Physics 101 Formulas

Last Name:
First Name:
Lab Section:
Exam Day: Exam Time

Kinematics

$\boldsymbol{v}_{ave} = \frac{\Delta x}{\Delta t}$ $\boldsymbol{a}_{ave} = \frac{\Delta v}{\Delta t}$

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

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

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

Dynamics

$\Sigma\boldsymbol{F} = m\boldsymbol{a}$ $Weight = mg$ (near Earth's surface)

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

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

Universal Gravitation

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

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

Work & Energy

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

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

Impulse & Momentum

Impulse: $\boldsymbol{I} = \boldsymbol{F}_{ave}\Delta t = \Delta\boldsymbol{p}$ $\boldsymbol{F}_{ave}\Delta t = \Delta\boldsymbol{p} = m\boldsymbol{v}_f - m\boldsymbol{v}_i$ $\boldsymbol{F}_{ave} = \Delta\boldsymbol{p}/\Delta t$

$\Sigma\boldsymbol{F}_{ext}\Delta t = \Delta\boldsymbol{P}_{total} = \boldsymbol{P}_{total,final} - \boldsymbol{P}_{total,initial}$ (momentum conserved if $\Sigma\boldsymbol{F}_{ext} = 0$)

$\boldsymbol{x}_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$

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

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

Rotational Kinematics

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

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

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

1 revolution $= 2\pi$ radians

Rotational Statics & Dynamics

$\tau = Fr\sin\theta$

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

$\Sigma\tau = I\alpha$

$W = \tau\theta$

$\boldsymbol{L} = I\boldsymbol{\omega}$ $\Sigma\boldsymbol{\tau}_{ext}\Delta t = \Delta\boldsymbol{L}$

(angular momentum conserved if $\Delta\boldsymbol{\tau}_{ext} = 0$)

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

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

$I = I_{cm} + mr^2$ Parallel axis theorem

Moments of Inertia (I)

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

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

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

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

$I = MR^2$ (hoop or hollow cylinder)

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

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

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Fluids

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

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

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

Flow rate $Q = v_1 A_1 = v_2 A_2$ continuity equation

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

$\rho_{water} = 1000 \text{ kg/m}^3$
$1 \text{ m}^3 = 1000 \text{ liters}$
$1 \text{ atm} = 1.01\, x\, 10^5 \text{ Pa}$
$1 \text{ Pa} = 1 \text{ N/m}^2$
(area of circle $A = \pi r^2$)

Simple Harmonic Motion

Hooke's Law: $F_s = -kx$

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

$x(t) = A\cos(\omega t)$ or $x(t) = A\sin(\omega t)$

$v(t) = -A\omega\sin(\omega t)$ *or* $v(t) = A\omega\cos(\omega t)$

$a(t) = -A\omega^2\cos(\omega t)$ or $a(t) = -A\omega^2\sin(\omega t)$

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

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

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

Harmonic Waves

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

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

Sound Waves

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

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

$f_{observer} = f_{source}\frac{(v_{wave} - v_{observer})}{v_{wave} - v_{source}}$ (Doppler Effect)

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Temperature and Heat

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

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

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

$Q = cM\Delta T$ specific heat capacity

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

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

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

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

Ideal Gas & Kinetic Theory

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

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

$KE_{ave} = \frac{3}{2}k_BT = \frac{1}{2}mv_{rms}^2$ $\quad U = \frac{3}{2}Nk_BT$ (internal energy of a monatomic ideal gas)

$v_{rms}^2 = \frac{3k_BT}{m} = \frac{3RT}{M}$ (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)

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

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

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

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

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