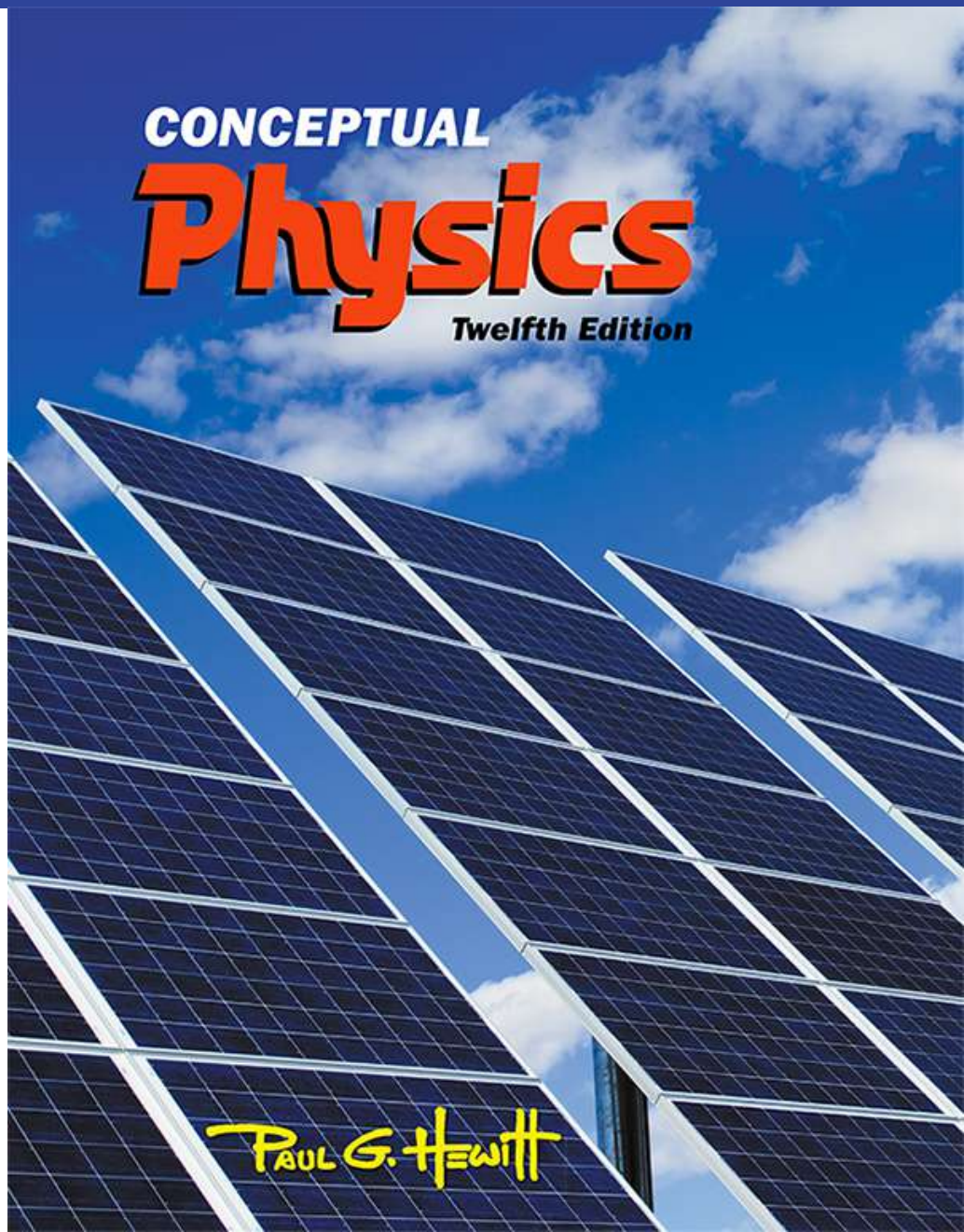
Lecture Outline

Chapter 29: Light Waves

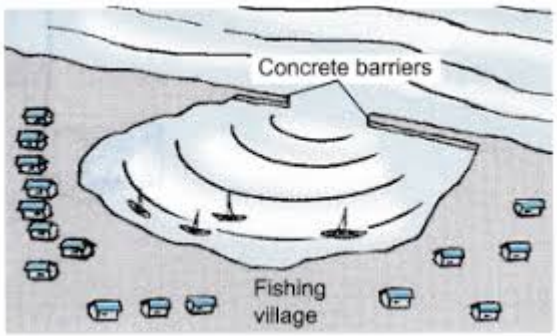


I. Diffraction

- The spreading or bending of a wave around a barrier or through an opening

  - Property of *all* kinds of waves
  - Seen around edges of many shadows

water



laser & razor:

Diffraction

- Plane waves can be generated in water by successively dipping a horizontally held straightedge into the surface

As waves passes through an opening, they spread out into the area behind the barrier.

Smaller hole → more diffraction

Classwork

3. Is diffraction more pronounced through a small opening or through a large opening?

- Amount of diffraction depends on wavelength λ of the wave compared to the size of the obstruction that casts the shadow.

  - wavelength about same size as object → diffraction

wavelength shorter than size as object

→ no diffraction

Classwork:

4. For an opening of a given size, is diffraction more pronounced for a longer wavelength or for a shorter wavelength?

Diffraction of Light

a. Light casts a sharp shadow with some fuzziness at its edges when the opening is large compared with the wavelength of the light.
b. When the opening is very narrow, diffraction is more apparent and the shadow is fuzzier.

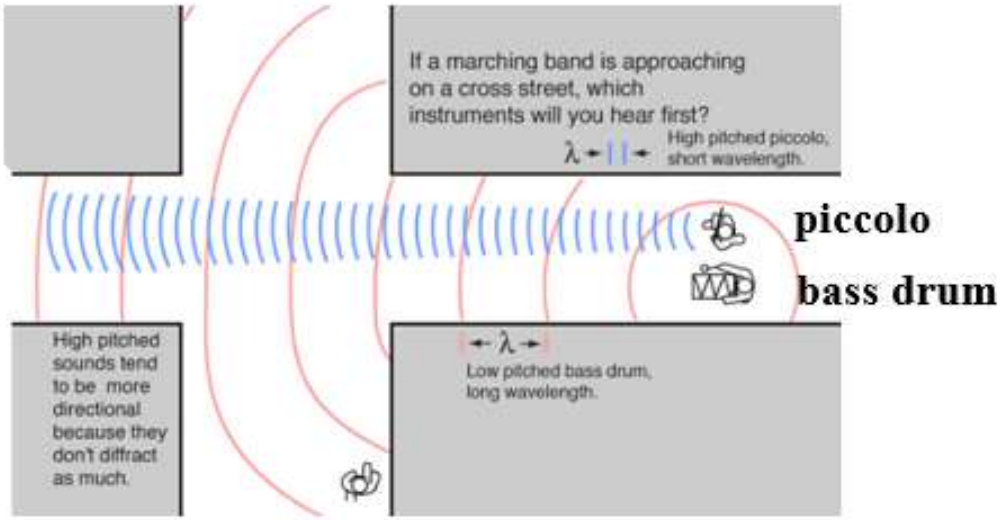
Long wavelengths diffract more:

Sound:

A longer λ diffracts more.

A low pitch has a longer λ than high pitch.

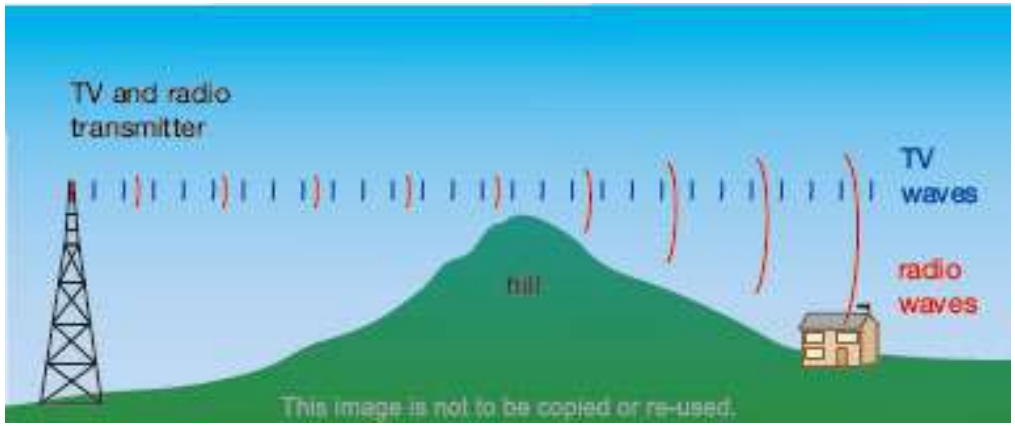
Low pitches (bass) diffract more.



