4.1 Moments, couples and torque

Name: _____ Class: _____ Date: _____ **Total: 31 marks**

KEY WORDS moment • couple • torque • line of action • perpendicular distance

Objective

Answer exam questions on the **turning effect of a force**: the **moment** of a force about a point, a **couple** and its **torque**. Syllabus 4.1, learning outcomes 2, 3 and 4.

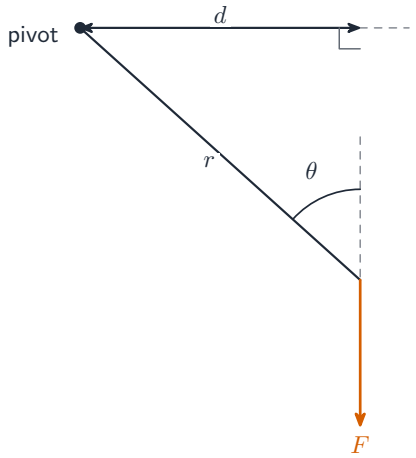
You must be able to:

- define the moment of a force and the torque of a couple in the examiner's words
- calculate a moment from the perpendicular distance to the line of action, and add moments with their sense, clockwise or anticlockwise
- decide whether two forces form a couple, and calculate its torque
- explain what a couple does to an object: it turns it, with no resultant force

1 Key knowledge and worked examples

■ Key knowledge: moments and couples

Quantity	Definition	Equation	Unit
moment of a force about a point	the force × the **perpendicular distance** from the point to the **line of action** of the force	$M = Fd$	N m
couple	a pair of forces, **equal** in size and **opposite** in direction, whose lines of action are **parallel but separated**	–	–
torque of a couple	**one** of the forces × the perpendicular distance **between** their lines of action	$\tau = Fd$	N m



The moment uses the perpendicular distance d from the pivot to the line of action

- a force whose line of action passes through the point has **zero** moment about it
- give every moment its sense about the point, clockwise or anticlockwise; resultant moment = total clockwise − total anticlockwise
- **principle of moments** (2 marks): for an object in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about the same point
- a couple has **zero resultant force**: it turns the object but does not accelerate it along
- the torque uses one force and the separation of the two lines: for forces at opposite ends of a wheel's diameter, d is the **diameter**
- two equal forces in the **same** direction, or two unequal forces, are **not** a couple
- the newton metre of a moment is not the joule: a moment is a force times a perpendicular distance, not a distance moved

■ Worked example: adding moments about a pivot

A beam is pivoted at its centre. Forces act downwards on it: 40 N at 1.5 m to the left of the pivot, and 25 N at 1.0 m and 30 N at 0.50 m to the right. Ignore the weight of the beam.

1. **Anticlockwise** – moment of a force, $M = Fd$: $M_{\text{acw}} = Fd = 40 \times 1.5 = 60$ N m.
2. **Clockwise** – add the moments of the two forces on the right: $M_{\text{cw}} = F_1 d_1 + F_2 d_2 = 25 \times 1.0 + 30 \times 0.50 = 40$ N m.
3. **Resultant moment** – the difference: $M_{\text{acw}} - M_{\text{cw}} = 60 - 40 = 20$ N m **anticlockwise**, so the left end goes down.

■ Worked example: a couple on a steering wheel

A driver turns a steering wheel of diameter 0.36 m with two tangential forces of 15 N at opposite ends of a diameter.

1. **Couple?** – the forces are equal, opposite and parallel, with separate lines of action: yes.
2. **Torque** – torque of a couple, $\tau = Fd$, with one force and d the diameter: $\tau = Fd = 15 \times 0.36 = 5.4$ N m.
3. **Resultant force** – the two forces are equal and opposite, so they add to zero: the wheel turns but its centre does not accelerate.

■ Worked example: a couple, or not?

