PHYSICS 2C QUIZ 5 WINTER QUARTER 2018
PROF. HIRSCH

Formulas:

$T_3 = 273.16K = 0.01^o C$; water freezes/boils at $T = 0^o C = 32^o F / T = 100^o C = 212^o F$

$1cal = 4.1868J$; $N_A = 6.02 \times 10^{23}$

Thermal expansion: $\Delta L = L\alpha\Delta T$; $\Delta V = V\beta\Delta T$; $\beta = 3\alpha$

Heat capacity and specific heat: $Q = C\Delta T$; $Q = cm\Delta T$

Heat of vaporization, fusion: $Q = L_V m$; $Q = L_F m$

First law of thermodynamics: $\Delta E_{\text{int}} = Q - W$; $\text{d}E_{\text{int}} = dQ - dW$; $\text{W}=\int_{V_i}^{V_f} p\,dV$ work

Conduction: $\text{P}_{cond} = \frac{Q}{t} = kA\frac{T_H - T_L}{L}$; $R = \frac{L}{k}$ k,R=thermal conductivity, resistance

Radiation: $P_{rad} = \sigma\varepsilon AT^4$; $\sigma = 5.67 \times 10^{-8} W / m^2K^4$ $\varepsilon = 1$ for black body

Ideal gas: $PV = nRT = NkT = nN_A kT$; R=8.31J/molK ; $k = 1.38 \times 10^{-23} J / K$

Pressure: $P = \frac{Nm}{3V}(v^2)_{avg}$ Kinetic energy: $K_{avg} = \frac{1}{2}m(v^2)_{avg} = \frac{3}{2}kT$

Internal energy: $E_{\text{int}} = NK_{avg}$; $C_V = \frac{3}{2}R$ for monoatomic gas; $C_P = C_V + R$

C_V, C_P = molar heat capacity at constant volume, pressure

$C_V = \frac{f}{2}R$ for polyatomic gases with f degrees of freedom per molecule

Adiabatic expansion of ideal gas: $PV^\gamma = const$, $TV^{\gamma-1} = const$; $\gamma = C_P / C_V$

Distribution of molecular speeds: $P(v) = 4\pi(\frac{m}{2\pi kT})^{3/2} v^2 e^{-mv^2/(2kT)}$

Velocity distribution: $F(v_x, v_y, v_z) = f(v_x)f(v_y)f(v_z)$, $f(v_x) = (\frac{m}{2\pi kT})^{1/2} e^{-mv_x^2/(2kT)}$

Mean free path: $\lambda = 1/(\sqrt{2}\pi d^2 N / V)$, d=diameter ; $v_{rms} = \sqrt{(v^2)_{avg}}$

Entropy: $dS = dQ / T$ in a reversible process. S is a function of state. $\Delta S = \int_i^f dQ / T$

$\Delta S \geq 0$ for a closed system. = if reversible process, > if irreversible process

Ideal gas: $S(T,V) = nR\ln V + nC_v \ln T + const$

Heat engine: $\varepsilon = \frac{|W|}{|Q_H|}$; Carnot engine: $\varepsilon = 1 - \frac{|Q_L|}{|Q_H|} = 1 - \frac{T_L}{T_H}$

Refrigerator coefficient of performance $K = \frac{|Q_L|}{|W|}$; Carnot refrigerator $K_C = \frac{T_L}{T_H - T_L}$

Statistical view of entropy: $S = k\ln W$; $W = N!/(n_1!\ n_2!\ ....)$; $N! \approx N(\ln N) - N$

Fluids: $\rho = m/V$, $p = F/A$, $1atm = 1.01x10^5 Pa = 760 torr$

Fluid at rest: $p_2 + \rho g y_2 = p_1 + \rho g y_1$; gauge pressure=p-p$_{atmospheric}$

Pascal's principle: $\Delta p = F_1/A_1 = F_2/A_2$

Archimedes principle: buoyant force $F_b = m_{fluid} g$

Continuity equation: volume flow rate = $R_V = Av$ = a constant

Bernoulli equation: $p + \frac{1}{2}\rho v^2 + \rho g y$ = a constant

Oscillations: simple harmonic motion: $x(t) = x_m \cos(\omega t + \phi)$; $\omega = 2\pi f = 2\pi / T$

spring: $F = -kx$, $\omega = \sqrt{k/m}$, energy: $E = U + K = \frac{1}{2}kx_m^2$; $U = \frac{1}{2}kx^2$, $K = \frac{1}{2}mv^2$

torsion pendulum: $\tau = -\kappa\theta$, $\omega = \sqrt{\kappa / I}$; simple pendulum: $\omega = \sqrt{g/L}$

physical pendulum: $\omega = \sqrt{mgh/I}$; $I = I_{CM} + mh^2 = \int r^2 dm$

Damped shm: $F_d = -bv$, $x(t) = x_m e^{-bt/2m}\cos(\omega' t + \phi)$, $\omega' = \sqrt{\omega^2 - (b/2m)^2}$

