Physics II

Electrodynamics:

Review of mathematical tools (Vector Algebra and Vector Calculus), Basic concepts of Electrostatics, gauss's Law and its application, electric potential, work and energy in Electrostatics, conductors, Electrostatic Fields in Matters, Magnetostatic Fields in Matter, electromotive force, Faraday's Law, Maxwell's equations, Electromagnetic waves

Quantum Mechanics:

Failure of Classical concepts, Wave particle duality, Photoelectric effect, Black body radiation, Stefan's law, Compton effect, concepts of wave packets: phase and group velocities, Heisenberg uncertainty principle and its applications, wave function and its physical interpretation, Probabilities, normalization, Expectation value, Eigen values, Eigen function, Time dependent and independent Schrödinger's equation and its application in one dimension, Quantum statistics (Bose Einstein and Fermi Dirac)

Semiconductor Physics

Crystal Structure of semiconductor materials, Energy band of solids, Semiconductor in equilibrium, carrier transport phenomena, Physics of p-n junction in equilibrium and non equilibrium conditions

Suggested reading

A. Beiser - Concept of Modern Physics

D. Neamen – Semiconductor Physics and Devices

D. Griffiths - Introduction to Electrodynamics

Other helpful books:

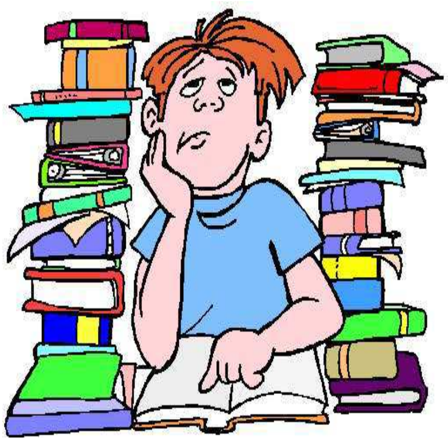
3,000 Solved Problems in Physics (Schaum's Solved Problems)

The Feynman Lectures on Physics by Richard Phillips Feynman (Author)

My lectures will be a mix of PPT slides and Black board!

All my Power Point lectures will be at GOOGLE DRIVE
https://drive.google.com/#folders/0B3KbtOX3Yx-ZU2hBcnBmbWNzSXM

Homework/Assignments



Some problem will be either beginning or end of the class in lecture classes.
You can work with others on homework (I encourage you to do so! Because you will be benefitted by discussion), but write it up yourself.

Quizzes

There will be one or two quizzes and will be used for your grades. If you miss one you do not need any justification, the other 3 quizzes will be automatically considered. The quiz dates are either announce earlier or may be surprise in any class.

The Importance of Having Class

You should come to class because there's a lot that I'll say that won't be in the Power Point files. And which will be on the quizzes/Exams.

In general people who have skipped a lot of classes have received very bad grades. Conversely, people who've come to most or all of the classes nearly always receive good grades.

So please all of you attend every lecture.

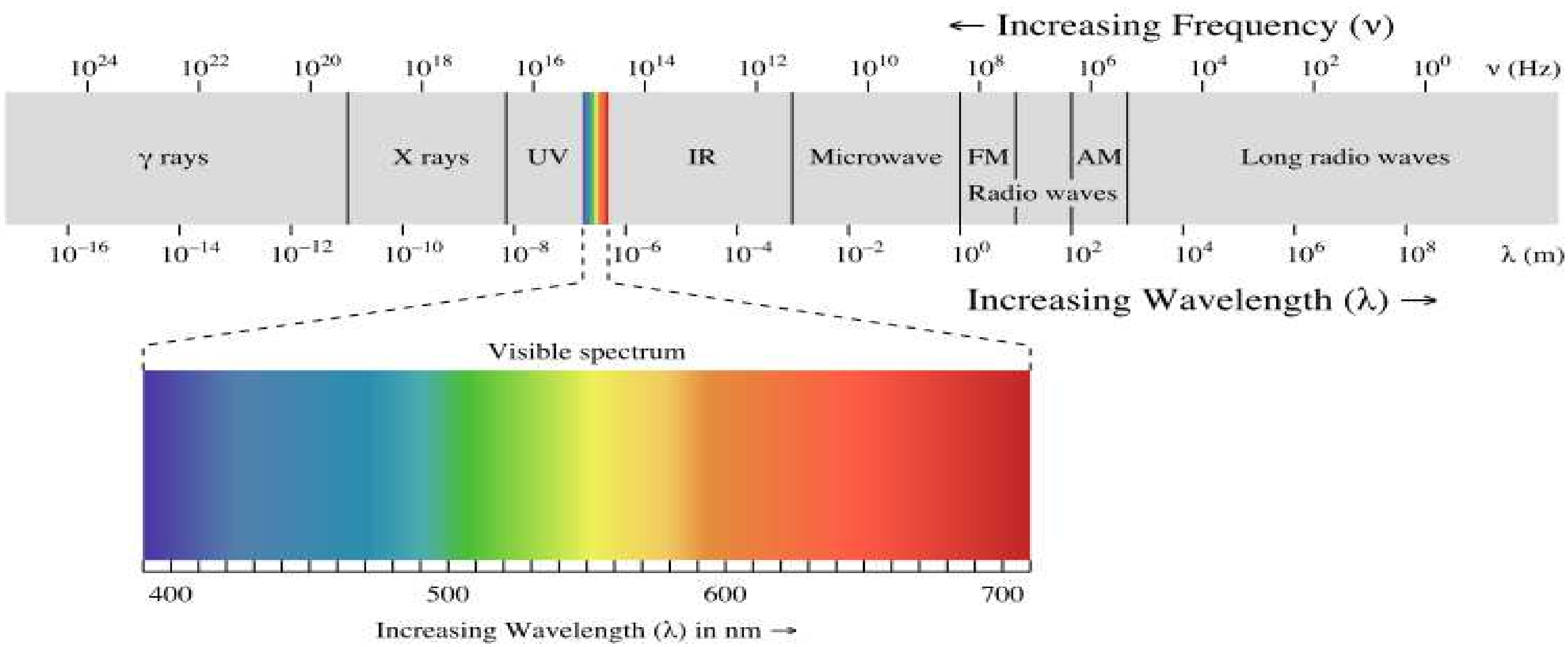
Where did the Quantum theory come from?

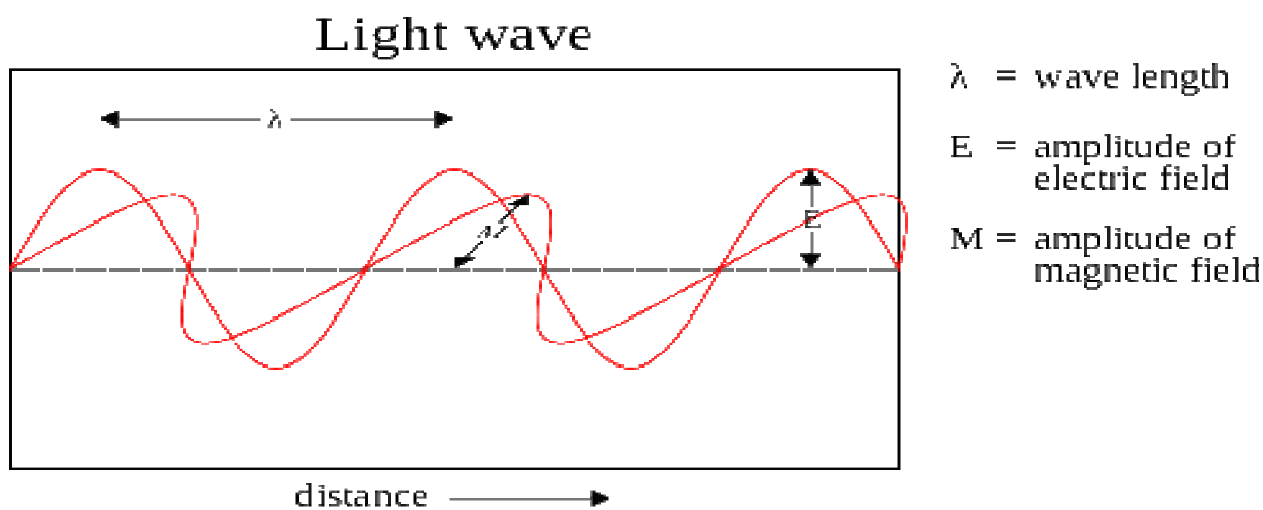
Thomas Allva Edison's first successful light bulb model, used in public demonstration at Menlo Park, December 1879

Max Planck (1858–1947), a German physicist considered to be the founder of quantum theory

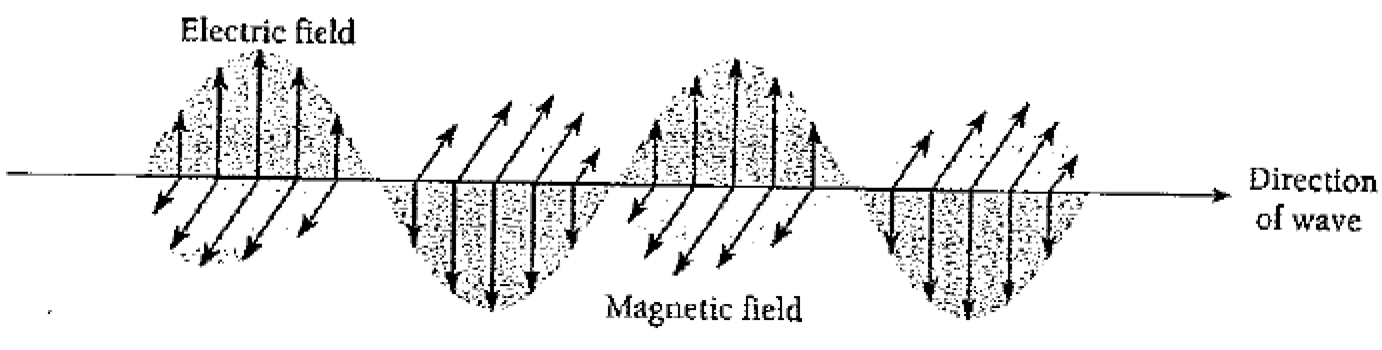
What is LIGHT?

- Light consist of electromagnetic waves .
- Visible Light is simply a name for a range of electromagnetic radiation that can be detected by the human eye.





Light waves carry energy only in packets, with high frequency consisting of large packets of energy and low frequency light consisting of small packets of energy. The idea that light comes in packets or “**quanta**”



Waves and Particles

Wavelength

Frequency

Waves

Spread in space and time

Can be superposed – show interference effects

Pass through each other

Particles

Localized in space and time

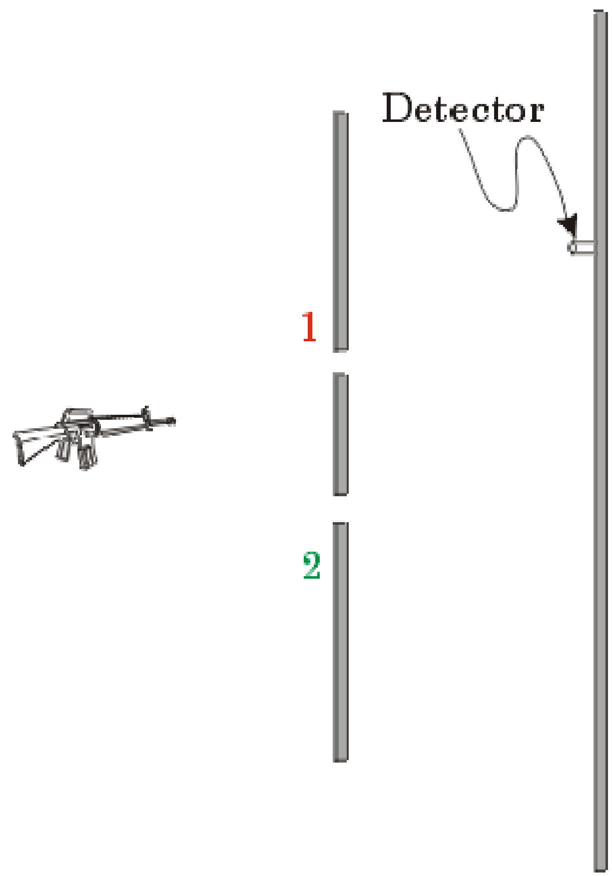
Cannot pass through each other - they bounce or shatter.

