Momentum

There are two factors that affect how difficult it is to change an object's motion:

1. The mass of the object.

   e.g. catching a rubber ball vs. catching a 16 lb shot

2. The velocity of the object.

   e.g. stopping a car moving at $0.25\ m/s$ vs. stopping a car moving at $25\ m/s$

Newton combined a moving object's mass and its velocity in an expression that he called "quantity of motion." We now call this quantity momentum, and give it the symbol $\vec{p}$.

The momentum of a moving object is defined as the product of its mass and velocity.

$$\boxed{\vec{p} = m\vec{v}}$$

Note: The units of momentum are $kg \cdot m/s$

Momentum is a vector quantity that has the same direction as the velocity of the object.

Example 1
What is the momentum of a $1000\ kg$ car moving east at $15\ m/s$?

Example 2

A baseball of mass $0.145\ kg$ is moving at $25\ m/s$.

a. Find the momentum of the baseball.

b. Find the velocity at which a bowling ball, mass $7.26\ kg$, would have the same momentum.

Homework

Momentum Worksheet #1

Physics 40S **Momentum Worksheet #1**

1. Can a bullet have the same momentum as a truck? Explain.

2. Calculate the momentum of the following objects:

   a. a $0.50\ kg$ ball thrown upward with a velocity of $30\ m/s$ ($15\ kg \cdot m/s\ \left[Up\right]$)
   b. a $2000\ kg$ railway car moving south at $10\ m/s$ ($2.0 \times 10^4\ kg \cdot m/s\ \left[S\right]$)
   c. an electron of mass $9.1 \times 10^{-31}\ kg$, moving at a velocity of $1.0 \times 10^7\ m/s$ ($9.1 \times 10^{-24}\ kg \cdot m/s\ \left[forward\right]$)
   d. the Earth, of mass $6.0 \times 10^{24}\ kg$, moving along its solar orbit with a velocity of $3.0 \times 10^4\ m/s$ ($1.8 \times 10^{29}\ kg \cdot m/s\ \left[forward\right]$)

3. What is the momentum of a $1500\ kg$ Mercedes-Benz 300E traveling east at $115.0\ km/h$? ($4.79 \times 10^4\ kg \cdot m/s\ [East]$)

4. The momentum of a $7.3\ kg$ shot is $22\ kg \cdot m/s\ \left[forward\right]$. What is its velocity? ($3.0\ m/s\ \left[forward\right]$)

5. A bullet traveling at $900\ m/s$ has a momentum of $4.5\ kg \cdot m/s$. What is its mass? ($0.0050\ kg$ or $5.0\ g$)

6. What is the speed of an $1800\ kg$ car with a momentum of $3.0 \times 10^4\ kg \cdot m/s$? ($16.7\ m/s$)

7. (a) What is the magnitude of the momentum of a $109\ kg$ football player running at a top speed of $9.86\ m/s$? (b) What is the magnitude of the momentum of a $9.72\ g$ rifle bullet travelling at $728\ m/s$? ($1.07 \times 10^3\ kg \cdot m/s$, $7.08\ kg \cdot m/s$)

8. Jenny has a mass of $35.6\ kg$ and her skateboard has a mass of $1.3\ kg$. What is the momentum of Jenny and her skateboard together if they are going $9.50\ m/s$? ($350.55\ kg \cdot m/s$)

9. Which is greater, the momentum of a $1645\ kg$ Cadillac DeVille traveling at $32\ km/h$ or a $1061\ kg$ Mazda Miata traveling at $47\ km/h$? (Cadillac)

10. A $1.73\ kg$ physics book flies through the air with a momentum of $18.8\ kg \cdot m/s$. What is its speed? ($10.9\ m/s$)

11. How many times greater is the momentum of a $230000\ kg$ jet airplane flying at $960\ km/h$ than a $1.1\ kg$ pitching horseshoe moving at $11.3\ m/s$? (4.9×10^{6})

12. The momentum of an object traveling at $5.3\ m/s$ is determined to be $350\ kg\cdot m/s$. Could the moving object be an automobile? Explain.

13. A detector of subatomic particles measures the momentum of a particle directly, without the mass being known. In one experiment, the particle's momentum was determined to be $1.82\times10^{-26}\ kg\cdot m/s$. (a) What was the particle's speed if it was an electron? (b) What was the particle's speed if it was a proton? ($2.0\times10^{4}\ m/s$, $10.9\ m/s$)

Note:

Mass of an Electron $m_e = 9.11\times10^{-31}\ kg$

Mass of a Proton $m_p = 1.67\times10^{-27}\ kg$