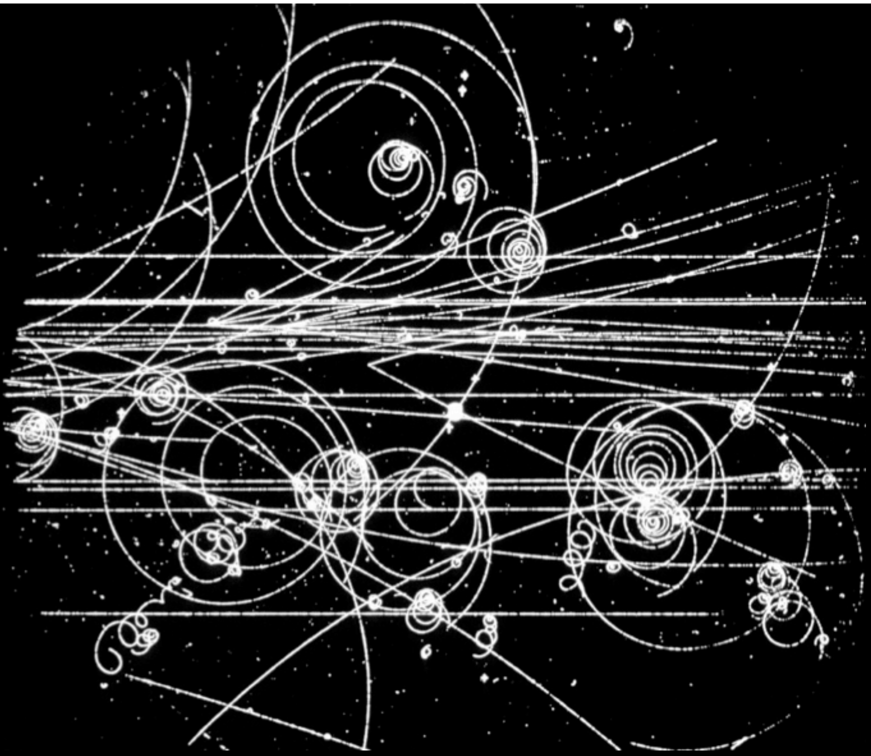
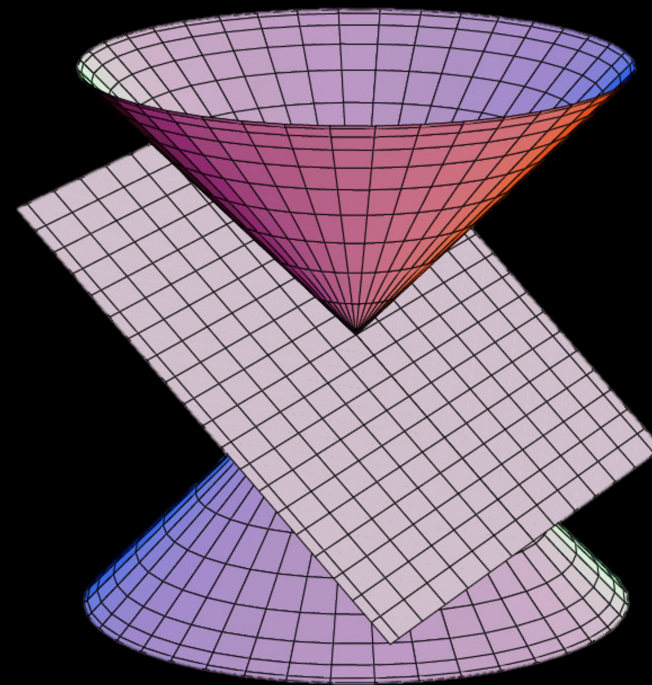




Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
Van Allen 70
MWF 12:30-1:20 Lecture

Announcements

- Final exam is scheduled for Friday May 11 7:30-9:30 am in Van 70 (this room).
  - I'm certainly not happy either!
- Midterm #1 is next Wednesday 2/21 in class
  - Midterm #1 covers Ch. 1-4 in the book
  - Two practice exams have now been posted
  - Remember to put together your equation sheet
  - Next Monday is a review day

