$10^9$ *giga* – $G$
$10^6$ *mega* – $M$
$10^3$ *kilo* – $k$
$10^2$ *hecto* – $h$
$10^1$ *deka* – $da$

$10^{-2}$ *centi* – $c$
$10^{-3}$ *milli* – $m$
$10^{-6}$ *micro* – $\mu$
$10^{-9}$ *nano* – $n$
$10^{-12}$ *pico* – $p$

$1\,N = 1\,kg \cdot m/s^2$

$1\,J = 1\,kg \cdot \frac{m}{s^2} m = 1\,N \cdot m$

$1\,watt = 1\,W = 1\,J/s$

$1\,g = 9.8 \frac{m}{s^2}$ ($g$ *unit*)

A=cB → ΔA=|c|ΔB,

$A=B^n \rightarrow \Delta A = A|n|\,\Delta B/B$,

C=A+-B→ $\Delta C = \sqrt{(\Delta A^2 + \Delta B^2)}$,

C=A*/B→ $\Delta C = |C|\sqrt{((\Delta A/A)^2 + (\Delta B/B)^2)}$

---

$\Delta\vec{x} = \vec{x_2} - \vec{x_1}$

$\vec{v}_{avg} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x_2} - \vec{x_1}}{t_2 - t_1}$

$\vec{v}_{ins} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$

$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v_2} - \vec{v_1}}{t_2 - t_1}$

$\vec{a}_{ins} = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$

$v = v_0 + at$

$x - x_0 = v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$v_0 = v_{0x} i + v_{0y} j$

$v_{0x} = v_0 \cos\theta_0$

$v_{0y} = v_0 \sin\theta_0$

$x - x_0 = v_{0x} t$

$x - x_0 = \frac{v_0^2}{g} \sin 2\theta_0$

$y - y_0 = v_{0y} t - \frac{1}{2} g t^2$

$y = (\tan\theta_0)x - \frac{g\,x^2}{2\,(v_0 \cos\theta_0)^2}$

---

$v_y^2 = (v_0 \sin\theta_0)^2 - 2g(y - y_0)$

$v_y = v_0 \sin\theta_0 - gt$

$\Delta\vec{r} = \vec{r_2} - \vec{r_1}$,

$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r_2} - \vec{r_1}}{t_2 - t_1}$

$\vec{v}_{ins} = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$

$\vec{a}_{ins} = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dr}{dt}\right) = \frac{d^2r}{dt^2}$

---

$\vec{s} = \vec{a} + \vec{b}$

(*commutative law*)

$\vec{a} + \vec{b} = \vec{b} + \vec{a}$

(*associative law*)

$(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$

*vector substraction*

$\vec{d} = \vec{a} - \vec{b} = \vec{a} + (-\vec{b})$

$\vec{a} = a_x i + a_y j$

$\vec{b} = a_x i + a_y j$

$a_x = a\,\cos\theta$

$a_y = a\,\sin\theta$

$a = \sqrt{a_x^2 + a_y^2}$

$\tan\theta = \frac{a_y}{a_x}$

$\vec{a} \cdot \vec{b} = ab\,\cos\phi$

$\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$

$\vec{a} \times \vec{b} = ab\,\sin\phi$

$\vec{a} \times \vec{b} = (a_y b_z - b_y a_z)i + (a_z b_x - b_z a_x)j + (a_x b_y - b_x a_y)k$

