LECTURE 12
CHAPTER 14

PHY 100. QUANTUM UNCERTAINTY

NO RECITATIONS THE WEEK AFTER SPRING BREAK

PRESENTATION GROUPS MADE:
START ORGANIZING SOON
I'LL MEET WITH EACH GROUP IN EARLY APRIL

GREAT PHYSICIST LIFE (Apr. 14)
Nicholas Cacciola, Lauren Dougherty, Monique Mottler, Daniel Rosens, Michael Wexler

CONTROLLED FUSION (Apr. 14)
Adam Davis, Alexander Lyubarsky, Alex Perry, Tyler Robins, Cristin Stephen

NUCLEAR POWER (Apr. 19)
Rahul Edirisinghe, David Levy, Bennett Parmington, Joshua Stillman, Elise Van Pelt, Cainaan Webb

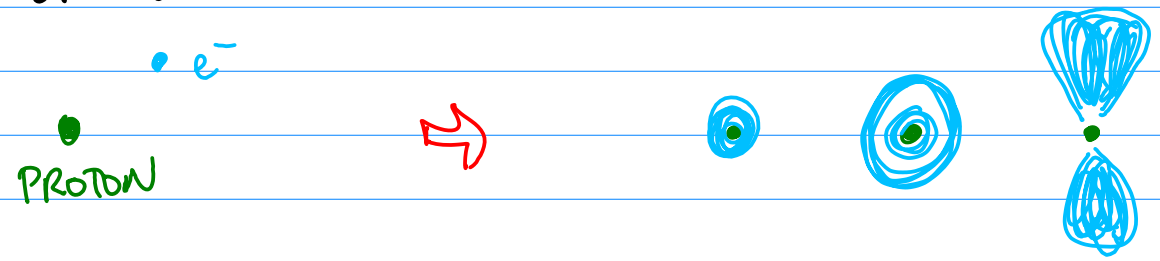
SERCH FOR ET LIFE (Apr. 19)
Kevin Bain, David Copeland, Sean Kelly, Jonah Rifkin, Lance Taubin, William Urciuoli

MUSIC (Apr. 21)
Stacey Chou, Rebecca Holtzman, Rebecca Kennedy, Edward Merrit, Megan Steron

NUCLEAR TERRORISM (Apr. 21)
Amanda Davis, Tye Johnson, Steven McIlveen, Aaron Rubin, Rainie Spiva, Jeffrey Terril, James Zin

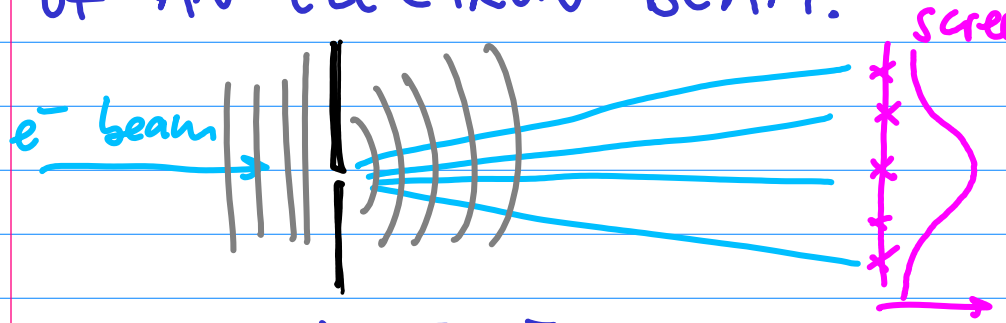
RECAP: SCHRÖDINGER EQ. ALLOWS US TO DETERMINE THE ALLOWED ENERGIES AND SPATIAL CONFIGURATIONS OF A SYSTEM.

FOR EXAMPLE: HYDROGEN ATOM



$\psi(x)$ → WAVE FUNCTION OF PARTICLE

SCHRÖDINGER EQ. ALSO APPLIES TO THE DIFFRACTION OF AN ELECTRON BEAM.

