

PHY 231C FORMULAS

Quadratic Formula

$$ax^2 + bx + c = 0$$

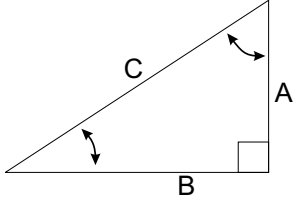
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Geometry

Circle: circumference= $2\pi R$, area= πR^2

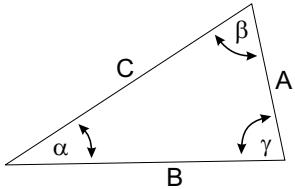
Sphere: area= $4\pi R^2$, volume= $4\pi R^3/3$

Trigonometry



$$\sin \alpha = \frac{A}{C}, \quad \cos \alpha = \frac{B}{C}$$

$$\tan \alpha = \frac{A}{B}$$



$$\frac{\sin \alpha}{A} = \frac{\sin \beta}{B} = \frac{\sin \gamma}{C}$$

$$A^2 + B^2 - 2AB \cos \gamma = C^2$$

Polar Coordinates

$$x = r \cos \theta, \quad y = r \sin \theta$$

$$r = \sqrt{x^2 + y^2}, \quad \tan \theta = y/x$$

SI Units and Constants

quantity	unit	abbreviation
Mass m	kilograms	kg
Distance x	meters	m
Time t	seconds	s
Force F	Newtons	N=kg m/s ²
Energy E	Joules	J=N m
Power P	Watts	W=J/s
Temperature T	°C, °K or °F	$T_{°F} = 32 + (9/5)T_{°C}$
Pressure P	Pascals	Pa=N/m ²

$g = 9.8 \text{ m/s}^2$, $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$, $0^\circ\text{C} = 273.15^\circ\text{K}$

$R = 8.31 \text{ J}/(\text{mol}^\circ\text{K})$, $N_A = 6.023 \times 10^{23}$

$k_B = R/N_A = 1.38 \times 10^{-23} \text{ J}/^\circ\text{K}$, $1 \text{ cal} = 4.1868 \text{ J}$

$\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2\text{K}^4)$, $v_{\text{sound}} = 331\sqrt{T/273} \text{ m/s}$.

1-d motion, constant a

$$a = \frac{v_f - v_0}{t}$$

$$v_{\text{av}} = \frac{v_0 + v_f}{2}, \quad (x_f - x_0) = v_{\text{av}}t$$

$$(x_f - x_0) = v_0t + \frac{1}{2}at^2 = v_f t - \frac{1}{2}at^2$$

$$\frac{1}{2}v_f^2 - \frac{1}{2}v_0^2 = a(x_f - x_0)$$

Projectile Motion

$$\text{Range} = \frac{v^2}{g} \sin 2\theta, \quad \text{Max. height} = \frac{v_0^2}{2g} \sin^2 \theta$$

Momentum, Force and Impulse

$$p = mv, \quad F = \frac{\Delta p}{\Delta t} = ma, \quad I = F\Delta t = \Delta p$$

Work, Energy and Power

$$W = \vec{F} \cdot (\vec{r} - \vec{r}_0), \quad KE = \frac{1}{2}mv^2, \quad P = \frac{\Delta E}{\Delta t}$$

Gravity and circular orbits

$$PE = -G\frac{Mm}{r}, \quad \Delta PE = mgh(\text{small } h), \quad F = G\frac{Mm}{r^2} = mg$$

$$a = \frac{v^2}{r}, \quad \frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$

Rotational Motion & Gravity

$$v = \omega r = \frac{2\pi r}{T}, \quad \omega = 2\pi f = \frac{2\pi}{T}, \quad f = 1/T$$

$$\alpha = \frac{\omega_f - \omega_0}{t} = \frac{a}{r}$$

$$L = I\omega = mvr \sin \theta, \quad (\theta = \text{angle between } v \text{ and } r)$$

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

$$\tau = rF \sin \theta, \quad I\alpha = \tau, \quad I_{\text{point}} = mR^2$$

$$I_{\text{cyl. shell}} = mR^2, \quad I_{\text{sphere}} = \frac{2}{5}mR^2, \quad I_{\text{solid cyl.}} = \frac{1}{2}mR^2.$$

Gases, liquids and solids

$$PV = NRT, \quad \Delta P = \rho gh, \quad \langle \frac{1}{2}mv^2 \rangle = \frac{3}{2}k_B T$$

$$F_{\text{buoyant}} = \rho_{\text{displaced liq.}} V_{\text{displaced liq.}} g$$

$$\text{Stress} = F/A, \quad \text{Strain} = \Delta L/L, \quad Y = \text{Stress/Strain}$$

$$\frac{\Delta L}{L} = \frac{F/A}{B} = \frac{-\Delta P}{B}$$

$$P_a + \frac{1}{2}\rho_a v_a^2 + \rho_a g h_a = P_b + \frac{1}{2}\rho_b v_b^2 + \rho_b g h_b$$

$$\Delta L/L = \alpha \Delta T, \quad \Delta V/V = 3\alpha \Delta T$$

$$Q = mC_v \Delta T + mL(\text{if phase trans.}), \quad \Delta Q/\Delta t = \frac{kA(T_b - T_a)}{x_b - x_a}$$

