WHY DO WE TEACH GEOMETRICAL OPTICS BEFORE WAVE OPTICS?

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GEOMETRICAL VS WAVE OPTICS

- In most college physics textbooks (with a few exceptions) various topics on waves appear in the following order:

1. Wave phenomena in general
2. Sound phenomena
3. Electromagnetic waves
4. Geometrical optics
5. Wave optics

- Geometrical optics traditionally appear before wave optics because it is considered "easier"

EXAMPLE 1: CUTNELL & JOHNSON

- Chapter 16: Waves and Sound
- Chapter 17: The Principle of Linear Superposition and Interference Phenomena

- Chapters on Electromagnetism

- Chapter 24: Electromagnetic Waves
- Chapter 25: The Reflection of Light: Mirrors
- Chapter 26: The Refraction of Light: Lenses and Optical Instruments
- Chapter 27: Interference and the Wave Nature of Light

EXAMPLE 2: GIORDANO

- Chapter 12: Waves
- Chapter 13: Sound

- Chapters on Thermodynamics and Electromagnetism

- Chapter 23: Electromagnetic Waves
- Chapter 24: Geometrical Optics
- Chapter 25: Wave Optics

DOES THE TRADITIONAL ORDER MAKE SENSE?

1. We first teach various wave phenomena using sound including reflection, refraction, interference, diffraction, Doppler effect, etc.

2. We then teach electromagnetism and emphasize that light is a wave

3. Then in the chapter on Geometrical Optics, we suddenly change gears and claim that light propagation can be analyzed using "rays" (whatever they are)

4. Then in the chapter of Wave Optics, we go back to treating light as a wave

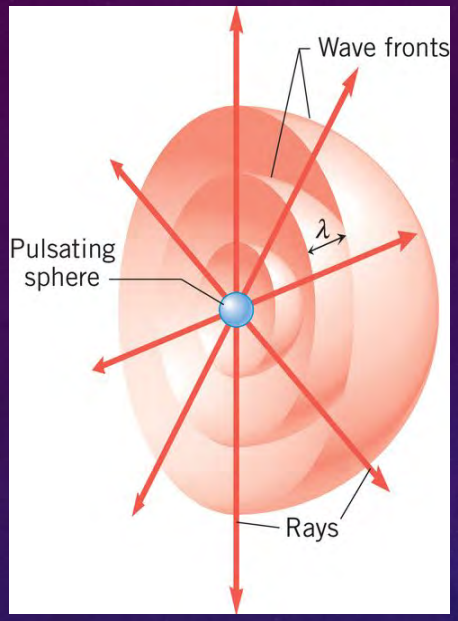
- Doesn't Geometrical Optics disrupt the narrative? What is the flow of the logic here?

