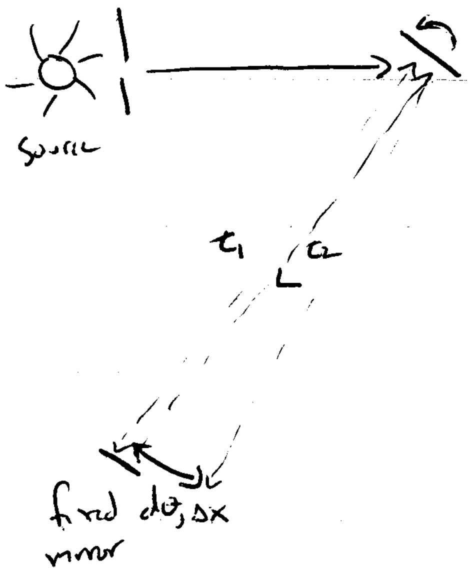
HW 1



$$t_1 + t_2 = \frac{2L}{c} = t$$

$$\frac{d\theta}{2} = \omega \cdot t$$

$$\frac{d\theta}{2} = \omega \frac{2L}{c}$$

$\sin d\theta = \frac{\Delta x}{L}$

$d\theta \cdot L = \Delta x$

$$c = \frac{4\omega L}{d\theta}$$

if $L = 10\,m$

$$d\theta \cdot L = \Delta x \qquad d\theta = \frac{\Delta x}{L}$$

$$\cancel{c = \frac{4\omega L}{d\theta L}} \qquad c = \frac{4\omega L^2}{\Delta x}$$

if $L = 10m$, $\Delta x = 1mm$

$$c = \frac{400}{1\times10^{-3}}\,\omega = 4\times10^{5}\,\omega$$

so if $\omega \sim 10^3$, can find c!

2) $x' = \gamma(x - vt)$ $\quad x = \gamma(x' + vt)$

$$x' = \gamma(\gamma(x' + vt') - vt)$$

$$x'/\gamma = \gamma x' + \gamma v t' - vt$$

$$t = 1/v\,(\gamma x' + \gamma v t' - x'/\gamma)$$

$$t = \gamma/v\,(x' + vt' - x'/\gamma^2)$$

$$\gamma^2 = \frac{1}{1 - v^2/c^2}$$

$$t = \gamma/v\,(\cancel{x'} + vt' - \cancel{x'} + x'v^2/c^2)$$

$$\boxed{t = \gamma(t' + x'v/c^2)}$$

Reverse substitution to get expression for t'

2)

$\underline{\text{Event 1}}$ $\quad\quad$ $\underline{\text{Event 2}}$

$x_1 \quad t_1$ $\quad\quad$ $x_2 \quad t_2$

$$\Delta x = x_2 - x_1$$

$$x_1' = \gamma(x_1 - Vt_1) \qquad x_2' = \gamma(x_2 - Vt_2)$$

$$\Delta x' = \gamma(\Delta x - V\Delta t)$$

$$\Delta t = t_2 - t_1 \qquad t_1' = \gamma(t_1 - x_1V/c^2)$$

$$t_2' = \gamma(t_2 - x_2V/c^2)$$

$$\Delta t' = \gamma(\Delta t - V\Delta x/c^2)$$

$$u_x' = \frac{\Delta x'}{\Delta t'} = \frac{\Delta x - V\Delta t}{\Delta t - V\Delta x/c^2} = \frac{\Delta x/\Delta t - V}{1 - \frac{V}{c^2}\frac{\Delta x}{\Delta t}}$$

$$\boxed{u_x' = \frac{u_x - V}{1 - u_xV/c^2}} \qquad \boxed{u_x = \frac{u_x' + V}{1 + Vu_x'/c^2}}$$

$$u_y' = \frac{\Delta y}{\gamma(\Delta t - V\Delta x/c^2)} = \frac{\Delta y/\Delta t}{\gamma(1 - \frac{V}{c^2}\frac{\Delta x}{\Delta t})}$$

$$\boxed{u_y' = \frac{u_y}{\gamma(1 - Vu_x/c^2)}} \qquad \boxed{u_y = \frac{u_y'}{\gamma(1 + Vu_x/c^2)}}$$

1-4) $L = 12.5$ $c = 130$ mph $v = 20$ mph

a) $$\Delta t = \frac{Lv^2}{c^3} = \frac{12.5\,mi \cdot 20\,mph^2}{130\,mph^3} = \underline{\underline{8.2\,s}}$$

b) $$\theta_1 = \sin^{-1} 20/130 = 8.8^\circ$$
$$\theta_2 = 0^\circ$$

1-13)

S: $x = 75\,m$ $y = 18\,m$ $z = 4\,m$ $t = 2\times10^{-5}$
S': $v_x = 0.85c$

$t = t' = 0$ ← origins coincide

a) $$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - \frac{.85^2\cancel{c^2}}{\cancel{c^2}}}} = 1.898$$

$$x' = \gamma(x - vt) = 1.898\,(75\,m - 0.85c \cdot 2\times10^{-5}\,s)$$
$\rightarrow$ $x' = -9.537\times10^3\,m$
$\rightarrow$ $y' = y = 18\,m$
$\rightarrow$ $z' = z = 4\,m$

$$t' = \gamma(t - vx/c^2) = 1.898\left(2\times10^{-5} - \frac{0.85c \cdot 75}{c^2}\right)$$

