UNIT 7: TORQUE & ROTATIONAL MOTION

AP Physics

LEARNING OBJECTIVES – UNIT 7

- Explain the connections between rotational and linear motion
- Define and explain the relationships among:
  - Angular displacement (ΔØ)
  - Angular speed (ω)
  - Angular acceleration (α)
  - Torque (τ)
  - Rotational Inertia (I)

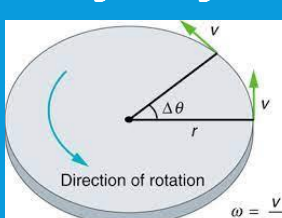
AP PHYSICS EQUATIONS

Linear Eqn

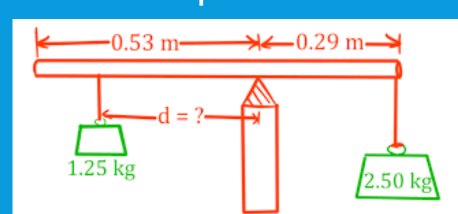
$\alpha = \frac{\Sigma\tau}{I} = \frac{\tau_{net}}{I}$	Angular Acceleration	$a = \frac{\Sigma F}{m} = \frac{F_{net}}{m}$
$\tau = rF = rF\sin\emptyset$	Torque	
$L = I\omega$	Angular Momentum	$p=mv$
$\Delta L = \tau\Delta t$	Change Angular Momentum	$\Delta p = F\Delta t$
$K = \frac{1}{2}I\omega^2$	Rotational Kinetic energy	$K = \frac{1}{2}mV^2$
$T = \frac{2\pi}{\omega} = \frac{1}{f}$	Period	

WHEN TO USE – ROTATIONAL MOTION & TORQUE

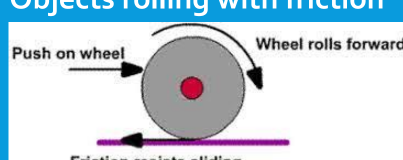
- Looking for angular acceleration of an object



Looking for balancing force on objects in rotational equilibrium



Objects rolling with friction



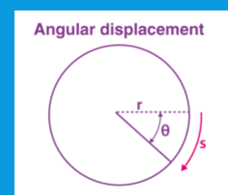
ROTATIONAL MOTION DEFINITIONS - REVIEW

Angular position (θ): The angle at which some object has been rotated relative to some reference position (equivalent to x in translational motion). Traditionally measured in radians.

Angular displacement ($\Delta\theta$): The difference between an object's initial and final angular positions; θ_f - θ_i; how far the object has been rotated (equivalent to Δx in translational motion). Measured in radians.

Angular displacement ($\Delta\theta$): When an object rotates, each point on that object travels through an arc. The length of that arc (Δs) is related to the angular displacement by:

$\Delta\theta = \Delta s/r$



Where r is the radius of that arc. We can consider Δs the distance that that point on the rotating object travels

ROTATIONAL MOTION RELATIONSHIPS - REVIEW

Average angular velocity(ω_{av}): The rate at which an object rotates over a given time period. $\omega_{av} = \Delta\theta/\Delta t$. (Equivalent to $\mathbf{v}_{av}$ in translational motion). Measured in rads/s.

Average angular acceleration (α_{av}): The rate of change of angular velocity over time. $\alpha_{av} = \Delta\omega/\Delta t$. (Equivalent to $\mathbf{a}_{av}$ in translational motion). Measured in rads/s^2.

Angular velocity(ω) and angular acceleration (α): Angular velocity & accel relate to linear velocity and accel in a similar way:

$\omega = v/r$

$\alpha = a/r$

Not on AP Eqn Sheet

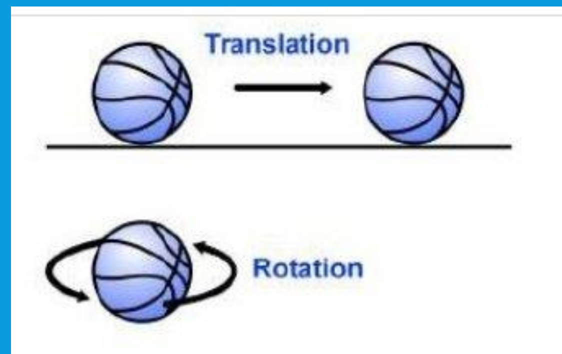
Angular kinematics: Our kinematic eqns from unit 1 have equivalent rotational versions:

$$\theta = \theta_0 + \omega_0 t + 1/2\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

