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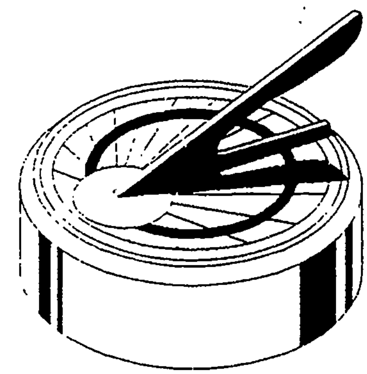
ABSTRACT

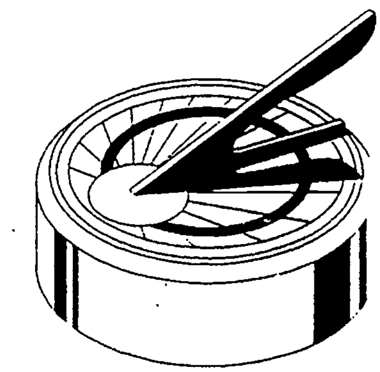
This curriculum guide, the second in a set of six, contains teacher and student materials for a unit on the electromagnetic spectrum prepared as part of a seventh- and eighth-grade agricultural science curriculum that is integrated with science instruction. The guide contains the state goals and sample learning objectives for each goal for students in grades 8-10 and a teacher presentation outline for the unit. The unit, which begins by listing the agricultural practices and science concepts to be taught, along with activities and applications, contains the following components: teaching steps, lesson outlines, teacher's presentation outlines for each day, student information guide, terms and definitions, worksheets, student activity note sheets, student activity information sheets, student activity record sheets, quizzes, practice problems, and 15 transparency masters. Teacher's activity sheets and tests have answers provided. The unit covers the following topics: ornamental plant and crop production; growing plants under supplemental or artificial lights; design of greenhouse facilities; and evaluating plant growth. (KC)

7th and 8th Grade Agriculture Science Curriculum

Electromagnetic Spectrum

Teacher Materials





1. Heat Energy
2. Electromagnetic Spectrum
3. Solar Energy
4. Mechanical Advantage
5. Electrical Energy
6. Energy Conservation

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LIGHT - PART OF THE ELECTROMAGNETIC SPECTRUM
BIOLOGICAL AND PHYSICAL SCIENCES
STATE GOAL FOR LEARNING 1

As a result of their schooling, students will have a working knowledge of the concepts and basic vocabulary of biological, physical and contemporary technological society.

SAMPLE LEARNING OBJECTIVES FOR GOAL 1

By the end of GRADE 8, students should be able to:

A2. Compare symmetry and patterns found in plants and animals.
B1. Demonstrate the necessity for organizing orderly systems of related facts.
D1. Understand how man interacts with other organisms in a food chain.
E1. Understand how organisms live in habitats, fill niches and interact with other parts of a community.
M3. Compare the characteristics of a single cell to these of a multi-celled organism.
N5. Relate the parts of flowering plants and explain their functions.
N6. Relate environmental conditions to the diversity of the structures and functions among plants and animals.

By the end of GRADE 10, students should be able to:

E1. Understand the interactions among populations of plants, herbivores and carnivores.
I3. Recognize that the populations of plants and animals change as the environment changes.
J3. Relate the processes by which organisms capture, utilize and release energy.
P1. Differentiate between color and pigmentation.
P3. Know sources of visible and invisible radiations.
P5. Observe the results of wave refraction.

STATE GOAL FOR LEARNING 2

As a result of their schooling, students will have a working knowledge of the social and environmental implication and limitations of technological development.

SAMPLE LEARNING OBJECTIVES FOR GOAL 2

By the end of GRADE 8, students should be able to:

F1. Identify interacting elements within a community.

STATE GOAL FOR LEARNING 3

As a result of their schooling, students will have a working knowledge of the principles of scientific research and their application in simple research projects.

SAMPLE LEARNING OBJECTIVES FOR GOAL 3

By the end of GRADE 8, students should be able to:

A1. Compare experimental data to those obtained by others.
A2. Recognize that experimental results are replicable.
A5. Demonstrate effective participation as a member of a laboratory group.
B1. Relate hypotheses or working assumptions in a concise manner.
B2. Demonstrate alternative procedures for solving a problem.
B3. Understand the need to acquire, organize, and evaluate data.
B4. Relate why controlled variables are used in an experiment.
B5. Demonstrate accurate measuring techniques.
B6. Relate a laboratory procedure that another student can follow.

By the end of GRADE 10, students should be able to:

A1. Replicate the results of an experiment.
A2. Recognize that their experimental results must by open to the scrutiny of others.
A5. Evaluate reasons for obtaining conflicting data.
B2. Relate data that reflect the accuracy of measuring devices.
B3. Demonstrate the ability to draw conclusions from collected data.

STATE GOAL FOR LEARNING 4

As a result of their schooling, students will have a working knowledge of the processes, techniques, methods, equipment and available technology of science.

SAMPLE LEARNING OBJECTIVES FOR GOAL 4

By the end of GRADE 8, students should be able to:

A1. Recognize the need for appropriate instruments to aid in observation.
C1. Recognize an inference based upon experimental observation.
D1. Evaluate the validity of a prediction through experimentation.
E1. Use standard units to measure properties of objects.
F1. Report the results of an experiment using tables and graphs.
G1 Develop an appropriate procedure for analyzing data.
J1. Identify the variables in an experiment and suggest ways to control them.
L1. Demonstrate reliability by repeating an experiment.

By the end of GRADE 10, students should be able to:

A1. Apply quantitative observational methods to accumulate precise data.

C1. Evaluate and revise an inference based u[on additional data.

D1. Revise a prediction on the basis of additional information.

F1. Analyze the results of an experiment.

G1. Evaluate the interpretation of data collected during an experiment.

PHYSICAL DEVELOPMENT

STATE GOAL FOR LEARNING 3

As a result of their schooling, students will be able to understand consumer health and safety, including environmental health.