Long wavelengths diffract more:

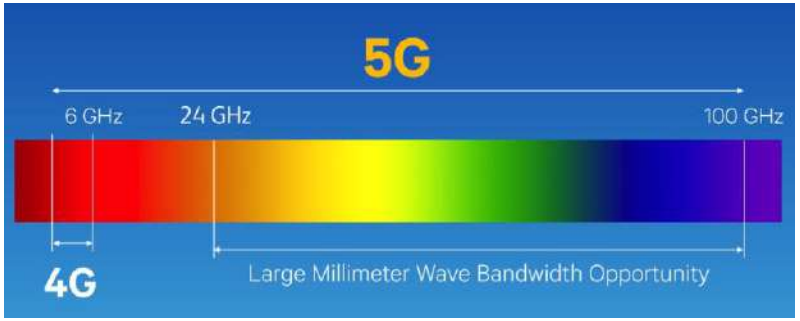
Radio waves:

AM: longer λ than FM
→ more diffraction
→ fills in around obstacles like hills:



Microwaves:

4G: longer λ than 5G
→ more diffraction
→ better reception



Classwork:

5. Which more easily diffracts around buildings: AM or FM radio waves? Why?

Shorter wavelength light reads tinier bits

- **Features of diffraction**
  - Limitations with focusing images in optical instruments
    - If object is about the same size as wavelength λ of light, diffraction blurs its image
    - If object is smaller than λ of light, no image

This limits the magnification of optical (visible light) telescopes to about 1000X.

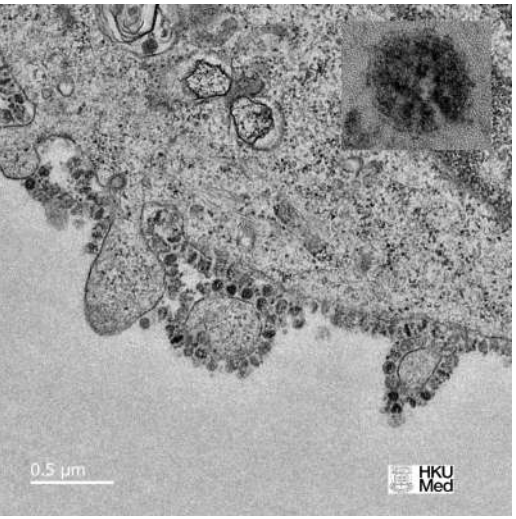
Electron microscopes use electric and magnetic fields to focus and magnify images

