

National Defense Education Program Conservation of Energy Workshop

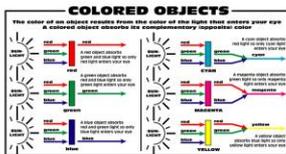
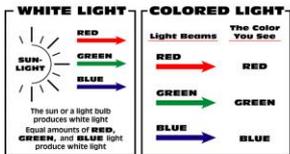
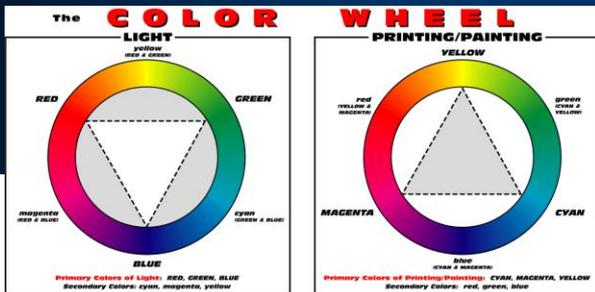
6 August 2010

Dr. Larry Woolf

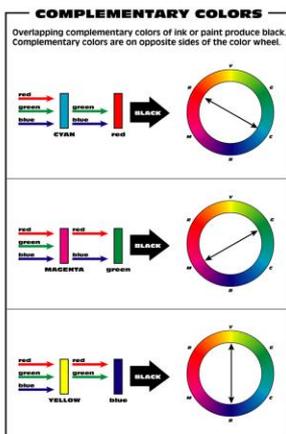
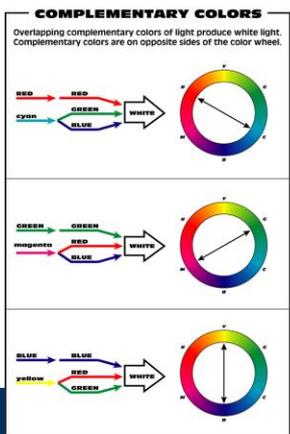
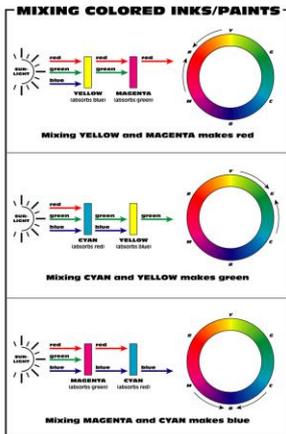
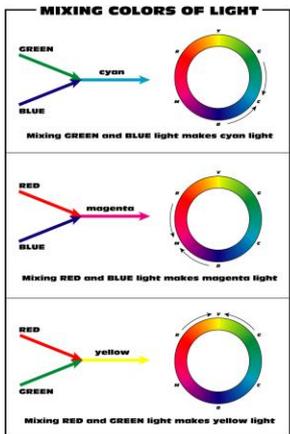
General Atomics

www.sci-ed-ga.org

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- Color wheel poster shows additive and subtractive color mixing
- Subtractive color mixing can be discussed using energy conservation



Concept Map for Color

**Energy is
conserved**

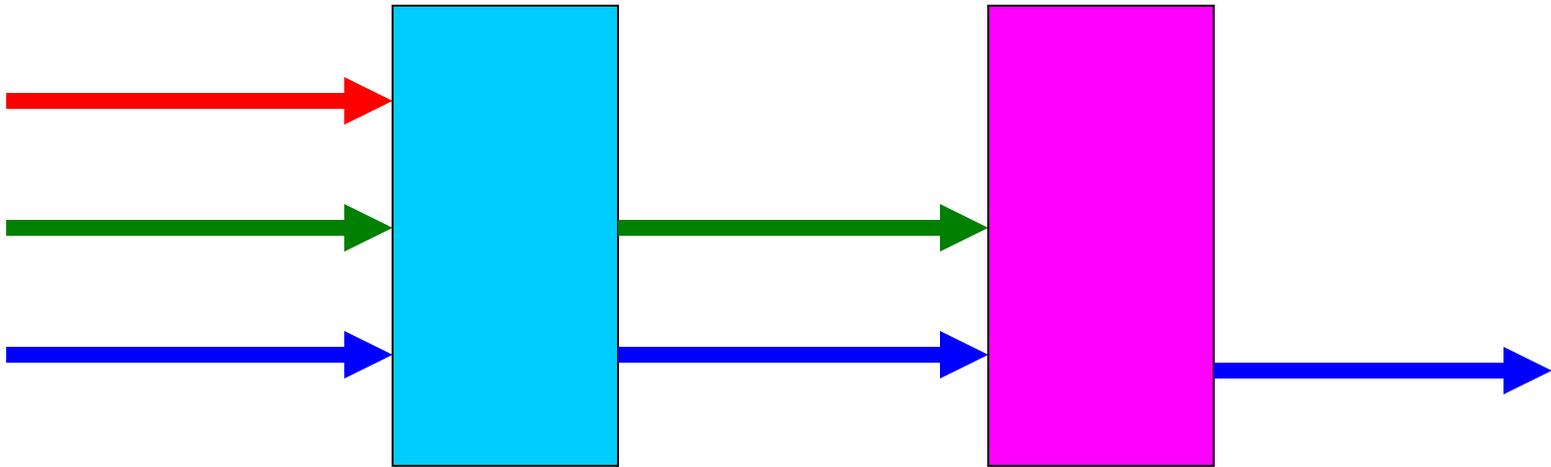
Energy is conserved when light interacts
with matter:

