**Momentum Worksheets**

Momentum in One Dimension

1.   What is the momentum of a 0.25 g bug flying with a speed of 12 m/s? 3.0 x 10-3 kg m/s

2.   a) What is the momentum of a 112 kg quarterback running with a speed of 4.8 m/s? 5.4 x 102 kg•m/s

      b) What impulse must a tackler impart to the quarterback to stop him? -5.4 x 102 N•s

      c) If the tackle is completed in 1.2 s, what average force is exerted by the tackler on the quarterback? –4.5 x 102 N

3.   Imagine you are doing a space walk outside a space shuttle, with no cable between you and the shuttle. (Actually, there is one, but you cannot see it because you don't have Cablevision!) Your small maneuvering rocket pack suddenly quits on you and you are stranded in space with nothing but your $10,000 camera in your hands. What will you do to get back to the shuttle? Throw the camera in a direction away from the shuttle.

4.   A rocket expels 1.2 x 103 kg of gas each second, at a speed of 5.0 x 104 m/s. Will the thrust produced by this rocket be sufficient to lift it off the launch pad if the force of gravity on the rocket is 5.8 x 107 N? Thrust is 6.0 x 107 N, which is greater than the force of gravity on the rocket.

5.   A 3.2 kg cart traveling 1.2 m/s collides with a stationary 1.8 kg cart, and the two carts stick together. What is their common velocity after the collision? 0.77 m/s

6.   A 6.0 x 103 kg railway car is coasting along the track at 7.0 m/s. Suddenly a 2.0 x 103 kg load of coal is dumped into the car. What is its new velocity? 5.3 m/s

7.   A 1.2 x 103 kg car traveling 33 m/s collides head-on with a 1.8 x 103 car traveling 22 m/s in the opposite direction. If the cars stick together, what is the velocity of the wreckage immediately after impact? Zero

8.   A 0.060 kg rifle bullet leaves the muzzle with a velocity of 6.0 x 102 m/s. The 3.0 kg rifle is held firmly by a 60.0 kg man. With what initial velocity will the man and rifle recoil? –0.57 m/s

9.   A bullet of mass *m* is fired into a steel wall with a velocity *v*, and then rebounds with *-1/2v* velocity. A second bullet of the same mass *m* is fired into a wall covered with Plasticine, and it does not rebound. Which bullet exerts a greater force on the wall: the one that rebounds or the one that does not? Show your reasoning! The bullet which rebounds has ∆p = -3/2mv. The bullet hitting Plasticine has ∆p = -mv. Since F  ∆p , the rebounding bullet must exert a larger force.

10.  a) What impulse must be imparted to a 100.0 g baseball to change its velocity from 40.0 m/s south to

      50.0 m/s north? -9.0 N•s

      b) If the collision between the baseball and the bat lasted 1.00 ms (milliseconds), what force did the

            bat exert on the baseball? -9.0 x 103 N

11. To measure the speed of a bullet, a physicist fired the 45 g bullet into a large block of Plasticine that rested on a metal disk floating on a large air table. The combined mass of the Plasticine and disk was 18.0 kg. By using strobe photography, the speed of the disk was measured to be 0.900 m/s immediately after the impact of the bullet. What was the speed of the bullet? 3.6 x 102 m/s

12.  A 2.0 x 103 kg car traveling 15 m/s “rear ends” another car of mass 1.0 x 103 kg. The second car was initially moving 6.0 m/s in the same direction as the first car. What is the common velocity of the two cars after the collision if they lock together during impact? 12 m/s

13.  What impulse is needed to change the speed of a 10.0 kg body from 20.0 m/s to 12.0 m/s in a time of 5.0 s? What force is needed to do this? –8.0 x 101 N•s, F = -16 N

Momentum in Two Dimensions

14. A hockey player of mass 82 kg is traveling north with a velocity of 4.1 m/s. He collides with a 76 kg player traveling east at 3.4 m/s. If the two players "lock   together momentarily, in what direction will they be going immediately after the collision? How fast will they be moving? 2.7 m/s, 37.5° E of N

15. A 2.5 x 103 kg car traveling west at 6.0 m/s is hit by a 6.0 x 103 kg truck going south at 4.0 m/s. The two vehicles lock together on impact. What is the speed and direction of the wreckage immediately after impact? 3.3 m/s, 58° S of W

16. A frustrated physics student blew up her Physics textbook using a small amount of explosive. It broke into three pieces, which miraculously flew off in directions that were all in the same plane. A 0.200 kg piece flew off at 20.0 m/s and a 0.100 kg piece went off at 90° to the first piece, at 30.0 m/s.

