SCIENCE 10 HONOURS MOMENTUM Name:

Newton related a moving object's mass to its velocity in what he called "quantity of motion". We call this quantity "momentum".

$p = mv$ p = momentum in kg·m/s
m = mass in kg
v = velocity in m/s

Momentum is a vector quantity and always has the same direction as the velocity.

Example: What is the momentum of a 1000 kg car traveling along a highway at 15 m/s?

1. Calculate the momentum of each of the following moving objects:
   a. a 0.50 kg ball is thrown at 30 m/s

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

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

2. The momentum of a 7.3 kg shot is 22 kg·m/s. What is its velocity?

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

What will happen to an object's momentum if either its mass or velocity changes?

$$\Delta p = \Delta(mv)$$

A ball of mass 2.5 kg speeds up from 6.0 m/s to 8.0 m/s. Determine its change in momentum.

A wagon of mass 10 kg is rolling along at a velocity of 3.0 m/s when a small girl of mass 30 kg jumps onto it. The wagon continues to move on at the same velocity. Determine the change in momentum of the wagon.

When an object is acted upon by a net force, it is accelerated, and the relationship between an object's mass, its acceleration, and the force acting on it is expressed by $F = ma$ (Newton's second law). Newton also said the rate of change in the momentum of an object is directly proportional to the force applied, and that the change in momentum is in the same direction as the applied force.

$$F = \frac{\Delta p}{\Delta t} \quad \text{or} \quad F\Delta t = \Delta p$$

Whenever there is an impact or collision between objects, $F\Delta t$ is called impulse.

$\text{impulse} = F\Delta t$ where F is the net force acting on the object in N
Δt is the time for which the force acts in seconds
impulse is N·s

The unit of impulse, N·s is the same unit for momentum, kg·m/s. For an objects momentum to change, the object must receive an impulse equal to its change in momentum.

$F\Delta t = \Delta p$ impulse = change in momentum

What is the impulse exerted on a golf ball by a club if they are in contact for 0.05 s and the club exerts a force of 500 N on the ball?

What velocity will a 40kg child on a 10kg wagon attain if pushed from rest with a force of 75 N for 2.0 s?

What force is required to stop a 1000 kg car in 15 s if the car is traveling at 22 m/s?

1. What impulse is exerted in each of the following cases?
   a. a force of 25 N pushing on a cart for 3.2 s

   b. a tennis racquet exerting a force of 60 N on a tennis ball during the 0.04 s they are in contact

   c. the Earth pulling down on a 12 kg rock during the 3.0 s it takes to fall from a cliff

2. A billiard ball of mass 200 g is rolling towards the right-hand cushion of a billiard table at 2.0 m/s and rebounds straight back at 2.0 m/s.
   a. What is its change in momentum as a result of the collision?

   b. What impulse is exerted on the ball?

3. A puck of mass 0.20 kg is sliding along a smooth flat section of ice at 18 m/s when it encounters some snow. After 2.5 s of sliding through the snow, it returns to smooth ice, continuing at a velocity of 10 m/s.
   a. What is the change in momentum of the puck?

   b. What impulse is exerted on the puck by the snow?

   c. What average force does the snow exert on the puck?

4. A frictionless disc of mass 0.50 kg is moving in a straight line across an air table at a speed of 2.4 m/s when it bumps into an elastic band stretched between two fixed posts. If the elastic band exerts an average force of 1.2 N on the disc for 1.5 s, what will be the final velocity of the disc?

5. A skateboard of mass 2.0 kg is rolling along a smooth flat floor when a small girl pushes it, causing it to speed up to 4.5 m/s in 0.5 s. If the force exerted by the girl on the skateboard, in its direction of motion, was 6.0 N, with what initial velocity was it moving?

<u>During a Collision</u>:
The total change in momentum of a system is zero. One object will acquire momentum in one direction while the other acquires an equal amount of momentum in the opposite direction (negative momentum), so that the total change in momentum is zero.

