Physics 122 – Class #11 – Outline

- Announcements
- Coulomb's Law
- Interferometer
- Interference
    - Single slit
    - Huyghens principle

Reading – This Week

ALL of Chapter 25 …

It is key to rest of course.

Next Week – Chapter 26

Main Concepts – Ch 25.

Coulomb's Law, Charge, Electric Field

Applies to lab

Chance to catch up … (HW due a week from Thursday)

Exam #1

THURSDAY 2/19/2014

… in CLASS

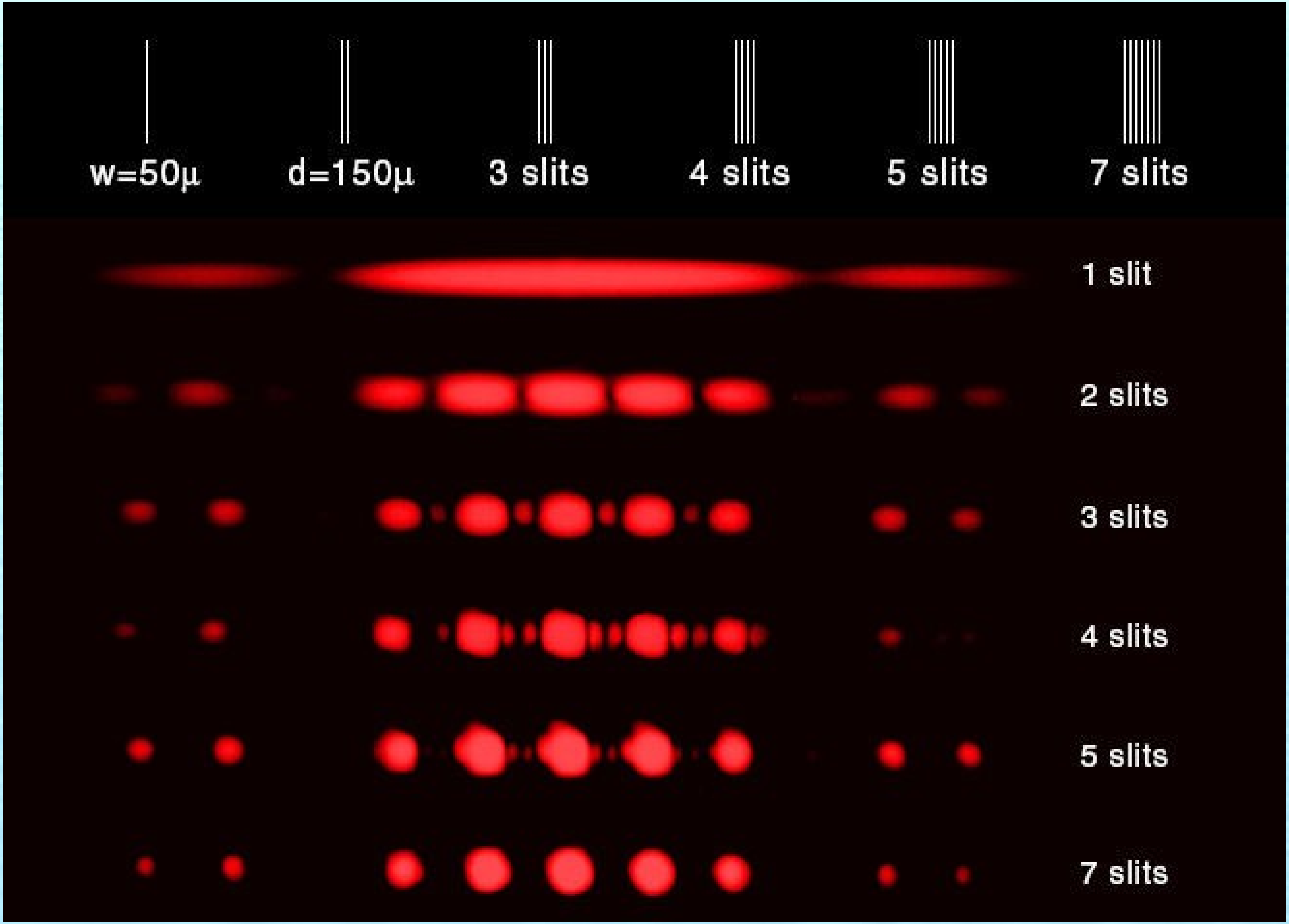
Covers Ch. 20, 21, 22, 23

Review Homework

Review Workbook (recitation questions)

One 3x5 card. One side. With equations only. No words / no pictures. Card submitted with exam.

From single slit to diffraction grating ...



Diffraction and small angle approximation

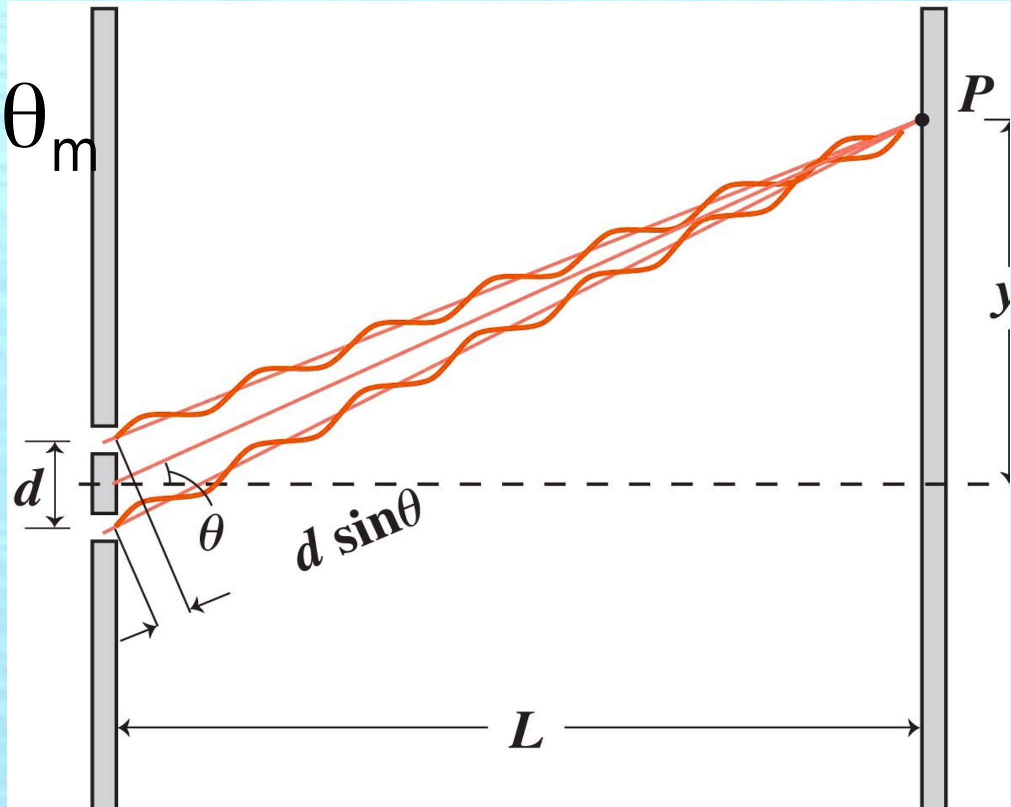
$$\text{Exact: } d\sin\theta_m = m\lambda$$

