Momentum and Impulse

WORKSHEET #3

Name: ________________________

1. A 1.15 kg block is pressed into a spring, compressing it by 15.0 cm. The spring constant is 455 N/m. The entire deal rests on a flat, low friction table that is 75.0 cm above the deck. The block is released. It crashes head-on into a 0.750 kg block that is at rest. The first block ends up with a velocity of 0.585 m/s in the same direction after the collision. (a) What is the PE in the spring before the block is released? (b) What is the momentum of the block just before it hits the second block? (c) What is the final velocity of the second block? (d) The second block reaches the end of the table, what is its KE? (e) The block falls off the table. How far from the edge of the table does it land? (f) What is its KE just before it hits?

a. $PE_{spring} = \frac{1}{2} kx^2 = 0.5 \cdot 455\ N/m \cdot (0.15\ m)^2 = 5.11875\ J = \boxed{5.12\ J}$

b. $\frac{1}{2} mv^2 = PE_{spring}$ {PE_{spring} is all converted to kinetic energy}

$v = (2 \cdot PE_{spring} / m)^{\frac{1}{2}} = (2 \cdot 5.11875\ J / 1.15\ kg)^{\frac{1}{2}} = 2.9836511\ m/s$

$p = mv = 1.15\ kg \cdot 2.9836511\ m/s = 3.43119877\ kg{\cdot}m/s = \boxed{3.43\ kg{\cdot}m/s}$

c. $m_1v_1 + m_2v_2 = m_1v_1 + m_2v_2$

$1.15\ kg \cdot 2.9836511\ m/s + 0.750\ kg \cdot 0\ m/s = 1.15\ kg \cdot 0.585\ m/s + 0.750\ kg \cdot v$

$v = 1.15\ kg\ (2.9836511\ m/s - 0.585\ m/s) / 0.750\ kg = 3.677931687\ m/s = \boxed{3.68\ m/s}$

d. $KE = \frac{1}{2} mv^2 = 0.5 \cdot 0.750\ kg\ (3.677931687\ m/s)^2 = 5.0726930594\ J = \boxed{5.07\ J}$

e. $d = \frac{1}{2} at^2$

$t = (2d/a)^{\frac{1}{2}} = (2 \cdot 0.75\ m/9.8\ m/s^2)^{\frac{1}{2}} = 0.3912304\ s$

$d = vt = 3.677931687\ m/s \cdot 0.3912304\ s = 1.4389186785\ m = \boxed{1.44\ m}$

f. $KE_f = KE_i + PE = 5.0726930594\ J + 0.750\ kg \cdot 9.8\ m/s^2 \cdot 0.750\ m = 10.585193\ J = \boxed{10.6\ J}$

2. A boy on roller blades throws a jug of water away from himself, giving it a speed of 14 m/s. The boy's mass is 38 kg and the mass of the jug and water is 7.9 kg. What is the velocity gained by the lad?

$m_{jug}v_{jug} = m_{boy}v_{boy}$

$7.9\ kg \cdot 14\ m/s = 38\ kg \cdot v$

$v = (7.9\ kg \cdot 14\ m/s) / 38\ kg = 2.910526316\ m/s = \boxed{2.9\ m/s}$

3. A 350 g hockey puck moving at 62 m/s is captured by the stationary goalie. Now this goalie has a mass of like 74 kg, so at what speed does the goalie go sliding down the ice?

$m_{puck}v_{puck} + m_{goalie}v_{goalie} = m_{both}v_{both}$

$0.350\ kg \cdot 62\ m/s + 74\ kg \cdot 0\ m/s = 74.035\ kg \cdot v$

$v = 0.350\ kg \cdot 62\ m/s / 74.035\ kg = 0.2931046\ m/s = \boxed{0.29\ m/s}$

4. A 725.0 g emu egg moving at 8.75 m/s thrown by an obnoxious juvenile is caught by an alert lady. (a) If the time of the interaction is 0.197 sec, what is the average force on the egg? (b) If the maximum force the egg can withstand is 650.0 N, what minimum time is required to keep the egg intact?

a. $J = \Delta p$

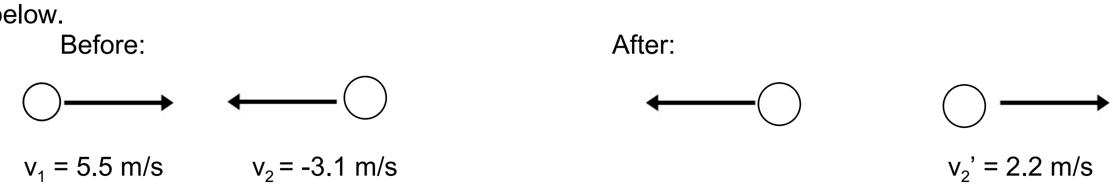
$F \cdot t = m\Delta v$

$F = m\Delta v/t = 0.7250\ kg \cdot 8.75\ m/s / 0.197\ s = 32.20177665\ N = \boxed{32.2\ N}$

b. $F \cdot t = m\Delta v$

$t = m\Delta v/F = 0.7250\ kg \cdot 8.75\ m/s / 650.0\ N = 0.0097596154\ s = \boxed{0.00976\ s}$

5. A 4.2 kg ball traveling to the right collides with a 5.7 kg ball traveling to the left at 3.1 m/s as shown below.



Find the velocity of the first ball after the collision.

