B & Momentum

If You See	Try	Keep in Mind
A collision or an explosion	Conservation of momentum Elastic: $m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$ Inelastic: $m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = (m_1+m_2)\mathbf{v}_f$ Explosion: $(m_1+m_2)\mathbf{v}_i = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$	Add plus and minus signs, indicating vector direction, to the velocities. This allows you to solve the equations as scalar quantities.
An inelastic collision	Kinetic energy lost $K_{1i} + K_{2i} - K_{\text{lost}} = K_{1f} + K_{2f}$	When kinetic energy is lost, it becomes thermal energy.

PRACTICE EXERCISES

1. Which of the following quantities is conserved in a perfectly elastic collision?

   (A) Velocity only
   (B) Linear momentum only
   (C) Kinetic energy
   (D) Both A and C
   (E) Both B and C

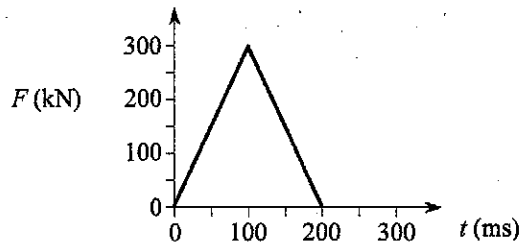
2. During an inelastic collision, which of the following quantities decreases?

   (A) Linear momentum only
   (B) Total energy only
   (C) Mass only
   (D) Kinetic energy only
   (E) Both B and D

3. Impulse is equal to:

   I. $\mathbf{F}\,\Delta d$
   II. $\mathbf{F}\,\Delta t$
   III. $m\mathbf{v}$
   IV. $m\,\Delta\mathbf{v}$

   (A) I only
   (B) II only
   (C) II and III only
   (D) II and IV only
   (E) II, III, and IV



4. The force versus time graph above shows the force acting to stop a 1,500-kilogram car during an accident. Determine the initial speed of the car.

   (A) 10 m/s
   (B) 15 m/s
   (C) 20 m/s
   (D) 25 m/s
   (E) 30 m/s

5. Two ice skaters, one with a mass of 75 kg and the other with a mass of 50 kg, are initially stationary and standing together on the ice. If they push off of each other, which statement below will be true?

   (A) The 50 kg skater receives a larger impulse than the 75 kg skater.
   (B) The 50 kg skater receives a smaller impulse than the 75 kg skater.
   (C) The 50 kg skater experiences a greater change in momentum.
   (D) The 50 kg skater experiences a greater change in velocity.
   (E) A, C, and D are all true

6. An 80-kilogram person running at 2.0 meters per second jumps onto a 20-kilogram stationary cart. What is the resulting speed of the combined cart and person?

   (A) 1.2 m/s
   (B) 1.6 m/s
   (C) 1.8 m/s
   (D) 2.0 m/s
   (E) 2.4 m/s

7. Five objects have the same initial speed of 10 meters per second. After striking a wall, some of them are stopped and some of them bounce back with varying speeds. Which object experiences the greatest change in momentum?

   (A) A 1.0 kilogram mass stopping.
   (B) A 1.0 kilogram mass bouncing back at 10 meters per second.
   (C) A 2.0 kilogram mass stopping.
   (D) A 2.0 kilogram mass bouncing back at 5.0 meters per second.
   (E) A 2.0 kilogram mass bouncing back at 10 meters per second.

ANSWERS EXPLAINED

	Key Words	Needed for Solution	Now Solve It
1. **(E)**	Conserved; perfectly elastic collision	Knowledge/definitions	Momentum is conserved for both elastic and inelastic collisions. However, kinetic energy is also conserved in perfectly elastic collisions.
2. **(D)**	Inelastic collision; quantities decrease	Knowledge/definitions	Linear momentum, total energy, and mass are always conserved in collisions. However, kinetic energy is not conserved in inelastic collisions. During these collisions, some kinetic energy is lost. This energy becomes thermal energy. This conversion to another form of energy keeps the total energy constant.
3. **(D)**	Impulse is equal to	Knowledge/definitions	Answer I is the expression for work, not impulse. Answer III is not correct because impulse does not equal momentum. Impulse is equal to both $\mathbf{F}\,\Delta t$ and a change in momentum, $m\Delta\mathbf{v}$.
4. **(C)**	Force versus time graph; initial speed	Graphing knowledge and the impulse–momentum theorem	$\mathbf{J} = \mathbf{F}\,\Delta t = m\mathbf{v}_f - m\mathbf{v}_i = \text{area}_{F-t\,\text{graph}}$ Use the two expressions on the right. $m\mathbf{v}_f - m\mathbf{v}_i = \frac{1}{2}(\text{height} \times \text{base})$ $(1{,}500\text{ kg})(0) - (1{,}500\text{ kg})\,v_i = \frac{1}{2}(300\text{ kN})(200\text{ ms})$ $v_i = 20\text{ m/s}$ Note: the conversion factors for kilonewtons and milliseconds cancel each other. These units are frequently encountered in force versus time graphs.
5. **(D)**	Ice skaters; initially stationary; push off of each other	Several possible solutions exist involving Newton's third law, the impulse–momentum theorem, and the conservation of momentum in an explosion	The easiest solution involves seeing the separating skaters as an explosion starting from rest. $m_1 v_{1f} = m_2 v_{2f}$ The skater with less mass must have a greater velocity in order to have equal and opposite momentum. Answers A, B, and C cannot be correct. Newton's third law dictates that the force on each skater will be identical. If the force is the same, then the impulse and the change in momentum of each skater is the same.

	Key Words	Needed for Solution	Now Solve It
6. **(B)**	Person running; stationary cart; resulting speed of combined cart and person	Conservation of momentum in an inelastic collision	$m_{person}\mathbf{v}_{person} + m_{cart}\mathbf{v}_{cart}$ $= (m_{person} + m_{cart})\,\mathbf{v}_{person\text{-}cart}$ $(80\text{ kg})(2.0\text{ m/s}) + (20\text{ kg})(0\text{ m/s})$ $= (80\text{ kg} + 20\text{ kg})\mathbf{v}_{person\text{-}cart}$ $\mathbf{v}_{person\text{-}cart} = 1.6\text{ m/s}$
7. **(E)**	Striking a wall; some of them are stopped; some of them bounce back; greatest change in momentum	Change in momentum $\Delta\mathbf{p} = m\,\Delta\mathbf{v}$ $\Delta\mathbf{p} = m\mathbf{v}_f - m\mathbf{v}_i$	Objects that bounce have a greater change in momentum. Essentially, they are changing momentum twice. First they slow down, then they speed back up. The object with the largest combination of mass and change in velocity will have the greatest change in momentum. $\Delta\mathbf{p} = m\mathbf{v}_f - m\mathbf{v}_i$ $\Delta\mathbf{p} = 2.0\text{ kg}(-10\text{ m/s} - 10\text{ m/s})$ $\Delta\mathbf{p} = -40\text{ N} \bullet \text{s}$ Remember that when an object bounces, it reverses direction and its final velocity is now negative. This results in a negative change in momentum, which is consistent with the force acting opposite the initial velocity of the ball. Although negative, it still has the largest magnitude and creates the greatest change.