a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

# Physics

## Momentum

Science and Mathematics
Education Research Group

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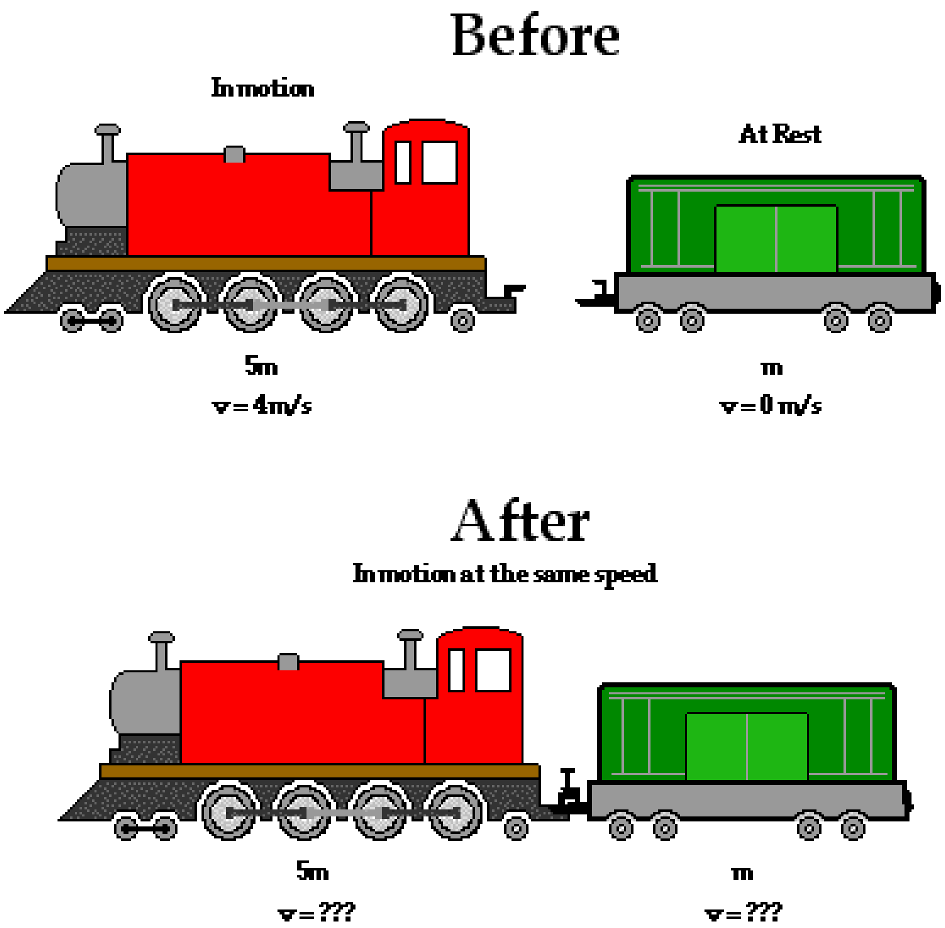
# Momentum




http://www.physicsclassroom.com/class/momentum/Lesson-2/Using-Equations-as-a-Guide-to-Thinking

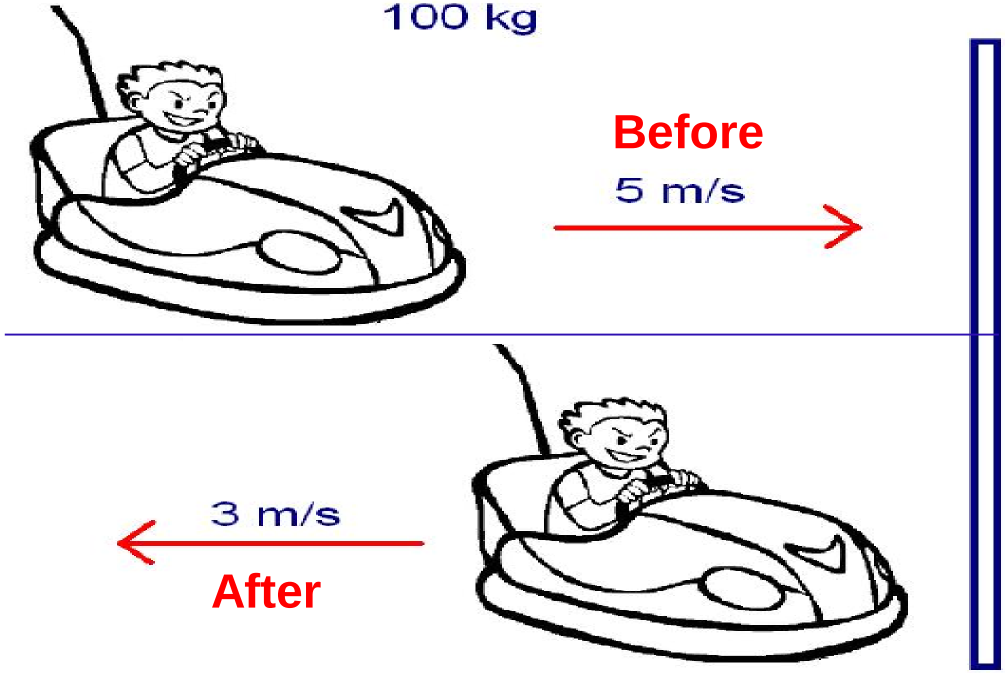
# Momentum

The following questions have been compiled from a collection of questions submitted on PeerWise (https://peerwise.cs.auckland.ac.nz/) by teacher candidates as part of the EDCP 357 physics methods courses at UBC.

