# Physics I: Mechanics — Equation Sheet

**Motion Vectors:**

displacement $\quad \triangle\vec{\mathbf{r}} = (x_2 - x_1)\,\hat{\imath} + (y_2 - y_1)\,\hat{\jmath}$

average velocity $\quad \vec{\mathbf{v}}_{\text{av}} = \dfrac{\triangle\vec{\mathbf{r}}}{\triangle t}$ $\qquad$ instantaneous velocity $\quad \vec{\mathbf{v}} = \dfrac{d\vec{\mathbf{r}}}{dt} = v_x\hat{\imath} \;+\; v_y\hat{\jmath}$

average acceleration $\quad \vec{\mathbf{a}}_{\text{av}} = \dfrac{\triangle\vec{\mathbf{v}}}{\triangle t}$ $\qquad$ instantaneous acceleration $\quad \vec{\mathbf{a}} = \dfrac{d\vec{\mathbf{v}}}{dt} = a_x\hat{\imath} \;+\; a_y\hat{\jmath}$

**Kinematic Equations of Motion:**

$$x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2$$
$$v_x = v_{0x} + a_x t \qquad v_y = v_{0y} + a_y t$$
$$v_x^2 = v_{0x}^2 + 2a_x(x - x_0) \qquad v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$$

**Circular Motion:** $\quad a_{\text{centripetal}} = \dfrac{v^2}{r}$

**Forces:**

$$\sum \vec{\mathbf{F}} = m\vec{a} \qquad \sum F_x = ma_x \qquad \sum F_y = ma_y \qquad f_s = \mu_s N \quad f_k = \mu_k N$$

**Work and Power:**

$$W = \vec{\mathbf{F}} \cdot \vec{\mathbf{d}} = Fd\cos\phi \qquad W = \int_{x_1}^{x_2} F_x\, dx \qquad P = \frac{dW}{dt} \qquad P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$$

**Energy**

$$W_{\text{net}} = \triangle K \qquad K = \frac{1}{2}mv^2 \qquad U = mgh \qquad \textbf{Springs :} \quad F = -kx \qquad U = \frac{1}{2}kx^2$$

conservative forces $\quad W_{\text{c}} = -\triangle U$

work done by friction: $\quad W_{\text{nc}} = -f_k d = -\mu_k N d$

$$W_{\text{nc}} = \triangle K + \triangle U \qquad \text{or} \qquad K_i + U_i + W_{\text{nc}} = K_f + U_f$$

**Center of Mass:** $\quad x_{\text{cm}} = \dfrac{1}{M}\displaystyle\sum_{i=1}^{n} m_i x_i$

**Momentum:** $\quad \vec{\mathbf{p}} = m\vec{\mathbf{v}}$

**Impulse** $\quad \vec{\mathbf{I}} = \triangle\vec{\mathbf{p}} \qquad I = \displaystyle\int_{t_1}^{t_2} F(t)\, dt$

**Rotational Motion:**

angular position $\theta$

angular velocity $\omega = \dfrac{d\theta}{dt}$

angular acceleration $\alpha = \dfrac{d\omega}{dt}$

$$\alpha = \text{constant} \begin{cases} \omega = \omega_0 + \alpha t \\ \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \\ \omega^2 = \omega_0^2 + 2\alpha\,(\theta - \theta_0) \end{cases}$$

**Relationship between linear and rotational quantities:**

$$s = \theta r \qquad v = \omega r \qquad a_t = \alpha r \qquad a_r = \omega^2 r$$

**Rotational Inertia:** $I = \sum m_i r_i^2$ $\qquad I = I_{\text{cm}} + Mh^2$

**Torque:** $\tau = rF\sin\phi$ $\qquad \vec{\tau} = \vec{\mathbf{r}} \times \vec{\mathbf{F}}$ $\qquad \sum \tau = I\alpha$

**Work, Energy, Power:** $W = \displaystyle\int_{\theta_0}^{\theta} \tau\, d\theta = \triangle K$ $\qquad K = \frac{1}{2} I\omega^2$ $\qquad P = \dfrac{dW}{dt} = \tau\omega$

**Angular Momentum** $L = I\omega$ $\qquad \vec{\mathbf{L}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}}$ $\qquad \tau = \dfrac{dL}{dt}$

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**Gravity** $\vec{\mathbf{F}}_{12} = -\dfrac{Gm_1 m_2}{r^2}\hat{\mathbf{r}}_{21}$ $\qquad G = 6.67{\times}10^{-11}\,\text{Nm}^2/\text{kg}^2$

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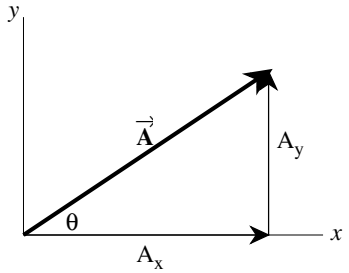
## MATH HELP

**Vectors:**




$$A_x = A\cos\theta$$
$$A_y = A\sin\theta$$
$$|\,\vec{\mathbf{A}}\,| = \sqrt{A_x^2 + A_y^2}$$
$$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

**Quadratic Equation:** $ax^2{+}bx{+}c = 0 \qquad \Longrightarrow \qquad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

## CONSTANTS:

$g = 9.8\,\text{m/s}^2$