$$E_{\text{in}} = E_{\text{reflected}} + E_{\text{transmitted}} + E_{\text{absorbed}}$$

Color results from selective
absorption of visible light

Energy conservation: colored objects

Energy = energy + energy
 in absorbed transmitted



Energy = energy + energy
 in absorbed transmitted

$$(R + G + B)$$

$$-R$$

$$= G + B$$

$$G + B$$

$$-G$$

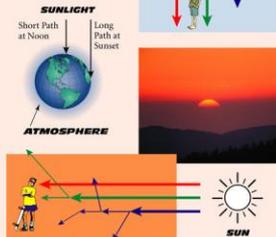
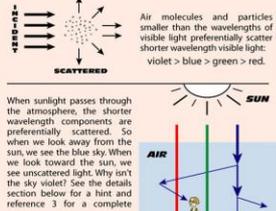
$$= B$$

Interaction of Light with Matter in context of Energy Conservation

Energy in = energy transmitted (scattered)

Energy in = energy reflected + energy transmitted + energy absorbed

MOLECULES AND SMALL PARTICLES SCATTER LIGHT



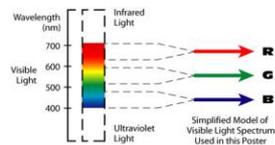
Sunlight passes through a longer length of atmosphere at sunset than at noon, which leads to increased scattering. When we look toward the sun at sunset, we see the unscattered light that is enriched in light of longer wavelengths. This results in a yellow or orange or even red sun.

Some Details and Clarifications

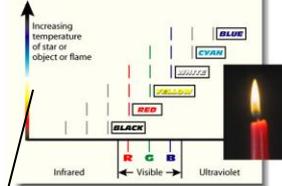
- Light is not colored. Color is a human visual response that depends on the spectrum of visible light entering our eyes - the color that we observe then depends on the responsiveness of the long, middle, and short wavelength sensitive cones in our eyes and the processing of these signals by the brain.
- The color of an object seen by reflected light depends on both the light spectrum illuminating the object as well as the reflectance spectrum of the object. This is why the color of clothes changes with illumination conditions.
- Light of a single wavelength corresponds to a definite percent of color. Most perceived colors can be evoked by a large number of different light spectra entering our eyes.
- For further details about and limitations of the explanations given in this poster, consult the references.

LIGHT MATTERS

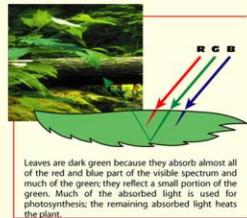
LIGHT EMISSION



HOW COLOR CHANGES WITH INCREASING TEMPERATURE



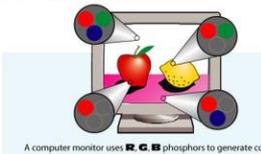
Objects emit light over a wide continuous range of wavelengths. At each temperature, this range can be approximated by three separated wavelengths. The rules for additive color mixing can then be used to predict how the color of hot objects changes with increasing temperature.



ABSORPTION

Water in a glass does not appear colored because the short path of light through the glass of water results in almost no light absorption.

Deep water appears blue because absorption of visible light by water is gradual as well as selective: greatest at the red end of the spectrum, least at the violet and blue end.

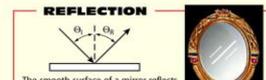
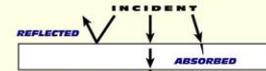


References

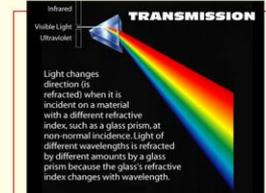
1. Clouds in a Glass of Beer, Craig F. Bohren, John Wiley & Sons, 1987. The Physics Teacher, May 1985, pp.267-272.
2. What Light Through Yonder Window Breaks, Craig F. Bohren, John Wiley & Sons, 1991.
3. "Colors of the Sky," C.F. Bohren and A. B. Fraser, The Physics Teacher, May 1985, pp.267-272.
4. "Confusing Color Concepts Clarified," L. D. Woolf, The Physics Teacher, April 1999, pp.204-206.
5. www.sci-ed-ga.org/modules/materialscience/color/
6. Light and Color in Nature and Art, S. J. Williamson and H. Z. Cummins, John Wiley & Sons, 1983.