# Momentum Problems I

A bumper car is initially driving to the right at 5 m/s. After bouncing off a wall, the bumper car is moving backwards (to the left) at 3 m/s. The car, including driver, is 100 kg. What is the change in momentum? (Consider moving to the right as moving in the positive direction)

A. 800 kg m/s
B. 500 kg m/s
C. 300 kg m/s
D. -500 kg m/s
E. -800 kg m/s



# Solution

**Answer:** E

**Justification:** Recall that the quantity $m.v$ is the momentum, whereas $m.\Delta v$ is the change in momentum. The change in momentum is also referred to as an **impulse**. Impulse is defined as the product of the force acting on a body and the time interval during which the force is exerted. The impulse-momentum change equation is given by $\boldsymbol{Impulse = change\ in\ momentum}$**.**

$change\ in\ momentum = m.\Delta v$, where $\Delta v = final\ velocity - initial\ velocity = -3 - 5 = -8\ m/s$ is the change in velocity and $m = 100\ kg$ is the mass of the bumper car. Thus, $m.\Delta v = 100 \times (-8) = -800\ kg\ m/s$ is the change in momentum (or impulse) of the car. Therefore, **E** is the correct answer.

# Momentum Problems II

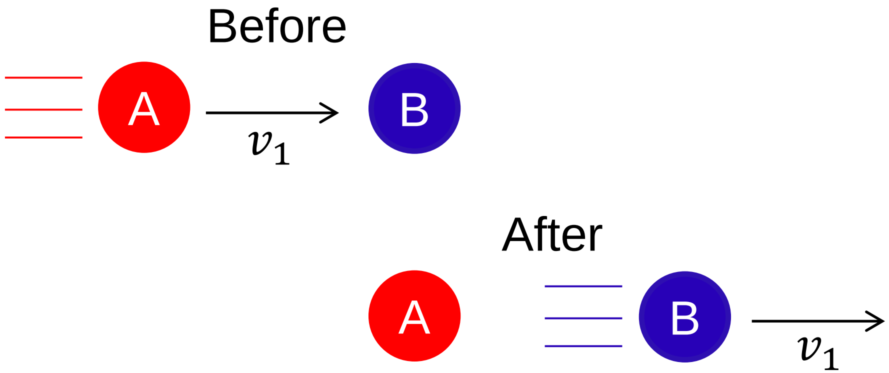
An object A, with mass $m_A$ and velocity $v_1$, collides with a stationary object B, with mass $m_B$. After the collision, B is travelling at $v_1$ and A is stationary. Which of the following are necessarily true?

A. The collision is perfectly elastic.

B. Total momentum is conserved.

C. The system is closed.

D. None of the above.



# Solution

**Answer:** D

**Justification:** We cannot assume that the masses are equal.

**Case 1:** Let $m_A > m_B$. If we look at the momentum before and after the collision, we notice:

Momentum before = $m_A v_A + m_B v_B = m_A v_1 + m_B(0) = m_A v_1$

Momentum after = $m_A v_A + m_B v_B = m_A(0) + m_B v_1 = m_B v_1$

Since $m_A > m_B$, then $m_A v_1 > m_B v_1$.

Therefore, after the collision we can see that some of the momentum is lost. This implies that the system is not closed (a **closed system** is one in which the total momentum does not change).

# Solution continued

**Case 2:** If $m_A = m_B$, we can use the same equations as above to determine that $m_A v_1 = m_B v_1$. Therefore the collision was a perfectly elastic collision (no loss of momentum).

Since we cannot assume that we are operating under Case 2 ($m_A = m_B$), we cannot say for sure whether the collision is elastic, momentum is conserved, or the system is closed.

Therefore, **D** is the correct answer.

**Note:** We cannot have another case, i.e. $m_A < m_B$. This is because it is impossible for object A (smaller mass) travelling at $v_1$ to collide with object B (larger mass) and make object B travel at the same speed ($v_1$). In other words, we cannot have an increase in momentum after a collision (at least not without external forces taking part).

# Momentum Problems III

There is a collision between two 1 kg carts. One is initially moving at 5 m/s and the other is initially at rest. With the information provided, can we solve for the final velocities of the carts?

A. Yes, we can use the law of conservation of momentum.
B. Yes, we can use the law of conservation of energy.
C. Yes, we can use the law of the conservation of momentum and the conservation of energy.
D. No, we cannot apply the law of conservation of energy.

