Ex4 Sheet 2 Angelo Valentino Brade (Jonas Wortmann and Noa Goedee) 22.04.2024

Exercise 1:

a) $F_a = \rho_{oil} \cdot V_{oil} \cdot g$

$F_B = \rho_{air} \cdot V_{oil} \cdot g$

$F_E = N \cdot q E$

$F_{ges} = \sum F_i$

$0 \overset{!}{=} (\rho_{air} - \rho_{oil}) V_{oil} \cdot g + NqE$

I need $E = \frac{U}{d}$ at the condensator.

b)

$F = -6\pi \eta_{air} r v$

$\Rightarrow (\rho_{air} - \rho_{oil}) V_{oil} \cdot g + NqE = 6\pi \eta_{air} r v$

c) $V_{oil} = \frac{4}{3}\pi r^3$

$\Rightarrow (\rho_{air} - \rho_{oil}) \frac{4}{3}\pi r^3 \cdot g + NqE = 6\pi \eta_{air} \cdot r \cdot v \quad | E = 0$

$\Rightarrow (\rho_{air} - \rho_{oil}) \frac{4}{3}\pi r^2 g = 6\pi \eta_{air} \cdot v$

$\Rightarrow r = \sqrt{\frac{9 \eta_{air} \cdot v}{(\rho_{air} - \rho_{oil}) 2 \cdot g}} \quad \Big| \; \rho_{oil} = 0{,}8129 \cdot 10^3 \, kg/m^3, \; \rho_{air} = 8{,}0013 \, kg/m^3, \; \eta_{air} = 18{,}2 \cdot 10^{-6} \, Pa \cdot s$

$\approx 1{,}12 \cdot 10^{-6} \, m$

d) $v = 0$

$\Rightarrow (\rho_{air} - \rho_{oil}) \frac{4}{3}\pi r^3 \cdot g + NqE = 0$

$\Rightarrow N = -\frac{d(\rho_{air} - \rho_{oil}) \frac{4}{3}\pi r^3 g}{qU} \quad \Big| \; U = 500V, \; d = 10^{-2} m$

$\approx 7{,}02$

Exercise 2:

a) $F_L = q v B$

$= I \cdot t \cdot \frac{L}{t} B$

$= I L B$

$F_L = F_a$

$\Rightarrow ILB = mg$

b) $F_L = q v B$

$q \frac{U}{L} = q v B$

$U = L v B$

$\Rightarrow I \cdot L \frac{U}{Lv} = mg$

$\Rightarrow m = \frac{I \cdot U}{v}$

c) $ILB = mg$

$\Rightarrow I = \frac{mg}{LB} \quad \Big| \; m = 4kg, \; g = 9{,}81 m/s^2, \; B = 0{,}55T, \; L = 0{,}43cm$

$50{,}36 = A$

d) $I = U_{Jos.} / R_{Hall} = n_J \cdot n_H \cdot f \cdot e/2$

$n_J \sim n_H \sim 1, \; f = 5 GHz, \; e = 1{,}6 \cdot 10^{-19} C$

$\Rightarrow I \approx 4 \cdot 10^{-10} A$

$m = \frac{I \cdot L \cdot B}{g}$

$\approx \pi \cdot 10^{-8} kg$

A difference of $3{,}14 \cdot 10^{-8} kg$ is measurable.

Exercise 3:

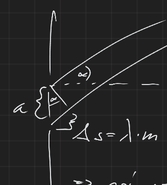
a) The slits are required to generate a prallel beam, where the source is distant enough. To adjust the source opening width, the slits also have to be adjustable.

b) $\lambda_{dB} = \frac{h}{p} = \frac{h}{720 \cdot 1{,}66 \cdot 10^{-27} kg \cdot 220 m/s}$

$= 2{,}519 \cdot 10^{-12} m$

The wavelength is way smaler as the diameter of one Atom:

$\lambda_{dB} \ll Å = 10^{-10} m$



As the scetch shows: $d \sin\alpha = \lambda \cdot m$

$\Rightarrow \alpha = \sin^{-1} \frac{\lambda}{d}$

$= 2{,}519 \cdot 10^{-3}$

$\Rightarrow a \sin\alpha = \lambda \cdot m$

c) With larger Molecules the diffraction angle narrows.

When C_{70} is $\frac{70}{60}$ havier as C_{60}, then follows:

$m_{60} = \frac{6}{7} m_{70}$

$\Rightarrow \lambda_{70} = \frac{6}{7} \lambda_{60} \quad | \alpha \approx \frac{\lambda}{d}$

$\Rightarrow \alpha_{70} \approx \frac{6}{7} \alpha_{60}$

The angle is expected to be $\frac{6}{7}$ narrower.

Exercise 4:

a) $E\psi(x,t) = i\hbar \frac{\partial}{\partial t} \psi(x,t) = \frac{\hat{p}^2}{2m} \psi(x,t), \quad E = \frac{p^2}{2m}$

ω:

$\Rightarrow E e^{i(kx - \omega t)} = \hbar \omega e^{i(kx - \omega t)}$

$\Rightarrow \omega(E) = \frac{E}{\hbar}$

$\Rightarrow \omega(p) = \frac{p^2}{2m\hbar}$

k:

$\Rightarrow E e^{i(kx - \omega t)} = \frac{i^2 \hbar^2}{2m} \partial_x^2 e^{i(kx - \omega t)}$

$= \frac{\hbar^2 k^2}{2m} e^{i(kx - \omega t)}$

$\Rightarrow k(E) = \frac{\sqrt{2Em}}{\hbar}$

$\Rightarrow k(p) = \frac{p}{\hbar}$

$\Rightarrow \lambda_{dB} = \frac{h}{p} = \frac{h}{\hbar k} = \frac{2\pi}{k}$

$\Rightarrow v_{ph} = \frac{\omega}{k} = \frac{p^2}{2m\hbar} \frac{\hbar}{p} = \frac{p}{2m} = \frac{v}{2}$

b) $\psi(x,t) = \psi_a(x,t) + \psi_b(x,t)$

$= e^{i(kx - \omega t)} + e^{i(kx + dkx - \omega t - d\omega t)}$

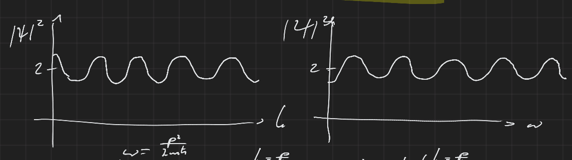
$= e^{i(kx - \omega t)} (1 + e^{i(dkx - d\omega t)})$

$\Rightarrow |\psi|^2 = \psi^* \psi$

$= (1 + e^{-i(dkx - d\omega t)})(1 + e^{i(dkx - d\omega t)})$

$= 1 + e^{i(dkx - d\omega t)} + e^{-i(dkx - d\omega t)} + e^0$

$= 2 + \frac{1}{2} \cos(dkx - d\omega t)$



$v_{gr} = \frac{d\omega}{dk} \overset{\omega = \frac{p^2}{2m\hbar}}{=} \frac{d}{dk} \frac{p^2}{2m\hbar} \overset{k = \frac{p}{\hbar}}{=} \frac{d}{dk} \frac{\hbar k^2}{2m} = \frac{\hbar k}{m} \overset{k = \frac{p}{\hbar}}{=} \frac{p}{m} = v$

The group velocity v_{gr} of "wave packets" is $v_{gr} = \frac{\hbar k}{m}$.

The group velocity v_{gr} of the classical particle is thus $v_{gr} = v$.