$\rightarrow t' = 3.756\times10^{-5}\,s$

1-13 b

$$x = \gamma(x' + vt') = 1.898(-9.537\times10^{3}\,m + 0.85c \cdot 3.756\times10^{-5}$$

$$\boxed{x = 75\,m}$$

$$y = y' = 18$$
$$z = z' = 4$$

$$t = \gamma(t' + vx'/c^2) = 1.898\left(3.756\times10^{-5} + \frac{0.85c \cdot -9.537\times10^{3}}{c^2}\right)$$

$$\boxed{t = 2\times10^{-5}\,s}$$

1-21

$$\Delta t = \gamma \Delta t'$$

$$\Delta t' = 1.01\,\Delta t$$

$$\gamma = 1.01 = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$\boxed{v = 0.14c}$$

27)

S

$L_A = 100m$ $\qquad$ $L^*_B = 36m$

S'

$$L'_A = L_A / \gamma = 100m \cdot \sqrt{1-(0.92)^2} = 39.2$$

$$L_0 = 36m / \gamma = 91.9m$$

54)

$$x^2 + y^2 + z^2 = (ct)^2$$

$$\left[\gamma(x' + vt')\right]^2 + y'^2 + z'^2 = c^2\left(\gamma(t' + \frac{vx'}{c^2})\right)^2$$

$$\gamma^2\left[x'^2 + 2vx't' + v^2t'^2\right] + y'^2 + z'^2 = c^2\gamma^2\left[t'^2 + \frac{2vx't'}{c^2} + \frac{v^2x'^2}{c^4}\right]$$

Group Terms

$$x'^2 \underbrace{\left[\gamma^2 - \frac{\gamma^2 v^2}{c^2}\right]} + y'^2 + z'^2 = \underbrace{t'^2\left[c^2\gamma^2 - \gamma^2 v^2\right]} + x't'\underbrace{\left[\cancel{2v\gamma^2 - 2v\gamma^2}\right]}_{0}$$

$$\gamma^2(1 - v^2/c^2)$$

$$\gamma^2(1/\gamma^2) = 1$$

$$\Downarrow$$

$$1 \cdot x'^2$$

$$c^2\gamma^2 - \gamma^2 v^2$$

$$\gamma^2(c^2 - v^2)$$

$$\frac{1}{\cancel{1 - v^2/c^2}} \cdot c^2\cancel{(1 - v^2/c^2)}$$

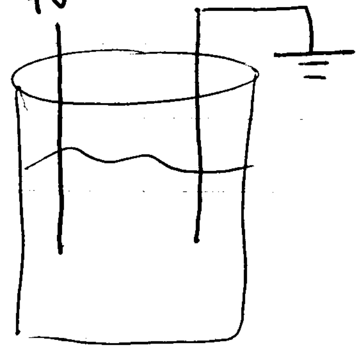
$$\Downarrow$$

$$c^2 \cdot t'^2$$

$$x'^2 + y'^2 + z'^2 = (ct')^2$$

CLASSICAL / PRE-MODERN PHYSICS

1)



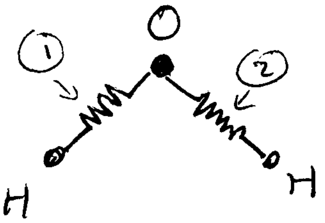
→ Apply voltage in NaCl solution
→ NaCl ionizes
→ + ions go to ⏚, − ions go to +V
→ measure change in mass of electrodes

ration of Δm's should give atomic mass ratios of Na, Cl

2)

Momentum is conserved. So if you have molecule w/ V_x and it hits stationary molecule, stationary molecule acquires V_x ... continues on towards wall... doesn't matter which molecule actually hits the wall!

3)



Translational Energy $\Rightarrow v_x^2, v_y^2, v_z^2 = \frac{3}{2}KT$

Rotation about Center of Mass in 3D $\Rightarrow I_y\omega_y^2, I_z\omega_z^2, I_x\omega_x^2$
$= \frac{3}{2}KT$

Vibrational Energy $=$ (1) $\frac{1}{2}Kx_1^2 + \frac{1}{2}mv_1^2 = KT$
(2) $\frac{1}{2}Kx_2^2 + \frac{1}{2}mv_2^2 = KT$

Twist

$\frac{1}{2}K_3 x_1^2 + \frac{1}{2}mv_3^2 = KT$

Total $E = \left(\frac{3}{2} + \frac{3}{2} + 2 + 1\right)KT = 6KT$

$= 6 \cdot .0259\ eV \cong 0.155\ eV$ per H_2O

$M_{H_2O} = 18$

3 grams $= \frac{1}{6}$ mole $= \frac{6.022\times10^{23}}{6}$ molecules

$E_{total} = 1\times10^{23} \cdot .155\ eV \cdot 1.6\times10^{-19}\ \frac{J}{eV}$

$E_{total} = 2480\ J$

4)

Monatomic Gas in 2D

2 Degrees of Freedom $= 2 \cdot \frac{1}{2} KT$

$$\bar{E} = KT = U/N_A$$

$$\left(\partial U / \partial T \right)_V = \boxed{C_V = R}$$

$$\boxed{C_p = C_V + R = 2R}$$

$$\boxed{\gamma = C_p / C_V = 2}$$