Radiation

$$P = e\sigma AT^4$$

Thermodynamics

$\Delta U = Q - W$, $W = P\Delta V$, ideal gas: $\Delta U = nC_v \Delta T$

Adiabatic exp: $pV^\gamma = \text{const}$, $TV^{\gamma-1} = \text{const}$

$\gamma = C_p/C_v = 5/3$ for monotonic gas= $7/5$ for diatomic gas

$Q = T\Delta S$, $\Delta S > 0$

Engines: $\epsilon = W/Q_H < (T_H - T_L)/T_H < 1$

Refrigerators and heat pumps: $\epsilon = Q_L/W < T_L/(T_H - T_L)$

Simple Harmonic Motion and Waves

Spring: $F = -kx$, $PE = (1/2)kx^2$, $\omega = \sqrt{k/m}$

$f = \omega/(2\pi)$, $x(t) = A \cos(\omega t) + B \sin(\omega t)$

Pendulum: $T = 2\pi\sqrt{L/g}$

Waves: $y(x, t) = A \sin[2\pi(ft - x/\lambda + \delta)]$, $v = f\lambda$

$I = \text{const} A^2 f^2$, $I_2/I_1 = R_1^2/R_2^2$

Standing waves: $\lambda_n = 2L/n$

Strings: $v = \sqrt{T/\mu}$, Solid/Liquid: $v = \sqrt{B/\rho}$

Sound: $I = E/(A \cdot \Delta t) = \text{Power}/A$

$I_0 \equiv 10^{-12}$, $\beta = 10 \log_{10}(I/I_0)$, $I = I_0 10^{\beta/10}$

Beat freq.= $|f_1 - f_2|$, Doppler:

$$f_{\text{obs}} = f_{\text{source}}(V_{\text{sound}} \pm v_{\text{obs}})/(V_{\text{sound}} \pm v_{\text{source}})$$

Pipes: same at both ends: $L = \lambda/2, \lambda, 3\lambda/2$

Pipes: open at only one end: $L = \lambda/4, 3\lambda/4, \dots$

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SI Units and Constants

quantity	unit	abbreviation
Charge Q	Coulombs	C
Voltage V	Volts	V = J/C
Electric Field \vec{E}	Volts per meter	V/m = N/C
Capacitance C	Farads	f=C/V
Current I	Amperes	A=C/s
Resistance R	Ohms	Ω =V/A
Magnetic Field \vec{B}	Tesla	T=Ns/(mC)
Lens Strength	Diopters	D=1/m
Atomic mass m	amu	u

Charge of a proton= $e = 1.602 \times 10^{-19}$ C,
 $k = 8.99 \times 10^9$ Nm²/C², $\epsilon_0 = 8.85 \times 10^{-12}$ C²/(Nm²)
 $\mu_0 = 4\pi \times 10^{-7}$ T·m/A, $c = 2.99792 \times 10^8$ m/s
 $m_{\text{prot}} = 1.007276$ u, $m_{\text{neut}} = 1.008665$ u
 1 u=931 MeV/c² = 1.67×10^{-27} kg
 $h = 6.626 \times 10^{-34}$ J·s = 4.136×10^{-15} eV·s

Electric Forces, Potentials and Fields

$\vec{F} = q\vec{E}$, $\vec{E} = kQ\hat{r}/(r^2)$, $PE = qV$, $V = kQ/r$

Gauss's Law: $E_{\perp}A = Q/\epsilon_0$

Circuits

1) Sum of voltage drops around close loop = 0
 2) Sum of currents into any node = 0
 $V = Q/C$, $V = IR$, $V = -L\Delta I/\Delta t$
 parallel: $C_{\text{eff}} = C_a + C_b$, series: $1/C_{\text{eff}} = 1/C_a + 1/C_b$
 series: $R_{\text{eff}} = R_a + R_b$, parallel: $1/R_{\text{eff}} = 1/R_a + 1/R_b$
 $P_{\text{resistor}} = IV = I^2R = V^2/R$
 $U_{\text{capacitor}} = Q^2/(2C) = CV^2/2 = QV/2$
 $U_{\text{inductor}} = LI^2/2$.
 parallel plates: $C = \epsilon_0 A/d$
 wire: $R = \rho L/a$, a =cross-sectional area
 solenoid: $L = N\Phi/I = \mu_0 AN^2/\ell$.

