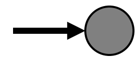
Summary

Phenomena → Motion 

Parameters to describe the motion →

Linear motion:

- **Position: x, y, z**
- **Velocity: v**
- **Acceleration: a**
- **Mass: m**
- **Force: F**
- **Linear momentum: $P = m * v$**
- **Kinetic Energy: $E_k = ½ m * V^2$**
- **Potential: E_p (conservative forces)**

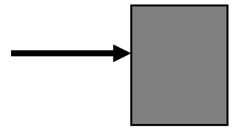
Newton's 2^{nd} Law → **Linear motion: $F = m * a$**

→ **If the forces are conservative:**

$E_k + E_p = E_k' + E_p' = \text{Constant}$

Phenomena

Motion



Parameters to describe the motion

The Center of Mass:

$$r_{cm} = (\sum m_i * r_i) / \sum m_i$$

Linear motion of the Center of Mass

$x_{cm}, \; y_{cm}, \; z_{cm}$

v_{cm}, a_{cm}

Linear Kinetic Energy:

$$E_k = ½ \, m * v_{cm}^2$$

Rotation around the Center of Mass:

Angle: θ

Angular velocity: ω

Angular acceleration: α

Moment of Inertia: $I = \sum m_i * r_i^2$

Torque: $T = r * \sin\varphi * F$

Angular Momentum: $L = I * \omega$

Rotational Kinetic Energy:

$$E_k = ½ \, I * \omega^2$$

Laws

Linear motion of the center of mass:

$$F = m * a_{cm}$$

Rotation around Center of Mass:

$$T = I * \alpha$$

If the forces are conservative:

$$E_{kl} + E_{kr} + E_p = E_k' + E_{kr}' + E_p' = \text{Const.}$$

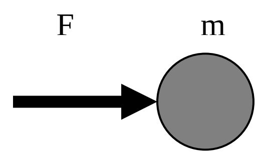
A Brief Review

Newton's laws

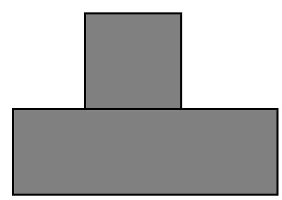
One particle & one force

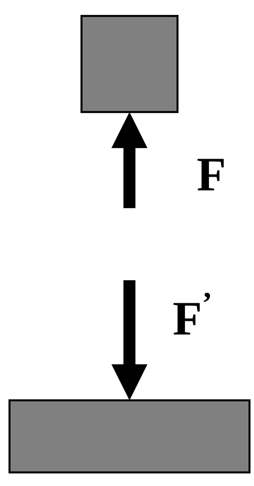
1st: if F = 0, then v = const.

2nd: F = m * a



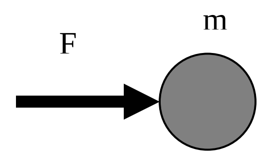
3rd: F = F'





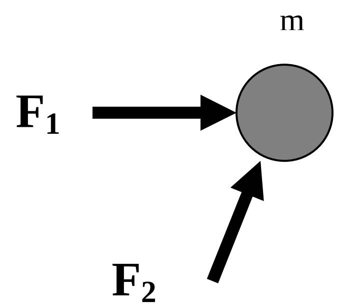
One particle, one force

$$F = m * a$$



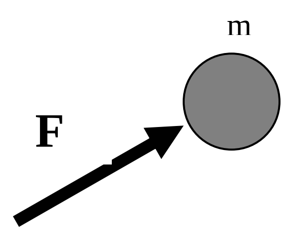
One particle, many forces

$$F = \Sigma F_i = m * a$$

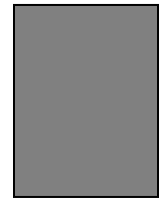


$$F = F_1 + F_2$$

$$F = m * a$$



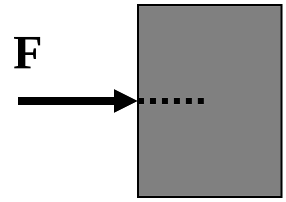
One object



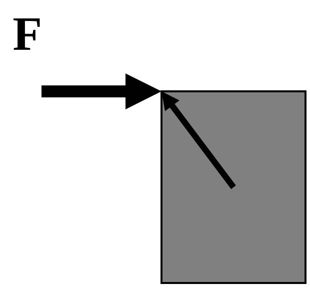
Center of mass:

$$r_{cm} = (\Sigma\, m_i * r_i) / (\Sigma\, m_i)$$

$$F = m * a_{cm}$$



Only linear motion



$$F = m * a_{cm}$$
$$T = I_{cm} * \alpha_{cm}$$

Linear motion & rotation

Torque: $T = r * F * \sin\varphi$ ⇨ **Rotation**

Rotation:

