1. Kinematics of Particles

Position, Velocity, Acceleration:

$$\mathbf{r}(t), \quad \mathbf{v} = \frac{d\mathbf{r}}{dt}, \quad \mathbf{a} = \frac{d\mathbf{v}}{dt} = \frac{d^2\mathbf{r}}{dt^2}$$

Constant Acceleration (1D):

$$v = v_0 + at$$

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

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

Projectile Motion:

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

$$R = \frac{v_0^2 \sin(2\theta)}{g}, \quad H = \frac{v_0^2 \sin^2\theta}{2g}$$

Circular Motion:

$$s = r\theta, \quad v = r\omega, \quad a_t = r\alpha$$

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

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2. Newton's Laws of Motion

First Second Law:

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

where momentum $\mathbf{p} = m\mathbf{v}$.

Friction:

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

Drag Force (Fluid):

$$F_d = -cv \quad \text{(linear)}, \quad F_d = -cv^2 \quad \text{(quadratic)}$$

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3. Work, Energy, and Power

Work:

$$W = \int_{\mathbf{r}_1}^{\mathbf{r}_2} \mathbf{F} \cdot d\mathbf{r}, \quad W_{\text{net}} = \Delta K$$

Conservative Forces Potential Energy:

$$\mathbf{F} = -\nabla U, \quad \Delta U = -W_{\text{conservative}}$$

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

Mechanical Energy Conservation:

$$E = K + U, \quad \Delta E = W_{\text{non-conservative}}$$

Power:

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

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4. Systems of Particles Momentum

Center of Mass:

$$\mathbf{R}_{cm} = \frac{1}{M}\sum m_i \mathbf{r}_i, \quad \mathbf{R}_{cm} = \frac{1}{M}\int \mathbf{r}\, dm$$

Conservation of Momentum: If $\sum \mathbf{F}_{ext} = 0$, then $\mathbf{p}$ = constant.

Impulse:

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

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5. Rotational Dynamics

Torque Angular Momentum:

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

Newton's Second Law (Rotation):

$$\sum \tau = I\alpha = \frac{d\mathbf{L}}{dt}$$

Moment of Inertia:

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

Parallel Perpendicular Axis Theorems:

$$I = I_{cm} + Md^2, \quad I_z = I_x + I_y \quad \text{(planar)}$$

Rotational Kinetic Energy:

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

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6. Gravitation

Newton's Law of Gravitation:

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

Gravitational Potential Energy:

$$U = -G\frac{Mm}{r}$$

Kepler's Third Law:

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

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7. Oscillations

Simple Harmonic Motion (SHM):

$$\frac{d^2x}{dt^2} + \omega^2 x = 0, \quad \omega = \sqrt{\frac{k}{m}}$$

Solution to SHM:

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

Pendulums:

$$T_{\text{simple}} = 2\pi\sqrt{\frac{L}{g}}, \quad T_{\text{physical}} = 2\pi\sqrt{\frac{I}{mgd}}$$