Week 5 Assessment

- The pace of class so far has been:

A. Relativistic
B. Too fast
C. About right
D. Too slow
E. Like a rollercoaster

Week 5 Assessment

- On the material we've covered so far, I feel:

A. Like a superior human being
B. Pretty confident about everything
C. Confident about some topics, not about others
D. A bit shaky on most topics
E. Completely lost

Week 5 Assessment

- The homework so far has been:

A. Too much for 25% of the grade
B. Too little for 25% of the grade
C. About right
D. We have homework?

Week 5 Assessment

- The labs so far have been:

A. Interesting and useful
B. Not interesting/not useful
C. A mix
D. I'm too distracted by Erik's awesome sweaters

Week 5 Assessment

- For an average lab report, I spend:

A. Less than 2 hours outside of lab time
B. 2-4 hours per lab report outside of lab time
C. 4-6 hours per lab report outside of lab time
D. 6-8 hour per lab report outside of lab time
E. More than 8 hours per lab report outside of lab time

Any thoughts/issues?

- If something’s not going the way you want, it’s not to late to fix it

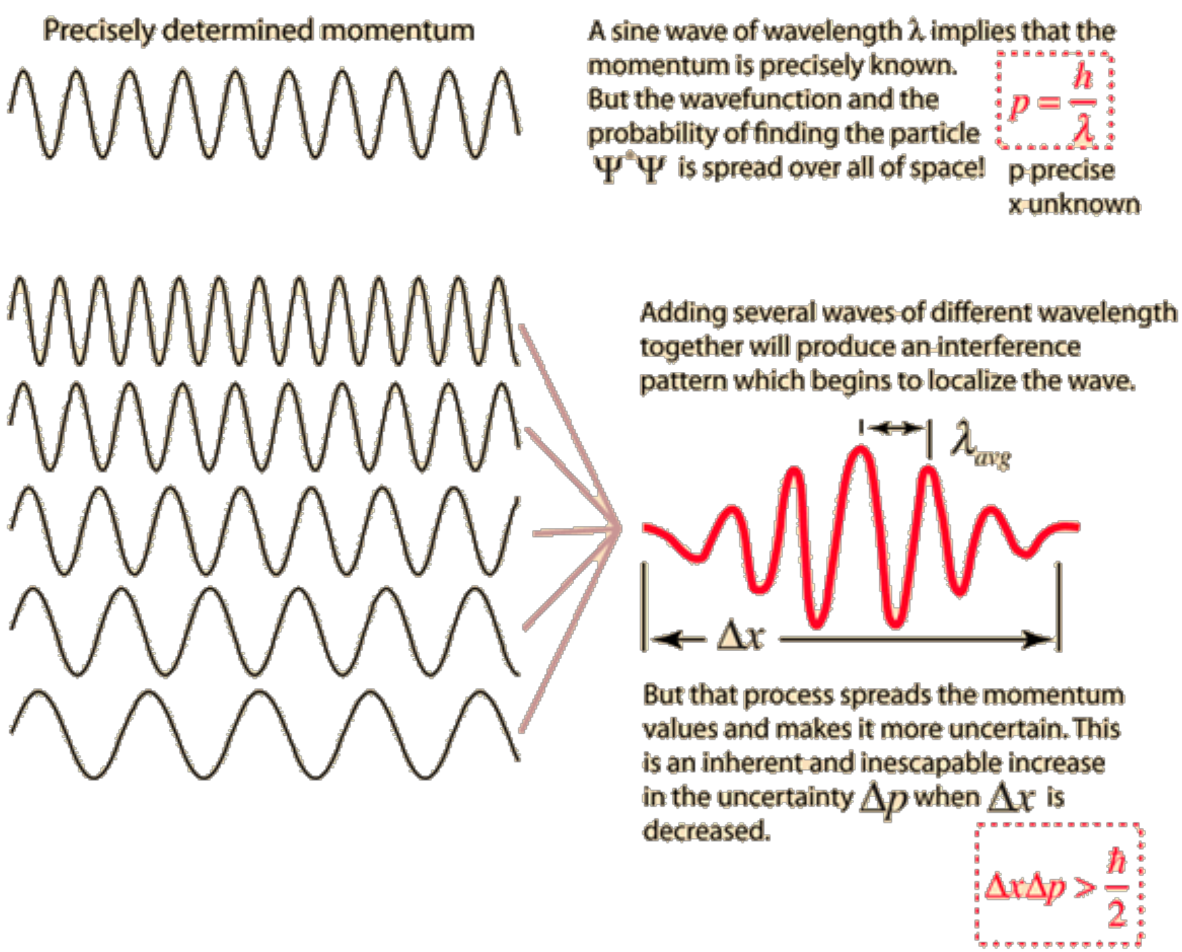
Heisenberg Uncertainty Principle(s)