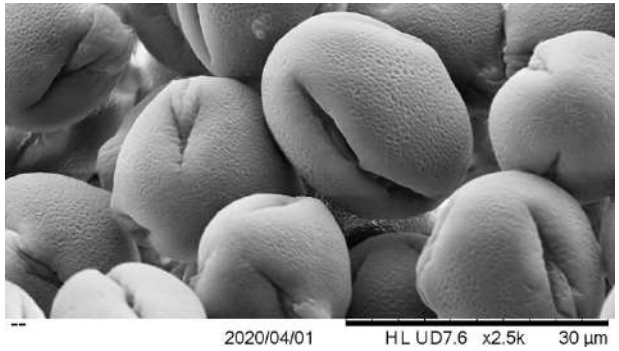
Magnification up to 100,000x

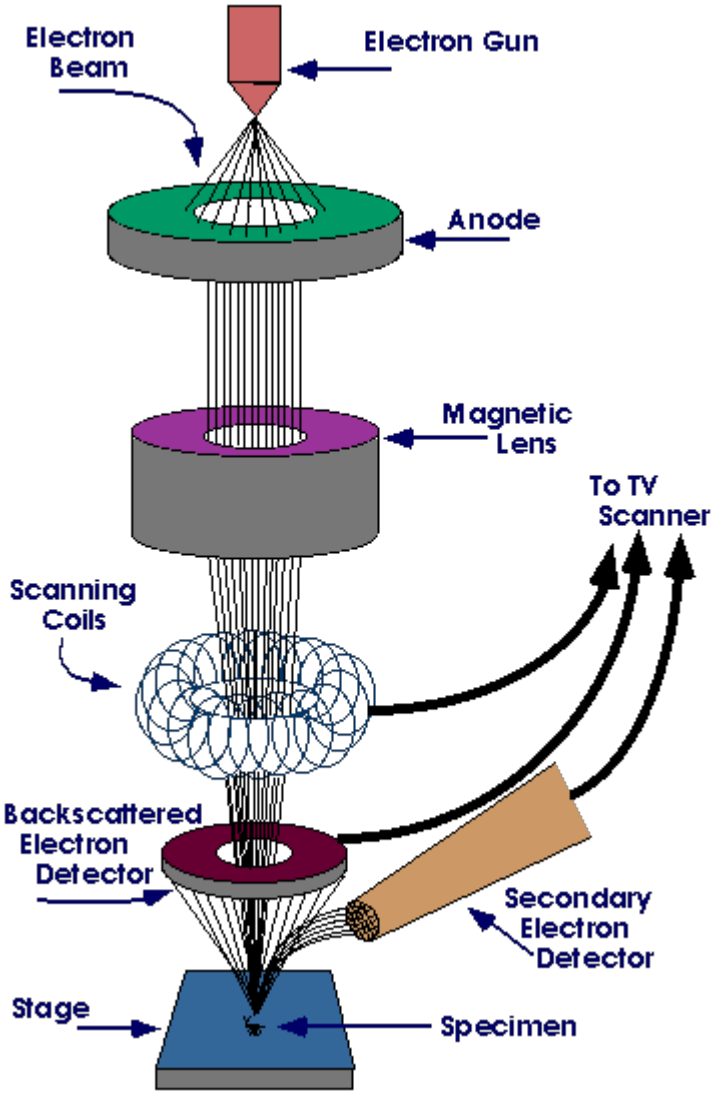
An electron beam has extremely short λ

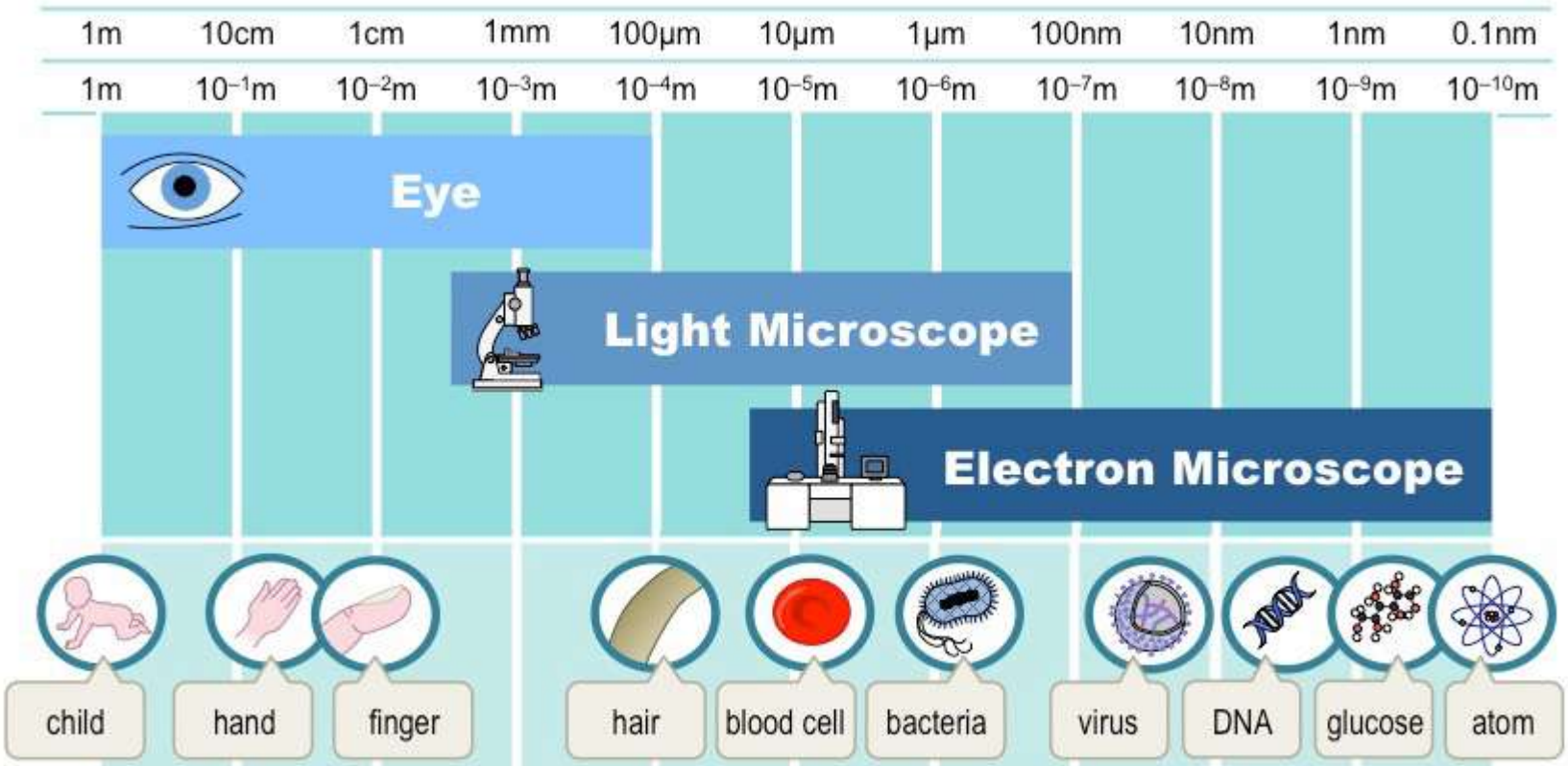
→ very sharp images

→ can see viruses and smaller

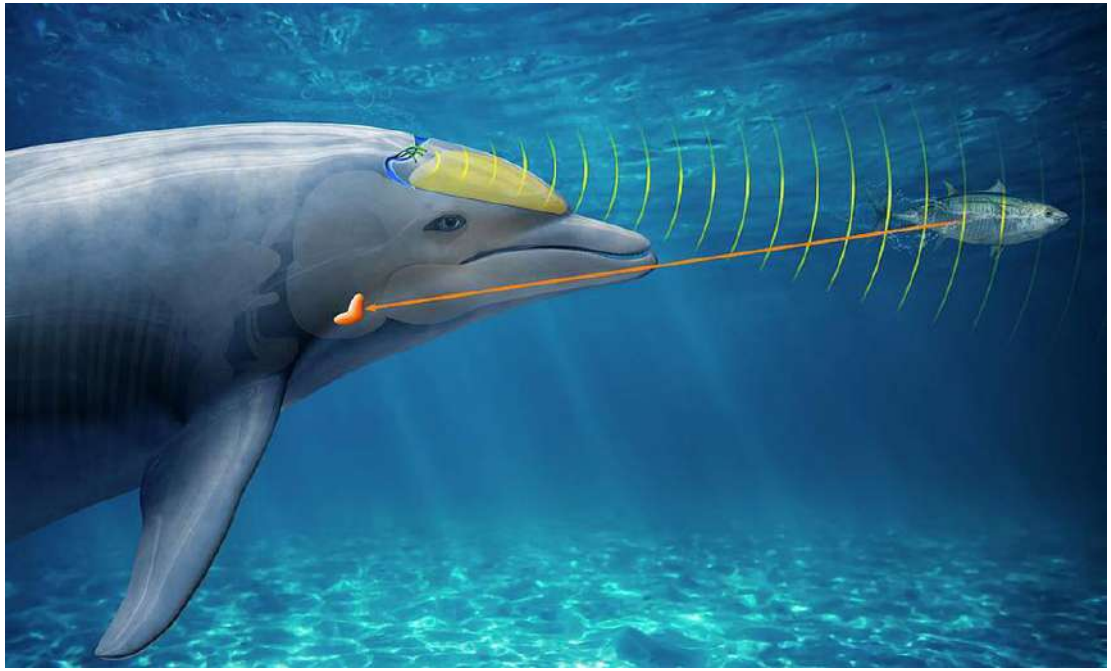








– For dolphins, use of shorter wavelengths gives finer detail—ultrasound



II. Superposition and Interference

- Superposition of waves

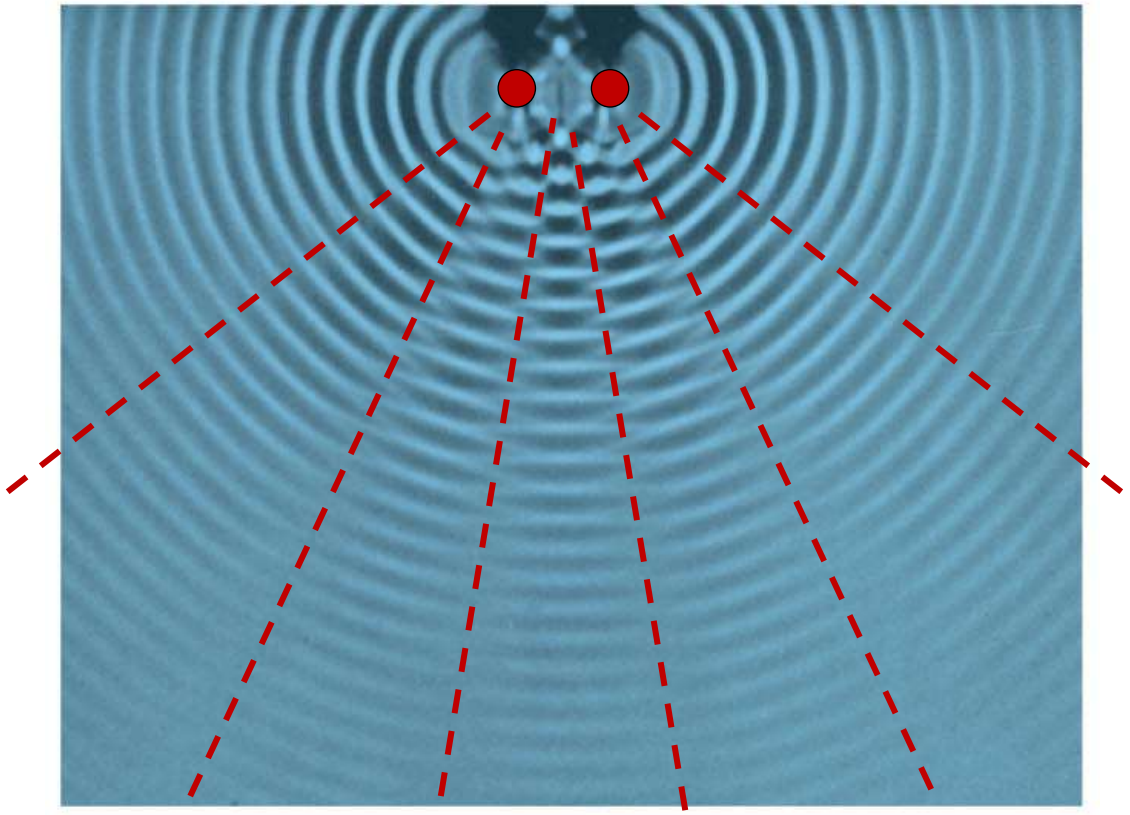
constructive interference

completely destructive interference

partially destructive interference

Two source interference patterns

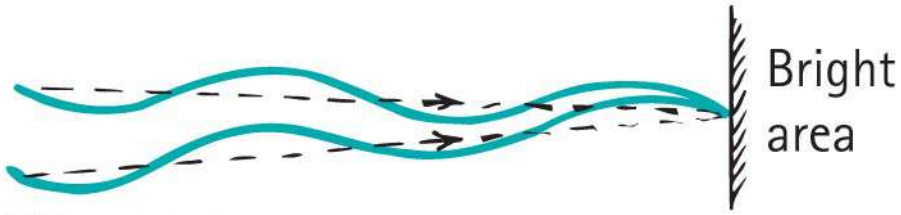
- Interference patterns of overlapping waves from two vibrating sources



Dashed lines shown where waves interfere constructively.

