QUARKNET

Race & Associates, Ltd.

Rice University/University of Houston 2023-2025

Coding Projects and Implementation Plans Proposed by Participating Teachers

The following pages provide examples of proposed coding projects (2023) and implementation plans (2024 and 2025) created by participating teachers during the workshops across three years. Projects and plans are numbered to preserve the identity of the individual teacher.

August 2026

Examples of Implementation Plan/Coding Projects Summer 2023

Table
Workshop Implementation Plans/Coding Projects Summer **2023**

Rice University/University of Houston Short Workshop June 19-21, 2023[a]		
Project	Title	Brief Description
1	Simulation of Radioactive Decay[c]	Using non-radioactive materials (e.g., dice, pennies) determine the probability of that nucleus decays over a given time period
2	Pullback Car Lab	Graphing position vs. time – difference in motion between pullback car and a buggy
3	Projectile Motion in Air	Lists of free falls to show how the air drag numbers differ.
4	Free Fall	Design a program to analyze the motion of a free-falling object
5	How fast? With coding[d]	Calculate how fast an object moves and observe the motion on a position vs. time graph
6	Calculating Pi	Understanding the difference between random and systematic error
7	Constant Motion	Measuring Distance and Displacement
8	Rebound Starman	How the solar system planets affect the orbit of the SpaceX Roadster over time.
9	Graphs: Changing axis and fit curves	Implementation plan under development for students to use in analyses
10	Graphing Position, Velocity, and Acceleration	Measure and plot the motion of a falling object
11	Homework	Creating a scatterplot in Python.
12	Hertzsprung-Russell Diagram	Coding project in progress
13	Collection of colab notebooks	A compendium of notebooks (over a 3-year period) including concepts such as Photometry, Kepler's 3rd Law, Plotting H-R Diagrams to compare groups of stars

Note. [a]As posted as of July 12, 2023. [c] Created by a pair of teachers. [d] Created by another pair of teachers

Implementation Plans

QuarkNet, Rice University, Summer 2024

Teacher #1

Ideas:

-Introduce Linearization

-Rolling w/ Rutherford

-Dice Statistics

-Quark Workbench

-Particle Transformations

-Looking at and classifying Data

-Post-It Note Histogram

When and where in school year:

-AP Physics 2 (Beginning of Year)

-Honors & AP Physics 2 (Q2-Energy)

-AP Physics 2 (Thermodynamics Unit)

-Honors & AP Physics (Modern Unit)

-AP Physics 2 (Modern Unit)

- AP Physics 2 and select Honors students (Modern Unit)

-All levels throughout the year (e.g., calculating g)

Group 2: Two Teachers

Ideas:

Chem I KP / Physics I KP

What science and/or engineering practices do you want to try with your students?

Bowling for Rutherford (Atomic History, Atom)

a. ***Describe how you will implement the chosen activity or series of activities. Include where this activity might fit into your existing curriculum plan.***

Bowling for Rutherford - I will need to create a cardboard device for students to use during the activity. 10 marbles per group. Post it notes

a. ***Are there any cross-curricular applications?***

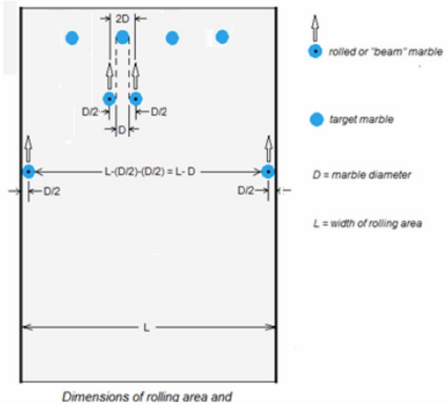
This lesson applies both to Chemistry and Physics

a. ***Suggest other ways you may use content and skills covered in the activities you have reviewed.***

I will use cross-curricular knowledge to develop student understanding

When and where in school year:

I will continuously incorporate valued skills learned during quarknet throughout my educational timeline.