Forced oscillations: $F_f = f\cos(\omega_d t)$, $x(t) = x_m \cos(\omega_d t + \phi)$; resonance: $\omega_d = \omega$

$$x_m = (f/m)/\sqrt{(\omega_d^2 - \omega^2) + b^2\omega_d^2/m^2}, \ \tan\phi = (b/m)\omega_d/(\omega_d^2 - \omega^2)$$

Waves:

$y(x,t) = y_m \sin(kx - \omega t)$; $\omega = 2\pi f = 2\pi/T$; $k = 2\pi/\lambda$; $v = \omega/k = \lambda f = \lambda/T$

string: $v = \sqrt{\tau/\mu}$; power: $P_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2$

interference: $y'(x,t) = [2y_m \cos\frac{1}{2}\phi]\sin(kx - \omega t + \frac{1}{2}\phi)$

standing waves: $y'(x,t) = [2y_m \sin(kx)]\cos\omega t$; resonance: $f = \frac{v}{\lambda} = n\frac{v}{2L}$

speed of sound: $v = \sqrt{\frac{B}{\rho}}$; $B = -V\frac{\partial P}{\partial V})_S$; ideal gas: $B = \gamma P$

$s = s_m \cos(kx - \omega t)$; $\Delta p = \Delta p_m \sin(kx - \omega t)$; $\Delta p_m = v\rho\omega s_m$

interference: $\phi = \frac{\Delta L}{\lambda}2\pi$; constructive $\phi = 2\pi m$, destructive $\phi = \pi(2m+1)$

sound intensity $I = \frac{P}{A} = \frac{1}{2}\rho v \omega^2 s_m^2 = \frac{P_s}{4\pi r^2}$; decibels β=(10dB)$\log\frac{I}{I_0}$, $I_0 = 10^{-12} W/m^2$

pipes: $f = \frac{nv}{2L}$, $n = 1,2,3$ or $f = \frac{nv}{4L}$, $n = 1,3,5$; beats $f_{beat} = f_1 - f_2$

Doppler: $f' = f\frac{v \pm v_D}{v \pm v_s}$; shock wave $\sin\theta = \frac{v}{v_S}$

Electromagnetic waves and optics:

$E = E_m \sin(kx - \omega t)$; $c = E/B = 1/\sqrt{\mu_0 \varepsilon_0} = 2.998\times 10^8 m/s \approx 3\times 10^8 m/s$

$B = B_m \sin(kx - \omega t)$; $\mu_0 = 4\pi \times 10^{-7} Tm/A$; $\varepsilon_0 = 8.85\times 10^{-12} C^2/Nm^2$

Energy flow: $\vec{S} = (1/\mu_0)\vec{E}\times\vec{B}$; $S_{av} = I = 1/(c\mu_0)E_{rms}^2 = P_s/(4\pi r^2)$

Energy density: $u = u_E + u_B$; $u_E = (1/2)\varepsilon_0 E^2 = 1/(2\mu_0)B^2 = u_B$; $S = cu$

Radiation pressure: $p_r = I/c$ (absorption), $p_r = 2I/c$ (reflection)

Polarization: $I = (1/2)I_0$ if unpolarized, or $I = I_0 \cos^2\theta$ if polarized

Reflection, refraction: $\theta_1 = \theta_1'$, $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Total internal reflection $\theta_c = \sin^{-1}(n_2/n_1)$; Brewster angle $\theta_B = \tan^{-1}(n_2/n_1)$

Spherical mirror: $1/p + 1/i = 1/f = 2/r$; thin lens: $1/p + 1/i = 1/f$

lateral magnification (spherical mirror or thin lens) $m = -i/p$, $|m| = h'/h$

Index of refraction $n = c/v$, $\lambda_n = \lambda/n$

Young slits: $\Delta L = d\sin\theta = m\lambda$ (bright), $d\sin\theta = (m + 1/2)\lambda$ (dark); $\phi = 2\pi\Delta L/\lambda$

Intensity: $I = 4I_0\cos^2(\phi/2)$; thin film $2L = (m + 1/2)(\lambda/n_2)$(bright), (m) (dark)

Single slit diffraction: $a\sin\theta = m\lambda$ (minima), $I(\theta) = I_m(\sin\alpha/\alpha)^2$, $\alpha = (\pi a/\lambda)\sin\theta$

Circular aperture diffraction first minimum $\sin\theta = 1.22\lambda/d$, Raleigh criterion $\theta_R = 1.22\lambda/d$

Double slit diffraction: $I(\theta) = I_m\cos^2\beta(\sin\alpha/\alpha)^2$, $\beta = (\pi d/\lambda)\sin\theta$, $\alpha = (\pi a/\lambda)\sin\theta$

Diffraction gratings: $d\sin\theta = m\lambda$ (maxima), half widths $\Delta\theta_{hw} = \lambda/(Nd\cos\theta)$

Dispersion and resolving power: $D = \Delta\theta/\Delta\lambda = m/(d\cos\theta)$; $R = \lambda_{av}/\Delta\lambda = Nm$

X-ray diffraction: $2d\sin\theta = m\lambda$ (Bragg's law)