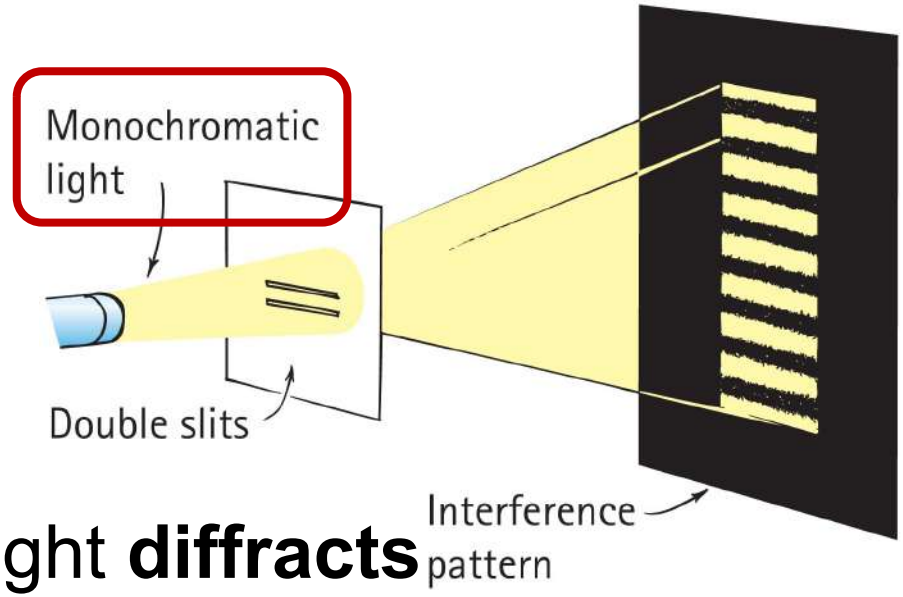
We listened to 2 speakers and heard loud and soft areas….

- Interference pattern
  - Caused by interference between a pair of waves



  - *Constructive* interference produces bright region where waves reinforce each other (waves arriving in phase).
  - *Destructive* interference produces dark region where waves cancel each other (waves arriving half a wavelength out of phase).

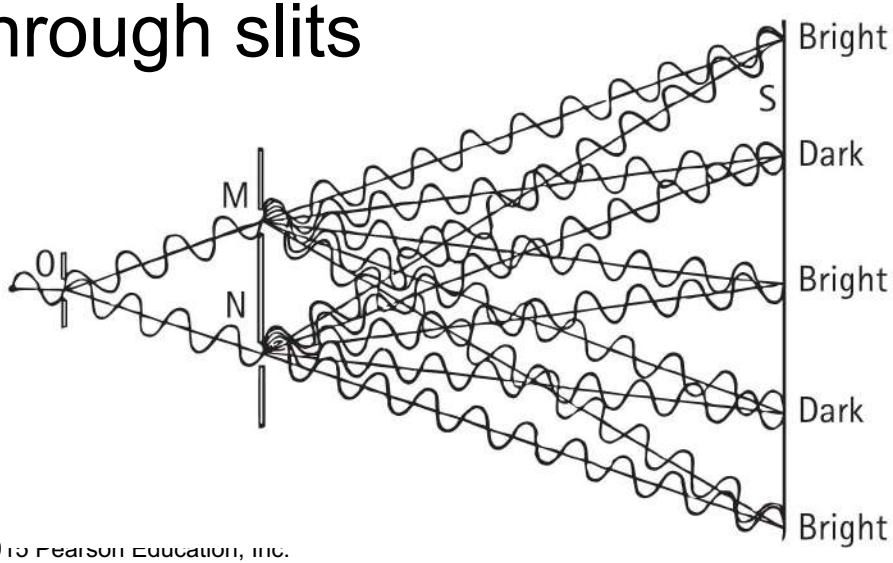
Young's Double-Slit Interference Experiment



Bright bands are areas of constructive **interference**

Dark areas are due to destructive **interference**

Light **diffracts** through slits



Details of the Interference Pattern.

→ *Young proved that light acts like a wave.*

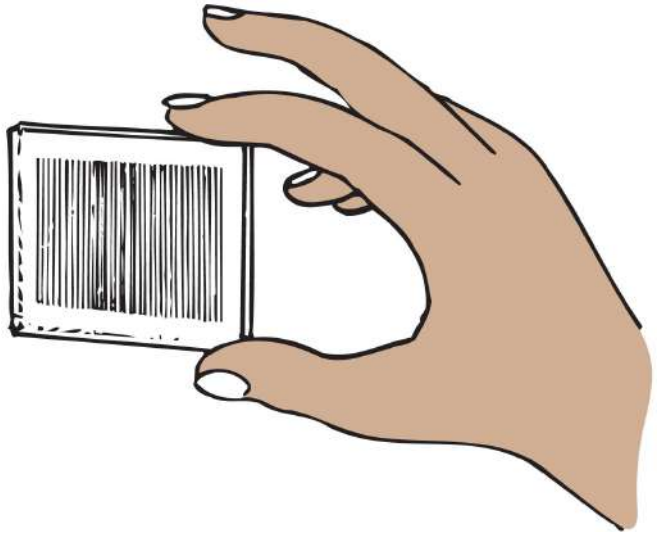
Classwork

6. Is interference restricted to only some types of waves, or does it occur for all types of waves?

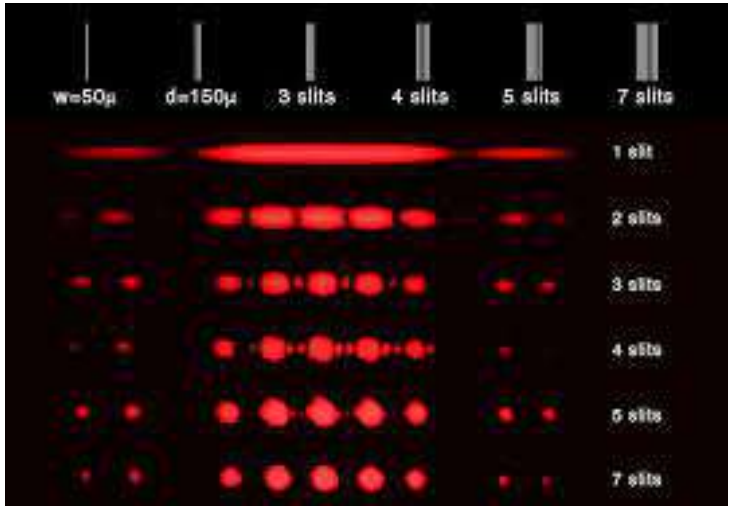
7. What aspect of light did Thomas Young demonstrate in his famous light experiment?

A diffraction grating has 1000s of slits instead of 2.

diffraction grating



More slits makes the bright areas more distinct.



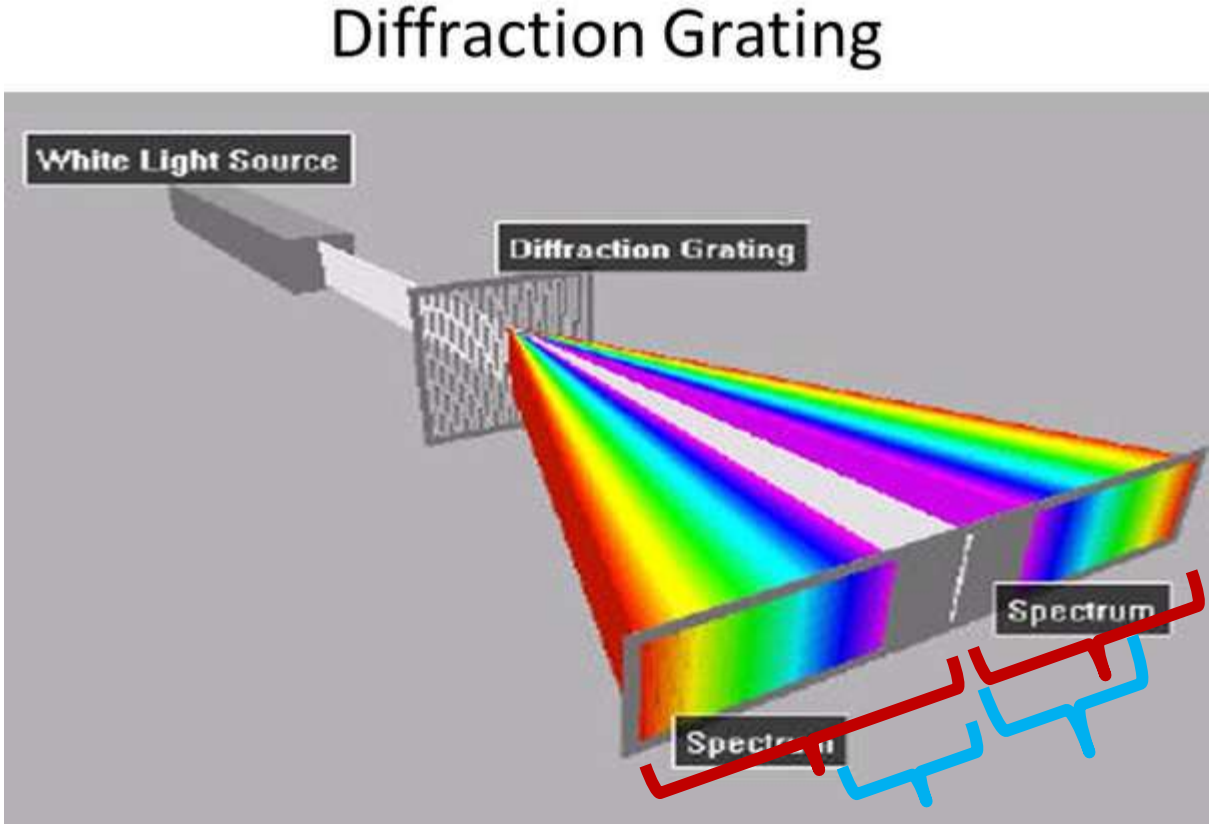
Instead of shining *monochromatic* (one color) light through a diffraction grating, shine white light.

