Mechanics Formula Sheet

Comprehensive Summary of Classical Mechanics

1. Kinematics

Linear Motion (Constant a):

$$v = v_0 + at$$
$$nx = x_0 + v_0 t + \frac{1}{2}at^2$$
$$nv^2 = v_0^2 + 2a(x - x_0)$$

Projectile Motion:

$$x(t) = (v_0 \cos\theta)t$$
$$ny(t) = (v_0 \sin\theta)t - \frac{1}{2}gt^2$$
$$nR = \frac{v_0^2 \sin(2\theta)}{g}, \quad H = \frac{v_0^2 \sin^2\theta}{2g}$$

2. Newton's Laws & Dynamics

Newton's Second Law:

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

—**Friction:**

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

Centripetal Force:

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

3. Work, Energy & Power

Work (W):

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

Potential Energy (U):

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

$$U_{\text{grav}} = mgh, \quad U_{\text{spring}} = \frac{1}{2}kx^2$$

Conservation of Mechanical Energy:

$$E = K + U = \text{const. (konzervativ forces)}$$

Power (P):

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

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4. Momentum & Collisions

Linear Momentum:

$$\mathbf{p} = m\mathbf{v}, \quad \mathbf{J} = \int \mathbf{F}dt = \Delta\mathbf{p}$$

—**Center of Mass:**

$$\mathbf{R}_{cm} = \frac{\sum m_i \mathbf{r}_i}{\sum m_i}$$

—**Elastic Collisions (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 Analogy:

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

Moment of Inertia (I):

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

Parallel Axis Theorem:

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

Torque (τ) Angular Momentum (L):

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

—**Rotational Kinetic Energy:**

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

6. Oscillations

Simple Harmonic Motion (SHM):

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

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

Energy in SHM:

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

7. Gravitation

Newton's Law of Gravitation:

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

—**Gravitational Potential Energy:**

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

—**Kepler's Third Law:**

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$