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SCIENCE EDUCATION FOUNDATION
GENERAL ATOMS

BULK MATTER REFLECTS, TRANSMITS, AND ABSORBS LIGHT



The surface of a white piece of paper diffusely reflects the incident light because the surface is optically rough at visible wavelengths.

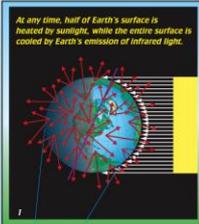


Energy in (heating) = energy emitted (light)

"Potential energy" of electron in atom = energy of emitted photon

THE SEASONS

A TALE OF THE SUN, EARTH, AND TWO CITIES



Some Details and Clarifications

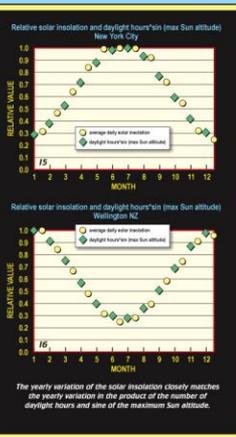
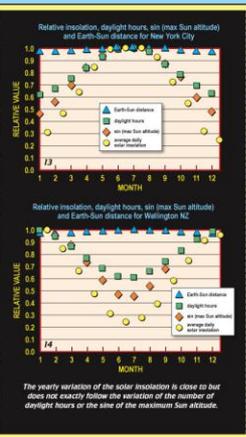
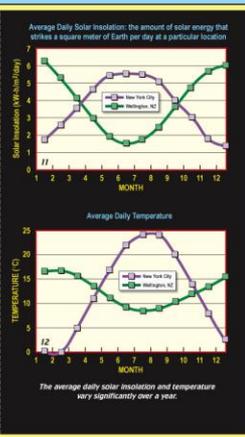
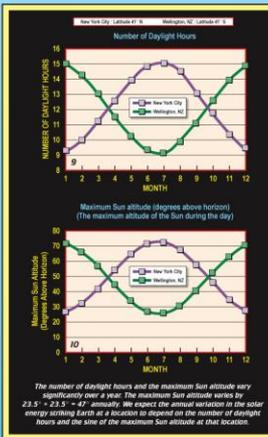
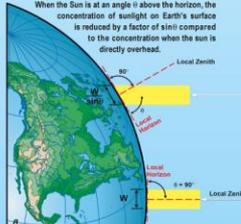
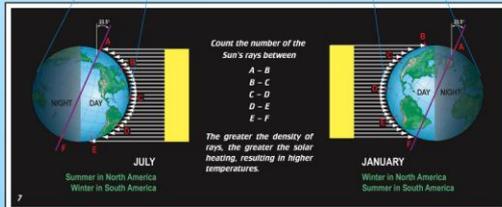
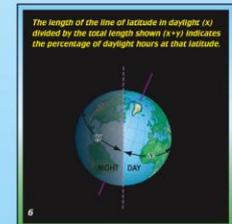
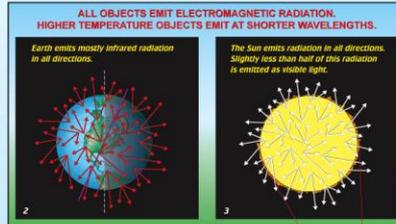
The tropics receive roughly constant solar heating throughout the year. As a result, they essentially have no seasons.

At the tropics, the annual solar radiation absorbed by Earth exceeds the annual emitted infrared radiation. At the mid-latitudes, the annual solar radiation absorbed by Earth is approximately equal to the annual emitted infrared radiation. At the poles, the annual infrared radiation emitted by Earth exceeds the annual absorbed solar radiation.

In most scientific literature, the angle of the Sun is measured with respect to the zenith, not the horizon as is done in this poster. The angle of the Sun measured from the zenith is called the zenith angle.

Created by Dr. Lawrence Mitrov, General Atomics Employee, Arlington, Virginia. Diagrams written for educational use without permission. See www.iaea.org/infocentre/questions/04-06-2009.pdf