Light: A Particle or Wave

- Different tests support different sides of the argument
- Today: dual theory
- Young Experiment

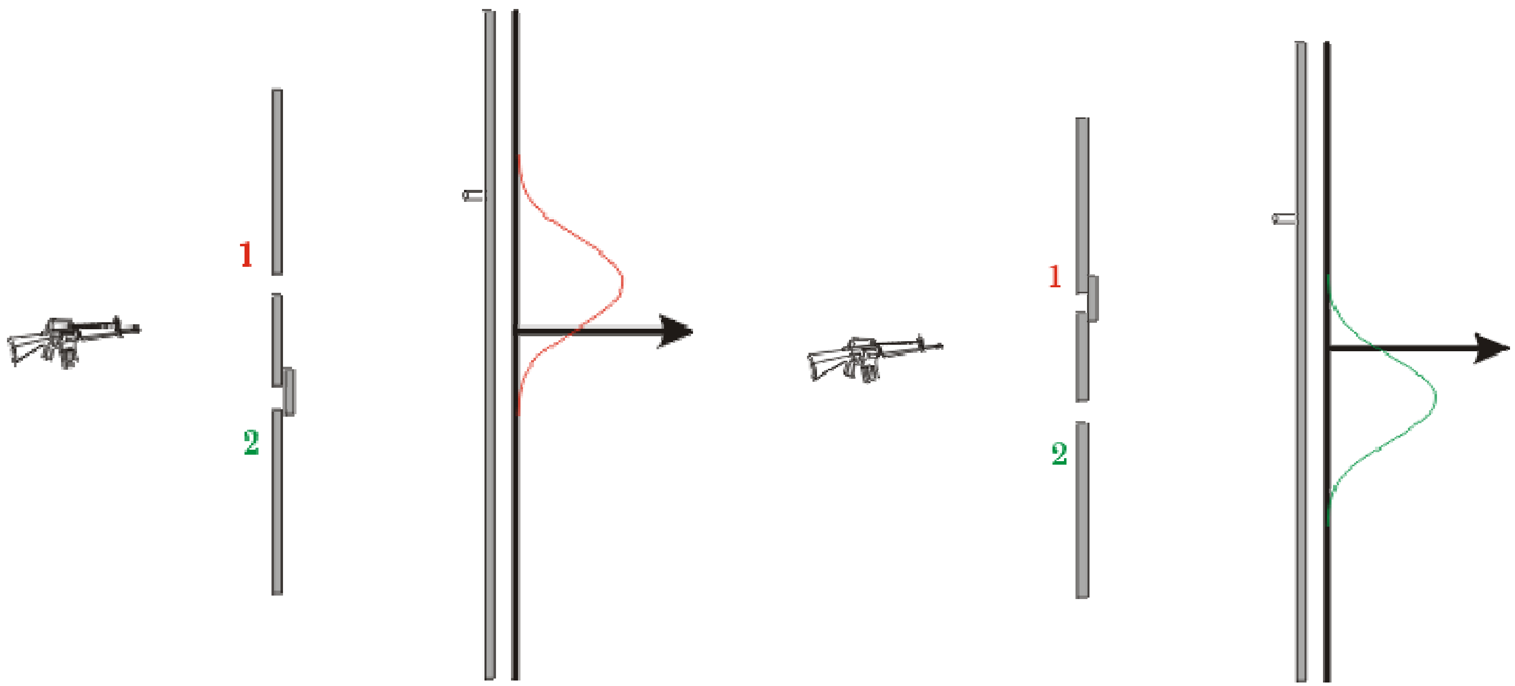
Double Slit Analogy

An experiment with bullets



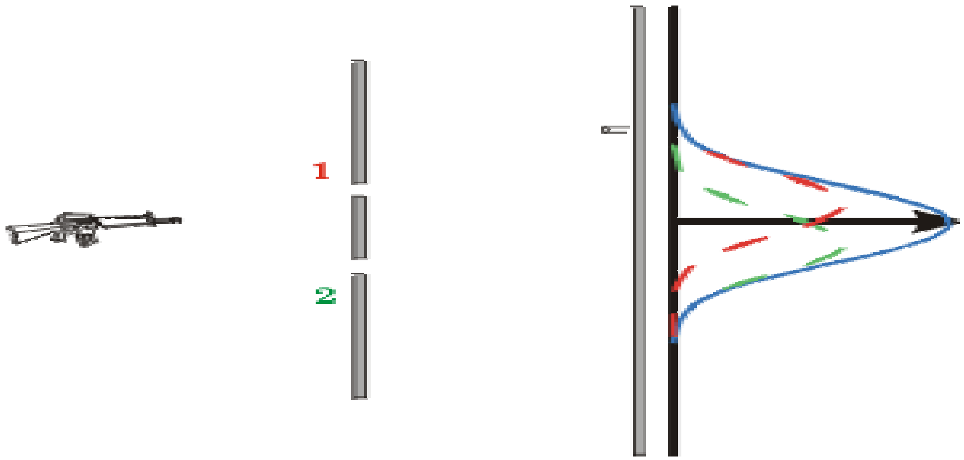
Particles Through One Slit

An experiment with bullets



Particles Through Both Slits

An experiment with bullets



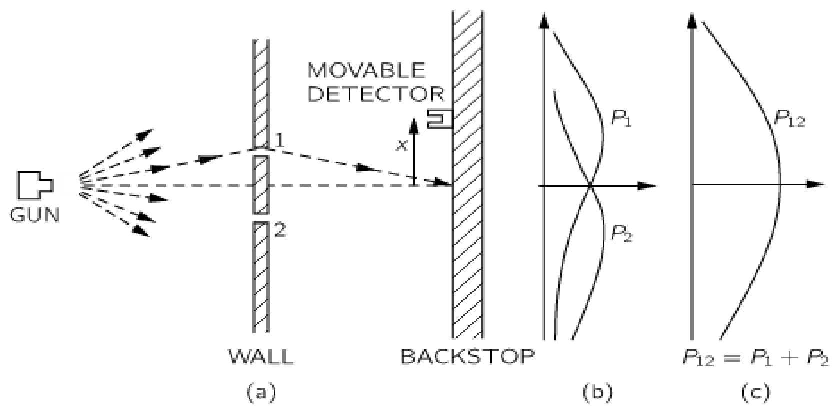
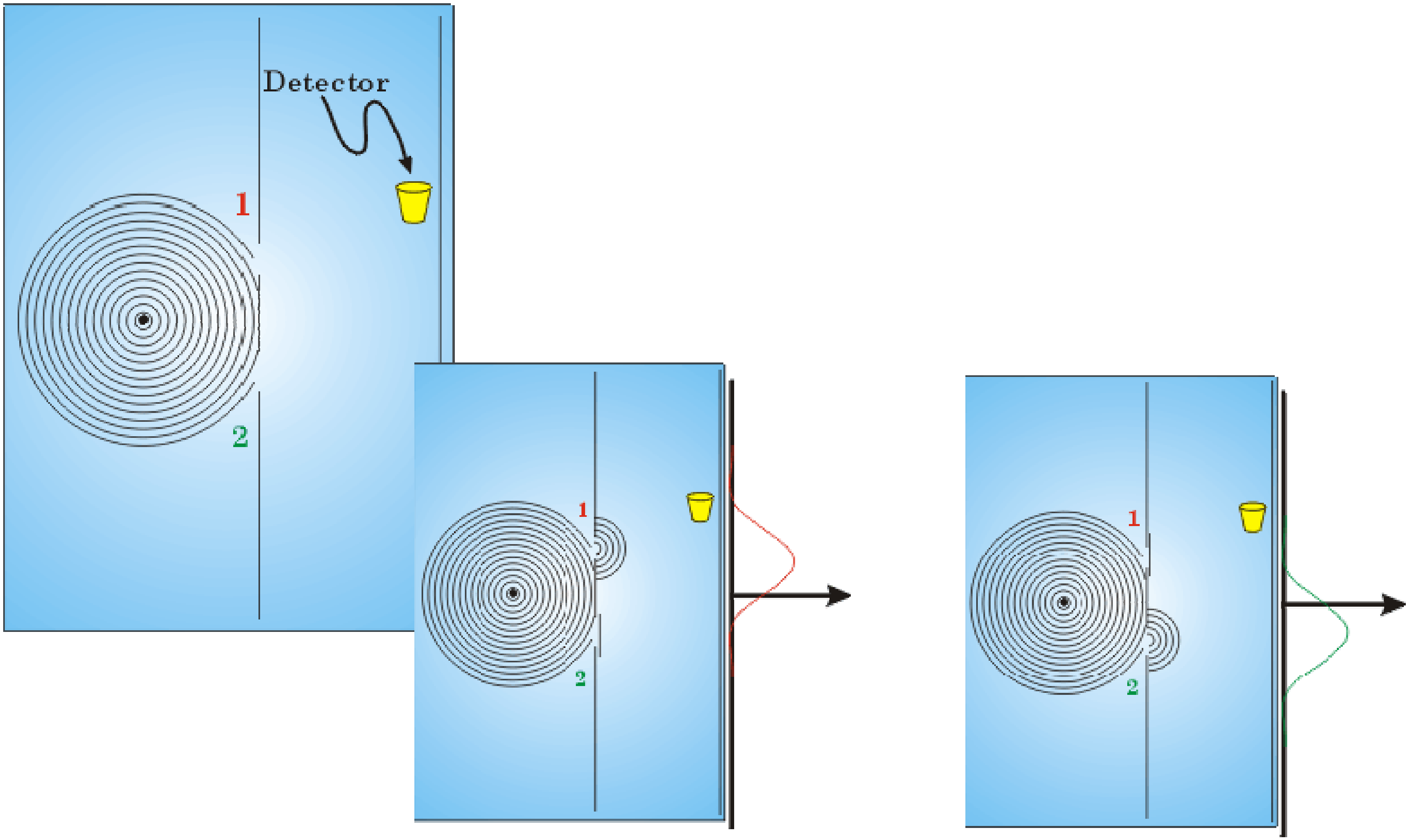


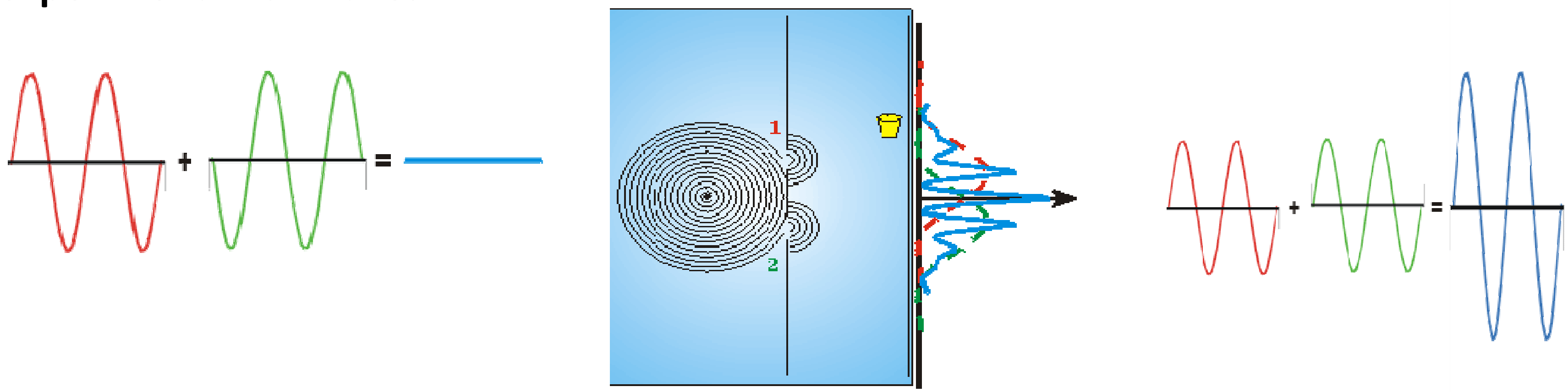
Fig. 1–1. Interference experiment with bullets.

