AP PHYSICS 1 • EXERCISE SHEET

2.1 Systems and Center of Mass

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS system 系统 • force 力 • centre of mass 质心 • internal 内力 • external forces 外力

Objective

Build the skills to answer exam questions on **systems and centre of mass**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ **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.

■ **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.

■ **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.

2 Practice

2.1 Masses 1.0 kg at $x = 0$ and 4.0 kg at $x = 10$ m. Find the centre of mass. [2]

2.2 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. [1]

2.3 Two equal masses sit at $x = 2.0$ m and $x = 8.0$ m. State the centre of mass without calculating, and justify. [2]

3 Exam-style questions

3.1 The acceleration of a system's centre of mass depends only on [1]

- **A** the internal forces
- **B** the net external force
- **C** the largest mass
- **D** the total kinetic energy

3.2 Three 2.0 kg masses lie at $x = 0$, 3.0 m and 6.0 m. The centre of mass is at [1]

- **A** 2.0 m
- **B** 3.0 m
- **C** 4.5 m
- **D** 6.0 m

3.3 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. [2]

(b) State where they meet, and explain why. [1]

Solutions

2.1 $x_{cm} = \dfrac{1.0(0) + 4.0(10)}{5.0} = 8.0$ m.

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

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

3.1 B.

3.2 B — by symmetry, $x_{cm} = 3.0$ m.

3.3 (a) $x_{cm} = \dfrac{60(0) + 40(5.0)}{100} = 2.0$ m. (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.