$$\Delta p \, \Delta x \geq \frac{1}{2} \hbar$$

$$\Delta E \, \Delta t \geq \frac{1}{2} \hbar$$

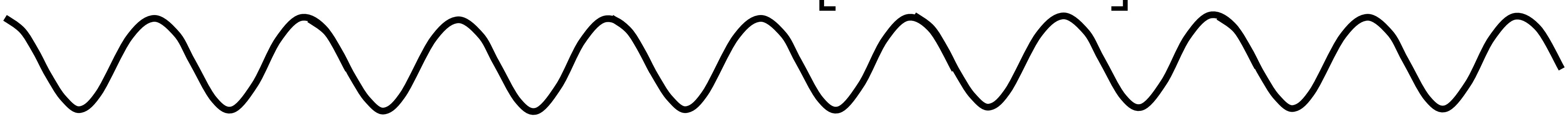
Ehhh… not that one…

Uncertainty Principle Interpreted



Plane Waves Vs. Wave Packets

$$\Psi(x,t) = A\exp\left[i\left(kx-\omega t\right)\right]$$



$$\Psi(x,t) = \sum_n A_n \exp\left[i\left(k_n x-\omega_n t\right)\right]$$

Wave Notation

Traveling waves

$\sin(kx - \omega t)$

$k = 2\pi/\lambda$

$\omega = 2\pi\nu$

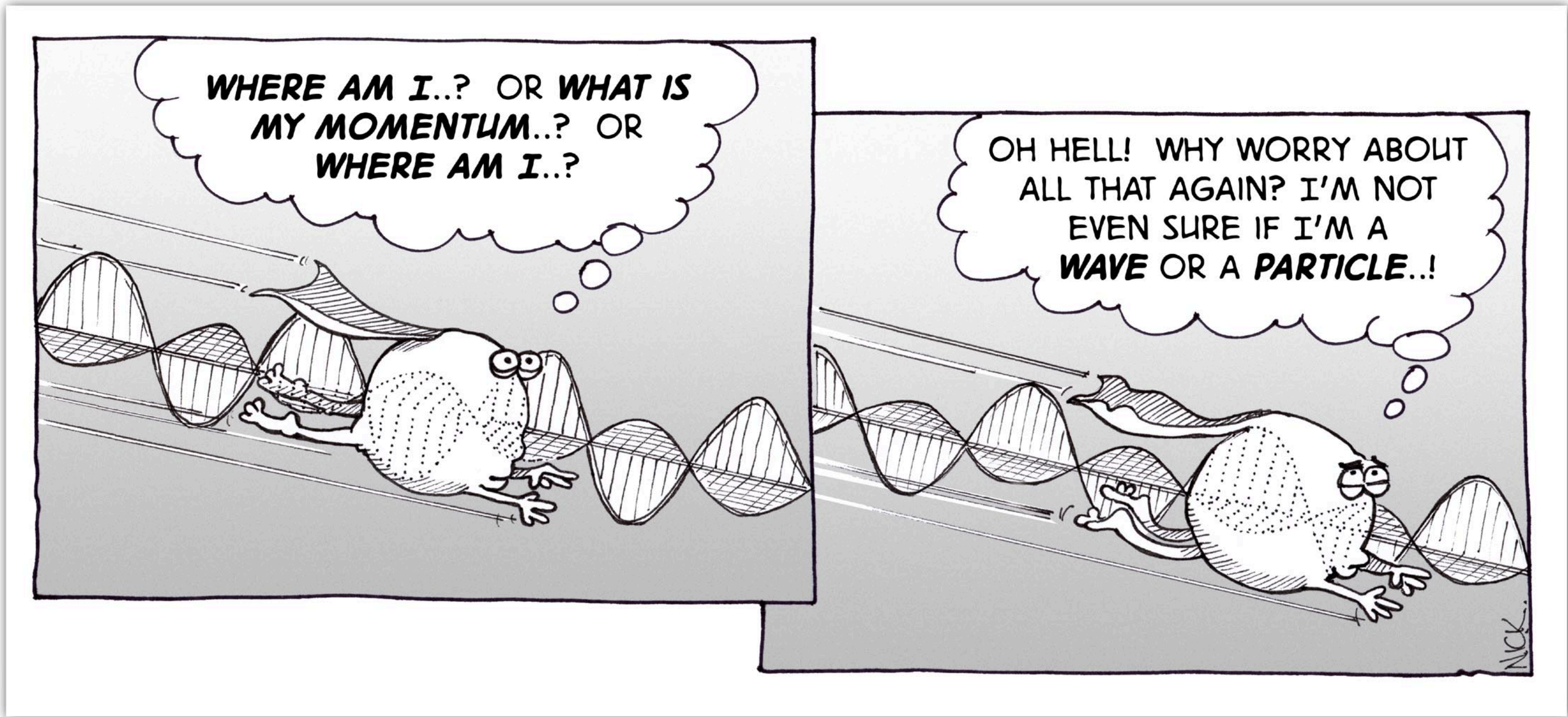
Note $p = h/\lambda$

$= hk/2\pi = \hbar k$

$E = h\nu$ (for $m = 0$)