$$\text{Approximate: } d\theta_m \sim m\lambda \rightarrow \theta_m = m\frac{\lambda}{d}$$

$$\text{Exact: } y_m = L\tan\theta_m$$

$$\text{Approximate: } y_m \sim L\sin\theta_m$$

$$y_m \sim Lm\frac{\lambda}{d}$$



Taylor series and small angle approximation

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} \ldots$$

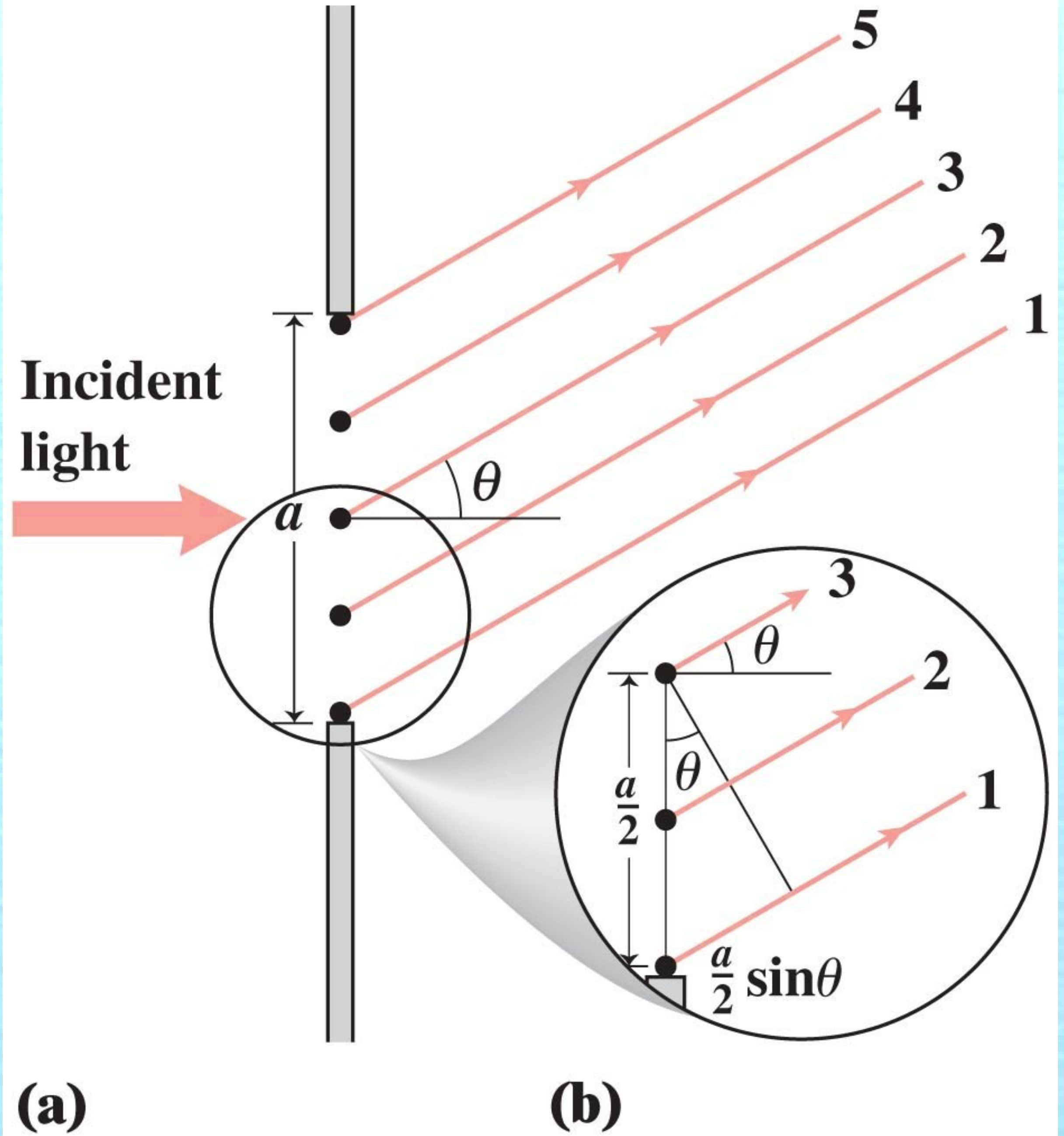
$$\tan\theta = \theta + 2\frac{\theta^3}{3!} + 16\frac{\theta^5}{5!} + \ldots$$

Single slit diffraction

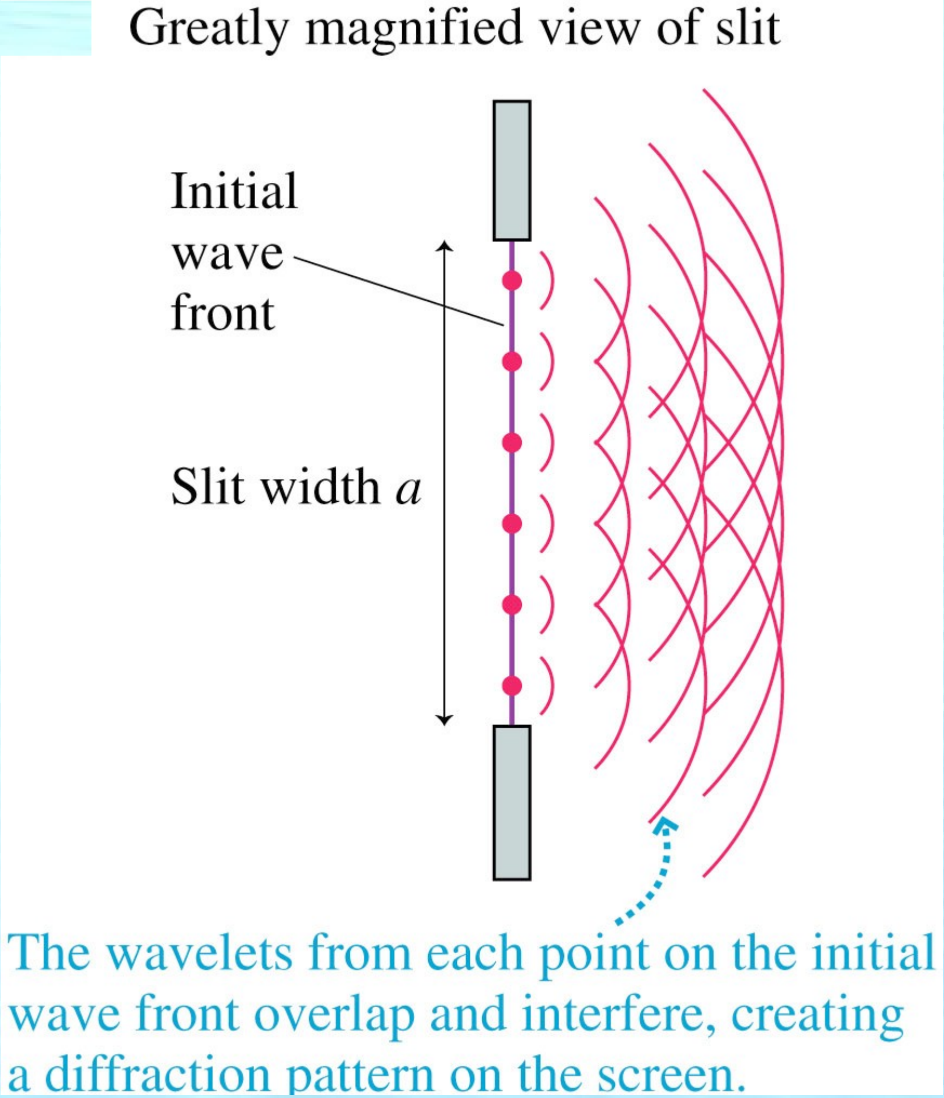
Light from different
Parts of a single
slit interferes
with itself
Destructive
Condition:

$$\frac{a}{2}\sin\theta = \lambda/2$$

$$a\sin\theta = m\lambda$$



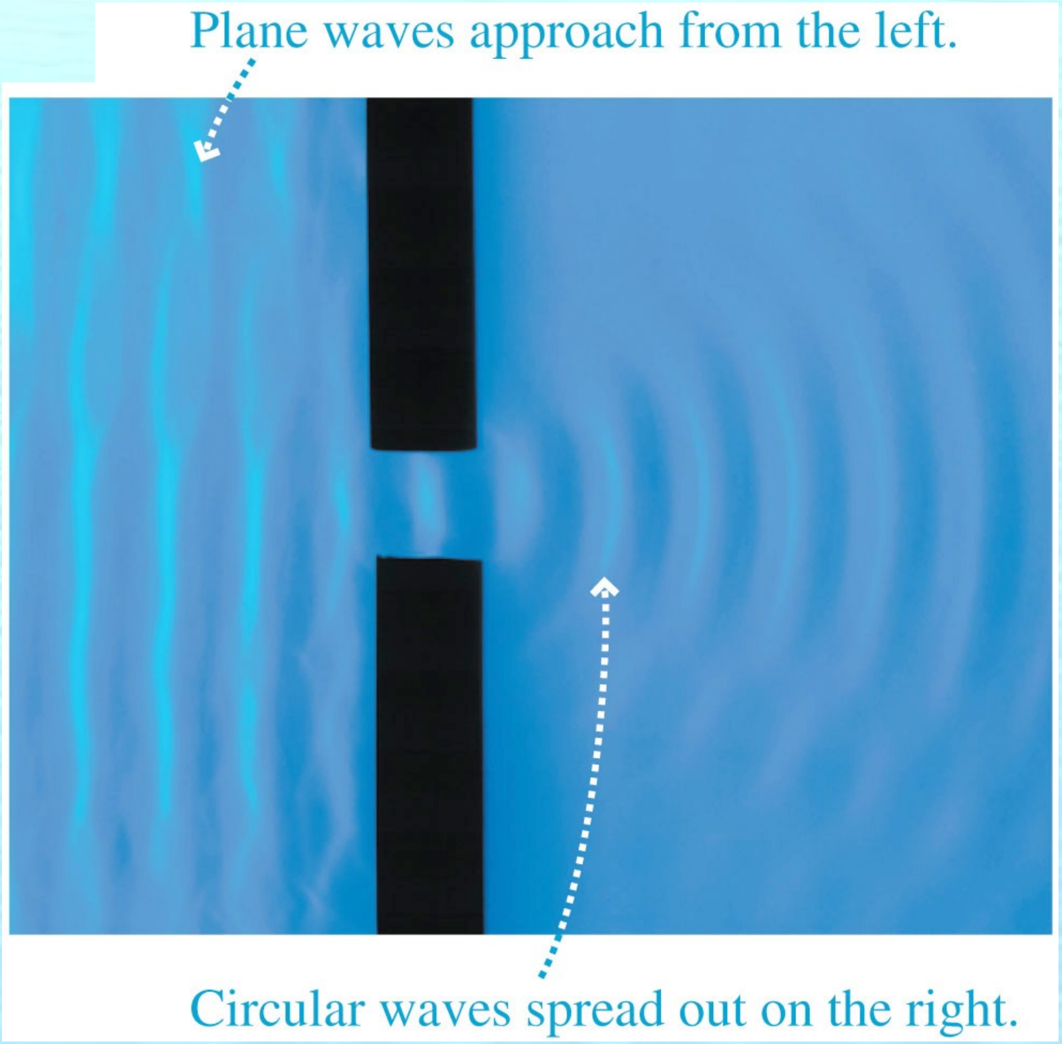
Analyzing Single-Slit Diffraction



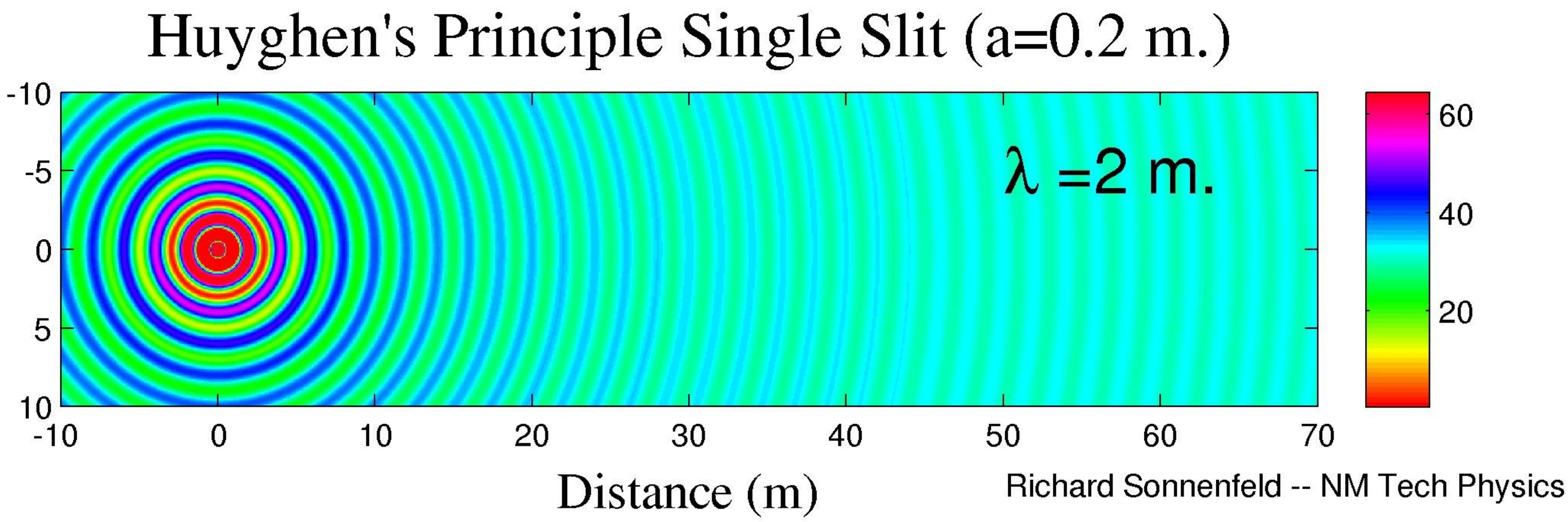
- The figure shows a wave front passing through a narrow slit of width *a*.
- According to Huygens' principle, each point on the wave front can be thought of as the source of a spherical wavelet.

