

1.5 Moments and equilibrium

Name: _____ Class: _____ Date: _____

Total: 16 marks

KEY WORDS moment • pivot • perpendicular distance
 • principle of moments • uniform

Objective

Build the skills to answer WPH11 questions on **moments** and **equilibrium**
 : compute the moment of a force about a pivot, apply the principle of moments to balanced objects, and use the centre of gravity of an extended body. This sheet covers Unit 1 statements 15–16.

You must be able to:

- calculate a moment as $\text{moment} = Fx$ with the **perpendicular distance**
- handle a force at an angle: the perpendicular component $F \sin \theta$, or the perpendicular distance
- state and apply the principle of moments for a body in equilibrium
- place the weight of a uniform body at its centre of gravity
- give **both** conditions for equilibrium: resultant force zero and resultant moment zero

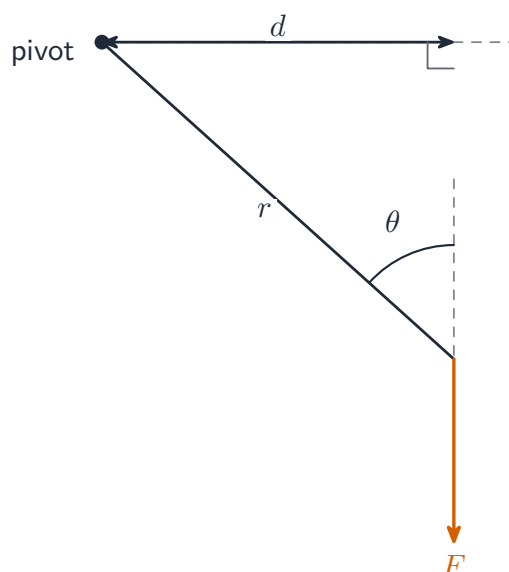
1 Key knowledge and worked examples

■ The moment of a force

The **moment of a force** about a pivot is the turning effect:

$$\text{moment} = Fx$$

where x is the perpendicular distance from the pivot to the force's **line of action**
 . Unit: N m.



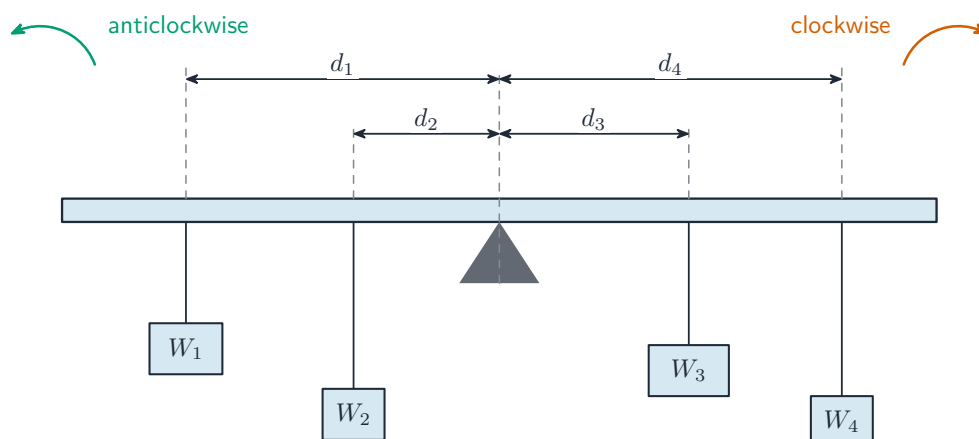
When the force is not perpendicular to the lever, use **either** the perpendicular component of the force ($F \sin \theta$ with the full length) **or** the perpendicular distance to the line of action – never both.

■ The principle of moments

For a body in equilibrium:

$$\text{total clockwise moment} = \text{total anticlockwise moment}$$

about any pivot. Equilibrium also needs the resultant force to be zero – a see-saw with equal children at equal distances satisfies both; move one child and the forces still balance but the moments do not, and the see-saw turns.



The weight of a **uniform** beam acts at its centre – its centre of gravity.