$= h\omega/2\pi = \hbar\omega$

Identity Problems



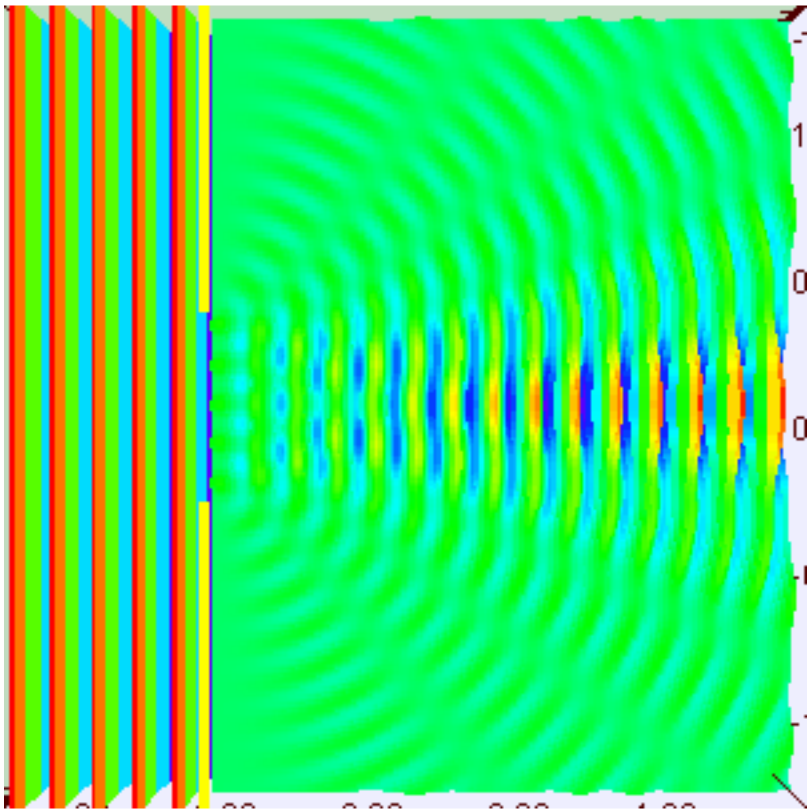
Photon self-identity issues

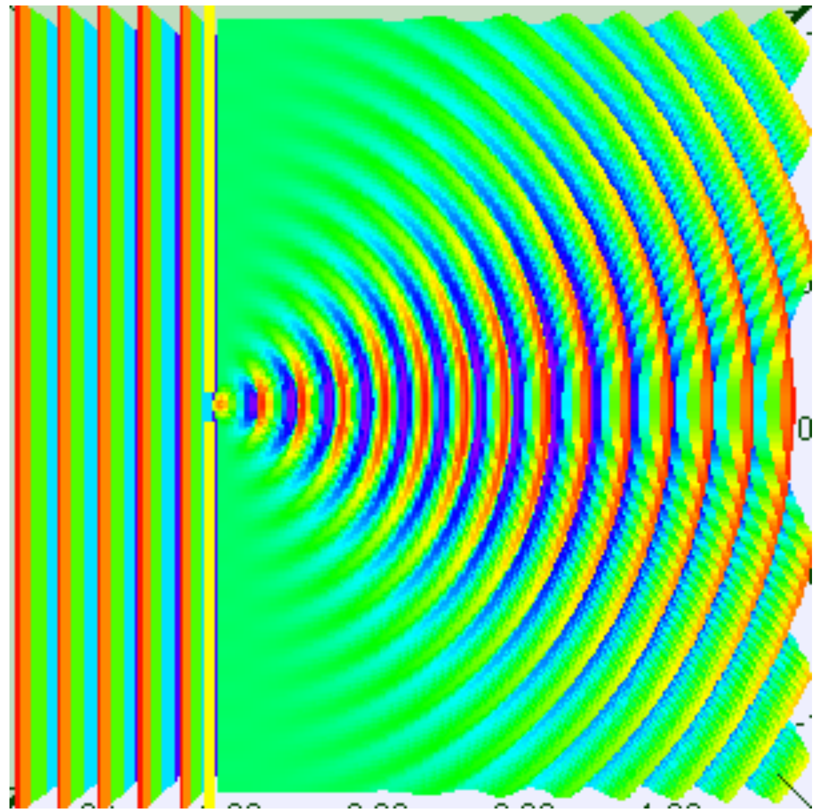