Dimensions of rolling area and

Teacher #3

High School

Ideas:

I plan on giving the “standard model” talk when I am teaching the structure of an atom. Most kids have heard of quarks, but I give them the rest of the story!

I also plan on using a modified version of Rolling for Rutherford. I have boards with objects on the bottom. Students roll marbles repeatedly and watch how the marble deflects off the unknown shape. They draw on paper what they think the shape is, and then check how they did. This shows them how Rutherford used indirect evidence to determine that an atom was mostly empty space with a nucleus in the middle.

When and where in school year:

Early in the year during our Periodic Table unit.

Later in the year during the Atomic Theory unit when I am reviewing the different models and how they evolved over time.

Teacher #4

Ideas:

- Topic 1: Start the year with energy mass and momentum and linearization that way. Use their handouts for linearization along with the practice that I already do.

- IB Topic 7:
  - Particle cards and then do the quark workbench
  - Particle transformations for finding the rules for conservation
  - Feynman diagrams activity to see how particles work
  - Half life activities

- IB Topics for fields use the Making it around the bend
- Get the CRD working and collect data

When and where in school year:

High school 2024-2025 school year

IB Physics

Teacher #5

1. Dice: Mean Lifetime

Students represent “particles” with six-sided dice, and determine the “decay time” using a histogram of the number of dice remaining after each roll. Dice are removed if their value matches a “decay” criterion. The students find half-life and mean lifetime from the plot.

2. How Speedy are These Muons

students use authentic detector data to apply simple 1D kinematics (v=d/t), interpret graphical data, and evaluate measurement uncertainties.

The Summit: Pasadena ISD

School Year: 2024-25

Both lab will be done at the end of SWK3 and SWK5.

Student also do research on CERN and make a powerpoint about their understanding of Quarknet

They also learn about muon detector.

Ideas:

Two Teachers #6

Mass of U.S. Pennies

Students create and interpret a histogram of penny masses.

Students will represent data through histograms for analysis and interpretation. Students will use an electronic balance to determine the mass of many, many U.S. pennies (a one-cent coin) of varying ages. The metallic composition of the penny has changed over the years. Different compositions can have significantly different masses.

Skills: Developing Models, Histogram, Uncertainty, and Spreadsheets.

Mean Lifetime Part 1: Dice (Pennium, Dicium-6, Dicium-12 & Dicium-20)

Rolling dice serves as the model for decaying particles.

Students represent “particles” with six -sided dice, and determine the “decay time” using a histogram of the number of dice remaining after each roll. Dice are removed if their value matches a “decay” criterion. The students find half -life and mean lifetime from the plot.

Skills: Developing Models, Histogram, Uncertainty, and Spreadsheets. **Compare the stable nucleus hadrons to free hadrons and life time.**

When and where in school year:

High School

US Pennies: Quarter 1 - when covering composition of matter

Mean Lifetime - Quarter 3? when covering kinetics

Teacher #7 Implementation Plan

What to Implement	When?
Making it round the bend activity Linearization Mass of a penny Mean lifetime- dice and muons E-labs Cosmic ray: ToF (then velocity) Cloud Chamber Particle cards - make presentation on a specific particle.	Include in beginning of year unit, so that students can take actual data and linearize data from actual experiments Bring the kinematics into mini-units with AP1 and honors Cloud chamber and some of the more indepth investigations into particles during AP Physics 2

Teacher #8

Idea	**When/Where?**
Linearization	Earlier in the year
Post-it Histogram - error might be “small” but still not as good as other groups	Throughout the year
Card Shuffle - dealing with unknowns, making connections	Throughout the year, review
Speed of Muon	Early in the year (constant velocity)
Dice Decay Lab	End of the year extension

Teacher #9

Ideas:

I would like to do the **Mean Lifetime with Dice Activity**

I would also like to have student groups create posters on assigned topics as an intro to the day's activities.

Sticky note histograms

When and where in school year:

Beginning of year / End of year extension(?)

Throughout the year

Teacher #10

Ideas:

1. **Mass of US Pennies**

https://quarknet.org/data-portfolio/activity/mass-us-pennies
In this activity, students will know and be able to make a histogram to determine if the mass of all U.S. pennies is the same within experimental uncertainty.

