

Linear and angular analogs

Linear		Rotational
x	θ	position
Δx	$\Delta\theta$	displacement
v	ω	velocity
a	α	angular acceleration

Vector vs rotational motion

Use the right hand rule to determine direction of the vector!

Cross Product (rotational acceleration)

$\vec{a}_t = \vec{\omega} \times \vec{v} = r\omega^2$

Kinematic equations for angular and linear motion

Kinematic Equation 1

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

Kinematic Equation 2

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

Kinematic Equation 3

$v^2 = v_0^2 + 2a(\Delta x) = \omega^2 r^2$

$\omega^2 = \omega_0^2 + 2\alpha(\Delta\theta) = \alpha r$

Moment of Inertia

Moment of Inertia of mass

For point masses

$I = \sum mr^2$

I : rotational inertia (kg m²)

m : mass (kg)

r : radius of rotation (m)

For solid objects

$I = I_{cm} + Md^2$

Parallel Axis Theorem

$I = I_{cm} + Md^2$

I : rotational inertia about center of mass

M : mass

d : distance between axis of rotation and axis through center of mass

Kinetic Energy

$K_{trans} = \frac{1}{2}Mv_{cm}^2$

$K_{rot} = \frac{1}{2}I\omega^2$

$K_{total} = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}I\omega^2$

Rolling without slipping (near both ends)

$K = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}I\omega^2$

$v = \omega r$

$K = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}I_{cm}v_{cm}^2/R^2$

$K = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}I_{cm}\omega^2$

Torque

Torque is the rotational analog of force

A "torque" (influence) force is a push or pull

Torque is a vector

$\vec{\tau} = \vec{r} \times \vec{F}$

$\tau = rF \sin\theta$

r : moment arm length

F : force

θ : angle between moment arm and point of application of force

$\Delta\vec{L} = \vec{\tau} \Delta t$ (about $\Delta\theta = \omega\Delta t$)

τ : torque

L : rotational inertia

α : angular acceleration

Work in rotating systems

$W_{rot} = \tau \cdot \Delta\theta$ (about $W = F \cdot \Delta x$)

W_{rot} : work done in rotation

τ : torque

$\Delta\theta$: angular displacement

Power in rotating systems

$P_{rot} = \tau \cdot \omega$ (about $P = F \cdot v$)

P_{rot} : power expended

τ : torque

ω : angular velocity

Static Equilibrium

$\sum \vec{F} = 0$

$\sum \vec{\tau} = 0$

Angular momentum

For a particle

$\vec{L} = \vec{r} \times \vec{p}$

For a system of particles

$\vec{L} = \sum \vec{L}_i$

For a rigid body

$\vec{L} = I\vec{\omega}$ (about $P = mv$)

Conservation of Angular Momentum

Angular momentum of a system will not change unless an external torque is applied to the system.

$L_0 = L_f$

$I_0\omega_0 = I_f\omega_f$ (rigid body)

$\sum L_i = \sum L_f$ (a system of particles)

Angular momentum and torque

$\vec{\tau} = d\vec{L}/dt$ (about $P = dP/dt$)

τ : torque

L : angular momentum

t : time

Torque increases angular momentum when parallel

Torque decreases angular momentum when antiparallel

Torque changes the direction of the angular momentum vector in all other situations.

Precession

The rotating motion made by a spinning top or gyroscope

Precession is caused by the interaction of torque and angular momentum vectors

$\vec{\omega} = d\vec{L}/dt$

$\vec{\omega} = \vec{\tau} \times \vec{L}$

2004 Ap Physics B Multiple Choice Answer Key

Marcel A. Müller



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