Ampere's Law and Magnetic Forces

$$\sum_{\text{closed path}} Bl = \mu_0 I. \text{ for single wire } B = \frac{\mu_0 I}{2\pi r}$$

$F = qvB \sin \theta$, $F = ILB \sin \theta$

Circular motion: $r = \frac{mv}{qB}$

Moments and torques: $\mu = nIA$, $\tau = \mu B \sin \theta$

Induced EMFs:

$$V_{\text{induced}} = -N \frac{\Delta \Phi}{\Delta t}, \quad \Phi = BA \cos \theta,$$

θ = angle between B and plane

$$= -NA \cos \theta \frac{\Delta B}{\Delta t}, \quad (\text{Fixed coil, changing B})$$

$$= -NB \cos \theta \frac{\Delta A}{\Delta t}, \quad (\text{Fixed B, changing area})$$

$$= NBA \omega \sin \omega t, \quad (\text{Fixed B, rotating coil})$$

RC and LR Circuits:

RC : $\tau = RC$, $Q = Q_0 e^{-t/\tau}$ or $Q_f(1 - e^{-t/\tau})$, $I = I_0 e^{-t/\tau}$
 LR : $\tau = \frac{L}{R}$, $I = I_0 e^{-t/\tau}$ or $I_f(1 - e^{-t/\tau})$

AC Circuits:

LC : $\omega_R = \frac{1}{\sqrt{LC}}$, $f_R = \omega_R/(2\pi)$
 LRC : $X_C = \frac{1}{\omega C}$, $X_L = \omega L$
 $Z = \sqrt{(X_L - X_C)^2 + R^2}$, $I = V/Z$

Transformers:

$V_a/N_a = V_b/N_b$, $I_A N_A = I_B N_B$, $P_A = P_B$

Electromagnetic Waves:

$c_{\text{vac.}} = 1/\sqrt{\epsilon_0 \mu_0}$, $c = \lambda f$
 $\lambda_{\text{matter}} = \lambda_{\text{vac}}/n$, $f_{\text{matter}} = f_{\text{vac}}$, $c_{\text{matter}} = c_{\text{vac}}/n$
 $n_a \sin \theta_a = n_b \sin \theta_b$, $\sin \theta_{\text{crit}} = \frac{n_b}{n_a}$
 $U = \epsilon_0 E^2/2 + B^2/(2\mu_0) = \text{energy/volume}$
 $S = \text{Energy}/(A\Delta t) = cU$

Polarization Filters: $S_f = S_0 \cos^2 \theta$

Primary Colors

Add: Red-Green-Blue Subtr: Cyan-Magenta-Yellow

Mirrors and Lenses

Mirror: $f = R/2$, Lens: $1/f = (n_b - n_a)(1/R_{\text{left}} - 1/R_{\text{right}})$
 $1/f = 1/p + 1/q$, $m = -q/p$

Human Eye: $f_{\text{normal}} = 25$ cm

$D = 1/f = 1/0.25 - 1/(\text{Near Point})$

Microscope: $m = 25L/(f_o f_e)$ **Telescope:** $m = -f_o/f_e$

Interference and Diffraction

Slits and gratings maxima: $\sin \theta_m = m\lambda/d$
 Slits and gratings minima: $\sin \theta_m = (m + 1/2)\lambda/d$
 Position of max/min on screen: $x_m = L \tan \theta_m$
 Single slit minimum: $\theta_m = m\lambda/b$
 Spherical aperture minimum: $\theta_{\text{min}} = 1.22\lambda/d$
 Thin films ($n_1 > n_2 > n_3$ or $n_1 < n_2 < n_3$):
 reflection max: $2t = m\lambda/(n_2)$, min: $2t = (m + 1/2)\lambda/n_2$
 Thin films ($n_1 > n_2 < n_3$ or $n_1 < n_2 > n_3$):
 reflection max: $2t = (m + 1/2)\lambda/(n_2)$, min: $2t = m\lambda/n_2$

Black body: $\lambda_{\text{max}} T = 2.9 \times 10^{-3}$ m·K

Quantum Mechanics:

Uncertainty: $\Delta p \Delta x > h/(4\pi)$, $\Delta E \Delta t > h/(4\pi)$

$E = hf$, $p = h/\lambda$

Atoms

Photon frequency: $hf = |E_f - E_i|$
 Sizes: $r_n = n^2 a_0$, $a_0 = \hbar^2/(mke^2)$, $\hbar = h/(2\pi)$
 Energies: $E_n = -E_0/n^2$, $E_0 = -ke^2/(2a_0) = -13.6$ eV
 $1/\lambda = R(1/n_f^2 - 1/n_i^2)$, $R = 1.097 \times 10^7$ m⁻¹
 $L = \hbar \sqrt{\ell(\ell + 1)}$, $L_z = m_\ell \hbar$, $m_\ell = -\ell, \dots, \ell$
 $S = \hbar \sqrt{s(s + 1)}$, $s = 1/2$, $S_z = \pm 1/2$

Subatomic Physics

Binding energy = $(Nm_n + Zm_p - m_N)c^2$
 Nuclear radius = $A^{1/3} \cdot 1.2$ fm
 $\tau_{1/2} = \ln(2)\tau$, $N = N_0 \exp(-t/\tau)$