PHYSICS 2C QUIZ 4 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: $P_{rad} = \sigma\varepsilon AT^4$; $\sigma = 5.67 \times 10^{-8} W / m^2K^4$ $\varepsilon = 1$ 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 ; $v_{rms} = \sqrt{(v^2)_{avg}}$

<u>Entropy:</u> $dS = dQ / T$ 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: $S = k\ln W$; $W = N!/(n_1!\ n_2!\ \ldots.)$; $N! \approx N(\ln N) - N$

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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)$\log\frac{I}{I_0}$, $I_0 = 10^{-12} W/m^2$

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

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

For problems 1, 2: A traveling sinusoidal wave propagates along a string of mass density 0.5kg/m. The amplitude of the string oscillation is 1cm, the wavelength of the wave is 10cm and the frequency of the wave is 100 Hz.

Problem 1: What is the tension on the string?
A: 30N; B: 10N; C: 50N; D: 70N; E: 90N

Problem 2: What is approximately the kinetic energy of the string in one wavelength?
A: 1J; B: 0.5J; C: 2J; D: 5J; E: 10J

Problem 3
The power transmitted by a sinusoidal wave traveling along a string is 200W. Adding a second wave of the same wavelength and amplitude traveling in the same direction, the power transmitted is 600W. What is the phase difference between the two waves?
A: 15º ; B: 30º; C: 45º; D: 60º; E: 90º

Problem 4
A spring that obeys Hooke's law has length 5cm with no tension. When it is stretched to 10cm length its second harmonic frequency is 100 Hz. If it is now stretched to 20cm length, what will be its second harmonic frequency?
A: 48 Hz ; B: 244 Hz; C: 82 Hz; D: 168 Hz; E: 122 Hz

Problem 5
What is the amplitude of the air oscillations for a sound wave of frequency 1000 Hz and intensity 20 dB?
Sound velocity=343m/s, air density 1.21 kg/m^3
A: 100nm; B: 10nm; C: 1nm; D: 0.5nm; E: 0.1nm

Problem 6
The speed of waves in a violin string is 170m/s, the length of the string is 12cm. What is the third largest sound wavelength that will set up a standing wave in this string? Assume sound velocity is 340m/s.
A: 6cm; B: 16cm; C: 12cm; D: 20cm; E: 24cm

Problem 7 (for extra credit)
There is a police chase going on, one police car races by you and another is approaching you, they go at the same speed of 120km/h and their siren's frequency is f. Assume v_{sound}=330m/s. You hear beats of frequency
A: 0.05f; B: 0.1f; C: 0.15f; D: 0.2f; E: 0.25f