# Solution

**Answer:** D

**Justification:** The **law of conservation of energy** states that, in a closed system (isolated from its surroundings), the total energy of the system is conserved. In our case, we cannot apply the law of conservation of energy, because we don't know whether the collision is elastic or inelastic.

Also, the **law of conservation of momentum** states that the total momentum of a closed system does not change. That is, the total momentum of the objects before the collision is the same as the total momentum of the objects after the collision.

By using the law of conservation of momentum, we are unable to determine the final velocities of the carts, as shown on the next slide.

# Solution continued

**Answer:** D

$$p_i = p_f$$ Law of conservation of momentum

$$m_1 v_{1,i} + m_2 v_{2,i} = m_1 v_{1,f} + m_2 v_{2,f}$$ Application of the law

$$(1\ kg)(5\ m/s) + (1\ kg)(0\ m/s) = (1\ kg)\ v_{1,f} + (1\ kg)\ v_{2,f}$$

$$5 = v_{1,f} + v_{2,f}$$

That is, we have one equation with two unknowns. Thus, **D** is the correct answer.

**Note:** The law of conservation of energy is completely different from energy conservation. Energy conservation deals with saving energy, such as insulating your home, using the public transit, or switching the lights off when not in use.

# Momentum Problems IV

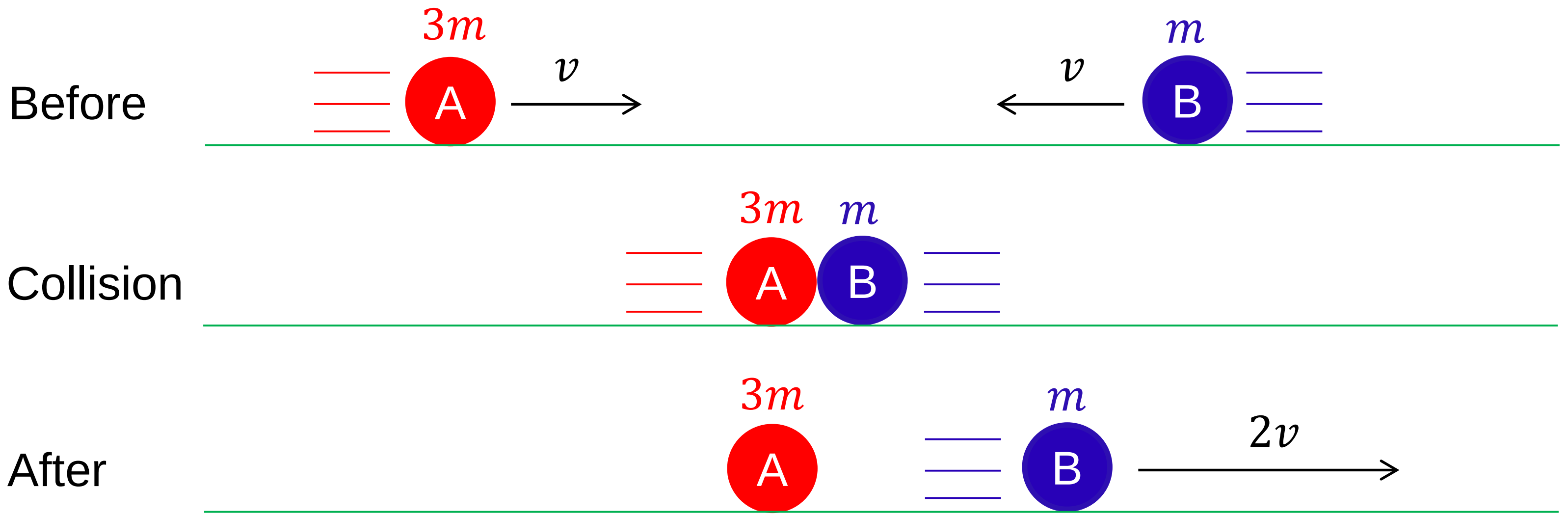
Two objects (A and B) of different mass are moving in opposite directions, but at the same speed, before a head-on collision. Object A is three times more massive than object B. After the collision: object A comes to rest; the direction of object B is reversed and its speed is increased by a factor of 2. Is the momentum conserved in this collision? Is the kinetic energy conserved?

A. Only the total momentum is conserved.
B. Only the kinetic energy is conserved.
C. Both kinetic energy and total momentum are conserved.
D. Total momentum is conserved, but not the kinetic energy
E. Kinetic energy is conserved, but not the total momentum

# Solution

**Answer:** C

**Justification:**



# Solution continued

**Answer:** C

Let the direction of object A be the positive direction.

Initial momentum $= 3\,m\,v - m\,v = 2\,m\,v$

Final momentum $= 0\,m\,v + 2\,m\,v = 2\,m\,v$

Initial kinetic energy $= \frac{1}{2}\left[3\,m\,v^2 + m\,v^2\right] = 2\,m\,v^2$

Final kinetic energy $= \frac{1}{2}\left[0\,m\,v^2 + m\,(2\,v)^2\right] = 2\,m\,v^2$

Note that both the kinetic energy and the total momentum are conserved. Thus, **C** is the correct answer.