AP PHYSICS C: MECHANICS • EXERCISE SHEET

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

Name: _____ Class: _____ Date: _____ **Total: 16 marks**

Objective

Build the skills to answer exam questions on **rotational equilibrium**.

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

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 condition

An object is in rotational equilibrium when

$$\sum \tau = 0,$$

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

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:

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

Full equilibrium

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

2 Practice

Now apply the methods above.

2.1 State the condition for rotational equilibrium. [1]

2.2 A 30 N weight sits 0.4 m from a pivot. Find its torque. [2]

2.3 For full equilibrium, name the two conditions that must both hold. [2]

2.4 A beam balances with 40 N m clockwise. State the anticlockwise torque. [1]

3 Exam-style questions

3.1 An object is in rotational equilibrium when [1]

- **A** the net force is zero
- **B** the net torque is zero
- **C** it is at rest
- **D** it has no mass

3.2 A seesaw balances. The clockwise and anticlockwise torques are [1]

- **A** both zero
- **B** equal in size
- **C** unequal
- **D** in the same direction

3.3 A uniform beam pivots at its centre. A 50 N weight hangs 0.6 m to the left.

(a) Find the torque it produces. [2]

(b) A 30 N weight is placed on the right to balance it. Find its distance from the pivot. [2]

3.4 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. [1]

(b) Explain, using torque, why the plank would tip without extra support. [2]

4 Go further

You are ready for more on this subtopic:

- work through the interactive **5.5 Rotational Equilibrium and Newton's First Law in Rotational Form** lesson on the **Learn** page;
- read the **Torque and Rotational Dynamics** section of the AP Physics C: Mechanics handout on the **Know** page for the full explanation and worked diagrams.

Solutions

2.1 The net torque about any axis is zero.

2.2 $\tau = 30 \times 0.4 = 12$ N m.

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

2.4 40 N m.

3.1 B —the net torque is zero.

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

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

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