ROTATIONAL MOTION RELATIONSHIPS - REVIEW

- **Translation** refers to the motion of the center of mass of a system (or object) from one point to another through space
- **Rotation** refers to the spinning motion of a system of connected objects (or extended objects)

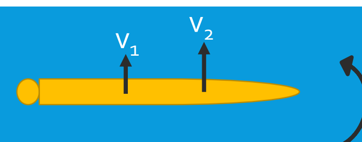


SPEED VS ANGULAR SPEED - REVIEW

A turbine blade is rotating at 25.0 rev/min. How fast (in m/s) is a point on the blade moving that is

a) V1 = ? @ 0.500 m form rotation axis

b) V2 = ? @ 1.00 m from rotation axis



We are given the angular speed in rev/min.
Need to convert this to rad/s

ω = 25.0 rev/min

$$\omega = \left(\frac{25.0\ rev}{min}\right)\left(\frac{2\pi\ rad}{1\ rev}\right)\left(\frac{1\ min}{60s}\right)$$

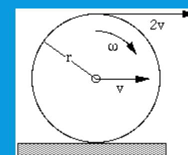
ω = 2.62 rad/s

Must be in rad/s to use that eqn: $V_1 = r_1\,\omega$

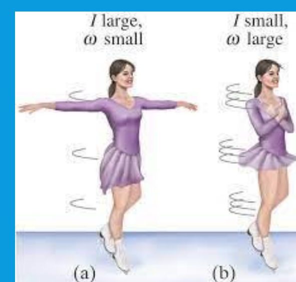
a) $V_1 = r_1\,\omega$
= (0.500m) (2.62 rad/s)
= 1.31 m/s

b) $V_2 = r_2\,\omega$
= (1.00m) (2.62 rad/s)
= 2.62 m/s

TYPES OF "OBJECTS" MODELS IN ROTATION

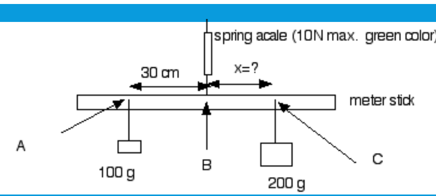


- **Object** – very point on it moves with the same velocity at all times
  - Objects can translate but not rotate
- **Rigid extended objects** – (also called **rigid bodies)** – maintain a constant shape, but rigid extended objects are able to rotate
  - Example – sphere, hoop, disk



- **Extended objects** – are not rigid and able to change their shape
- In AP Physics the term "object" is only used when you can model something as if all its mass were located at its center of mass and every point on it must move in the same way.
- In the "real" world the term *object* typically refers to things that can rotate and/or deform.

TORQUE - INTRO



Torque is a twist or turn that tends to produce rotation

Torque is defined as the tendency to produce a change in rotational motion

Torque is a force exerted at some distance perpendicular to a point of rotation

- If there is a net torque action on an object, that object will experience an angular acceleration (just like a net force causes linear acceleration)
  - The magnitude of angular acceleration depends on the net torque and rotational inertia of the object

TORQUE

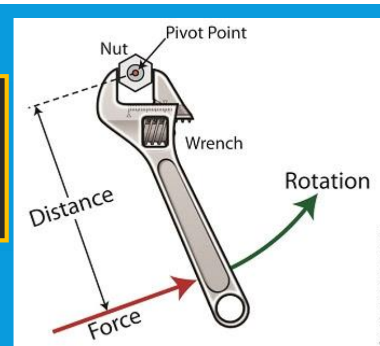
AP Eqn:

τ = rF = rFsinØ

Force perpendicular!!

Torque is determined by 3 Factors

- The magnitude of the applied force.
- The direction of the applied force.
- The location of the applied force.



The forces nearer the end of the wrench have greater torques.

Location of force