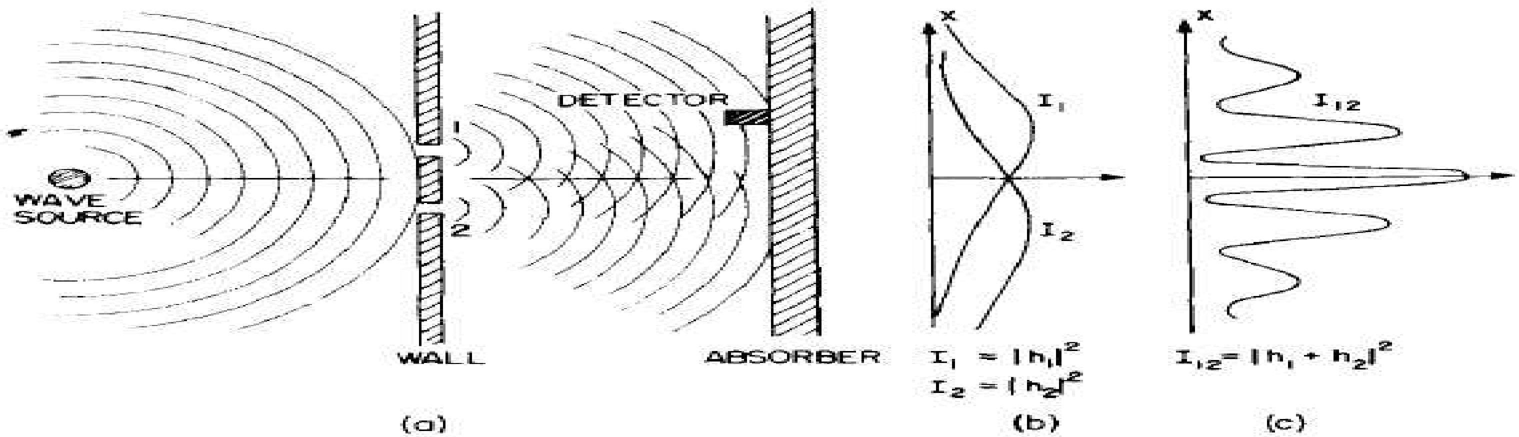
We shall call this result an observation of “*no interference*,” for a reason that you will see later. So much for bullets. They come in lumps, and their probability of arrival shows no interference.

An experiment with waves



An experiment with waves

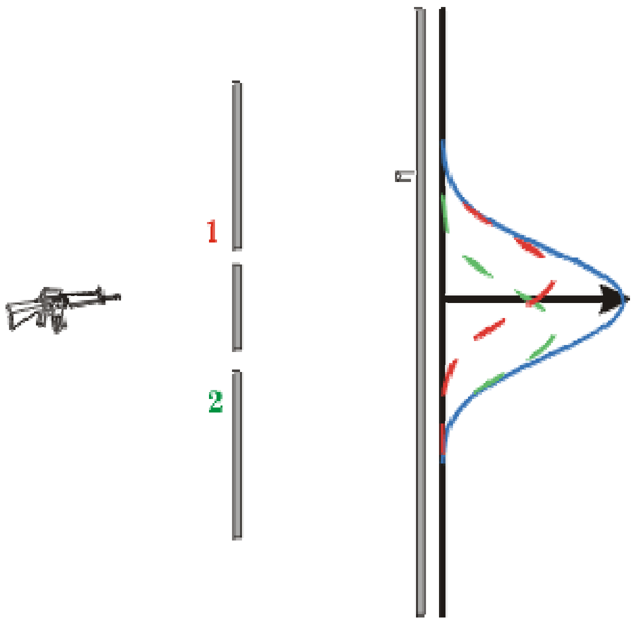


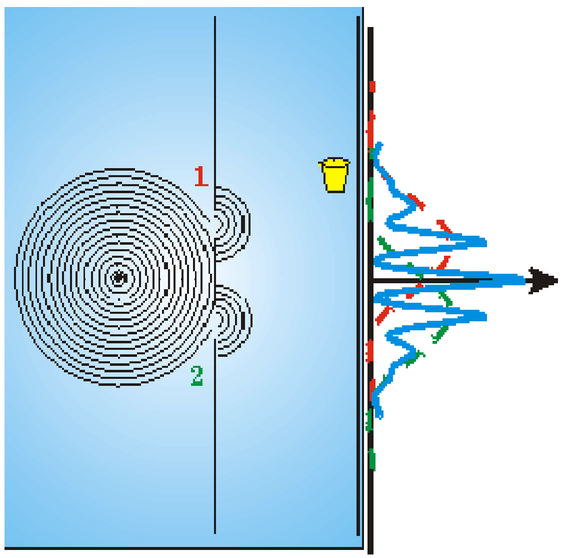


$$I_1 = |h_1|^2, \quad I_2 = |h_2|^2, \quad I_{12} = |h_1 + h_2|^2. \qquad I_{12} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta.$$

where δ is the phase difference between h_1 and h_2

Interference or Not?





An experiment with electrons

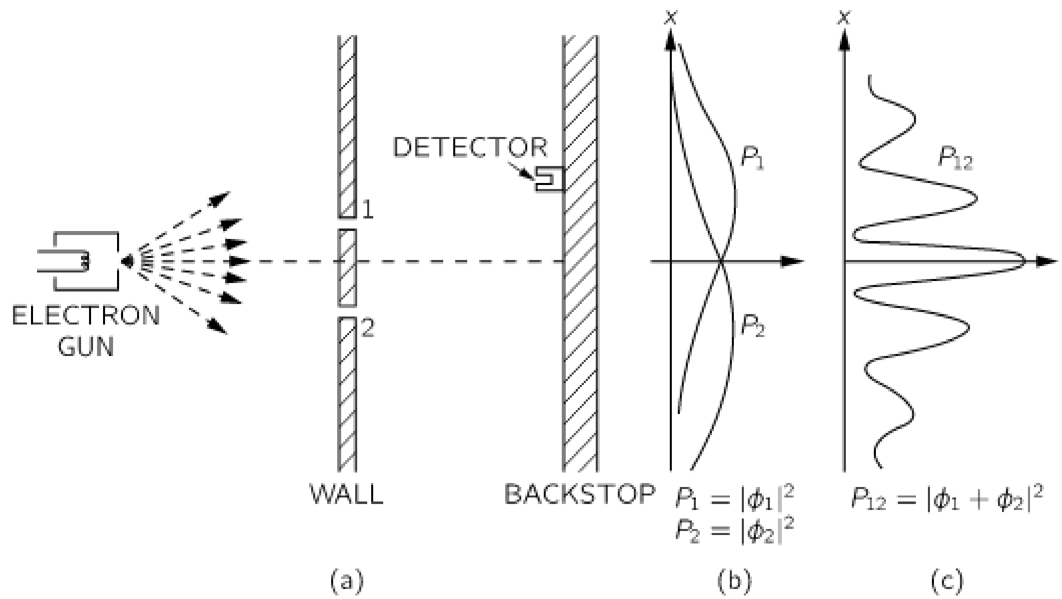


Fig. 1–3. Interference experiment with electrons.

"What is the relative probability that an electron 'lump' will arrive at the backstop at various distances x from the center?"

The result of our experiment is the interesting curve marked P_{12} in part (c). This is the way electrons go.

The interference of electron waves

Proposition A: Each electron *either* goes through hole 1 *or* it goes through hole 2.

The result P_{12} obtained with *both* holes open is clearly not the sum of P_1 and P_2, the probabilities for each hole alone. In analogy with our water-wave experiment, we say: "There is interference."

$$\text{For electrons:} \qquad P_{12} \neq P_1 + P_2.$$

Yet, surprisingly enough, the *mathematics* for relating P_1 and P_2 to P_{12} is extremely simple. For P_{12} is just like the curve I_{12} of Fig. and *that* was simple. What is going on at the backstop can be described by two complex numbers that we can call ϕ_1 and ϕ_2 (they are functions of x, of course). The absolute square of ϕ_1 gives the effect with only hole 1 open. That is, $P_1 = |\phi_1|^2$. The effect with only hole 2 open is given by ϕ_2 in the same way. That is, $P_2 = |\phi_2|^2$. And the combined effect of the two holes is just $P_{12} = |\phi_1 + \phi_2|^2$.

We conclude the following: The electrons arrive in lumps, like particles, and the probability of arrival of these lumps is distributed like the distribution of intensity of a wave. It is in this sense that an electron behaves "sometimes like a particle and sometimes like a wave."

Since the **probability** of arrival through both holes is given so simply, although it **is not equal to (*P*1+*P*2),** that is really all there is to say. But there are a **large number of subtleties involved** in the fact that nature does work this way. We would like to illustrate some of these subtleties for you now. First, since the number that arrives at a particular point is *not* equal to the number that arrives through 1 plus the number that arrives through 2, as we would have concluded from **Proposition A**, undoubtedly we should conclude that ***Proposition A is false***. It is *not* true that the electrons go *either* through hole 1 or hole 2. But that conclusion can be tested by another experiment.

Watching the electrons

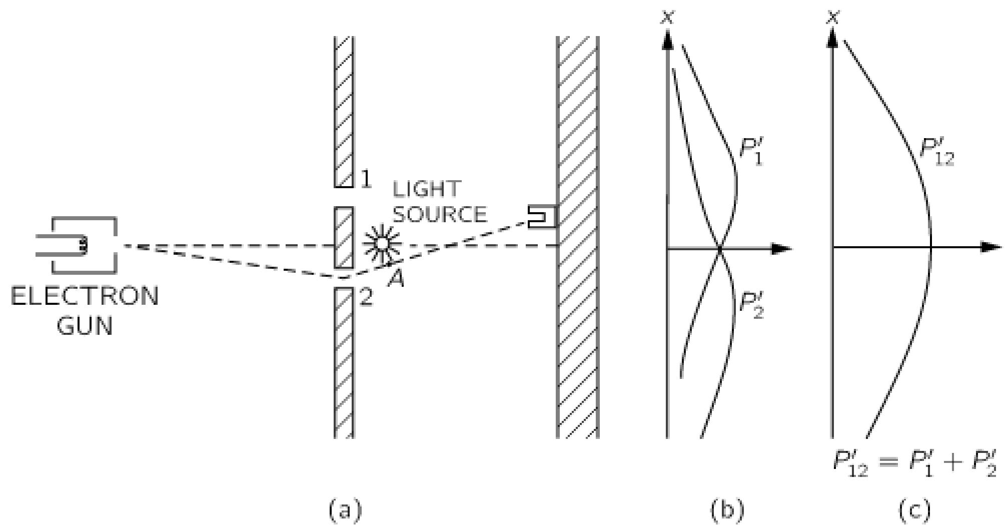


Fig. 1–4. A different electron experiment.

