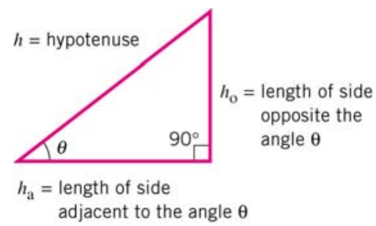
PHYSICS 201 — FORMULA SUMMARY — MODULE 1

Quadratic Equation

$$ax^2 + bx + c = 0 \quad \Rightarrow \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Trigonometry

$$\sin\theta = \frac{h_o}{h} \quad \cos\theta = \frac{h_a}{h} \quad \tan\theta = \frac{h_o}{h_a} \qquad h^2 = h_a^2 + h_o^2$$



Scalar Components of a Vector

$$A_x = |\vec{\boldsymbol{A}}|\cos\theta \quad \text{and} \quad A_y = |\vec{\boldsymbol{A}}|\sin\theta$$

Magnitude / Direction of a Vector

$$|\vec{\boldsymbol{A}}| = \sqrt{A_x^2 + A_y^2} \qquad \theta = \tan^{-1}\left(\frac{|A_y|}{|A_x|}\right)$$

Vector Addition

$$\vec{\boldsymbol{C}} = \vec{\boldsymbol{A}} + \vec{\boldsymbol{B}} \quad \Rightarrow \quad C_x = A_x + B_x \quad \text{and} \quad C_y = A_y + B_y$$

Kinematic Displacement

$$\Delta\vec{\boldsymbol{r}} = \vec{\boldsymbol{r}}_{\text{final}} - \vec{\boldsymbol{r}}_{\text{initial}} = (\Delta r_x)\hat{\boldsymbol{x}} + (\Delta r_y)\hat{\boldsymbol{y}} = (\Delta x)\hat{\boldsymbol{x}} + (\Delta y)\hat{\boldsymbol{y}} = \left(x(t) - x_o\right)\hat{\boldsymbol{x}} + \left(y(t) - y_o\right)\hat{\boldsymbol{y}}$$

Kinematic Velocity / Kinematic Acceleration

$$\vec{\boldsymbol{v}}_{\text{average}} = \frac{\Delta\vec{\boldsymbol{r}}}{\Delta t} \qquad \vec{\boldsymbol{v}}_{\text{instantaneous}} = \lim_{\Delta t \to 0}\frac{\Delta\vec{\boldsymbol{r}}}{\Delta t} \qquad \vec{\boldsymbol{a}}_{\text{average}} = \frac{\Delta\vec{\boldsymbol{v}}}{\Delta t} \qquad \vec{\boldsymbol{a}}_{\text{instantaneous}} = \lim_{\Delta t \to 0}\frac{\Delta\vec{\boldsymbol{v}}}{\Delta t}$$

Motion with Constant Acceleration

$$v_x(t) = v_{ox} + a_x \cdot t$$
$$x(t) = x_o + \tfrac{1}{2}(v_{ox} + v_x) \cdot t$$
$$x(t) = x_o + v_{ox} \cdot t + \tfrac{1}{2} a_x \cdot t^2$$
$$v_x{}^2(x) = v_{ox}{}^2 + 2a_x \cdot (x - x_o)$$

$$v_y(t) = v_{oy} + a_y \cdot t$$
$$y(t) = y_o + \tfrac{1}{2}(v_{oy} + v_y) \cdot t$$
$$y(t) = y_o + v_{oy} \cdot t + \tfrac{1}{2} a_y \cdot t^2$$
$$v_y{}^2(y) = v_{oy}{}^2 + 2a_y \cdot (y - y_o)$$

Acceleration due to the Earth's Gravity

$$g = 9.80\ m/s^2$$

Newton's Second Law of Motion

$$\vec{\boldsymbol{a}} = \frac{\sum \vec{\boldsymbol{F}}}{m} \quad \text{or} \quad \sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$$

Dynamic Equilibrium

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0$$

Force Exerted by an Ideal Spring

$$\vec{\boldsymbol{F}}_{\text{spring}} = -k\Delta\vec{\boldsymbol{r}} \quad \text{or} \quad F_x = -kx$$

Static / Kinetic Friction

$$\left|\vec{\boldsymbol{f}}_s^{\text{maximum}}\right| = \mu_s|\vec{\boldsymbol{n}}| \quad \text{and} \quad \left|\vec{\boldsymbol{f}}_k\right| = \mu_k|\vec{\boldsymbol{n}}|$$

