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General Physics I, Final 1
PHYS10400, Class year 99
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1.

In a adiabatic process, $Q=0$, for ideal gas.

$dE_{int} = dQ - dW$, $Q=0$. dW = Work done by the system

$nC_v\,dT = -p\,dV$

$n\,dT = -\left(\frac{p}{C_v}\right)dV$, but $pV = nRT$

$\therefore\ p\,dV + V\,dp = nR\,dT$

$n\,dT = \frac{p\,dV+V\,dp}{R}$

$= \frac{p\,dV+V\,dp}{C_p - C_v}$

$\therefore\ \frac{p\,dV+V\,dp}{C_p-C_v} = -\left(\frac{p}{C_v}\right)dV$

$\frac{dp}{p} + \left(\frac{C_p}{C_v}\right)\frac{dV}{V} = 0$

$\ln p + \gamma \ln V = \text{constant}$, $\gamma = \frac{C_p}{C_v}$

$pV^{\gamma} = \text{constant}$

2.

For a Solid Cylinder as shown on the right

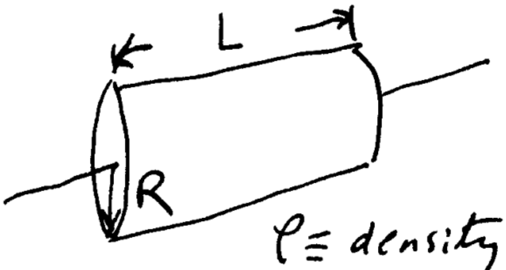
$I = \int r^2\,dm$

$= \int r^2\, 2\pi r\,dr\, L\rho$

$= 2\pi L\rho \int_0^R r^3\,dr$

$= 2\pi L\rho\,\frac{R^4}{4}$

$= \frac{1}{2} M R^2$



$\rho \equiv$ density of the cylinder

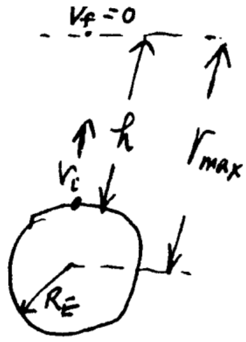
$M = \pi R^2 \cdot \rho$

3.

2.

(a) $$\frac{1}{2} m V_i^2 - \frac{G M_E m}{R_E} = -\frac{G M_E m}{r_{max}}$$

if $V_f = 0$



$$\therefore V_i^2 = 2 G M_E \left(\frac{1}{R_E} - \frac{1}{r_{max}} \right) \rightarrow \text{Ans (a)}$$

(b) if $r_{max} = \infty$ $\quad V_i^2 = 2 G M_E \left(\frac{1}{R_E} \right) = V_{Esc}^2$

$$V_{Esc} = \sqrt{\frac{2 M_E G}{R_E}} \approx \text{plug in numbers} \doteqdot 10\ \text{Km/sec}$$

4.

Let $\cancel{x(t)}$ $x(t) = A(\cos \omega t + \phi)$ represents a SHO's Amplitud

then $v = \frac{dx(t)}{dt} = -\omega A \sin(\omega t + \phi)$

Total energy of a SHO $\quad E_{tot} = E_K + E_u$

$$E_K = \frac{1}{2} m v^2 = \frac{1}{2} m \omega^2 A^2 \sin^2(\omega t + \phi)$$

$$E_U = \frac{1}{2} k x^2 = \frac{1}{2} k A^2 \cos^2(\omega t + \phi)$$

$$E_{total} = \frac{1}{2} m \omega^2 A^2 \sin^2(\omega t + \phi) + \frac{1}{2} k A^2 \cos^2(\omega t + \phi)$$

$$= \frac{1}{2} k A^2 = \text{Constand}.$$

E_{total} determined by k and Max. Amplitude A

5.

Parallel Theorem, $I = I_{cm} + MD^2$

$I = \int r^2 dm = \int (x^2 + y^2) dm$. But $x = x' + x_{cm}$, $y = y' + y_{cm}$

$$\therefore I = \int [(x' + x_{cm})^2 + (y' + y_{cm})^2] dm$$

$$= \int [x'^2 + 2x'x_{cm} + x_{cm}^2 + y'^2 + 2y'y_{cm} + y_{cm}^2] dm$$

$$= \underbrace{\int (x'^2 + y'^2) dm}_{= I_{cm}} + \underbrace{2x_{cm}\int x' dm}_{=0} + \underbrace{2y_{cm}\int y' dm}_{=0} + \underbrace{(x_{cm}^2 + y_{cm}^2)\int dm}_{D^2 M}$$

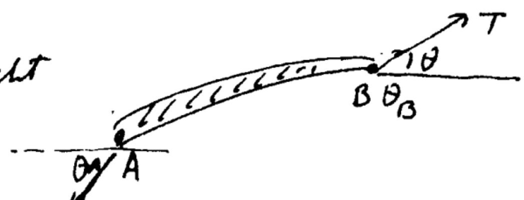
definition of center of Mass

$$= I_{cm} + MD^2$$

6.