Thruster A is 1.8 m left of a spacecraft's centre of gravity, pushing up with 50 N. Thruster C is 0.35 m above the centre, pushing left with 200 N.

1. About the centre, $M_A = F_A d_A = 50 \times 1.8 = 90$ N m clockwise.
2. $M_C = F_C d_C = 200 \times 0.35 = 70$ N m anticlockwise.
3. $M_{\text{net}} = M_A - M_C = 90 - 70 = 20$ N m clockwise.
4. This is not a couple: the forces are neither equal nor opposite/parallel, and there is a resultant force.

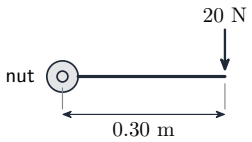
2 Practice

Now apply the methods above.

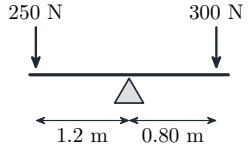
2.1 Define the **moment of a force** about a point. [2]

moment of a force

2.2 A force of 20 N acts at right angles to a spanner, 0.30 m from the nut. Calculate its moment about the nut. [2]



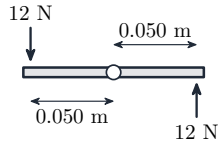
2.3 A see-saw is pivoted at its centre. A child of weight 250 N sits 1.2 m to the left of the pivot and a child of weight 300 N sits 0.80 m to the right. Calculate the resultant moment about the pivot, and state which way the see-saw starts to turn. [3]



2.4 State the **conditions** for two forces to form a couple. [2]

couple

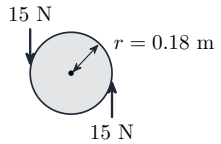
2.5 A tap handle is turned by two forces of 12 N, in opposite directions and at right angles to the handle, applied 0.050 m on either side of its axis. Calculate the torque of the couple. [2]



3 Exam-style questions

3.1 Two forces of 15 N act tangentially, in opposite directions, at opposite ends of a diameter of a wheel of **radius** 0.18 m. What is the torque of the couple? [1]

- ☐ **A** 2.7 N m
- ☐ **B** 5.4 N m
- ☐ **C** 11 N m
- ☐ **D** 83 N m



3.2 Which statement about a couple acting on an object is correct? [1]

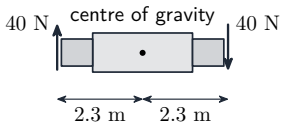
couple

- ☐ **A** It produces rotation only, because the resultant force is zero.
- ☐ **B** It produces a resultant force equal to twice one of the forces.
- ☐ **C** It accelerates the object in the direction of the larger force.
- ☐ **D** Its torque is the sum of the two forces multiplied by the distance between them.

3.3 A satellite uses two thrusters to turn. Each thruster exerts a force of 40 N on the satellite. The two forces are parallel, act in opposite directions, and each has a line of action 2.3 m from the centre of gravity of the satellite, on opposite sides.

(a) **Define** the torque of a couple. [2]

(b) Calculate the torque of the couple on the satellite. [2]



(c) State the resultant force on the satellite, and describe its motion while the thrusters fire. [2]

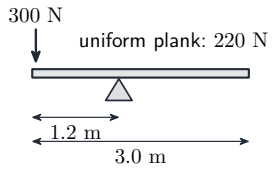
(d) One thruster stops. State and explain how the motion of the satellite changes. [2]

3.4 A uniform plank of weight 220 N and length 3.0 m rests on a pivot 1.2 m from its left-hand end. A child of weight 300 N stands on the left-hand end.

(a) State where the weight of the plank acts, and explain why. [2]

(b) Calculate the moment of the child's weight about the pivot. [2]

(c) Calculate the moment of the plank's weight about the pivot. [2]



(d) State whether the plank turns, and in which direction, explaining your answer. [2]

(e) A second child stands on the right-hand end. Calculate the smallest weight this child can have if the plank is not to turn anticlockwise. [2]