PHYSICS 201 — FORMULA SUMMARY — MODULE 2

Uniform Circular Motion

$$\left|\vec{\boldsymbol{v}}_{\text{tangential}}\right| = \frac{2\pi|\vec{\boldsymbol{r}}|}{T} \quad \text{or} \quad v_{\text{tangential}} = \frac{2\pi R}{T} \qquad\qquad \left|\vec{\boldsymbol{a}}_{\text{radial}}\right| = \frac{|\vec{\boldsymbol{v}}|^2}{|\vec{\boldsymbol{r}}|} \quad \text{or} \quad a_{\text{radial}} = \frac{v^2}{R}$$

Newton's Law of Universal Gravitation

$$\left|\vec{\boldsymbol{F}}_{\text{gravity}}\right| = G\,\frac{m_1 m_2}{r^2}$$

Universal Gravitation and Weight

$$G\,\frac{m_E m}{R_E^2} = mg$$

Kepler /Newton Law of Periods for Satellite and Planetary Motion

$$\frac{T^2}{r^3} = \frac{4\pi^2}{Gm_E} \quad \text{and} \quad \frac{T^2}{r^3} = \frac{4\pi^2}{Gm_{Sun}}$$

Mechanical Work

$$W = F_x \Delta x + F_y \Delta y \quad \text{or} \quad W = \left|\vec{\boldsymbol{F}}\right| \left|\Delta\vec{\boldsymbol{r}}\right| \cos\theta$$

Work–Energy Theorem

$$W_{\text{total}} = \Delta K = \frac{1}{2} m v_{\text{final}}^2 - \frac{1}{2} m v_{\text{initial}}^2$$

Gravitational Work

$$W_{\text{gravity}} = mgy_{\text{initial}} - mgy_{\text{final}}$$

Gravitational Potential Energy

$$\Delta U_{\text{gravity}} = mgy_{\text{final}} - mgy_{\text{initial}} = -W_{\text{gravity}}$$

Elastic Work

$$W_{\text{elastic}} = \frac{1}{2}kx^2_{\text{initial}} - \frac{1}{2}kx^2_{\text{final}}$$

Elastic Potential Energy

$$\Delta U_{\text{elastic}} = \frac{1}{2}kx^2_{\text{final}} - \frac{1}{2}kx^2_{\text{initial}} = -W_{\text{elastic}}$$

Conservation of Total Mechanical Energy

$$\Delta E = \Delta(K + U_{\text{gravity}} + U_{\text{elastic}}) = W_{\text{nonconservative}}$$

Instantaneous Power

$$P = \lim_{\Delta t \to 0} \frac{\Delta W}{\Delta t} \quad \text{or} \quad P = F_x v_x + F_y v_y \quad \text{or} \quad P = |\vec{\boldsymbol{F}}||\vec{\boldsymbol{v}}|\cos\theta$$

Simple Harmonic Motion

$$\begin{aligned} x(t) &= A\cos\omega t \\ v_x(t) &= -A\omega\sin\omega t \\ a_x(t) &= -A\omega^2\cos\omega t \end{aligned} \qquad \text{where} \qquad \omega = \frac{2\pi}{T} = 2\pi f = \sqrt{\frac{k}{m}}$$

Period of an Ideal Pendulum

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Center of Mass for a System of Particles

$$\vec{\boldsymbol{r}}_{\text{CM}} = \frac{m_1\vec{\boldsymbol{r}}_1 + m_2\vec{\boldsymbol{r}}_2 + ... + m_N\vec{\boldsymbol{r}}_N}{m_1 + m_2 + ... + m_N}$$

$$\vec{\boldsymbol{v}}_{\text{CM}} = \frac{m_1\vec{\boldsymbol{v}}_1 + m_2\vec{\boldsymbol{v}}_2 + ... + m_N\vec{\boldsymbol{v}}_N}{m_1 + m_2 + ... + m_N}$$

$$\vec{\boldsymbol{a}}_{\text{CM}} = \frac{m_1\vec{\boldsymbol{a}}_1 + m_2\vec{\boldsymbol{a}}_2 + ... + m_N\vec{\boldsymbol{a}}_N}{m_1 + m_2 + ... + m_N}$$