If the motion of all matter—as well as electrons—must be described in terms of waves, what about the bullets in our first experiment? **Why didn't we see an interference pattern there?** It turns out that for the **bullets the wavelengths were so tiny that the interference patterns became very fine.** So fine, in fact, that with any detector of finite size one could not distinguish the separate maxima and minima. What we saw was only a kind of average, which is the classical curve. In Fig. 1–5 we have tried to indicate schematically what happens with large-scale objects. Part (a) of the figure shows the probability distribution one might predict for bullets, using quantum mechanics. **The rapid wiggles** are supposed to **represent the interference** pattern one gets for **waves of very short wavelength**. Any physical detector, however, straddles several wiggles of the probability curve, so that the measurements show the smooth curve drawn in part (b) of the figure.

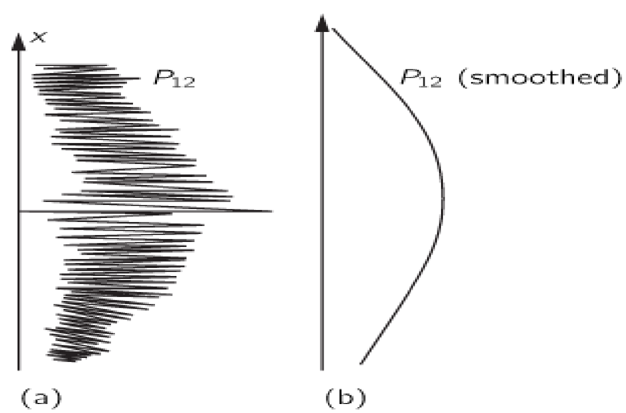


Fig. 1–5. Interference pattern with bullets: (a) actual (schematic), (b) observed.

The Experiment

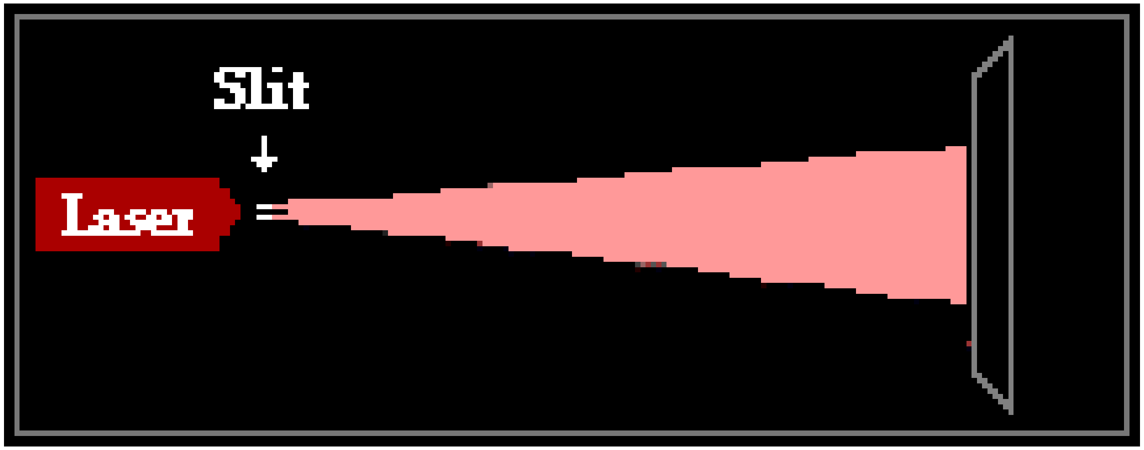
Components:

Light Source: Lasers

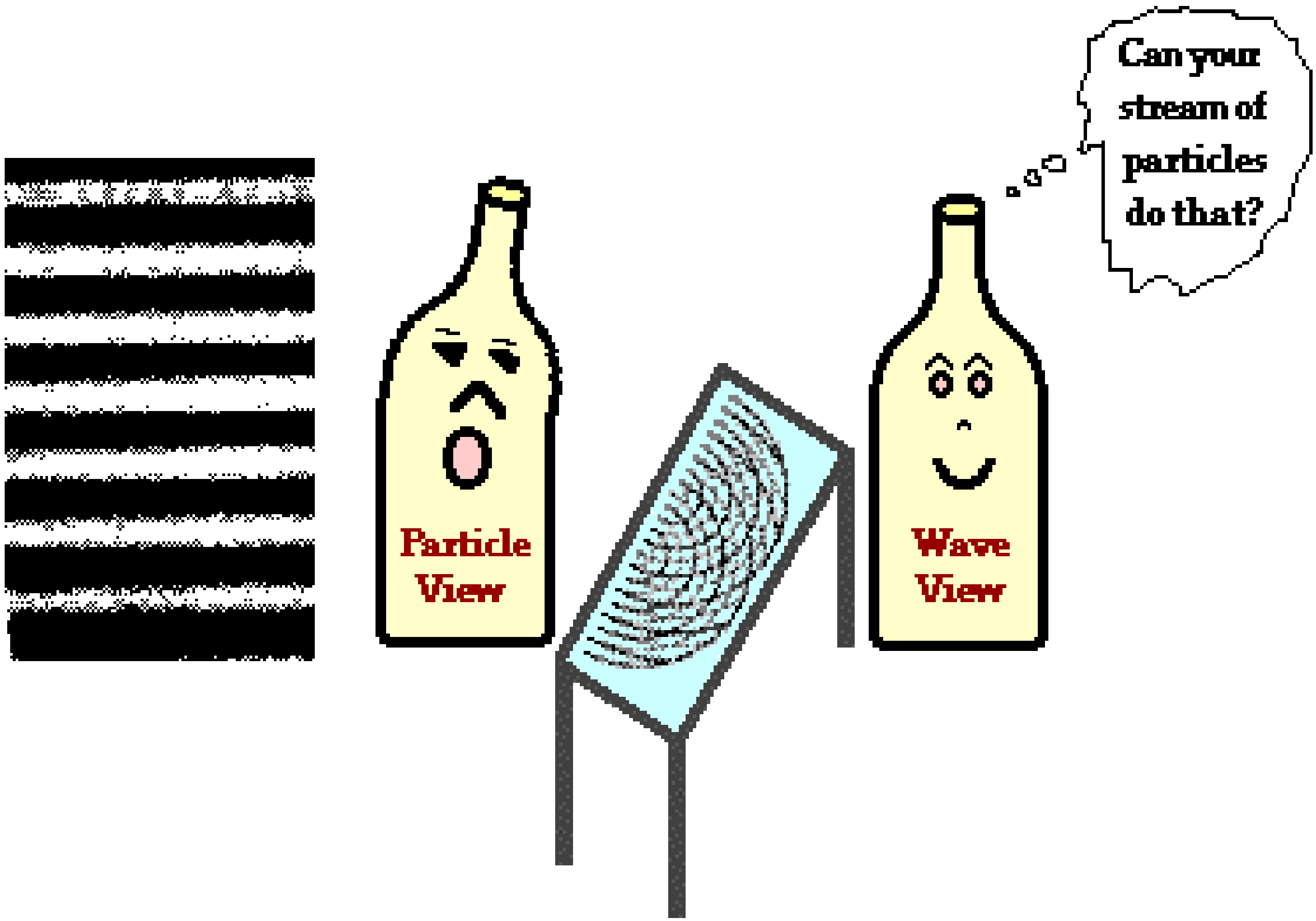
Double Slit: Pre-made slits

Detector: Smooth surface

Top View of Experimental Set-Up

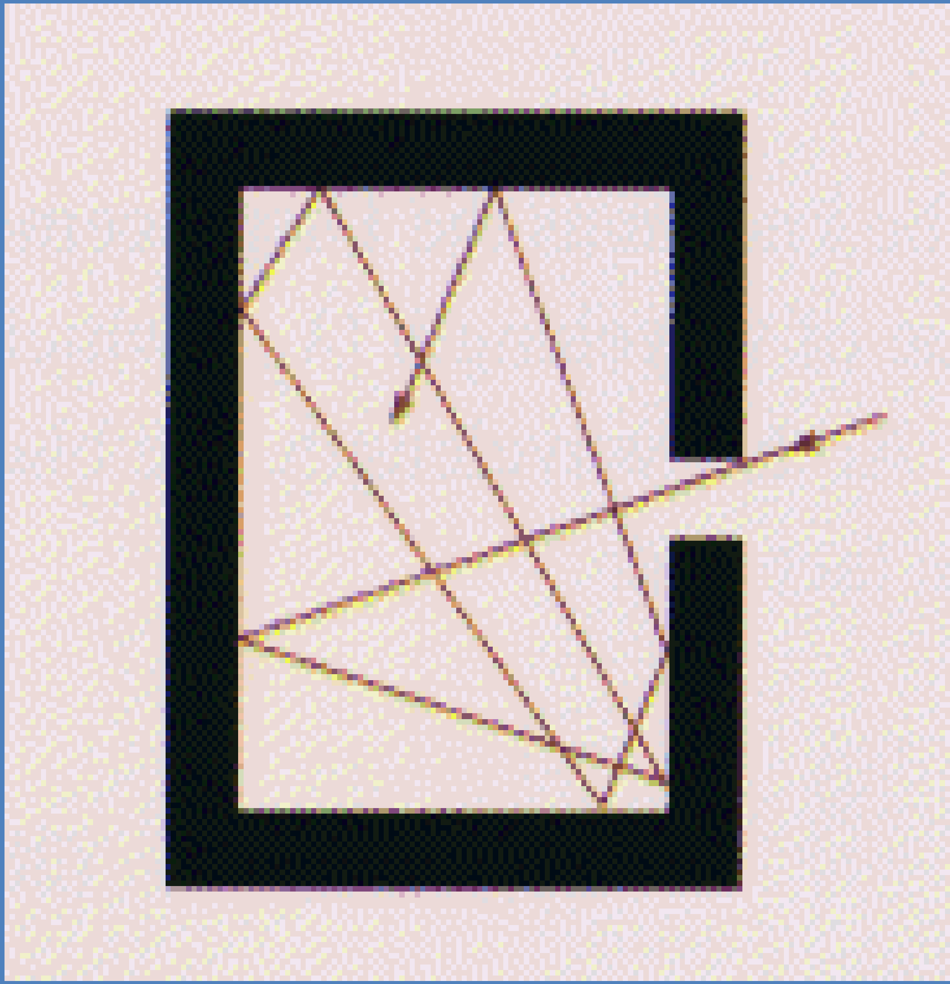


INTERFERENCE!



Definition of a black body

A black body is an ideal body which allows the whole of the incident radiation to pass into itself (without reflecting the energy) and absorbs within itself this whole incident radiation (without passing on the energy). This propety is valid for radiation corresponding to all wavelengths and to all angels of incidence. Therefore, the black body is an ideal absorber of incident radaition.

