PURDUE UNIVERSITY DEPARTMENT OF PHYSICS

Physics 21900

General Physics II

Electricity, Magnetism and Optics

Lecture 16 – Chapter 21.1-2

Propagation and Reflection of Light

Fall 2015 Semester

Prof. Matthew Jones

Announcement

Exam #2 will be on November 5th

in Phys 112 at 8:00 pm

Electric current, DC circuits, Kirchhoff's Rules

Magnetic Fields, Lorentz Force, Forces on Currents

Ampere's Law, Magnetic Induction, Lenz's Law

Induced EMF, AC Voltage, Transformers

Historical Context

- Optics is arguably the oldest discipline in physics
- https://en.wikipedia.org/wiki/History_of_optics
- The European scientific establishment (1600's) debated whether light was a wave phenomena or a stream of particles
  - Arguments for and against either viewpoint
  - Not satisfactorily resolved until the introduction of Quantum Mechanics in the early 20th century
- A theory of light first needs to describe the obvious:
  - Reflection (mirrors)
  - Refraction (lenses)

Connection With Electricity and Magnetism

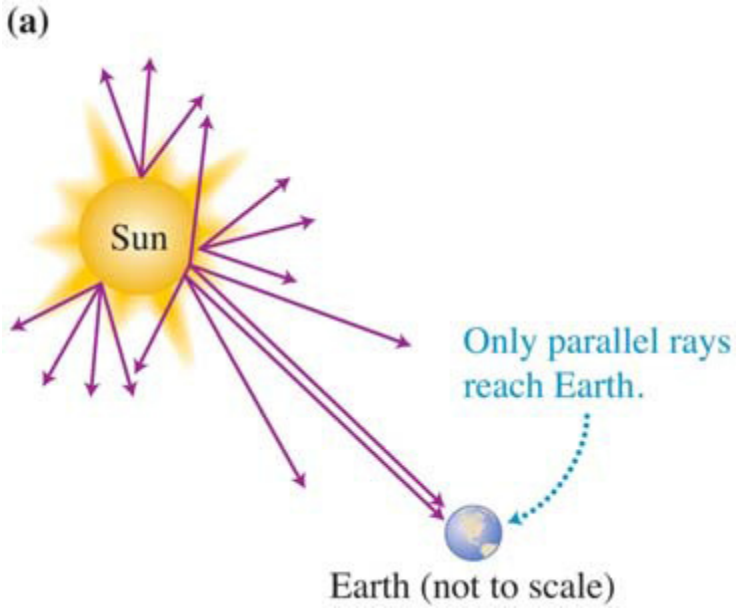
- Faraday's law:

$$\mathcal{E} = -\frac{\Delta \Phi_B}{\Delta t}$$

- The changing magnetic field creates an electric field (which produces the EMF)
- It turns out that likewise, a changing electric field produces a magnetic field.
- This process can continue indefinitely…
- Light is an oscillating electric-magnetic field propagating through free space.
- Speed of light is $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ in terms of electric and magnetic constants.

Ray Diagrams

- For practical purposes (for now) light travels in straight lines, *away* from a source.
- So we draw a light ray as an arrow pointing away from the source
- Diagrams that have rays in them are called ray diagrams.



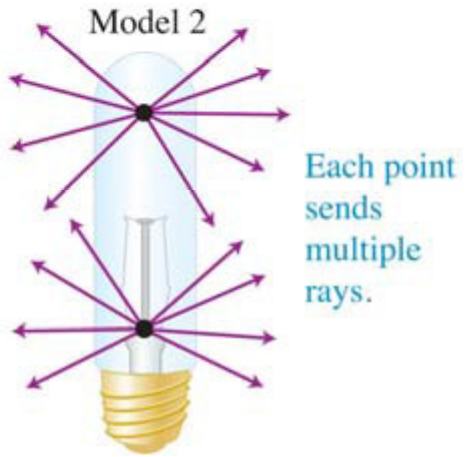
Ray Diagrams

Each point on an extended light source emits rays in many different directions

This can be represented by many different rays diverging from that point.

