Thermo

$\Delta U = \Delta Q - W_{by}$ $\quad W_{by} = \int P dV$ $\quad dQ = T dS$

$PV = nRT$

Closed Cycle: Counterclockwise $\Delta Q < 0$, $W < 0$, $\Delta S < 0$

Clockwise $\Delta Q > 0$, $W > 0$, $\Delta S > 0$

$\Delta U = 0$ $\quad |Q| = |W| =$ Area Enclosed

Adiabatic $\Delta S = \Delta Q = 0$ $\quad PV^\gamma = \text{Const}$ $\quad W_{by} = \frac{1}{1-\gamma}(P_2V_2 - P_1V_1)$

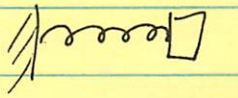
Isotherm $\Delta T = \Delta U = 0$ $\quad W = nRT \ln\left(\frac{V_2}{V_1}\right) = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$

Partition Function $\Omega = \sum_i g_i e^{-E_i/kT}$ $\quad g_i =$ degeneracy

$$\bar{E} = \frac{\sum g_i E_i e^{-E_i/kT}}{\sum g_i e^{-E_i/kT}}$$

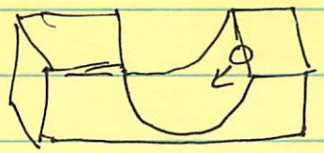
$$\bar{n}_i = \frac{g_i e^{-E_i/kT}}{\sum g_i e^{-E_i/kT}}$$

Equipartition $\Rightarrow \bar{E} = \frac{1}{2}kT$ per quadratic energy



$\bar{E} = kT$

Parabolic Ramp $z = ax^2$



$\bar{E} = \frac{3}{2}kT$

3D SHO $\quad \bar{E} = 3kT$

Special Relativity

Transforms
$$\Delta x' = \gamma(\Delta x - v\Delta t)$$
$$\Delta y' = \Delta y$$
$$\Delta z' = \Delta z$$
$$\Delta t' = \gamma(\Delta t - \Delta x \cdot v/c^2)$$

Length Cont $L' = L/\gamma$

Time Dil. $\Delta t' = \Delta t\,\gamma$

Velocity Addition
$$u_{\parallel} = \frac{u'_{\parallel} + v}{1 + u'_{\parallel} v/c^2} \quad \text{Parallel}$$

$$u_{\perp} = \frac{u'_{\perp}}{\gamma(1 + u_{\parallel} v/c^2)} \quad \text{Perp}$$

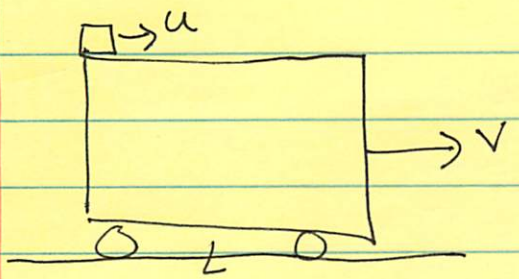
Doppler
$$f = f'\sqrt{\frac{c+v}{c-v}} \quad \text{Parallel}$$

$$f = f'\sqrt{1 - v^2/c^2} \quad \text{Perp}$$

Momentum $= \gamma m v$

$E^2 = m_0^2 c^4 + p^2 c^2$

$\gamma(\beta = .1) = 1.005$
$\gamma(\beta = .5) = 1.155$
$\gamma(\beta = .9) = 2.29$
$\gamma(\beta = .95) = 3.20$
$\gamma(\beta = .99) = 7.09$



How long in Lab Frame?
Rest length L
u Relative to Car

1) Car Frame $\Delta t = \frac{L}{u}$

Lab Frame $\Rightarrow \Delta t' = \gamma \Delta t$

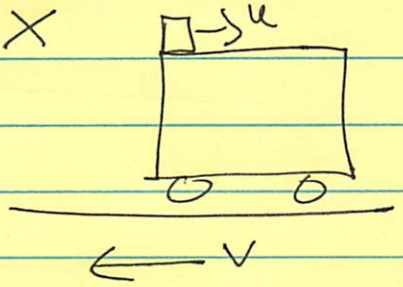
2) Lab Frame $\Rightarrow \Delta t' = \gamma(\Delta t - \Delta x\, v/c^2) = \gamma(\Delta t - L\frac{v}{c^2})$

3) $D = L + v\Delta t'$ $\quad u' = \frac{u+v}{1+uv/c^2}$ $\quad \Delta t' = \frac{D}{u'}$

$\Rightarrow \Delta t' = \ldots$

1) X Car frame, not little box frame $\Rightarrow \Delta x \neq 0$

2) X



Δx ∦ V in opposite direction
so $\Delta x \cdot V < 0$

3) In lab frame car size $= L' = L/\gamma$

4) $\boxed{\Delta t' = \gamma(\Delta t + Lv/c^2)}$