MSE 405: PHYSICS OF SOLIDS

LECTURE #1

RECALL CLASSICAL PHYSICS:

CONSIDER A PARTICLE OF MASS m IN 1-D SUBJECTED TO A FORCE $F(x,t)$

GOAL: FIND $x(t)$

NEWTON'S 2nd LAW: $F = ma$

$$\text{i.e.,} \quad -\frac{\partial V}{\partial x} = m\frac{d^2x}{dt^2}, \quad V = \text{POTENTIAL ENERGY}$$

THIS EQUATION PLUS 2 INITIAL CONDITIONS (TYPICALLY $x(t=0)$ AND $v_0 = \left.\frac{dx}{dt}\right|_{t=0}$) UNIQUELY DETERMINE $x(t)$

ONCE $x(t)$ IS KNOWN, OTHER PARAMETERS CAN BE CALCULATED.

e.g., VELOCITY: $v = \frac{dx}{dt}$

MOMENTUM: $p = mv$

KINETIC ENERGY: $T = \frac{1}{2}mv^2$

CLASSICAL PHYSICS IS LARGELY DETERMINISTIC.

QUANTUM MECHANICS APPROACHES THIS PROBLEM VIA THE 1-D SCHRÖDINGER EQUATION:

$$i\hbar\frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2 \Psi}{\partial x^2} + V\Psi$$

WHERE $i = \sqrt{-1}$, $\hbar = \frac{h}{2\pi} = 1.054572 \times 10^{-34}$ J·S

h ← PLANCK'S CONSTANT

$\Psi(x,t)$ IS THE PARTICLE'S <u>WAVE FUNCTION</u>

GIVEN SUITABLE INITIAL CONDITIONS (TYPICALLY $\Psi(x,0)$), THE SCHRÖDINGER EQUATION DETERMINES $\Psi(x,t)$

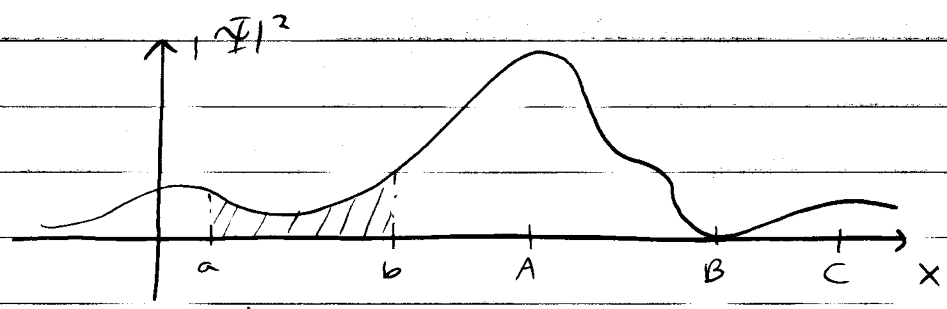
<u>WHAT IS $\Psi(x,t)$?</u>

<u>BORN'S STATISTICAL INTERPRETATION:</u>

$$\int_a^b |\Psi(x,t)|^2 dx = \left\{ \begin{array}{l} \text{PROBABILITY OF FINDING THE PARTICLE} \\ \text{BETWEEN } a \text{ AND } b \text{ AT TIME } t \end{array} \right\}$$

<u>NOTE</u>: $|\Psi|^2 = \Psi^* \Psi$

(IN GENERAL, Ψ IS COMPLEX ⇒ Ψ^* IS COMPLEX CONJUGATE)



PROBABILITY IS THE AREA UNDER THE CURVE $|\Psi|^2$

IN THIS CASE, THE PARTICLE IS MORE LIKELY TO BE FOUND NEAR A THAN NEAR B.

STATISTICAL INTERPRETATION ⇒ <u>INDETERMINACY</u>

SUPPOSE THAT THE PARTICLE IS MEASURED TO BE AT POINT C. WHERE WAS THE PARTICLE IMMEDIATELY PRECEDING THE MEASUREMENT?

3 SCHOOLS OF THOUGHT

(1) REALIST POSITION: THE PARTICLE WAS AT C.

EINSTEIN: "GOD DOESN'T PLAY DICE"

IF THE REALIST POSITION IS CORRECT, THEN Ψ IS NOT THE WHOLE STORY. THERE MUST BE A HIDDEN VARIABLE.

(2) ORTHODOX POSITION: THE PARTICLE WASN'T ANYWHERE.
(A.K.A., COPENHAGEN INTERPRETATION)

THE MEASUREMENT FORCES THE PARTICLE TO TAKE A STAND.

THIS IS THE MOST WIDELY ACCEPTED POSITION MOST FAMOUSLY TAKEN BY BOHR.

(3) AGNOSTIC POSITION: REFUSE TO ANSWER.

IT IS METAPHYSICS/PHILOSOPHY TO WORRY ABOUT SOMETHING THAT CANNOT BE TESTED.

1964 → BELL'S THEOREM STATES THAT THERE IS A MEASURABLE DIFFERENCE BETWEEN (1) AND (2)

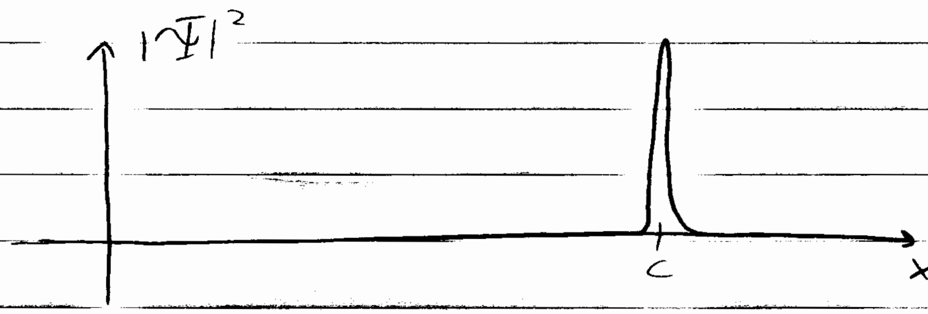
EXPERIMENTS HAVE CONFIRMED THE ORTHODOX POSITION.

HOWEVER, OTHER MORE RADICAL INTERPRETATIONS CIRCUMVENT BELL'S THEOREM (e.g., MANY WORLDS)

WHAT IF A SECOND MEASUREMENT IMMEDIATELY FOLLOWS THE FIRST?

EVERYONE AGREES THAT THE PARTICLE IS AGAIN FOUND AT C.

$\Rightarrow$ THE WAVEFUNCTION <u>COLLAPSES</u> UPON MEASUREMENT:



THE WAVEFUNCTION THEN EVOLVES AGAIN ACCORDING TO THE SCHRÖDINGER EQUATION UNTIL THE NEXT MEASUREMENT.

$\Rightarrow$ THERE ARE TWO DISTINCT TYPES OF PHYSICAL PROCESSES IN QUANTUM MECHANICS:

(1) <u>ORDINARY</u>: Ψ EVOLVES ACCORDING TO SCH. EQ.

(2) <u>MEASUREMENTS</u>: Ψ DISCONTINUOUSLY COLLAPSES