1. **Mean Lifetime Part 1: Dice**
   https://quarknet.org/data-portfolio/activity/mean-lifetime-part-1-dice

Rolling dice serves as the model for decaying particles.

In this experiment, , students represent “particles” with six-sided dice, and determine the “decay time” using a histogram of the number of dice remaining after each roll. Dice are removed if their value matches a “decay” criterion. The students find half-life and mean lifetime from the plot.

When and where in school year:

Physics

2024-25

-I would implement the activities during the second semester with the Atomic Physics unit.

-Teach how to create histogram

Teacher #11

Ideas:

- **Start the year with “mass of US Pennies” to introduce histograms.**
- **All year use the “Name Dropping” activity**
- **“Card Sort” activity**
- **“Mean Lifetime Dice 1” activity**
- **Integrate the Muon speed exercise for my AP classes.**

When and where in school year:

- **High School**
- **Start of the 24-25 year and continue adding activities as the year progresses.**
- **In both AP Physics 1 and Astronomy.**

Teacher #12

Ideas:

I will use some of the activities on Quarknet to work on my physics students data analysis skills. I think they would benefit from looking at different sets of data and then graphing it not only in linear graphs which they are somewhat familiar with but also histograms. I also plan on using some of the other activities in my homeroom to build on my regular students skills.

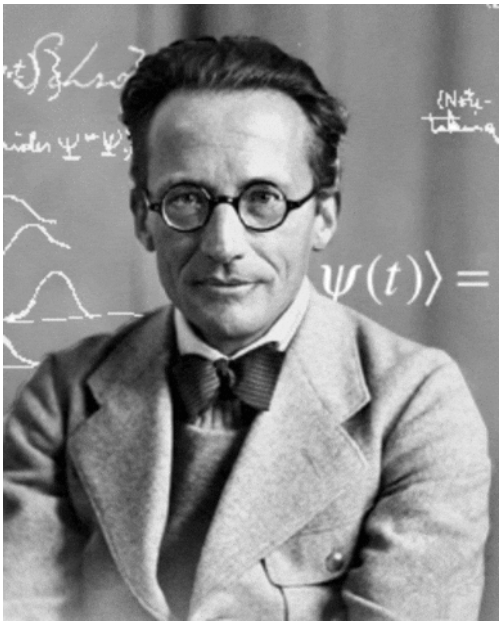
When and where in school year:

High School

Early 24-25 school year: data analysis and graphing for my physics students

Mid 24-25 school year: random activities throughout tor my regular homeroom students

Quantum Activity: Quantum Concepts Quantum Data Workshop 2025
Group 1:

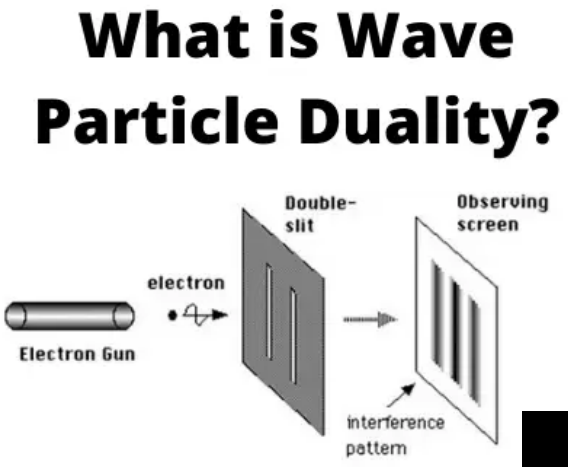


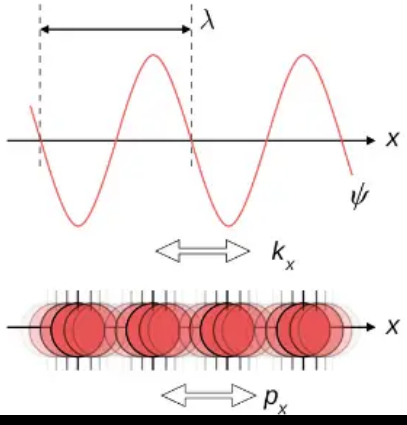
Foundational Question: What is the meaning of the word "quantum" in physics?