SAMPLE LEARNING OBJECTIVES FOR GOAL 3

By the end of GRADE 8, students should be able to:

A2. Perform with appropriate safety equipment in safe environments.

G1. Know safety procedures needed in schools and the home to prevent accidents.

By the end of GRADE 10, students should be able to:

A2. Perform with appropriate safety equipment in safe environments.

LANGUAGE ARTS

STATE GOAL FOR LEARNING 4

As a result of their schooling, students will be able to use spoken language effectively in formal and informal situations to communicate ideas and information and to ask and answer questions.

SAMPLE LEARNING OBJECTIVES FOR GOAL 4

By the end of GRADE 8, students should be able to:

C2. Distinguish among statements of observation, opinion, and judgment.

MATHEMATICS

STATE GOAL FOR LEARNING 1

As a result of their schooling, students will be able to perform the computations of addition, subtraction, multiplication, and division using whole numbers, integers, fractions, and decimals.

SAMPLE LEARNING OBJECTIVES FOR GOAL 1

By the end of GRADE 8, students should be able to:

H4. Read diagrams, flowcharts, and schematics.

STATE GOAL FOR LEARNING 4

As a result of their schooling, students will be able to identify, analyze and solve problems using algebraic equations, inequalities, functions and their graphs.

SAMPLE LEARNING OBJECTIVES FOR GOAL 4

By the end of GRADE 8, students should be able to:

G1. Make a table of values for a linear function or other simple functions.

By the end of GRADE 10, students should be able to:

A1. Compare different powers of the same number or the same power of different numbers.

ELECTROMAGNETIC SPECTRUM

TEACHER PRESENTATION OUTLINE

ELECTROMAGNETIC SPECTRUM

AGRICULTURAL PRACTICES

Ornamental Plant and Crop Production
Growing Plants under Supplemental/Artificial Lights
Design of Greenhouse facilities
Evaluating Plant Growth

SCIENCE CONCEPTS

Diffraction of Light through Diffraction Grating
Wave Model of Light
Scientific Comparison of Plant Growth

Light is the most important factor in a green plant's ability to carry on photosynthesis. By understanding the properties of light and how plants respond to light, better growing conditions can be provided for crops, especially those grown in greenhouses, saran houses, or growth chambers.

AGRICULTURAL APPLICATIONS FOR 7&8TH GRADE PHYSICAL SCIENCES:

UNIT TITLES:	ACTIVITIES & APPLICATIONS
Electromagnetic Spectrum	Planting corn; pg. 7 Experimentation with plastic mulch; pg. 8 Refraction of light on greenhouse; pg. 11 Color of pots affecting soil temperature; pg. 11 Importance of light to plants; pg. 23 Light quality on plants; pg. 24 Light intensity & plant production; pg.25 Daylength & plant production; pg. 25

TEACHING STEPS
(for teacher to follow)

A. Materials Provided in Teaching Kit:

green cellophane
red cellophane
clear cellophane
waterproof marker
labels
aluminum foil
blue cellophane
yellow cellophane
corn seeds
2" plastic pots
potting soil
diffraction grating

B. Additional Materials Needed for Student Activities:

clear tape
ruler
scissors
masking tape
knife
cardboard tubes (from inside wrapping paper, paper towel, etc.)

C. Lesson Outline

D. Teacher's Presentation Outline

E. Audio Visual Materials:

1. ELECTROMAGNETIC RADIATION
2. TRANSVERSE WAVES
3. COMPARING TWO WAVE MODELS
4. ELECTROMAGNETIC SPECTRUM
5. VISIBLE SPECTRUM/ELECTROMAGNETIC SPECTRUM
6. VISIBLE SPECTRUM
7. A FEW SOURCES OF LIGHT
8. TRANSMITTING LIGHT
9. REFLECTING LIGHT
10. ABSORBING LIGHT
11. IMPORTANCE OF LIGHT TO PLANTS
12. FACTORS THAT EFFECT PHOTOSYNTHESIS
13. HOW LIGHT QUALITY EFFECTS PLANTS
14. HOW LIGHT INTENSITY EFFECTS PLANTS
15. HOW DAYLENGTH EFFECTS PHOTOSYNTHESIS

F. Student Handouts and Quizzes

Student Information Guide
Work Sheet A
Work Sheet B
Work Sheet C
Work Sheet D
Student Activity Note Sheet
Student Activity - 1 Information Sheet
Student Activity - 2 Information Sheet
Student Activity - 2 Record Sheet
Student Activity - 3 Information Sheet
Student Activity - 3 Record Sheet
Quiz 1

LESSON OUTLINE:

Day 1:

Demonstration of Activity - 1, "Planting Corn Seeds".
Student Activity of "Planting Corn Seeds".
Discussion of Attention Step/Problem Statement.
Explanation of Electromagnetic Spectrum.
Individual Study using Computer Study Guide.

Day 2:

Explanation of Visible Spectrum & Characteristics of Light.
Assignment of Student Information Guide on Light: Part of the Electromagnetic Spectrum.
Student Completion of Work Sheet A during class.
Explanation of Scientific Terms.
Student Completion of Work Sheet B during class or as homework.
Discussion of Scientific Terms Work Sheet (Work Sheet B).
Individual Study using Computer Study Guide.

Day 3:

Explanation of The Importance of Light To Plants.
Student Completion of Work Sheet C during class.
Demonstration of Activity - 2 "Growing Plants under Different Colors of Light".
Student Activity of "Growing Plants under Different Light".
Assignment of Part A & B of the Student Activity - 2 Record Sheet.
Individual Study using Computer Study Guide.

Day 4:

Discussion of Part A of Student Activity - 2 Record Sheet.
Demonstration of Activity - 3, "Diffraction of Light through Different Colors of Cellophane".
Student Activity of "Diffraction of Light through Different Colors of Cellophane ."
Review of information on the Electromagnetic Spectrum, Visible Spectrum, Characteristics of Light, & Importance of Light to Plants.
Individual Evaluation using Computer Quiz.

