Mechanics Formula Sheet

Comprehensive Summary of Classical Mechanics

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1. Kinematics

Average Velocity:

$$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t}$$

Instantaneous Velocity:

$$\vec{v} = \frac{d\vec{r}}{dt}$$

Constant Acceleration Equations:

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

2. Dynamics (Newton's Laws)

Newton's Second Law:

$$\sum \vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$

Momentum:

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

Friction Force:

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

Centripetal Acceleration:

$$a_c = \frac{v^2}{r} = \omega^2 r$$

3. Work, Energy, and Power

Work Done:

$$W = \int \vec{F} \cdot d\vec{r}$$

Kinetic Energy:

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

Potential Energy (Gravity/Spring):

$$U_g = mgh, \quad U_s = \frac{1}{2}kx^2$$

Work-Energy Theorem:

$$W_{net} = \Delta K$$

Power:

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

4. Momentum and Collisions

Impulse:

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

Conservation of Momentum ($\sum \vec{F}_{ext} = 0$):

$$\sum \vec{p}_i = \sum \vec{p}_f$$

Coefficient of Restitution (e):

$$e = \frac{v_{2f} - v_{1f}}{v_{1i} - v_{2i}}$$

5. Rotational Motion

Angular Kinematics:

$$\omega = \frac{d\theta}{dt}, \quad \alpha = \frac{d\omega}{dt}$$

Rotational Kinetic Energy:

$$K_{rot} = \frac{1}{2}I\omega^2$$

Moment of Inertia:

$$I = \sum m_i r_i^2 = \int r^2 dm$$

Parallel Axis Theorem:

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

Torque:

$$\vec{\tau} = \vec{r} \times \vec{F}, \quad \tau = I\alpha$$

Angular Momentum:

$$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$$

6. Gravitation Oscillations

Newton's Law of Gravitation:

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

Gravitational Potential Energy:

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

Simple Harmonic Motion (SHM):

$$x(t) = A\cos(\omega t + \phi)$$

Angular Frequency (Spring/Pendulum):

$$\omega = \sqrt{\frac{k}{m}}, \quad \omega = \sqrt{\frac{g}{L}}$$