Physics….Worksheet 1

Impulse, Motion and Momentum

The concept of impulse and momentum is discerned by using Newton's 2nd Law:

F = ma but $a = \frac{v_f - v_i}{t}$ so substitute $F = m(\frac{v_f - v_i}{t})$

Take t to the other side:

$F(t) = mv_f - mv_i = \Delta mv = p_f - p_i = \Delta p$

F(t) is called IMPULSE. It is defined as a force acting through time. Momentum is the product of a velocity and time. It is symbolized by p. Impulse is numerically equal to the change of momentum. So a force acting through some time on some object give rise to a change of the object's momentum. Momentum is classified as a vector (you need a quantity and a direction)

Units:
Put Forces in Newtons
Put time in seconds
Put mass in kilograms
Put velocity in meters/second

Problems

1. Calculate the momentum of each of the following objects:

a) a 0.50 kg ball thrown straight up with a velocity of 30 m/s.

b) a 2000 kg railway car moving south at 10 m/s.

c) an electron of mass, 9.1×10^{-31} kg moving at a velocity of 1×10^{7} m/s.

d) the Earth of mass, 6.0×10^{24} kg, moving in its orbit with a velocity of 3.0×10^{4} m/s.

(answers: a) 15 kg m/s upward; b) 20,000 kg m/s South; c) 9.1×10^{-24} kg m/s; d) 1.8×10^{29} kg m/s)

2. The momentum of a 7.3 kg shotput is 22 kgm/s. What is its velocity in m/s?

3. A bullet traveling at 900 m/s has a momentum of 4.5 kg m/s. What is its mass in kilograms and grams?

4. What impulse is exerted in each of the following cases?

a) a force of 25 N on a car for 3.2 seconds.

b) a hockey stick exerts a force of 120 N on a puck during the 0.05 seconds of contact.

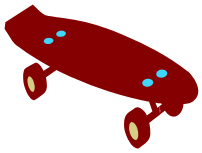
c) The Earth pulling down on a 12 kg rock during the 3 seconds it takes to fall freely.

5. A billiard ball of mass 0.2 kg rolls towards the right-hand cushion of a pool table at 2 m/s and rebounds straight back at the same speed but opposite in direction.

a) What is the change of momentum as a result of hitting the cushion?

b) What impulse is given to the ball by the cushion?

6. A 2 kg skateboard is rolling across a smooth, flat floor when a girl kicks it, causing it to speed up to 4.5 m/s in 0.5 seconds without changing direction. If the average force exerted by the girl on the skateboard in its direction of motion was 6 N, with what initial velocity was it moving?



answers: 2) v = 3.01 m/s 3) mass = 0.005 kg or 5 grams 4a) 80 Ns 4b) 6 Ns 4c) 352.8 Ns
5a) – 0.80 kg m/s 5b) – 0.80 Ns (Note: Ns = kg m/s) 6) v_i = 3 m/s

Physics Worksheet 2 The conservation of momentum in various collisions

When we ignore external forces such as friction and air resistance, we say that momentum is conserved or stays constant for objects before a collision and then after the collision.

We will look at three types of collisions:

ELASTIC: these are perfectly 'bouncy' collision. Objects hit each other and move off with no loss of energy.

Elastic equation: $m_A v_A + m_B v_B = m_A v'_A + m_B v'_B$ where A and B are the objects. The prime symbol (v') means the velocity after the collision.

INELATIC: these collisions are also called 'sticky' collisions. Two objects collide and then stick together and move as a common unit with a common velocity.

Inelastic equation: $m_A v_A + m_B v_B = m_{(A+B)} v'_{common}$

RECOIL: The objects start at rest and then separate out. One object moves one way and the other object moves in the opposite way.

Recoil equation: Since both objects are initially at rest, the initial momenta of the objects is 0. So:

$$m_A v_A + m_B v_B = m_A v'_A + m_B v'_B >>>>>> 0 = m_A v'_A + m_B v'_B$$

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1. A loaded railway car of mass 6000 kg is rolling to the right at 2 m/s when it collides and sticks to an empty railway car of mass 3000 kg rolling to the left on the same track at 3 m/s (-3 m/s). What is their speed and direction of the pair after the collision? (answer = 0.33 m/s to the right)

2. Calculate the recoil velocity of an unconstrained rifle of mass 5 kg after it shoots a 50 gram (0.050 kg) bullet at a speed of 300 m/s. (answer = -3 m/s, the negative sign means it moves in the opposite direction than the bullet)

3. A 5000 kg train car moving at 5.2 m/s on a level, frictionless track, runs into a stationary 8000 tank car. If they hook together in the collision, how fast will they be moving afterwards? (answer = 2 m/s)

4. A riderless 10 kg sled is moving at a speed of 2 m/s. A 75 kg running at 3 m/s in the same direction jumps onto this sled. What will be the final velocity of the girl and the sled, assuming that the sled is on level snow and that there is negligible friction? (answer = 2.88 m/s)

