

Mechanics Formula Sheet

Comprehensive Summary of Classical Mechanics Principles

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1. Kinematics

Linear motion with constant acceleration (a):

$$v = v_0 + at \quad \Delta x = v_0 t + \frac{1}{2}at^2 \quad v^2 = v_0^2 + 2a\Delta x$$

Projectile Motion:

$$x(t) = v_0 \cos(\theta)t \quad y(t) = v_0 \sin(\theta)t - \frac{1}{2}gt^2$$

2. Dynamics Newton's Laws

Newton's Second Law:

$$\mathbf{F}_{net} = \frac{d\mathbf{p}}{dt} = m\mathbf{a}$$

Friction Force:

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

Centripetal Force:

$$F_c = \frac{mv^2}{r} = m\omega^2 r$$

3. Work, Energy Power

Work done by a force:

$$W = \int \mathbf{F} \cdot d\mathbf{r} = \Delta K$$

Potential Energy (Conservative):

$$\mathbf{F} = -\nabla U$$

Conservation of Mechanical Energy:

$$E = K + U = \text{constant}$$

Power:

$$P = \frac{dW}{dt} = \mathbf{F} \cdot \mathbf{v}$$

4. Momentum Collisions

Linear Momentum:

$$\mathbf{p} = m\mathbf{v}$$

Impulse:

$$\mathbf{J} = \int \mathbf{F} dt = \Delta \mathbf{p}$$

Elastic Collision (1D):

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} v_1 + \frac{2m_2}{m_1 + m_2} v_2$$

5. Rotational Motion

Kinematics analogs:

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2, \quad \omega = \omega_0 + \alpha t$$

Moment of Inertia:

$$I = \int r^2 dm$$

Parallel Axis Theorem:

$$I = I_{cm} + Md^2$$

Torque Angular Momentum:

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} = I\boldsymbol{\alpha}, \quad \mathbf{L} = I\boldsymbol{\omega} = \mathbf{r} \times \mathbf{p}$$

6. Gravitation

Newton's Law of Gravitation:

$$\mathbf{F} = -G \frac{m_1 m_2}{r^2} \hat{\mathbf{r}}$$

Gravitational Potential Energy:

$$U = -G \frac{m_1 m_2}{r}$$

Kepler's Third Law:

$$T^2 = \left(\frac{4\pi^2}{G(m_1 + m_2)} \right) r^3$$

7. Oscillations

Simple Harmonic Motion (SHM):

$$\frac{d^2x}{dt^2} + \omega^2x = 0$$

Angular Frequency:

$$\omega = \sqrt{\frac{k}{m}} \quad (\text{Spring}), \quad \omega = \sqrt{\frac{g}{L}} \quad (\text{Pendulum})$$

Total Energy in SHM:

$$E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$