WAVES VS RAYS

Photo from Giordano

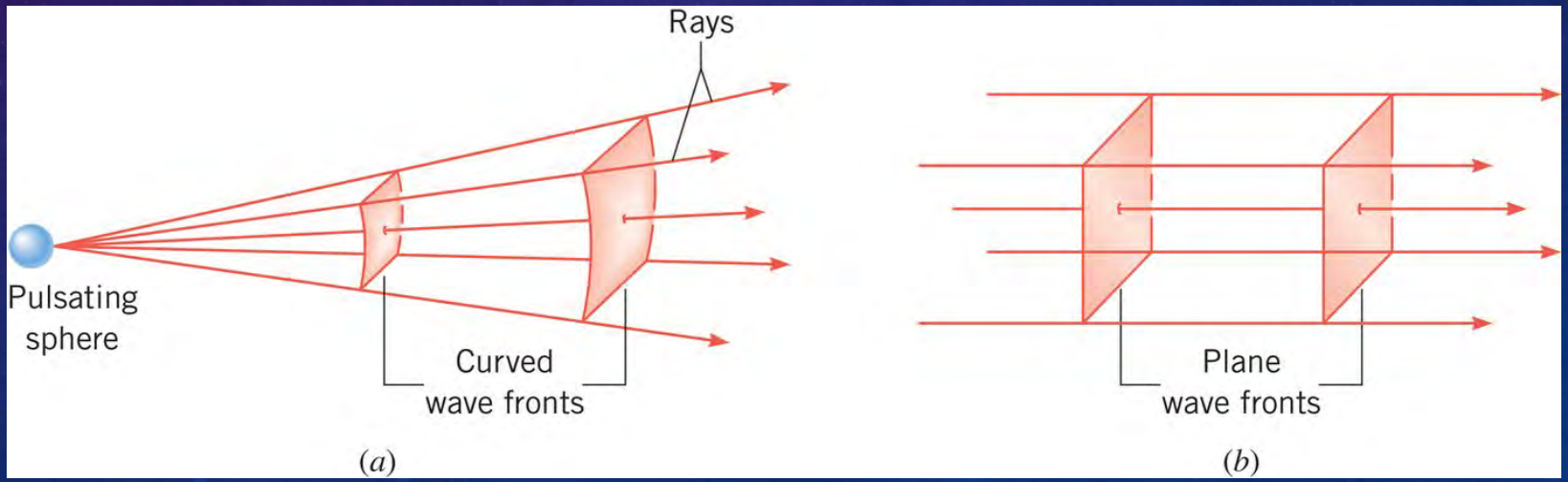
Image from https://www.biblicalarchaeology.org
Akhenaten worshiping the Sun Disk Aten

WHAT ARE "RAYS" ANYWAY?



- Defined as lines perpendicular to wave fronts indicating the direction of wave propagation
- Not a very "wavy" description
- Conceptually, they are narrow "beams" of light that propagate independently and in straight lines