Each color has a different λ.

Longer λ's diffract more.

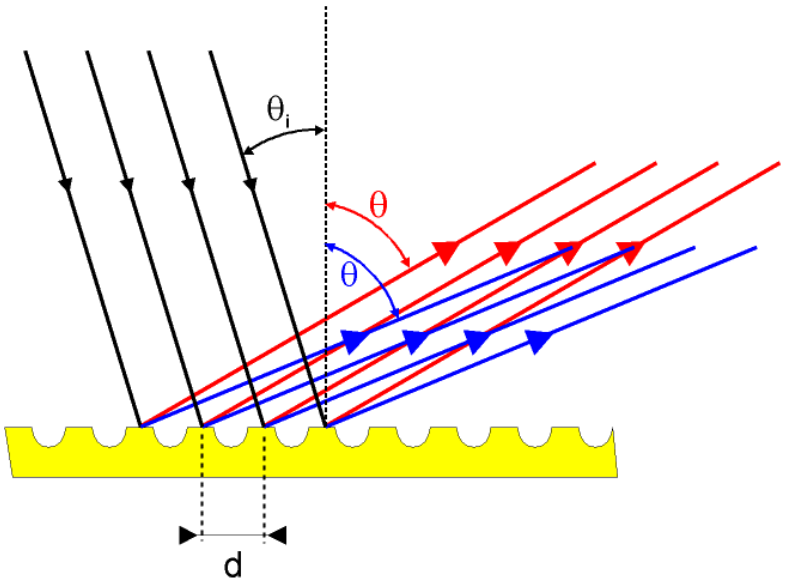
Red spreads out more.

Blue spreads less.



CDs and DVDs act like diffraction gratings, but they reflect.

Each color interferes at different angles because each color has a different λ.



Interference of Light
CHECK YOUR NEIGHBOR

The phenomenon of interference occurs for

A. sound waves.
B. light waves.
C. Both A and B.
D. Neither A nor B.

Interference of Light
CHECK YOUR NEIGHBOR, Continued

The phenomenon of interference occurs for

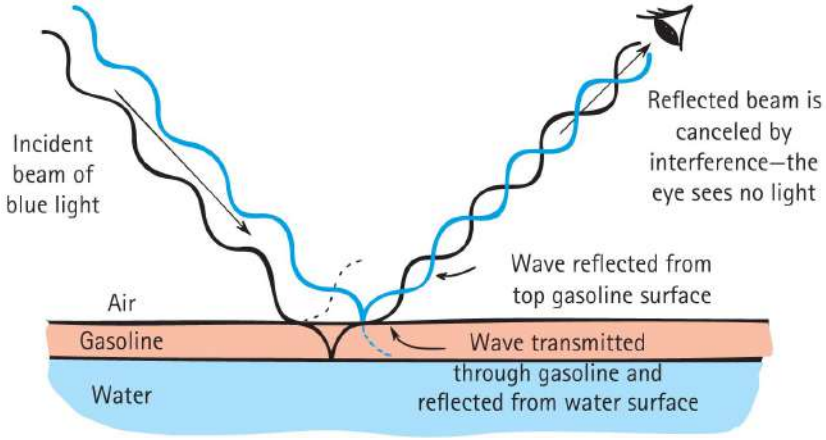
C. Both A and B.

Explanation:

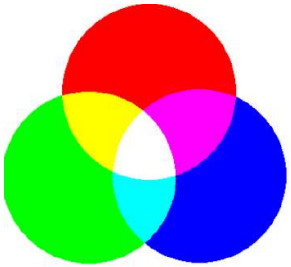
Interference is the property that characterizes waves in general.

Iridescence: produced by light interference

Light reflects from the top and bottom of thin films like gasoline on water.



- The thin film of gasoline is just the right thickness to result in the destructive interference of blue light.
- White – blue = ?
- If gas is on dry pavement, no colors because there is less reflection.



Different film thicknesses cancel different colors and cause a spectrum of colors to be seen.

Superposition and Interference
CHECK YOUR NEIGHBOR

If the thin film of gasoline was a bit thicker, the wavelength to be canceled would be

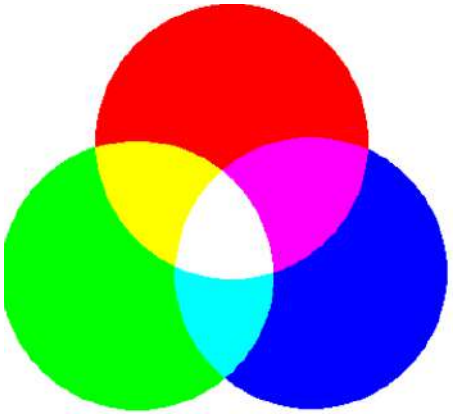
A. shorter than that of blue.
B. longer than that of blue.
C. white.
D. None of the above.

11. What produces iridescence?

12. What causes the spectrum of colors seen in gasoline splotches on a wet street? Why aren't these splotches seen on a dry street?

Thin film: Soap bubbles

- Light reflection from the inside surface is canceling light reflecting from the outside surface.
- Red, blue or green are cancelled at certain angles.



- What color is white minus…
- green? blue? red?

- The color that is canceled depends on the thickness of the thin film.

- **Interference colors**
- Caused by the interference of light reflected from two surfaces.

  - The colors in the bubble are the result of the cancellation of the primary colors (red, blue and green), each of which is a single frequency.

Classwork

13. What accounts for the different colors in either a soap bubble or a layer of gasoline on water?

14. Why are interference colors primarily cyan, magenta, and yellow?

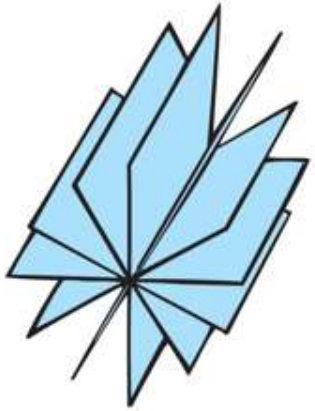
Iridescence

Wave interference occurs often in living things!