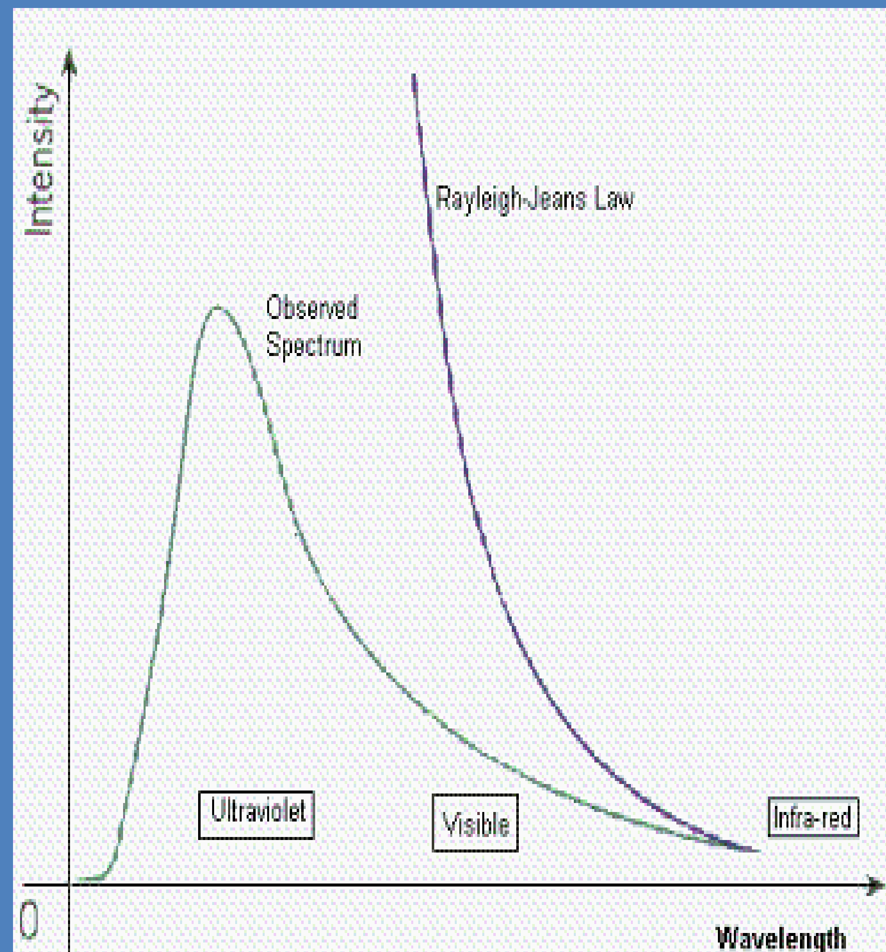


Black-Body Radiation Laws (1)

1- The Rayleigh-Jeans Law.

$$I(\lambda, T) = \frac{2\pi ckT}{\lambda^4}$$

* It agrees with experimental measurements for long wavelengths.
* It predicts an energy output that diverges towards infinity as wavelengths grow smaller.
* The failure has become known as the ultraviolet catastrophe.

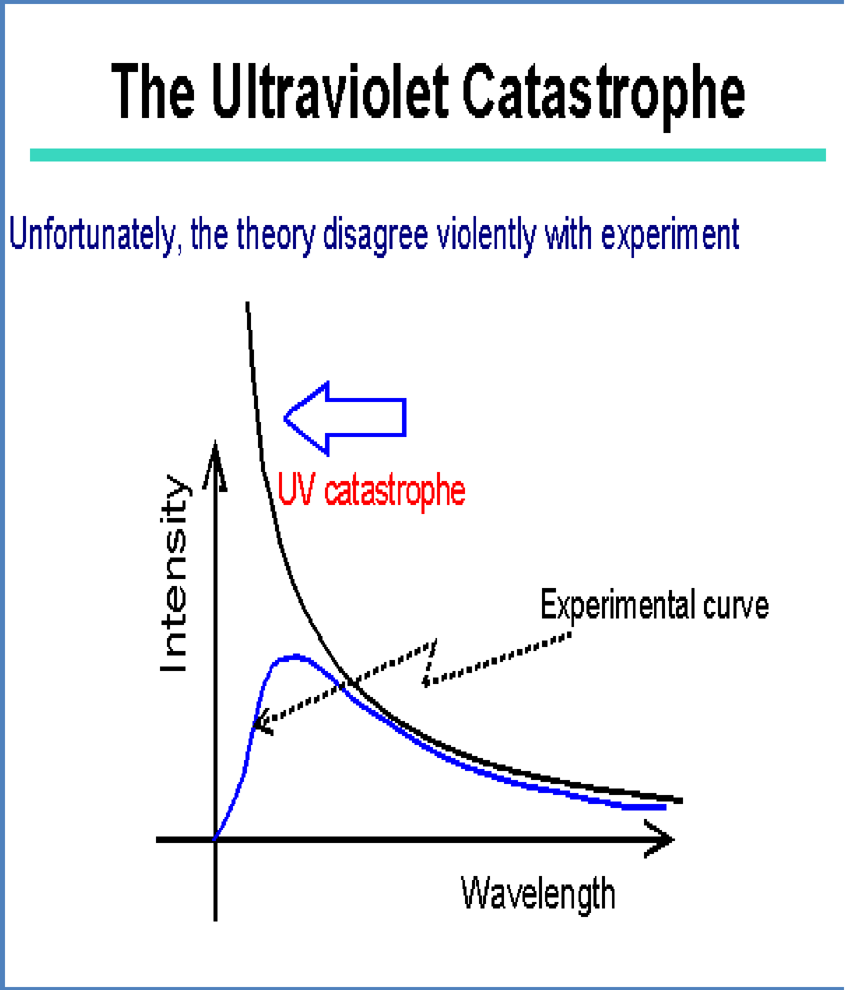


http://www.egglescliffe.org.uk/physics/astronomy/blackbody/Image22c.gif

Ultraviolet Catastrophe

$$I(\lambda,T)=\frac{2\pi ckT}{\lambda^4}$$

- This formula also had a problem. The problem was the term λ in the denominator.
- For large wavelengths it fitted the experimental data but it had major problems at shorter wavelengths.



http://theory.uwinnipeg.ca/users/gabor/foundations/quantum/images/slide5.gif

Black-Body Radiation Laws (2)

2- Planck Law

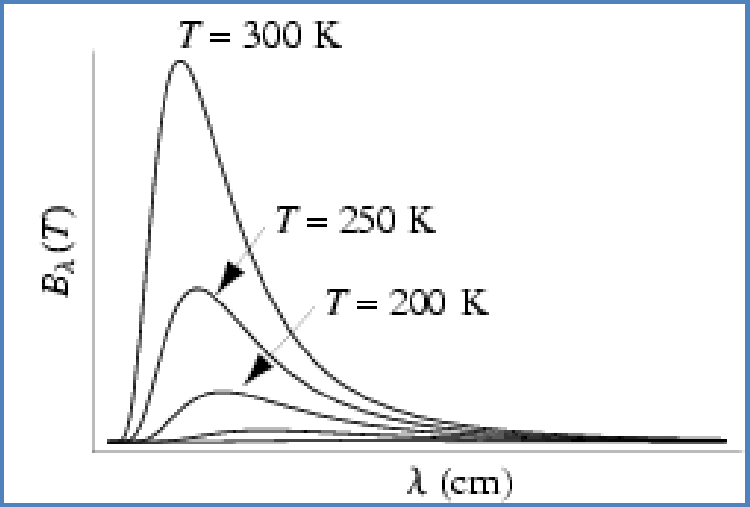
- We have two forms. As a function of wavelength.

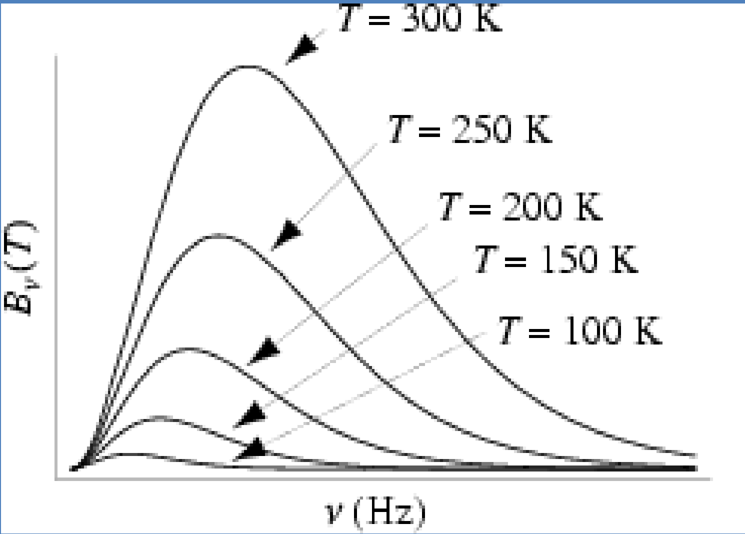
$$I(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

And as a function of frequency

$$I(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{kT}} - 1}$$

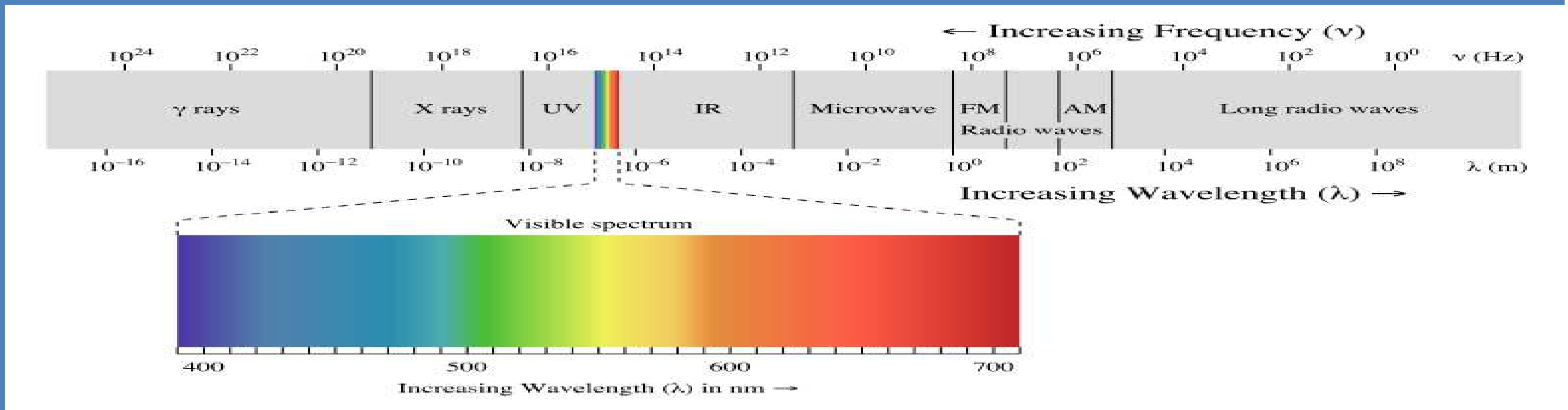
The Planck Law gives a distribution that peaks at a certain wavelength, the peak shifts to shorter wavelengths for higher temperatures, and the area under the curve grows rapidly with increasing temperature.