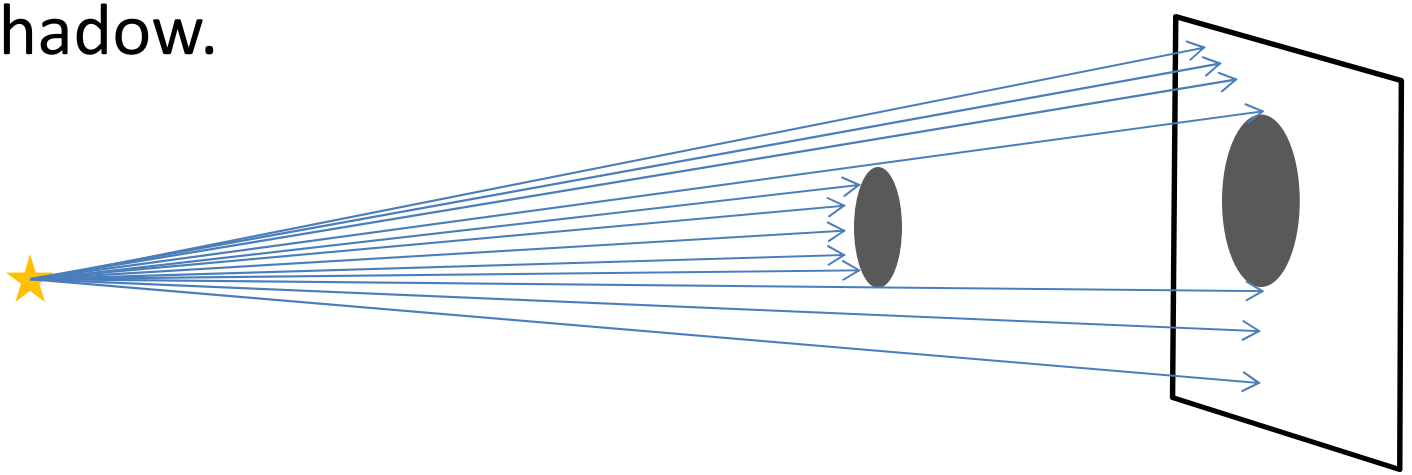
The rays propagate in straight lines until they encounter an interface to another type of material.

This defines the ray model of light.



Shadows

- Light will be blocked by an opaque object and form a shadow.

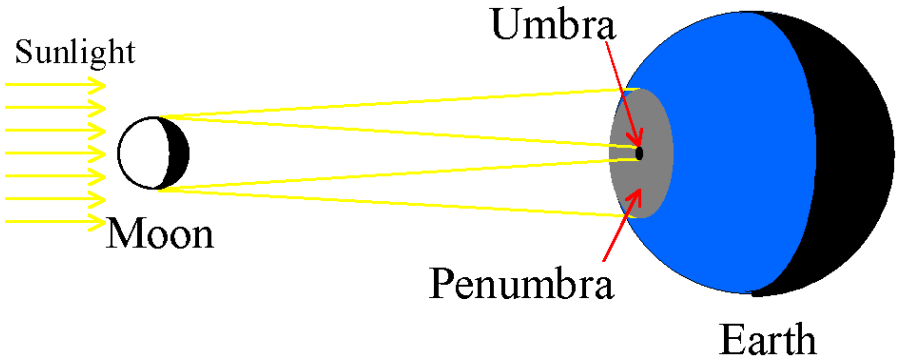


- A shadow (in case you didn't already know) is a dark area behind an object where no light reaches.
- The Latin word for shadow is *umbra*.
- A dim region that is reached by a little bit of light is called a *penumbra*.

Umbra and Penumbra

- Point light sources produce *umbras.*
- Multiple point sources or extended light sources *penumbras*.