III. Polarization

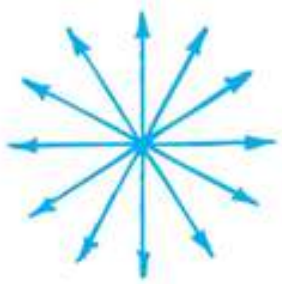
- In most common light sources:
  - Electrons vibrate → produce transverse electric fields.
  - The fields vibrate in same directions as electrons.
  - But the electrons vibrate in random directions.
  - So electric fields are in random directions,

Shows planes of electric fields in light



(a)

Same, but shown as rays



(b)

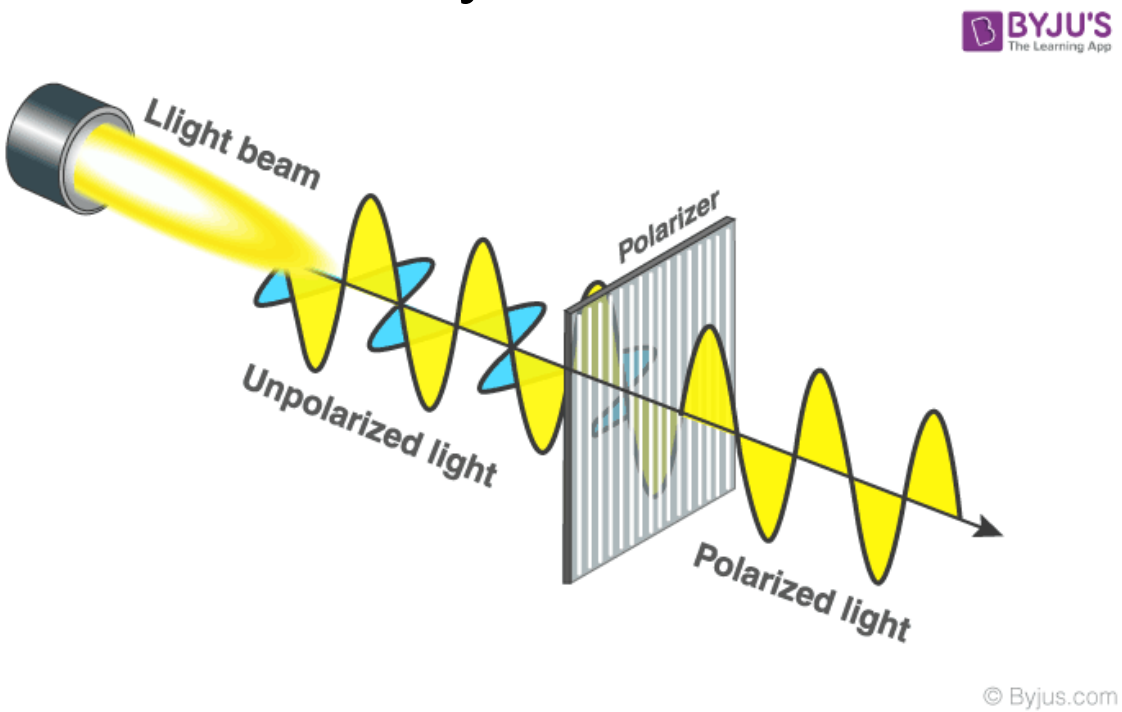
Unpolarized light is made up of randomly oriented electric and magnetic fields.

Classwork

16. How does the direction of polarization of light compare with the direction of vibration of the electron that produces it?

Polarization

Waves are polarized when they vibrate in one direction only.



Only transverse waves (like light) can be polarized.

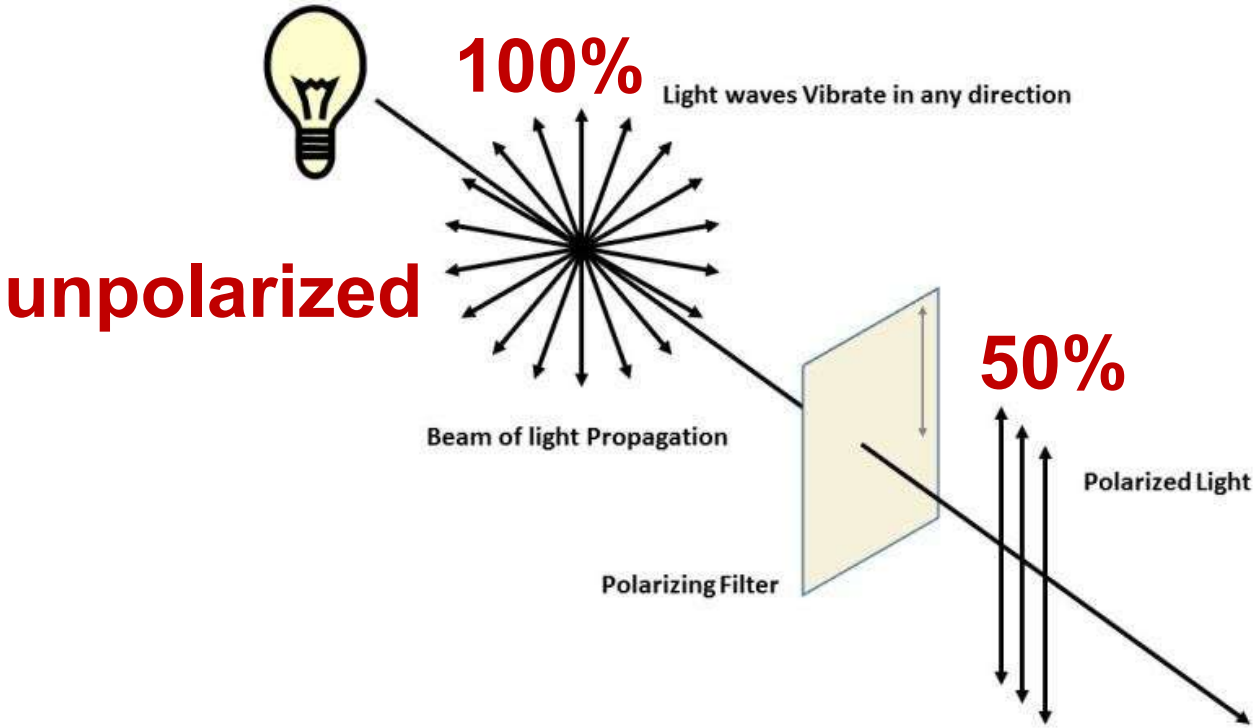
Longitudinal waves (sound) cannot be polarized.

Classwork

15. What phenomenon distinguishes longitudinal waves from transverse waves?

A polarizing filter removes all of the light that vibrates in one direction and leaves the rest.

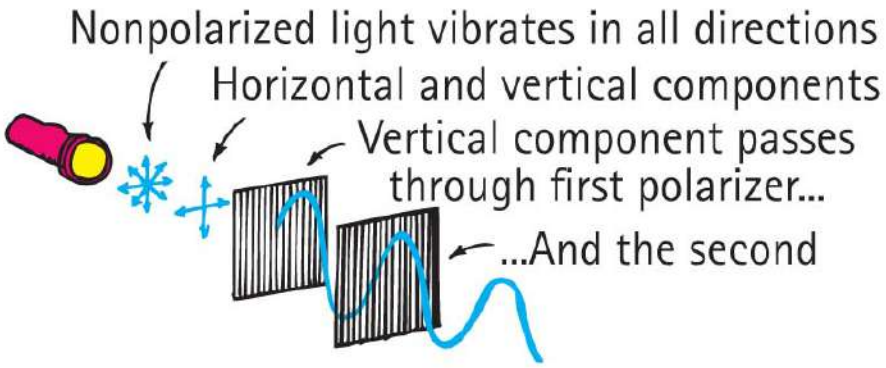
An ideal polarizer transmits 50% of the light:



Classwork

18. How much ordinary light will an ideal Polaroid transmit?

- Think of polarizers as gates that only allow one component (part) of light through:

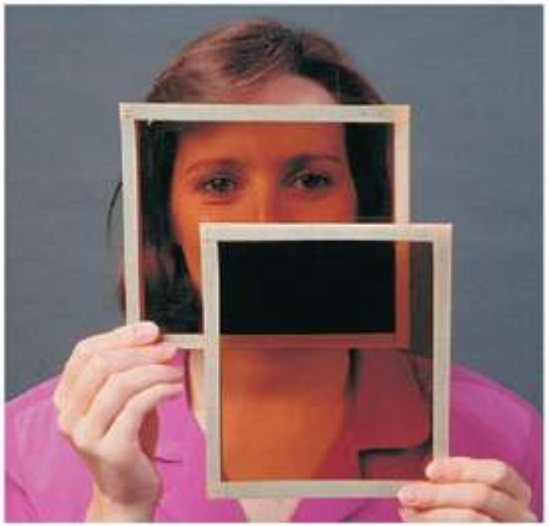


Polarization

aligned polarizers:

light that gets through one gets through the other

polarizers at right angles:



light that gets through one is absorbed by the other

Classwork

17. Why will light pass through a pair of Polaroids when the axes are aligned but not when the axes are at right angles to each other?