Day 5:

Student Completion of Work Sheet D during class.
Individual Evaluation using Computer Quiz.
Student Completion of Quiz 1.

LIGHT--PART OF THE ELECTROMAGNETIC SPECTRUM

TEACHER'S PRESENTATION OUTLINE

DAY 1

OBJECTIVES:

KNOWLEDGE OBJECTIVES:
Students will know:

- Definition of electromagnetic radiation
- How electromagnetic waves travel
- How types of electromagnetic waves are different
- How light is measured
- Definition of the visible spectrum
- The colors of light found in white light
- Arrangement of colors of the visible spectrum
- Definition of light
- Sources of light
- How light is transmitted
- How the color of object effects the reflection of light
- Why light is necessary for plant growth
- How light affects the rate of photosynthesis in plants
- Quality of light needed for plant growth
- How light intensity affects plant growth

PERFORMANCE OBJECTIVES:

Students will:

- Plant seed
- Observe plants growing under different colors of light
- Measure plants
- Observe plant growth
- Observe light that passes through the colored cellophane through diffraction grating

Teaching Note: *The following activity, "Planting Corn Seeds" can either be completed on Day 1 of this unit or done by the students up to a week ahead of starting the unit. It works well if this activity is done at the end of the previous week before the unit is started on a Monday. Activity - 2 "Growing Plants Under Different Colors of Light" cannot begin until the corn seedlings emerge.*

Teaching Note: *The steps and procedures for this activity are found in the Student Activity - 1 Information Sheet, "Planting Corn Seeds". Students can take notes an record them on the Student Activity Sheet during the teacher demonstration. The activity and demonstration steps are summarized below.*

Activity Summary: *Students can work in groups of 2 - 5 students. Show students where to write their names on the pots. Demonstrate how to plant two corn seeds in a pot.*

Teaching Note: *Assign and discuss Student Activity - 1 Information Sheet, "Planting Corn Seeds". Provide the students with supplies for the student activity and answer any questions. Coordinate the Student Activity.*

STUDENT ACTIVITY NOTE SHEET

List steps to follow:

1. Writing information on pots

2. Planting Corn Seeds

3. Taping cellophane tent over pots

4. Measuring plants

5. Observing Plant Appearance

6. Observing light as it passes through the colored cellophane with a diffraction grating

STUDENT ACTIVITY - 1
INFORMATION SHEET

PLANTING CORN SEEDS

a. **Purpose:** To produce 5 uniform pots of corn seedlings.

b. **What Each Group of Students Needs:**

10 corn seeds
waterproof marker
5 plastic pots
5 labels
potting soil

c. **Here's How:**

1. Work in your assigned group.
2. Get 10 corn seeds and 5 pots from your teacher.
3. Write your names on the pots and number the pots 1 - 5 with a waterproof marker.
4. Fill the pots 2/3 full (about 1 1/4 ") with potting soil.
5. Put 2 corn seeds in each pot.
6. Cover the seeds with about 1/2" of potting soil. There should be about 1/2" of space left at the top of the pot.
7. Water media thoroughly.
8. Insert a plant label into the soil at the center of the pot.
9. Place all 5 plants together in a warm place where they will receive plenty of light. (Be careful not to place the pots in a location where they will get too hot.)
10. Water pots as needed to keep the soil moist but not soggy.
11. Clean up your work area.

Teaching Note: *Discuss the Attention Step/Problem Statement with the class.*

ATTENTION STEP/PROBLEM STATEMENT

Some gardeners are experimenting with a plastic mulch for plants that turns from the color black in the spring to the color white in the summer. What is the advantage of having a mulch that turns colors? Why would it be beneficial to have a black mulch in the spring and a white mulch in the summer?

Dark colors absorb light. Light colors reflect light. It would be beneficial to have a black mulch in the spring because the mulch conserves moisture and the black plastic absorbs heat and warms the roots of the plant. However, in the summer extreme heat build-up can occur under the black plastic and injure plants. A white mulch reflects most of the sun's warming rays and prevents heat build-up from occurring while still helping to conserve moisture and reduce weed growth.

LIGHT--PART OF THE ELECTROMAGNETIC SPECTRUM

Teaching Note: *Explain the following information about the electromagnetic spectrum to the class.*

ELECTROMAGNETIC SPECTRUM

Lecture Note: *Use overhead #1 (ELECTROMAGNETIC RADIATION).*

- The sun's energy travels through space to the earth as electromagnetic radiation waves. Any energy that moves through empty space at the speed of light is called electromagnetic radiation. Electromagnetic waves travel at the speed of 300,000 kilometers per second (186,000 miles per second.

- Some examples of electromagnetic radiation are cosmic waves, gamma waves, x-rays, ultraviolet light, visible light, infrared radiation, microwaves, and radio waves. The cosmic and gamma wavelengths are very short when compared to radio waves.

Lecture Note: *Use overhead #2 (TRANSVERSE WAVE).*

- Electromagnetic waves are classified as transverse waves. They travel like the waves on a rope or waves of water on a lake. The transfer of energy by electromagnetic waves is called radiation.

Lecture Note: *Use overhead #3 (COMPARING TWO WAVE MODELS).*

- Two properties that differ from one type of electromagnetic waves to another are frequency and wavelengths. For example, visible light waves are different from other electromagnetic waves by their frequency and wavelengths. The frequency of electromagnetic waves is defined as the number of waves that pass a given point per second. Electromagnetic wavelength is defined as the distance between two neighboring crests in a wave. Electromagnetic waves that have long wavelengths and low frequency are less energetic than wavelengths that have short wavelengths and high frequency.