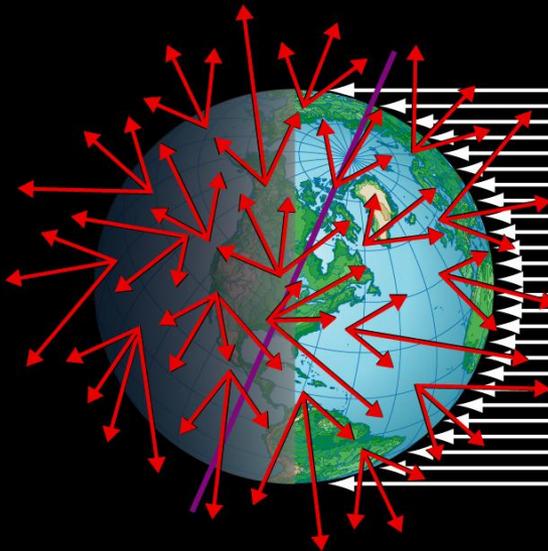
The seasons are almost entirely a consequence of the yearly changes in daylight hours and the angle between the Sun's rays and Earth's surface. Small variations in the Earth-Sun distance over a year are mostly irrelevant. The top half of the poster illustrates the causes of the seasons. The bottom half compares daylight hours, maximum daily Sun altitude, daily solar energy, and temperature data from a northern hemisphere city (New York City - 41° north latitude) and a southern hemisphere city (Wellington, New Zealand - 41° south latitude). The data analysis shown confirms these causes of the seasonal variations in solar energy.



Understanding reasons for seasons in context of energy conservation

Energy conservation: temperature of the entire Earth

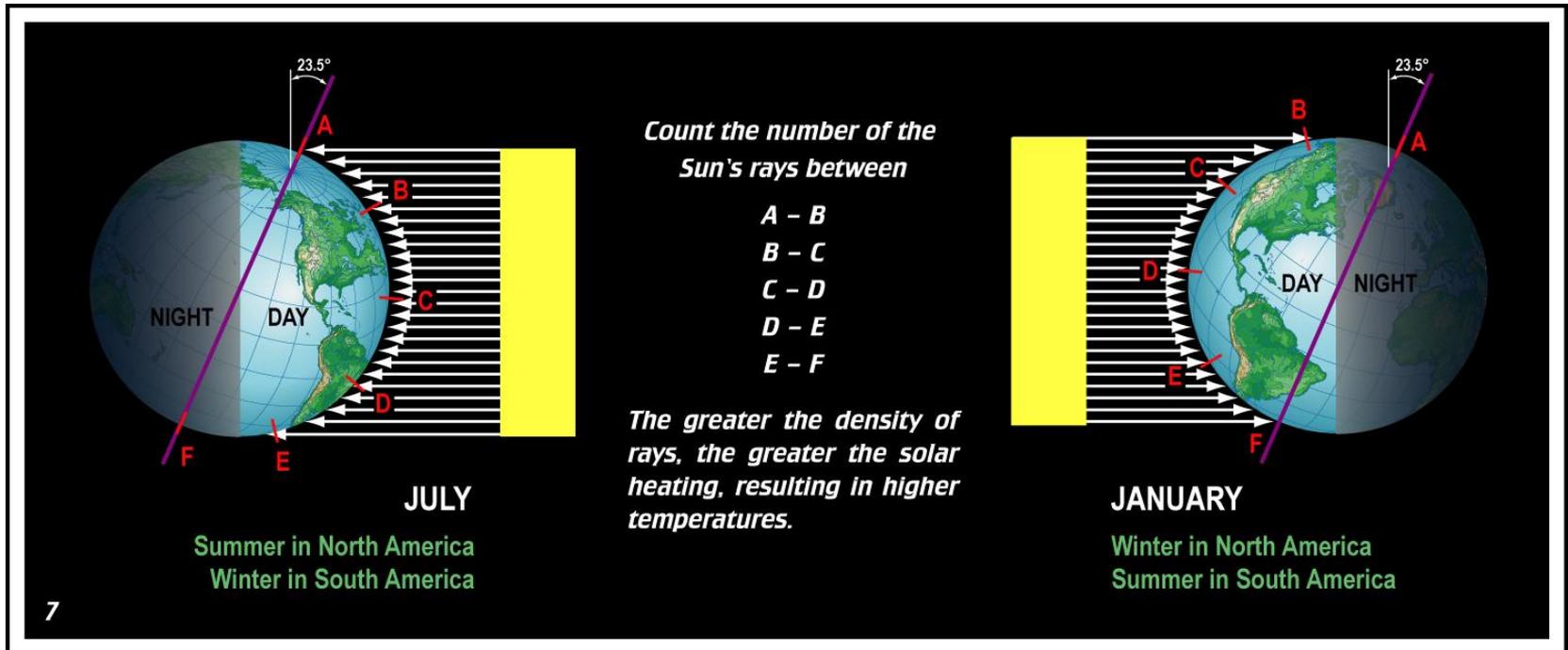
At any time, half of Earth's surface is heated by sunlight, while the entire surface is cooled by Earth's emission of infrared light.



Energy in (sunlight) =
Energy absorbed (heating) =
Energy out (infrared light)

(Simplification: Actual energy flows are complex)

Energy conservation: climate variation



Energy in (from sunlight) = Energy absorbed (heating)