## Constants and Units

k = $10^3$, μ = $10^{-6}$, n = $10^{-9}$ $c = 3.0\times10^8$ m/s $g = 9.80$ m/s$^2$

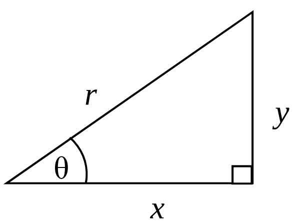
## Mathematics

Quadratic equation:

$$ax^2 + bx + c = 0$$
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Trigonometry

$$x^2 + y^2 = r^2$$




$$\sin\theta = y / r$$
$$\cos\theta = x/r$$
$$\tan\theta = y/x$$
$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

Calculus:

$$\frac{d}{dt}(a \cdot t^n) = a \cdot nt^{n-1}$$
$$\int x^n dx = \frac{x^{n+1}}{n+1}$$

## Translational Kinematics

Three dimensions:

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

$$\vec{v}_{av} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} \qquad v = \lim_{\Delta t \to 0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

$$\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} \qquad \vec{a} = \lim_{\Delta t \to 0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{v}}{dt}$$

One dimension:

$$v_{x,av} = \frac{\Delta x}{\Delta t} \qquad v_x = \lim_{\Delta t \to 0}\frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

$$a_{x,av} = \frac{\Delta v_x}{\Delta t} \qquad a_x = \lim_{\Delta t \to 0}\frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt}$$

Constant acceleration in one dimension:

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$
$$v_x = v_{0x} + a_x t$$
$$v^2{}_x = v^2{}_{0x} + 2a_x(x - x_0)$$

Uniform circular motion:

$$a = \frac{v^2}{r}$$

## Particle Dynamics

$$f_s \le \mu_s N, \quad f_k = \mu_k N$$

$N$ = normal force

## Relative Motion

$\vec{v}_{PA} = \vec{v}_{PB} + \vec{v}_{BA}$ (*PA* means *P* relative to *A*, etc.)

## Work, Kinetic Energy, Potential Energy

$$W = \vec{F}\cdot\vec{s} \qquad W = \int_A^B \vec{F}\cdot d\vec{s}$$

$$\Sigma\vec{F} = m\vec{a}$$

$$W = mg \qquad \vec{A}\cdot\vec{B} = |\vec{A}|\,|\vec{B}|\cos\theta$$

$$K = \frac{1}{2}mv^2$$

$$W = \Delta K = K_f - K_i \qquad E = K + U$$

$$\Delta E = E_f - E_i = W_{nc}$$

$$U_s = \frac{1}{2}kx^2 \qquad F_x = -kx$$

(spring)

$$U_g = mgy$$ (gravity)

$$\text{Power} = \frac{dW}{dt} = \vec{F}\cdot\vec{v}$$

## Momentum and Collisions

$$\vec{p} = m\vec{v} \qquad \vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{J} \equiv \int \vec{F}\, dt = \vec{F}_{av}\Delta t = \Delta\vec{p}$$ (impulse)

$$\vec{r}_{cm} = \frac{1}{M}\sum_i m_i\vec{r}_i \qquad \vec{v}_{cm} = \frac{1}{M}\sum_i m_i\vec{v}_i$$

$$\vec{P} = \sum_i \vec{p}_i = \sum_i m_i\vec{v}_i = M\vec{v}_{cm} \qquad \vec{F}_{ext} = \frac{d\vec{P}}{dt}$$

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

(conservation of momentum)

$$\frac{1}{2}m_1 v_{1i}^2 + \frac{1}{2}m_2 v_{2i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2$$

(elastic collision)

## Rotational Kinematics

$$\omega = \frac{d\theta}{dt} \qquad \alpha = \frac{d\omega}{dt}$$

$$\mathrm{v} = \omega r \qquad a_T = \alpha r \qquad a_R = \frac{\mathrm{v}^2}{r} = \omega^2 r$$

$$\left.\begin{aligned} \theta &= \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \\ \omega &= \omega_0 + \alpha t \\ \omega^2 &= \omega_0^2 + 2\alpha(\theta - \theta_0) \end{aligned}\right\} \text{constant acceleration } \alpha$$

## Torque and Angular Momentum

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{\ell} = \vec{r} \times \vec{p}$$

$$\vec{\tau} = \frac{d\vec{\ell}}{dt}$$

$$\left|\vec{A} \times \vec{B}\right| = \left|\vec{A}\right| \left|\vec{B}\right| \sin\theta$$

$$\left.\begin{aligned} L &= I\omega \\ \tau &= I\alpha \\ I &= \sum_i m_i r_i^2 \end{aligned}\right\} \text{(rotating rigid object)}$$

## Special Relativity

$$\left.\begin{aligned} x' &= \gamma(x - \mathrm{v}t) \\ y' &= y \\ z' &= z \\ t' &= \gamma(t - \mathrm{v}x/c^2) \end{aligned}\right\} \text{Lorentz transformation} \quad \left(\gamma = \frac{1}{\sqrt{1 - \frac{\mathrm{v}^2}{c^2}}}\right)$$

$$L = L_0/\gamma \qquad \Delta t = \gamma \Delta t_0$$

Relative velocity formula for motion in one dimension:

$$u = \frac{u' + \mathrm{v}}{\left(1 + \frac{\mathrm{v}u'}{c^2}\right)}$$

Energy and momentum:

$m$ = rest mass

$$\vec{p} = \gamma m \vec{\mathrm{v}}$$

$$E = K + mc^2 = \gamma mc^2$$

$$E^2 = c^2 p^2 + m^2 c^4$$