The Law of Conservation of Momentum: If no net external force acts on an object, or system of objects, the momentum of the system remains constant ($\Delta p = 0$) for an isolated system.

A loaded railway car, of mass 6000 kg and velocity of 2.0 m/s, rolling to the right collides with an empty railway car, of mass 3000 kg and velocity of 3.0 m/s, rolling to the left on the same smooth, level railway track. They stick together and roll along, but at what velocity?

A 60 kg halfback running at 20 m/s runs into an 80 kg tackle running in the opposite direction at 15 m/s. What happens in the collision?

1. A 5000 kg boxcar runs into a stationary 8000 kg tank car at 5.2 m/s. They hook together and move off down the track. How fast will they be going?

2. A large compressed spring is placed between a 4000 kg railway car and a 6000 kg boxcar at rest. The spring is released and the two cars move off in opposite directions. If the heavier car moves at 2.4 m/s, how fast will the other move?

3. A 0.20 kg golf ball, moving at 80 m/s, hits a watermelon of 10 kg mass at rest on a frictionless table, and sticks in it. How fast does the watermelon move?

Some Practice For You: Please do these on a separate piece of paper. Answers are on the back page.

1. An object is pushed with a force of 6.0 N for 0.5 s. What impulse is given to it?

2. What impulse produces a velocity change of 4.00 m/s in a 12.5 kg mass?

3. A 15 kg wagon is accelerated by a constant force of 60 N from 5.0 m/s to 13.0 m/s.
   a. What impulse does the wagon receive? b. For how long was the force acting on the wagon?

4. A freight car with a mass of 6.0×10^4 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 N, how long would it take to stop the car?
   b. How far would the car move before it could be stopped?

5. What average force will stop a hammer with a momentum of 48 N·s in 0.030 s?

6. A stone of mass 10 kg slides along the ice in a straight line with a constant velocity of 8.0 m/s. A constant force then acts on the stone for 2.5 s, changing its velocity to 2.0 m/s.
   a. What is the momentum of the stone before and after the force acts?
   b. Calculate the impulse acting on the stone.
   c. What is the magnitude and direction of the force that is acting?

7. Two frictionless discs on an air table, initially at rest, are driven apart by an explosion with velocities of 9.0 m/s and 5.0 m/s. What is the ratio of their masses?

8. A proton of mass 1.67×10^{-27} kg, traveling with a velocity of 1.0×10^7 m/s, collides with a helium nucleus at rest. The proton rebounds straight back with a speed of 6.0×10^6 m/s while the helium nucleus moves forward with a speed of 4.0×10^6 m/s.
   a. What was the total momentum before the collision?
   b. What was the momentum of the proton after the collision?
   c. What was the momentum of the helium nucleus after the collision?
   d. Determine the mass of the helium nucleus.

9. A stationary flatcar of mass 4.0×10^4 kg is rammed by a locomotive with a mass of 6.0×10^4 kg and a velocity of 4.5 m/s. If they stick together, with what velocity will they continue to move?

10. 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?
    b. What was the momentum of the front cart after the explosion?
    c. What was the velocity of the second cart after the explosion?
    d. What velocity would the front cart have had to acquire for the second cart to remain stationary after the explosion?

11. 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?

12. 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?

13. 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?

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

1. *3.0 N·s* 2. *50.0 N·s* 3a. *1.2×10^2 N·s* b. *2.0 s* 4a. *75 s* b. *15 m* 5. *1.6×10^3 N* 6. a. *80 kg·m/s, 20 kg·m/s* b. *–60 N·s* c. *–24 N* 7. *0.56 or 1.8* 8a. *1.67×10^{-20} kg·m/s* b. *-1.0×10^{-20} kg·m/s* c. *2.67×10^{-20} kg·m/s* d. *6.68×10^{-27} kg* 9. *2.7 m/s* 10a. *10 kg·m/s* b. *7.5 kg·m/s* c. *1.0 m/s* d. *4.0 m/s* 11. *0.50 m/s* 12. ask me 13. *0.22 m/s* 14. *–1.6 m/s*