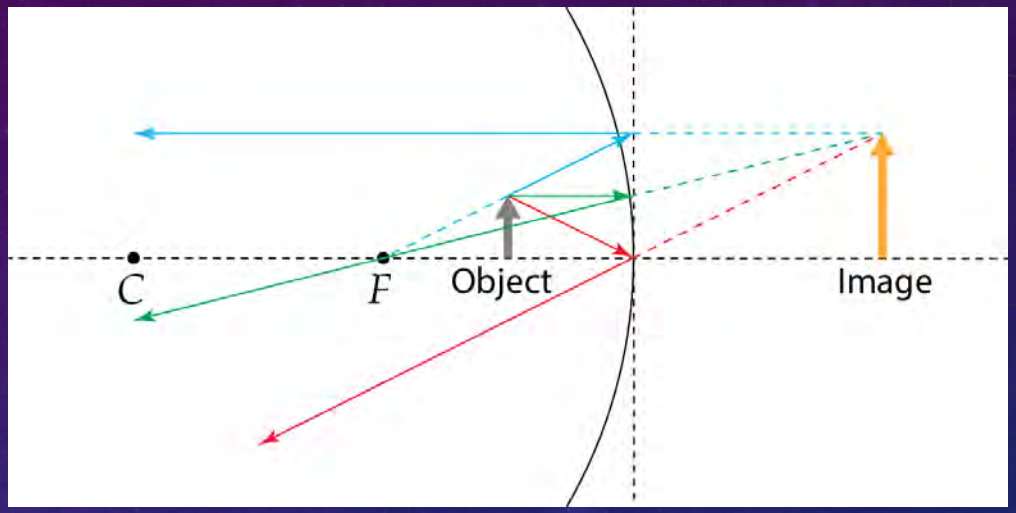
Figures from Cutnell & Johnson

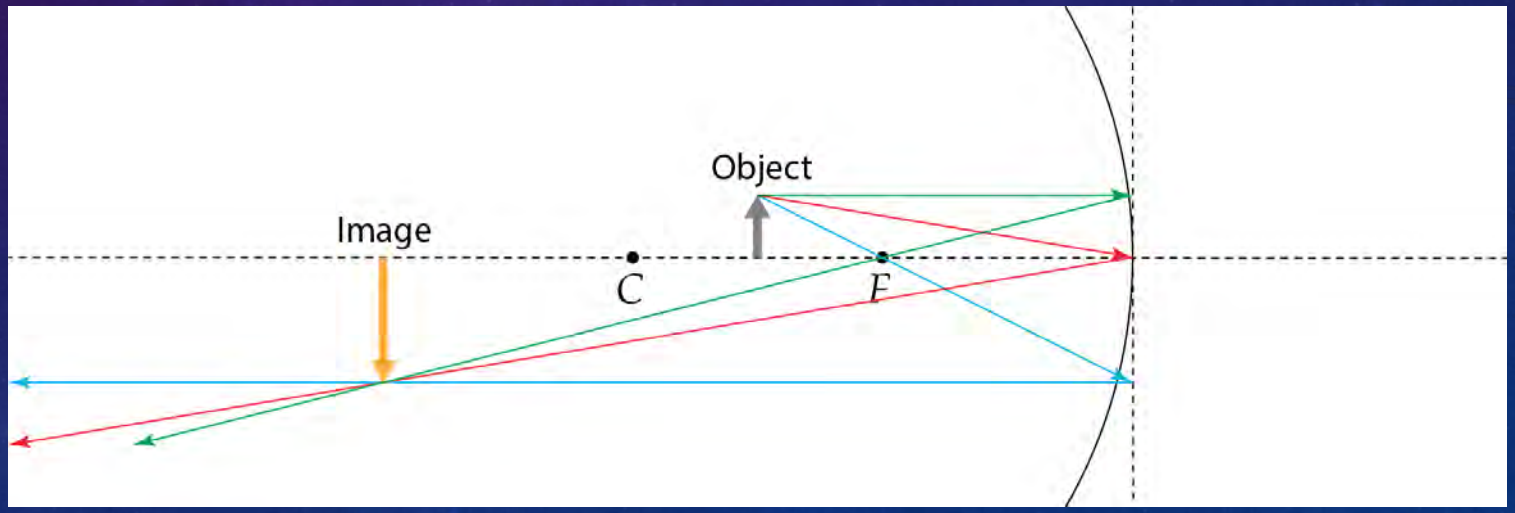


RAY TRACING

Example: image formation by a concave mirror

If we isolate each ray, they will follow the paths indicated





WHEN IS THE "RAY" DESCRIPTION VALID?

- Answer: When diffraction can be neglected

Photo from https://www.awatrees.com

- And when is that?
  → We need Wave Optics to answer this question!

TOPICS COVERED IN WAVE OPTICS

- Double slit interference
- Thin film interference
- Single slit interference
- Diffraction Grating
- X-ray diffraction
- Etc.