Huyghens Principle

- Every point on a wave can be considered a new source for a spherical wave.
- Add up all the spherical waves to find out what diffraction pattern you get.

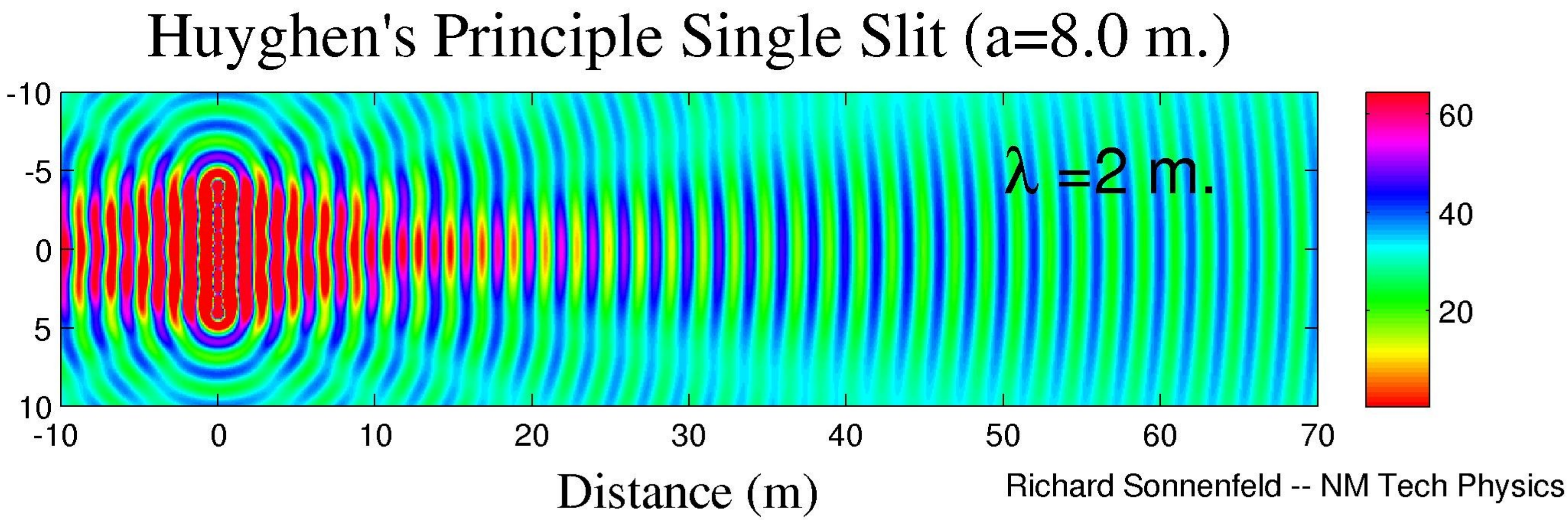


Huyghens



Huyghen's Principle Single Slit (a=0.2 m.)
λ =2 m.
-10
-5
0
5
10
-10
0
10
20
30
40
50
60
70
Distance (m)
60
40
20
Richard Sonnenfeld -- NM Tech Physics

Huyghens



Huyghen's Principle Single Slit (a=8.0 m.)
λ =2 m.
-10
-5
0
5
10
-10
0
10
20
30
40
50
60
70
60
40
20
Distance (m)
Richard Sonnenfeld -- NM Tech Physics

Huyghens principle in action …
watch time dependence of wave

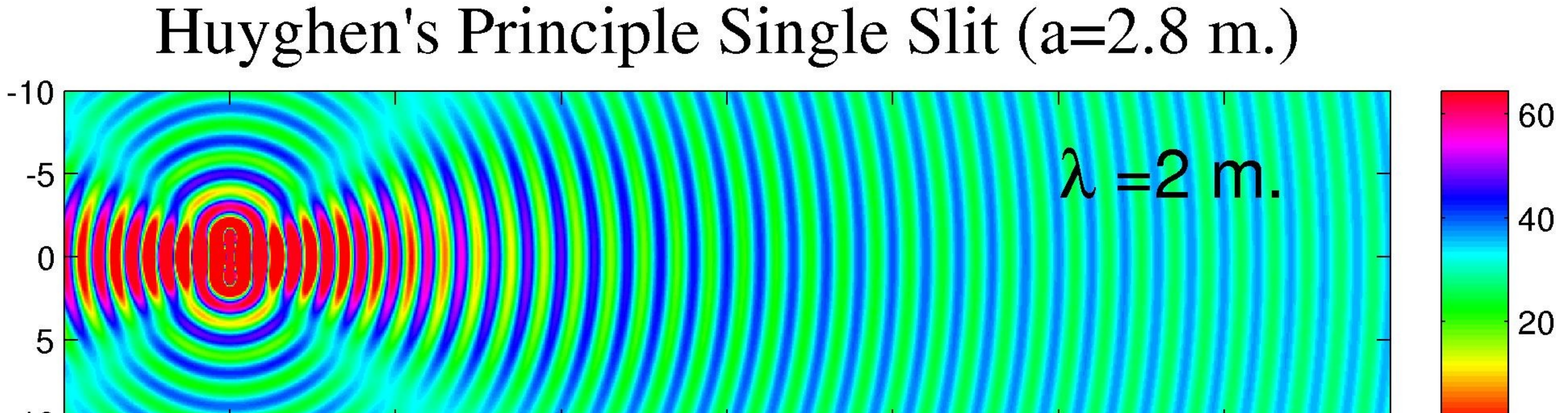
Single slit

A slit is 2.8 microns wide and an infrared laser with wavelength 2 microns shines through it. At what angle is the first null?

