Section 4
Elements of Quantum Mechanics

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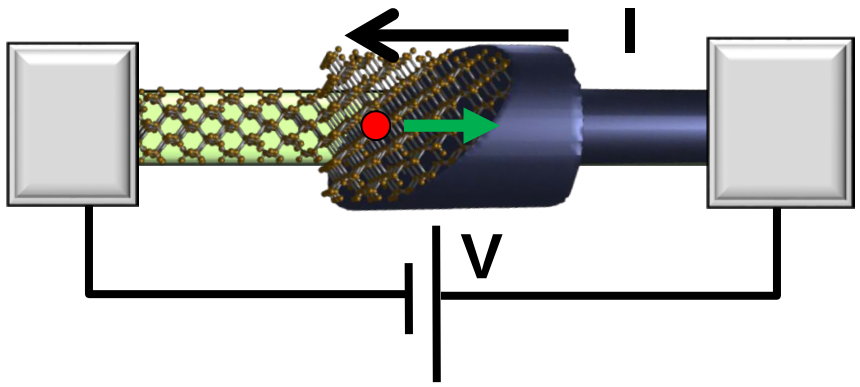
Why do we need Quantum Mechanics?



$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area

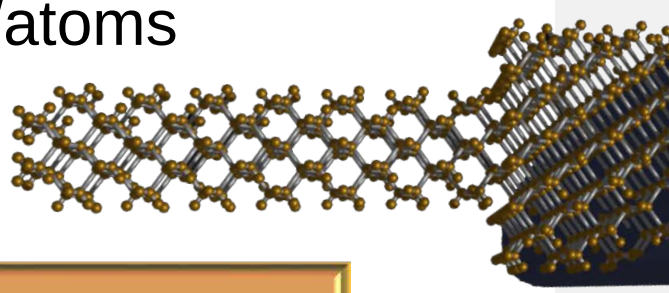
II	III	IV	V	VI
4 Be	5 B	6 C	7 N	8 O
12 Mg	13 **Al**	14 **Si**	15 **P**	16 S
30 **Zn**	31 **Ga**	32 Ge	33 **As**	34 **Se**
48 Cd	49 In	50 Sn	51 Sb	52 Te
80 Hg	81 Tl	82 Pb	83 Bi	84 Po

$$n \neq \rho \times N$$

Number of electrons available for conduction

Number of atoms/volume from crystal structure

Number of electrons/atoms



- All electrons may be created equally,
  but they appear do not behave identically!

Section 4
Elements of Quantum Mechanics

One Video Segment

- 4.1 Classical Systems
  - » Particles
  - » Propagating Waves
  - » Standing Waves
  - » Chromatography

One Video Segment

- 4.2 Strange Experimental Results => The Advent of Quantum Mechanics
  - » Black Body Radiation => light emission is quantized
  - » Discrete Optical Spectra => light emission/absorption quantized – Bohr Atom
  - » Photoelectric Effect => light is described by particles
  - » Particle-Wave Duality

One Video Segment

- 4.3 Why do we need quantum mechanics?

One Video Segment

- 4.4 Formulation of Schrödinger's Eq.

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One Video Segment

- 4.1 Classical Systems
  - » **Classical Macroscopic Particles**
  - » Propagating Waves
  - » Standing Waves
  - » Chromatography

One Video Segment

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One Video Segment

- 4.3 Why do we need quantum mechanics?

One Video Segment

- 4.4 Formulation of Schrödinger's Eq.