      a) What was the momentum of the third piece? 5.0 kg m/s

      b) If the mass of the third piece was 0.150 kg, what was its velocity right after the explosion? 33 m/s, 37° to the direction of the first mass

17. A proton of mass M collides obliquely with another proton. The first proton is moving with a speed of 6.0 x 106 m/s before it hits the second, stationary proton. Assuming the collision is perfectly elastic (no kinetic energy is lost), and using the fact that the first proton is moved 30° from its initial path after the collision, figure out the speed and direction of each proton after the collision. Note that after the collision the two protons travel at 90˚ to each other. Struck proton 3.0 x 106 m/s, 60° from the incident proton’s original direction; incident ball 5.2 x 106 m/s

18. A 0.40 kg model airplane is traveling 20 km/h toward the south. A 0.50 kg model airplane traveling 25 km/h in a direction 20° east of south collides with the first model airplane. The two planes stick together on impact. What is the direction and magnitude of the velocity of the combined wreckage immediately after the collision? 22 km/h, 12° E of S

19. What impulse is needed to change the velocity of a 90.0 kg football player from 3.6 m/s toward the north and make it 1.2 m/s toward the northeast? In what direction must the force be exerted? ∆p = 259 kg m/s, the force is exerted at 17° E of S.

20. A car of mass 3000 kg moving due South at 15 m/s collides completely inelastically (i.e. stick together) with a second car of mass 2000 kg moving West at 12 m/s.

a) Draw a vector diagram representing the total momentum before the collision.

b) What is the total momentum after the collision (both magnitude and direction)? 51 000 kgm/s at 28.1º W of S

c) What is the velocity of the combined vehicles after the collision? 10.2 m/s

21. A car moving North at 12 m/s strikes a stationary car of equal mass. The first car moves off after the collision at an angle of 30 East of North with a speed of 8.0 m/s.

a) What is the velocity of the struck car just after the collision? 6.5 m/s

b) Show that the collision is inelastic. Determine EK before and after – not the same.

c) Explain how dents, skid marks etc. show that kinetic energy has been lost. Any energy that is used to do work or is transformed into sound or heat will be an energy loss to the system.

d) If the collision were perfectly elastic what would the speeds of the cars be after the collision if the

first car moved off at the same 30º angle? 8.9 m/s

22. A steel ball of mass 10 kg moves due East at 5.0 m/s. It collides with a rubber ball of mass 5.0 kg moving at 10 m/s due North. After the collision the steel ball moves at an angle of 60 East of North with a speed of 4.0 m/s. What is the velocity of the rubber ball after the collision? 6.74 m/s

23. A child’s ball, of mass 250 g, rolls due East along the ground at 4.2 m/s towards a stationary bowling ball, of mass 3.2 kg. After the collision, the bowling ball travels in a direction 32 South of East at 38.7 cm/s.

a) What is the speed of the child’s ball after the collision? 2.62 m/s

b) What is the direction in which the child’s ball travels? 90º to original momentum of child’s ball or Due North.

c) What fraction of the original kinetic energy is transformed into heat? 50.2%

24.  A bowling ball, of mass 4.00 kg, strikes a bowling pin of mass 110.0 g obliquely. Before the collision, the ball was travelling at 3.10 m/s down the alley; after the collision it travels at 2.99 m/s and its direction has changed by 1.3.

a) Calculate the speed of the pin immediately after the collision. 4.72 m/s

b) In what direction does the pin travel immediately after the collision? 31.5º relative to ball’s initial movement

c) What fraction of the ball’s kinetic energy is transferred to the pin? 6.4 %

Momentum Problems

1.     Two train cars approach each other, one of mass 113 000 kg traveling at 1.20 m/s, the other of mass   75 000 kg traveling at 2.30 m/s. After the collision, the two cars lock together.