(A) 30 degrees
(B) 45 degrees
(C) 60 degrees
(D) 90 degrees
(E) There is no first null

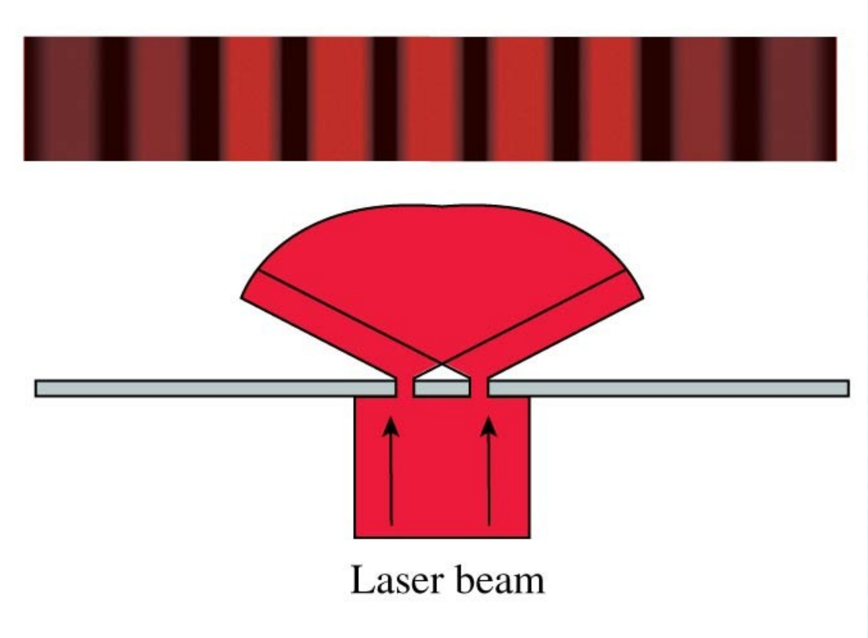
Single slit

A slit is 2.8 m wide and a water wave with wavelength 2 microns passes through it. At what angle is the first null?



Clicker Questions

A laboratory experiment produces a double-slit interference pattern on a screen. If the left slit is blocked, the screen will look like



Michelson Interferometer

Youtube tsgphysics michelson
LIGO Grav Wave Observatory

Can measure displacements a tiny fraction of wavelength of light.

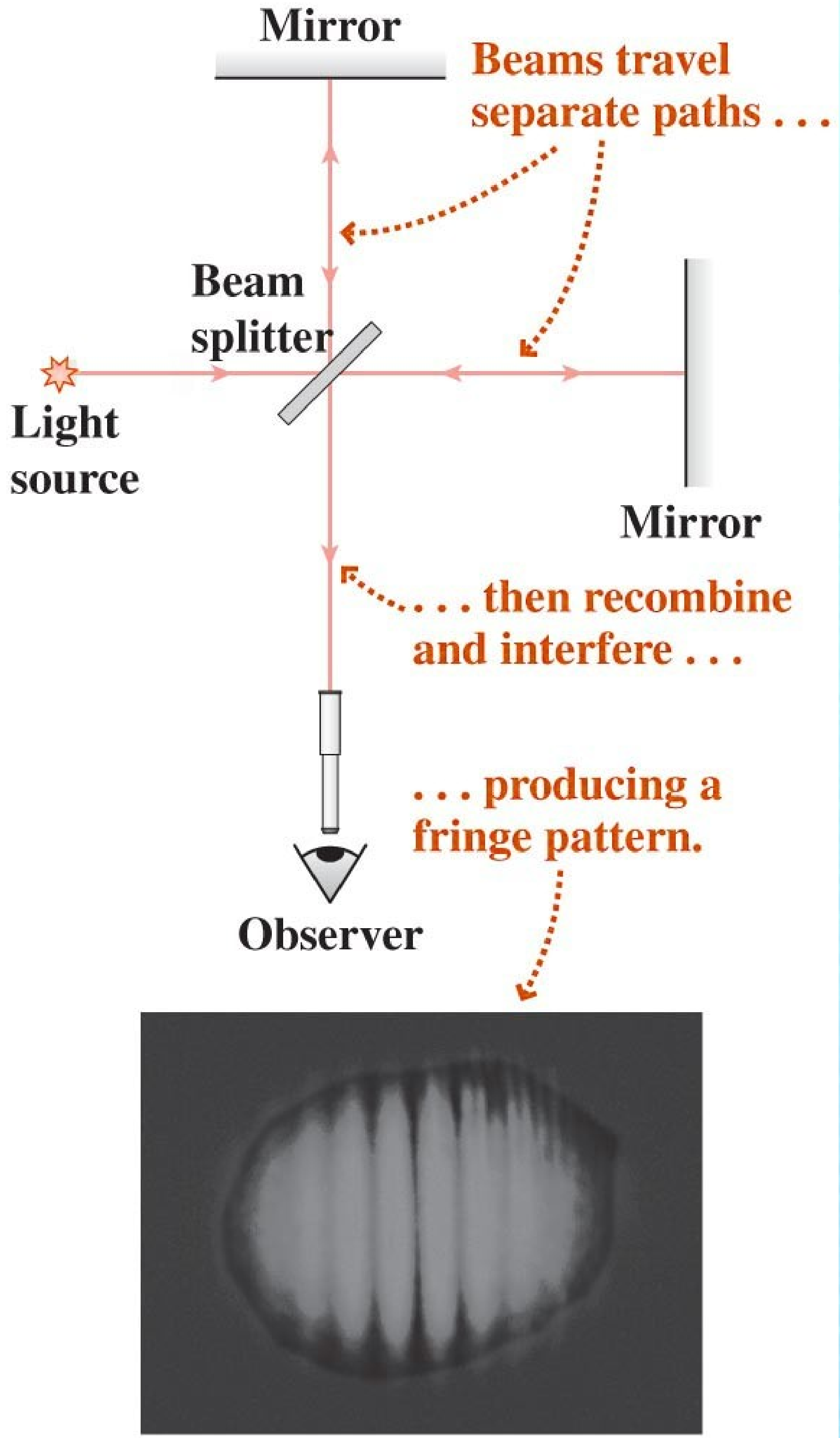
Apps:

Small indexes of refraction

Nano-controllers

grav-wave detection.

Relativity



Problems

Find the wavelength of light used in a Michelson interferometer if 550 bright fringes go by a fixed point when the mirror moves 0.15 mm.

$$\Delta x = 2\Delta L \qquad \Delta x = m\lambda$$

$$\lambda = \frac{2\Delta L}{m} = \frac{2\times 1.5\times 10^{-4}\ m}{550}$$

Problems

22-65) One arm of a Michelson interferometer is 42.5 cm long and enclosed in a box that can be evacuated. 388 fringes pass a point when the air is pumped out. For 641.6 nm laser light, what is the refractive index of air?