Newton's Laws for a System of Particles

$$M\vec{\boldsymbol{a}}_{\text{CM}} = (m_1 + m_2 + ... + m_N)\vec{\boldsymbol{a}}_{\text{CM}} = m_1\vec{\boldsymbol{a}}_1 + m_2\vec{\boldsymbol{a}}_2 + ... + m_N\vec{\boldsymbol{a}}_N = \sum\vec{\boldsymbol{F}}_{\text{external}}$$

$$\sum\vec{\boldsymbol{F}}_{\text{internal}} = 0$$

Linear Momentum of a System of Particles

$$M\vec{\boldsymbol{v}}_{\text{CM}} = m_1\vec{\boldsymbol{v}}_1 + m_2\vec{\boldsymbol{v}}_2 + ... + m_N\vec{\boldsymbol{v}}_{\text{N}} = \vec{\boldsymbol{p}}_1 + \vec{\boldsymbol{p}}_2 + ... + \vec{\boldsymbol{p}}_{\text{N}} = \vec{\boldsymbol{P}}_{\text{CM}}$$

Conservation of Linear Momentum for a System of Particles

$$\sum\vec{\boldsymbol{F}}_{\text{external}} = 0 \quad \Rightarrow \quad \vec{\boldsymbol{P}}_{\text{CM}} = \text{constant}$$

$$\Delta\vec{\boldsymbol{P}}_{\text{CM}} = (m_1\vec{\boldsymbol{v}}_1 + m_2\vec{\boldsymbol{v}}_2 + ... + m_N\vec{\boldsymbol{v}}_N)_{\text{final}} - (m_1\vec{\boldsymbol{v}}_1 + m_2\vec{\boldsymbol{v}}_2 + ... + m_N\vec{\boldsymbol{v}}_N)_{\text{initial}} = 0$$

PHYSICS 201 — FORMULA SUMMARY — MODULE 3

Angular Displacement / Arc Length

$$\Delta\theta \text{ (radians)} = \theta(t) - \theta_o = \frac{s}{r}$$

Angular Velocity / Angular Acceleration

$$\omega_{\text{average}} = \frac{\Delta\theta}{\Delta t} \qquad \omega_{\text{instantaneous}} = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$$

$$\alpha_{\text{average}} = \frac{\Delta\omega}{\Delta t} \qquad \alpha_{\text{instantaneous}} = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$$

Corresponding Linear Velocity / Linear Acceleration

$$v_{\text{tangential}} = r\omega \qquad a_{\text{tangential}} = r\alpha \qquad a_{\text{radial}} = r\omega^2$$

Rotation with Constant Angular Acceleration

$$\omega(t) = \omega_o + \alpha \cdot t$$
$$\theta(t) = \theta_o + \tfrac{1}{2}(\omega_o + \omega) \cdot t$$
$$\theta(t) = \theta_o + \omega_o \cdot t + \tfrac{1}{2}\alpha \cdot t^2$$
$$\omega^2(\theta) = \omega_o{}^2 + 2\alpha \cdot (\theta - \theta_o)$$

Torque about an Arbitrary Axis

$$\tau = \left|\vec{\boldsymbol{F}}_{\text{tangential}}\right|\left|\vec{\boldsymbol{r}}\right| = \left|\vec{\boldsymbol{F}}\right|\left|\vec{\boldsymbol{r}}\right|\sin\theta = \left|\vec{\boldsymbol{F}}\right|\ell$$

Newton's Laws for Fixed–Axis Rotation

$$\sum \vec{\tau}_{\text{external}} = I\vec{\alpha} \quad \text{where} \quad I = \sum mr^2$$

$$\sum \vec{\tau}_{\text{internal}} = 0$$

Rotational Equilibrium

$$\sum \vec{\tau}_{\text{external}} = 0$$

Work–Energy Theorem for Fixed–Axis Rotation

$$\tau_{\text{external}}\Delta\theta = W_{\text{rotation}} = \frac{1}{2}I\omega_{\text{final}}^2 - \frac{1}{2}I\omega_{\text{initial}}^2$$

Work–Energy Theorem for Combined Rotation and Translation

$$W_{\text{translation}} + W_{\text{rotation}} = \left(\frac{1}{2}Mv_{\text{CM final}}^2 - \frac{1}{2}Mv_{\text{CM initial}}^2\right) + \left(\frac{1}{2}I\omega_{\text{CM final}}^2 - \frac{1}{2}I\omega_{\text{CM initial}}^2\right)$$

$$W_{\text{translation}} = F_x\Delta x_{\text{CM}} + F_y\Delta y_{\text{CM}}$$

Conservation of Angular Momentum for a Rotating Body

$$\sum \vec{\tau}^{\,\text{external}} = 0 \quad \Rightarrow \quad \vec{\boldsymbol{L}} = I\vec{\omega} = \text{constant}$$