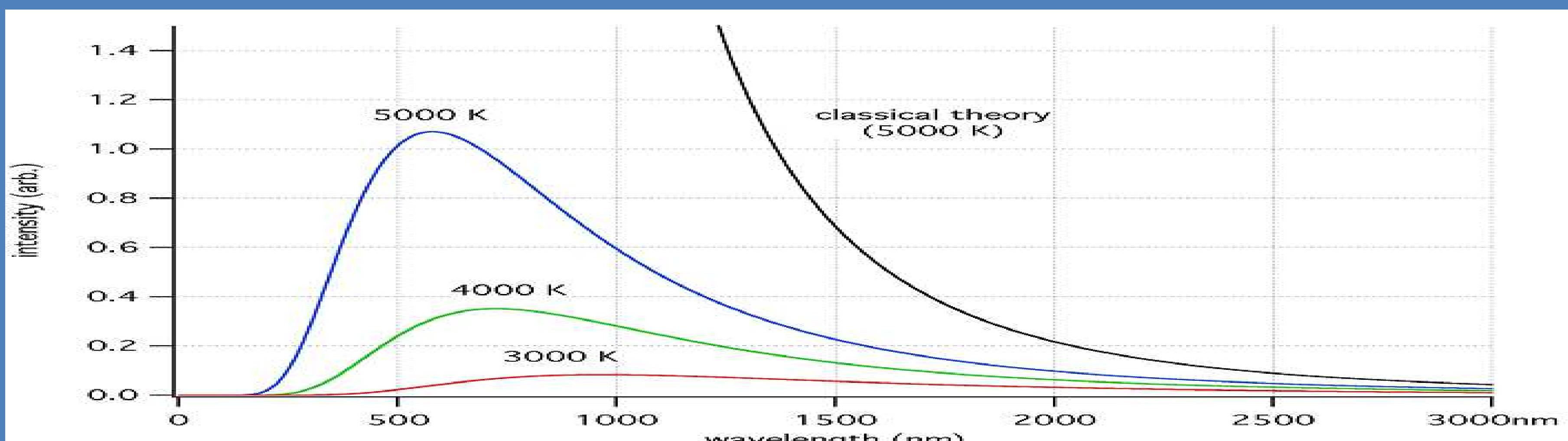




http://scienceworld.wolfram.com/physics/PlanckLaw.html

Comparison between Classical and Quantum viewpoint

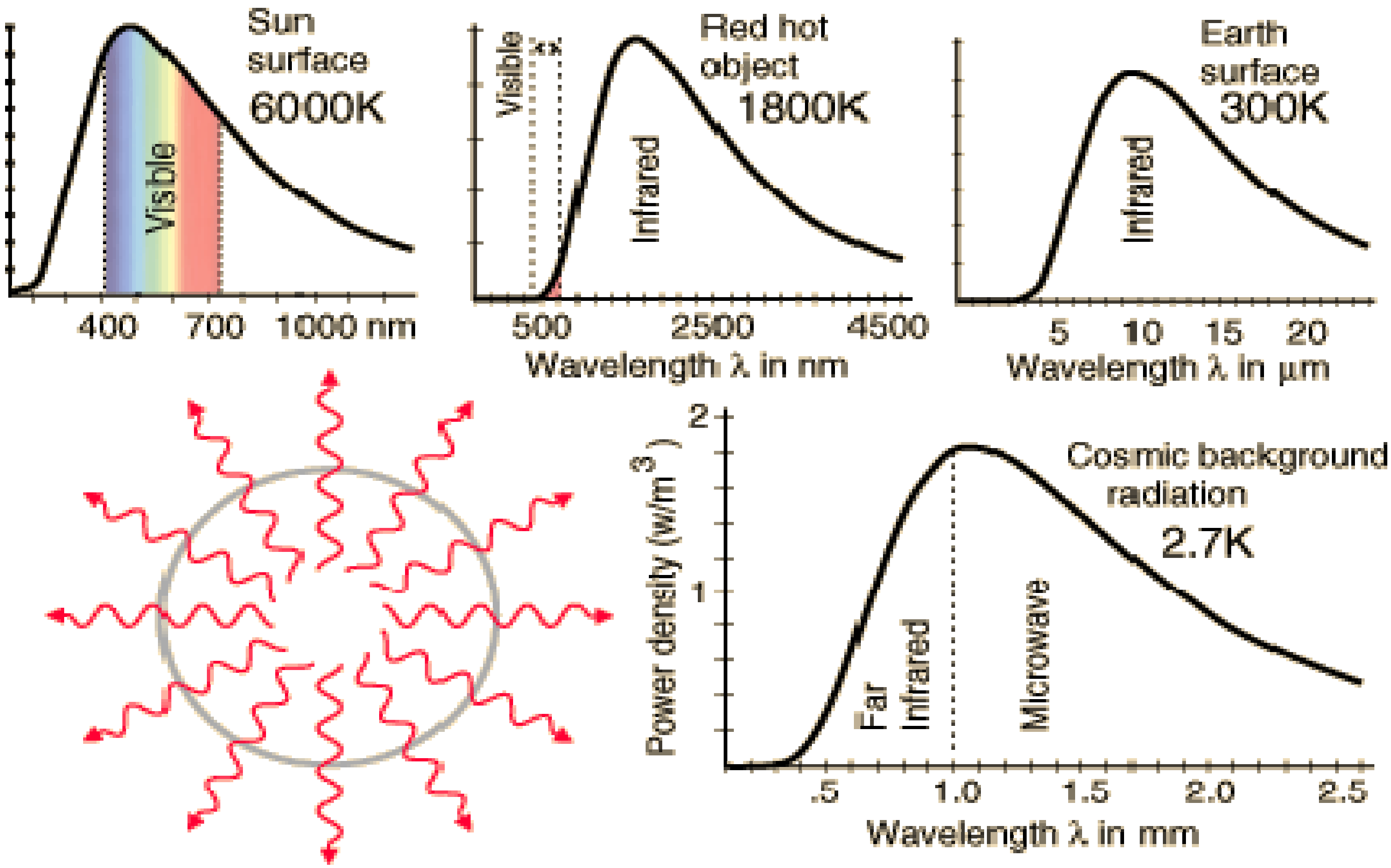




There is a good fit at long wavelengths, but at short wavlengths there is a major disagreement. Rayleigh-Jeans → ∞, but Black-body → 0.

http://upload.wikimedia.org/wikipedia/commons/a/a1/Blackbody-lg.png

Radiation Curves



Numerical

Assume that a certain 660-Hz tuning fork can be considered as a harmonic oscillator whose vibrational energy is 0.04 J. Compare the energy quanta of this tuning fork with those of an atomic oscillator that emits and absorbs orange light whose frequency is 5.00×10^{14} Hz.

Application for Black Body

- The area of Earth's disk as viewed from space is, Area $= \pi r^2$.
- The total energy incident on Earth is, Incident energy $= (\pi r^2)S_o$.
- The energy absorbed by the Earth/atmosphere system, as viewed from space is

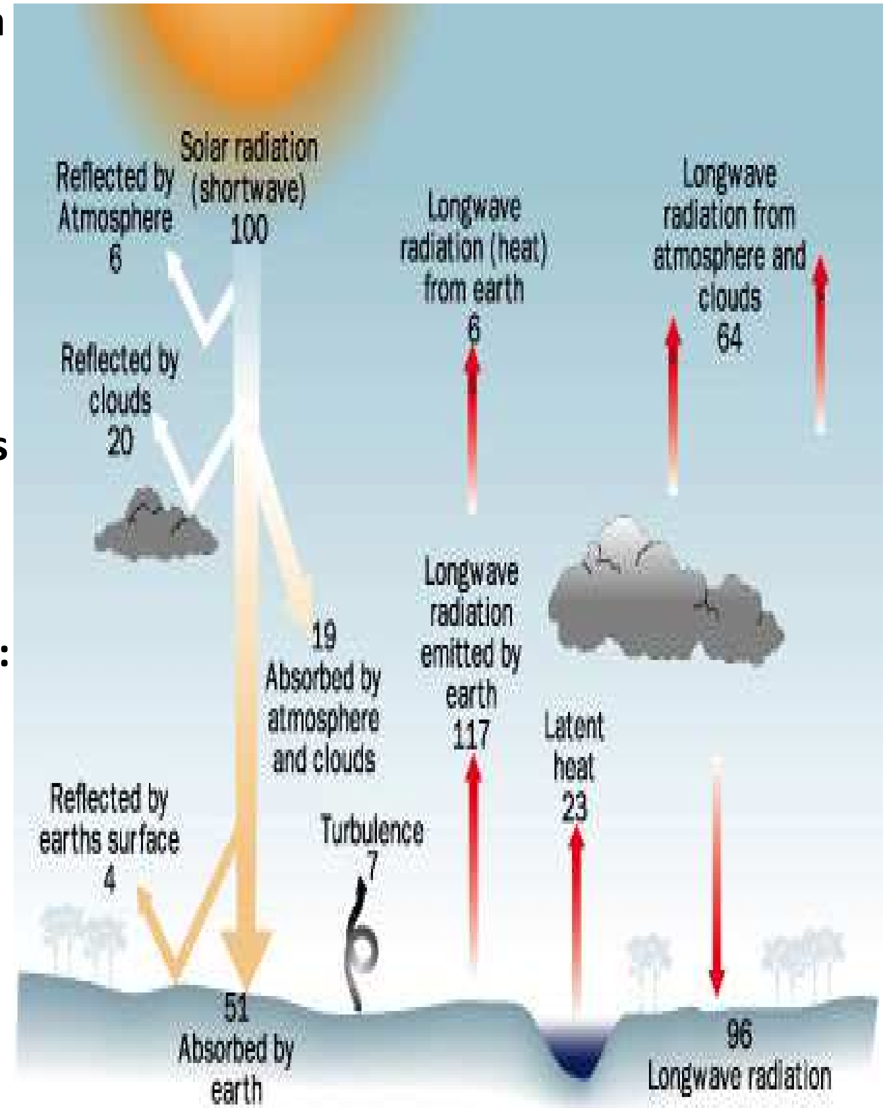
Absorbed energy $= (\pi r^2)S_o(1 - A)$. As we know that bodies must be in radiative equilibrium. The solar energy striking Earth's disk as viewed from space is re-emitted as thermal radiation by the surface of the entire globe, as described by the Stefan-Boltzmann Law, Emitted energy $= (4\pi r^2)\sigma T^4$.