$p = p'$

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

$4.2\ kg \cdot 5.5\ m/s + 5.7\ kg \cdot (-3.1\ m/s) = 4.2\ kg \cdot v_1' + 5.7\ kg \cdot 2.2\ m/s$

$v_1' = (4.2\ kg \cdot 5.5\ m/s + 5.7\ kg \cdot (-3.1\ m/s) - 5.7\ kg \cdot 2.2\ m/s) / 4.2\ kg = -1.692857\ m/s = \boxed{-1.7\ m/s}$

6. An 80.0 kg astronaut in space throws a 10.0 kg oxygen tank away from himself with a speed of 4.30 m/s. With what velocity does the astronaut start to move through space?

$m_{astro}v_{astro} = m_{tank}v_{tank}$

$v_{astro} = m_{tank}v_{tank}/m_{astro} = 10.0\text{ kg} \cdot 4.30\text{ m/s} / 80.0\text{ kg} = 0.5375\text{ m/s} = \boxed{0.538\text{ m/s}}$

7. A 135 kg bomb lying in a field suddenly explodes into 3 pieces having respective masses of 20.0, 47.0 and 68.0 kg. The 20.0 kg piece is thrown horizontally North with an initial speed of 25.0 m/s; the 47.0 kg piece is thrown horizontally East with an initial speed of 40.0 m/s. Find (a) What is the net momentum of the bomb before the explosion? (b) How much is the net momentum of the 3 pieces after the explosion? (c) If the third piece flies off horizontally to the Southwest, what is its speed?

a. $p_{net\ initial} = \boxed{0\text{ kg}\cdot\text{m/s}}$ ($p = m \cdot v = 135.0\text{ kg} \cdot 0\text{ m/s} = 0\text{ kg}\cdot\text{m/s}$)

b. $p_{net\ final} = \boxed{0\text{ kg}\cdot\text{m/s}}$ ($\sum p_{initial} = \sum p_{final}$ conservation of momentum)

c. $p_{3\ south} = 20.0\text{ kg} \cdot 25.0\text{ m/s} = 500.\text{ kg}\cdot\text{m/s}$ (conservation of momentum in N/S direction)

$p_{3\ west} = 47.0\text{ kg} \cdot 40.0\text{ m/s} = 1880\text{ kg}\cdot\text{m/s}$ (conservation of momentum in E/W direction)

$p_{3\ total} = ((500\text{ kg}\cdot\text{m/s})^2 + (1880\text{ kg}\cdot\text{m/s})^2)^{\frac{1}{2}} = 1945.353438\text{ kg}\cdot\text{m/s} = 1950\text{ kg}\cdot\text{m/s}$

$v_3 = p_3 / m_3 = 1945.353438\text{ kg}\cdot\text{m/s} / 68.0\text{ kg} = 28.6081388\text{ m/s} = \boxed{28.6\text{ m/s}}$

8. A steel ball bearing is dropped from the roof of a building (the initial velocity of the ball is zero). An observer standing in front of a 120 cm tall window notes that the ball takes 0.125 s to fall from the top to the bottom of the window. The ball bearing continues to fall, makes a completely elastic collision with a horizontal sidewalk, and reappears at the bottom of the window 2.0 s after it went by the bottom of the window. How tall is the building?'

$v_{avg} = d/t = 1.2\text{ m}/0.125\text{ s} = 9.6\text{ m/s}$ (average velocity across window, speed at center of window)

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

$h = v^2/2g = (9.6\text{ m/s})^2/19.6\text{ m/s}^2 = 4.702040816\text{ m}$ (this is how far ball fell to center of window)

bottom of window = 5.302040816 m from top

$d = \frac{1}{2}at^2$

$t = (2d/a)^{\frac{1}{2}} = (2 \cdot 5.302040816\text{ m}/9.8\text{ m/s}^2)^{\frac{1}{2}} = 1.040215913\text{ s}$ (time to bottom of window)

$t_{top\ to\ ground} = t_{window\ bottom} + 1\text{ s}$ (2 s round trip from bottom of window to ground and back up)

$t = 1.040215913\text{ s} + 1\text{ s} = 2.040215913\text{ s}$

$d = \frac{1}{2}at^2 = 0.5 \cdot 9.8 \cdot (2.040215913\text{ s})^2 = 20.39615677\text{ m} = \boxed{20.4\text{ m}}$