Momentum

FORMULAS

momentum: $p = mv$ measured in $\text{kg}\cdot\text{m/s}$

impulse: $\Delta p = F\Delta t = m(\Delta v) = mv_f - mv_i$ measured in $\text{N}\cdot\text{s}$

elastic collision (kinetic energy is conserved): $m_a v_a + m_b v_b = m_a v_a' + m_b v_b'$

inelastic collision (energy escapes): $m_a v_a + m_b v_b = (m_a + m_b)v'$

LAW OF CONSERVATION OF MOMENTUM

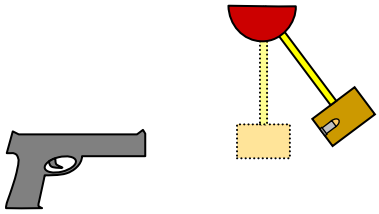
When no external force acts on a system, the total momentum of the system remains constant.

total momentum before collision = total momentum after collision

Example 1: What is the momentum of a 1500-kg car moving at 10 m/s?

Solution: $p = mv = (1500\text{ kg})(10\text{ m/s}) = 1.5 \times 10^4\text{ kg}\cdot\text{m/s}$

Example 2: A 3.50-g bullet is fired into a 3.75-kg block of wood suspended from a string. The bullet is embedded in the block of wood, and they move off together with a speed of 0.885 m/s. What was the velocity of the bullet before the collision?



Solution: This is an example of an inelastic collision, since some energy went into deforming the block (specifically, making a hole in it).

$$m_{bullet} \cdot v_{bullet} + m_{wood} \cdot v_{wood} = (m_{bullet} + m_{wood})v'$$

$$(3.50 \times 10^{-3}\text{ kg})(v_{bullet}) + (3.75\text{ kg})(0) = (3.50 \times 10^{-3} + 3.75\text{ kg})(0.885\text{ m/s})$$

$$v_{bullet} = \frac{3.7535 \times 0.885}{3.50 \times 10^{-3}} \approx 949\text{ m/s}$$

EXERCISES

A. What is the momentum of an electron with a mass of 9.11×10^{-31} kg, moving at a velocity of 3.25×10^7 m/s?

B. The momentum of a 2.25-kg object is 55.5 $\text{kg}\cdot\text{m/s}$. At what velocity is it moving?

C. A bullet travelling at 750 m/s has a momentum of 6.6 $\text{kg}\cdot\text{m/s}$. What is its mass?

D. What impulse is exerted by a hockey stick exerting a force of 115 N on a puck during the 0.06 s they are in contact?

E. What velocity will a 40-kg child sitting on a 50-kg wagon acquire, if pushed from rest by a force of 85 N for 2.0 s?

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F. What average force will stop a 1200-kg car in 1.5 s, if the car is moving at 28 m/s?

G. A freight car of mass 4×10^4 kg is coasting along a track at 4 m/s. A second freight car of twice the mass comes toward it in the opposite direction. If both cars come to rest upon collision, how fast was the second car moving?

H. A loaded railway car of mass 5000 kg is rolling to the right at 2.5 m/s when it collides and couples with an empty freight car of mass 3000 kg, rolling to the left on the same track at 5.0 m/s. What is the speed and direction of the pair after collision?

I. While lost in thought about the wonders of physics, you drive down an icy Glen Street at 50 km/h in search of a parking space. You ram your physics teacher's brand new 1.5×10^3-kg Volkswagen Rabbit (while it was parked) with your old 1.3×10^3-kg Ford Pinto. If they lock bumpers upon collision, how fast will the pair move then?

J. A 1.55×10^4-kg railroad car is coasting along a level, frictionless track at a constant speed of 35.5 m/s, when a 3500-kg load is dropped vertically onto the car from above. What will its new speed be, assuming the load stays in the car?

K. A 55.0-kg girl is running at 3.50 m/s when she jumps onto a 15.0-kg toboggan at rest on a frozen lake. What is the velocity of the toboggan afterwards, if she holds on?

L. A 3.00-g bullet is fired from a 2.6-kg rifle with a muzzle velocity of 365 m/s. Assuming that no other bodies are involved, find:

1) the bullet's momentum
2) the recoil velocity of the rifle

M. Britney Spears is at rest in the middle of a pond on perfectly frictionless ice. How does she get herself to shore?

N. An 8.55-kg shell leaves the muzzle of a 525-kg cannon with a horizontal velocity of 655 m/s. Find the recoil velocity of the cannon.

O. An arrow travelling at 45.7 m/s strikes and embeds itself in a 0.375-kg apple, which was at rest. The apple, with the arrow in it, moves off horizontally at 11.5 m/s after the impact. What is the mass of the arrow?

P. An 895-kg Sasquatch, wearing a regulation 10.0-kg bulletproof vest, lies sleeping on the ice of wintry Lake Frictionless. A hunter, with thoughts of grandeur in mind, fires a 55.0-g bullet at the Sasquatch with a speed of 975 m/s. The bullet bounces straight back toward the hunter with negligible change in speed. How fast does the Sasquatch slide after being hit?

SOLUTIONS

A. 2.96×10^{-23} kg·m/s B. 24.7 m/s C. 8.8 g D. 7 N·s E. 1.9 m/s F. 2.2×10^4 N
G. half the velocity, 2 m/s H. 0.31 m/s to the left I. 23 km/h or 6.4 m/s J. 29.0 m/s
K. 2.75 m/s L. (1) 1.10 kg·m/s (2) 0.42 m/s M. She takes something she no longer wants, like Kevin Federline, and throws it in the opposite direction of the way she wants to go. N. 10.7 m/s O. 0.126 kg P. 0.119 m/s .