AP PHYSICS C: MECHANICS • EXERCISE SHEET

7.1 Defining Simple Harmonic Motion (SHM)

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS equilibrium 平衡位置 • simple harmonic motion 简谐运动 • restoring force 回复力 • amplitude 振幅

Objective

Build the skills to answer exam questions on **defining simple harmonic motion (SHM)**.

You must be able to:

- state the defining condition of **simple harmonic motion** 简谐运动: $F = -kx$
- explain the minus sign (the **restoring force** 回复力 points back toward equilibrium)
- use $a = -\omega^2 x$ with $\omega^2 = k/m$
- identify where the acceleration is largest and where it is zero

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.

■ The defining condition

SHM happens when the restoring force is proportional to the displacement and points back toward equilibrium:

$$F = -kx.$$

■ The acceleration form

Dividing by mass,

$$a = -\frac{k}{m}x = -\omega^2 x, \qquad \omega^2 = \frac{k}{m}.$$

Acceleration is proportional to displacement but opposite in direction.

■ Where it is largest

The acceleration is greatest at the extremes (largest x) and zero at equilibrium ($x = 0$) – the opposite of the speed.

2 Practice

Now apply the methods above.

2.1 A spring with $k = 20$ N m^{-1} is stretched 0.15 m. Find the restoring force. [2]

2.2 State the meaning of the minus sign in $F = -kx$. [1]

2.3 For SHM with $\omega^2 = 25$ s^{-2} at $x = 0.2$ m, find the acceleration magnitude. [2]

2.4 Where in the motion is the acceleration largest? [1]

3 Exam-style questions

3.1 A motion is simple harmonic when the restoring force is [1]

- **A** constant
- **B** proportional to displacement and opposite in direction
- **C** proportional to speed
- **D** zero

3.2 In SHM, the acceleration is zero at the [1]

- **A** extremes
- **B** equilibrium position
- **C** turning points
- **D** it is never zero

3.3 A 0.5 kg mass on a spring ($k = 8$ N m^{-1}) is pulled 0.1 m and released.

(a) Find the restoring force at release. [2]

(b) Find the acceleration at release. [2]

3.4 A pendulum swings with a small amplitude.

(a) State whether its motion is SHM. [1]

(b) State the condition (angle) required for this to hold. [1]

Solutions

2.1 $|F| = kx = 20 \times 0.15 = 3$ N.

2.2 The force opposes the displacement (points back to equilibrium).

2.3 $|a| = \omega^2 x = 25 \times 0.2 = 5$ m s^{-2}.

2.4 At the extremes (largest x).

3.1 B — proportional to displacement and opposite in direction.

3.2 B — at equilibrium, $x = 0$ so $a = 0$.

3.3 (a) $F = -kx = -8 \times 0.1 = -0.8$ N (magnitude 0.8 N). (b) $\omega^2 = k/m = 16$; $a = -\omega^2 x = -1.6$ m s^{-2}.

3.4 (a) Yes (approximately). (b) Small angles (roughly under 15°).