Mechanics I (Physics 3221) Formula Sheet

Kinematics

Constant Acceleration Equations:

$$v = u + at, \quad s = ut + \frac{1}{2}at^2, \quad v^2 = u^2 + 2as, \quad s = \frac{1}{2}(u+v)t$$

where u is initial velocity, v is final velocity, a is acceleration, s is displacement, t is time.

Position and Velocity in 2D:

$$\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}}, \quad \mathbf{v} = \frac{d\mathbf{r}}{dt}, \quad \mathbf{a} = \frac{d\mathbf{v}}{dt}$$

Projectile Motion:

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

where v_0 is initial speed, θ is launch angle, $g \approx 9.81\,\mathrm{m\,s^{-2}}$.

Newton's Laws

Newton's Second Law:

$$\mathbf{F} = m\mathbf{a}, \quad F = ma$$

where **F** is the net force, m is mass, **a** is acceleration.

Weight:

$$W = mg$$

Friction:

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

where f_s is static friction, f_k is kinetic friction, μ_s and μ_k are coefficients of friction, N is the normal force.

Work and Energy

Work:

$$W = \mathbf{F}\cdot\mathbf{d} = Fd\cos\theta$$

Kinetic Energy:

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

Work-Energy Theorem:

$$W_{\text{net}} = \Delta K = K_f - K_i$$

Potential Energy (Gravitational):

$$U = mgh$$

where h is height.

Conservation of Mechanical Energy:

$$K_i + U_i = K_f + U_f \quad \text{(no non-conservative forces)}$$

Power:

$$P = \frac{W}{t} = \mathbf{F} \cdot \mathbf{v}, \quad P = Fv\cos\theta$$

Momentum and Collisions

Linear Momentum:

$$\mathbf{p} = m\mathbf{v}, \quad p = mv$$

Impulse-Momentum Theorem:

$$\mathbf{J} = \Delta\mathbf{p}, \quad J = F\Delta t$$

Conservation of Momentum:

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f} \quad \text{(no external forces)}$$

Elastic Collisions (1D):

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_{1i} + \frac{2m_2}{m_1 + m_2}v_{2i}, \quad v_{2f} = \frac{2m_1}{m_1 + m_2}v_{1i} + \frac{m_2 - m_1}{m_1 + m_2}v_{2i}$$

Rotational Motion

Angular Kinematics:

$$\omega = \omega_0 + \alpha t, \quad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2, \quad \omega^2 = \omega_0^2 + 2\alpha\theta$$

where ω is angular velocity, α is angular acceleration, θ is angular displacement.

Relation to Linear Motion:

$$v = r\omega, \quad a = r\alpha$$

Torque:

$$\tau = rF\sin\theta, \quad \tau = I\alpha$$

where I is the moment of inertia.

Rotational Kinetic Energy:

$$K = \frac{1}{2} I \omega^2$$

Angular Momentum:

$$L = I\omega, \quad \tau_{\text{net}} = \frac{dL}{dt}$$

Conservation of Angular Momentum:

$$I_i \omega_i = I_f \omega_f \quad \text{(no external torques)}$$

Gravitation

Newton's Law of Gravitation:

$$F = G\frac{m_1 m_2}{r^2}, \quad G = 6.674\,30 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$$

Gravitational Potential Energy:

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