Exercise walk-through

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

eXercise

You must be able to

- state the condition for **rotational equilibrium 转动平衡**: the net torque is zero
- combine it with translational equilibrium (net force zero)
- balance clockwise and anticlockwise torques about a pivot
- solve for an unknown force or distance in a balanced system

Method — The condition

An object is in rotational equilibrium when

$$\sum \tau = 0,$$

i.e. the clockwise torques equal the anticlockwise torques about any axis.

Method — A balanced beam

A pivot supports a beam. A 20 N weight sits 0.5 m left of the pivot; an unknown weight W sits 1 m right. Balance:

$$20 \times 0.5 = W \times 1 \Rightarrow W = 10 \text{ N}.$$

Method — Full equilibrium

Complete equilibrium needs **both** $\sum F = 0$ and $\sum \tau = 0$: no linear acceleration and no angular acceleration.

Practice 2.1 ▪ 1 mark

State the condition for rotational equilibrium.

Solution 2.1

Method: The condition

Worked steps

The net torque about any axis is zero B1.

Practice 2.2 ▪ 2 marks

A 30 N weight sits 0.4 m from a pivot. Find its torque.

Solution 2.2

Method: A balanced beam

Worked steps

$\tau = 30 \times 0.4 = 12$ N m **M1** **A1**.

Practice 2.3 ▪ 2 marks

For full equilibrium, name the two conditions that must both hold.

Solution 2.3

Method: Full equilibrium

Worked steps

Net force zero ($\sum F = 0$) and net torque zero ($\sum \tau = 0$) B1 B1.

Practice 2.4 ▪ 1 mark

A beam balances with 40 N m clockwise. State the anticlockwise torque.

Solution 2.4

Worked steps

40 N m B1.

Exam-style 3.1 ▪ 1 mark

An object is in rotational equilibrium when

A the net force is zero

B the net torque is zero

C it is at rest

D it has no mass

Solution 3.1

Method: The condition

A the net force is zero

B the net torque is zero ✓

C it is at rest

D it has no mass

Worked steps

B — the net torque is zero.

Exam-style 3.2 ▪ 1 mark

A seesaw balances. The clockwise and anticlockwise torques are

A both zero

B equal in size

C unequal

D in the same direction

Solution 3.2

Method: The condition

A both zero

B equal in size ✓

C unequal

D in the same direction

Worked steps

B — the two torques are equal in size (and opposite in sense).

Exam-style 3.3 ▪ 2 marks

A uniform beam pivots at its centre. A 50 N weight hangs 0.6 m to the left.
(a) Find the torque it produces.
(b) A 30 N weight is placed on the right to balance it. Find its distance from the pivot.

Solution 3.3

Method: A balanced beam

Worked steps

(a) $\tau = 50 \times 0.6 = 30$ N m M1 A1. (b) $30 = 30 \times d \Rightarrow d = 1.0$ m M1 A1.

Exam-style 3.4 ▪ 1 mark

A 2 m uniform plank of weight 60 N rests on a pivot 0.5 m from its left end.
(a) State where the plank's weight effectively acts.
(b) Explain, using torque, why the plank would tip without extra support.

Solution 3.4

Method: A balanced beam

Worked steps

(a) At its centre, 1 m from each end B1. (b) The weight acts 0.5 m right of the pivot, giving an unbalanced clockwise torque, so it rotates unless supported M1 A1.