Parameters to describe rotation:

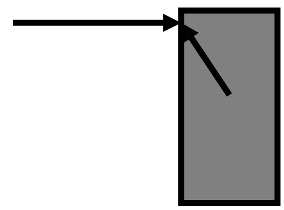
θ, ω, α

Angular momentum $L = I * \omega$

$T = r * F * \sin\theta$

$= r * (F * \sin\theta)$

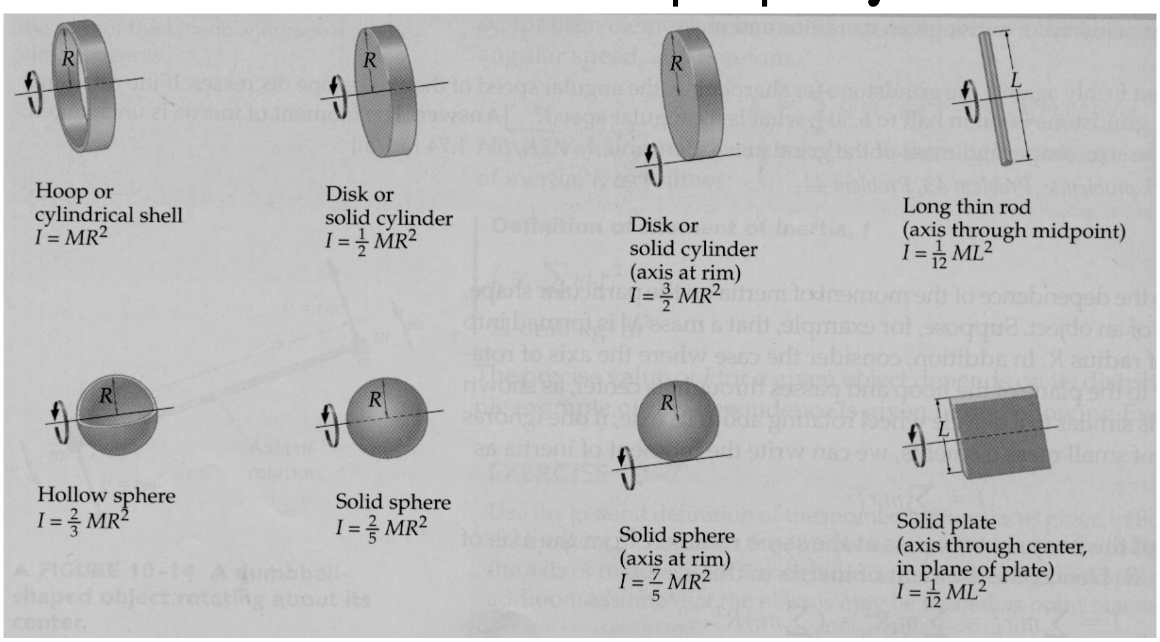
$= (r * \sin\theta) * F$



Law: **$T = I * \alpha$**

T & I ~ r

Moment of Inertia: $I = \Sigma\, m_i * r_i^2 = \int r^2\, dm$



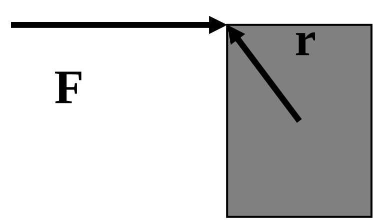
We separate the motion of an object into parts:

linear motion of center of mass: r_{cm}
&
rotation around the center of mass: θ_{cm}

Also

Use the torque relative to the center of mass

$T = r * F * \sin \varphi$

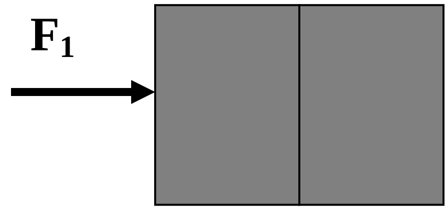


Law: $F = m * a_{cm}$

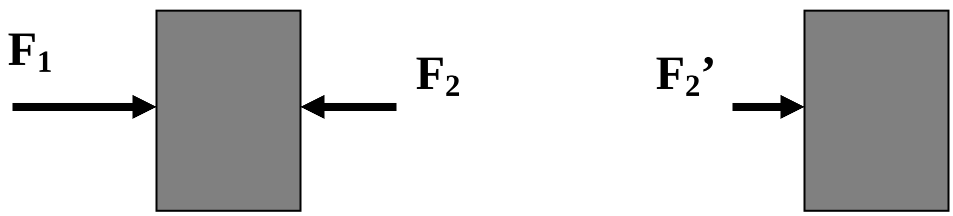
& $T = I_{cm} * \alpha$

$Ek = E_{kcm} + E_{krcm}$

Many body problems



Free body diagram



Energy conservation
(Only if the forces are conservative,
or the nonconservative forces are not doing work)

