

10: Rotational Motion and Equilibrium

Key Physics Terms

- **Vector:** A quantity that represents magnitude (size) and direction. It is usually represented with an arrow to indicate its direction; arrow may be drawn to scale.
- **Vector Component:** The perpendicular parts into which a vector can be separated and that act in different directions from the vector.
- **Resultant:** The result of adding two or more vectors; vector sum.
- **Vector Addition:** The process of combining vectors; added tip to tail.
- **Force:** A vector quantity that tends to accelerate an object; a push or a pull.
- **Centripetal Force:** A center seeking force for an object
- **Linear Speed:** Straight path distance moved per unit of time, also referred to as tangential speed.
- **Rotational Speed:** Number of rotations or revolutions per unit of time, often measured in rpm, revolutions per minute.
- **Lever Arm:** The distance from the axis of rotation to the location where the force is applied.
- **Torque:** The rotational quantity that causes rotation; the product of force times lever arm.
- **Moment of Inertia:** A measure of the ease of rotating some object. The rotational equivalent of linear inertia.
- **Angular Momentum:** The tendency of an object to continue rotating. The rotational equivalent of linear momentum.
- **Rotational Equilibrium:** The situation when the net torque on an object equals zero.
- **Radian:** A unit of rotational displacement; one revolution equals 2π radians.

Variables Used

- v = velocity (usually average velocity or constant velocity)
- Δ = change in
- t = time
- θ = angular displacement
- r = radius
- l = lever arm
- Σ = sum over
- m = mass
- d = distance
- ω = angular speed
- α = angular acceleration
- T = torque
- I = moment of interial

Key Formulas

- Pythagorean Theorem: $c^2 = a^2 + b^2$
- $\sin \theta = \text{opp} / \text{hyp}$
- $\cos \theta = \text{adj} / \text{hyp}$
- $\tan \theta = \text{opp} / \text{adj}$
- $F_{\text{net}} = ma$
- $I = \Sigma mr^2$
- $L = I\omega$
- $T = Fl$

Linear motion formula	Rotational motion formula
$v = \frac{d}{t}$	$\omega = \frac{\Delta\theta}{\Delta t}$
$a = \frac{\Delta v}{\Delta t}$	$\alpha = \frac{\Delta\omega}{\Delta t}$
$d = v_i t + at^2/2$	$\theta = \omega_i t + \alpha t^2/2$
$v_f^2 = v_i^2 + 2ad$	$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

Key Metric Units

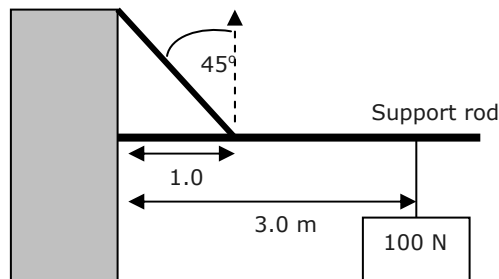
- Velocity: m/s
- Linear speed: m/s
- Rotational speed: revolutions per unit of time
- Linear Distance: meters, m
- Time: seconds, s
- Linear Acceleration: m/s^2
- Force: Newtons, N
- Torque: Nm
- Mass: kilograms, kg
- Moment of Inertia: $kg \cdot m^2$
- Angular displacement: radians
- Angular speed: radians/s
- Angular acceleration: radians/s/s
- Angular momentum: $kg \cdot m^2/s$

Rotational Motion Problem Solving Tips

- These tips will make it easier to solve any physics problems:
- Thoroughly read the entire problem.
 - Draw a diagram if needed. Identify all given information. Be sure to make diagrams or calculations with direction in mind.
 - Identify the quantity to be found.
 - Select appropriate formula(s) that incorporate what you know and what you want to find.
 - When calculating torque, be sure to only use the component of force that is perpendicular to the lever arm.
 - Convert units if needed. Use units throughout your calculations. For rotational problems, be sure to convert any angular measurements to radians.
 - Do any mathematical calculations carefully.

Typical Rotational Equilibrium Problem

Example: What is the minimum force needed in the cable to hold the sign in the diagram. Consider the mass of the support rod to be negligible.



For the sign to hang, the torques acting on it must be equal.

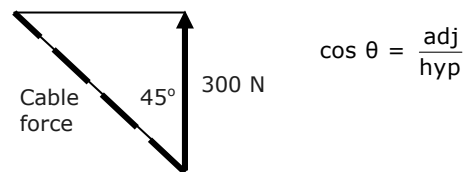
$$T_{\text{sign}} = T_{\text{cable}}$$

$$Fl_{\text{sign}} = Fl_{\text{cable}}$$

$$100 \text{ N} (3.0 \text{ m}) = F (1.0 \text{ m})$$

$$F_{\text{cable}} = 300 \text{ N}$$

This is only the upward force exerted by the cable which is at a 45 degree angle as shown.



$$\cos \theta = \frac{\text{adj}}{\text{hyp}}$$

$$\text{Cable force} = \text{hyp} = 300 \text{ N} / \cos 45^\circ = 424 \text{ N}$$

How to Use This Cheat Sheet: These are the keys related this topic. Try to read through it carefully twice then write it out on a blank sheet of paper. Review it again before the exams.