

At the end of this worksheet, you should be able to

- find the momentum of an object or collection of objects.
- find the change in momentum of an object or collections of objects due to an impulse.
- use the conservation of momentum to solve for an unknown quantity.
- use the principle of relative velocity to solve for an unknown in elastic collisions.

This week we are ignoring friction and air resistance. When using the conservation of momentum, we restrict ourselves to talking about the motion of the objects *immediately before* they collide and *immediately after* they collide. Friction and energy losses are insignificant compared to the force of the impact.

1. In this problem, a bug and a car collide.

- a) A 1 g bug flies east along a road at 5 m/s. What is the bug's momentum?  
Momentum is a vector, and the east is the positive direction in this class.
- b) A 1000 kg car travels west along this same road at a speed of 20 m/s. What is the car's momentum?
- c) What is the total momentum of this system?
- d) When the bug collides with the windshield of the car, what is the momentum of the bug-car system?

2. You want to close a door, but you do not want to get up. You look around and see that there is a bouncy ball that looks like you could throw it fast. For some reason there is also a wad of clay that you know would stick to the door if you threw it. The ball and the clay have the same mass. Which one should you throw against the door to close it most effectively?

Some starters:

- Choose a mass for your ball and clay and choose a velocity. Or leave it as  $m$  and  $v$  and work it *in general*.

- a) The ball hits the door and bounces back perfectly (its speed doesn't change after it bounces off the door).

i. How has its velocity changed?

ii. What is the ball's change in momentum?

iii. What is the door's change momentum?

- b) The clay hits the door and sticks. Its speed is zero after the collision.

i. How has its velocity changed?

ii. What is the ball's change in momentum?

iii. What is the door's change momentum?

- c) Assume that the time interval of the collision is about the same for both cases. From Newton's 3<sup>rd</sup> Law, the force on the door by the thrown object is equal and opposite to the force on the thrown object by the door.
  - i. Which one of these scenarios imparts a larger force on the door?
  - ii. What is the ratio of the force from the bouncy ball to the force of the clay wad?
- 3. I drop a 0.60-kg basketball from a height of 1.0 m, and it bounces off the floor and rises to a height of 0.75 m.
  - a) What is the basketball's velocity right before it hits the ground?
  - b) What is the basketball's velocity right after it hits the ground? Think about what it must be for it to rise to 0.75 m.
  - c) What is the change in momentum of the ball?
  - d) Is momentum conserved here? Why or why not?
  - e) What is the ratio of the change in kinetic energy?
  - f) What is the change in kinetic energy?

4. The kinetic energy of a 10 kg object is 100 J, then what is the momentum of the object? Now do this inside out. Now, do it *in general*. In other words, derive  $K = \frac{p^2}{2m}$ .
5. An empty 10-kg wagon is rolling past me at a speed of 5 m/s. I drop a 30-kg bag of concrete into the wagon right as it passes by. What is its speed immediately after I drop the bag?
6. Explosions are actually a kind of collision, but in reverse. Two indestructible objects are tied together with a stick of dynamite between them, and everything is at rest. When it explodes, the two objects fly away from each other in opposite directions. One of the objects has a mass of 10 kg and the other a mass of 3 kg. The 10 kg object flies away at a speed of 100 m/s.
- a) What is the velocity of the 3 kg object?
  - b) How much energy did the explosion give to the two objects? (There was more put into internal energy and sound but let's not consider that.)
  - c) What other problems in this worksheet is this similar to?

7. A 5 kg gun fires a 10 g bullet at a velocity of 500 m/s. The explosion that causes this shot takes place in 1 millisecond.
- a) What force is exerted on the gun?
  - b) What is the gun's recoil velocity?
  - c) Is energy conserved?
8. Two objects collide elastically, one has a mass of 1 kg and the second has a mass of 3 kg. The first object is traveling to the right at a speed of 3 m/s and the second is traveling in front of it initially at a speed of 1 m/s. What is the velocity of the objects after the collision? Think of and work as many variations of this problem as you can.
- a) What is the final velocity of the two objects if they collide perfectly inelastically and stick together?
    - i. What is each object's change in momentum due to the collision?
  - b) What is the final velocity of the objects if they are moving in the same direction, and they collide elastically?
    - i. What is each object's change in momentum due to the collision?

- c) What is the final velocity of the objects if they are moving in the opposite directions, and they collide elastically?
- i. What is each object's change in momentum due to the collision?
9. Reverse problem: Two objects collide elastically, one has a mass of 1 kg and the second has a mass of 3 kg. The first object is traveling to the right at a speed of 3 m/s. With what velocity would the second object need to be travelling so that after the collision, the first object was motionless?
10. A massive object moving with a velocity  $v$  collides elastically with a very small object that is initially at rest. What is the velocity of these two objects after they collide? (By massive and very small I mean when you add or subtract  $m_1$  and  $m_2$  they are indistinguishable from  $m_1$  due to the rules of significant figures.)

11. Reverse problem: A tiny object is colliding with velocity  $v$  with a huge object that is at rest. What is the final velocity of the two objects?
12. Let's work on the ballistic pendulum problem like we do in the lab and do it *in general*. So, we have a bullet of initial velocity  $v_{bi}$  and mass  $m_b$  and a target initially at rest with mass  $m_t$ . The collision is perfectly inelastic, and the pendulum (with the bullet inside) rises to a height  $h$  after the collision takes place. What is the initial velocity of the bullet?
13. Now in question #2 of the lab write-up it asks could this experiment be done with an elastic collision, given that we only measure the same things as we did in the inelastic collision case. So same parameters as before, but this time when the ball bounces off the target it has a speed  $v_{bf}$  and the pendulum rises to a height  $h$  but this time without the bullet embedded in it.