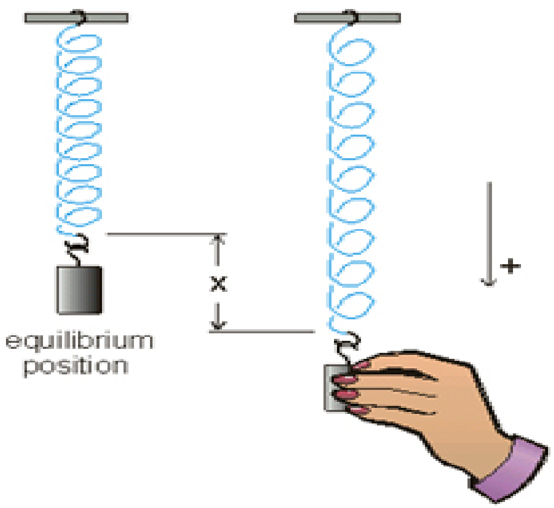
$$E_{kl} + E_{kr} + E_p \quad = \quad E_k' + E_{kr}' + E_p'$$

Position 1 Position 2

Oscillation

Oscillation: motion of an object; x, v, a, t, T, f, ω

Simple harmonic motion:



$$x = A \cos(\omega * t)$$

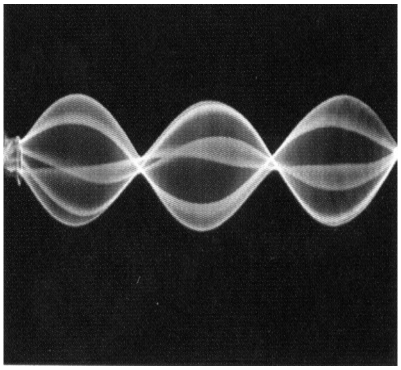
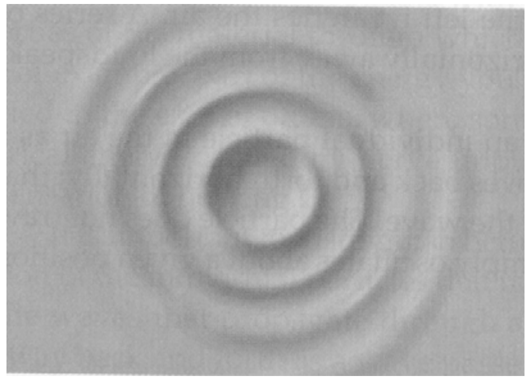
$$= A \cos(2\pi * t / T) = A \cos(2\pi * f * t)$$

$$v = - A * \omega * \sin(\omega * t)$$

$$a = - A * \omega^2 * \cos(\omega * t) = - \omega^2 * x$$

Waves:

Oscillation of many objects; y, x, t, T, λ, f, ω, V, k

$$y = A \cos [(k * x) - (\omega * t)]$$

$$= A \cos 2\pi [(x / \lambda) - (t / T)]$$

$$= A \cos \omega (x / v - t)$$

$$= A \cos k * (x - v * t)$$

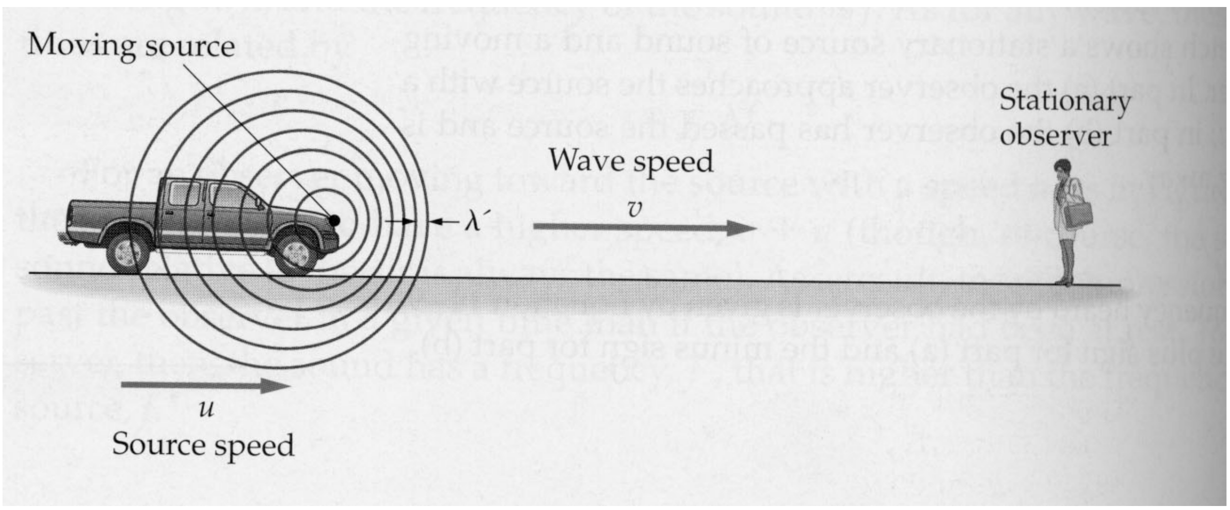
Because: $\cos \alpha = \cos (- \alpha)$