Important point

- The particle doesn't **have** a wave packet around it

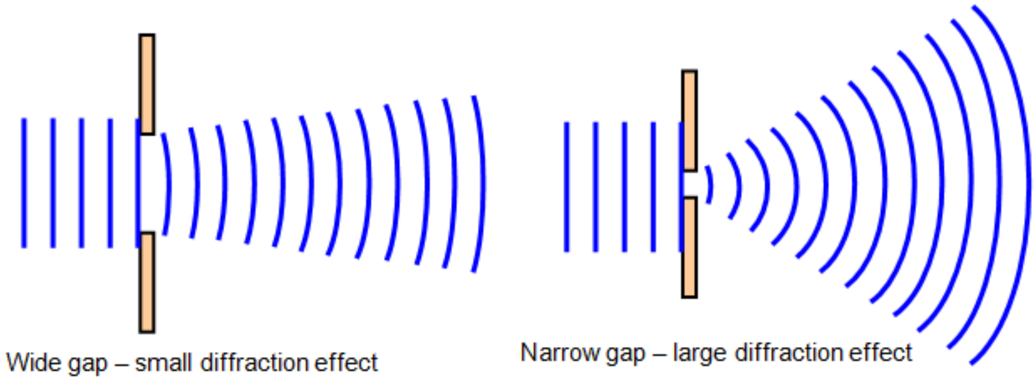
- The particle **<u>is</u>** the wave packet!!!