---

$F_{net,x} = ma_x,\ F_{net,y} = ma_y, F_{net,z} = ma_z$

$W = F_g = mg, \quad f_{s,max} = \mu_s F_N, \quad f_k = kF_N,$

*weight* $W$, *normal force* $F_N$, *frictional force* $f$

$D = \frac{1}{2} C\rho A v^2, \quad v_t = \sqrt{\frac{2F_g}{C\rho A}}$

$\vec{F}_s = -k\vec{d}, F_x = -kx$

$W = \vec{f}\vec{d}$

$W = \sum \Delta w_j = \sum F_{j,avg} \Delta x$

$W = \int_{xi}^{xf} F(x)dx$

$W = \Delta K = K_f - K_i$

$K = \frac{1}{2} m v^2$

$W_g = mgd\,\cos\phi$

$W_s = -\frac{1}{2} k\,x^2$

---

$P_{avg} = \frac{W}{\Delta t}, P = \frac{dW}{dt}$

$P_{avg} = \frac{\Delta E}{\Delta t}, P = \frac{dE}{dt}$

$P = \vec{F} \cdot \vec{v}$

$\Delta U = -\int_{xi}^{xf} F(x)dx$

$\Delta U = \frac{1}{2} k x_f^2 - \frac{1}{2} k\,x_i^2$

$\Delta U = -W$

$W_{ab,2} = -W_{ba,2}$

$U(y) = -mgy$

$E_{max} = K + U$

$K_2 + U_2 = K_1 + U_1$

$W = \Delta E_{mec} + \Delta E_{th}$

$W = \Delta E = \Delta E_{mec} + \Delta E_{th} + \Delta E_{int}$

$\Delta E_{max} = \Delta K + \Delta U = 0$

$F(x) = -\frac{dU(x)}{dx} \quad \Delta E = f_k d$

$\rho = \frac{dm}{dV} = \frac{m}{V}$

$F = m\,\frac{v^2}{R}, \ a = \frac{v^2}{r}$

$T = \frac{2\,\pi\,r}{v}$

$$x_{com} = \frac{1}{M}\sum_{l=1}^{n} m_l x_l \, , y_{com} = \frac{1}{M}\sum_{l}^{n} m_l y_l$$

$$Z_{com} = \frac{1}{M}\sum_{l}^{n} m_l Z_l \, , \vec{r}_{com} = \frac{1}{M}\sum_{l}^{n} m_l r_l$$

$$x_{com} = \frac{1}{V}\int x\, dV \quad y_{com} = \frac{1}{V}\int y\, dV$$

$$Z_{com} = \frac{1}{V}\int z\, dV \quad \vec{F}_{net} = M\vec{a}_{com}, \quad \vec{P} = M\vec{v}_{com},$$

$$\vec{p} = m\vec{v}, \vec{F}_{net} = \frac{d\vec{P}}{dt}$$

$$\vec{J} = \int_{ti}^{tf} \vec{F}(t)dt \quad F_{avg} = \frac{J}{\Delta t}$$

$$P_i = P_f$$

$$p_f - p_i = \Delta p = J$$

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

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

$$K_{1i} + K_{2i} = K_{1f} + K_{2f}$$

$$V = \frac{m_1}{m_1 + m_2} v_{1i}$$

$$\vec{v}_{com} = \frac{\vec{P}}{m_1 + m_2} = \frac{\vec{p}_{1i} + \vec{p}_{2i}}{m_1 + m_2}$$

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

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

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

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

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

$$\omega_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$$

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

$$\propto_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt}$$

$$a_t = \alpha r, \qquad a_r = \frac{v^2}{r} = \omega^2 r$$

$$v = \omega r, \qquad T = \frac{2\pi}{\omega}$$

$$\theta = \frac{s}{r} \qquad \Delta\theta = \theta_2 - \theta_1$$

$$1\, rev = 360 = \frac{2\pi r}{r} = 2\pi\, rad$$

$$v = v_0 + at$$

$$x - x_0 = v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x - x_0 = vt - \frac{1}{2}at^2$$

$$\omega = \omega_0 + \alpha t$$

$$\theta - \theta_0 = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$\theta - \theta_0 = \frac{1}{2}(\omega_0 + \omega)t$$

