

Physics 101 Formulas

Kinematics

$$v_{ave} = \frac{\Delta x}{\Delta t} \quad a_{ave} = \frac{\Delta v}{\Delta t}$$

$$v = v_0 + at \quad x = x_0 + v_0t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$g = 9.8 \text{ m/s}^2 = 32.2 \text{ ft/s}^2 \text{ (near Earth's surface)}$$

Dynamics

$$\Sigma F = ma \quad \text{Weight} = mg \text{ (near Earth's surface)}$$

$$f_{s,max} = \mu_s F_N$$

$$f_k = \mu_k F_N \quad a_c = \frac{v^2}{R} = \omega^2 R$$

Universal Gravitation

$$\text{Universal Gravitational Constant } G = 6.7 \times 10^{-11} \text{ N} \cdot \frac{\text{m}^2}{\text{kg}^2}$$

$$F_g = \frac{Gm_1m_2}{R^2} \quad U_g = -\frac{Gm_1m_2}{R}$$

Work & Energy

$$W_F = Fd\cos(\theta) \quad K = \frac{1}{2}mv^2 = \frac{p^2}{2m} \quad W_{NET} = \Delta K = K_f - K_i \quad E = K + U$$

$$W_{nc} = \Delta E = E_f - E_i = (K_f + U_f) - (K_i + U_i) \quad U_{grav} = mgy$$

Impulse & Momentum

$$\text{Impulse: } I = F_{ave}\Delta t = \Delta p \quad F_{ave}\Delta t = \Delta p = mv_f - mv_i \quad F_{ave} = \Delta p / \Delta t$$

$$\Sigma F_{ext}\Delta t = \Delta P_{total} = P_{total,final} - P_{total,initial} \quad (\text{momentum conserved if } \Sigma F_{ext} = 0)$$

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

Elastic Collisions: Mass m_i moving with v_i ; Stationary mass M

$$v_{m,f} = v_{m,i} \frac{m-M}{m+M} \quad v_{M,f} = v_{m,i} \frac{2m}{m+M}$$

Rotational Kinematics

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

$$\Delta x_T = R\Delta\theta \quad v_T = R\omega \quad a_T = R\alpha$$

$$(\text{rolling without slipping: } \Delta x = R\Delta\theta \quad v = R\omega \quad a = R\alpha)$$

$$1 \text{ revolution} = 2\pi \text{ radians}$$

Rotational Statics & Dynamics

$$\tau = Fr \sin \theta$$

$$\Sigma \tau = 0 \text{ and } \Sigma F = 0 \text{ (static equilibrium)}$$

$$\Sigma \tau = I\alpha$$

$$W = \tau\theta$$

$$L = I\omega \quad \Sigma \tau_{ext}\Delta t = \Delta L$$

$$(\text{angular momentum conserved if } \Delta \tau_{ext} = 0)$$

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

$$K_{total} = K_{trans} + K_{rot} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

Moments of Inertia (I)

$$I = \Sigma mr^2 \text{ (for a collection of point particles)}$$

$$I = \frac{1}{2}MR^2 \text{ (solid disk or cylinder)}$$

$$I = \frac{2}{5}MR^2 \text{ (solid ball)}$$

$$I = \frac{2}{3}MR^2 \text{ (hollow sphere)}$$

$$I = MR^2 \text{ (hoop or hollow cylinder)}$$

$$I = \frac{1}{12}ML^2 \text{ (uniform rod about center)}$$

$$I = \frac{1}{3}ML^2 \text{ (uniform rod about one end)}$$

Physics 101 Formulas

Fluids

$$P = \frac{F}{A}, \quad P(d) = P(0) + \rho g d \quad \text{change in pressure with depth } d$$

$$\rho = \frac{M}{V} \quad (\text{density})$$

$$\text{Buoyant force } F_B = \rho g V_{dis} = \text{weight of displaced fluid}$$

$$\text{Flow rate } Q = v_1 A_1 = v_2 A_2 \quad \text{continuity equation}$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \quad \text{Bernoulli equation}$$

$$\rho_{\text{water}} = 1000 \text{ kg/m}^3$$

$$1 \text{ m}^3 = 1000 \text{ liters}$$

$$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$$

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

$$(\text{area of circle } A = \pi r^2)$$

Simple Harmonic Motion

$$\text{Hooke's Law: } F_s = -kx$$

$$U_{\text{spring}} = \frac{1}{2} kx^2$$

$$x(t) = A \cos(\omega t) \quad \text{or} \quad x(t) = A \sin(\omega t)$$

$$v(t) = -A\omega \sin(\omega t) \quad \text{or} \quad v(t) = A\omega \cos(\omega t)$$

$$a(t) = -A\omega^2 \cos(\omega t) \quad \text{or} \quad a(t) = -A\omega^2 \sin(\omega t)$$

$$\omega^2 = \frac{k}{m} \quad T = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{m}{k}} \quad f = 1/T$$

$$x_{\text{max}} = A \quad v_{\text{max}} = \omega A \quad a_{\text{max}} = \omega^2 A \quad \omega = 2\pi f$$

$$\text{For a simple pendulum } \omega^2 = \frac{g}{L}, \quad T = 2\pi \sqrt{L/g}$$