Discrete units of matter and energy
Quantum refers to the discrete units of matter and energy. A quantum is the minimum amount of any physical entity involved in an interaction thus can be "quantized."

1. **What is wave-particle duality as applied to a standard model particle?**

Wave–particle duality is the concept in quantum mechanics that fundamental entities of the universe, like photons and electrons, exhibit particle or wave properties according to the experimental circumstances. The concept of duality arose to name these seeming contradictions.





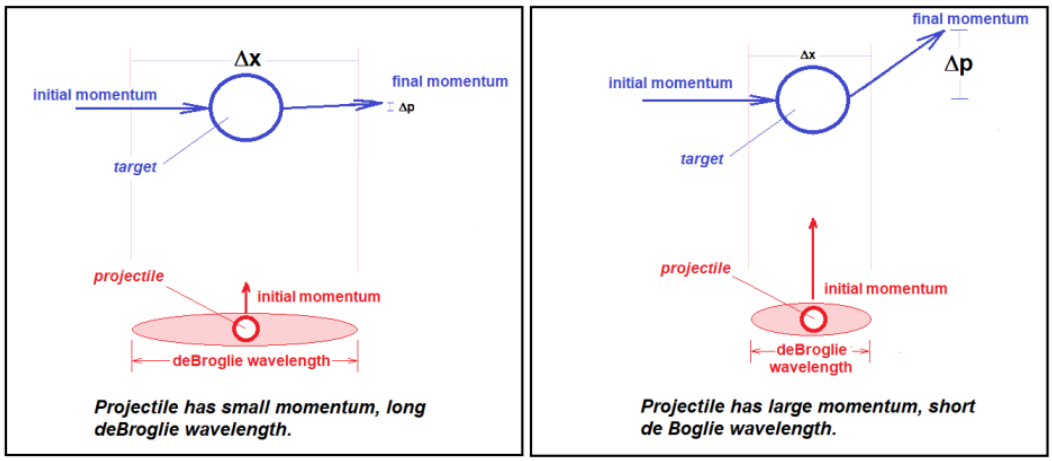
Group 2:

Foundational Question: What is the meaning of the word "quantum" in physics?

- It is the smallest measurement of physical properties.
- Smallest numerical amount of something.
- i.e. elementary charge
- For our purposes, we are looking at physics of objects that are at the most fundamental/smallest possible mass.