- A lot of emphasis on interference

SINGLE SLIT INTERFERENCE

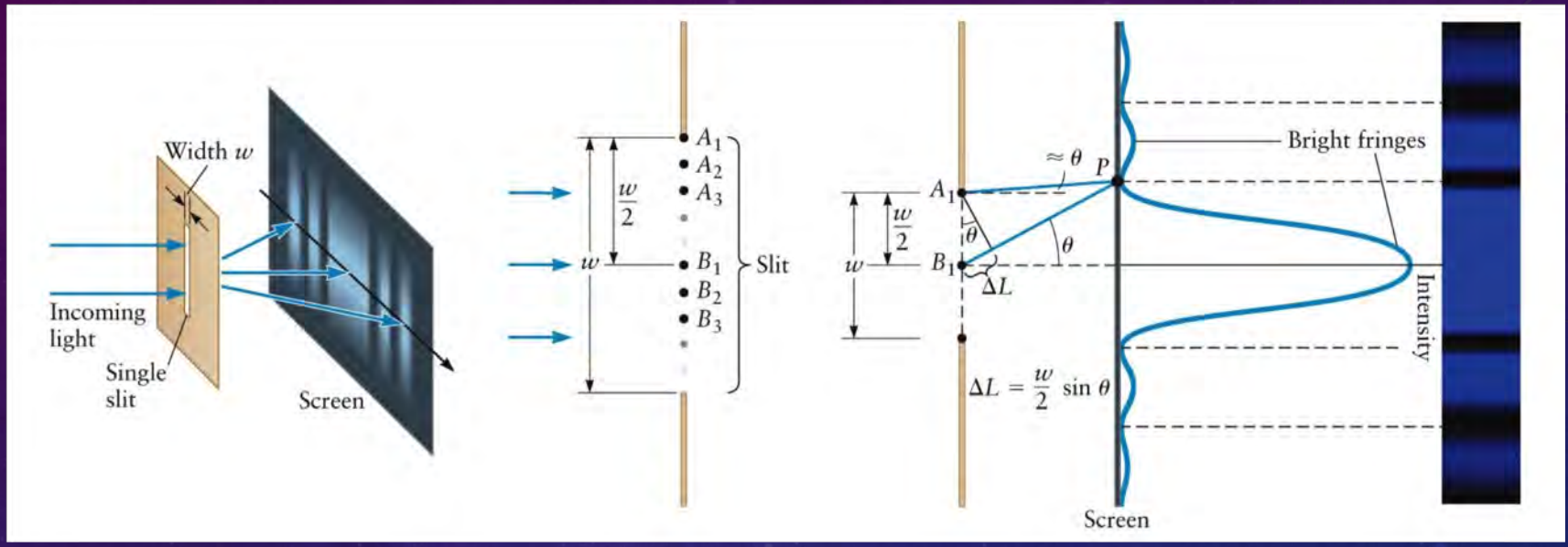


Image from Giordano

- The important message here is NOT that you can see interference effects with a single slit, but that the width of the central bright fringe decreases as the width of the single slit is increased
- Diffraction becomes negligible when the width of the slit is large compared to the wavelength of the light!