Classical Macroscopic Particles

Properties:

- Have a finite extent
- Have a finite weight
- Are countable with integers

- continuous (ignoring atomic granularity)
- continuous (ignoring atomic granularity)
- discrete

Laws of Motion

- Classical Newtonian Mechanics

Interactions with other particles

- Energy continuity
- Momentum continuity

Example

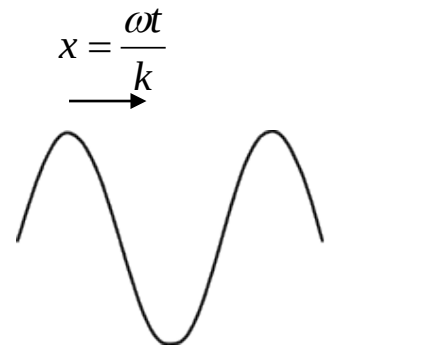
- Billiard balls

Propagating Plane Waves

Propagating Plane Waves

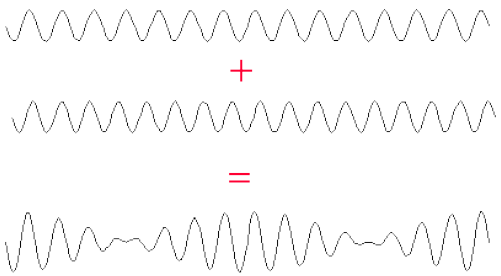
Properties:

- Have infinite extent
- Have finite wavelength
- Have a finite frequency



Laws of Motion

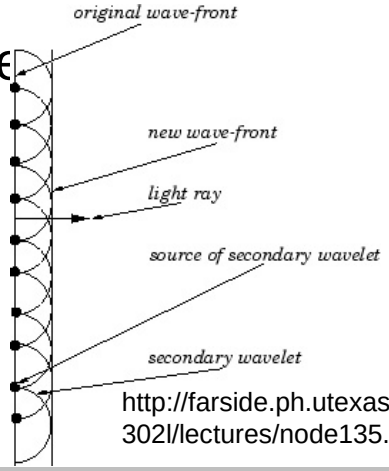
- Wave equation $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 x}{\partial x^2} = 0$
- One solution $u = u_0 \sin(kx - \omega t) \quad c = \pm \omega / k = \pm \lambda f$



http://www.qmw.ac.uk/~zgap118/5/

Interactions with other waves / environment

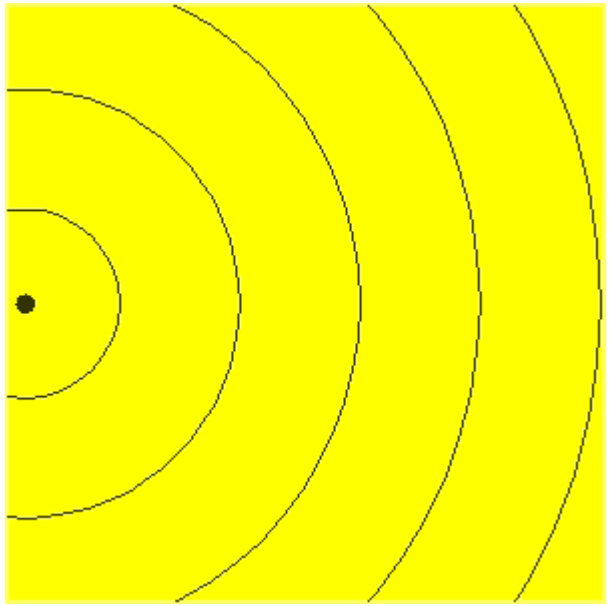
- Coherent superposition
  => interference, constructive and destructive
  => one wave can cancel out another
- Huygens principle:
  one plane wave made up by many circular waves
  => diffraction
  => waves go around corners



http://farside.ph.utexas.edu/teaching/302l/lectures/node135.html

Huygens' Principle

- All waves can be represented by point sources
- This animation shows an example of a single point source