Use the figure on the right

The total force F_y is



$\sum F_y = T\sin\theta_B - T\sin\theta_A$ for small θ . $\sin\theta \approx \tan\theta$

$$= T(\sin\theta_B - \sin\theta_A)$$

$$\doteq T(\tan\theta_B - \tan\theta_A)$$

$$= T\left(\left.\frac{\partial y}{\partial x}\right|_{\text{at } B} - \left.\frac{\partial y}{\partial x}\right|_A\right) = m a_y = \mu \Delta x \left(\frac{\partial^2 y}{\partial t^2}\right)$$

$$\therefore \mu \Delta x \left(\frac{\partial^2 y}{\partial t^2}\right) = T\left[\left(\frac{\partial y}{\partial x}\right)_B - \left(\frac{\partial y}{\partial t^2}\right)_A\right]$$

$$\text{or } \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2} = \frac{\left(\frac{\partial y}{\partial x}\right)_B - \left(\frac{\partial y}{\partial t^2}\right)_A}{\Delta x} = \frac{\partial^2 y}{\partial x^2}$$

$$\therefore \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2} = \frac{\partial^2 y}{\partial x^2} \quad \text{or} \quad \frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

is the wave equation describe a wave traveling in the String.

7.

In A Solid. , in x-axis direction, due to atom vibrat

$E_{int} = \frac{1}{2} m V_x^2 + \frac{1}{2} k x^2$ (two degree of freedom)

Take into account $\hat{y}$ and $\hat{z}$ dimension. there are total of 6 degree of freedoms, then Use equ-partition theo each degree of freedom take $\frac{1}{2} k_B T$ energy

$\therefore \quad E_{int} = 6 \times \frac{1}{2} k_B T = 3 k_B T = 3 n R T$, for $n=1$

$E_{int} = 3RT$ (for $n=1$). Thus $C_v = \frac{d}{dT}(E_{int}) = \underline{3R}$

9.

Mean free path $\lambda = \dfrac{\text{total length}}{\text{number of Collision}}$

$$\lambda = \frac{\bar{v} \Delta t}{\frac{N}{V} \pi d^2 \bar{v} \Delta t} = \frac{1}{\pi d^2 \frac{N}{V}}$$

$\Rightarrow$ Assume there is no relative motions betw the gas molecules

For details, check Textbook

8.

(a) A free expansion process is also an adiabatic process. Since this is an irreversible process, we can find an isothermal reversible process (expansion) to ~~et~~ calculate the entropy change of this system

$$\therefore \Delta S = \int_i^f \frac{dQ_r}{T} = \frac{1}{T}\int_i^f dQ_r. \quad dQ_r \text{ is the reversible case.}$$

in a reversible isothermal process,

$$dE_{in} = 0 \quad \therefore dQ_r = -dW$$

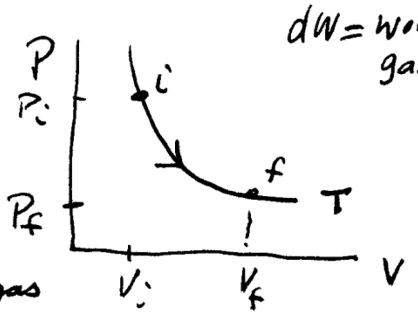
dW = work done to the gas

$$-W = +\int_{V_i}^{V_f} +P\,dV$$

$$= +\int_{V_i}^{V_f} \frac{nRT}{V}\,dV$$

$$= nRT\ln\left(\frac{V_f}{V_i}\right)$$

= work done by the gas to the environment



$$\therefore \int_i^f dQ_r = \int_i^f -dW = -W = nRT\ln\left(\frac{V_f}{V_i}\right)$$

Thus the total entropy change is

$$\Delta S = nR\ln\left(\frac{V_f}{V_i}\right)$$

(b) Since $dE_{int} = dQ_r + dW$, dW = work done on the gas $= -P\,dV$

$$dQ_r = dE_{int} - dW$$

$$= dE_{int} + P\,dV$$

$$= nC_v\,dT + nRT\frac{dV}{V}$$

$$\therefore \frac{dQ_r}{T} = nC_V\frac{dT}{T} + nR\frac{dV}{V}$$

$$\Delta S = \int_i^f \frac{dQ_r}{T} = nC_v\ln\left(\frac{T_f}{T_i}\right) + nR\ln\left(\frac{V_f}{V_i}\right)$$