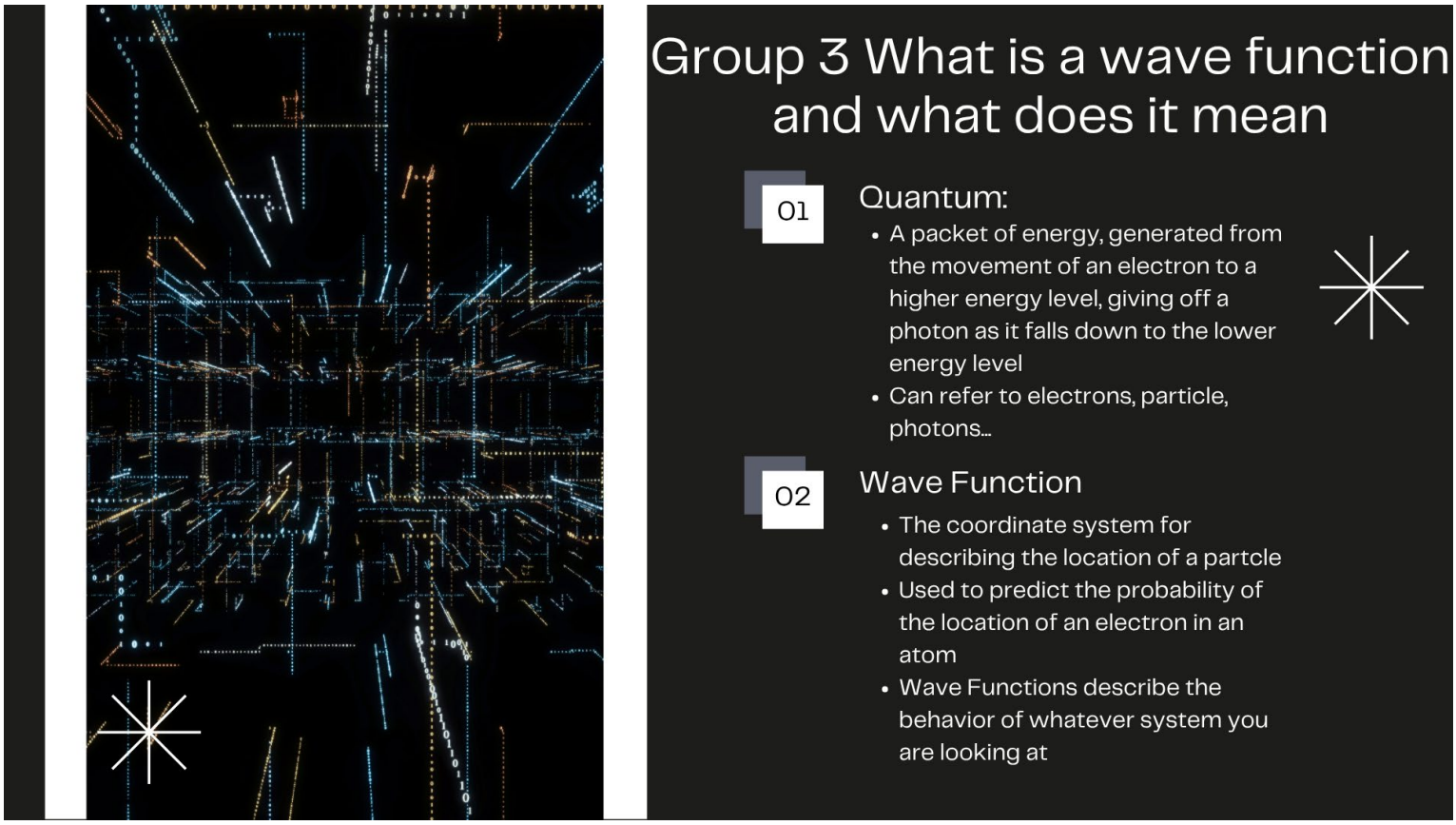
Based on the Heisenberg Uncertainty Principle, why does Ken not diffract when he walks through a door?

It's in the name. The more you know about an objects' location, the less you are certain about the objects' momentum.



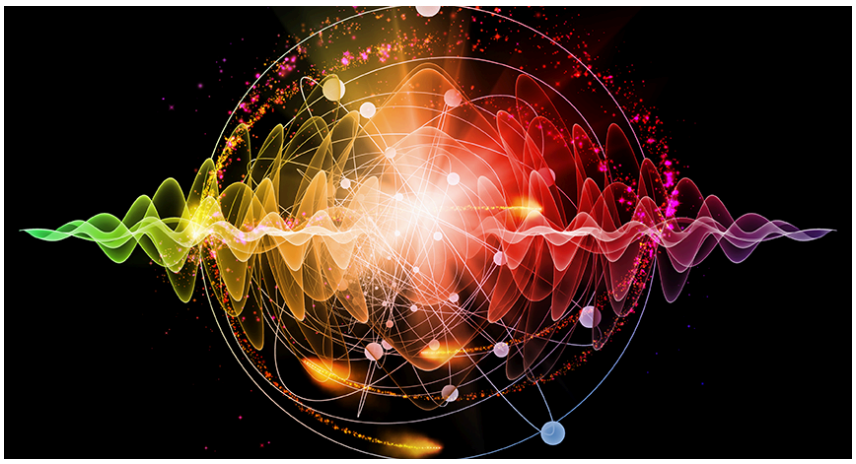
The wavelength of ken (10^{34}m) (his wave function) compared to the "door's width" (10^{1}m) is so many orders of magnitude apart. Because of this, there is very little interaction and scattering

Group 3:
Foundational Question: What is the meaning of the word "quantum" in physics?



