LESSON 4.1.2

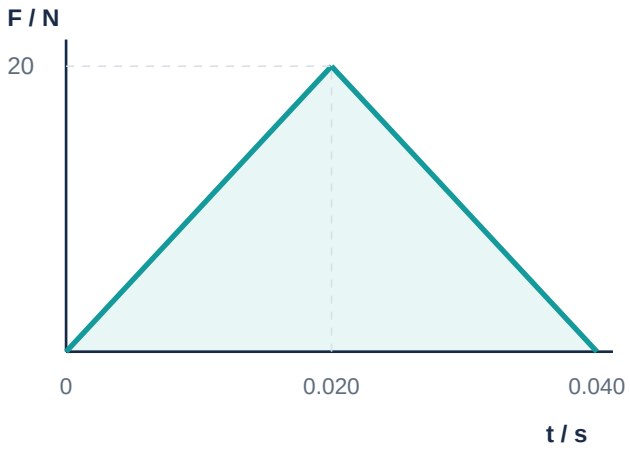
Momentum, Impulse and Collisions in 2D

Momentum and impulse are vectors. Choose positive directions first, then track the changes in each component separately.

$$p = mv \qquad J = F_{avg}\Delta t = \Delta p = m(v - u)$$

These equations apply along a chosen axis; m is constant. Momentum is measured in kg m/s, and impulse in N s (the same dimensions). Use the resultant force on the object.

IMPULSE IS THE SIGNED AREA UNDER A FORCE-TIME GRAPH



$$J = \frac{1}{2} \times 0.040 \times 20$$

$$= 0.40 \text{ N s}$$

The average force is 10 N, not the 20 N peak. A longer contact time reduces average force for the same impulse.

A REBOUND: DO NOT SUBTRACT SPEEDS

A 0.100 kg ball changes from +4.0 m/s to -3.0 m/s along the same axis:

$$\Delta p = 0.100 \times (-3.0 - 4.0) = -0.70 \text{ N s}$$

The negative sign gives the direction of the impulse on the ball.

1 Conserve momentum in two directions

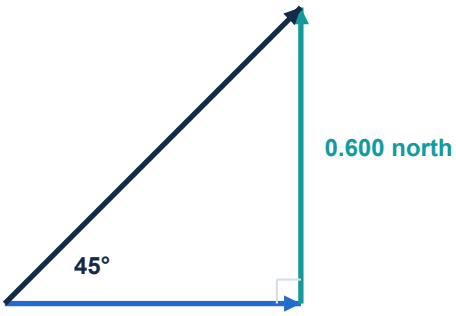
For the chosen system, total momentum is conserved when the external impulse is negligible.

ILLUSTRATIVE COLLISION ON A SMOOTH HORIZONTAL SURFACE

Puck A (0.200 kg) travels east at 3.00 m/s. Puck B (0.300 kg) travels north at 2.00 m/s. They collide and stick. Take east as +x and north as +y. Their combined mass is 0.500 kg.

The pucks exchange internal impulses; these cancel for the two-puck system.

ADD MOMENTUM VECTORS, NOT SPEEDS



Momentum components: kg m/s

Before: total x-momentum = 0.600 kg m/s; total y-momentum = 0.600 kg m/s.

After: the stuck pucks share one velocity. Both momentum components must be unchanged.

$$x:\ 0.200 \times 3.00 = 0.500 v_x \qquad v_x = 1.20 \text{ m/s}$$

$$y:\ 0.300 \times 2.00 = 0.500 v_y \qquad v_y = 1.20 \text{ m/s}$$

$$v^2 = v_x^2 + v_y^2 = 2.88 \text{ m}^2 \text{ s}^{-2}$$

$$\tan\theta = \frac{v_y}{v_x} = 1 \qquad \theta = 45.0°$$

Final speed = 1.70 m/s, at 45.0° north of east.

For separating objects, give each its own final velocity and resolve each component.

2 Check kinetic energy separately

Momentum conservation does not by itself tell you whether a collision is elastic.

ELASTIC COLLISION

Total kinetic energy is unchanged. Total momentum is also conserved when external impulse is negligible.

INELASTIC COLLISION

Total kinetic energy decreases. If the objects stick together, the collision is perfectly inelastic. Momentum can still be conserved.

ENERGY CHECK FOR THE TWO PUCKS

$$E_{before} = \frac{1}{2}(0.200)(3.00)^2 + \frac{1}{2}(0.300)(2.00)^2$$

$$= 0.900 + 0.600 = 1.50 \text{ J}$$

$$E_{after} = \frac{1}{2}(0.500)(2.88) = 0.720 \text{ J}$$

Kinetic energy decrease = 1.50 - 0.720 = 0.780 J

The missing kinetic energy becomes internal energy, deformation and sound. Total energy is conserved. Use the unrounded speed squared (2.88), not the rounded speed 1.70.

KINETIC ENERGY IN TERMS OF MOMENTUM

$$v = \frac{p}{m} \qquad E_k = \frac{1}{2}m\frac{p^2}{m^2} = \frac{p^2}{2m}$$

Here p is the momentum magnitude; the formula assumes non-relativistic motion.

Practical link: compare force-time area with the measured momentum change; use calibrated video and known frame intervals to obtain both velocity components before and after a collision.

Source: Pearson IAL Physics, Unit 4 p. 28, points 81-86 and Core Practicals 9-10.

Lesson numbering follows the Jimlaoshi course sequence. Example values are illustrative.