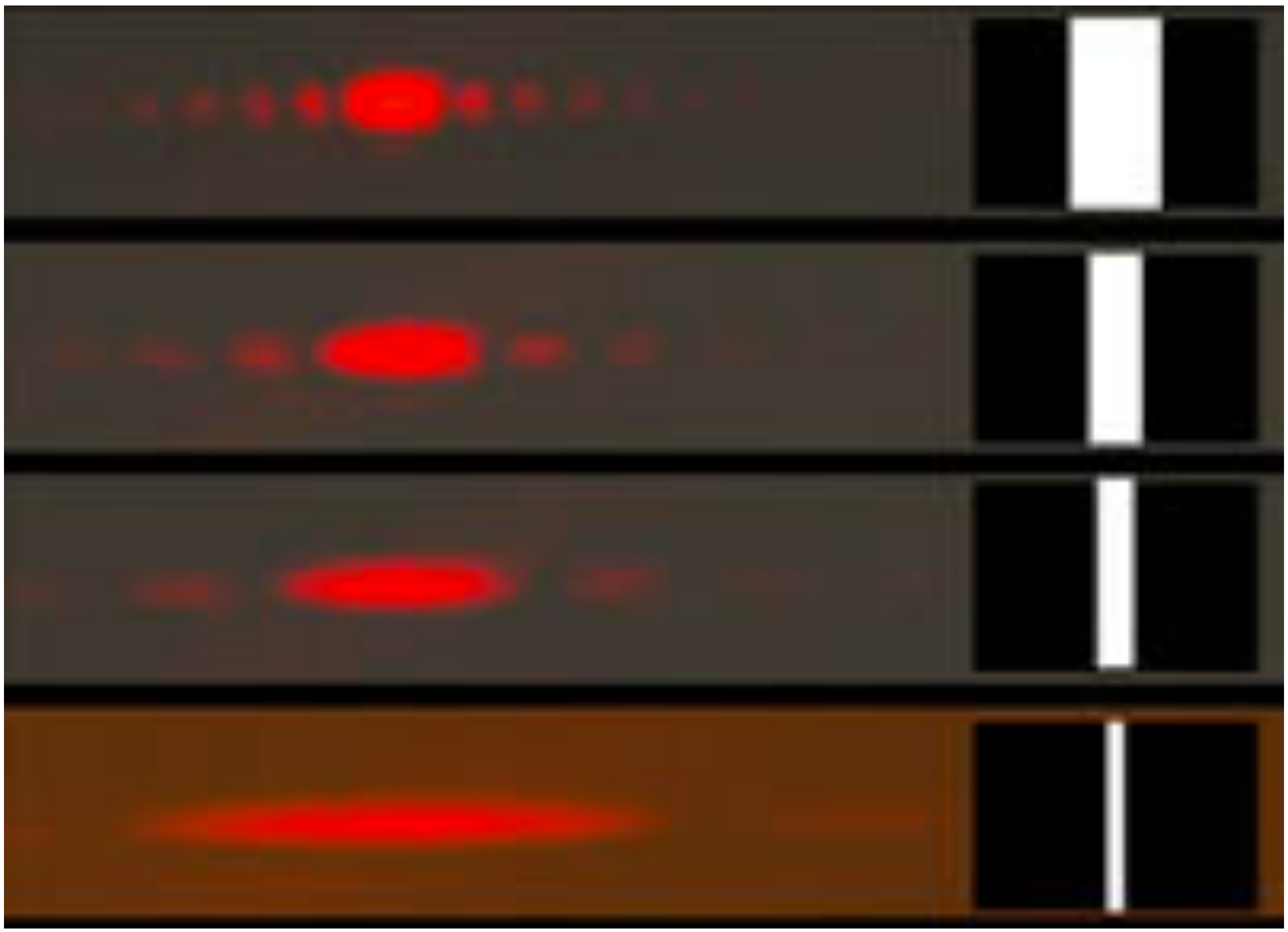
Diffraction



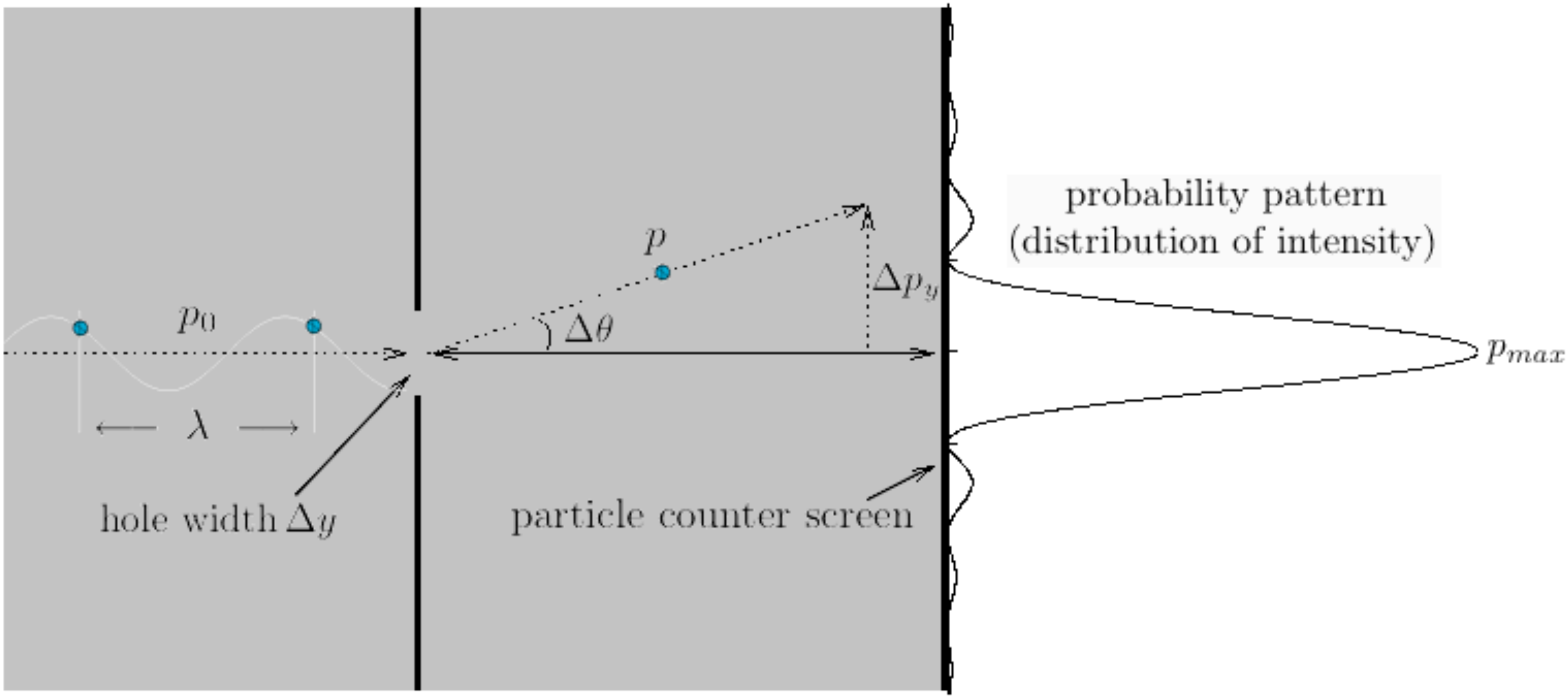


Diffraction





Diffraction and Uncertainty Principle

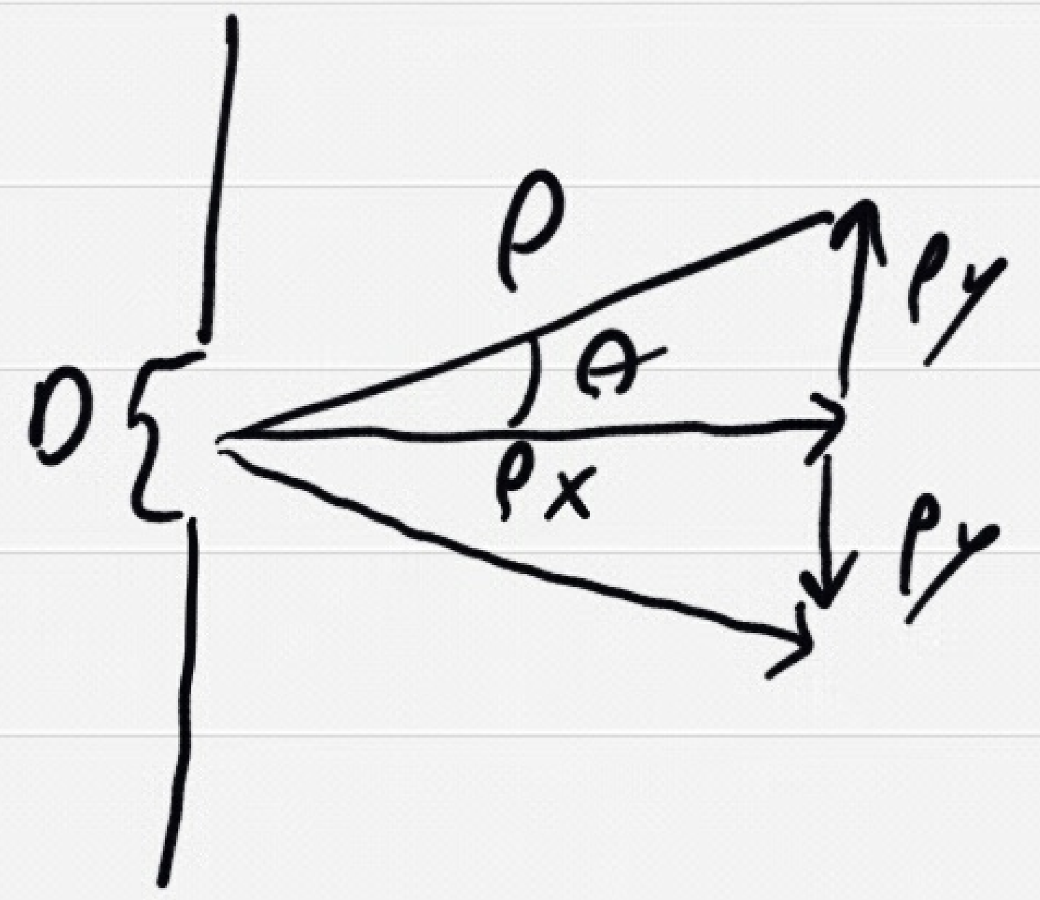


Diffraction

- classically, half width of central maximum

$$\sin\theta_{HW} = \lambda/D$$

w/ D = aperture diameter



$$\sin\theta = p_y/p$$

$$\sin\theta = p_{y\,max}/p$$
$$= \Delta p_y/2p$$
$$= \lambda/D$$
$$= \lambda/\Delta y$$
$$= h/p \cdot \frac{1}{\Delta y}$$

$$\Rightarrow \Delta p_y \Delta y \sim 2h$$

Heisenberg $\Delta y \Delta p_y \geq \hbar/2 = h/4\pi$

- Diffraction satisfies uncertainty principle

