PHYS 4C Exam 2 Reference Sheet (with LaTeX)

Write Units Anything not in here can be found in the textbook or your notes.

Laws of Thermodynamics

0. Transistive Thermodynamic Equilibrium
1. $\Delta E = Q_{in} + W_{in}$
2. $\Delta S \geq 0$
3. 0K can't be reached in finitely many steps

$$T_F = \frac{9}{5}T_C + 32$$

Thermal Expansion

$$\Delta L = \alpha L_i \Delta T$$
$$\Delta V = 3\alpha V_i \Delta T$$

Heat

Flows from hot to cold

$$Q = cm\Delta T (\text{Temperature change})$$
$$Q = L_m m (\text{Phase change})$$

Thermal processes

$$W = -p\Delta V = -\int p\, dV$$
$$PV = NkT = nRT; \Delta E = nC_V \Delta T$$
$$C_V = \left(\frac{f}{2}\right) R; C_p = C_V + 1; \gamma = \frac{C_p}{C_V}$$

Constant	Name	Formulae
p	Isobaric	$Q = nC_p\Delta T; W = -p\Delta V$
T	Isothermal	$Q = -W = nRT\ln(V_f/V_i)$
$pV^\gamma, TV^{\gamma-1}$	Adiabatic	$Q = 0; W = \Delta E$
V	Isochoric	$Q = nC_V\Delta T; W = 0$

Conductance equations

k is the conductance of a material. Conductance over multiple objects works like capacitance equivalence

$$\frac{\mathrm{d}Q}{\mathrm{d}t} = K\Delta T; K = \frac{kA}{L}$$
$$\frac{1}{A}\frac{\mathrm{d}Q}{\mathrm{d}t} = -k\frac{\mathrm{d}T}{\mathrm{d}x}; \vec{J} = -k\nabla T$$

Entropy (S) change

$$\Delta S = \int_i^f \frac{1}{T}\, dQ$$

Engines and Refrigerator

Carnot engines/fridges are perfect and ideal versions. Engine efficiency denoted ε

$$\varepsilon = \frac{|W_{out}|}{|Q_H|}; \varepsilon_C = 1 - \frac{|Q_L|}{|Q_H|} = 1 - \frac{T_L}{T_H}$$

Refrigerator efficiency denoted K

$$K = \frac{|Q_L|}{|W_{in}|}; K_C = \frac{|Q_L|}{|Q_H| - |Q_L|} = \frac{T_L}{T_H - T_L}$$

General Waves

$$\left(\nabla^2\vec{\psi} =\right)\frac{\partial^2\psi}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}$$
$$\psi(x,t) = \psi_m \cos(kx \mp \omega t)$$
$$v = \lambda f = \frac{\omega}{k}; f = \frac{\omega}{2\pi} = \frac{1}{T}; k = \frac{2\pi}{\lambda}$$

Consine can be exchanged with another function like $\sin(\theta)$ or $e^{i\theta}$.

Superposition of waves also fulfills wave equation.

Pulses tend to follow the Gaussian ($e^{-\alpha t}$; $\int_{-\infty}^{\infty} e^{-\alpha t}\, dt = \sqrt{\frac{\pi}{\alpha}}$)

Standing waves

Two traveling waves in opposite directions

$$\psi(x,t) = \psi_m \cos(kx + \phi)\cos(\omega t + \phi')$$
$$\psi(x,t) = \psi_m \left(e^{i(kx-\omega t)} + e^{i(kx+\omega t)}\right)$$

String Waves

String of tension τ, density μ, energy density $\langle \mu_E \rangle$.

$$\mu_K = \frac{1}{2}\mu\left(\frac{\mathrm{d}\psi}{\mathrm{d}t}\right)^2; \mu_U = \frac{1}{2}\tau\left(\frac{\mathrm{d}\psi}{\mathrm{d}x}\right)^2$$
$$\langle \mu_K \rangle = \langle \mu_U \rangle = \frac{1}{4}\mu\omega^2 y_m^2$$
$$v = \sqrt{\frac{\tau}{\mu}}; \langle \mu_E \rangle = \langle \mu_K \rangle + \langle \mu_U \rangle$$
$$P_{avg} = \frac{1}{2}\mu v\omega^2\psi_m^2$$

Resonance comes when one side is fixed and wavelength is a while number divisor of string length

$$f = \frac{v}{\lambda} = n\frac{v}{2L}, \text{for n = 1, 2, 3, ...}$$

For $n = 1$, called fundamental or first harmonic

Sound Waves

In air at 20°C, speed of sound is 343 m/s

Bulk modulus B, temperature T, density ρ

$$s(x,t) = s_m \cos(kx \mp \omega t)$$
$$\Delta p(x,t) = \Delta p_m \sin(kx \mp \omega t)$$
$$v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma k T}{m}}; \Delta p_m = (v\rho\omega)s_m$$

Interference comes from phase difference and path length difference

$$\Delta\phi = \frac{\Delta L}{\lambda}2\pi$$
$$\frac{\Delta L}{\lambda} \equiv 0 \mod 1 \text{ for constructive interference}$$
$$\frac{\Delta L}{\lambda} \equiv 0.5 \mod 1 \text{ for destructive interference}$$

Intensity of a sound wave is rate at which power is transmitted over an area

$$I = \frac{P}{A} = \frac{1}{2}\rho v \omega^2 s_m^2$$
$$I_\Sigma = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\phi)$$

Sound level defined in decibels

$$\beta = (10 \text{ dB}) \log_{10} \frac{I}{I_0}$$
$$f_{beat} = f_1 - f_2$$

Doppler effect comes from detector traveling away (+) from source traveling towards (+) detector

$$f' = f\frac{v_s - v_D}{v_s - v_S}$$