- Set the absorbed energy equal to the emitted energy:

$(\pi r^2)S_o(1 - A) = (4\pi r^2)\sigma T_E^4$, Solving for T yields:

$T_E = [S_o(1 - A)/(4\sigma)]^{(1/4)}$

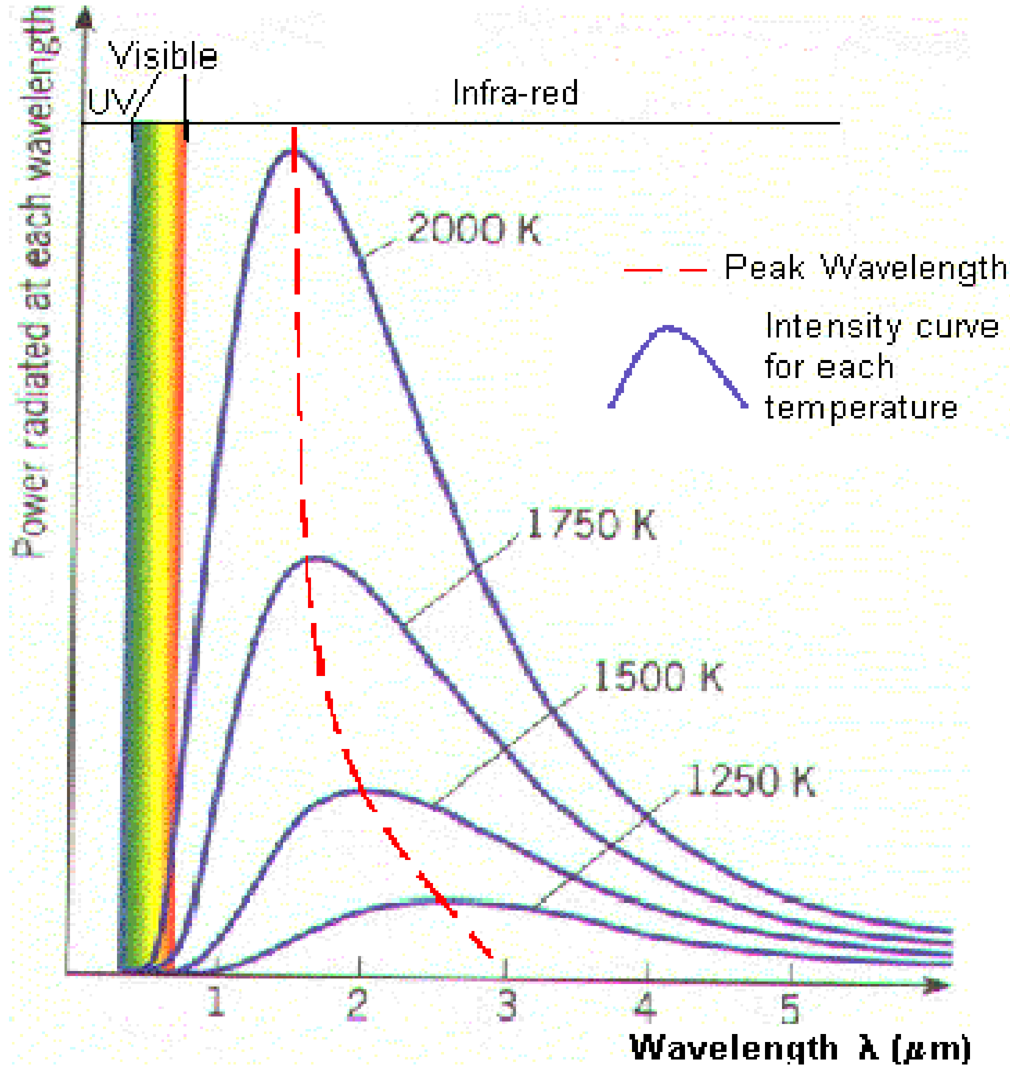
$= [1370 \bullet (1-0.3)/(4 \bullet 5.67x10^{-8})]^{(1/4)} = 255$ K.



http://soer.justice.tas.gov.au/2003/image/378/atm_structure/o_atm_Radn_Balance-m.jpg

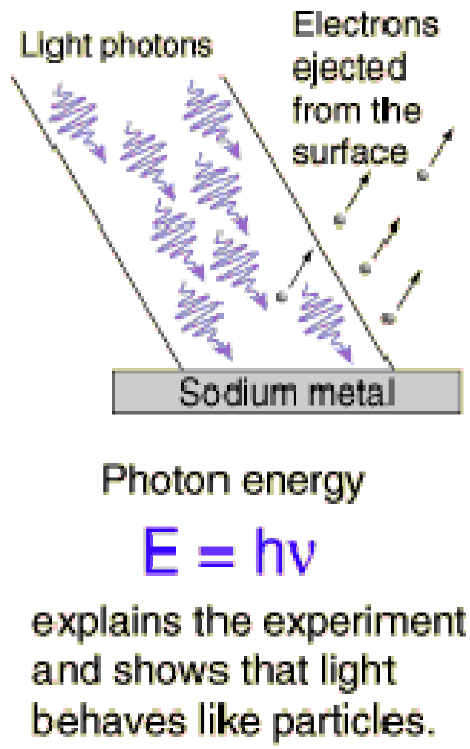
Conclusion

- As the temperature increases, the peak wavelength emitted by the black body decreases.
- As temperature increases, the total energy emitted increases, because the total area under the curve increases.
- The curve gets infinitely close to the x-axis but never touches it.



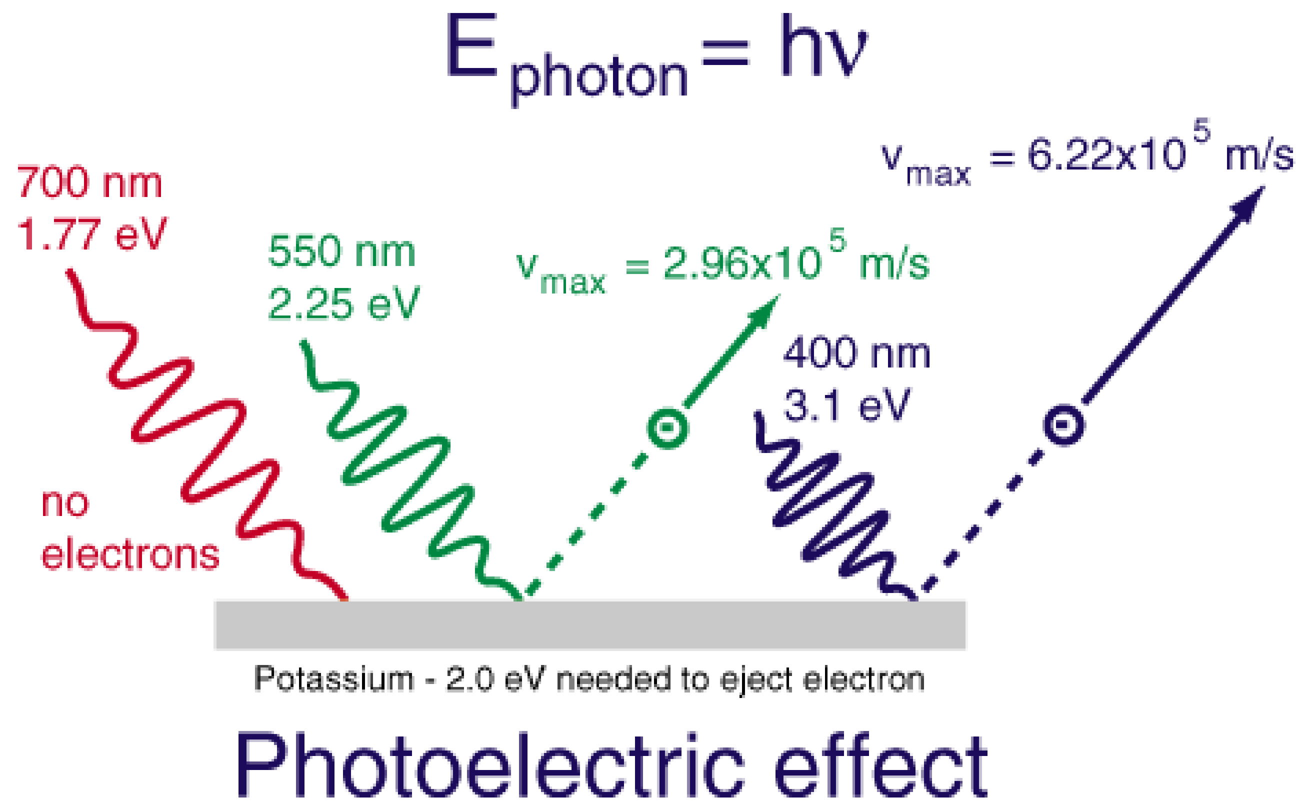
http://www.astro.ufl.edu/~oliver/ast3722/lectures/BasicDetectors/BlackBody.gif

The Photoelectric Effect



Analysis of data from the photoelectric experiment showed that the energy of the ejected electrons was proportional to the frequency of the illuminating light. This showed that whatever was knocking the electrons out had an energy proportional to light frequency. The remarkable fact that the ejection energy was independent of the total energy of illumination showed that the interaction must be like that of a particle which gave all of its energy to the electron! This fit in well with Planck's hypothesis that light in the blackbody radiation experiment could exist only in discrete bundles with energy

$$\boxed{E = h\nu}$$

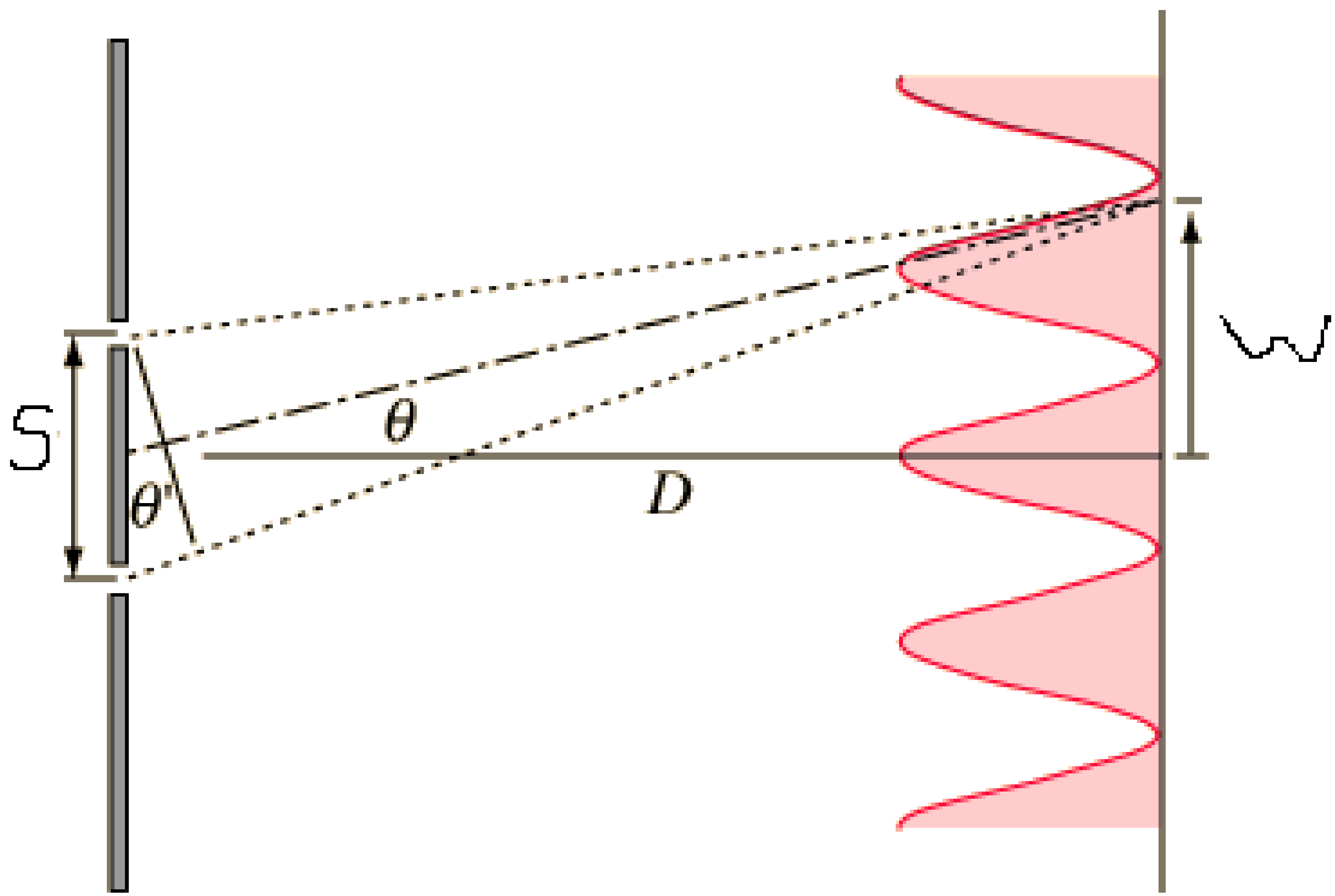


Most commonly observed phenomena with light can be explained by waves. But the photoelectric effect suggested a particle nature for light.