Lecture Note: *Use overhead #4 (ELECTROMAGNETIC SPECTRUM).*

- The energy of electromagnetic wavelengths depend on wavelength. Waves with shorter wavelengths have greater energy than those with longer wavelengths. The electromagnetic spectrum is the arrangement of electromagnetic waves according to their wavelength. The electromagnetic spectrum includes gamma rays, x-rays, ultraviolet light, light, infrared radiation, microwaves, and radio waves. Gamma radiation waves are the shortest wavelengths and have the greatest energy. Radio waves are the longest wavelengths and have the least energy.

Teaching Note: ***The students may use the Light--Part of the Electromagnetic Spectrum Study Guide Computer Program for individual study and review for this lesson.***

Day 2:

Teaching Note: *Explain the following information about the visible spectrum to the class.*

THE VISIBLE SPECTRUM

Lecture Note: *Use overhead #5 (VISIBLE SPECTRUM/ELECTROMAGNETIC SPECTRUM).*

- Since visible light is part of the electromagnetic spectrum it can be measured by its frequency and wavelength. It can also be measured by its intensity.

- Visible light waves are between 400 and 760 billionth of a meter long and are found near the middle of the electromagnetic spectrum. Light's wavelengths are shorter than infrared radiation, but longer than ultraviolet light. This results in visible light waves having more energy than infrared radiation and less energy than ultraviolet light waves.

Lecture Note: *Use overhead #6 (VISIBLE SPECTRUM).*

- Light is energy that we can see with our eyes. Sunlight appears white to our eyes, even though it is made up of all the colors of the visible spectrum. White light can be divided into all the colors of the visible spectrum (colors of the rainbow), by using a prism. When a prism is held up to bright sunlight, so that sunlight passes through it, part of a rainbow will appear. Just like a rainbow that appears in the sky after a rain, the band of colors always appear in the following order: violet, blue, green, yellow, orange, and red. Each color of light has a different frequency. Because our eyes are sensitive to the frequencies of visible light, it is special to us. Sunlight contains a nearly equal mixture of all the colors and frequencies of light.

- The wavelength of light varies from one color of light to another. Each color of light corresponds to a different wavelength. Violet light waves have the highest frequency and shortest wavelength of visible light and is refracted at the largest angle. Red light waves have the lowest frequency and longest wavelength of visible light and is refracted at the smallest angle. Yellow, green, and blue light are found in the middle of the visible spectrum.

Teaching Note: *Explain the following information about the characteristics of light to the class.*

- Objects can be a source of light or they may transmit, reflect, or absorb light.

Lecture Note: Use overhead # 7 (SOURCES OF LIGHT)

- The sun, fire, and light bulbs are all sources of light and are called luminous. Some materials give off light when they are heated. These materials are called incandescent.

Lecture Note: Use overhead # 8 (TRANSMITTING LIGHT)

- Light is transmitted when it passes through matter such as air, water, glass, or clear plastic. When light rays move from one substance into another (such as from air into paper) its speed changes. The change in speed causes the ray of light to be refracted or bent into a new path. The degree of refraction depends on the frequency of light. Light rays with the highest frequencies have the largest angle of refraction, or are bent the most. This is why only 70 - 90 % of available light is transmitted through the glass, plastic, or fiberglass of a greenhouse. The rest of the light is refracted away from the greenhouse.

Lecture Note: Use overhead # 9 (REFLECTING LIGHT)

- Most objects reflect some light. We can see things that are not luminous because they reflect some of the light that strikes them. This light is reflected back to our eyes.

- Light-colored objects reflect more light than dark-colored objects. This is the reason light colored clothes are cooler to wear in the summer than dark colored clothing. It is also one reason plants are often grown in white hanging baskets on porches and decks during the summer. The white pot reflects more light than a dark pot. The soil in a white pot stays cooler than the soil in a green or black pot.

- The colors of a substance depends on both the substance and the colors of light striking the substance. If white light strikes a violet object, all frequencies of light except violet are absorbed. Violet light is reflected.

Lecture Note: Use overhead # 10 (ABSORBING LIGHT)

- Matter can also absorb light. Dark-colored objects absorb more light than light-colored objects do. This is apparent when you compare two cars that have been parked in the sun in the summer. Heat buildup occurs more rapidly in a car with dark interior than a car with light interior.

- The principle of dark-colored objects absorbing more light than light-colored objects also explains why heat buildup occurs more rapidly under a black plastic mulch than a white plastic mulch. It also explains why heat buildup in container-grown nursery stock can be a problem in the summer. Nursery stock are woody trees and shrubs that are grown in nurseries to be sold commercially or to the public. Container grown nursery stock are often grown in black plastic pots. The soil inside the plastic pots can get so hot that it is detrimental to plant growth. Plants grown in white pots have a cooler soil temperature than plants grown in black pots.

Teaching Note: ***Assign Work Sheet A and Student Information Guide on Light--Part of the Electromagnetic Spectrum. Students can complete Work Sheet A either individually or in small groups during class time.***

STUDENT INFORMATION GUIDE

LIGHT--
PART OF THE ELECTROMAGNETIC SPECTRUM

ELECTROMAGNETIC SPECTRUM
The sun's energy travels through space to the earth as electromagnetic radiation waves. Any energy that moves through empty space at the speed of light is called electromagnetic radiation. Electromagnetic waves travel at the speed of 300,000 kilometers per second (186,000 miles per second.

Some examples of electromagnetic radiation are cosmic waves, gamma waves, x-rays, ultraviolet light, visible light, infrared radiation, microwaves, and radio waves. The cosmic and gamma wavelengths are very short when compared to radio waves.

Electromagnetic waves are classified as transverse waves. They travel like the waves on a rope or waves of water on a lake. The transfer of energy by electromagnetic waves is called radiation.

Two properties that differ from one type of electromagnetic waves to another are frequency and wavelengths. For example, visible light waves are different from other electromagnetic waves by their frequency and wavelengths. The frequency of electromagnetic waves is defined as the number of waves that pass a given point per second. Electromagnetic wavelength is defined as the distance between two neighboring crests in a wave. Electromagnetic waves that have long wavelengths and low frequency are less energetic than wavelengths that have short wavelengths and high frequency.

