AP PHYSICS 1 • EXERCISE SHEET

5.5 Rotational Equilibrium and Newton's First Law in Rotational Form

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS net torque 净力矩 • rotational equilibrium 转动平衡 • static equilibrium 静平衡 • torque 力矩

Objective

Build the skills to answer exam questions on **rotational equilibrium** and Newton's first law in rotational form.

You must be able to:

- state that **rotational equilibrium** 转动平衡 needs zero **net torque** 净力矩
- describe **static equilibrium** 静平衡 as zero net force **and** zero net torque
- apply the equilibrium conditions to beams, seesaws, and hanging signs
- choose a convenient **axis** to solve for unknown forces or distances

1 Worked examples

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

■ Two conditions for static equilibrium

$$\sum \vec{F} = 0 \quad \text{and} \quad \sum \tau = 0.$$

■ Choosing the axis

Take torques about the point where an **unknown** force acts — that force then has zero lever arm and drops out, leaving one unknown.

■ Example

A uniform 60 N beam 3.0 m long rests on a support at each end; a 30 N weight sits 1.0 m from the left support. Torques about the right support: $L(3.0) = 60(1.5) + 30(2.0) = 150$, so $L = 50$ N.

2 Practice

2.1 State the two conditions for an object to be in static equilibrium. [2]

2.2 A seesaw balances with a 200 N child 1.0 m left of the pivot. Find the clockwise torque needed on the right to balance it. [1]

2.3 A uniform 40 N plank 4.0 m long rests on a support at each end. State the force on each support, with reasoning. [2]

3 Exam-style questions

3.1 An object in rotational equilibrium has [1]

- **A** zero net force
- **B** zero net torque
- **C** constant speed
- **D** the maximum possible torque

3.2 To balance a seesaw, the clockwise and counterclockwise torques about the pivot must be [1]

- **A** both zero
- **B** equal in size
- **C** as large as possible
- **D** opposite in sign only

3.3 A uniform 80 N beam 4.0 m long rests on a support at each end. A 120 N box sits 1.0 m from the left support.

(a) Taking torques about the right support, find the force on the left support. [3]

(b) Find the force on the right support. [1]

Solutions

2.1 the net force is zero **and** the net torque is zero.

2.2 $200 \times 1.0 = 200$ N m clockwise.

2.3 20 N on each — the plank is uniform and symmetric, so its weight splits equally.

3.1 B.

3.2 B.

3.3 (a) torques about the right support: $L(4.0) = 80(2.0) + 120(3.0) = 160 + 360 = 520$, so $L = 130$ N. (b) $R = (80 + 120) - 130 = 70$ N.