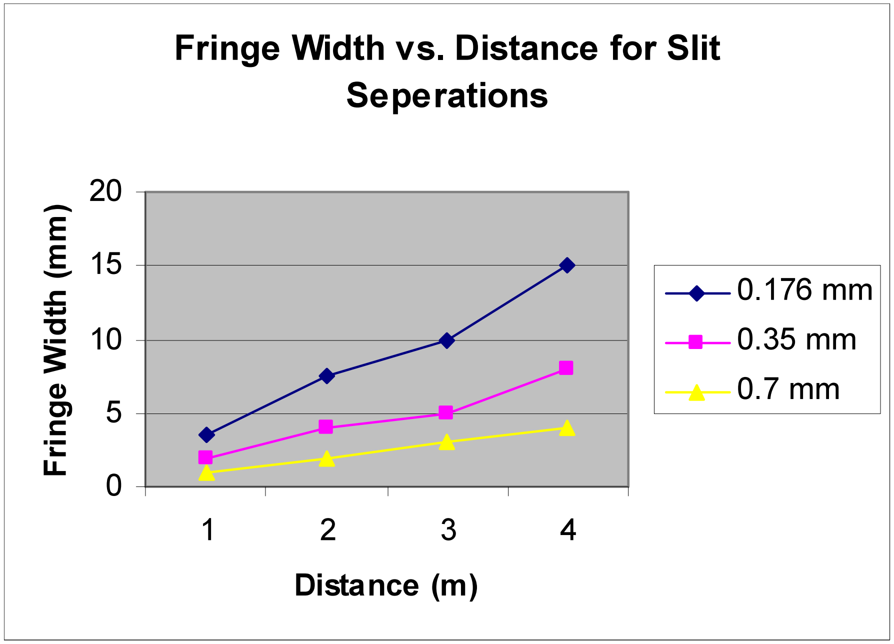
References

http://en.wikipedia.org/wiki/Thomas_Edison

Testing Variables



Distance and Fringe Width

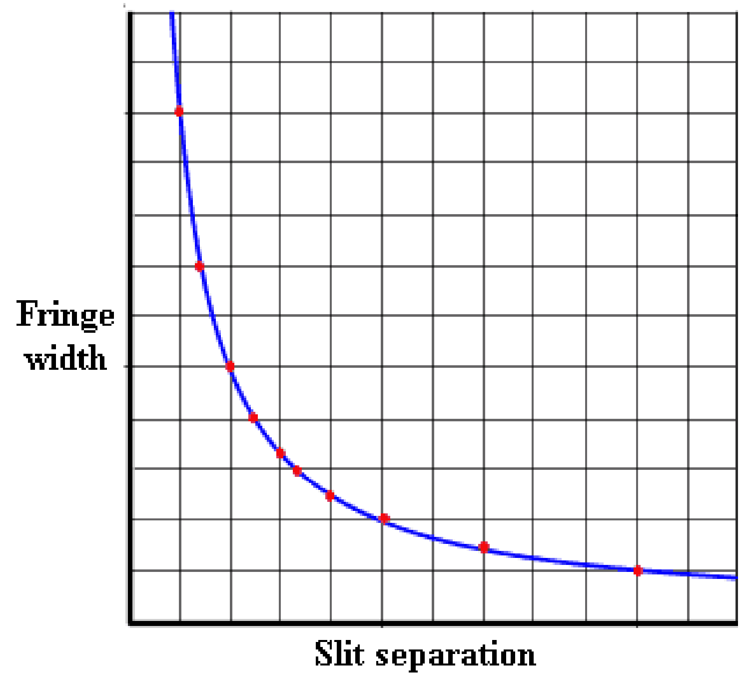


- w/D=C, DIRECT
  - Where w= fringe width

    D= distance between slits and detector

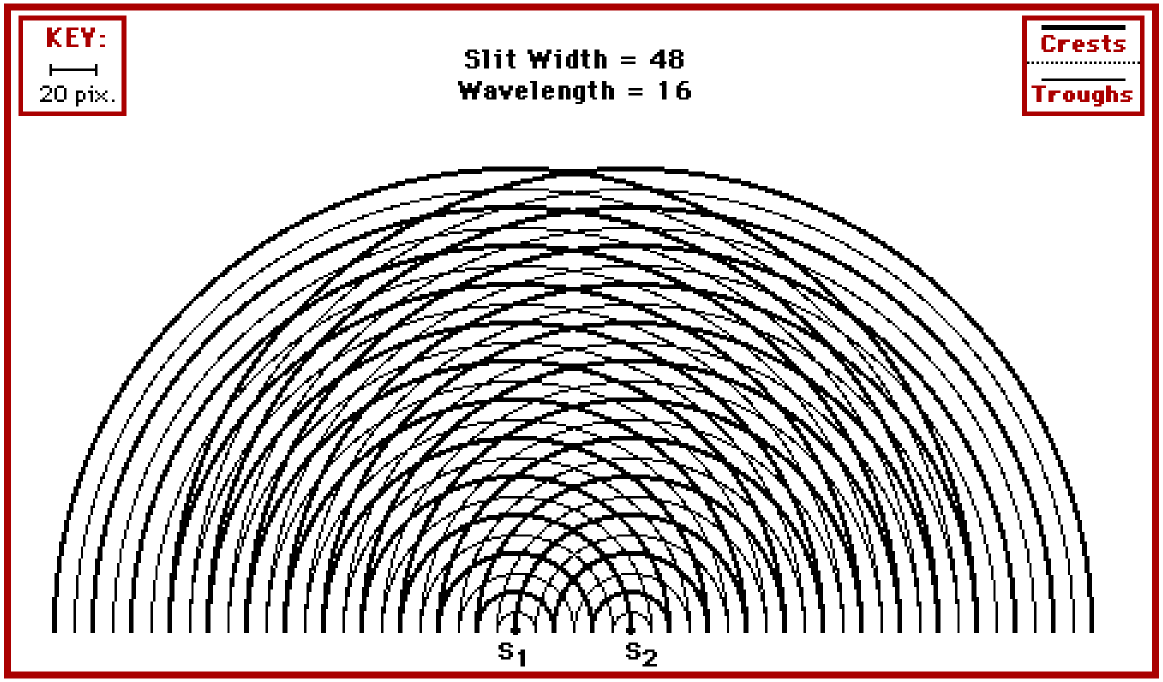
    C= constant

Slit Separation and Fringe Width



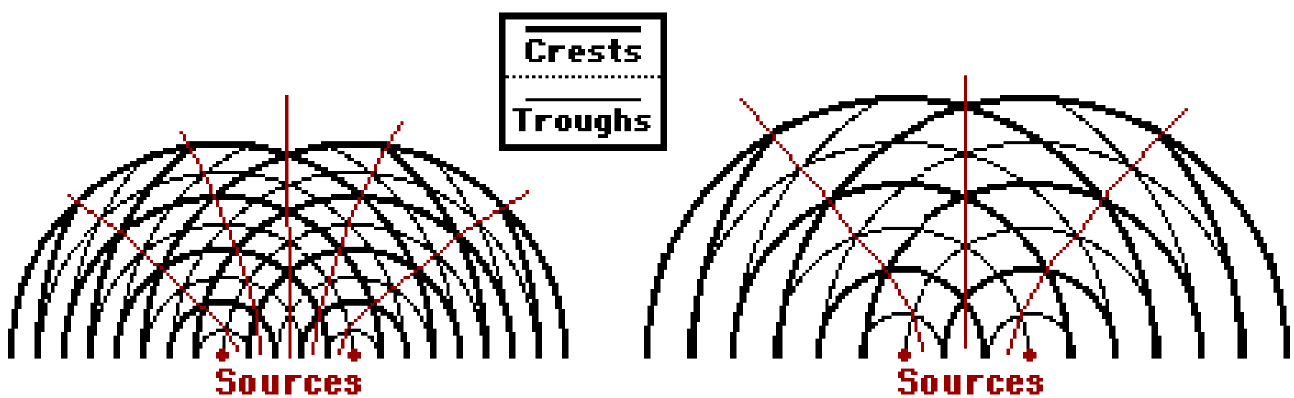
- w x s=C, INVERSE
  - Where w= fridge width
    s= slit separation
    C= constant

Understanding Inverse relation of slit separation and fringe width.



Wavelength and Fringe Width

- $w/\lambda = C$, DIRECT
  - Where w=fringe width
    λ= wavelength
    C= constant

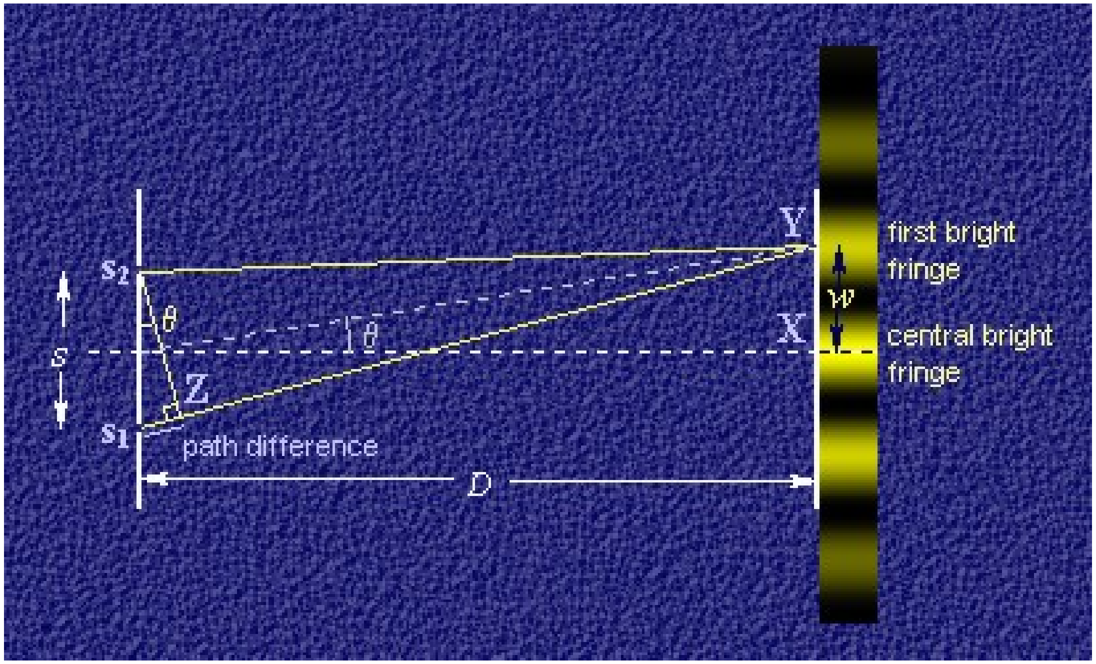


The proximity of the anti-nodal lines in a two-point source interference pattern is dependent upon the wavelength of the waves.

Recap of relationships

- $w/D=C$, Distance: direct
- $w*s=C$, Slit separation: inverse
- $w/\lambda=C$, Wavelength: direct
- Can we combine these into one larger equation?

What about Wavelength?



- $\lambda = (S \times W)/D$

Results

- Helium-neon laser
- Our calculation: 610.5 nm
- Real value: 632.5
- Percent Error: 3.5%

Particle Nature of Light

- Light consists of bundles of energy called photons
- What would happen if we slowed down the laser, so only one photon at a time arrived at the slits?