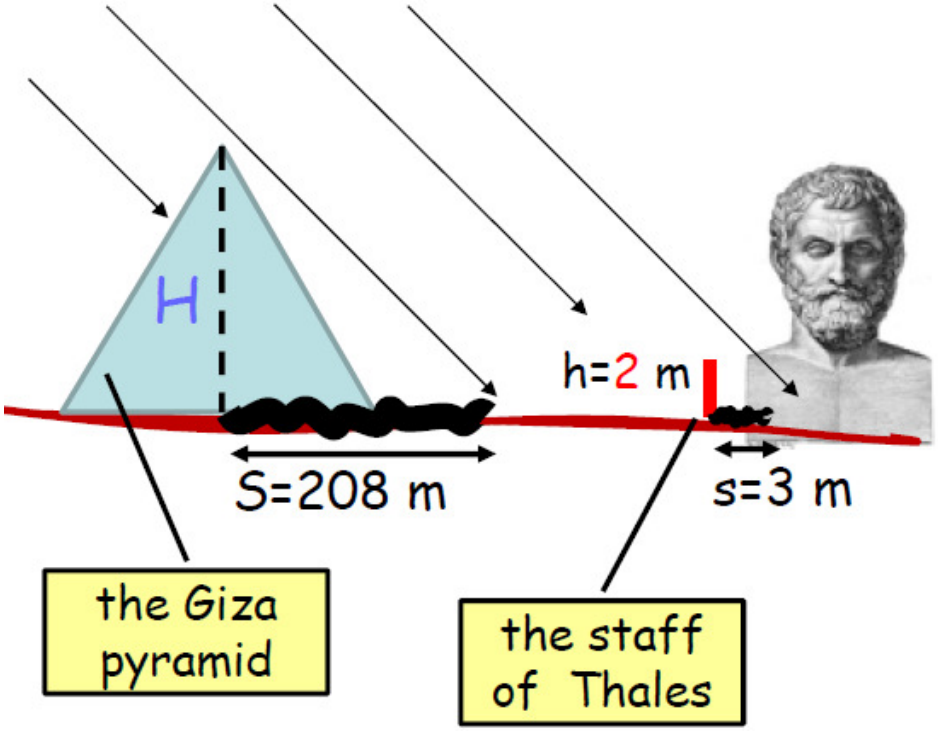
Example: fine art



Example: solar eclipse

Example

In ~2600 B.C., the Egyptians constructed the Great Pyramid of Giza. History records that ~2000 years after completion, in the 6th century B.C., Thales measured the height H of the Great Pyramid. How did he do it? And what value did he obtain for H?



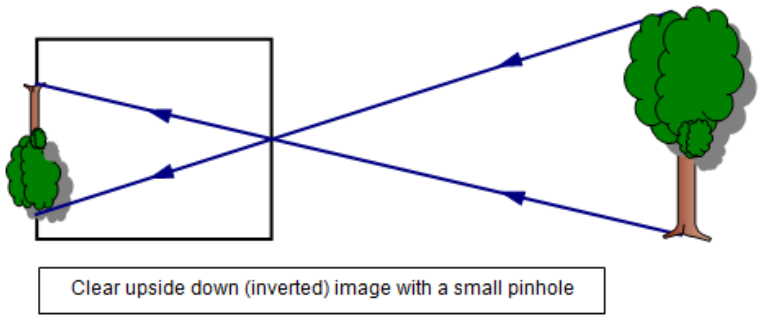
$$\frac{h}{H} = \frac{s}{S}$$

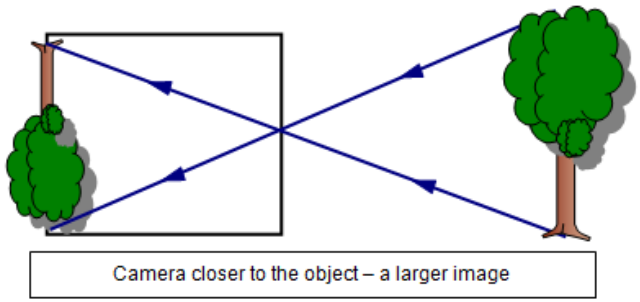
$$\frac{2\,m}{H} = \frac{3\,m}{208\,m}$$

$$H = \frac{2}{3}(208\,m) \approx 139\,m$$

Pinhole Camera

- A light-tight box with a small hole in it allows a (relatively) sharp image to be formed.
- This is called a "*pinhole camera*" or more artistically, a "*camera obscura*".
- The image can expose a photographic plate

