Solutions

Each answer shows the steps, then the **result**.

2.1

- hang the card from a pin through a hole near its edge, so that it can swing **freely**, and hang a **plumb line** from the same pin
- mark the vertical line on the card, then repeat from a **second** hole well away from the first
- the centre of gravity is where the two lines **cross**; a third hole can be used as a check

2.2

- the perpendicular distance from the pivot to the line of action is $d = L\sin\theta$

$$d = 0.25\ \text{m} \times \sin 60^\circ = 0.217\ \text{m}$$

$$\text{moment} = Fd = 40\ \text{N} \times 0.217\ \text{m} = \mathbf{8.7}\ \text{N m}$$

2.3

- the component of F perpendicular to the spanner is $F\sin\theta = 40\ \text{N} \times \sin 60^\circ = 34.6\ \text{N}$

$$\text{moment} = 34.6\ \text{N} \times 0.25\ \text{m} = \mathbf{8.7}\ \text{N m}$$

- the two methods give the **same answer**, because both amount to $FL\sin\theta$

2.4

- its **line of action passes through the pivot**
- so the perpendicular distance from the pivot to that line is **zero**, and the moment Fd is zero

2.5

- the torque of a couple is **one of the forces** multiplied by the **perpendicular distance between the lines of action** of the two forces
- its unit is the **newton metre, N m**

3.1 B

- the moment is the force times the **perpendicular distance to the line of action**, which is $L\sin\theta$
- **A** assumes the force is perpendicular to the bar; **C** uses the component that acts **along** the bar, whose line of action passes through the pivot

3.2

(a)

- the two forces are **equal in magnitude** (15 N each) and **opposite in direction**
- their lines of action are **parallel but separated**, so they produce a turning effect with no resultant force

(b)

- use one force and the separation of the lines of action, which here is the **diameter**

$$\tau = Fd = 15\ \text{N} \times 0.36\ \text{m} = \mathbf{5.4}\ \text{N m}$$

(c)

- the resultant force is **zero**, because the forces are equal and opposite
- so the centre of the wheel does not accelerate: the wheel **rotates only**, without moving off its axis

3.3

(a)

- the weight acts at the **centre of gravity**, which for a **uniform** plank is at its **midpoint**, 1.5 m from either end
- the plank is uniform, so its mass is evenly distributed and the whole weight may be taken to act at that single point

(b)

- the child is at the left end, 1.2 m from the pivot

$$\text{moment} = 300\ \text{N} \times 1.2\ \text{m} = \mathbf{360}\ \text{N m}$$

, anticlockwise

(c)

- the centre of gravity is 1.5 m from the left end, so it is $1.5 - 1.2 = 0.3$ m to the **right** of the pivot

$$\text{moment} = 220\ \text{N} \times 0.3\ \text{m} = \mathbf{66}\ \text{N m}$$

, clockwise

(d)

- the plank **turns anticlockwise**, so the left-hand end goes down
- the child's moment, 360 N m, is much larger than the plank's 66 N m in the opposite sense, so the moments are not balanced

(e)

- the second child is at the right end, $3.0 - 1.2 = 1.8$ m from the pivot, and must supply the missing clockwise moment

$$W \times 1.8\ \text{m} + 66\ \text{N m} = 360\ \text{N m} \quad\Longrightarrow\quad W = \frac{294\ \text{N m}}{1.8\ \text{m}} = \mathbf{160}\ \text{N}$$