 m/s. What is the magnitude of the astronaut's recoil velocity?

$p_i = 0 = p_f$ $\quad 0 = 1(8) + 70v_2$
$v_2 = -.11\ m/s$

Challenge

9. In order to complete a tough "split" in bowling, a bowling ball of mass 6.5 kg is rolled with a velocity of 12 m/s. The ball hits a 1.3 kg bowling pin, sending it off with a speed of 3.5 m/s at an angle of 80 degrees with respect to the original direction of the bowling ball. What is the angle and direction of the bowling ball's velocity after the collision with the pin?

Quiz for test

Key

Impulse, Momentum & Conservation of Momentum Worksheet

Momentum Worksheet.doc

Impulse and Momentum:

1. A compact car with a mass of 725 kg is moving at 90 km/hr toward the east.

a. Find the magnitude and direction of its momentum.

$p = mv$

$v = \frac{90\,km}{1\,hr} \cdot \frac{1\,hr}{3600\,s} \cdot \frac{1000\,m}{1\,km} = 25\ m/s$

$p = (725\,kg)(25\ m/s)$

$= 18{,}125\ kg\,m/s$ east

b. A second car, with a mass of 2175 kg, has the same momentum. What is its velocity?

$p = mv$

$18125 = 2175v$

$v = 8.3\ m/s$ east

2. The same compact car from question 1, suddenly applies the brakes hard for 2.0 s. As a result an average force of 5.0 x 10$_3$ N is exerted on the car to slow it.

a. What is the magnitude and direction of the impulse on the car?

$I = Ft = 5000\ N(2\,s) = 10000\ kg\,m/s$ west

b. What is the magnitude and direction of the change in momentum of the car?

$I = \Delta p = 10000\ kg\,m/s$ west

c. If the compact car was initially moving at 90 km/hr, what is its final velocity?

$I = m(v_f - v_i)$

$90\ km/hr = 25\ m/s$

$-10000 = 725(v_f - 25)$

$-13.8 = v_f - 25$

$v_f = 11.2\ m/s$

3. A snowmobile with a mass of 24.0 kg accelerates from 6.00 m/s to 28.0 m/s in 60.0 s.

a. What is the snowmobile's change in momentum?

$\Delta p = m(v_f - v_i)$

$24(28 - 6) = 528\ kg\,m/s$

b. What is the magnitude and direction of the average force exerted on the snowmobile?

$\Delta p = F \cdot t$

$528 = F \cdot 60$

$F = 8.8\ N$

4. A boy hits a 0.05 kg golf ball from rest to a speed of 75 m/s. What is the impulse given to the ball? If the impact lasted for 0.01 seconds, what was the average force of impact?

$I = \Delta p = m(v_f - v_i) = .05(75 - 0) = 3.75\ kg\,m/s = F \cdot t$

$3.75 = F(.01)$

$F = 375\ N$

5. A 0.144-kg baseball is pitched horizontally at 38.0 m/s. After the ball is hit by the bat, it moves in the opposite direction with a speed 42.0 m/s. If the bat and ball were in contact for 0.80 x 10-3 seconds, what was the average force the bat exerted on the ball?

$F \cdot t = m(v_f - v_i)$

$F(.0008) = .144(-42 - 38)$

$F = -14{,}400\ N$

6. During an automobile crash test, a 1000 kg car is sent towards a cement wall at a speed of 14 m/s. It is brought to rest in 0.08 sec. What was the average force ***of the car on the wall***?

$F \cdot t = m(v_f - v_i)$

$F(.08) = 1000(0 - 14)$ $\quad F = \boxed{-175000\ N}$

7. A bowling ball with a mass of 5.4 kg is moving at a velocity of 3 m/s. What is the bowling ball's momentum?

$p = mv$

$= 5.4(3) = \boxed{16.2\ kg\ m/s}$

8. A 10000 kg freight car is rolling along a track at 3 m/s. Calculate the time needed for a 1000 N force to stop it.

$Ft = m(v_f - v_i)$

$-1000\ t = 10000(0 - 3)$ $\quad \boxed{t = 30s}$

9. A 0.160 kg hockey puck is moving to the right at 3.00 m/s. What is the velocity of the puck after a force directed to the right with a magnitude of 25.0 N is applied for 0.050 s?

$Ft = m(v_f - v_i)$

$25(.05) = .16(v_f - 3)$

$1.25 = .16 v_f - .48$

$1.73 = .16 v_f$

$\boxed{10.8\ m/s = v_f}$

10. A 0.005 kg bullet is fired with a velocity of 100 m/s toward a 10 kg stationary solid block resting on a frictionless surface.

a. What is the change in momentum of the bullet if it is embedded in the block?

