Torque & Rotational Equilibrium

Rotation · 8 questions · step-by-step answers at the end

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USEFUL EQUATIONS

$\tau = rF\sin\theta = r_\perp F \quad \Sigma\tau = 0,\ \Sigma \mathbf{F} = 0 \quad \alpha = \Sigma\tau / I \quad I = \Sigma m_i r_i^2$

Questions

Show your working in the space under each question.

1. You pull on a 0.25 m wrench with 80 N at 60° to the handle. What torque do you apply?

2. A 30 kg child sits 1.5 m to the left of a seesaw's pivot. Where should a 45 kg child sit to balance it?

3. An 80 N force is applied to the end of a 0.25 m wrench, first at 90° and then at 30° to the handle. Compare the torques.

4. A wheel speeds up from rest to 30 rad/s in 6.0 s at constant α. How many revolutions does it make?

5. A 2.0 kg mass sits at x = 0 and a 3.0 kg mass at x = 1.0 m. Where is the centre of mass?

6. Find I for a 2 kg, 1 m rod about an axis 0.25 m from its centre.

7. Why is a racing car built low and wide?

8. A 4 m, 10 kg beam is held horizontally by a hinge at the wall and a vertical cable at its far end. Find the cable tension.

Step-by-step answers

Torque & Rotational Equilibrium

1. $\tau = rF \sin\theta = (0.25)(80)(\sin 60°) \approx$ **17 N·m**.

2. 1. For balance, the clockwise and counter-clockwise torques must be equal.
2. Left child: $\tau = (30)(9.8)(1.5)$. Right child: $\tau = (45)(9.8)(x)$.
3. Set them equal: $30 \times 1.5 = 45x$, so $x =$ **1.0 m** to the right of the pivot.
4. The heavier child sits closer in, so that $m_1 r_1 = m_2 r_2$.

Answer: 1.0 m to the right of the pivot

3. **20 N·m** vs $20 \sin 30° =$ **10 N·m**.

4. $\alpha = 5$ rad/s²; $\theta = \frac{1}{2}(5)(36) = 90$ rad = **14.3 rev**.

5. $x_{cm} = (3.0 \times 1.0)/5.0 =$ **0.60 m**.

6. $I = (2)(1)^2/12 + 2(0.25)^2 = 0.167 + 0.125 =$ **0.29 kg·m²**.

7. A **low centre of mass** over a **wide base** means it must tilt a long way before the centre of mass passes the wheels, so it is hard to tip.

8. Torques about the hinge: $T(4) = 98(2)$, so T = **49 N**.