Group 4:

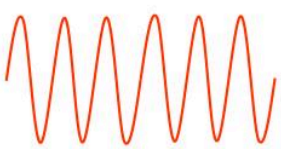
Foundational Question: What is the meaning of the word "quantum" in physics?



- The smallest amount of matter that will interact within a system.

Group Question: What is wave-particle duality as applied to a standard model particle?

The Wave – Particle Duality



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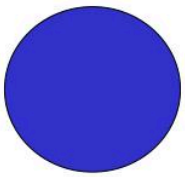
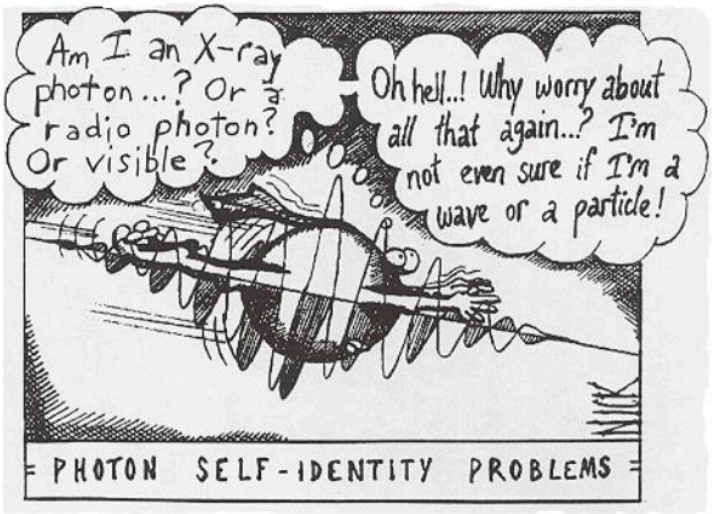




- A packet of energy that acts like a wave under certain conditions and a particle under other conditions.

- The type of particle could be a photon or an electron - both of which are included in the Standard Model.

QUANTUM QUESTIONS

GROUP 5

FUNDAMENTAL QUESTION

WHAT IS THE MEANING OF THE WORD "QUANTUM" IN PHYSICS?

In physics, a quantum is the minimum amount of any physical property involved in an interaction.*

*per Wikipedia

QUESTION #2

BASED ON THE HEISENBERG UNCERTAINTY PRINCIPLE, WHY DOES KEN NOT DIFFRACT WHEN HE WALK THROUGH THE DOOR?

Diffraction is wave phenomena. While all objects possess wave-like properties, the de Broglie wavelength of large objects are extremely small.

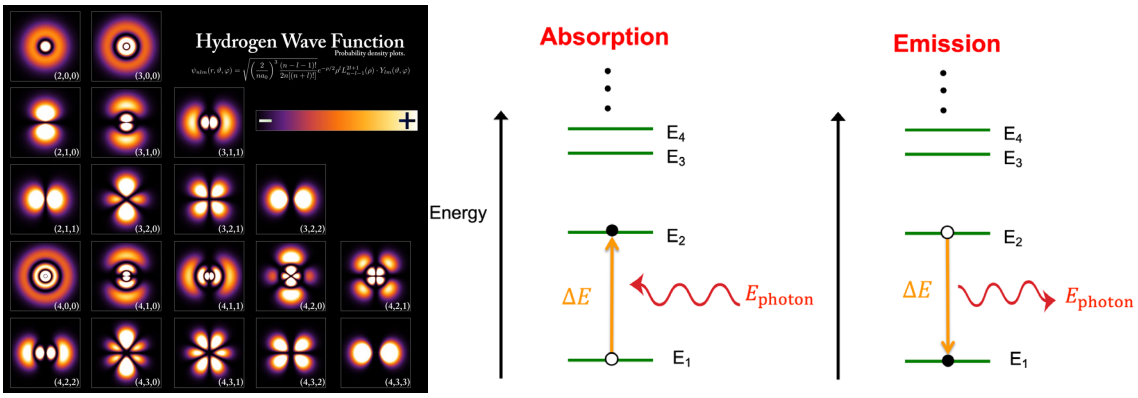
$$\lambda = \frac{h}{mv}$$

BASED ON THE HEISENBERG UNCERTAINTY PRINCIPLE, WHY DOES KEN NOT DIFFRACT WHEN HE WALK THROUGH THE DOOR?

