

## 5.3 Torque

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Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 16 marks

### Objective

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Build the skills to answer exam questions on **torque**.

**You must be able to:**

- calculate **torque** 力矩:  $\tau = rF \sin \theta$
- identify the **lever arm** 力臂 (perpendicular distance from the axis to the line of the force)
- explain how the angle and distance affect the turning effect
- add torques with signs (clockwise vs anticlockwise)

### 1 Worked examples

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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 torque formula

$$\tau = rF \sin \theta,$$

where  $r$  is the distance from the axis to where the force acts and  $\theta$  is the angle between  $\vec{r}$  and  $\vec{F}$ . A 10 N force at 0.5 m, perpendicular ( $\theta = 90^\circ$ ):  $\tau = 0.5 \times 10 \times 1 = 5 \text{ N m}$ .

#### ■ The lever arm

The perpendicular distance  $r \sin \theta$  is the lever arm. A force pushing straight toward or away from the axis ( $\theta = 0$ ) has zero lever arm and produces no torque.

#### ■ Balancing torques

Anticlockwise torques are usually taken positive, clockwise negative. Sum them to find the net turning effect.

### 2 Practice

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Now apply the methods above.

**2.1** A 20 N force acts perpendicular to a spanner 0.3 m from the bolt. Find the torque.[2]

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**2.2** State the torque when a force acts straight along the line toward the axis. [1]

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**2.3** Define the lever arm. [1]

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**2.4** A 50 N force acts at  $30^\circ$  to a 0.4 m arm. Find the torque. [2]

### 3 Exam-style questions

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**3.1** The torque of a force is greatest when the force acts [1]

- **A** along the arm toward the axis
  - **B** perpendicular to the arm
  - **C** at  $45^\circ$  to the arm
  - **D** at the axis
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**3.2** A force of 8 N acts at 0.25 m, perpendicular to the arm. The torque is [1]

- **A** 2 N m
  - **B** 32 N m
  - **C** 0.03 N m
  - **D** 8 N m
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**3.3** Two children sit on a seesaw. A 300 N child sits 1.5 m from the pivot.

(a) Find the torque this child produces. [2]

(b) State where a 450 N child must sit on the other side to balance it. [2]

**3.4** A 40 N force is applied to a door 0.8 m from the hinge, at  $60^\circ$  to the door.

(a) Find the torque about the hinge. [2]

(b) State how to increase the torque without changing the force. [1]

## 4 Go further

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You are ready for more on this subtopic:

- work through the interactive **5.3 Torque** 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

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**2.1**  $\tau = rF = 0.3 \times 20 = 6 \text{ N m}$ .

**2.2** Zero (the lever arm is zero).

**2.3** The perpendicular distance from the axis to the line of the force.

**2.4**  $\tau = rF \sin \theta = 0.4 \times 50 \times \sin 30^\circ = 10 \text{ N m}$ .

**3.1 B** —perpendicular gives the maximum torque.

**3.2 A** — $\tau = 0.25 \times 8 = 2 \text{ N m}$ .

**3.3** (a)  $\tau = 1.5 \times 300 = 450 \text{ N m}$ . (b)  $450 = 450 \times d \Rightarrow d = 1.0 \text{ m}$  from the pivot.

**3.4** (a)  $\tau = 0.8 \times 40 \times \sin 60^\circ = 27.7 \text{ N m}$ . (b) Apply it perpendicular to the door (or farther from the hinge).