

### Chapter 9

#### Angular Velocity and Acceleration

$$\Theta = \text{angle (radians)} \quad s = \text{length}$$

$$r = \text{radius} \quad 90^\circ = \pi/2 \text{ rad}$$

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

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

#### Angular Velocity (1st Derivative)

$$\omega = (\Theta_f - \Theta_i) / (t_f - t_i) \quad \omega = \text{"velocity"}$$

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

#### Angular Acceleration (2nd Derivative)

$$\alpha = (\omega_f - \omega_i) / (t_f - t_i) \quad \alpha = \text{"acceleration"}$$

#### Rotation w/ Constant Angular Acceleration

$$\alpha_f = (\omega_f - \omega_i) / (t - 0) \quad \alpha_f = \text{constant}$$

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

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

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

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

#### 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

$$a_{\text{tan}} = r \cdot \alpha$$

#### Centripetal Component of Acceleration

$$a_{\text{rad}} = (v^2/r) = \omega^2 \cdot r$$

#### Energy in Rotational Motion

$$K_E: 1/2 \cdot m \cdot v^2 = 1/2 \cdot m \cdot r^2 \cdot \omega^2$$

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

#### Gravitational Potential Energy for an Extended Body

$$U = M \cdot g \cdot y_{\text{cm}}$$

### Chapter 9 (cont)

#### Moment of Inertia

$$I_p = I_{\text{cm}} + Md^2$$

### Chapter 9 Cont:

#### Rotational Kinetic Energy

$$K = \text{Joules}$$

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

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

#### 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)

$$I = 1/3 M \cdot (a^2)$$

#### Hallow 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

$$r_{\text{cm}} = (m_1 \cdot r_1) / m_1$$

#### Solving Rigid-Body Equilibrium Problems

$$\Sigma F_x = 0$$

$$1st \text{ Condition} \quad \Sigma F_x = 0$$

$$\Sigma F_y = 0$$

$$2nd \text{ Condition (Forces xy-plane)} \quad \Sigma \tau_z = 0$$

### 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

$$(\text{Stress} / \text{Strain}) = \text{Elastic Modulus}$$

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

#### Tensile Stress

$$F / A$$

$$1 \text{ Pascal} = \text{Pa} = 1 \text{ N/m}^2 \quad 1 \text{ psi} = 6895 \text{ Pa}$$

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

#### Tensile Strain

$$(l_f - l_i) / (l_i)$$

#### Young Modulus

$$(\text{Tensile Stress}) / (\text{Tensile Strain})$$

#### 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

$$\text{Bulk Stress} / \text{Bulk Strain}$$

### Chapter 10: Dynamics of Rotational Motion

#### Torque

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

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

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

#### Torque and Angular Acceleration for a Rigid Body

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

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

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



### Chapter 10: Dynamics of Rotational Motion (cont)

#### Combined Translation and Rotation: Energy Relationships

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

**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  $\Theta_i$  to  $\Theta_f$        $W = \int_{\Theta_i}^{\Theta_f} \tau_f d\Theta$

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

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

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

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

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 [bigger]       $x$  = relative displacement (empty) [smaller]

**Shear Strain**       $x / h$



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Page 2 of 2.

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