Exercise walk-through

Conservation of Linear Momentum ▪ 4.3

eXercise

You must be able to

- state that the total momentum of an **isolated system** 孤立系统 is constant
- identify an isolated system as one with **zero net external force**
- explain that **internal forces** 内力 cannot change a system's total momentum
- apply conservation of momentum to **collisions** 碰撞 and **explosions** 爆炸 in one dimension

Method — Conservation of momentum

When the net external force is zero, $\sum p_{\text{before}} = \sum p_{\text{after}}$.

Method — Explosions

An object at rest has zero total momentum, so after it bursts apart the fragments carry **equal and opposite** momenta that still sum to zero.

Method — Example (collision)

A 2.0 kg cart at 3.0 m s^{-1} strikes a stationary 1.0 kg cart and they stick:

$$2.0(3.0) = (2.0 + 1.0)v \Rightarrow v = 2.0 \text{ m s}^{-1}.$$

Practice 2.1 ▪ 1 mark

State the condition for the total momentum of a system to be conserved.

Solution 2.1

Method: Explosions

Worked steps

the net external force on the system must be zero B1.

Practice 2.2 ▪ 2 marks

A 3.0 kg cart at 4.0 m s^{-1} hits a stationary 1.0 kg cart and they couple together. Find their common speed.

Solution 2.2

Method: Example (collision)

Worked steps

$$3.0(4.0) = (3.0 + 1.0)v \Rightarrow v = \frac{12}{4.0} = 3.0 \text{ m s}^{-1}$$ M1 A1.

Practice 2.3 ▪ 2 marks

A stationary 5.0 kg object explodes into two pieces; a 2.0 kg piece flies off at $+6.0$ m s^{-1}. Find the velocity of the 3.0 kg piece.

Solution 2.3

Method: Example (collision)

Worked steps

$$0 = 2.0(+6.0) + 3.0\,v \Rightarrow v = \frac{-12}{3.0} = -4.0 \text{ m s}^{-1}$$ M1 A1.

Exam-style 3.1 ▪ 1 mark

The total momentum of a system is conserved when

A kinetic energy is conserved

B the net external force is zero

C there is no friction anywhere

D the velocity is constant

Solution 3.1

Method: Explosions

A kinetic energy is conserved

B the net external force is zero ✓

C there is no friction anywhere

D the velocity is constant

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

A 2.0 kg rifle fires a 0.010 kg bullet at 400 m s^{-1}. The rifle recoils at

A 2.0 m s^{-1}

B 4.0 m s^{-1}

C 0.5 m s^{-1}

D 8.0 m s^{-1}

Solution 3.2

A $2.0\ \text{m s}^{-1}$ ✓

B $4.0\ \text{m s}^{-1}$

C $0.5\ \text{m s}^{-1}$

D $8.0\ \text{m s}^{-1}$

Worked steps

A — $0 = 0.010(400) + 2.0\,v \Rightarrow v = -2.0\ \text{m s}^{-1}$.

Exam-style 3.3 ▪ 2 marks

A 60 kg astronaut, initially at rest in space, throws a 2.0 kg tool at 5.0 m s^{-1}.
(a) Find the astronaut's recoil speed.
(b) State the direction of the recoil relative to the tool.

Solution 3.3

Worked steps

(a) $0 = 2.0(5.0) + 60\,v \Rightarrow v = \dfrac{-10}{60} = -0.17$ m s^{-1}, i.e. 0.17 m s^{-1} M1 A1. (b) opposite to the tool's direction B1.