5. A 0.1 kg ball moving at a constant velocity of 2 m/s strikes a 0.4 kg ball that is at rest. After the collision, the first ball rebounds straight back at 1.2 m/s. Calculate the final velocity of the second ball. (answer = 0.8 m/s in the positive direction)

6. A 25 kg object moving with a velocity of 3 m/s to the right collides with a 15 kg object moving to the left at 6 m/s. Find the velocity of the 25 kg object after the collision, if the 15 kg object

(a) continues to move to the left but at only 0.30 m/s [answer = -0.42 m/s (to the left)]

(b) rebounds to the right at 0.45 m/s [answer = -0.87 m/s (to the left)]

(c) sticks together with the 25 kg object [answer = -0.38 m/s (to the left)]

7. A 1.5 kg wooden block remains stationary on a level surface of ice. What will be the final velocity of this wood block if a 0.002 kg (2 gram) bullet is fired into the block with a velocity of 300 m/s and becomes embedded into the wood block? (answer = 0.4 m/s)

Physics…Worksheet 3, More with the Conservation of Momentum

See Worksheet 2 for the types of collisions and their associated equations.

1. Tubby and his twin brother Lubby have a combined mass of 200 kg and are zooming along in a 100 kg amusement park bumper car at 10 m/s. They bump into Flubby's bumper car which is stationary. Flubby is 25 kg in mass and his car is also 100 kg in mass. After the elastic collision, Tubby and Lubby continue to move in the same direction but their speed is lessened from 10 m/s to 4.12 m/s. How fast in Flubby's car moving? (answer = 14.1 m/s)

2. Sometimes the curiosity factor at the scene of a car accident is so great that it actually produces secondary accidents as a result, while people watch to see what is going on. If an 800 kg sports car slows down to 13 m/s to check out an accident scene and is rear-ended by a 1200 kg pickup truck traveling at 25 m/s. The bumpers of the vehicles lock and the two vehicles move off together as one unit. What is this post-colllision velocity? (answer = 20.2 m/s)

3. Charlotte, a 65 kg scuba diver, shoots a 2 kg spear from her spear gun with a speed of 15 m/s at a fish who darts quickly away without getting hit. What is Charlotte's recoil velocity? (answer = -0.46 m/s)

4. Anthony and Sissy are participating in the annual, "Roll-a-Rama" rollerskating dance championship. While 75 kg Anthony skates backwards at 3 m/s, 60 kg Sissy jumps into his arms with a velocity of 5 m/s in the same direction.

a) How fast does the pair roll backwards together? (answer = 3.9 m/s)
b) If Anthony instead is skating toward Sissy when she jumps, would their combined final velocity be larger or smaller than your answer in part a? (answer = smaller as Anthony's momentum is now opposing Sissy's)

5. Valentina, the Russian Cosmonaut, goes outside her ship for a spacewalk, but when she is floating 15 m from her ship, her tether catches on a sharp piece of metal and is severed. Valentina tosses her 2 kg oxygen tank away from the direction of the spaceship with a speed of 12 m/s. She recoils backwards towards the spaceship.

a) If Valentina has a mass of 68 kg, what will her recoil speed be?
b) And how long (in seconds) will it take to move back to her spacecraft if she maintains this velocity? (could she hold her breath this long?)

(answers: -0.353 m/s, it would take her around 42.5 seconds, she should be able to hold her breath this long)

6. Lee is riding on her 4 kg skateboard with a constant speed of 3 m/s. She jumps off of her skateboard and continues forward with a velocity of 2 m/s relative to the ground. This causes the skateboard to go flying forward with a speed of 15.5 m/s relative to the ground. What is Lee's mass? (answer = 50 kg)

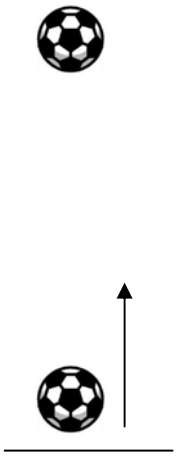
7. Old train locomotives used to have a 'cowcatcher' at the front to catch cows and other animals standing on the train tracks. If a 620 kg moose standing stationary on the tracks is caught by the 10,000 kg train traveling at 10 m/s, what is the common velocity of the train/moo se after the 'collision'? (answer = 9.42 m/s)

Worksheet 4: Additional momentum problems
General Physics

1. The second baseman throws a baseball to the catcher at home plate with a momentum of 6.9 kg·m/s. If the baseball has a mass of 0.15 kg, what is the baseball's velocity? *(answer = 46 m/s or 103 mph, pretty fast for a second baseman!)*

2. You are driving your car (mass = 1200 kg) down the K-10 with a velocity of 65 miles/hr (29 m/s). There is an accident ahead of you and your are required to stop your car. You slow your car down and eventually you bring the car to a stop. It takes you 2 seconds to stop your car. (a) What is your change of momentum (Δmv) of your car? (b) So, what force was required? *(answers: a) -34,800 kg·m/s; b) -17, 400 N)*