Ch. 22: Interference and Diffraction

$d \sin\theta = m\lambda$

Condition for constructive interference between slits separated by "d".

$a \sin\theta = m\lambda$

Condition for destructive interference for single slit of width "a".

In general: Phase difference of 2 pi m or path difference of lambda, constructive interference.

Coulomb's Law

$$F = k \frac{q_1 q_2}{r^2}$$

$$k = \frac{1}{4 \pi \epsilon_0} \qquad k = 9.0 \times 10^9 \, N m^2 / C^2$$

$$\text{Coulomb} = 6.242 \times 10^{18} \text{ electrons}$$

$$\text{Mole} = 6.02 \times 10^{23} \text{ atoms}$$

Making Connections

What does Coulomb's law remind you of? $F = k\frac{q_1 q_2}{r^2}$

(A) Christopher Co(u)lombus

(B) $E = mc^2$

(C) The combined gas law $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$

(D) $F = ma$

(E) Newton's law of gravity $F = -G\frac{m_1 m_2}{r^2}$

Coulomb's Law (and gravitation)

$$F = k \frac{q_1 q_2}{r^2}$$

$$F = -G \frac{m_1 m_2}{r^2}$$

$$k = \frac{1}{4\pi\epsilon_0}$$

$$k = 9.0 \times 10^9 \, N\,m^2/C^2$$

$$G = 6.67 \times 10^{-11} \, N\,m^2/kg^2$$

Coulomb's Law (and gravitation) – With vectors

$$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \widehat{r_{12}}$$

$$\vec{F}_{12} = -G \frac{m_1 m_2}{r_{12}^2} \widehat{r_{12}}$$

$$k = \frac{1}{4 \pi \epsilon_0}$$

$$k = 9.0 \times 10^9 \, N\, m^2 / C^2$$

$$G = 6.67 \times 10^{-11} \, N\, m^2 / kg^2$$

F_{12} Means force that particle one exerts on particle 2.

r_{12} Is a unit vector that points from particle 1 to particle 2

Chapter 25 key concepts

Coulomb's law
Principle of superposition.

Coulomb's Law – What is the force on an electron in a hydrogen atom?

$$F = k\frac{q_1 q_2}{r^2}$$

$$k = \frac{1}{4\pi\epsilon_0} \qquad k = 9.0\times10^9\,\mathrm{N\,m^2/C^2}$$

$$\text{Coulomb} = 6.242\times10^{18}\ \text{electrons}$$

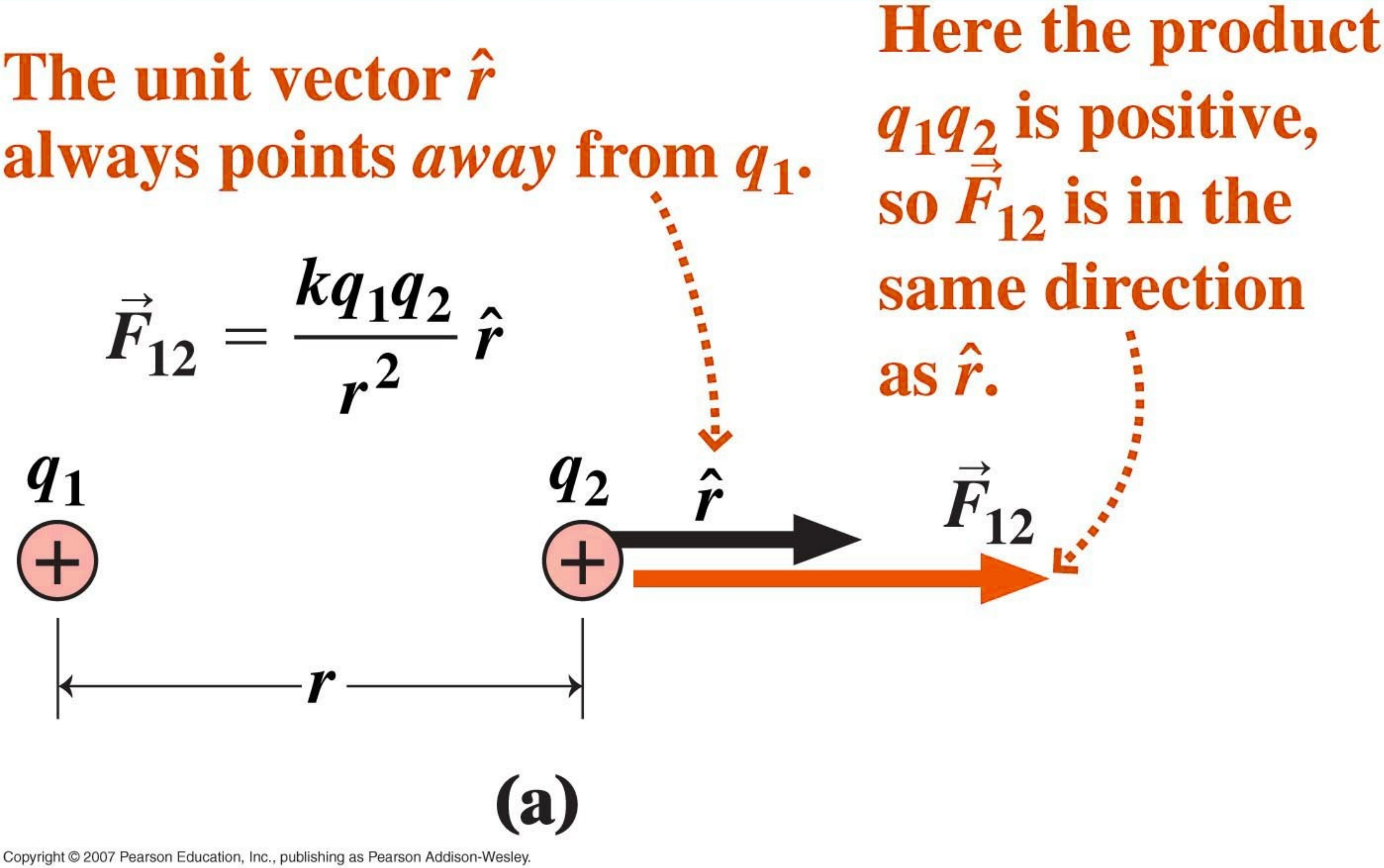
$$\text{Electron}(e) = 1.6\times10^{-19}\ \text{C}$$

Proton and electron have same magnitude, opposite sign charges.

Forces in Hydrogen atom

A hydrogen atom is composed of a proton and an electron with equal charges. The proton has roughly 1800 X the electron mass.
Compare the forces on electron and proton.