Harmonic Waves

$$v = \frac{\lambda}{T} = \lambda f \quad v = c = 3 \times 10^8 \text{ m/s for electromagnetic waves (light, microwaves, etc.)}$$

$$v^2 = \frac{F}{m/L} \quad \text{for wave on a string} \quad \lambda_n = \frac{2}{n} L \quad (\text{wavelength, of the } n^{\text{th}} \text{ harmonic})$$

Sound Waves

$$\text{Loudness: } \beta = 10 \log_{10} \left(\frac{I}{I_0} \right) \quad (\text{in dB}), \quad \text{where } I_0 = 10^{-12} \text{ W/m}^2 \quad I = \frac{P}{4\pi r^2} \quad (\text{sound intensity})$$

$$\beta_2 - \beta_1 = (10 \text{ dB}) \log \left(\frac{I_2}{I_1} \right)$$

Logarithm Rules

$$\log 10 = 1$$

$$\log AB = \log A + \log B$$

$$\log \frac{A}{B} = \log A - \log B$$

$$\log A^B = B \log A$$

Doppler Effect

$$f_{\text{listener}} = \left[\frac{v_{\text{sound}} \pm v_{\text{listener}}}{v_{\text{sound}} \mp v_{\text{source}}} \right] f_{\text{source}} \quad (\text{Doppler Effect})$$

Numerator: Use

+ if listener moves *toward* source

- if listener moves *away* from source.

Denominator: Use

- if source moves *toward* listener

+ if source moves *away* from listener.

Physics 101 Formulas

Temperature and Heat

Temperature: Celsius (T_C) to Fahrenheit (T_F) conversion: $T_C = \left(\frac{5}{9}\right)(T_F - 32^\circ)$

Celsius (T_C) to Kelvin (T_K) conversion: $T_K = T_C + 273$

$\Delta L = \alpha L_0 \Delta T$ $\Delta V = \beta V_0 \Delta T$ thermal expansion

$Q = cM\Delta T$ specific heat capacity

$Q = L_f M$ latent heat of fusion (solid to liquid) $Q = L_v M$ latent heat of vaporization

$Q = \kappa A \Delta T t / L$ conduction

$Q = e\sigma T^4 A t$ radiation ($\sigma = 5.67 \times 10^{-8} \text{ J}/(\text{s} \cdot \text{m}^2 \cdot \text{K}^4)$)

$P_{net} = e\sigma A(T^4 - T_0^4)$ (surface area of a sphere $A = 4\pi r^2$)

Ideal Gas & Kinetic Theory

$N_A = 6.022 \times 10^{23}$ molecules/mole Mass of carbon - 12 = 12.000 u

$PV = nRT = Nk_B T$ $R = 8.31 \frac{\text{J}}{(\text{mol} \cdot \text{K})}$ $k_B = \frac{R}{N_A} = 1.38 \times 10^{-23} \text{ J/K}$

$KE_{ave} = \frac{3}{2} k_B T = \frac{1}{2} m v_{rms}^2$ $U = \frac{3}{2} N k_B T$ (internal energy of a monatomic ideal gas)

$v_{rms}^2 = \frac{3k_B T}{m} = \frac{3RT}{M}$ ($M =$ molar mass = kg/mole)

Thermodynamics

$\Delta U = Q + W$ (1st Law)

$U = \left(\frac{3}{2}\right) nRT$ (internal energy of a monatomic ideal gas for fixed n)

$C_V = (3/2)R = 12.5 \text{ J}/(\text{mol} \cdot \text{K})$ (specific heat at constant volume for a monatomic ideal gas)

$Q_H + Q_C + W = 0$ (heat engine or refrigerator)

$e = \frac{W}{Q_H}$ $e_{max} = 1 - \frac{T_C}{T_H}$ (Carnot engine)

$W = P\Delta V$ (work done by an expanding gas)

$\Delta S = Q/T$ (entropy)