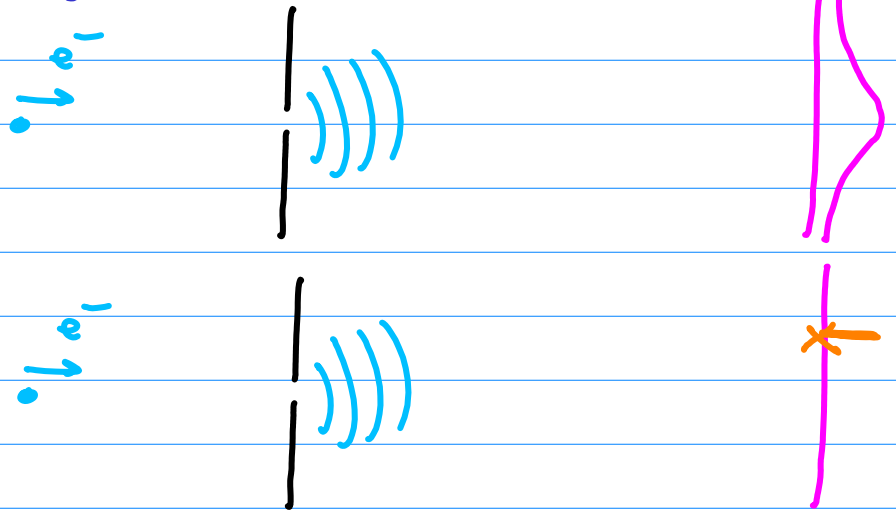


PROB. OF FINDING e^- DETECTED

$=$

$\psi^2(x)$ FOR THE e^- : DISTRIBUTION

CONSIDER SINGLE e^-



e^- COULD BE ANYWHERE ACCORDING TO Q.M.
YOU ONLY HAVE A PROB. OF WHERE THE e^- MIGHT FALL.

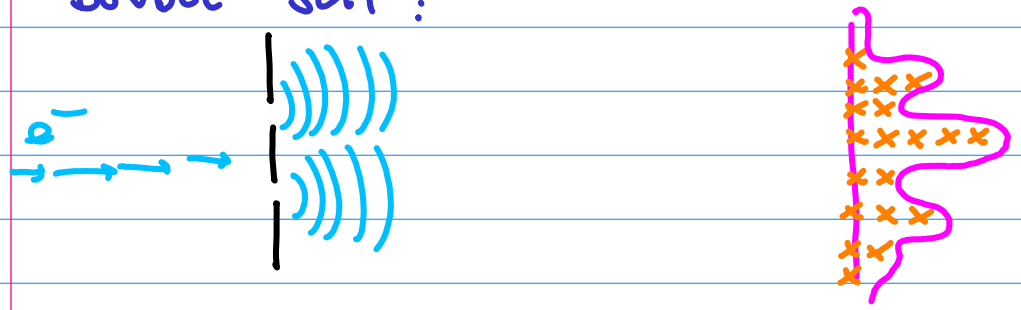
ONCE THE e^- IS OBSERVED: WAVEFUNCTION COLLAPSES

↳ WE KNOW WHERE THE e^- IS

A SECOND e^- WILL APPEAR AT A DIFFERENT LOCATION: IDENTICAL CAUSES CAN LEAD TO DIFFERENT OUTCOME!

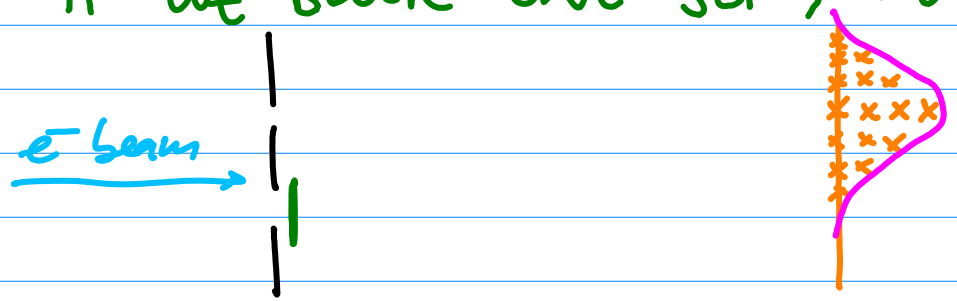
THERE IS RANDOMNESS IN INDIVIDUAL IMPACTS, BUT THE FINAL PATTERN IS PREDICTABLE.

DOUBLE SLIT:



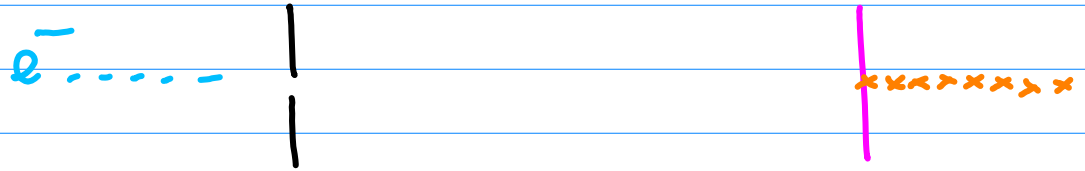
$\psi(x)$ INTERFERES WITH ITSELF JUST LIKE A WATER WAVE