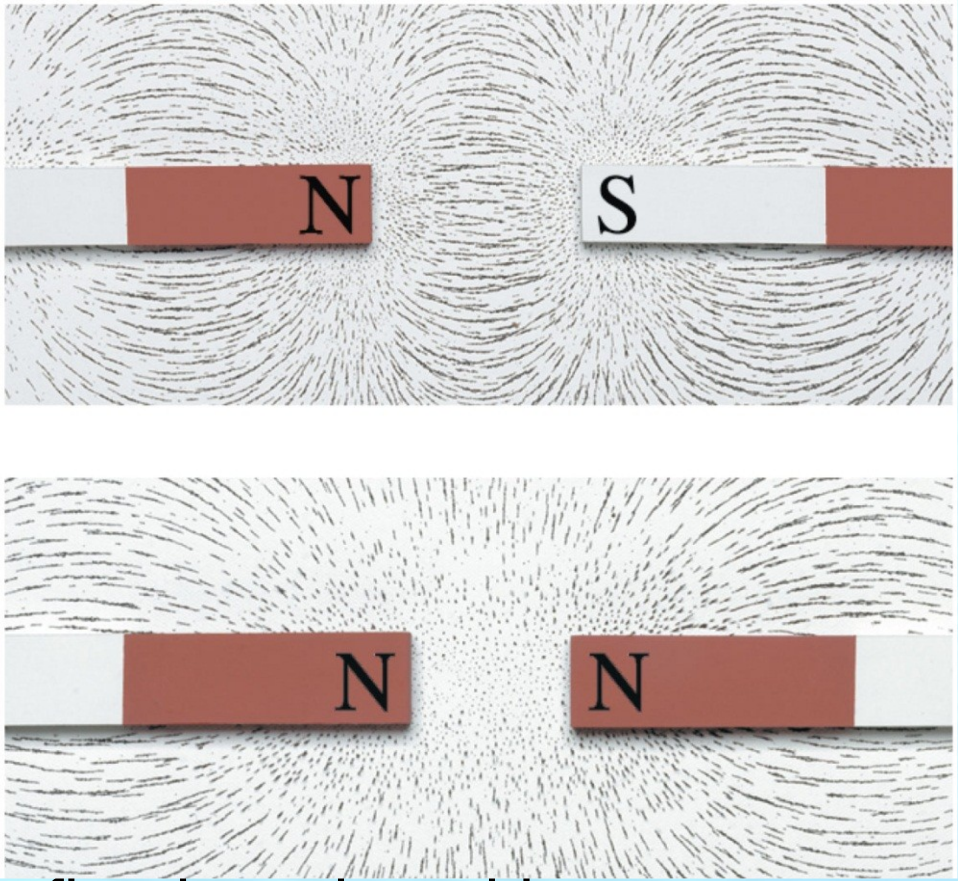
(A) The electron feels a greater force because it orbits the nucleus.
(B) The proton feels a greater force because it is larger and has a larger surface area.
(C) Depends on whether the atom is in a molecule.
(D) The electron and proton feel the same force because coulomb's law is symmetrical.



The unit vector $\hat{r}$ always points *away* from q_1.
Here the product q_1q_2 is positive, so $\vec{F}_{12}$ is in the same direction as $\hat{r}$.
$\vec{F}_{12} = \frac{kq_1q_2}{r^2}\hat{r}$
q_1
q_2
$\hat{r}$
$\vec{F}_{12}$
r
(a)

The Field Model

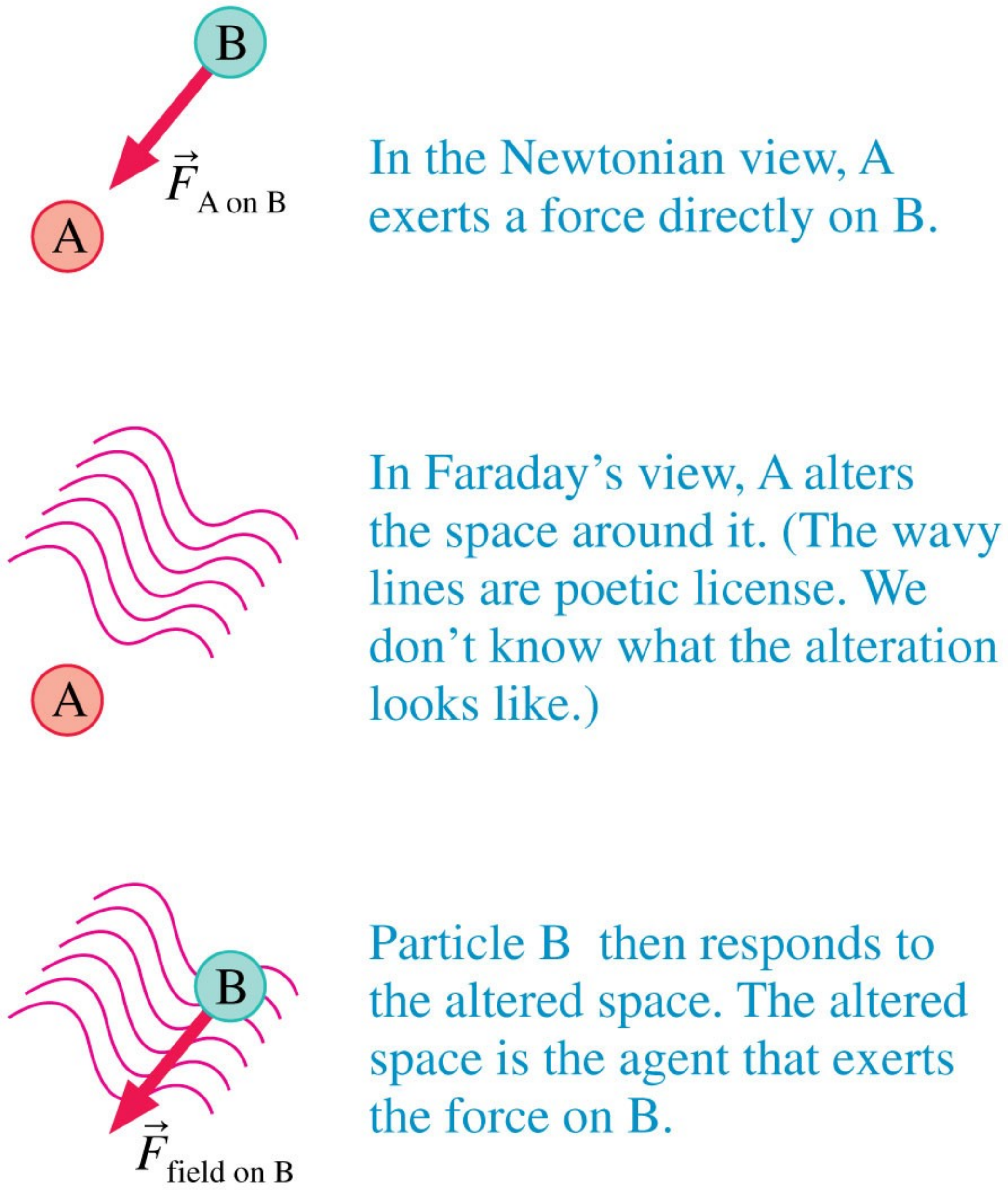
- The photos show the patterns that iron filings make when sprinkled around a magnet.
- These patterns suggest that *space itself* around the magnet is filled with magnetic influence.
- This is called the **magnetic field**.



