Exercise walk-through

Systems and Center of Mass ▪ 2.1

eXercise

You must be able to

- define a **system** 系统 and distinguish **internal** 内力 and **external forces** 外力
- define the **centre of mass** 质心 as the mass-weighted average position
- explain that a system's centre of mass accelerates only under the **net external force**
- calculate the centre of mass of a set of point masses

Method — Centre of mass of point masses

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}.$$

Masses 2.0 kg at $x = 0$ and 3.0 kg at $x = 5.0$ m: $x_{cm} = \dfrac{2.0(0) + 3.0(5.0)}{5.0} = 3.0$ m.

Method — Internal vs external forces

Forces **between** parts of the system are **internal** and cancel in third-law pairs; only **external** forces (from outside the system) change the motion of the centre of mass.

Method — Motion of the centre of mass

When a firework explodes, its fragments fly apart under **internal** forces, but the centre of mass keeps following the original projectile path — the only external force is gravity.

Practice 2.1 ▪ 2 marks

Masses 1.0 kg at $x = 0$ and 4.0 kg at $x = 10$ m. Find the centre of mass.

Solution 2.1

Method: Centre of mass of point masses

Worked steps

$$x_{cm} = \frac{1.0(0) + 4.0(10)}{5.0} = 8.0 \text{ m}$$ M1 A1.

Practice 2.2 ▪ 1 mark

Two blocks are joined by a string and pulled along. Taking the **system to be both blocks**, state whether the string tension is an internal or external force.

Solution 2.2

Worked steps

internal (it acts between two parts of the system) B1.

Practice 2.3 ▪ 2 marks

Two equal masses sit at $x = 2.0$ m and $x = 8.0$ m. State the centre of mass without calculating, and justify.

Solution 2.3

Method: Centre of mass of point masses

Worked steps

midpoint, $x = 5.0$ m **B1** — the masses are equal, so the centre of mass is exactly halfway between them **B1**.

Exam-style 3.1 ▪ 1 mark

The acceleration of a system's centre of mass depends only on

A the internal forces

B the net external force

C the largest mass

D the total kinetic energy

Solution 3.1

Method: Internal vs external forces

A the internal forces

B the net external force ✓

C the largest mass

D the total kinetic energy

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

Three 2.0 kg masses lie at $x = 0$, 3.0 m and 6.0 m. The centre of mass is at

A 2.0 m

B 3.0 m

C 4.5 m

D 6.0 m

Solution 3.2

Method: Centre of mass of point masses

A 2.0 m

B 3.0 m ✓

C 4.5 m

D 6.0 m

Worked steps

B — by symmetry, $x_{cm} = 3.0$ m.

Exam-style 3.3 ▪ 2 marks

A 60 kg skater and a 40 kg skater stand 5.0 m apart on frictionless ice and pull on a rope between them.

(a) Find the centre of mass, measured from the 60 kg skater.

(b) State where they meet, and explain why.

Solution 3.3

Worked steps

(a) $x_{cm} = \dfrac{60(0) + 40(5.0)}{100} = 2.0$ m M1 A1. (b) They meet at the centre of mass, 2.0 m from the 60 kg skater — with no external horizontal force, the centre of mass stays fixed B1.