Introduction
Welcome to PHYS234

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- On the smallest scales, nature behaves in fundamentally different ways than than on larger scales, where we as humans have some intuitive understanding.

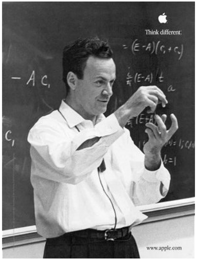

Figure: Richard Feynman

- *"Quantum mechanics is the description of the behavior of matter and light in all its details and, in particular, of the happenings on an atomic scale. Things on a very small scale behave like nothing that you have any direct experience about. They do not behave like waves, they do not behave like particles, they do not behave like clouds, or billiard balls, or weights on springs, or like anything that you have ever seen."*
- **The Feynman Lectures on Physics Vol. III**

Introduction

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- In the 17th century, Newton's laws were discovered, which successfully described the behaviour of celestial bodies. The laws of classical motion remain true today, provided that we are not considering the motion of particles near super-massive stars, or on atomic scales.

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- Newton's laws of motion rely on the concept of determinism; namely, that if we know the position and velocity of an object at an instant in time, and further if we know all of the forces that act upon that object, then we can determine it's position and velocity for all later times with arbitrarily high precision.

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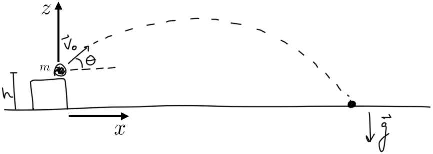

Figure: Projectile motion in a gravitational field.

- Newton's second law: $\mathbf{F} = m\mathbf{a}$.

$$\mathbf{F} = \dot{\mathbf{p}} = m\ddot{\mathbf{r}}$$

$$\dot{p}_x = 0 \qquad \dot{p}_z = -mg$$

$$p_x = m\dot{x}(t) = mv_0 \cos\theta \qquad p_z = m\dot{z}(t) = m(-gt + v_0 \sin\theta)$$

$$x(t) = v_0 t \cos\theta \qquad z(t) = -\frac{1}{2}gt^2 + v_0 t \sin\theta + h$$

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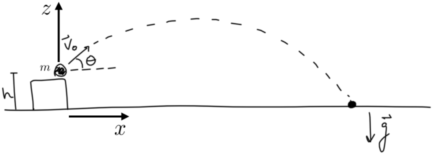

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- In the quantum world, we find that nature does not allow us to have full knowledge about the state of the particle. Our knowledge of one attribute, such as the position of a particle, introduces uncertainty into our knowledge of other attributes, such as its momentum, and visa versa.

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- Since the days of Newton, it was known that light exhibited interference phenomena. Interference is consistent with light being a wave, much like sound or water waves.

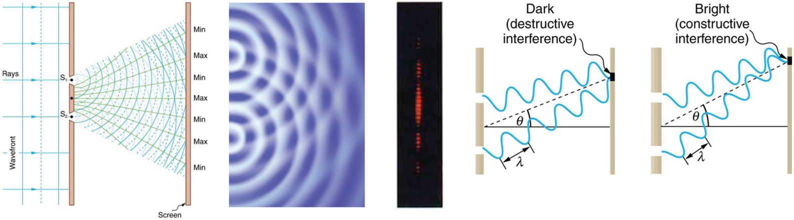

Figure: Young's double slit experiment.

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- Imagine if we perform Young's double slit experiment with a very week light source. (Movie)
- The double slit experiment embodies deeper truth: in the quantum description, quantum entities, e.g. photons, are fundamentally delocalized. They become localized when we measure them.
- This strange behaviour is not restricted to just light, but electrons, protons, atoms,...

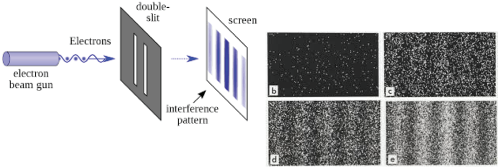

Figure: Single electron interference

- So in reality, electrons and photons are neither particles nor waves, although they can behave like either one. In fact, this duality applies to all matter on the atomic scale, and even larger structures like molecules! In fact, no one really knows if the laws of QM stop on some length or mass scale, or whether they persist up to the macroscopic world.

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- Different observations regarding the nature of light and matter created much confusion up to the first quarter of the twentieth century, until Schrödinger, Heisenberg and Bohr came along and provided a solid theoretical framework that unified the field, and allowed us to accurately describe quantum phenomena. Along the way, it completely upended our understanding of reality.

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- In contrast to the classical deterministic description of nature, QM predicts that nature is fundamentally nonlocal.
- It is the goal of this course to introduce you the basic theoretical framework to explain quantum phenomena, which we still use today.
- The foundations of quantum mechanics are encapsulated in 6 postulates that we will explore in this course. We will begin by studying the Stern-Gerlach (S-G) experiment, which will introduce the 6 foundational postulates of quantum mechanics.