Conservation of Angular Momentum for a System of Rotating Bodies

$$\sum \vec{\tau}^{\,\text{external}} = 0 \quad \Rightarrow \quad \vec{\boldsymbol{L}} = \sum I\vec{\omega} = \text{constant}$$

Frequency /Wavelength / Speed of Periodic Waves

$$v = \frac{\lambda}{T} = f\lambda \quad \text{where} \quad y(x,t) = A\sin 2\pi(\frac{t}{T} - \frac{x}{\lambda}) = A\sin 2\pi f(t - \frac{x}{v})$$

Speed of (Transverse) Mechanical Waves on a String

$$v = \sqrt{\frac{F}{m/L}}$$

Speed of (Longitudinal) Sound Waves in an Ideal Gas

$$v = \sqrt{\frac{\gamma k_B T}{m}} \quad \text{where} \quad \gamma = C_p / C_V$$

Standing Waves for a String Clamped at Both Ends or a Tube Open at Both Ends

$$\lambda_n = \frac{2L}{n} \quad \text{or} \quad f_n = n\left(\frac{v}{2L}\right)$$

Density / Pressure

$$\rho = \frac{m}{V} \qquad\qquad p = \frac{F_\perp}{A}$$

Atmospheric Pressure

$$1 \text{ atm} = 1.013 \text{ x } 10^5 \text{ Pa} = 1.013 \text{ x } 10^3 \text{ mbar} = 760 \text{ Torr}$$

Barometric Pressure Formula

$$p(h) = p(h=0) - \rho g h \quad \text{or} \quad p(h_<) = p(h_>) + \rho g(h_> - h_<)$$

Buoyant Force

$$F_B = \rho_{\text{fluid}} V_{\text{displaced}} g = m_{\text{fluid}} g$$

PHYSICS 201 — FORMULA SUMMARY — MODULE 4

Thermal Expansion of Solids

$$\frac{\Delta L}{L_o} = \alpha \Delta T \quad \text{and} \quad \frac{\Delta V}{V_o} = \beta \Delta T \quad \text{where} \quad \beta = 3\alpha$$

Specific Heat Capacity / Latent Heats

$$c = \frac{1}{m}\frac{Q}{\Delta T} \qquad\qquad L_{\text{f,v,s}} = \frac{1}{m}\left| Q_{\text{f,v,s}} \right|$$

Avogadro Number / Ideal Gas Constant / Boltzmann Constant

$$N_A = 6.02 \text{ x } 10^{23} \qquad R = 8.31 \text{ J/mole - K} \qquad k_B = 1.38 \text{ x } 10^{-23} \text{ J/K}$$

Ideal Gas Law

$$pV = nRT \quad \text{or} \quad pV = Nk_BT$$

Average Translational Kinetic Energy per Molecule

$$< \frac{1}{2}mv^2 > \; = \; \frac{1}{2}mv_{\text{rms}}{}^2 \; = \; \frac{3}{2}k_BT$$

Total Internal Energy of an Ideal (Monatomic) Gas

$$U = \frac{3}{2}nRT \quad \text{or} \quad U = \frac{3}{2}Nk_BT$$

Constant Volume Heat Capacity of an Ideal (Monatomic) Gas

$$C_V = \frac{3}{2}R \;\text{ (per mole)} \quad \text{or} \quad C_V = \frac{3}{2}k_B \;\text{ (per molecule)}$$

Constant Pressure Heat Capacity of an Ideal (Monatomic) Gas

$$C_p = \frac{5}{2} R \text{ (per mole)} \quad \text{or} \quad C_p = \frac{5}{2} k_B \text{ (per molecule)}$$

First Law of Thermodynamics

$$\Delta U_{\text{system}} = U_{\text{final}} - U_{\text{initial}} = Q - W$$

Isobaric (Constant Pressure) Work

$$W = p\Delta V = p(V_{\text{final}} - V_{\text{initial}})$$

Adiabatic Work for an Ideal (Monatomic) Gas

$$W = \frac{3}{2} nR(T_{\text{initial}} - T_{\text{final}}) \quad \text{or} \quad W = \frac{3}{2} Nk_B(T_{\text{initial}} - T_{\text{final}})$$

Adiabatic Expansion (Compression) of an Ideal (Monatomic) Gas

$$p_{\text{initial}} V_{\text{initial}}^{5/3} = p_{\text{final}} V_{\text{final}}^{5/3}$$