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Phy 283
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HW for 10/4/17

Q 5M.6, Q6M.2

2

QSM.6

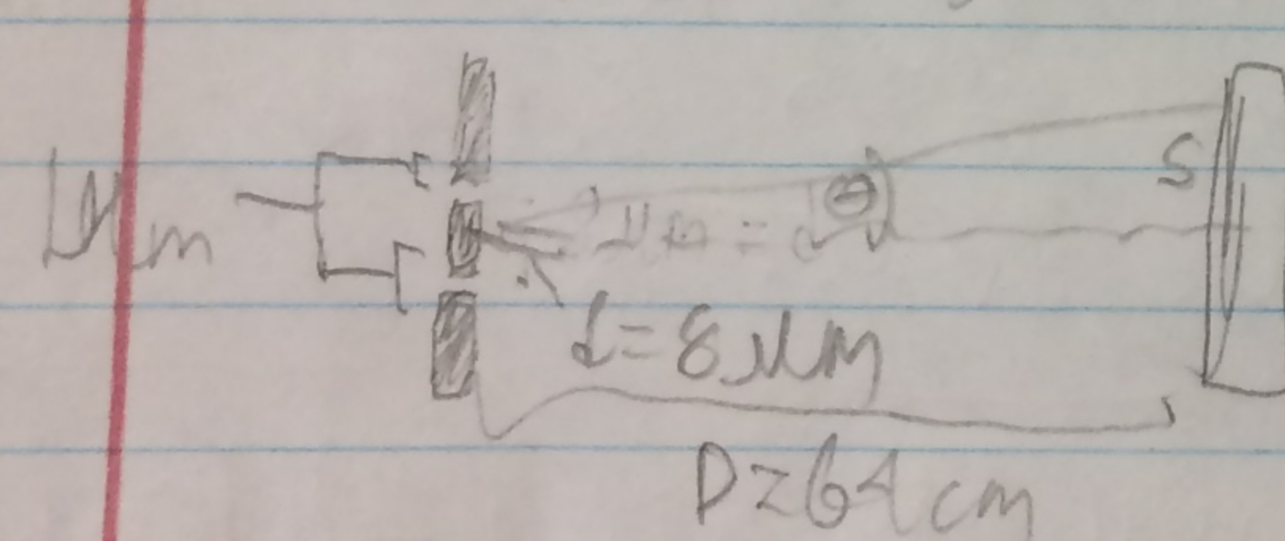
Consider the helium atom interference experiment discussed in section Q5.5. In this experiment, the detection screen was 64 cm from the slits

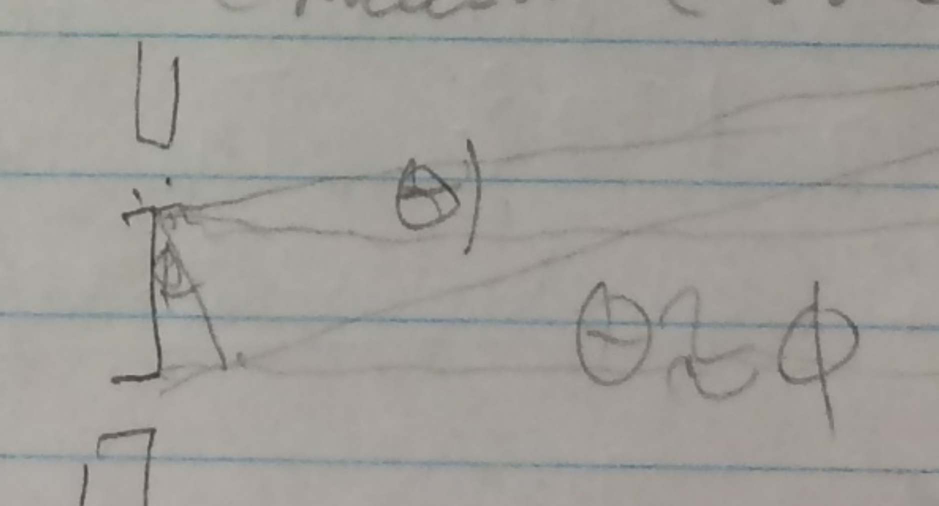
a) If the helium beam had a wavelength of 0.103 nm, what is the approximate speed of each atom?