            (a) What is the momentum of the heavier car? 136 000 kg•m/s

            (b) What is the momentum of the lighter car? 173 000 kg•m/s

            (c) What is the total momentum of the cars before the collision? 36 900 kg•m/s  (172500-135600 – using unrounded values)

            (d) What is the total momentum of the cars after the collision? 36 900 kg•m/s

            (e) What is the velocity of the cars after the collision? 0.20 m/s

2.   Two billiard balls, each of mass 565 g, approach each other, one with speed of 2.3 m/s and the other with a speed of 4.5 m/s. After the collision, the one that was traveling faster reverses its direction and travels at 2.3 m/s. What is the velocity of the other ball? 4.5 m/s in the opposite direction

3.   A child’s ball of mass 560 g rolls along the ground at 7.6 m/s towards a stationary bowling ball of mass 4.5 kg. After the collision, the bowling ball travels at 1.5 m/s. What is the velocity of the child’s ball?      -4.45 m/s

4.   Two train cars approach each other, one mass 76 000 kg traveling at 3.5 m/s, the other of mass 95000 kg traveling at 1.9 m/s. They are expected to lock together, but instead they bounce off each other, the lighter one reversing its direction and traveling with a speed of 0.42 m/s. What is the velocity of the other car? 1.24 m/s opposite to its original direction

5.   A car of mass 1500 kg traveling at 15.6 m/s loses its brakes and collides with the rear end of the car in front of it, which has a mass of 1020 kg and is traveling in the same direction at 12.5 m/s. If the smaller car is given a speed of 15.3 m/s by the collision, what is the speed of the larger car after the collision? 13.7 m/s in the original direction

6.   A tennis ball may leave the racket of a top player on the serve with a speed of 65.0 m/s. The ball’s mass is 0.0600 kg and it is in contact with the racket for 0.0300 s. (a) What is the impulse on the ball? Original momentum is zero, therefore the change in momentum is pfinal –pinitial or 3.9 N•s – 0 N•s = 3.9 N•s (b) What is the force on the ball? Use F = p/t= 130 N

7.   A 0.145 kg baseball pitched at 39.0 m/s is hit on a horizontal line drive straight back toward the pitcher at 52.0 m/s. If the contact time between bat and ball is 0.00100 s, calculate the impulse on the ball and the force between the ball and bat during contact. Impulse is 13.2 N•s and force = 13 200 N

Momentum And Impulse

1.    An object is pushed with a force of 6.0 N for 0.50 s. What impulse is given to it? 3.0 kg•m/s

2.    What impulse produces a velocity change of 4.00 m/s in a 12.5 kg mass? Δp=pfinal – pinitial = mΔv = 50.0 N•s

3.    A 15.0 kg wagon is accelerated by a constant force of 60.0 N from 5.00 m/s to 13.00 m/s.

(a)  What impulse does the wagon receive? 120 N•s

(b) For how long was the force acting on the wagon? 2.0 s

4.    A freight car with a mass of 6.0 x 104 kg is rolling along a level track at 0.40 m/s, dragging a chain behind it.

(a)  If the largest force that could be applied to the chain is 320.0 N, how long would it take to stop the car? Δt = Δp/F = 75 seconds

(b) How far would the car move before it could be stopped? Use kinematics equation, acceleration is -5.33 x 10-3 m/s2, therefore, 15.0 m

5.    What average force will stop a hammer with a momentum of 48.0 N•s in 0.030 s? 1600 N

6.    A stone of mass 10.0 kg slides along the ice in a straight line with a constant velocity of 8.00 m/s. A constant force then acts on the stone for 2.50 s, changing its velocity to 2.00 m/s.

(a)  What is the momentum of the stone before and after the force acts? Before is 80.0 kg•m/s while after is 20.0 kg•m/s

(b) Calculate the impulse acting on the stone. Δp = 60.0 kg•m/s

(c)  What is the magnitude and direction of the force that is acting? The force is 24.0 N opposing the original motion (and momentum).

7.    Two frictionless discs on an air table, initially at rest, are drive apart by an explosion with velocities of 9.0 m/s and 5.0 m/s. What is the ratio of their masses? pinitial is zero, after explosion masses go in opposite directions and have MUST have equal but oppositely directed momenta. The masses have to be in a 5:9 ratio in order to make the momenta equal. Best way to see this is as m2=5/9m1.

8.    Two dynamic carts are at rest with a compressed spring between them. When the spring is allowed to expand, the carts move apart. Both hit bricks at either end of the table, simultaneously, but cart A moves 0.60 m while cart B moves 0.90 m. What is the ratio of:

(a)  the speed of A to the speed of B after the expansion of the spring? Cart B must be moving faster since it went a further distance in the same amount of time as cart A. The ratio is 3:2. Best way to see this is as m2=3/2m1.

(b) their masses? Since each cart acquired the same momentum (equal but opposite since there was initially zero momentum), the ratio of the masses of the carts is 3:2 (Cart A: Cart B). Cart A is more massive than B, noted by the fact that cart A moves a smaller distance and has lees speed (but same momentum).

(c) the impulses applied to the carts? The impulses (read this as the change in momentum or Δp) would have to be equal.