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THE VISIBLE SPECTRUM

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Visible light waves are the light waves we can see with our eyes and are between 400 and 760 billionth of a meter long. They are found near the middle of the electromagnetic spectrum. Light's wavelengths are shorter than infrared radiation, but longer than ultraviolet light. This results in visible light waves having more energy than infrared radiation and less energy than ultraviolet light waves.

Light is energy that we can see with our eyes. Sunlight appears white to our eyes, even though it is made up of all the colors of the visible spectrum. White light can be divided into all the colors of the visible spectrum (colors of the rainbow), by using a prism. When a prism is held up to bright sunlight, so that sunlight passes through it, part of a rainbow will appear. Just like a rainbow that appears in the sky after a rain, the band of colors always appear in the following order: violet, blue, green, yellow, orange, and red. Each color of light has a different frequency. Because our eyes are sensitive to the frequencies of visible light, it is special to us. Sunlight contains a nearly equal mixture of all the colors and frequencies of light.

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Light is transmitted when it passes through matter such as air, water, glass, or clear plastic. When light rays move from one substance into another (such as from air into paper) its speed changes. The change in speed causes the ray of light to be refracted or bent into a new path. The degree of refraction depends on the frequency of light. Light rays with the highest frequencies have the largest angle of refraction, or are bent the most. This is why only 70 - 90 % of available light is transmitted through the covering of a greenhouse. The rest of the light is refracted away from the greenhouse.

Most objects reflect some light. We can see things that are not luminous because they reflect some of the light that strikes them. This light is reflected back to our eyes.

Light-colored objects reflect more light than dark-colored objects. This is the reason light colored clothes are cooler to wear in the summer than dark colored clothing. It is also one reason plants are often grown in white hanging baskets on porches and decks during the summer. The white pot reflects more light than a dark pot. The soil in a white pot stays cooler than the soil in a green or black pot.

The colors of a substance depends on both the substances and the colors of light striking the substance. If white light strikes a violet object, all frequencies of light except violet are absorbed. Violet light is reflected.

Matter can also absorb light. Dark-colored objects absorb more light than light-colored objects do. This is apparent when you compare two cars that have been parked in the sun in the summer. Heat buildup occurs more rapidly in a car with dark interior than a car with light interior.

THE IMPORTANCE OF LIGHT TO PLANTS

Only about 2 or 3% of the light that reaches the earth from the sun is used by plants to make food for themselves. However, almost all plants and animals depend on plant's ability to use photosynthesis to create food. Plants use light energy along with water and carbon dioxide to make the food. Plants need the green material called chlorophyll to carry on photosynthesis. Chlorophyll is green because it reflects green light. It is found in the chloroplasts in plant cells. Chloroplasts can be found in many parts of a plant, however the leaves of the plant is the primary location of chloroplasts.

Several factors affect the rate that photosynthesis occurs in plants. However, light accounts for several of the factors. Some of the factors that affect the rate of photosynthesis are:

1. Wavelength of Light (Light Quality)
2. Light Intensity (Brightness of Light)
3. Daylength
4. Concentration of Carbon Dioxide in the Atmosphere
5. Temperature
6. Amount of water available to the plant
7. Developmental Stage of the Plant

Sunlight appears white to our eyes, but remember that it is made up of rays of different wavelengths and different colors of light. The wavelengths of light are also known as light quality. Since each different color of light has a different wavelength, the energy level of different colors of light is different. Blue light has a shorter wavelength and higher frequency than red light.

The quality of light effects plant growth, by determining how well it carries on photosynthesis. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the red and blue portions of the visible spectrum, and reflect the green portion. Light quality is especially important when plants are grown under fluorescent, incandescent, or other artificial lights such as HID (High intensity Discharge) lamps. In order for photosynthesis to occur, plants grown under artificial lighting must receive enough of the blue and red wavelengths. The amount of blue and red wavelengths vary with the different lighting systems. Incandescent lights have a high proportion of red and far-red light waves. Florescent lights have a high proportion of blue waves. Special Grow light florescent lights emit more of the red and far-red light waves. The differences in light quality is apparent when you observe the color of clothing under fluorescent lights, incandescent lights, & sunlight. The diffraction, or spreading out of electromagnetic waves as a result of its passing through an opening in a barrier, can be used to examine the wavelength of light waves of a particular source of light.

Light intensity or the brightness of light also effects plant growth. The intensity of light influences the amount of photosynthesis taking place. Light intensity can be measured in footcandles or luxes.

Each species of plants has a light intensity range that they grow best. Some plants require being grown in "full sun" because they require high intensities of light. Other plants are grown in "full-shade" because they grow best when exposed to very little light. The important thing to remember is to grow the plants with the light intensity that suits them the best. The intensity of light directly effects the size and shape of leaves and the type of growth of a plant. Plants that are grown at higher intensities of light (within the normal light intensity range for that species) generally have thicker and larger leaves than plants that are grown at lower light intensities. Also higher light intensities (within the normal light intensity range of that species) generally result in plants having a good green color, strong & thick stem with short internodes, and large normal root systems. Plants grown at low light intensities, may have a more yellowish-green color, weak spindly stem with long internodes, and fine hairlike roots.

Since sunlight is needed for photosynthesis to occur, the length of day directly effects photosynthesis. Generally, plants will grow faster under long days than short ones because the plants can make food for a longer period of time during long days.

WORK SHEET A

DIRECTIONS: Complete the following questions.

1. Energy that moves through empty space at the speed of light is called ___*electromagnetic radiation*___.

2. Electromagnetic waves are classified as ___*transverse*___ waves because they move like waves on a rope or waves of water on a lake.

3. Radiation is the transfer of ___*energy*___ by electromagnetic waves.

4. Two properties that differ from one type of electromagnetic waves to another are frequency and ___*wavelengths*___.

5. Visible light waves are not any different from any other ___*electromagnetic waves*___ except in frequency and wavelengths.