- The concept of such a “field” was first introduced by Michael Faraday in 1821.

The Field Model

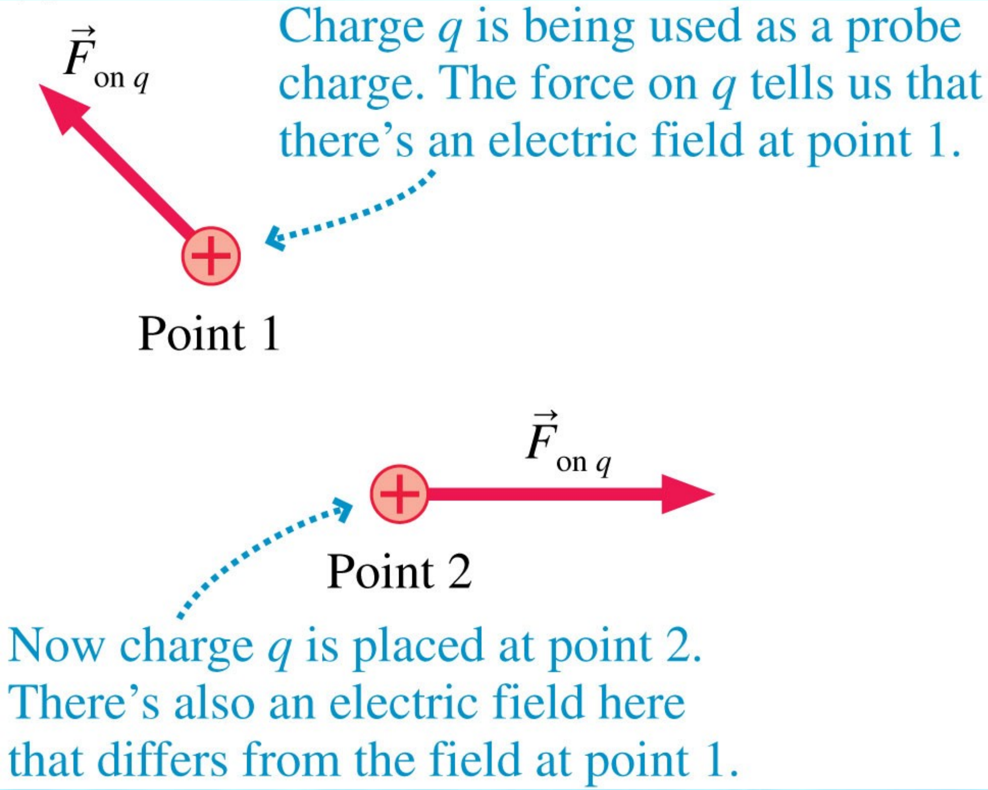
- A *field* is a function that assigns a vector to every point in space.
- The alteration of space around a mass is called the *gravitational field.*
- Similarly, the space around a charge is altered to create the **electric field**.



The Electric Field

- If a probe charge (or test charge) "q" experiences an electric force at a point in space, we say that there is an electric field $\vec{E}$ at that point causing the force.

$$\vec{E}(x, y, z) \equiv \frac{\vec{F}_{\text{on } q} \text{ at } (x, y, z)}{q}$$

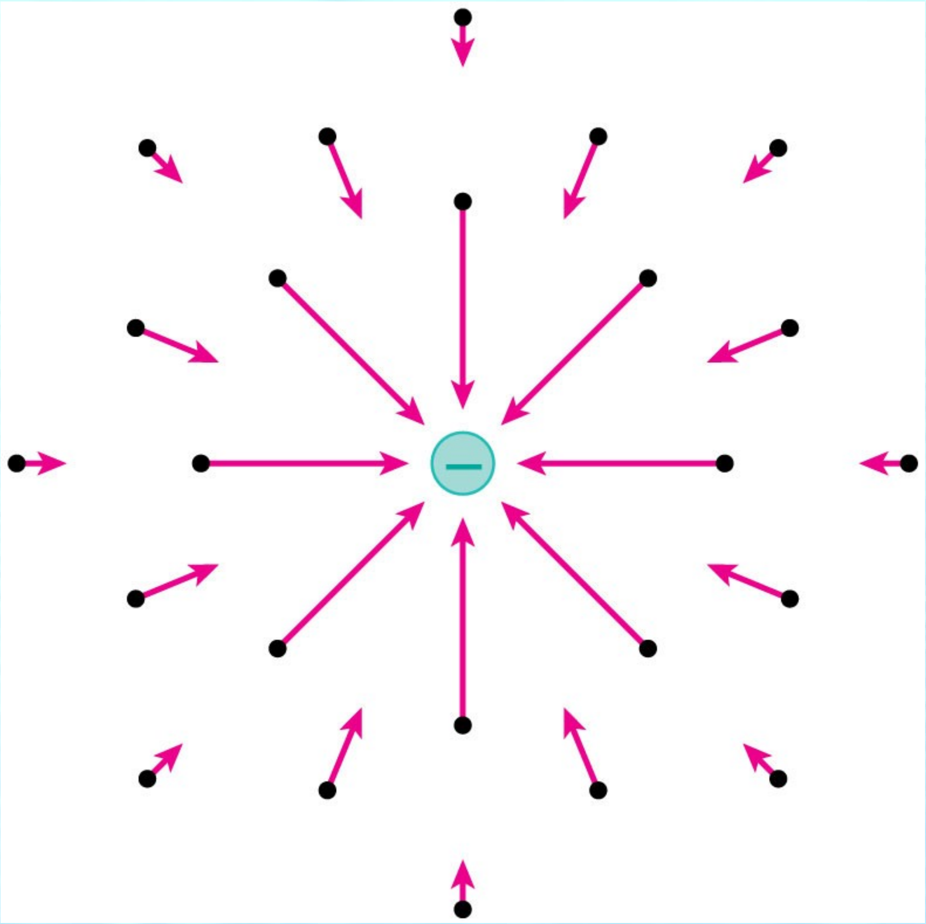


The units of the electric field are N/C. The magnitude E of the electric field is called the **electric field strength.**

The Electric Field of a Point Charge

- Using unit vector notation, the electric field at a distance r from a point charge q is:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$



- A negative sign in front of a vector simply reverses its direction.
- The figure shows the electric field of a negative point charge.