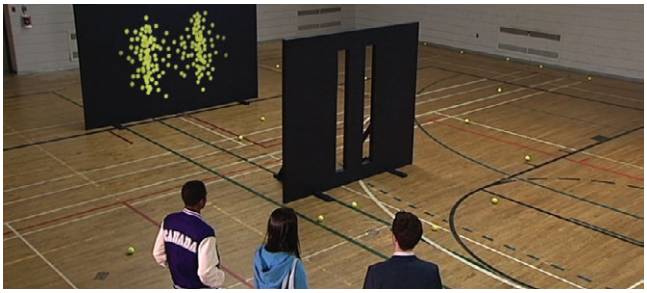
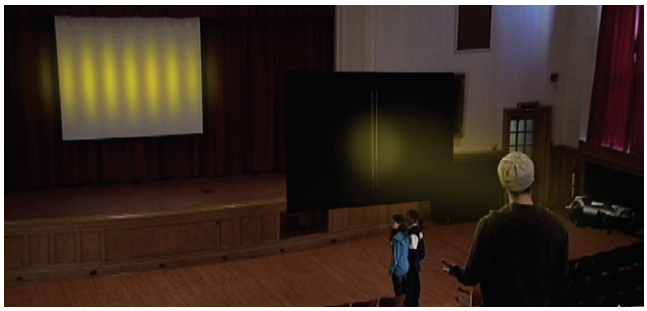
Quantum Physics
In a Nutshell

Classical Physics

- Classical physics is the physics of the motion, energies, and interactions of objects in the everyday world around us.
- In the double-slit experiment, tennis balls and all other *classical particles* move as localized particles through the slits and once they hit the screen they produce the following distribution:

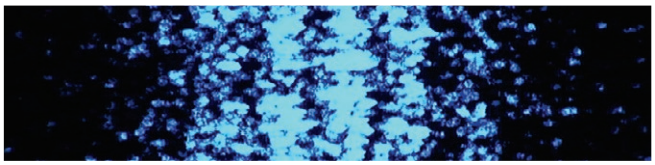


- If we use water waves, sound, or any other *classical* waves they spread out behind the double-slit barrier and produce an *interference pattern*.
- Light also spreads out behind the double-slit barrier and produces an interference pattern.



Quantum Physics

- Quantum physics is revealed in the physics of isolated processes, typically with very small subatomic objects.
- In the electron double-slit experiment, each electron hits the detection screen as a particle.
- After many electrons hit, an interference pattern forms, demonstrating wave behaviour.
- The same interference pattern forms even when we fire electrons one at a time, so we can rule out any particle to particle interactions.



- These results show that electrons exhibit both wave and particle behaviour, i.e., *wave-particle duality*.
- The de Broglie wavelength describes the wave behaviour of particles such as electrons. It is given by the equation

$$\lambda = h/p$$

- Light also exhibits wave-particle duality. In the double-slit experiment light hits the detection screen as an individual particle, but over time it forms an interference pattern like a wave.
- A particle of light is called a *photon* and its energy is given by

$$E = hf$$

- All quantum objects, including protons, neutrons, atoms, and molecules, exhibit wave-particle duality.
- When we look at the electron to see what it is doing while passing through the double-slit barrier, we are making a measurement which perturbs the electron and destroys the interference pattern. This demonstrates *measurement disturbance*.
- We can predict the overall behaviour of the electrons in the double-slit experiment, but nobody really knows what the electrons are doing between the source and the detector. To complete the picture, physicists have proposed various interpretations, including:

  Collapse Interpretation
  - thinking of electrons as spread-out waves that collapse to point-like particles once they are measured

  Pilot Wave Interpretation
  - thinking of electrons as particles that are guided by an invisible wave

  Many Worlds Interpretation
  - thinking of parallel universes that come into being when we make measurements at the quantum level

  Copenhagen Interpretation
  - thinking exclusively about the direct results of measurements.

- In spite of these differing views, quantum physics plays a crucial role in a number of everyday technologies including computers, remote control devices, lasers, and cell phones.