6. The ___*energy*___ of electromagnetic wavelengths depend on their wavelength.

7. Waves with shorter wavelengths have ___*greater*___ energy than those with longer wavelengths.

8. Visible light has ___*shorter*___ wavelengths than radio wavelengths.

9. Sunlight appears ___*white*___ to our eyes, even though it is made up of many different colors of light.

10. The ___*wavelength*___ of light varies from one color of light to another.

11. Violet light waves have the ___*highest*___ frequency of visible light and is refracted at the largest angle.

12. Violet light waves have the ___*shortest*___ wavelength of visible light.

13. Red light waves have the _lowest_ frequency of visible light and is refracted at the smallest angle.

14. Red light waves have the _longest_ wavelength of visible light.

15. When light rays move from one substance into another its _speed_ changes.

16. The path of light waves refracts or _bends_ as it moves from one substance to another substance.

17. We area able to see objects which are not luminous because most objects _reflect_ some light.

18. Light-colored objects _reflect_ more light than dark-colored objects.

19. Dark-colored objects _absorb_ more light than light-colored objects do.

20. The color of a substance depends on both the substance and the _color_ of light striking the substance.

Teaching Note: *Explain the following terms to the class and then assign Work Sheet B. The Students can find the definitions for these terms in the Student Information Guide. Students can complete Work sheet B during class or as homework.*

GLOSSARY OF SCIENTIFIC TERMS:

Diffraction - the spreading out of electromagnetic waves as a result of its passing through an opening in a barrier

Electromagnetic spectrum - the arrangement of electromagnetic waves according to their wavelength ranging from shortest to longest

Electromagnetic wave - a form of energy that moves through empty space at the speed of light

Energy - the capacity for moving matter from one place to another or changing matter from one substance to another

Frequency - the number of crests on a wave that pass a point in 1 second

Gamma rays - electromagnetic waves at the highest end of the spectrum often from nuclear radiation in the form of energy without mass or electrical charge

Hertz - unit of measure for measuring frequency of electromagnetic waves

Infrared radiation - electromagnetic waves with frequencies just lower than visible red light. Humans do not see infrared radiation but they feel it as heat.

Light Intensity - brightness of light measured in footcandles or luxes

Light Quality - the different wavelengths of light found in a source of light

Luminous - gives off light

Matter - anything that has mass and takes up space

Photosynthesis - plant's ability to make food from light, water, and carbon dioxide

Radiation - transfer of energy by electromagnetic waves

Refraction - the bending of waves as it moves from one substance to another because of a change in its speed.

Ultraviolet light - electromagnetic waves with frequencies just higher than visible violet light. Ultraviolet light is invisible to the human eye.

Visible light waves - light waves that we can see with our eyes

Visible spectrum - the band of colors that is produced when white light is refracted into its separate colors

Wavelength - the distance between 2 neighboring crests in a wave or the speed of the wave divided by its frequency

WORK SHEET B

Directions:

The answers to the following fill-in-the blank questions are terms which have something to do with Light--Part of the Electromagnetic Spectrum. Choose the term from the word list below that best answers each question. Each term may be used only once.

Word List:

Diffraction
Electromagnetic spectrum
Electromagnetic waves
Energy
Frequency
Gamma rays
Hertz
Infrared radiation
Light Intensity
Light Quality
Luminous
Matter
Photosynthesis
Radiation
Refraction
Ultraviolet light
Visible light waves
Visible spectrum
Wavelength

Fill-in-the blank:

1. Anything that has mass and takes up space is called *matter*.
2. Objects that give off light are called *luminous*.
3. *Hertz* is the unit of measure used for measuring the frequency of electromagnetic waves.
4. *Infrared radiation* are electromagnetic waves with frequencies just lower than visible red light.
5. The *visible spectrum* is the band of colors that is produced when white light can is refracted into its separate colors.

6. The bending of waves, or _refraction_ occurs as light rays move from one substance to another because of a change in its speed.

7. _Gamma Rays_ are electromagnetic waves at the highest end of the spectrum, often from nuclear radiation in the form of energy without mass or electrical charge.

8. _Ultraviolet light_ is invisible to the human eye and has frequencies just higher than visible violet light.

9. _Energy_ is the capacity of moving matter from one place to another or changing matter from one substance to another.

10. _Electromagnetic waves_ are a form of energy that move through empty space at the speed of light.

11. Electromagnetic waves are measured by their _frequency_, or number of crests that pass a point per second, as they travel.

12. The _electromagnetic spectrum_ is the range of electromagnetic waves from highest to lowest frequency.

13. Light waves that we can see are called _visible light waves._

14. The transfer of energy by electromagnetic waves is called _radiation._

15. _Photosynthesis_ is a plant's ability to make food from light, water, carbon dioxide.

16. _Light quality_ is another way of describing the wavelengths of light.

17. _Diffraction_ is the spreading out of electromagnetic waves as a result ` its passing through an opening in a barrier.

18. The distance between 2 neighboring crests in a wave is called _wavelength_.

19. The brightness of light, or _light intensity_ is measured in footcandles or luxes.

Teaching Note: *The students may use the Light--Part of the Electromagnetic Spectrum Study Guide Computer Program for individual study and review for this lesson.*

Day 3

Teaching Note: *Discuss the Scientific Terms Work Sheet (Work Sheet B) with the class.*

Teaching Note: *Explain the following information about the importance of light to plants to the class.*

Lecture Note: Use overhead # 11 (IMPORTANCE OF LIGHT TO PLANTS)

THE IMPORTANCE OF LIGHT TO PLANTS

- Only about 2 or 3% of the light that reaches the earth from the sun is used by plants to make food for themselves. However, almost all plants and animals depend on plant's ability to use photosynthesis to create food. People depend on plants to carry on photosynthesis so they can eat the plants, which is the case with fruits, vegetables, and grains that are used in breads and cereals, or they eat animals that are dependent on plants for food. Plants use light energy along with water and carbon dioxide to make the food. Plants need the green material called chlorophyll to carry on photosynthesis. Chlorophyll is green because it reflects green light. It is found in the chloroplasts in plant cells. Chloroplasts can be found in many parts of a plant, however the leaves of the plant is the primary location of chloroplasts.

