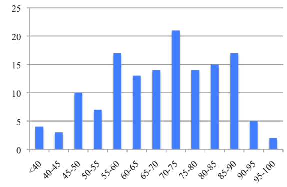
A rough guide to the translation from % grade to letter grade:

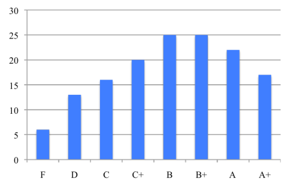


Winter 2015 data

Midterm $\bar{x} = 67\%$

Final $\bar{x} = 61\%$

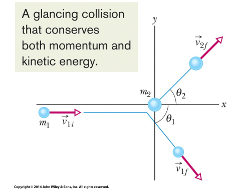
Overall $\bar{x} = 69 \pm 15\%$



Letter grade	Lower cutoff
A+	87.5
A	80
B+	72.5
B	65
C+	57.5
C	50
D	45

9-8 Collisions in Two Dimensions

- Apply the conservation of momentum along each axis
- Apply conservation of energy for elastic collisions



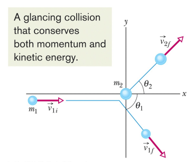
Example: For a stationary target:

- Along x: $m_1 v_{1i} = m_1 v_{1f} \cos\theta_1 + m_2 v_{2f} \cos\theta_2$
- Along y: $0 = -m_1 v_{1f} \sin\theta_1 + m_2 v_{2f} \sin\theta_2$
- Energy: $\frac{1}{2} m_1 v_{1i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$

- These 3 equations for a stationary target have 7 variables (3 speeds, 2 angles, 2 masses): if we know 4 of them we can solve for the remaining 3.
- Special case: $m_1 = m_2$

$$v_{1i}^2 = v_{1f}^2 + v_{2f}^2; \quad \therefore \vec{v}_{1f} \perp \vec{v}_{2f}$$

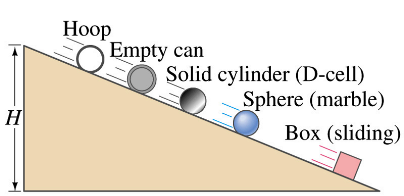
$$\therefore \theta_1 + \theta_2 = 90°$$



Chapter 10

Rotation

Which is fastest?



Does it depend on:
- mass? ✗ no
- width? ✗ no
- radius? ✗ no
- geometrical shape? ✓ yes

10.1 The Rotational Variables

A **rigid body** is a body that can rotate with all its parts locked together and without any change in its shape.

A **fixed axis** means that the rotation occurs about an axis that does not move.

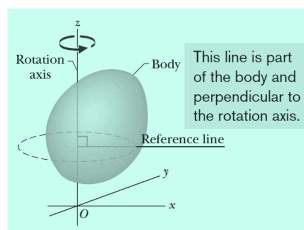
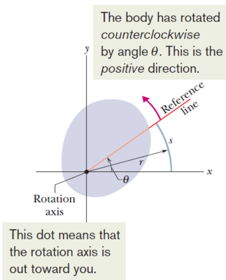


Fig. 10-2 A rigid body of arbitrary shape in pure rotation about the z axis of a coordinate system. The position of the *reference line* with respect to the rigid body is arbitrary, but it is perpendicular to the rotation axis. It is fixed in the body and rotates with the body.

10.1 The Rotational Variables: Angular Position



- For any point a distance r from the rotation axis

$$\theta = \frac{s}{r} \quad \text{radian measure}$$

- s is **arclength** along circle of radius r
- θ measured in **radians (rad)** wrt the positive x-axis

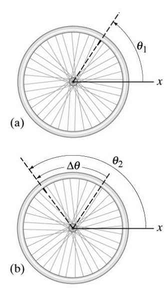
$$1 \text{ rev} = 360^\circ = \frac{2\pi r}{r} = 2\pi \text{ rad}$$
$$1 \text{ rad} = 57.3^\circ = 0.159 \text{ rev}$$

We **don't** reset θ to 0 when it passes through 2π. (Why?)

Velocity

- Average velocity $$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$
- Instantaneous velocity $$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Angular Displacement



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

An angular displacement in the counterclockwise direction is positive, and one in the clockwise direction is negative.

Angular Velocity

- Average angular velocity $$\omega_{avg} = \frac{\Delta\theta}{\Delta t} = \frac{\theta_2 - \theta_1}{t_2 - t_1}$$
- Instantaneous angular velocity $$\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$$

ω in units of rad/s

Frequency vs. angular velocity

- **Frequency** f
  - cycles per time interval
  - revolutions per time interval
  - units of Hertz (1 Hz = 1 rev/s)
- **Period** $T = 1/f$
  - time interval per revolution
  - units of s
- **Angular velocity** ω
  - radians per time interval
  - sometimes called angular frequency
  - units of rad/s

$$f \times \left(\frac{2\pi \text{ rad}}{\text{rev}}\right) = \omega$$
$$\therefore \omega = 2\pi f = \frac{2\pi}{T}$$

Acceleration

- Average acceleration $$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$
- Instantaneous acceleration $$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2 x}{dt^2}$$

Angular Acceleration

- Average angular acceleration $\alpha_{avg} = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$

- Instantaneous angular acceleration $\alpha = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$

α in units of rad/s^2

10.2: Rotation with Constant Angular Acceleration

Translation Table:

$$x \Leftrightarrow \theta$$

$$v \Leftrightarrow \omega$$

$$a \Leftrightarrow \alpha$$

TABLE 10-1

Equations of Motion for Constant Linear Acceleration and for Constant Angular Acceleration

Equation Number	Linear Equation	Missing Variable		Angular Equation
(2-11)	$v = v_0 + at$	$x - x_0$	$\theta - \theta_0$	$\omega = \omega_0 + \alpha t$
(2-15)	$x - x_0 = v_0 t + \frac{1}{2}at^2$	v	ω	$\theta - \theta_0 = \omega_0 t + \frac{1}{2}\alpha t^2$
(2-16)	$v^2 = v_0^2 + 2a(x - x_0)$	t	t	$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

Example 1

A record player is spinning at 33.3 rpm.

The motor is shut off, and the record player spins down and stops in 20 seconds (assume constant deceleration).

(a) What is the angular acceleration?

(b) How far does it turn during this spin down?