Ken’s wavelength compared to the width of the doorway is negligible. Diffraction only occurs when the width of the opening is similar or smaller than the wavelength of the wave.

Group 6:
Foundational Question: What is the meaning of the word "quantum" in physics?

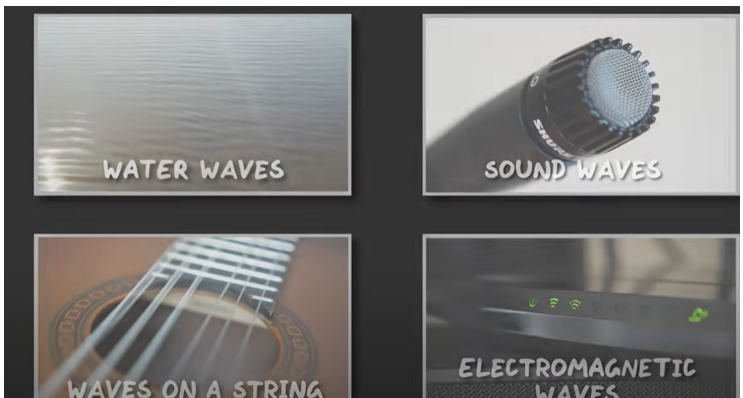
- Discrete versus Continuous
- Physical properties can have a minimum amount involved in an interaction
    - Quantum of EM radiation proportional to frequency: $E = hf$
    - Quantum of charge: $e/3 = 1.60/3 * 10^{-19}$C

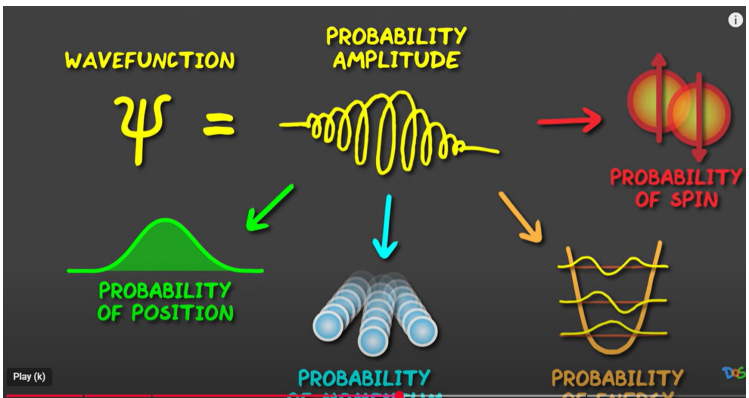


- Quanta are the smallest discrete unit (such as a particle) of a physical entity

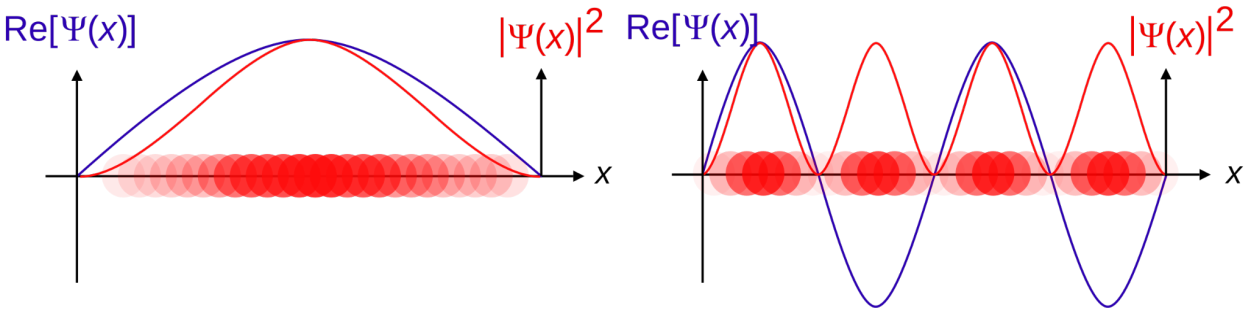
Question 3: What is a wavefunction and what does it mean?