The de Broglie wavelength of the beam is $\lambda = 0.103\,nm = 0.103 \cdot 10^{-9}\,m$. The relationship between a particle's relativistic momentum, $|\vec{p}|$, and its de Broglie wavelength λ, is $\lambda = \frac{h}{|\vec{p}|}$, where h is Planck's constant $(6.626 \cdot 10^{-34}\,J \cdot s)$

The relativistic momentum is $|\vec{p}| = \frac{m|\vec{v}|}{\sqrt{1-(\frac{v}{c})^2}}$. In this case, the helium atoms will not be moving an appreciable fraction of c, so we can approximate $|\vec{p}| \approx m|\vec{v}|$. So we can say $\lambda \approx \frac{h}{m|\vec{v}|}$. The mass of a helium atom is $6.6464 \cdot 10^{-27}\,kg$. So solving for $|\vec{v}|$, we get $|\vec{v}| = \frac{h}{m\lambda} = \frac{6.626 \cdot 10^{-34}\,J \cdot s}{6.6464 \cdot 10^{-27}\,kg \cdot 0.103 \cdot 10^{-9}\,m} = \boxed{968\,m/s.}$

b) Calculate the theoretical distance between adjacent interference maxima on the detection screen and compare it to the measured value.





$\lambda <<$ slit width, so we can use $d \cdot \sin\theta = n \cdot \lambda$.
In this case $\sin\theta \approx \tan\theta = \frac{S}{D}$, so we can substitute: $d \sin\theta = d \cdot \frac{S}{D}$
Solving for S, we see $S = \frac{n \cdot \lambda \cdot D}{d}$, and in this case $n = 1$.
So we get $S = \frac{0.103 \cdot 10^{-9}\,m \cdot 64 \cdot 10^{-2}\,m}{8 \cdot 10^{-6}\,m} = 8.24 \cdot 10^{-6}\,m \approx \boxed{8\,\mu m}$

This value is within the $\pm 1.0\,\mu m$ variance of the 7.7 µm as measured by Carnal and Mlynek.

2

QGM.2

Figure Q6.16 shows a sequence of Stern-Gerlach devices. Use analogies to the cases discussed in the chapter to determine the probabilities that an electron entering the final SG_z device will leave it via its plus and minus channels respectively. Express your answer in terms of θ and explain your reasoning.

The Stern-Gerlach device accepts an electron at its input end and emits electrons from two output channels "+" and "−". The probability that the electrons will be emitted from the "+" channel of an "SG_θ" device after having passed through an SG_z device is $\cos^2(\frac{1}{2}\theta)$. For the "−" end the probability is $\sin^2(\frac{1}{2}\theta)$. Electrons have a 100% probability of passing through the "+" channel of an SG_z device after having passed through another SG_z device.

Figure Q6.16 suggests that the probability of electrons passing through the "−" channel is 0, and the probability they will pass through the "+" channel is 100%. This would mean that $\theta = 0°$, so the SG_θ device is essentially an SG_z device.

So the probability the electrons will exit the "−" channel of the final SG_z device is $\sin^2(\frac{1}{2}\theta) = \sin^2(\frac{1}{2}\cdot 0) = 0\%$ and the probability that the electrons will exit the "+" channel is $\cos^2(\frac{1}{2}\cdot\theta) = \cos^2(\frac{1}{2}\cdot 0) = \cos^2(0) = 1^2 = 100\%$

Evals:

Q5M6: Right units, reasonable magnitude

QGM.2: Reasonable conclusion.