

# Chapter 9 – Rotation and Rolling

## I. Rotational variables

- Angular position, displacement, velocity, acceleration

## II. Rotation with constant angular acceleration

## III. Relation between linear and angular variables

- Position, speed, acceleration

## IV. Kinetic energy of rotation

## V. Rotational inertia

## VI. Torque

## VII. Newton's second law for rotation

## VIII. Work and rotational kinetic energy

## IX. Rolling motion

# I. Rotational variables

**Rigid body:** body that can rotate with all its parts locked together and without shape changes.

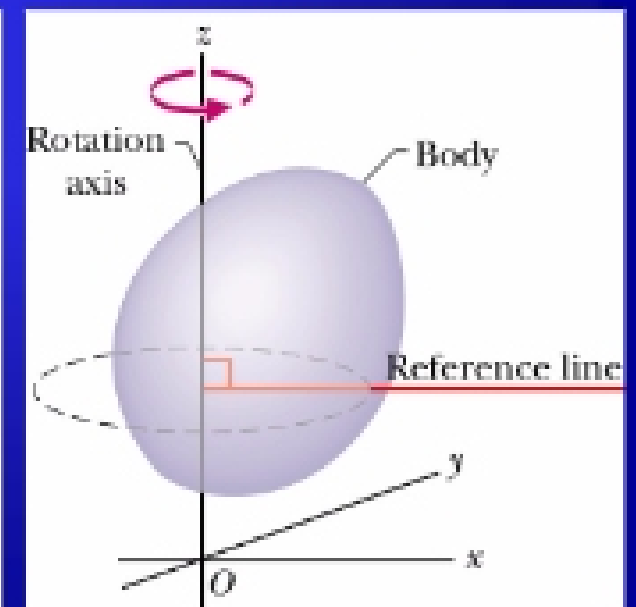
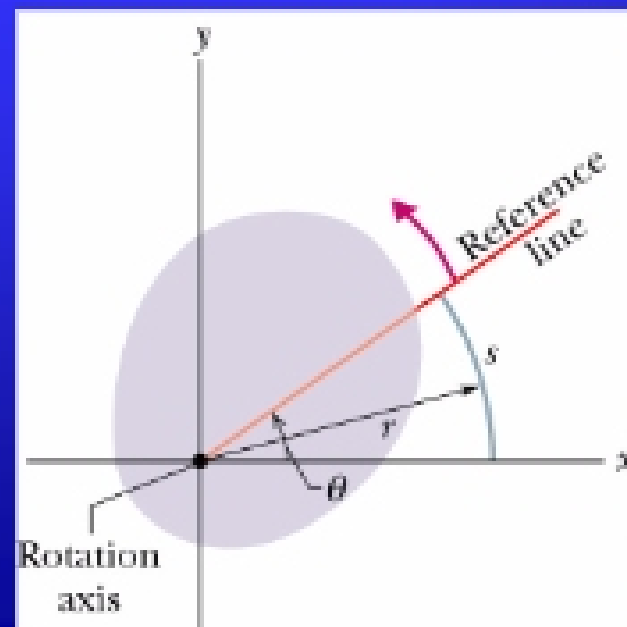
**Rotation axis:** every point of a body moves in a circle whose center lies on the rotation axis. Every point moves through the same angle during a particular time interval.

**Reference line:** fixed in the body, perpendicular to the rotation axis and rotating with the body.

**Angular position:** the angle of the reference line relative to the positive direction of the x-axis.

$$\theta = \frac{\text{arc length}}{\text{radius}} = \frac{s}{r}$$

**Units:** radians (rad)



$$1 \text{ rev} = 360^\circ = \frac{2\pi r}{r} = 2\pi \text{ rad}$$

$$1 \text{ rad} = 57.3^\circ = 0.159 \text{ rev}$$

**Note:** we do not reset  $\theta$  to zero with each complete rotation of the reference line about the rotation axis. 2 turns  $\rightarrow \theta = 4\pi$

**Translation:** body's movement described by  $x(t)$ .

**Rotation:** body's movement given by  $\theta(t)$  = angular position of the body's reference line as function of time.

**Angular displacement:** body's rotation about its axis changing the angular position from  $\theta_1$  to  $\theta_2$ .

$$\Delta\theta = \theta_2 - \theta_1$$

Clockwise rotation  $\rightarrow$  negative  
Counterclockwise rotation  $\rightarrow$  positive

**Angular velocity:**

**Average:**

$$\omega_{avg} = \frac{\theta_2 - \theta_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t}$$

**Instantaneous:**

$$\omega = \lim_{\Delta t \rightarrow 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$$

**Units:** rad/s or rev/s

