

2.1 Systems and Center of Mass

Name: _____ Class: _____ Date: _____

Total: 13 marks**KEY WORDS** center of mass 质心 • system 系统 • force 力 • kinetic 动能摩擦

Objective

Build the skills to answer exam questions on **systems and the center of mass**.**You must be able to:**

- treat a group of objects as a single **system** 系统
- find the **center of mass** 质心 of point masses: $x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$
- explain that the center of mass moves as if all mass and the net external force acted there
- use symmetry to locate the center of mass of a uniform object

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Center of mass of point masses

Weight each position by its mass and divide by the total mass:

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}.$$

For 2 kg at $x = 0$ and 3 kg at $x = 5$ m:

$$x_{cm} = \frac{2(0) + 3(5)}{2 + 3} = \frac{15}{5} = 3 \text{ m}.$$

It sits closer to the heavier mass.

■ The center of mass obeys Newton's second law

The center of mass of a system accelerates as if the total mass were there and the **net external force** acted on it. Internal forces cancel and never move it.

■ Symmetry

A uniform rod's center of mass is at its midpoint; a uniform disc's is at its centre.

2 Practice

Now apply the methods above.

2.1 Two masses, 1 kg at $x = 0$ and 1 kg at $x = 4$ m. Find the center of mass. [2]**2.2** Masses 2 kg at $x = 0$ and 6 kg at $x = 8$ m. Find the center of mass. [2]**2.3** State where the center of mass of a uniform metre ruler is located. [1]**2.4** Can internal forces alone move a system's center of mass? Answer yes or no. [1]

3 Exam-style questions

3.1 The center of mass of a system accelerates in response to the [1]

A	B
C	D

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

3.2 Two equal masses sit at $x = 2$ m and $x = 6$ m. Their center of mass is at [1]

A	B
C	D

- A 2 m
- B 4 m
- C 6 m
- D 8 m

3.3 Point masses: 4 kg at $x = 1$ m and 2 kg at $x = 7$ m.

(a) Find the center of mass. [2]

(b) State whether it is closer to the 4 kg or the 2 kg mass, and why. [1]

3.4 An astronaut floating in space throws a tool.

(a) State what happens to the center of mass of (astronaut + tool). [1]

(b) Explain your answer using external forces. [1]