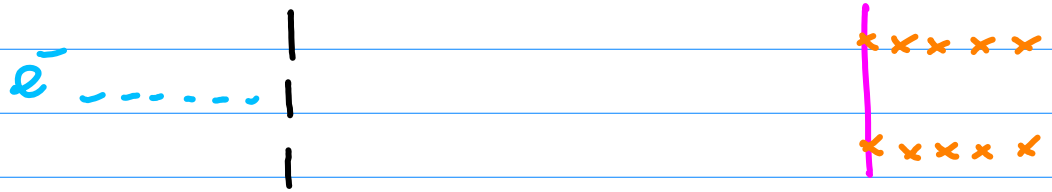
IF WE BLOCK ONE SLIT, WE GET BACK THE SINGLE SLIT DISTRIB.



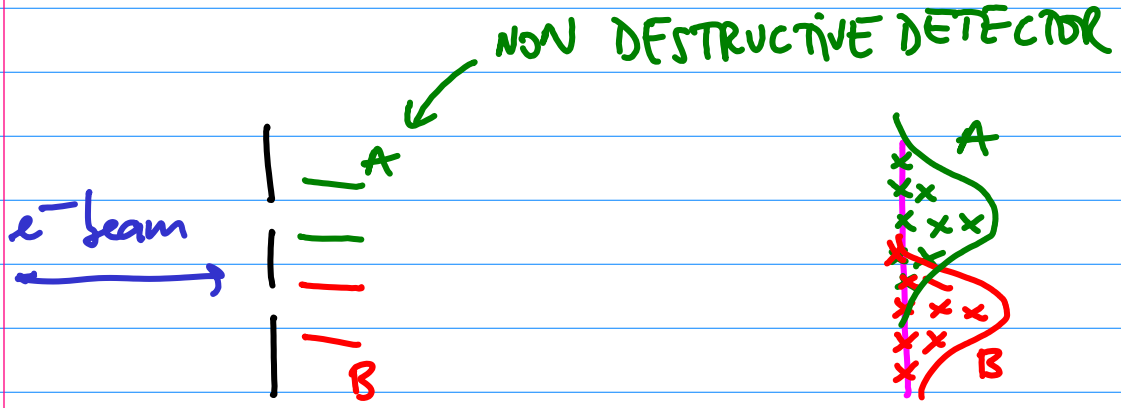
NO INTERFERENCE

CLASICALLY WE EXPECT TO SEE e^- LIKE A MARBLE





EFFECT OF OBSERVATION:



DETERMINING WHICH SLIT THE e^- WENT THROUGH CHANGES FROM INTERFER. TO NON-INTERFERENCE

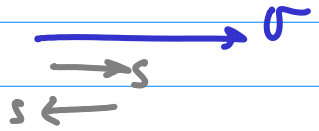
e^- IS A WAVE (FIELD) UP TO THE MOMENT OF IMPACT

IF YOU OBSERVE IT → YOU COLLAPSE ITS WAVEFUNCTION

BETWEEN SLITS AND THE SCREEN THERE IS A FIELD:
THE e^- ONLY APPEARS ON THE SCREEN AT THE MOMENT OF IMPACT (OBSERVATION).

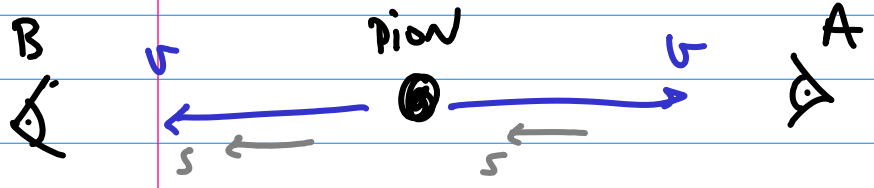
SPOOKY ACTION AT A DISTANCE
EPR PARADOX (EINSTEIN, PODOLSKI, ROSEN) 1935

PHOTON (SPIN 1): SPIN CAN BE IN DIRECTION OF MOTION OR OPPOSITE



PIONS DECAY TO TWO PHOTONS (PHOTONS ARE CORRELATED): IF ONE HAS SPIN ONE WAY, THE OTHER HAS IT THE OTHER WAY. THEY ARE IN AN ENTANGLED QUANTUM STATE

DESCRIBED BY THE SAME SCHR. EQ.



WHEN OBS. A MEASURES THE SPIN OF THE PHOTON: THE WAVEFUNC COLLAPSES AND THE SPIN OF THE PHOTON IN B IS DETERMINED

BUT COLLAPSE IS INSTANTANEOUS AND OBSERVER A & B ARE FAR APART

DOES THIS MEAN THAT INFORMATION TRAVELS FASTER THAN LIGHT?

