Torque Problem Types

A. Torque Balance – See Saw

Total Torque = 0 \rightarrow \text{clockwise torques = counterclockwise torques} \rightarrow \tau_{ccw} = \tau_{cw}

Where must a 50 N weight be placed to balance a 30 N weight located 2.0 m from the pivot point (fulcrum)?

Where must a 50 N weight be placed to balance a 30 N weight located 2.0 m from the pivot point (fulcrum)?

\tau_{ccw} = \tau_{cw}

General Relation

F_A \cdot r_A = F_B \cdot r_B

Specific Formula

Substitute

(50 \text{ N})(x) = (30 \text{ N})(2.0 \text{ m})

Solve

50x = 60

x = 1.2 \text{ m}

B. Bridge Question

Find the force of each support holding up a bridge, \(F_A\) and \(F_B\).

\[ F_A = 8000 \text{ N up} \]

\[ F_B = \tau_B / r_B = 5000 \text{ up} \]

\[ F_{\text{car}} = 5000 \text{ down} \]

\[ F_{\text{br}} = 8000 \text{ down} \]

General Strategy / Steps

1. Set the pivot point to one of the supports, \(A\)
   
   This will make the torque produced by \(F_A\) to be zero because the lever arm distance will be zero.

2. Calculate the torques for the known objects (car and bridge)

3. Solve for torque of \(B\), \(\tau_B\), knowing that torques must be balanced.

4. Solve for force of \(B\), \(F_B\), using torque

5. Solve for force of \(A\), \(F_A\), knowing that the vertical forces must be balanced

\[ F_{\text{up}} = F_{\text{down}} \]

\[ F_A + F_B = F_{\text{car}} + F_{\text{br}} \]

\[ F_A = F_{\text{car}} + F_{\text{br}} - F_B \]

Table

<table>
<thead>
<tr>
<th>Object</th>
<th>Force / N</th>
<th>Lever Arm / m (from B)</th>
<th>Torque / N m</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(\odot F_A = 8000 \text{ up})</td>
<td>(\odot r = 0)</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>(\odot F_B = \tau_B / r_B = 5000 \text{ up})</td>
<td>(25+15+10) = 50</td>
<td>25 000 ccw.</td>
</tr>
<tr>
<td>Car</td>
<td>(F_{\text{car}} = 5000 \text{ down})</td>
<td>10</td>
<td>(\odot \tau = F \cdot r = -50 000 \text{ cw})</td>
</tr>
<tr>
<td>Bridge</td>
<td>(F_{\text{br}} = 8000 \text{ down})</td>
<td>(\text{com} = 25)</td>
<td>(\odot \tau = F \cdot r = -200 000 \text{ cw})</td>
</tr>
<tr>
<td>Net</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
C. **EQUILIBRANT FORCE**

Determine the magnitude (value) and position of the force that is needed to bring equilibrium to a system.

Similar to Bridge Questions
1. Find the force needed, \( F_x \), to produce a net force of zero. \( F_{up} = F_{down} \)
2. Set a pivot point (anywhere, but keep it in place)
3. Calculate the known torques
4. Find the torque of X, using the total torque of zero. \( \tau_{cw} = \tau_{ccw} \)
5. Find the position, \( x \) of that force using torque ex.

![Diagram of forces and torques]

### Object | Force / N | Lever Arm / m (from B) | Torque / N m
--- | --- | --- | ---
A | −50 | 0 | 0
B | −40 | 50 | ③ −2000 cw
C | +120 | 65 | ③ +7800 ccw
X | ① −30 | \( x \) | ④ \( 30x = -5800 \) cw
 |  | \( x = 193 \) | 

Net | 0 | 0 | 0

\[ r_{\perp} = l \sin \theta \]

D. **SIGN / CRANE QUESTIONS**

Find the tension \( T \) on a wire or the weight \( F \) of an object that is hanging from a horizontal bar

* The wire is at an angle \( \theta \).

The lever arm is always the perpendicular line from the force toward the pivot point.

→ You must use trigonometry to determine the lever arm \( r \), using the angle \( \theta \) and the distance \( l \) from the wall (pivot point) where the wire is attached to the horizontal bar.

\[ \sin \theta = \frac{opp}{hyp} \]

\[ \sin \theta = \frac{r_{\perp}}{l} \]

\[ r_{\perp} = l \sin \theta \]
**E. Ladder Questions**

Find the lever arm and torque of a painter on a ladder that is leaning against a wall.

Find the force of friction between the floor and the ladder or the wall and the ladder.

Like the tension on the wire in sign/crane questions, the ladder is at an angle to a surface and the lever arm must be calculated using trigonometry.

In general, set the pivot point where the ladder touches the ground.

<table>
<thead>
<tr>
<th>Horizontal Forces</th>
<th>Vertical Forces</th>
<th>Torques</th>
<th>Lever Arm (base = pivot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{left} = F_{right}$</td>
<td>$F_{up} = F_{down}$</td>
<td>$\tau_{cw} = \tau_{cw}$</td>
<td>wall $r = l \sin \theta$</td>
</tr>
<tr>
<td>$F_{wall} = F_f$</td>
<td>$F_N = F_g\text{Ladder} + F_g\text{Painter}$</td>
<td>$\tau_{wall} = \tau_{\text{Ladder}} + \tau_{\text{Painter}}$</td>
<td>painter $r = l \cos \theta$</td>
</tr>
<tr>
<td>$F_W = F_{Gx}$</td>
<td>$F_{Gy} = mg + Mg$</td>
<td></td>
<td>ladder $r = l_{com} \cos \theta$</td>
</tr>
</tbody>
</table>