Exercise walk-through

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

eXercise

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

Method — Two conditions for static equilibrium

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

Method — 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.

Method — 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.

Practice 2.1 ▪ 2 marks

State the two conditions for an object to be in static equilibrium.

Solution 2.1

Method: Two conditions for static equilibrium

Worked steps

the net force is zero **and** the net torque is zero B1 B1.

Practice 2.2 ▪ 1 mark

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.

Solution 2.2

Method: Example

Worked steps

$200 \times 1.0 = 200$ N m clockwise B1.

Practice 2.3 ▪ 2 marks

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

Solution 2.3

Method: Example

Worked steps

20 N on each B1 — the plank is uniform and symmetric, so its weight splits equally B1.

Exam-style 3.1 ▪ 1 mark

An object in rotational equilibrium has

A zero net force

B zero net torque

C constant speed

D the maximum possible torque

Solution 3.1

A zero net force

B zero net torque ✓

C constant speed

D the maximum possible torque

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

To balance a seesaw, the clockwise and counterclockwise torques about the pivot must be

A both zero

B equal in size

C as large as possible

D opposite in sign only

Solution 3.2

A both zero

B equal in size ✓

C as large as possible

D opposite in sign only

Worked steps

B.

Exam-style 3.3 ▪ 3 marks

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.

(b) Find the force on the right support.

Solution 3.3

Method: Example

Worked steps

(a) torques about the right support: $L(4.0) = 80(2.0) + 120(3.0) = 160 + 360 = 520$, so $L = 130$ N **M1** **M1** **A1** *for torque equation, for values.* (b) $R = (80 + 120) - 130 = 70$ N **B1**.