$\Delta p = p_f - p_i = 0 - mv_i = 0 - (.005)(100\ m/s) = \boxed{-.5\ kg\ m/s}$

b. What is the change in momentum of the bullet if it ricochets in the opposite direction with a speed of 99 m/s?

$\Delta p = p_f - p_i$

$= m(v_f - v_i)$

$= .005(-99 - 100)$

$= \boxed{-.995\ kg\ m/s}$

Impulse, Momentum & Conservation of Momentum Worksheet

Conservation of Momentum:

11. A 95-kg fullback running at 8.2 m/s collides in midair with a 128-kg defensive tackle moving in the opposite direction. After the collision, both players come to rest. How fast was the tackle moving initially?

$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$, $v_f = 0$

$95(8.2) + 128 v_{2i} = 0$

$v_{2i} = -6.1\ m/s$

12. A thread holds two carts together as shown in the diagram below. After the thread is cut, a compressed spring pushes the carts apart, giving the 1.5-kg car a speed of 27 cm/s to the left. What is the velocity of the 4.5-kg car?

$p_i = p_f$

$0 = 1.5\,kg\,(-.27\ m/s) + 4.5\,kg\ v_f$

$v_f = .09\ m/s$

13. Two campers dock a canoe. Once the canoe comes to rest, one camper with a mass of 80.0-kg gets off the canoe with a velocity of +4.0 m/s. The canoe and the other camper drift off in the opposite direction with a speed of 2.78 m/s. What is the combined mass of the canoe and the second camper?

$p_i = p_f$

$0 = 80\,kg\,(4\ m/s) + m_2\,(-2.78\ m/s)$

$m_2 = 115\,kg$

14. A spaceship with a mass of 2.0×10^6 kg is cruising at a speed of 5.0×10^6 m/s when it blows up into two pieces. One section, with a mass of 7.5×10^5 kg is blown straight backwards with a speed of 1.0×10^6 m/s. What is the magnitude and direction of the velocity of the second piece of the spaceship?

$m_2 = 2\times10^6 - 7.5\times10^5 = 1250000\,kg$

$p_i = p_f$

$(2\times10^6\,kg)(5\times10^6\ m/s) = (7.5\times10^5\,kg)(-1\times10^6\ m/s) + 1250000\,v_2$

$1.075\times10^{13} = 1250000\,v_2$

$v_2 = +8600000\ m/s$

15. A ceramic penguin with a mass of 0.5 kg suddenly bursts apart into two pieces. One piece has a mass of 0.15 kg and has a velocity of -2m/s. What is the velocity of the second piece?

$p_i = 0 = p_f$

$0 = (.15\,kg)(-2\ m/s) + (.5-.15)\,v_2$

$0 = -.3 + .35\,v_2$

$v_2 = .86\ m/s$

16. The nucleus of an atom has a mass of 3.8×10^{-25} kg and is at rest. The nucleus is radioactive and suddenly ejects a particle of mass 6.6×10^{-27} kg at a speed of 1.5×10^7 m/s. Find the recoil speed of the nucleus that is left behind.

$p_i = 0 = p_f$

$0 = 6.6\times10^{-27}\,kg\,(1.5\times10^7\ m/s) + (3.8\times10^{-25} - 6.6\times10^{-27})\,v_2$

$0 = 9.9\times10^{-20} + 3.73\times10^{-25}\,v_2$

$v_2 = -265416\ m/s$

4

17. A 0.2 kg plastic ball moves with a velocity of .3 m/s. It collides with a second plastic ball of mass 0.1 kg, moving along the same line at a velocity of .1 m/s. After the collision, the velocity of the 0.1 kg ball is 0.26 m/s. What is the new velocity of the first ball?

$.2(.3) + (.1)(.1) = .1(.26) + .2(v_2)$

$.07 = .026 + .2(v_2)$

$v_2 = .22\ m/s$

18. A 40 kg girl is running along at 5.2 m/s and jumps into a 20 kg wagon. How fast will the wagon move with the girl in it?

$40(5.2) + 20(0) = (40+20)v_f$

$208 = 60v_f$

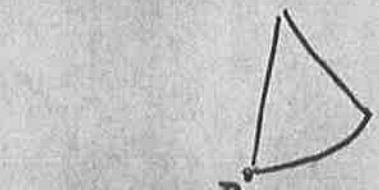
$v_f = 3.5\ m/s$

19. A 0.12 kg bullet with a velocity of 400 m/s is shot into a ballistic pendulum with a mass of 6.00 kg and a string length of 70 cm. How fast will the pendulum and the embedded bullet be moving just after the collision? What is the vertical height the pendulum will reach at the top of its swing?

