## Chapter 9

### Angular Velocity and Acceleration

| | |
|---|---|
| $\Theta$ = angle (radians) | s = length |
| r = radius | $90^o = \pi/2$ rad |
| $\Theta = (s/r)$ | $s = r \cdot \Theta$ |
| 1 rad = $(360^o / 2\pi)$ = 57.3$^o$ | $180^o = \pi$ rad |

### Angular Velocity

| | |
|---|---|
| | (1st Derivative) |
| $\omega = (\Theta_f - \Theta_i) / (t_f - t_i)$ | $\omega$ = "velocity" |
| 1 rev/s = $2\pi$ rad/s | 1 rev/min = 1 rpm = $2\pi/60$ rad/s |

### Angular Acceleration

| | |
|---|---|
| | (2nd Derivative) |
| $\alpha = (\omega_f - \omega_i) / (t_f - t_i)$ | $\alpha$ = "acceleration" |

### Rotation w/ Constant Angular Acceleration

| | |
|---|---|
| $\alpha_f = (\omega_f - \omega_i) / (t - 0)$ | $\alpha_f$ = 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 = Joules |
| $K = 1/2 \cdot I \cdot \omega^2$ | R = Radius |
| M = 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 | $r_{cm} = (m_1 \cdot r_1) / m_1$ |
| 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 = Magnitude of Force |
| Tensile Stress | F / A |
| 1 Pascal = Pa = 1 N/m$^2$ | 1 psi = 6895 Pa |
| I = length | 1 Pa = $1.450 \cdot 10^4$ |
| Tensile Strain | $(l_f - l_i) / (l_i)$ |
| Young Modulus | (Tensile Stress) / (Tensile Strain) |
| Pressure | p = F (Force Fluid is Applied) / A (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 = Magnitude of F | || || = Magnitude Symbol |
| $\tau = F \cdot l = r \cdot F \cdot \sin\Theta = F_{tan} r$ | L = 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 = rigid body about z-axis |

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

| | |
|---|---|
| **Combined Translation and Rotation: Energy Relationships** | |
| $K = 1/2 M \cdot v^2 + 1/2 \cdot I \cdot \omega^2$ | |
| **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 $\Theta_i$ to $\Theta_f$ | $W = \int (\Theta_f$ to $\Theta_i) \tau_f \, d\Theta$ |
| When the torque remains constant while angle changes | $W = \tau_f (\Theta_f$ to $\Theta_i)$ |
| Total WorkDone 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 | $L = r \times p \,(r \times m \cdot v)$ |
| 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 [bigger] | x = relative displacement (empty) [smaller] |
| **Shear Strain** | x / h |