Physics in Entertainment and the Arts

Chapter XIV

Polarization

Electromagnetic Waves

- We now know that electromagnetic waves (EM waves) are an oscillating combination of E and B fields
- To make it less confusing to illustrate – we’ll only show the E field from now on

Electromagnetic Waves

- This is how we will depict an EM wave from a dipole antenna

Electromagnetic Waves

- If all the waves in an EM wave are oscillating in the same plane – we call these waves **plane polarized** waves
- Of course, the plane of polarization could be at any angle to our line of sight!

Polarization

- This drawing shows the effect of polarization on wave transmission

Polarization

- At first glance, the last picture seems counterintuitive…
  - It seems the wave should more easily pass through the grid that is oriented vertically (Case A)
  - But this is not the actual case!!

Polarization

- Since the grid is aligned with the wave’s E field in Case A – the E field is able to more easily oscillate the electrons in the metal of the grid
- The electrons gain energy at the expense of the wave – and the wave loses energy!
  - It is absorbed by the metal

Polarization

- In case B, the grid is perpendicular to the wave’s E field
  - so the electrons in the metal cannot absorb as much of the wave’s energy since they cannot move as much
  - They are restricted to only moving the diameter of the wire in the grid instead of along the wire’s length!
  - The wave passes easily through in Case B!
Polarization

- The wave's absorption is maximized when the grid is parallel to its \textbf{E} field – and hence perpendicular to its \textbf{B} field!
- Why is this important? – Let's look at a real-life example...

**Example: Polarization**

- Television signals in the U.S. are plane polarized in the \textit{horizontal} plane
- So to maximize signal reception, we must place the receiving antenna so that the oscillating fields undergo the most absorption

**Example: Polarization**

- Antenna orientation to \textit{maximize} reception

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**Example: Polarization**

- \textit{Antenna orientations to minimize} reception

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**Light Polarization**

- To simplify our drawings, we use a head-on view of the light wave's \textbf{E} field

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**Light Polarization by Selective Absorption**

- One way to get polarized light is to selectively absorb all of the wave not oriented in the desired direction

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**Light Polarization by Selective Absorption**

- As we saw with the radio wave example – the metal grid absorbed the parts of the wave which were vertically aligned
Light Polarization by Selective Absorption

- Other materials can also selectively absorb certain orientations of waves
- One type of material is called **polaroid**
  - It has long molecules which are stretched out and aligned in one direction
  - This direction will act like the metal grid of the previous example

Light Polarization by Selective Absorption

- The polaroid material will pass light waves that are aligned with its **transmission axis**

Light Polarization by Selective Absorption

- Ideally ½ of the light will be passed and ½ absorbed by the polaroid
- This means that crossed polaroids should block all light incident upon them

Light Polarization by Reflection

- Another way to get polarized light is by reflection off a non-metallic surface
- At the correct angle of incidence…
  - which depends upon the type of material
- …the reflected light will be polarized parallel to the surface

Light Polarization by Reflection

- If not at the correct incident angle, only partial polarization occurs

Light Polarization by Reflection

- If the reflected light is viewed through a polarizer whose transmission axis is parallel to the surface, the maximum light will be transmitted

Light Polarization by Reflection

- Based on that last drawing, which way should the transmission axis of a pair of Polaroid sunglasses be oriented to cut down on blinding glare?
  - Horizontally?
  - Vertically?
  - Some other angle?
  - Hint: What is the source of the glare?

Light Polarization by Scattering

- Light scattered off of molecules, dust, water droplets, etc
  - is polarized perpendicular to the direction of scattering

Light Polarization by Scattering

- [http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polar.html](http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polar.html)
Light Polarization by Scattering

• Sunlight scattered in the atmosphere is partially plane polarized especially at right angles to the Sun

Uses of Polarized Light

• Light polarization is useful for:
  – Sunglasses to reduce blinding glare off horizontal surfaces
  – Camera lens filters to reduce glare and allow photography from behind glass surfaces
  – Camera lens filters to enhance blue light scattered by the atmosphere

Uses of Polarized Light

• Light polarization is useful for:
  – False 3-D movie images

Filmed with 2 lenses spaced a few inches apart – like our eyes!