$.12kg(400\ m/s) + 6kg(0\ m/s) = (.12+6)v_2$

$48 = 6.12v_2$

$v_2 = 7.8\ m/s$



$TE = KE + PE$ (PE = 0)

$TE = \frac{1}{2}mv^2$

$= \frac{1}{2}(6.12)(7.8)^2$

$= 186\ J = PE$

$186 = mgy$

$186 = 6.12(9.8)y$

$y = 3.1\ m$

Elastic Collisions — Key

Before	After

1)

Before: 2m/s, Equal Mass, 2m/s

After: 2m/s, Equal Mass, 2 m/s

$(2m)+(-2m) = 0 = p_f$

$p_f = 0$

$2(2) + 4v_{2f} = 0$

2)

Before: 4m/s, 2kg; 2m/s, 4kg

After: 2m/s, 2kg; 1 m/s, 4kg

$p_i = p_f = 0$

$4(2)+(-2\times4) = 0$

3)

Before: 10 m/s, 2kg; 8m/s, 2kg

After: 8m/s, 2kg; 10m/s, 2kg

$2(v_i) + 2(-8) = 2(-8) + 2(10)$

$2v_i - 16 = 4$

$v_i = 10\ m/s$

4)

Before: 5m/s, 12kg; 0m/s, 6 kg

After: 0m/s, 12kg; 10m/s, (same as before) 6 kg

$12(5) + m_2(0) = 12(0) + m_2(10)$

$60 = m_2(10)$

$m_2 = 6\ kg$

5)

Before: 6m/s, 8kg; 3m/s, 4kg

After: 3m/s, 8kg; 9 m/s, 4kg

$8(6) + 4(3) = 8(3) + 4v_{2f}$

$60 = 24 + 4v_{2f}$

$9\ m/s = v_{2f}$

6)

Before: 8m/s, 4kg; -8 m/s, 4kg

After: 8m/s, 4kg; 8m/s, 4kg

$4(8) + 4v_{2i} = 4(-8) + 4(8)$

$32 + 4v_{2i} = 0$

$v_{2i} = -8\ m/s$

~~7)~~ Omit

Before: 0m/s, 10kg; 4m/s, 10kg

After: 2m/s, 10kg; ____ m/s, 10kg

$10(0) + 10(4) = 10(-2) + 10v_{2f}$

$-40 = -20 + 10v_{2f}$

$-20 = 10v_{2f}$

$v_{2f} =$

Negation

Inelastic Collisions

Before	After

1)

2m/s Equal mass 0m/s

$m(2) + m(0) = 2m(v)$

$2m = 2m(v)$ $v = 1$ m/s

1 m/s

2)

4m/s 2m/s

9kg 20kg

$9(4) + 20(-2) = 29(v_2)$

$-.14 \text{ m/s} = v_2$

← .14 m/s

29kg

(specify ± direction)

3) o.t. - no solution

6m/s 3m/s

2kg ____kg

3m/s

(2+_____)kg

$4(6) + 4(2) = 8v_2$

4)

6m/s 2m/s

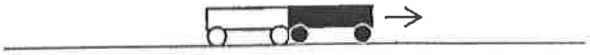
4kg 4kg

$32 = 8v_2$

$v_2 = 4$ m/s

4 m/s

8kg



5) $m_1(3) + -60 = (m_1 + 5)6$

3m/s 12m/s

_____kg 5kg

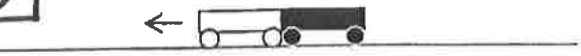
$3m_1 - 60 = 6m_1 - 30$

$9m_1 = 30$

$m_1 = 3.3$ kg

6m/s

(_____+5)kg



$m_1(0) + 3(-8) = (m_1 + 3)(-2)$

6)

0m/s 8m/s

9 kg

_____ 3kg

$-24 = -2m_1 - 6$

$-18 = -2m_1$

$m_1 = 9$ kg

2m/s

(_____+3)kg

$x(6) + 2x(0) = 3x(2)$

7) (tricky tricky)

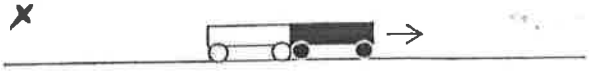
6m/s 0m/s

x 2x

$6x = 6x$

2m/s

3x



What is x equal to?

Any value of x will work.