- A function in space and time that describes the physical properties of a quantum system
- Travels, spreads, interferes like a classical wave
    - Classical wave equation
    - Schrodinger's equation
- Complex valued
- Symbol: Ψ
- Proportional to probability amplitude at a given position
    - $|\Psi|^2 \propto (probability\ per\ unit\ space)$
- Operations on Ψ produce functions of other measurable variables
    -

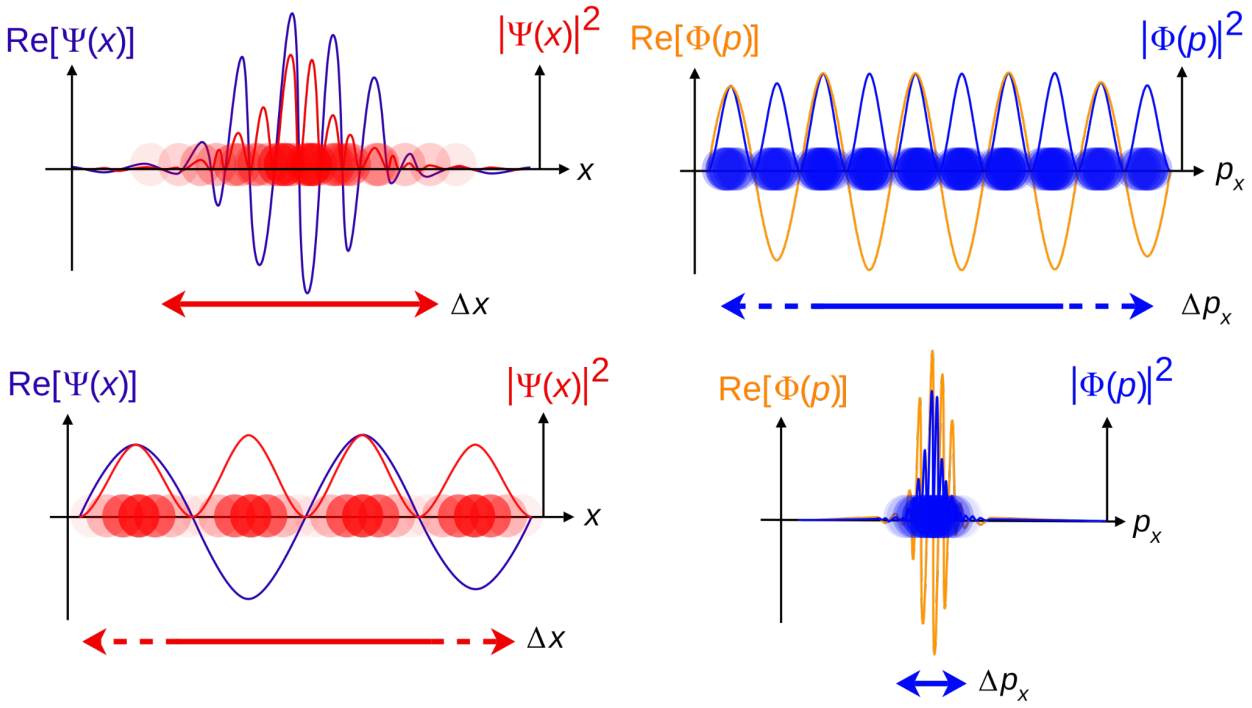




Wavefunction in 1D: red dot opacity is probability - wikipedia



Position (left) and Momentum (right) -wikipedia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