

Sunlight 1

## Sunlight

Sunlight 2

### Introductory Question

- When you look up at the sky during the day, is the light from distant stars reaching your eyes?
- A. Yes
- B. No

Sunlight 3

### Observations about Sunlight

- Sunlight appears whiter than most light
- Sunlight makes the sky appear blue
- Sunlight becomes redder at sunrise and sunset
- It reflects from many surfaces, even nonmetals
- It bends and separates into colors in materials
- Sunlight a key source of renewable energy

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### Reading Question 14.1a

- The sky is blue because
- A. blue light scatters off air better than red light
- B. air glows blue when exposed to sunlight
- C. sunlight reflected from the earth surface is blue
- D. sunlight contains more blue light than red light

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### Reading Question 14.1b

- Light partly reflects from transparent objects because light
- A. changes speed as it enters or leaves objects.
- B. can't travel well through transparent objects.
- C. is unstable inside transparent objects.
- D. has no magnetic field in nonmagnetic objects.

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### 5 Questions about Sunlight

- Why does sunlight appear white?
- Why does the sky appear blue?
- How does a rainbow break sunlight into colors?
- Why are soap bubbles and oil films so colorful?
- Why do polarizing sunglasses reduce glare?

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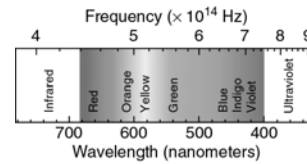
### Question 1

- Why does sunlight appear white?

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### Light

- Light is a class of electromagnetic waves
  - Long-wavelength EM waves: Radio & Microwave
  - Medium-wavelength: IR, Visible, UV light
  - Short-wavelength: X-rays & Gamma-rays



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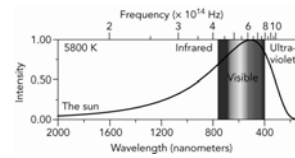
### Clicker Question

- How does the sun’s hot surface emit light?
  - Its hot atoms glow with their characteristic colors, like those in a neon sign.
  - Its hot atoms escape from its surface and become light waves.
  - Thermal energy causes its charged particles to accelerate rapidly and thus emit EM waves.

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### Spectrum of Sunlight

- Sunlight is thermal radiation—heat from the sun
  - Charges in the sun’s hot photosphere jitter thermally
  - Accelerating charges emits electromagnetic waves
  - The sun emits a black-body spectrum at 5800 K
- We perceive thermal light at 5800 K as “white”



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### Clicker Question

- If you compare a sheet of white paper that’s illuminated by direct sunlight to an identical sheet illuminated by an incandescent lightbulb,
  - both sheets will appear equally white.
  - the sunlit sheet will appear more blue.
  - the sunlit sheet will appear more green.
  - the sunlit sheet will appear more red.

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### Question 2

- Why does the sky appear blue?
  - Why is the sun reddish at sunrise and sunset?

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### Clicker Question

- When a light wave encounters an atom, its electric field polarizes that atom slightly
- A. so the atom can absorb and reemit the wave.  
B. but the atom cannot absorb the wave.  
C. but the atom cannot emit a wave.

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### Rayleigh Scattering

- Rayleigh scattering occurs when
  - passing sunlight electrically polarizes tiny particles in the air.
  - That alternating polarization acts as a source of light waves,
  - so air particles scatter light—they absorb and then reemit it.
- Air particles are too small to be good antennas for light,
  - so long-wavelengths (reds) scatter poorly
  - while shorter-wavelengths (violets) scatter better.
- Rayleigh scattered sunlight is bluish in appearance
- The missing blue light reddens the solar disk itself
  - particularly at sunrise and sunset

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### Introductory Question (revisited)

- When you look up at the sky during the day, is the light from distant stars reaching your eyes?
- A. Yes  
B. No

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### Question 3

- How does a rainbow break sunlight into colors?

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### Light and Refraction

- Sunlight slows while it passes through matter
  - Light waves electrically polarize matter
  - That polarization delays the light wave's passage
  - Each material has an "index of refraction"—the factor by which it reduces light's speed.
- When light changes speed at an interface,
  - it bends toward the perpendicular if it slows down
  - it bends away from the perpendicular if it speeds up

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### Clicker Question

- Glass is much more polarizable than air. When a light wave moves from air into glass, the sudden increase in polarization causes
- A. part of the wave to be reflected.  
B. part of the wave to be absorbed.  
C. all of the wave to be transmitted.  
D. some of the wave to travel along the surface.

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## Light and Reflection

- Light polarizes different materials differently,
  - which affects both how fast light travels in them and
  - relationship between its electric & magnetic fields.
- Changes in how light travels causes reflections
  - Sunlight partially reflects from most surfaces
  - Sunlight reflects almost completely from metals

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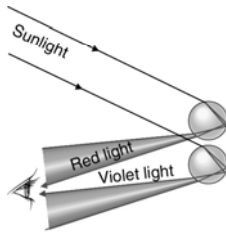
## Light and Dispersion

- The different colors of light in sunlight
  - have different frequencies
  - and polarize a material slightly differently,
  - so they travel at slightly different speeds.
  - Violet light usually travels slower than red
- Refraction (bending) depends speed change
  - so violet light usually bends more than red

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## Rainbows

- Occur when sunlight encounters water droplets
  - and undergoes refraction, reflection, and dispersion.



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## Clicker Question

- Faceted diamonds sparkle with color when illuminated by sunlight. Most imitations can't match this color because light's speed in them
  - is faster than in diamond.
  - is slower in them than in diamond.
  - is less dependent on frequency than in diamond.
  - is more dependent on frequency than in diamond.

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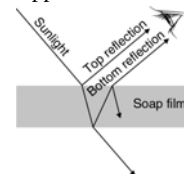
## Question 4

- Why are soap bubbles and oil films so colorful?

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## Light and Interference

- Overlapping waves superpose and may interfere
- Light following different paths can interfere
  - constructively if fields point in the same direction
  - or destructively if fields point in opposite directions.
- The two reflections from a soap or oil film interfere
- Different colors often interfere differently



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### Clicker Question

- Sunlight consists of countless independent light waves. What waves are interfering to produce the colors of a soap film?
  
- A. Parts of the same light wave are interfering.
- B. Different light waves are interfering.

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### Question 5

- Why do polarizing sunglasses reduce glare?

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### Clicker Question

- When light hits a transparent surface at a shallow angle, it polarizes the surface. That polarization is strongest when the light's electric field points
  
- A. along (parallel to) the surface.
- B. at right angles to (perpendicular to) the surface.

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### Reflection of Polarized Light

- Angled reflections depend on polarization
- When light's electric field is parallel to a surface
  - there is a large fluctuating surface polarization
  - and thus a strong reflection.
- When electric field is perpendicular to a surface
  - there is a small fluctuating surface polarization
  - and thus a weak reflection.
- Glare is mostly polarized parallel to the surface

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### Polarization and Sunlight

- Polarizing sunglasses
  - block horizontally polarized light
  - and thus block glare from horizontal surfaces.
- Rayleigh scattering has polarizing effects,
  - so much of the blue sky is polarized light, too.

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### Summary about Sunlight

- Sunlight is thermal light at about 5800 K
- It undergoes Rayleigh scattering in the air
- It bends and reflects from raindrops
- It interferes colorfully in soap and oil films
- It reflects in a polarizing fashion from surfaces