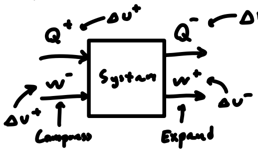
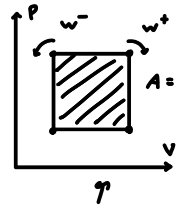
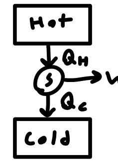
Process	state	W	Q	$\Delta U = Q - W$	$PV = nRT$
Isochoric	$\Delta V = 0$	0	$nC_v\Delta T$ [1]	Q	$P_1/T_1 = P_2/T_2$
Isobaric	$\Delta P = 0$	$P\Delta V \} nR\Delta T$	$nC_p\Delta T$ [2]	$nC_v\Delta T$	$V_1/T_1 = V_2/T_2$
Isotherm	$\Delta T = 0$	$nRT\ln\left(\frac{V_f}{V_0}\right)$	$nRT\ln\left(\frac{P_0}{P_f}\right)$	$Q = W$	$P_1V_1 = P_2V_2$
Adiabatic	$Q = 0$	$-nC_v\Delta T$	0	$-W$	———

1st law: $\Delta U = Q - W$







$W = Q_H^+ + Q_c^-$

$\varepsilon = \frac{W}{Q_H} \times 100\%$ per cycle ← Real

$P = W/t$ °K

$\varepsilon_{carnot} = 1 - \frac{T_c}{T_H}$ ← Ideal

W, Q depend on path

ΔU, P, T, V don't

1hp = 746 W

$\frac{T_H}{T_c} = \frac{|Q_H|}{|Q_c|}$

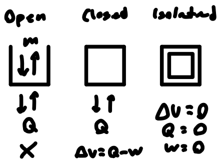
Monoatomic gas: $C_v = \frac{3}{2}R$, $C_p = \frac{5}{2}R$

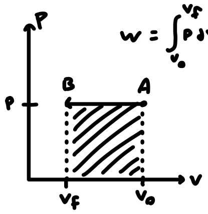
Diatomic gas: $C_v = \frac{5}{2}R$, $C_p = \frac{7}{2}R$

$n = \frac{m}{M}$ M = atomic # $\frac{g}{mol}$

[1] $Q = \frac{C_v \Delta P V}{R}$

[2] $Q = \frac{C_p \Delta V P}{R}$





$W = \int_{V_0}^{V_f} P\,dV$

ΔT — °C or °K

T — °K

1000 L = 1 m³

J = Pa · m³

R = 8.3145 J/mol·K

0.000001 m³ = 1 cm³

101,325 Pa = 1 atm

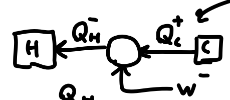
$T_K = T_C + 273$

2nd law ⇒ ΔS > 0

if ΔT = 0 then ΔU = 0

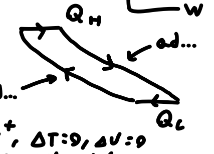
Calorimetry —— $Q_{net} = \sum_i Q_i = 0$

Refrigerator



$K = \frac{|Q_c|}{|W|}$

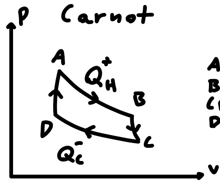
Brayton cycle: ad...



$K_{carnot} = \frac{T_c}{T_H - T_c}$

$P = FA^{-1}$

Carnot



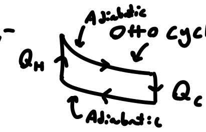
AB: Isotherm → Q_H^+, W^+, ΔT=0, ΔU=0

BC: Adiabatic → W^+, Q=0, ΔU = −W

CD: Isotherm → ΔT=0, ΔU=0, Q_c^-, W^-

DA: Adiabatic → W^-, Q=0, ΔU = −W

Otto cycle



Thermal Expansion:

$\Delta L / L = \alpha \Delta T$

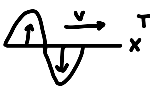
$\Delta V / V = \beta \Delta T$

Textbook sign convention:

$\Delta E_{th} = W + Q$

$W^- \rightarrow W^+$

$W^+ \rightarrow W^-$



Transverse wave

$v = \sqrt{F_T/\mu}$

$v_{air} = 343$ m/s @ 20°C

$= \sqrt{\frac{\gamma k T}{m}}$ ← mass of gas molecule

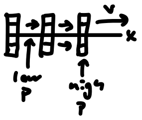
$v_{air} = 331 + 0.6(T)$

$\boxed{v = \lambda f}$

$\boxed{D(x,t) = A\sin(kx - \omega t + \varphi)}$

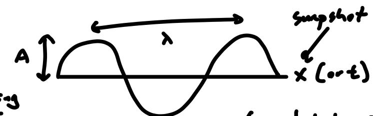
$k = \frac{2\pi}{\lambda}$ $\omega = \frac{2\pi}{T}$

$-\omega \rightarrow +\omega$ for wave traveling in −x direction



Longitudinal wave

$f = T^{-1}$



Sound Intensity:

$I = P/A = P/4\pi R^2 \longrightarrow I \propto \frac{1}{R^2}$

Decibels: $\beta = 10\,dB \log_{10}\left(\frac{I}{I_0}\right)$ $I_0 = 10^{-12}$ W/m²

$f^+ = (1 + V_0/v) f_0$ Observer approaching V_0 — Observer

$f^- = (1 - V_0/v) f_0$ Observer receding v — wave

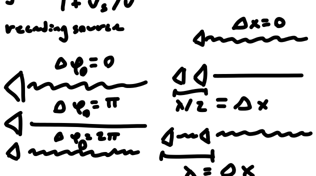
I	dB	L
10^{-12}	0	1
10^{-11}	10	2
10^{-10}	20	4
10^{-9}	30	8

Doppler: $f^+ = \frac{f_0}{1 - v_s/v}$ approaching source v_s — Source, v — wave

$f^- = \frac{f_0}{1 + v_s/v}$ receding source ← Stationary observer

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $I = 2\pi^2 \rho v f^2 A^2$

Bernoulli: $p_1 + \frac{\rho v_1^2}{2} + \rho g h_1 = (\cdots)_2$



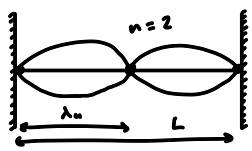
Construct: $\Delta\varphi = 2\pi n$ → n = 0, 1, 2 ...

Destruct: $\Delta\varphi = 2\pi(n + 1/2)$

$\Delta\varphi = \Delta\varphi_0 + \Delta\varphi_{PL}$

$\Delta\varphi_{PL} = \frac{2\pi\Delta x}{\lambda}$ → 2D: $\Delta x \rightarrow \Delta r$

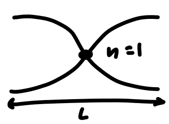
Beat frequency: $f_1 \pm f_B = f_2$



$L = \frac{n}{2}\lambda_n$ $f_n = nf_1$

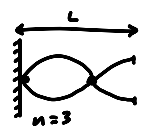
$f_n = \frac{nv}{2L}$ $\lambda_n = \lambda_1/n$

nodes = n+1 antinodes = n



$L = \frac{n}{2}\lambda_n$ ...

Open is the same



n = 1, 3, 5, 7 ...

$L = \frac{n}{4}\lambda_n$ $f_n = nf_1$

$f_n = \frac{vn}{4L}$ $\lambda_n = \frac{\lambda_1}{n}$