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Solutions

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

$$dE_{int} = dQ - dW \quad , \quad Q=0. \quad dW = \text{work done by the system}$$

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

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

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

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

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

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

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

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

2.

(a)
$$\frac{1}{2}mV_i^2 - \frac{GM_E m}{R_E} = -\frac{GM_E m}{r_{max}}$$

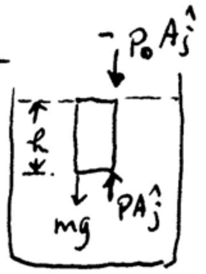
if $V_f = 0$

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

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

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

3. Refer to the figure on the right



If the cylinder is in equilibrium

$$\Sigma F = 0 \quad (\hat{y}\text{-axis})$$

$$\Sigma F = PA\hat{j} - P_0 A\hat{j} - Mg\hat{j} = 0$$

$$PA - P_0 A - \rho A h g = 0$$

$$P = P_0 + \rho g h$$

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

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

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

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

$$E_U = \frac{1}{2}kx^2 = \frac{1}{2}kA^2\cos^2(\omega t + \phi)$$

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

$$= \frac{1}{2}kA^2 = \text{Constant}.$$

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

5. Refer to the figure

$$F_r = 2T\sin\theta \approx 2T\theta \quad \text{if } \theta \text{ is small},$$

$$m = \mu\Delta s = \mu R 2\theta = 2\mu R\theta$$

But $F_r = ma = \dfrac{mv^2}{R} = 2T\theta$

$$\therefore 2T\theta = \frac{mv^2}{R} = \frac{2\mu R\theta v^2}{R} \rightarrow v = \sqrt{\frac{T}{\mu}}$$

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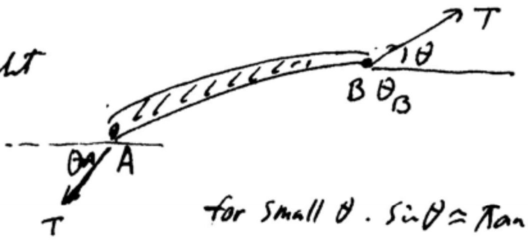
6 Use the figure on the right

The total force F_y is



$$\sum F_y = T\sin\theta_B - T\sin\theta_A \qquad \text{for small } \theta .\ \sin\theta \simeq \tan\theta$$

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

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

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

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

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

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

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

7. $$f' = f\,\frac{v \pm v_D}{v \mp v_s} = f(v \pm v_D)(v \mp v_s)^{-1}$$

$$= f\left(1 \pm \frac{v_D}{v}\right)\left(1 \mp \frac{v_s}{v}\right)^{-1}$$

$$= f\left[1 \pm \frac{v_D}{v} + \cdots\right]\left[1 \pm \frac{v_s}{v} + \cdots\right] \qquad u = v_s \pm v_D$$

$$= f\left(1 \pm \frac{v_s}{v} \pm \frac{v_D}{v} + \frac{v_s v_D}{v} + \cdots\right)$$

$$= f\left(1 \pm \frac{v_s \pm v_D}{v} + \cdots\right) \qquad \therefore\ \underline{f' = f\left(1 \pm \frac{u}{v}\right)}$$

8 A constant pressure, C_p

$$\Delta E_{int} = Q + W = nC_p\Delta T + (-P\Delta V)$$

W defined as work done on the system

$$nC_v\Delta T = nC_p\Delta T - nR\Delta T$$

$$\therefore C_p - C_v = R,$$

$$C_p = C_v + R = \frac{3}{2}R + R = \frac{5}{2}R$$

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

$$E_{int} = \frac{1}{2}mV_x^2 + \frac{1}{2}kx^2 \quad \text{(two degree of freedom)}$$

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

$$\therefore E_{int} = 6\times\frac{1}{2}k_BT = 3k_BT = 3nRT \quad \text{, for } n=1$$

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

10. 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