Polarization
CHECK YOUR NEIGHBOR

Polarization occurs for waves that are

A. transverse.
B. longitudinal.
C. Both A and B.
D. Neither A nor B.

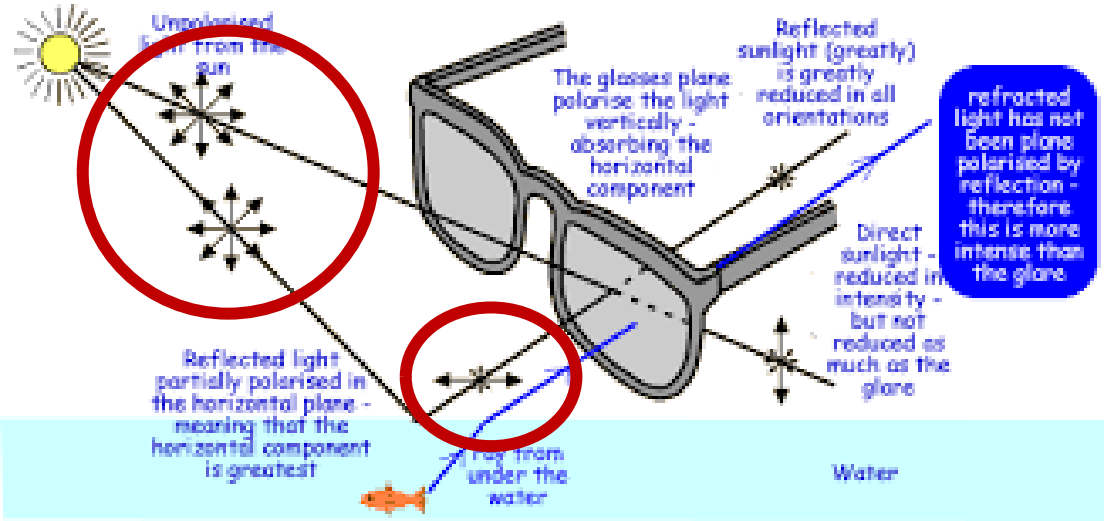
Polarization
CHECK YOUR ANSWER

Polarization occurs for waves that are

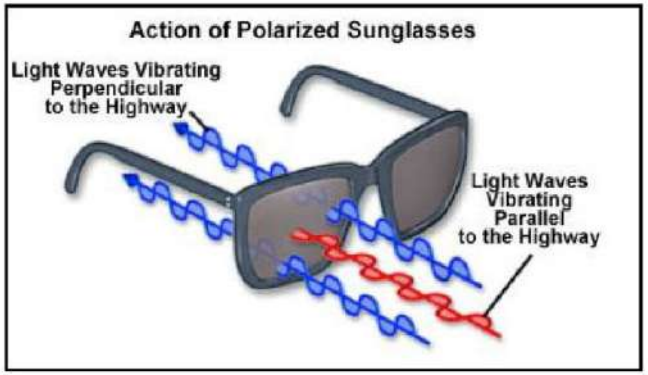
A. transverse.

When light reflects off of a horizontal surface, it loses the *vertical* part of its polarization.

The reflected light is mostly horizontally polarized.



Polaroid sunglasses block horizontally polarized light.

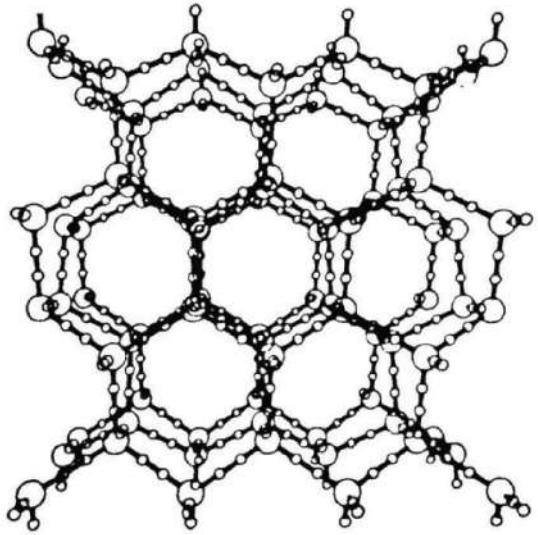


Classwork

19. When *ordinary* light is incident at an oblique angle upon water, what can you say about the *reflected* light?

Polarization and 3-D.

- Three-dimensional (3-d) viewing
  - Vision in three dimensions depends primarily on the fact that both eyes give their impressions simultaneously (or nearly so), each eye viewing the scene from a slightly different angle.
  - Also known as *stereo viewing.*



Stereo Viewers

Two photos are taken of the same scene from 2 slightly different angles, just like your eyes.

Then you view each photo with separate eyes.

Stereo Viewers depend on *parallax*:

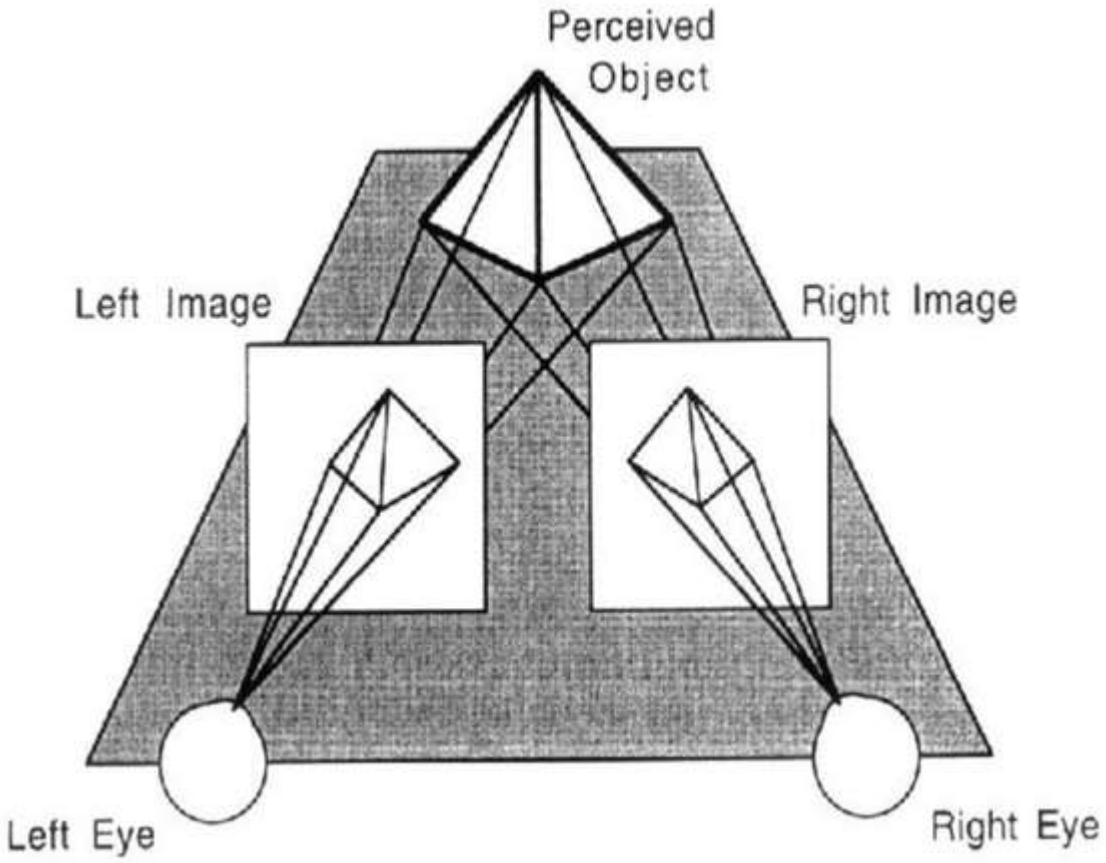
Slightly different view from different directions.

So two eyes provides depth perception.

You cannot experience parallax with one eye only.

Is this true?

Eye, eye!



Classwork

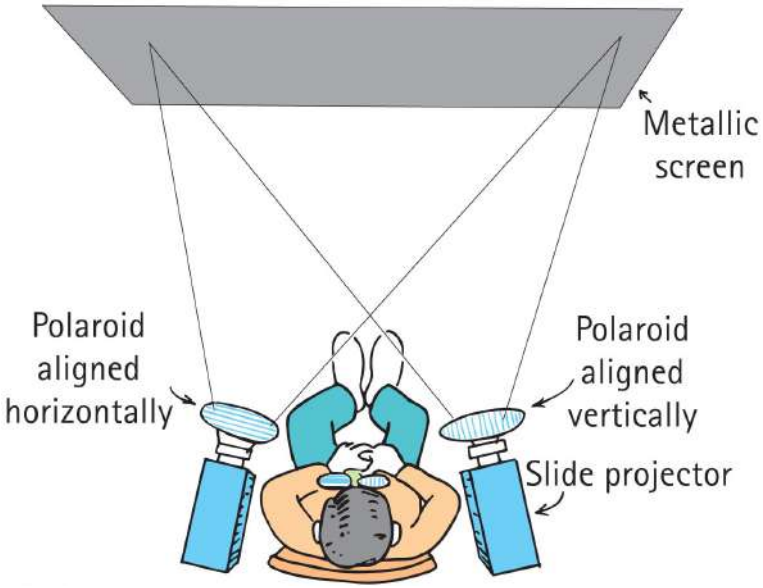
20. Is parallax evident when you close one eye?