(d) the acceleration of the carts while the spring was pushing them apart? Since acceleration is the change in velocity over time, Cart B must have greater acceleration … again in a 3:2 ratio.

9.    A proton of mass 1.67 x 10-27 kg, traveling with a speed of 1.0 x 107 m/s, collides with a helium nucleus at rest. The proton rebounds straight back with a speed of 6.0 x 106 m/s while the helium nucleus moves forward with a speed of 4.0 x 106 m/s.

(a)  What was the total momentum before the collision? 1.67 x 10-20 kg•m/s

(b) What was the momentum of the proton after the collision? 1.00 x 10-20 kg•m/s in opposite direction!

(c)  What was the momentum of the helium nucleus after the collision? 2.67 x 10-20 kg•m/s

(d) Determine the mass of the helium nucleus. 6.68 x 10-27 kg

10.  A stationary flatcar of mass 4.0 x 104 kg is rammed by a locomotive with a mass of 6.0 x 104 kg and a velocity of 4.5 m/s. If they stick together, with what velocity will they continue to move? 2.7 m/s

11.  Two 2.5 kg carts are moving along together with a velocity of 2.0 m/s when a spring compressed between them expands rapidly. The front cart continues with a velocity of 3.0 m/s, in the same direction.

(a)  What was the momentum of the two carts before the explosion? 10. kg•m/s

(b) What was the momentum of the front cart after the explosion? 7.5 kg•m/s

(c)  What was the velocity of the second cart after the explosion? 1.0 m/s

(d) What velocity would the front cart have had to acquire for the second cart to remain stationary after the explosion? 4.0 m/s

12.  A 1.5 kg brick is dropped vertically onto a 2.5 kg toy truck, which is moving across a level floor at 0.80 m/s. With what velocity do the truck and brick continue to move, after the brick has landed on the truck? 0.50 m/s

13.  Explain how an astronaut who is stranded in free space a short distance from his spacecraft might employ his knowledge of momentum to return safely to the craft. Why must he be very careful about his momentum? He or she may have to throw something away from themself (directly away from the direction that they would like to head) in order to gain momentum towards the spacecraft. The astronaut must be careful since, without the effects of gravity and/or something to grab onto, he/she could find themselves carrying on in a straight line forever – the astronaut must make sure that their momentum is lines up correctly in order not to miss the shuttlecraft!

14.  A sandbag is mounted on a cart that is at rest on a horizontal frictionless surface, and their total mass is 4.5 kg. What will be the velocity of the cart and sandbag if a bullet of mass 2.0 g is fired into the sandbag with a horizontal velocity of 500. m/s? The p of the bullet is 1.0 N•s. This will be transferred to the sandbag etc (note that the bullet’s mass is too small to worry about in comparison to the other masses). The momentum of the sandbag etc will now be 1.0 N•s, which gives it a velocity of 0.22 m/s.

15.       Two boys of mass 45 kg and 60 kg, respectively, are sitting on two separate 15 kg wagons, facing each other and holding a rope taut between them. The lighter boy pulls on the rope and acquires a velocity of 2.0 m/s. What is the velocity of the other boy? 1.6 m/s towards the lighter boy.

Momentum in 2 Dimensions

1. A 38 kg child is standing on a 43 kg raft that is drifting with a velocity of 1.1 m/s [N] relative to the water. The child then walks on the raft with a net velocity of 0.71 m/s[E] relative to the water. Fluid friction between the raft and water is negligible. Determine the resulting velocity of the raft relative to the water. {2.2 m/s[17 ºW of N]}

2. A 52 kg student is standing on a 26 kg cart that is free to move in any dirction. Initially, the cart is moving with a velocity of 1.2 m/s [S] relative to the floor. The student then walks on the cart and has a net velocity of 1.0 m/s[W] relative to the floor. Determine the approximate final velocity of the cart. {4.1 m/s [61º S of E}}

3. Two automobiles collide at an intersection. One car of mass 1.4x103 kg is traveling at 45 km/h [S]; the other car of mass 1.3x103 kg is traveling at 39 km/h [E]. If the cars have a completely inelastic collision, what is their velocity just after the collision? {30 km/h [51ºS of E]}

4. Two balls of equal mass m undergo a collision. One ball is initially stationary. After the collision, the velocities of the balls make angles of 31.1º and 48.9º relative to the original direction of motion of the moving ball.

a) If the initial speed of the moving ball is 2.25 m/s, what are the speeds of the balls after collision? {1.18m/s at 48.9º&1.72 m/s at 31.1º}

b) Is this collision elastic? {No}