- smaller D → bigger $\Delta\theta$
  = smaller Δy → bigger Δp_y

Delta, Standard Deviation, RMS

- Standard deviation $\sigma_A = \sqrt{(<A^2>-<A>^2)}$
- Define $\Delta p = \sigma_p$
- Special Case: $<p> = 0$
  - $\Delta p = \sqrt{(<p^2>)} = p_{rms}$
  - Δp gives a measure of rms momentum

Concept Check

- The size of a Hydrogen atom is approximately 10^{-10} m. What is a good approximation for the rms momentum of the electron in the atom? Recall h= 6.6×10^{-34}.

A. $p_{rms} = 10^{-44}$ kg m/s
B. $p_{rms} = 10^{-24}$ kg m/s
C. $p_{rms} = 10^{-43}$ kg m/s
D. $p_{rms} = 10^{-23}$ kg m/s

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Hydrogen atom

$$\Delta p \, \Delta x \sim \hbar \sim 10^{-34} \text{ J s}$$

$$p_{rms} = \Delta p \sim 10^{-24} \text{ kg m/s}$$

classically $KE = \frac{1}{2} m v^2$

$= p^2/2m$

$$\langle KE \rangle = p_{rms}^2/2m$$

$$\frac{10^{-48}}{2 \cdot 10^{-30}}$$

$$= 0.5 \times 10^{-18} \text{ J}$$

$$\langle KE \rangle_{eV} = 0.5 \times 10^{-18}/e$$

$$= 0.5 \times 10^{-18}/1.6 \times 10^{-19}$$

$$\sim 3.1 \text{ eV}$$

- Actual average kinetic energy of electron in H atom

$$= 13.6 \text{ eV}$$

pretty close!!