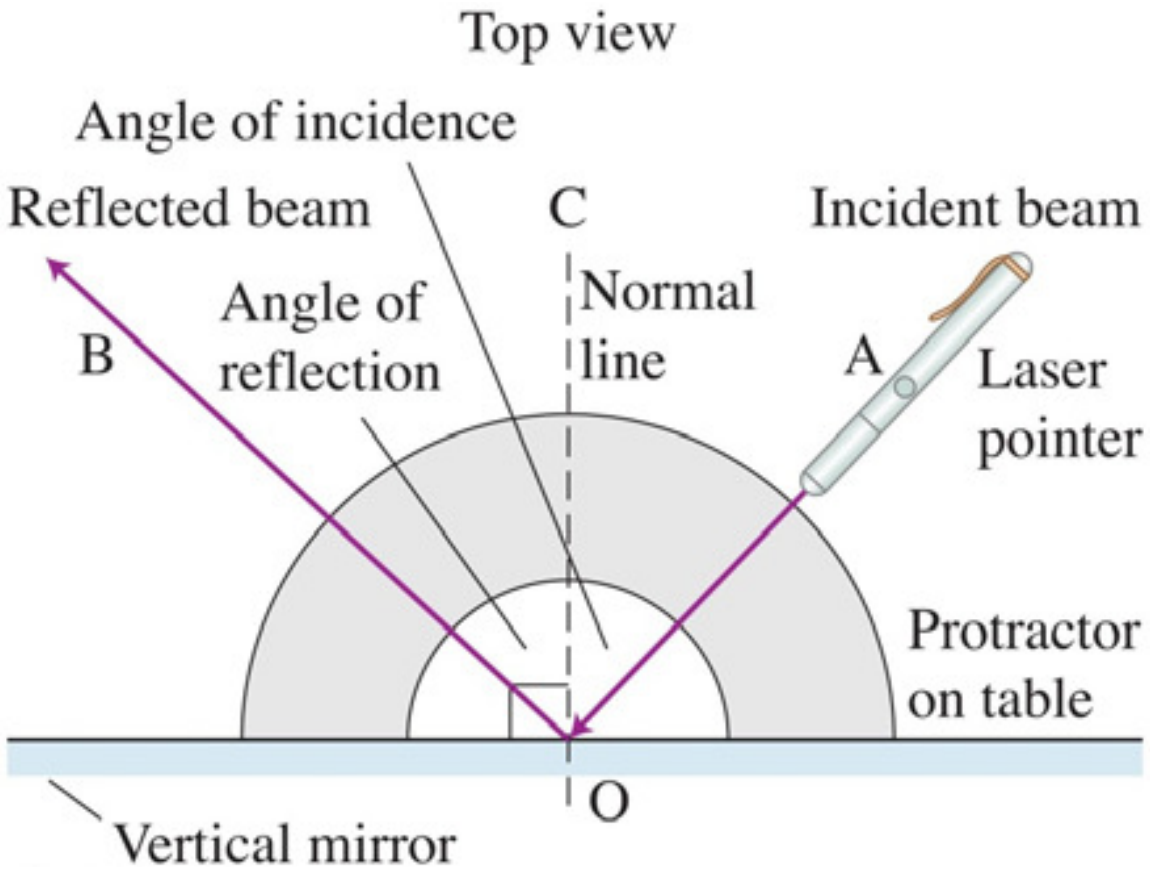




Cool art although it's upside down.

Reflection of Light

- When viewed from above, light from a laser pointer reflects off a vertical mirror:



Definitions

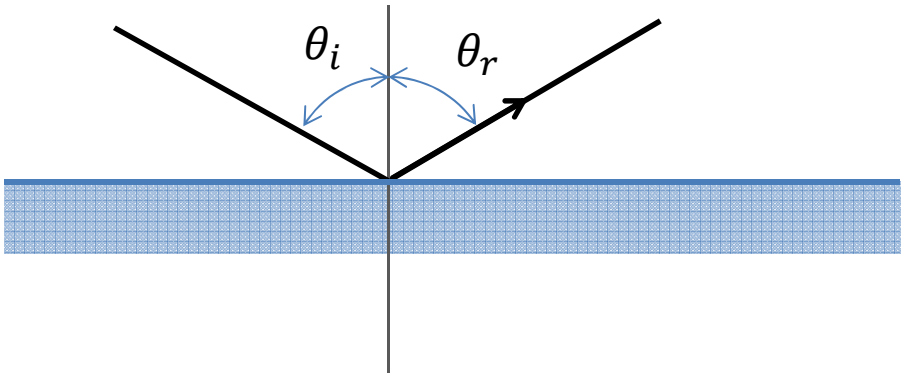
- **Incident light**: *the light striking the mirror.*
- **Normal line**: *a line perpendicular to the surface of the mirror at the point where the light hits it.*
- **Angle of incidence**: *angle between the incident beam and the normal line.*
- **Angle of reflection**: *angle between the reflected beam and the normal line.*

> **TIP** The angle of incidence and the angle of reflection are always the angles that the light beams form with the normal line and not the angles that they form with the surface of the mirror.

The Law of Reflection

Law of reflection When a narrow beam of light, represented by one ray, shines on a smooth surface such as a mirror, the angle between the incident ray and the normal line perpendicular to the surface equals the angle between the reflected ray and the normal line (the angle of reflection equals the angle of incidence). The incident beam, reflected beam, and the normal line are in the same plane.