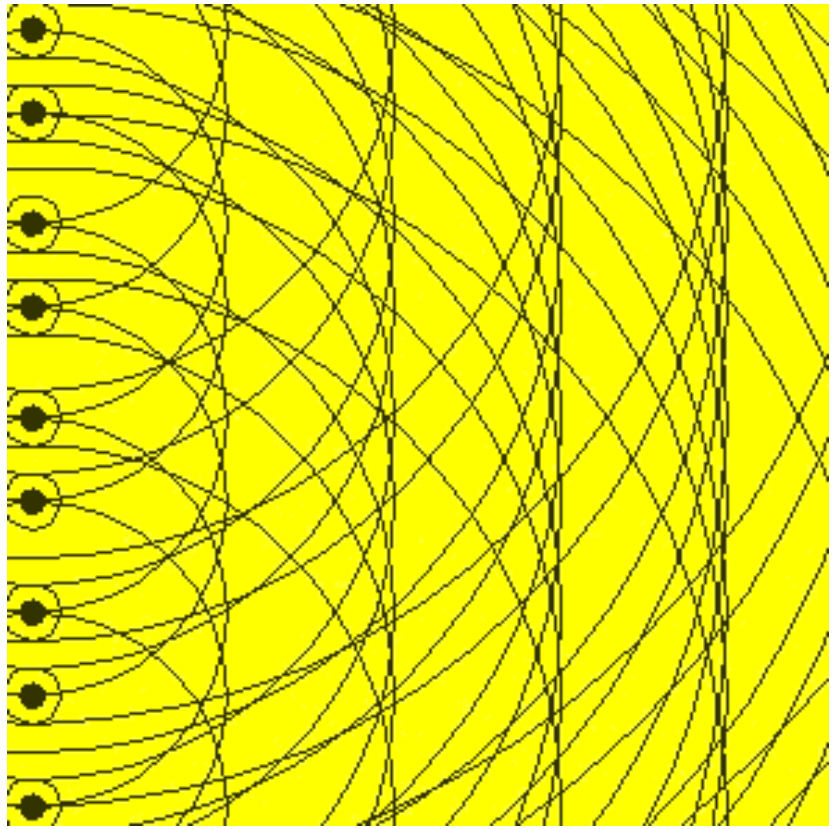


http://id.mind.net/~zona/mstm/physics/waves/propagatio

Huygens' Principle

- All waves can be represented by point sources

- This animation shows an example of multiple single point sources creating a wavefront.



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Propagating Plane Waves
Light is an Electromagnetic Wave

Properties:

- Have infinite extent
- Have finite wavelength
- Have a finite frequency

- Not countable
- Continuous
- Continuous

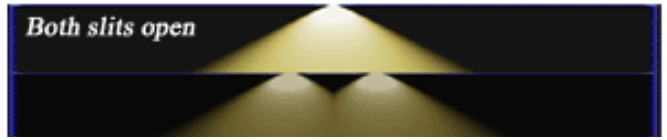
Laws of Motion

- Wave equation
- One solution

$$\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 x}{\partial x^2} = 0$$

$$u = u_0 \sin(kx - \omega t) \quad c = \pm \omega / k = \pm \lambda f$$

Double Slit Experiment



Interactions with other waves / environment

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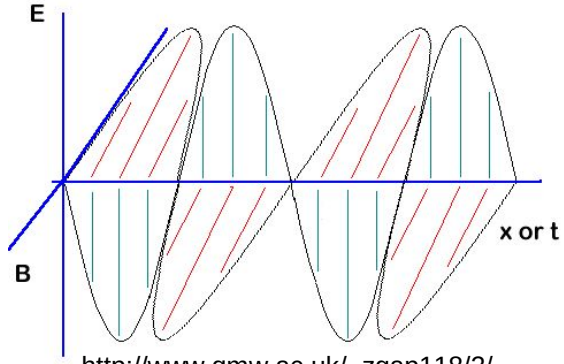
  => light goes around corners

http://en.wikipedia.org/wiki/Double-slit_experiment



http://www.qmw.ac.uk/~zgap118/2/

Accepted Proof:

- Light is an electromagnetic wave

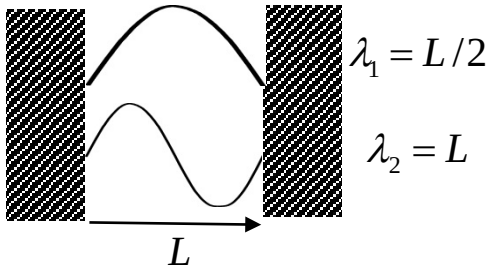
Standing Waves

Standing Waves

Properties:

- Have finite extent
- Have discrete wavelengths
- Have discrete frequencies

- Countable in 1/2 wavelength
- Integer multiples
- Integer fractions



Laws of Motion

- Wave equation $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 x}{\partial x^2} = 0$
- One solution $u = \begin{cases} u_0 \sin(kx - \omega t); & 0 \le x \le L \\ 0; & x < 0; x > L \end{cases}$

$k_j = j \frac{\pi}{L}$

- Quantized momentum k_j

Interactions with other waves / environment

- Coherent superposition
  => e.g. sounds add in an instrument
- A standing wave is a resonator
- one resonator can couple to another
  => e.g. string <=> guitar
  => energy is transferred between resonators
  => energy conservation
- resonators must be “in-tune”
  => momentum conservation

Particles and Waves

Classical Particles:

- Have a finite extent
- Have a finite weight
- Are countable with integers

- continuous (ignoring atomic granularity)
- continuous (ignoring atomic granularity)
- discrete

Standing Waves:

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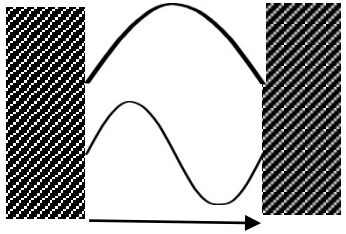


$\lambda_1 = L/2$

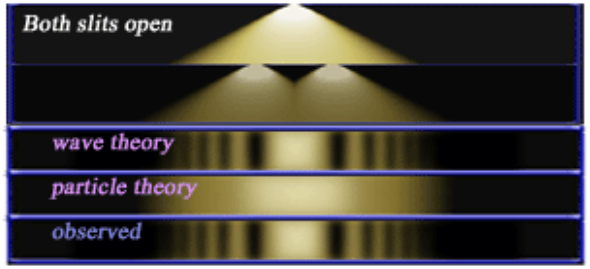
$\lambda_2 = L$

- Quantized momentum k_j

Propagating Waves:

- Have infinite extent
- Have finite wavelength
- Have a finite frequency

- Not countable
- Continuous
- Continuous



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Particles and Waves

Classical Particles:

- Have a finite extent — continuous (ignoring atomic granularity)
- Have a finite weight — continuous (ignoring atomic granularity)
- Are countable with integers — discrete

Standing Waves:

- Have finite extent — Countable in 1/2 wavelength
- Have discrete wavelengths — Integer multiples
- Have discrete frequencies — Integer fractions

Propagating Waves:

- Have infinite extent — Not countable
- Have finite wavelength — Continuous
- Have a finite frequency — Continuous

- “White” light consists of a broad spectrum of colors
- Each individual color is associated with a particular frequency of wave
- A prism can dissect white light into its frequency components
- Is there some information in this kind of frequency spectrum?
  => chromatography

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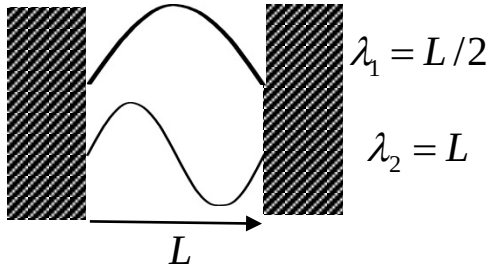

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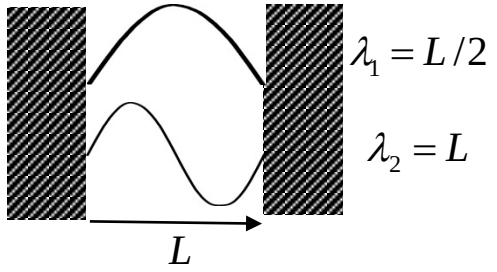

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