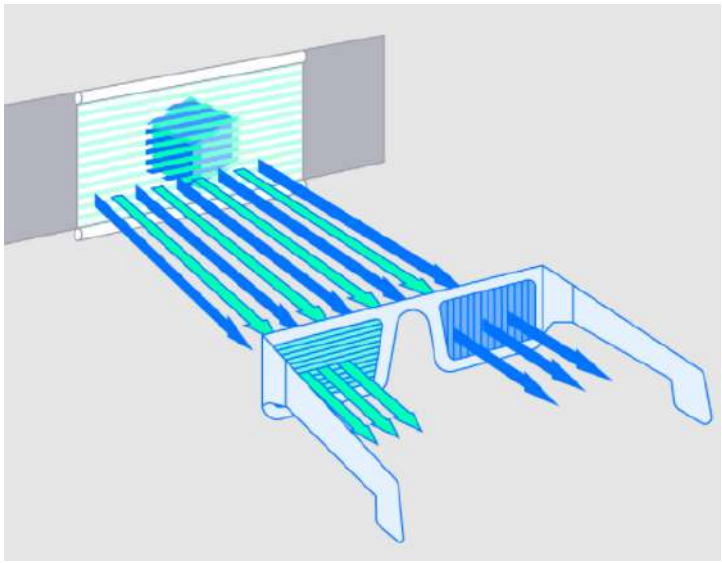
21. Does parallax underlie the depth perceived in stereo views?

If you place Polaroids in front of movie projectors so that they are at right angles to each other, and you view the polarized image with polarized glasses of the same orientation….

…the right eye gets only the view from the right

…the left eye gets only the view from the left.

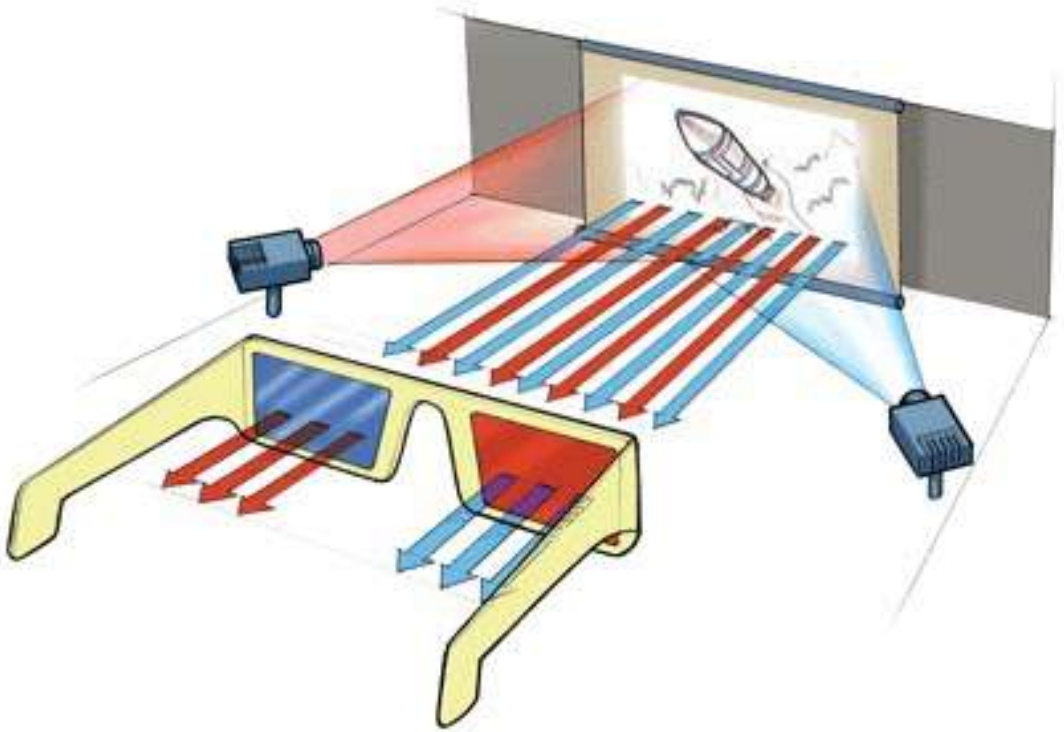




Classwork

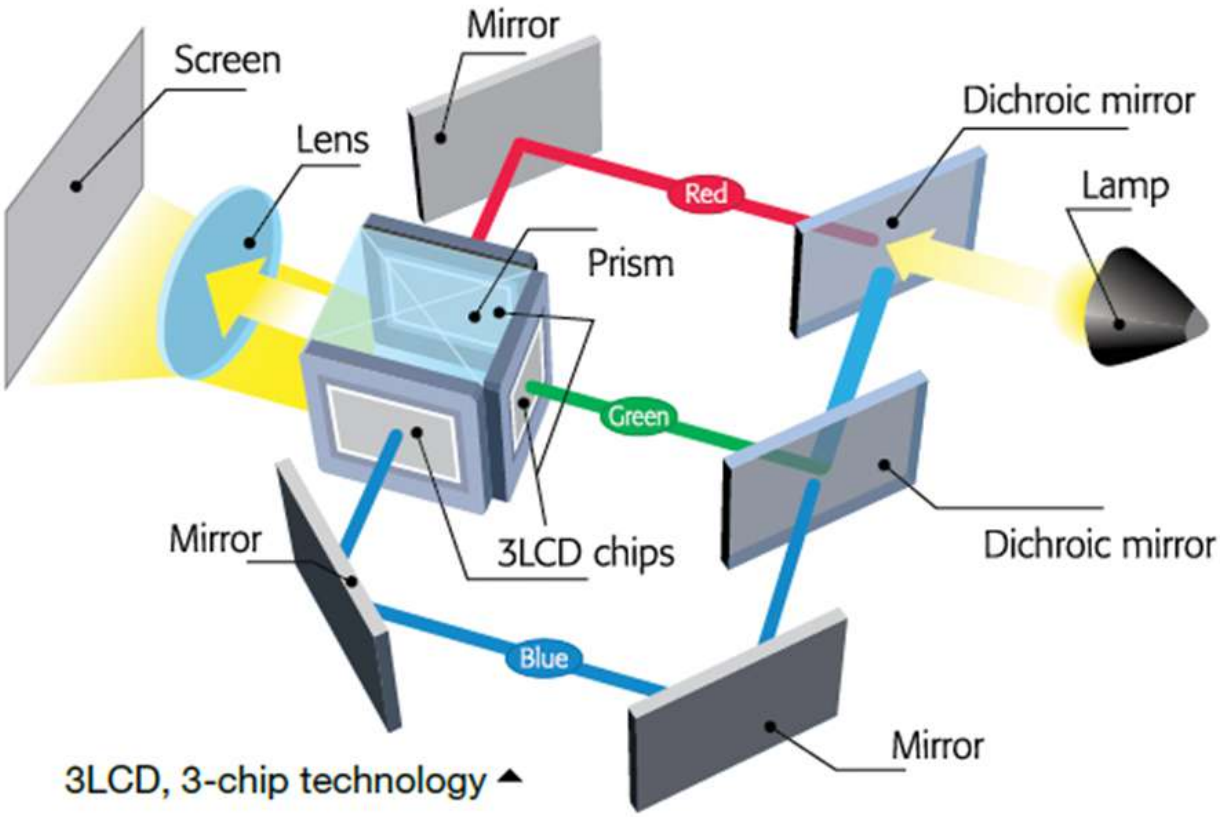
23. What role do polarization filters play in 3-D projection?

3-d with colors:



This can also be done with red and blue filters, but the colors are limited.

LCD projects use polarized light:



3LCD, 3-chip technology ▲

Upload Classwork

Test Tomorrow on:

All of Chapter 28

and

Sections 2-4 of chapter 29 (today's lesson)