$$y = A \cos [(\omega * t) - (k * x)]$$

Doppler effect of sound:

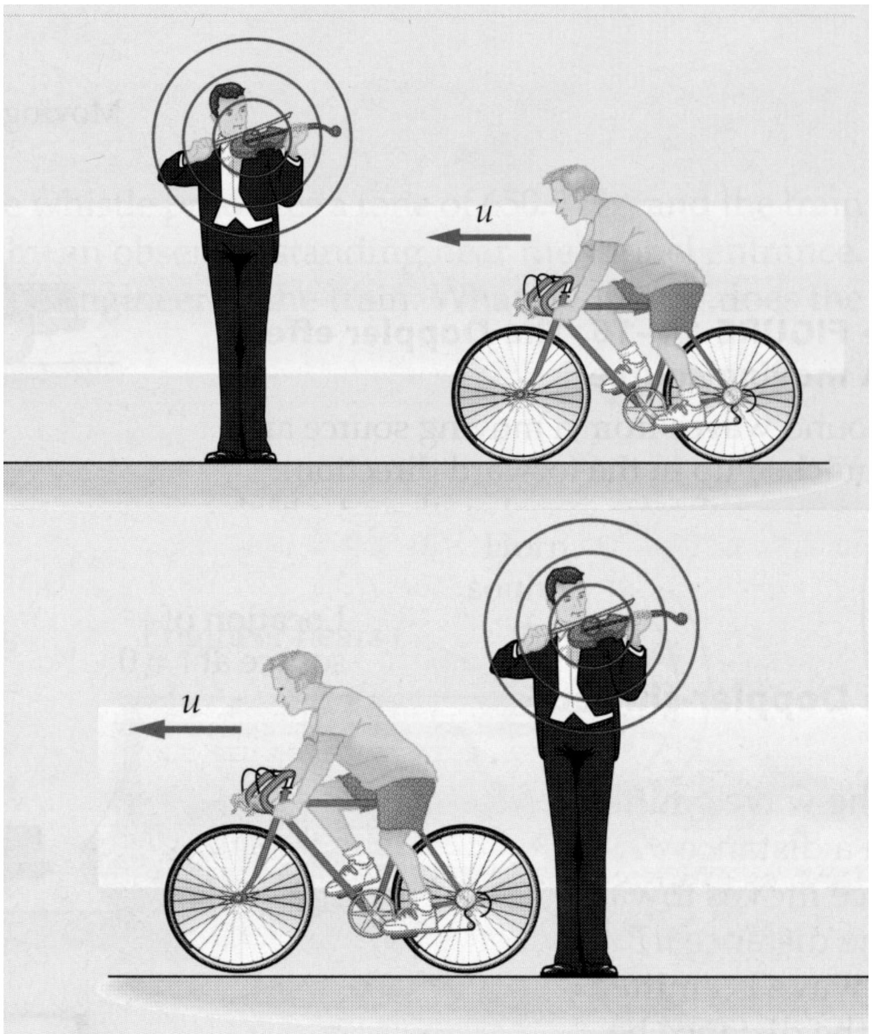
Doppler Effect for Moving Source

$$f' = \left(\frac{1}{1 \mp u/v}\right) f$$



Doppler Effect for Moving Observer

$$f' = (1 \pm u/v)f$$



Doppler Effect for Moving Source and Observer

$$f' = \left(\frac{1 \pm u_o/v}{1 \mp u_s/v}\right) f$$

General steps of solving problems

Understand the description of the problem.

Draw a diagram if possible

Find out what physics principles should be used to solve the problem (key step)

Write down the formula

Mathematical derivations (symbolic)

Plug in the data and get the results.