SOLUTIONS: 1) COPENHAGEN $\Psi(x)$ NOT REAL
THINGS ONLY BECOME REAL WHEN AN OBSERVATION

2) MANY WORLDS

UNIVERSE SPLITS → ONE WHERE SPIN IS ONE WAY
→ ONE " " IS THE OTHER WAY

EFFECT IS REAL.

MANY EXPERIMENTS HAVE PROVEN THE ENTANGLEMENT.

→ POSSIBILITIES IN QUANTUM TELEPORTATION

HEISENBERG UNCERTAINTY PRINCIPLE:

$$\Delta x \, \Delta p > \frac{h}{2\pi}$$

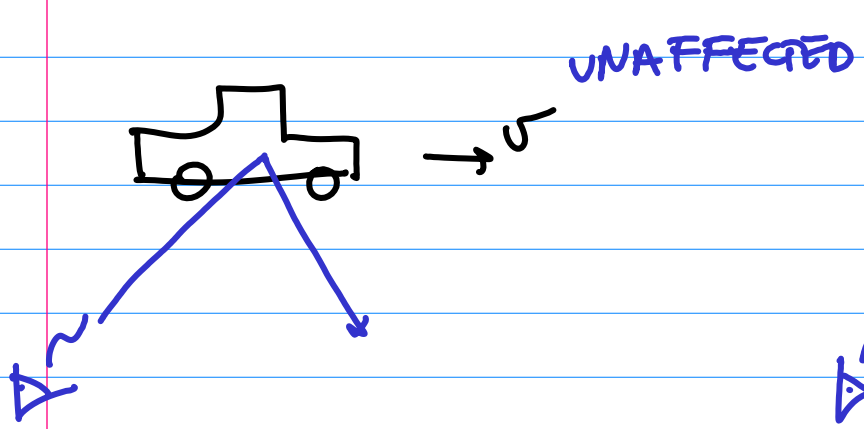
$h \rightarrow$ PLANCK'S CONST. $\sim 10^{-34}$ Js

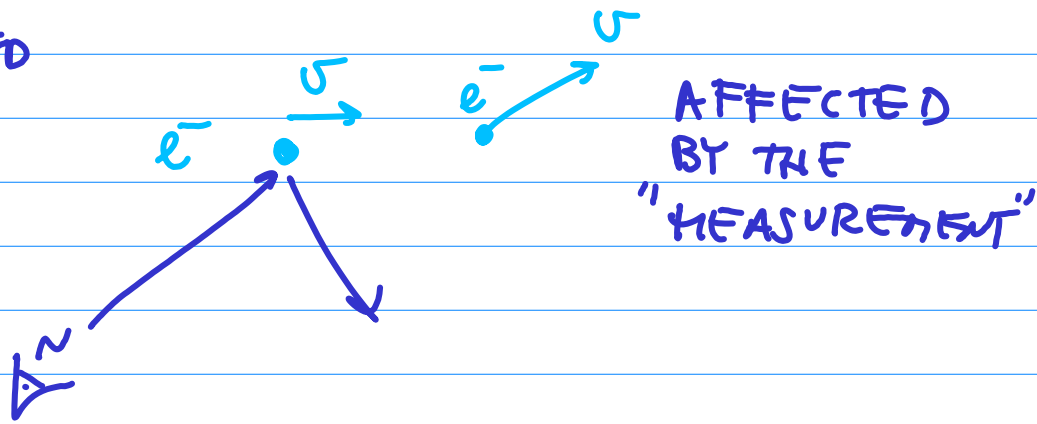
Δx: UNCERTAINTY ON POSITION

Δp: UNC. ON MOMENTUM ($p = mv$)

CANNOT KNOW BOTH THE POSITION AND MOMENTUM WITH ARBITRARY GOOD PRECISION

SIZE REALLY DOES MATTER





A DIFFERENT FORM OF THE SAME PPLE:

$$\Delta E \, \Delta t > \frac{\hbar}{2\pi}$$

UNC. IN ENERGY

UNC. IN TIME (TIME OVER WHICH THIS PARTICLE CAN EXIST)

CAN BREAK CONSERVATION OF ENERGY. SO LONG AS YOU DO IT OVER A SHORT PERIOD OF TIME.

HUGE IMPLICATIONS:

→ QUANTUM COMPUTING

→ RADIOACTIVE DECAY

→ BIG-BANG, LARGE SCALE STRUCTURE

→ PARTICLE PRODUCTION

→ VACUUM IS NOT VOID!