$$\theta_{incidence} = \theta_{reflection} \qquad (21.1)$$



Many optical manipulations can be performed using just mirrors

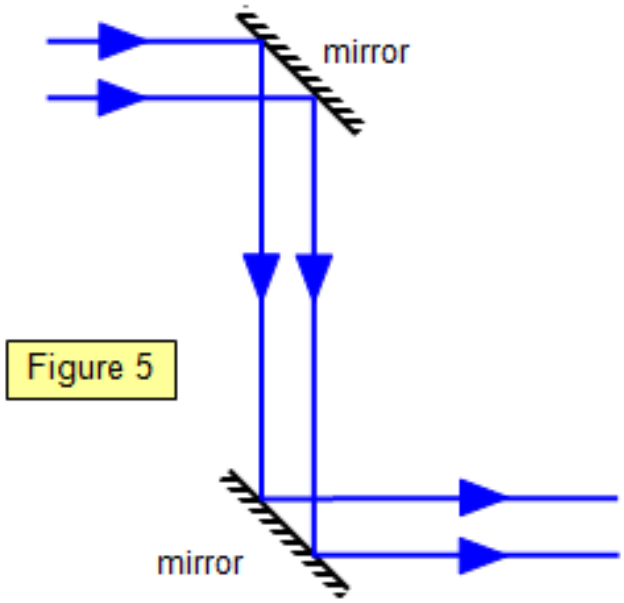


Figure 5

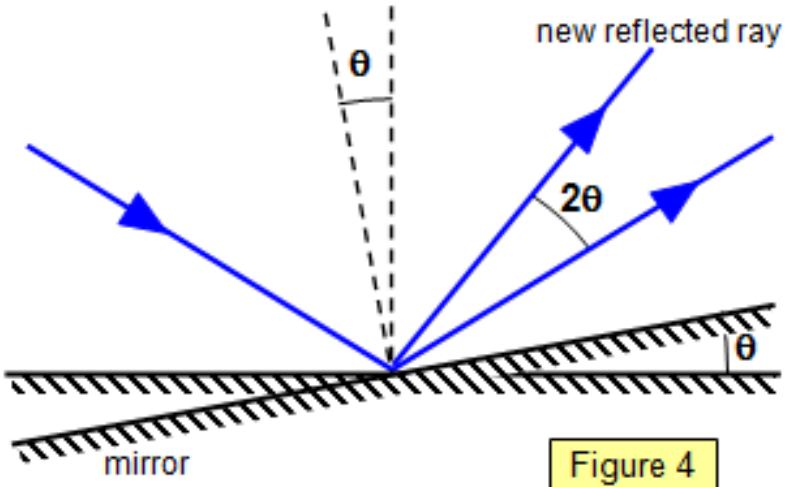
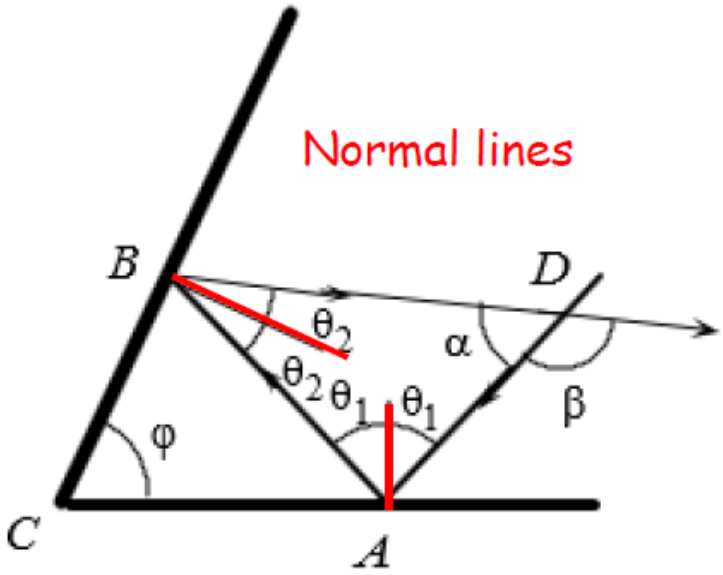


Figure 4

Most of the complications come from working out the geometry.

EXAMPLE

Show that if two plane mirrors meet at an angle φ, a single ray reflected successively from both mirrors is deflected through an angle of 2φ from the incident beam, independent of the incident angle.



Assume φ < 90 ° and that only two reflections, one from each mirror, take place.

1. *From* ΔABC

$$\phi + \left(\frac{\pi}{2} - \theta_1\right) + \left(\frac{\pi}{2} - \theta_2\right) = \pi$$

$$\phi = \theta_1 + \theta_2$$

2. *From* ΔABD

$$\alpha + 2\theta_1 + 2\theta_2 = \pi$$

$$\alpha = \pi - 2\left(\theta_1 + \theta_2\right) = \pi - 2\phi$$

3. *At point D*

$$\beta = \pi - \alpha = \pi - \left(\pi - 2\phi\right) = 2\phi$$

Specular and diffuse reflection