

Chapter 9

Angular Velocity and Acceleration

Θ = angle (radians) s = length

r = radius $90^\circ = \pi/2$ rad

$\Theta = (s/r)$ $s = r \cdot \Theta$

$1 \text{ rad} = (360^\circ / 2\pi) = 57.3^\circ$ $180^\circ = \pi \text{ rad}$

Angular Velocity (1st Derivative)

$\omega = (\Theta_f - \Theta_i) / (t_f - t_i)$ ω = "velocity"

$1 \text{ rev/s} = 2\pi \text{ rad/s}$ $1 \text{ rev/min} = 1 \text{ rpm} = 2\pi/60 \text{ rad/s}$

Angular Acceleration (2nd Derivative)

$\alpha = (\omega_f - \omega_i) / (t_f - t_i)$ α = "acceleration"

Rotation w/ Constant Angular Acceleration

$\alpha_f = (\omega_f - \omega_i) / (t - 0)$ α_f = constant

$\omega_f = \omega_i + \alpha_f \cdot t$

$\Theta_f - \Theta_i = 1/2(\omega_i + \omega_f) \cdot t$

$\Theta_f = \Theta_i + (\omega_i \cdot t) + 1/2(\alpha_f \cdot t^2)$

$\omega_f^2 = \omega_i^2 + 2 \cdot \alpha_f(\Theta_f - \Theta_i)$

Relating Linear and Angular Kinematics $K = 1/2(m \cdot v^2)$

Linear Speed in Rigid-Body Rotation $s = r \cdot \Theta$

Linear Speed $v = r \cdot \omega$

Linear Acceleration in Rigid-Body Rotation $a_{tan} = r \cdot \alpha$

Centripetal Component of Acceleration $a_{rad} = (v^2/r) = \omega^2 \cdot r$

Energy in Rotational Motion $K_E: 1/2 \cdot m \cdot v^2 = 1/2 \cdot m \cdot r^2 \cdot \omega^2$

$K = 1/2 \cdot m \cdot r^2 \cdot \omega^2$ $I = m \cdot r^2$

Gravitational Potential Energy for an Extended Body $U = M \cdot g \cdot y_{cm}$

Chapter 9 (cont)

Moment of Inertia $I_p = I_{cm} + Md^2$

Chapter 9 Cont:

Rotational Kinetic Energy $K = \text{Joules}$

$K = 1/2 \cdot I \cdot \omega^2$ $R = \text{Radius}$

$M = \text{mass pivoted about an axis}$

Perpendicular to the Rod $I = (M \cdot L^2) / 3$

Slender Rod (Axis Center) $I = 1/12 M \cdot L^2$

Slender Rod (Axis End) $I = 1/3 M \cdot L^2$

Rectangular Plate (Axis Center) $I = 1/12 M \cdot (a^2 + b^2)$

Rectangular Plate (Axis End) $I = 1/3 M \cdot (a^2)$

Hollow Cylinder $I = 1/2 M(R_i^2 + R_f^2)$

Solid Cylinder $I = 1/2 MR^2$

Hollow Cylinder (Thin) $I = MR^2$

Solid Sphere $I = 2/5 MR^2$

Hollow Sphere (Thin) $I = 2/3 MR^2$

Chapter 11: Equilibrium and Elasticity

1st Condition of Equilibrium (at rest) $\Sigma F = 0$

2nd Condition of Equilibrium (nonrotating) $\Sigma \tau = 0$

Center of Gravity $r_{cm} = (m_1 \cdot r_1) / m_1$

Solving Rigid-Body Equilibrium Problems $\Sigma F_x = 0$

1st Condition $\Sigma F_x = 0$
 $\Sigma F_y = 0$

2nd Condition (Forces xy-plane) $\Sigma \tau_z = 0$

Chapter 11: Equilibrium and Elasticity (cont)

Stress, Strain, and Elastic Moduli
Stress = Force Applied to deform a body
Strain = how much deformation

Hooke's Law (Stress / Strain) = Elastic Modulus

A = Area $F = \text{Magnitude of Force}$

Tensile Stress F / A

1 Pascal = Pa = 1 N/m² $1 \text{ psi} = 6895 \text{ Pa}$

$l = \text{length}$ $1 \text{ Pa} = 1.450 \cdot 10^{-4}$

Tensile Strain $(l_f - l_i) / (l_i)$

Young Modulus (Tensile Stress) / (Tensile Strain)

Pressure $p = F (\text{Force Fluid is Applied}) / A (\text{Area which force is exerted})$

Bulk Stress $(p_f - p_i)$

Bulk Strain $(V_f - V_i) / (V_i)$

Bulk Modulus Bulk Stress / Bulk Strain

Chapter 10: Dynamics of Rotational Motion

Torque

$F = \text{Magnitude of } F$ $|| || = \text{Magnitude Symbol}$

$\tau = F \cdot l = r \cdot F \cdot \sin \Theta = F_{tan} r$ $L = \text{lever arm of } F$

$\tau = ||r|| \times ||F||$

Torque and Angular Acceleration for a Rigid Body

Newtons 2nd Law of Tangential Component $F_{tan} = m_1 \cdot a_1$

Rotational analog of Newton's second law for a rigid body

$\Sigma \tau_z = I \cdot \alpha_z$ $z = \text{rigid body about } z\text{-axis}$



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Published 1st December, 2021.

Last updated 1st December, 2021.

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Chapter 10: Dynamics of Rotational Motion (cont)

Combined Translation and Rotation: Energy Relationships

$$K = 1/2 M \cdot v^2 + 1/2 I \cdot \omega^2$$

Rolling without Slipping $v = R \cdot \omega$

Combined Translation and Rotation: Dynamics

Rotational Motion about the center of mass $\Sigma \tau_z = I \cdot \alpha_z$

Work and Power in Rotational Motion $F = M \cdot a$

When it rotates from Θ_i to Θ_f $W = \int_{\Theta_i}^{\Theta_f} \tau_f d\Theta$

When the torque remains constant while angle changes $W = \tau_f (\Theta_f - \Theta_i)$

Total Work Done on rotating rigid body $W = 1/2 (\omega_f^2 - \omega_i^2)$

Power due to torque on rigid body $P = \tau_z \cdot \omega_z$

Angular Momentum $L = r \times p (r \times m \cdot v)$

Angular Momentum of a Rigid Body $L = m_i \cdot r_i^2 \cdot \omega$

Chapter 11: Equilibrium and Elasticity (cont.)

F = Force acting tangent to the surface divided by the Area

Shear Stress F / A

h = transverse dimension x = relative displacement (empty) [smaller] [bigger]

Shear Strain x / h



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Published 1st December, 2021.
Last updated 1st December, 2021.
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