Lecture Note: Use overhead # 12 (FACTORS THAT EFFECT PHOTOSYNTHESIS)

- Several factors effect the rate that photosynthesis occurs in plants. However, light accounts for several of the factors. Some of the factors that affect the rate of photosynthesis are:
  1. Wavelength of Light (Light Quality)
  2. Light Intensity (Brightness of Light)
  3. Daylength
  4. Concentration of Carbon Dioxide in the Atmosphere
  5. Temperature
  6. Amount of water available to the plant
  7. Developmental Stage of the Plant

- Sunlight appears white to our eyes, but remember that it is made up of rays of different wavelengths and different colors of light. The wavelengths of light are also known as light quality. Since each different color of light has a different wavelength, the energy level of different colors of light is different. Blue light has a shorter wavelength and higher frequency than red light.

Lecture Note: Use overhead # 13 (HOW LIGHT QUALITY EFFECTS PLANTS)

- The quality of light effects plant growth, by determining how well it carries on photosynthesis. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the red and blue portions of the visible spectrum, and reflect the green portion. Light quality is especially important when plants are grown under fluorescent, incandescent, or other artificial lights such as HID (High-Intensity-Discharge) lamps. In order for photosynthesis to occur, plants grown under artificial lighting must receive enough of the blue and red wavelengths. The amount of blue and red wavelengths vary with the different lighting systems. Incandescent lights are not used to any great extent as supplemental light in the production of plants because they give off so much heat and and because they have a high proportion of red and far-red light waves which causes plants to have a tall soft growth. Florescent lamps are used primarily in growth chambers and growing rooms for the production of seedlings. Traditional fluorescent lamps emit light mainly in the blue range of the visible spectrum. Special grow lights are available which emit more light waves in the red and far-red range. The differences in light quality is apparent when you observe the color of clothing under fluorescent lights, incandescent lights, & sunlight. The color of the clothing changes as the type of light changes.

- The diffraction, or spreading out of electromagnetic waves as a result of its passing through an opening in a barrier, can be used to examine the wavelength of light waves of a particular source of light.

Lecture Note: Use overhead # 14 (HOW LIGHT INTENSITY EFFECTS PLANTS)

- Light intensity or the brightness of light also effects plant growth. The intensity of light influences the amount of photosynthesis taking place. Light intensity can be measured in footcandles or luxes.

- Each species of plants has a light intensity range that they grow best. Some plants require being grown in "full sun" because they require high intensities of light. Other plants are grown in "full-shade" because they grow best when exposed to very little light. The important thing to remember is to grow the plants with the light intensity that suits them the best. The intensity of light directly effects the size and shape of leaves and the type of growth of a plant.

- Plants that are grown at higher intensities of light (within the normal light intensity range for that species) generally have thicker and larger leaves than plants that are grown at lower light intensities. Also higher light intensities (within the normal light intensity range of that species) generally result in plants having a good green color, strong & thick stem with short internodes, and large normal root systems.

- Plants grown at low light intensities, may have a more yellowish-green color, weak spindly stem with long internodes, and fine hairlike roots.

Lecture Note: Use overhead # 15 (HOW DAYLENGTH EFFECTS PHOTOSYNTHESIS)

- Since sunlight is needed for photosynthesis to occur, the photoperiod, or length of day directly effects photosynthesis. Generally, other factors being equal plants will grow faster under long days than short ones because the plants can make food for a longer period of time during long days. This is why so many plants that are grown in the greenhouse in the late spring, grow more rapidly and are of better quality than plants grown during the winter.

- Many other plant responses are influenced by photoperiod. Photoperiod can also affect other aspects of plant production such as flowering or fruit production. These are not related to how light influences photosynthesis and plant growth.

WORK SHEET C

A. Fill-in-the blank:

1. Almost all plants and animals depend on plant's ability to use *photosynthesis* to create food.

2. Plants use *light energy* along with water and carbon dioxide to make the food.

3. Plants need the green material called *chlorophyll*, found in the chloroplasts of the leaves, to carry on photosynthesis.

4. Chlorophyll is *green* because it reflects green light.

5. Sunlight is made up of *all* colors of light.

6. Since each different color of light has a different wavelength, the *energy* level of each color of light is different.

7. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the *red* and *blue* portion of the visible spectrum.

8. *Light quality* is especially important when plants are grown under artificial lights.

9. Each species of plants has a *light intensity* range they grow best.

10. Plants generally grow *faster* during long days than short ones.

B. Short Answer:

11. What factors affect the rate of photosynthesis?

Some of the factors that affect the rate of photosynthesis are:

1. *Wavelength of Light (Light Quality)*
2. *Light Intensity (Brightness of Light)*
3. *Daylength*
4. *Concentration of Carbon Dioxide in the Atmosphere*
5. *Temperature*
6. *Amount of water available to the plant*
7. *Developmental Stage of the Plant.*

12. What are the characteristics of plants grown at higher light intensities?

Plants that are grown at higher intensities of light (within the normal light intensity range for that species) generally have thicker and larger leaves than plants that are grown at lower light intensities. Also higher light intensities (within the normal light intensity range of that species) generally result in plants having a good green color, strong & thick stem with short internodes, and large normal root systems.

13. What are the characteristics of plants grown at lower light intensities?

Plants grown at low light intensities, may have a more yellowish-green color, weak spindly stem with long internodes, and fine hairlike roots.

