Momentum

Momentum is the tendency of a moving object to continue moving. The more momentum a moving object has, the harder it is to stop.

- Momentum is denoted as $\vec{p}$, its formula is $\vec{\boldsymbol{p}} = \boldsymbol{m}\vec{\boldsymbol{v}}$. Its unit is kg·m/s or N·s.
- Momentum is a vector, **direction** matters!
- If no external force is applied to the system, momentum of the system is conserved. $\vec{\boldsymbol{p}}_i = \vec{\boldsymbol{p}}_f$. We apply conservation of momentum principle:
  - ✓ If there is a collision.
  - ✓ If two objects/persons push against each other.
  - ✓ If one large object breaks down into small pieces.
- If an external force is applied to the system, that force will create an impulse (J) and **along the line of impact**, the momentum relationship becomes:

$$\boldsymbol{p_i + J = p_f}$$

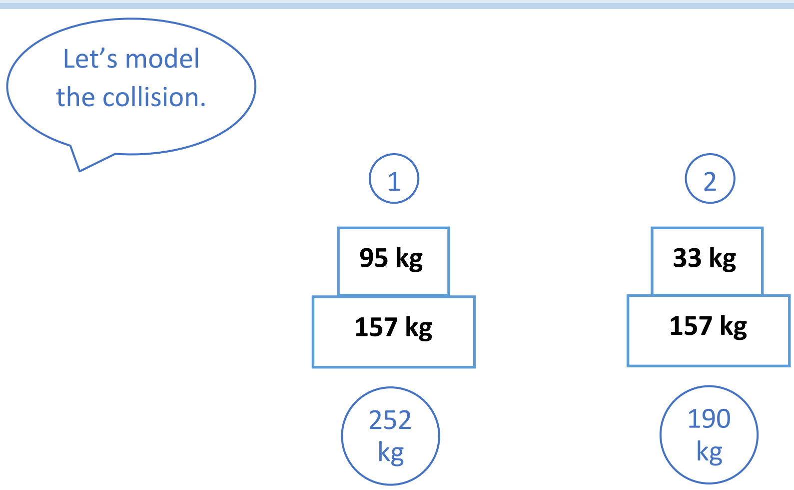
$$\boldsymbol{J = p_f - p_i = m\,(v_f - v_i)}$$

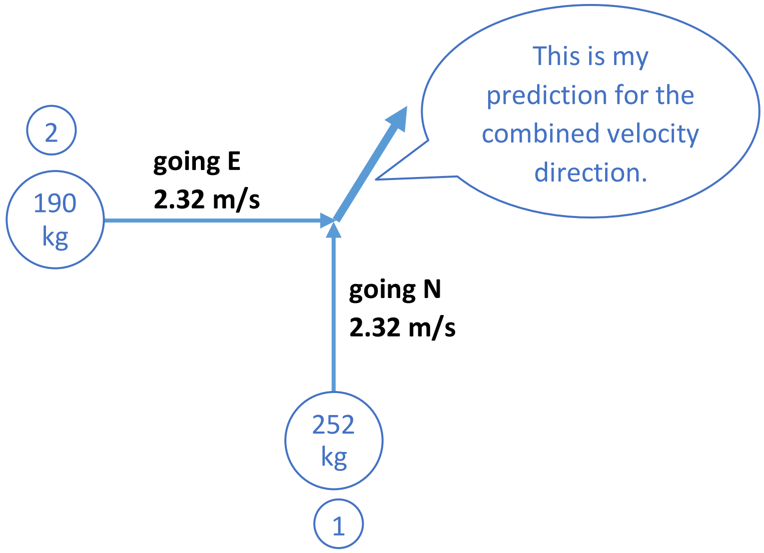
$$\boldsymbol{J = \int F\,dt = F_{avg}\,\Delta t = Area\ under\ the\ F - t\ curve}$$

- If the system is 2-D, we must think x-direction and y-direction separately.
- For perfectly elastic collisions only, kinetic energy is conserved as well as momentum.

Example:

In an amusement park, Scott (95.0 kg) was driving a bumper car (157 kg) towards north and hit an identical bumper car that was driven by Natasha (33.0 kg) that was going east without mercy. If speed of both cars were 2.23 m/s before the collision, what is the combined speed of their cars after the collision?





Momentum will be conserved both in x-direction and y-directions.

x-direction:

$m_2 v_{2i} = (m_1 + m_2)\, v_x$

$$v_x = \frac{m_2}{m_1 + m_2} \times v_{2i}$$

$$v_x = \frac{190}{190 + 252} \times 2.32$$

$v_x = 1.8215\ m/s$

I keep four decimals to avoid rounding mistakes.

y-direction:

$m_2 v_{1i} = (m_1 + m_2)\, v_y$

$$v_y = \frac{m_1}{m_1 + m_2} \times v_{1i}$$

$$v_y = \frac{252}{190 + 252} \times 2.32$$

$v_y = 1.3227\ m/s$

$$v = \sqrt{v_x^2 + v_y^2}$$

$$v = \sqrt{1.8215^2 + 1.3227^2}$$

$v = 2.25\ m/s$

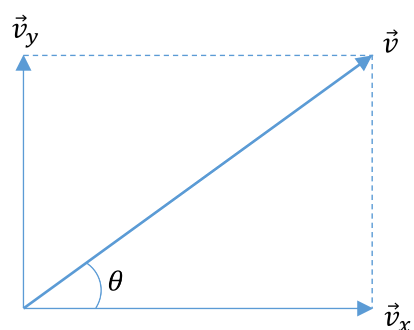
Final answer should be reported in three significant figures.

$\theta = \tan^{-1}(v_y/v_x)$

$\theta = \tan^{-1}(1.3227/1.8215)$

$\theta = 36°$

The angle is in the line with my prediction.



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