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

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

Radiation: $P_{rad} = \sigma\varepsilon A T^4$; $\sigma = 5.67 \times 10^{-8} W / m^2 K^4$ $\varepsilon = 1$ 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 <u>reversible</u> process. S is a function of state. $\Delta S = \int_i^f dQ / T$

$\Delta S \geq 0$ for a <u>closed</u> 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)

Problem 1:
A plane electromagnetic wave of wavelength 3m propagates in vacuum. At a certain position and time, the electric field has its maximum magnitude which is 3V/m. What is the magnitude of the magnetic field at that position 1.25 ns later?
A: 2nT; B: 5nT; C: 7nT; D: 10nT; E: 12nT

Problem 2:
The maximum electric field on a screen due to light coming from a lightbulb that is 3m away is 20V/m. What is the power of the lightbulb?
A: 30W ; B: 60W; C: 120W; D: 240W; E: 15W

Problem 3
A fish swimming at distance 8m from the lake's shore at depth 2m sees an 6m tall fisherman standing at the shore. How tall is the fisherman really? n=1.33 for water.
A: 2m ; B: 1.8m; C: 1.6m; D: 2.2m; E: 1.4m

Problem 4
Consider an object of height h and a thin convergent lens of focal length f. Suppose the object is placed a distance (3/4)f to the left of the lens. What is the height of the image, and is it real (r) or virtual (v)?
A: 3h, r; B: 4h, r; C: 1.33h, r; D: 3h, v; E: 4h, v

Problem 5
In a double slit experiment where the slits are 1mm apart and the screen is 10m away, the intensity of the light of wavelength 600nm at the center of the screen, when one of the slits is closed, is $1W/m^2$. When both slits are open, what is the smallest distance to the center where the intensity of the light on the screen is $1W/m^2$?
A: 2mm; B: 3mm; C: 4mm; D: 5mm; E: 6mm

Problem 6
A soap film of thickness 900nm illuminated with red light in direction perpendicular to it appears bright. Wavelength of red light is approximately 680nm. What is the closest smaller wavelength for which the film appears dark? Assume index of refraction of soap film = 1.33 independent of wavelength.
A: 650nm; B: 625nm; C: 600nm; D: 575nm; E: 550nm

Problem 7 (for extra credit)
For a screen that is 10m away from a single long narrow slit of width 1mm, what is the width of the central diffraction maximum for light of wavelength 500nm?
A: 4cm; B: 3cm; C: 2cm; D: 1cm; E: 0.5cm