PHY 231C FORMULAS

Quadratic Formula

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

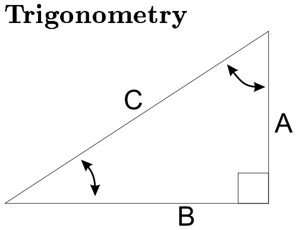
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Geometry

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

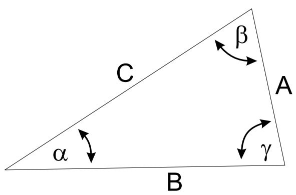
Sphere: area=$4\pi R^2$, volume=$4\pi R^3/3$

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	$T_{\circ F} = 32 + (9/5)T_{\circ C}$
Pressure P	Pascals	Pa=N/m^2

$g = 9.8$ m/s^2, G=6.67×10^{-11} Nm^2/kg^2, 0°C=273.15°K

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

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

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

1-d motion, constant a

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

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

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

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

Projectile Motion

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

Momentum, Force and Impulse

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

Work, Energy and Power

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

Gravity and circular orbits

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

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

Rotational Motion & Gravity

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

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

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

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

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

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

Gases, liquids and solids

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

$$F_{\rm bouyant} = \rho_{\rm displaced\ liq.} V_{\rm displaced\ liq.} g$$

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

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

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

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

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

Radiation

$$P = e\sigma A T^4$$

Thermodynamics

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

Adiabatic exp: pV^γ =const, $TV^{\gamma-1}$ =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: $I = E/(A\cdot\Delta t) = \text{Power}/A$

$I_0 \equiv 10^{-12}$ W/m^2, Intensity in decibels=$10\log_{10}(I/I_0)$

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

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

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

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

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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=$e = 1.602^{-19}$ C,
$k = 8.99 \times 10^9$ Nm^2/C^2, $\epsilon_0 = 8.85 \times 10^{-12}$ C^2/(Nm^2)
$\mu_0 = 4\pi 10^{-7}$ T·m/A, $c = 2.99792 \times 10^8$ m/s
$m_{\text{prot}} = 1.007276$ u, $m_{neut} = 1.008665$ u
1 u=931 MeV/c^2= 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

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

$F = qvB\sin\theta$, $F = ILB\sin\theta$
Circular motion:$r = \frac{mv}{qB}$
Moments and torques:$\mu = nIA$, $\tau = \mu B \sin\theta$
Induced EMFs:

$$\begin{aligned} V_{\text{induced}} &= -N\frac{\Delta\Phi}{\Delta t},\ \Phi = BA\cos\theta, \\ &\qquad \theta = \text{angle between B and plane} \\ &= -NA\cos\theta\frac{\Delta B}{\Delta t},\ \text{(Fixed coil, changing B)} \\ &= -NB\cos\theta\frac{\Delta A}{\Delta t},\ \text{(Fixed B, changing area)} \\ &= NBA\omega\sin\omega t,\ \text{(Fixed B, rotating coil)} \end{aligned}$$

RC and LR Circuts:
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:
$c_{\text{vac.}} = 1/\sqrt{\epsilon_0\mu_0}$, $c = \lambda f$
$\lambda_{\text{matter}} = \lambda_{\text{vac}}/n, f_{\text{matter}} = f_{\text{vac}}$, $c_{\text{matter}} = c_{\text{vac}}/n$
$n_a \sin\theta_a = n_b \sin\theta_b$, $\sin\theta_{\text{crit}} = \frac{n_b}{n_a}$
$U = \epsilon_0 E^2/2 + B^2/(2\mu_0)$ = energy/volume
S = Energy/(AΔt) = 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
$D = 1/f = 1/0.25 - 1/$(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}
$L = \hbar\sqrt{\ell(\ell+1)}, L_z = m_\ell\hbar, m_\ell = -\ell, ..\ell$
$S = \hbar\sqrt{s(s+1)}, s = 1/2, S_z = \pm 1/2$

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