PhyzExamples: Impulse & Momentum

Physical Quantities • Symbols • Units • Brief Definitions

Momentum • p • kg·m/s, N·s • "Quantity of motion," "Inertia in motion." A measure of how hard it is to stop a body. The product of a body's mass and speed.
Impulse • Δp, I • N·s, kg·m/s • Change in momentum. (**Not** the *rate* of change in momentum, just the *change* in momentum.)
Force • F • N • The rate of change in momentum.

Equations

$p = mv$ • momentum = mass · speed (or velocity)
$\Delta p = m\Delta v$ • impulse = mass · change in speed
$F = \Delta p/\Delta t$ • force = impulse / time interval [Newton's second law, original form]
$F\Delta t = m\Delta v$ • force · time interval = mass · change in velocity (or speed)
$p' = p$ • momentum after an event = momentum before event [conservation of momentum]
$m_1v_1' + m_2v_2' = m_1v_1 + m_2v_2$ • conservation of momentum applied to two bodies in one dimension.

Smooth Operations Examples

1. What is the momentum of a 4 kg object moving with a velocity of 7 m/s?

1. m = 4 kg v = 7 m/s p = ?
p = mv
p = 4 kg · 7m/s
p = 28 kg·m/s

2. What is the speed of a 9 kg object whose momentum is 54 kg·m/s?

2. m = 9 kg p = 54 kg·m/s v = ?
p = mv
v = p/m
v = 54 kg·m/s / 9 kg
v = 6 m/s

3. How much force causes a 500 kg car to accelerate from rest to a speed of 25 m/s in 10 s?

3. m = 500 kg v = 25m/s t = 10 s F = ?
F t = m v
F = m v/ t
F = (500 kg · 25 m/s) / 10 s
F = 1250 N

4. A rocket is propelled forward by a 10 N force as exhaust gas is expelled out the back at 100 m/s. What is the mass flow rate of the exhaust?

4. v = 100 m/s F = 10 N m / t = ?
F t = m v => m/ t = F / v
m / t = 10 N / 100 m/s
m / t = 0.1 kg/s

5. William Tell fires a 0.1 kg arrow at a 1.2 kg block of wood on his son's head. If the arrow hits the block at 50 m/s and sticks into it and the son's head is frictionless, how fast will the arrow/block combination travel directly thereafter?

5. m_1 = 0.1k g m_2 = 1.2 kg v_1 = 50 m/s v_2 = 0
$p' = p$: $m_1v_1' + m_2v_2' = m_1v_1 + m_2v_2$
final speeds of objects will be the same: v'
$(m_1 + m_2)v' = m_1v_1$
$v' = m_1v_1/(m_1 + m_2)$
$v' = (0.1 \text{ kg} \cdot 50 \text{ m/s}) / (0.1\text{kg} + 1.2\text{kg})$
$v' = 3.8$ m/s

6. A 2 kg pumpkin is bowled at 6 m/s across a frozen pond ($\mu = 0$). Shortly after its release, an explosion within causes the pumpkin to separate into a 1.5 kg piece and a 0.5 kg piece. If the 1.5 kg piece continues forward at 3 m/s, what is the final speed of the 0.5 kg piece?

6. m_1=1.5kg, m_2=0.5kg, v_1=v_2=6m/s, v_1'=3m/s
$p' = p$: $m_1v_1' + m_2v_2' = m_1v_1 + m_2v_2$
$m_1v_1' + m_2v_2' = (m_1 + m_2)v$ [Note: v=v_1=v_2]
$v_2' = ((m_1 + m_2)v - m_1v_1') / m_2$
$v_2' = ((1.5 \text{ kg} + 0.5 \text{ kg})\ 6 \text{ m/s} -$
$1.5 \text{ kg} \cdot 3\text{m/s}) / (0.5 \text{ kg}) = 15$ m/s