Worked example (angled forces, June 2025 Q19 style). A uniform gate of weight 120 N is 2.0 m wide and hinged at one side. A strut pushes up at the far end

with force S perpendicular to the gate. What is the smallest S that holds the gate horizontal?

- Known: $W = 120 \text{ N}$ at the centre ($x = 1.0 \text{ m}$); S perpendicular at 2.0 m . Why: just balanced, so the principle of moments about the hinge.

clockwise moment = anticlockwise moment

$$W \times x = S \times L$$

$$120 \text{ N} \times 1.0 \text{ m} = S \times 2.0 \text{ m} \quad \Rightarrow \quad S = \frac{120 \text{ N m}}{2.0 \text{ m}} = 60 \text{ N}$$

- Check: the weight acts at half the width, so half the weight at the far end balances it – 60 N is half of 120 N ✓.

■ Choosing the pivot

Take moments about a pivot that removes an unknown force: the force at the pivot has zero distance, so zero moment. This is why the hinge is the natural pivot in every gate, rail and see-saw question.

2 Practice

2.1 A force of 25 N acts perpendicular to a spanner 0.30 m from the pivot. Calculate the moment. [1]

2.2 The same force now acts at 50° to the spanner at the same point. Calculate the new moment. [2]

2.3 State the two conditions for an extended body to be in equilibrium. [2]

2.4 A uniform beam of weight 40 N and length 4.0 m balances on a pivot at its centre. A child of weight 300 N sits 1.5 m to the right of the pivot. Where must a second child of weight 400 N sit to balance the beam? [3]

3 Exam-style questions

3.1 Two children of equal weight sit on a see-saw at equal distances from the support. Which row describes the resultant force and the resultant moment on the beam? [1]

- ☐ **A** zero – zero
B zero – anticlockwise
C downwards – zero
D downwards – anticlockwise

3.2 A door handle is fitted 0.80 m from the hinges. Which change reduces the force needed to open the door? [1]

- ☐ **A** pushing nearer the hinges
B pushing at a smaller angle to the door
C pushing perpendicular to the door at the handle
D pushing with the same force at half the distance

3.3 A uniform metre rule of weight 1.2 N is suspended from a string at its 50 cm mark. A dish is hung at the 20 cm mark.

(a) State the principle of moments. [1]

(b) The rule balances horizontally with a dish of total weight 1.8 N at the 20 cm mark and a counterweight at the 85 cm mark. Calculate the weight of the counterweight. [3]

(c) The string is moved to the 60 cm mark. Explain, without further calculation, whether the rule can still balance with the dish at 20 cm and the counterweight at 85 cm . [2]

Solutions

2.1 $\text{moment} = Fx = 25 \text{ N} \times 0.30 \text{ m} = 7.5 \text{ N m}$.

2.2 Only the perpendicular component turns the spanner: $\text{moment} = F \sin \theta \times x = 25 \text{ N} \times \sin 50^\circ \times 0.30 \text{ m} = 5.7 \text{ N m}$.

2.3 Resultant force is zero and resultant moment about any point is zero.

2.4 The beam's weight acts at the pivot, so it has no moment. $300 \text{ N} \times 1.5 \text{ m} = 400 \text{ N} \times x$, so $x = \frac{450 \text{ N m}}{400 \text{ N}} = 1.1 \text{ m}$ to the left of the pivot.

3.1 A. Equal weights give zero resultant moment about the support, and the support's upward force balances both weights, so the resultant force is also zero. B and D keep a turning effect that symmetry removes; C forgets the support force.

3.2 C. For a fixed force, the moment is greatest when the force is perpendicular and the distance is greatest. A and D shrink the distance; B shrinks the perpendicular component.

3.3 (a) In equilibrium, the total clockwise moment equals the total anticlockwise moment. (b) About the string: the dish acts at 0.30 m; the counterweight at 0.35 m; the rule's weight has no moment. $1.8 \text{ N} \times 0.30 \text{ m} = W \times 0.35 \text{ m}$, so $W = \frac{0.54 \text{ N m}}{0.35 \text{ m}} = 1.5 \text{ N}$. (c) No: moving the string to 60 cm shortens the counterweight's distance to 0.25 m, so its moment falls below the dish's moment, and the rule tips towards the dish.