$$\theta - \theta_0 = \omega t - \frac{1}{2}\alpha t^2$$

$$I = \sum m_l r_l^2, \quad I = \int r^2 dm \, , \quad I = I_{com} + Mh^2$$

$$K = \frac{1}{2}I\omega^2, \qquad K = \frac{1}{2}I_{com}\omega^2 + \frac{1}{2}Mv_{com}^2$$

$$\Delta K = K_f - K_i = \frac{1}{2}I\omega_f^2 - \frac{1}{2}Iw_i^2 = W$$

$$\tau_{net} = I\alpha, \qquad \tau = (r)(F\sin\phi).$$

$$v_{com} = \omega R, \qquad a_{com} = \alpha R$$

$$\vec{l} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v})$$

$$L = I\omega, \quad \vec{L}_i = \vec{L}_f\, , \quad l = rp_\perp = r_\perp mv$$

| | |
|---|---|
| $x$ | $\theta$ |
| $v = dx/dt$ | $\omega = d\theta/dt$ |
| $a = dv/dt$ | $\alpha = d\omega/dt$ |
| $m$ | $I$ |
| $F_{net} = ma$ | $\tau_{net} = I\alpha$ |
| $W = \int F\, dx$ | $W = \int \tau\, d\theta$ |
| $K = 1/2\ mv^2$ | $K = 1/2\ I\omega^2$ |
| $P = Fv$ | $P = \tau\omega$ |
| $W = \Delta K$ | $W = \Delta K$ |

$$W = \int_{\theta i}^{\theta f} \tau\, d\theta,$$

$$W = \tau(\theta_f - \theta_i),$$

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

$$\tau = rF\ \sin\phi = rF_\perp = r_\perp F,$$

$$P = \frac{dW}{dt} = \tau\omega$$

$$f_s = -I_{com}\ \frac{a_{com,x}}{R^2}$$

$$a_{com,x} = -\frac{g\ \sin\theta}{1 + I_{com}/MR^2}$$

| | |
|---|---|
| $\vec{F}$ | $\vec{\tau}(= \vec{r} \times \vec{F})$ |
| $\vec{P}$ | $\vec{l}(= \vec{r} \times \vec{p})$ |
| $\vec{P}(= \sum \vec{p}_i)$ | $\vec{L}(= \sum \vec{l}_i)$ |
| $\vec{P} = M\vec{v}_{com}$ | $\vec{L} = I\omega$ |
| $\vec{P} = a\ cons$ | $\vec{L} = a\ cons$ |
| $\vec{F}_{net} = \frac{d\vec{P}}{dt}$ | $\vec{\tau}_{net} = \frac{d\vec{L}}{dt}$ |
| | $\frac{dL}{dt} = \sum_{i=1}^{n} \vec{\tau}_{net,l}$ |

$$x(t) = x_m\ \cos(wt + \phi)$$

$$v(t) = -\omega x_m\ \sin(wt + \phi)$$

$$a(t) = -\omega^2 x_m \cos(wt + \phi)$$

$$F = ma = -(m\omega^2)x$$

$$y(x,t) = y_m \sin(kx - \omega t)$$

$$T = 2\pi\sqrt{\frac{m}{k}} \quad T = 2\pi\sqrt{\frac{I}{\kappa}}$$

$$T = 2\pi\sqrt{\frac{l}{g}} \quad T = 2\pi\sqrt{\frac{I}{mgh}}$$

$$E = U + K = \frac{1}{2}kx_m^2$$

$$K(t) = \frac{1}{2}\ mv^2 = \frac{1}{2}kx_m^2 \sin^2(wt + \phi)$$

$$U(t) = \frac{1}{2}kx^2$$

$$U(t) = \frac{1}{2}kx_m^2 \cos^2(wt + \phi)$$

$$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f, \qquad k = \frac{2\,\pi}{\lambda}$$

$$T = \frac{1}{f}, \quad \omega = \frac{2\pi}{T} = 2\pi f \quad \omega = \sqrt{\frac{k}{m}}$$