3. You throw a soccer ball (mass = 0.5 kg) directly up with a velocity of 15 m/s. As the ball goes up, it slows down and eventually stops at the apex. (a) What is the ball's initial momentum? (b) What is the ball's final momentum? (c) What is the ball's change of momentum? (d) What impulse acts on the ball? (e) If the force of gravity acting on the ball is - 4.9 N, how long does it take for the ball to reach the apex? *(answers: a) 7.5 kg·m/s; b) 0 kg·m/s; c) -7.5 kg·m/s; d) -7.5 Nsec; e) 1.53 sec)*



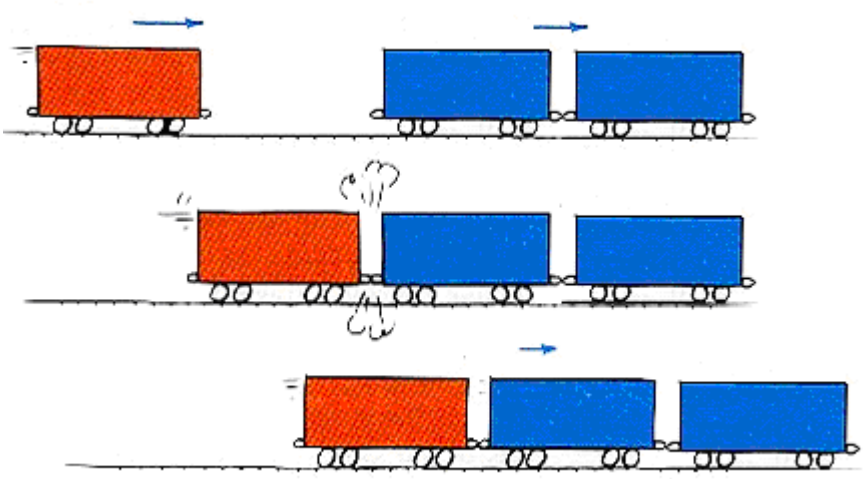
4. You throw your 4 kg medicine ball at a wall with a velocity of 8.5 m/s (the pic at the right shows me with my 4 kg medicine ball). It bounces off the wall with with an opposite-directed velocity that is slightly smaller (7.5 m/s). (a) What is the initial momentum of the ball? (b) What is the final momentum of the ball? (c) What is the change of momentum? (d) What is the impulse acting on the medicine ball? (e) If the wall interacts with the ball for 0.25 seconds, what force is exerted on the ball by the wall? *(answers: a) 34 kg·m/s; b) -30 kg·m/s; c) -64 kg·m/s; d) -64 N·s; e) -256 N)*

Collision problems:

5. An 65 kg ice skater moving forward with a velocity of 2.5 m/s, throws a 0.15 kg snowball forward with a velocity of 32 m/s. (a) what is the velocity of the ice skater after throwing the snowball if we can neglect any friction? (b) Let's say that the flying snowball inelastically hits a second skater who is initially at rest (this second skater catches this snowball). This 60 kg skater is pushed backwards by this flying snowball. What is this skater's velocity after she catches the flying snowball?
(answers: (a) v of the skater after throwing the snowball = 2.43 m/s; (b) velocity of the second skater and snowball after the collision = 0.08 m/s)

6. A tennis player places a 55 kg ball machine on a frictionless surface. The machine fires a tennis ball (mass = 0.057 kg) horizontally with a velocity of 36 m/s in one direction. What is the recoil velocity of the tennis ball machine? *(answer = -0.0373 m/s in the opposite direction as the ball)*

7. A railroad car with a mass of 2 x 10^4 kg moving forward at 3 m/s collides and joins with two railroad cars already joined together. EACH of these joined cars has the same mass as the single car. These joined cars were moving forward with a velocity of 1.2 m/s before the collision. Find the final common velocity of the three joined cars after the collision. *(answer = 1.8 m/s)*



8. Two shuffleboard disks of different mass are involved in an elastic collision. Disk A (mass = 0.5 kg) was initially at rest before the collision while disk B (mass = 0.25 kg) was initially moving to the right at 5 m/s. After the elastic collision, disk A is moving to the right at 1 m/s. What is the velocity of disk B after the collision? *(answer = 3m/s to the right)*

9. A 90 kg fullback moving east with a speed of 7 m/s is tackled by a 120 kg linebacker moving at 6 m/s west. The collision is perfectly inelastic. Calculate the velocity of the players immediately following the collision. *(v = -0.43 m/s in the westerly direction or direction opposing the fullback's motion)*

10.A 2 Dimensional momentum inelastic problem:

At an intersection, a 1200 kg car traveling east at 30 m/s collides with a 1500 vehicle traveling north at 25 m/s as shown in the figure. Find the direction and magnitude of the velocity of the wreckage immediately after the collision, assuming the vehicles stick together.

(answers: the final common velocity = 19.2 m/s and the final angle of motion is 46 degrees, first quadrant)