DIFFRACTION GRATING

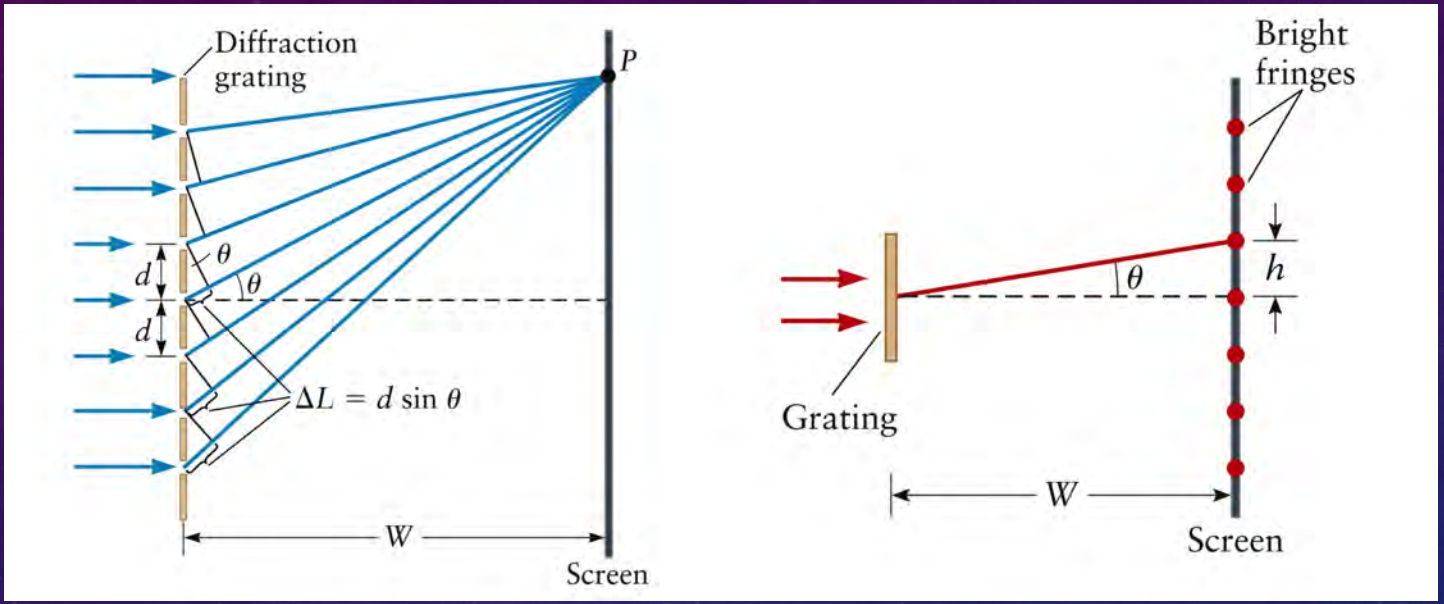
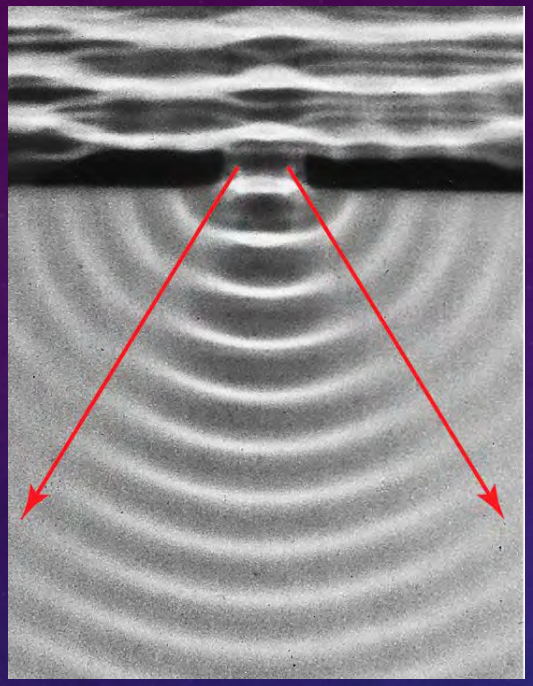
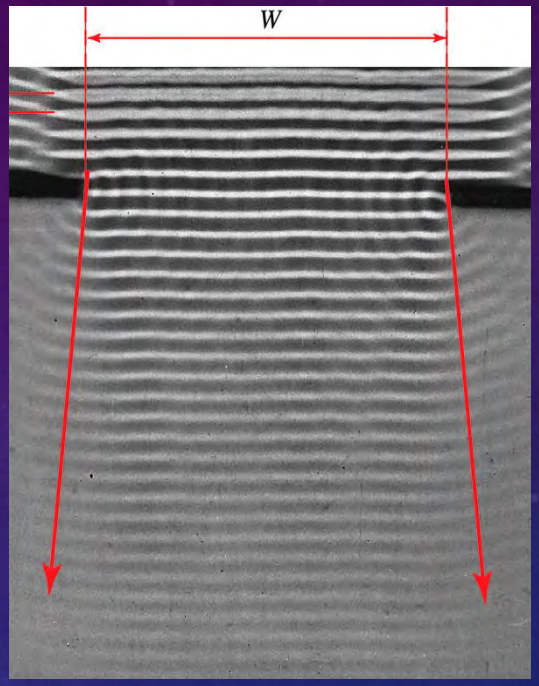


Image from Giordano

- The wide single slit can be considered the limit of a diffraction grating in which the spacing of the slits is taken to zero → only the central bright fringe will remain

IMPORTANCE OF INTERFERENCE!





Images from Cutnell & Johnson

- Though Huygens' Principle suggests that all waves should diffract and spread out, interference actually collimates the beam!
- Effective interference requires the light to be monochromatic and coherent
  - This is why flash lights do not make good pointers but lasers do

LOGICAL ORDER OF INSTRUCTION

1. Discuss Wave Optics first as a continuation of the discussion on generic wave phenomena
2. Establish that diffraction can be neglected when the sizes of the objects involved is much larger than the wavelength of the light
   - Emphasize that the suppression of diffraction is an interference effect!
3. Then, and only then discuss Geometrical Optics!