

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

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Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 11 marks

## Objective

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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

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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

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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]

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**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]

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### 3 Exam-style questions

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**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
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**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
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**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]

## 4 Go further

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- work through the **5.5 Rotational Equilibrium** lesson on the **Learn** page;
- read the **Torque and Rotational Dynamics** section of the AP Physics 1 handout on the **Know** page.

## Solutions

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**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.