Teaching Note: *The next activity, "Growing Plants under Different Colors of Light" cannot be performed until after the corn seedlings from Activity 1 emerge. The steps and procedures for the following activity are found in Student Activity - 2 Information Sheet, "Growing Plants under Different Levels of Light. Plants are observed for 3 weeks during this activity. Students can take notes and record them on the Student Activity Sheet during the teacher demonstration. The activity and demonstration steps are summarized below.*

Activity Summary: *Students can work in the same groups of 2 - 5 students as previous activity. After corn seedlings have emerged, show students how to thin plants to one plant per pot. (Scissors can be used to snip out the extra plant.) Demonstrate measuring plants to the class. Demonstrate taping colored cellophane over the top of the pot to the class. Students will complete Parts A & B of the Student Activity Record Sheet.*

Teaching Note: *Assign and discuss Student Activity - 2 Information Sheet, "Growing Plants Under Different Colors of Light". Provide the students with supplies for the student activity and answer any questions. Coordinate the Student Activity.*

Teaching Note: *After plants have been observed for 3 weeks, Parts C & D of the Student Activity Record Sheet need to be completed. Plant height, stem width, & plant appearance will be used to determine which plant grew the best. After the 3 week observation period, several other variables may be used if equipment is available and time allows. Mass of plant can be determined by cutting the plant off at the soil surface and measuring the weight of the plant on a triple beam balance. Stem strength can be determined by attaching a spring scale around the stem of the plant at the lower set of leaves. The scale is pulled until the stem breaks and the measurement is recorded. Light intensity under the different cellophane sheets may also be taken if a light meter is available.*

STUDENT ACTIVITY - 2
INFORMATION SHEET

GROWING PLANTS UNDER DIFFERENT COLORS OF LIGHT.

a. **Introduction:** Research in the production of plants grown under artificial light is an ongoing area of plant production. Scientists need to understand how light quality affects plant growth in order to develop new and more efficient lighting systems for plant production.

b. **Purpose:** To determine which wavelengths of light (colors) have the greatest effect on plant growth.

c. **What Each Group of Students Needs:**

green cellophane	clear tape
blue cellophane	ruler
red cellophane	scissors
yellow cellophane	5 corn plants
clear cellophane	potting soil

d. **Here's How:**

1. Wait until a corn seedling emerges in each pot that was planted in Student Activity - 1, before starting this activity. After a seeding emerges in each pot, complete the following steps.

2. After seedlings in all 5 pots have emerged, thin plants so there is only 1 plant in each pot.

3. Measure the height of each plant in centimeters. (Measure from the bottom of the pot to the tip of the plant shoot.) Then measure the width of the stem in millimeters. This measurement should be taken at the same place on each of the corn plants.

4. Record the plant's measurements in Part B of the Student Activity Record Sheet.

5. Water plants, if needed so soil is moist but not soggy.

6. Get a green, blue, red, yellow, and clear piece of cellophane from your teacher.

7. Using a different color of cellophane for each pot, make a cellophane tent covering the corn plant in the pot. Make the tent large enough to allow for the corn plant to grow. Tape the cellophane tent together so it covers the corn plant in the pot. Tape the cellophane to the pot to hold it in place.

8. Place all 5 plants together in a place where they will receive plenty of light. (Be careful not to place the pots in a location where they will get too hot.)

9. Clean up your work area.

10. Make predictions about the outcome of this activity and record the predictions in Part A of your Student Activity Record Sheet.

11. Observe the plants for 3 weeks and record measurements and observations in Part B of the Student Activity Record Sheet. Measurements of the corn plant should be taken 3 times a week. The height of each plant should be recorded in centimeters. The stem width of each plant should be recorded in millimeters. Loosen the cellophane on the pot on one end if necessary to make the measurements. Remember to tape the cellophane back onto the pot when you are finished taking measurements.

12. Water the plants as needed, so soil is moist but not soggy.

13. Complete Part C & D of the Student Activity Record Sheet after you have observed the plants for 3 weeks.

STUDENT ACTIVITY - 2
RECORD SHEET

A. Predictions:

1. What do you predict will happen with the 5 plants?

Answers will vary.

2. Describe the color of light that will pass through the clear cellophane.

The light passing through the clear cellophane is white light, containing all the colors of visible light.

3. How will the color of light change as it passes through the colored cellophane?

Answers will vary. However, by doing Student Activity-3, students will get a better understanding of how the color of light does change as it passes through the cellophane.

4. Which plant will grow the most? Which color of light will it receive?

Answers will vary.

5. Which plant will grow the least? Which color of light will it receive?

Answers will vary.

6. Why will plant growth vary with the color of light that the plant receives?

Plants grow better under certain wavelengths than other.

B. Observations--Plant Growth:

Measure the height of each plant in centimeters & record measurements of each plant in the table below.(Measure from the bottom of the pot to the tip of the plant shoot.) Measurements of stem width (in mm) can be recorded in the table below also. Measurements should be taken 3 times a week for 3 weeks.

WEEK #	DATE		COLOR OF CELLOPHANE			
		GREEN	BLUE	RED	YELLOW	CLEAR
1						
1						
1						
2						
2						
2						
3						
3						
3						

B. Observations--Plant Appearance:

Observations about each plant's appearance should be recorded in the table below. Note plant color, size of leaves, stem diameter, and space between internodes when making your observations.

WEEK #	DATE		COLOR OF CELLOPHANE			
		GREEN	BLUE	RED	YELLOW	CLEAR
1						
1						
1						
2						
2						
2						
3						
3						
3						

C. Final Data:

1. Rank the plants by their height (from tallest to shortest) and record the final measurement of height.

2. Rank the plants by their stem diameter (from thickest to thinnest) and record the final measurement of stem diameter.

3. Rank the plants by their appearance (from healthiest to least healthy).

Complete Questions 4, 5, & 6 only if your instructor assigns them.

4. Rank the plants by plant mass.

5. Rank the plants by stem strength.

6. Rank the different colors of cellophane by the light intensity plants received (most to least).

D. Conclusions:

Teaching Note: *The results to the activity may not be as predicted because the colored cellophane may not change the wavelength (color) as expected. Activity - 3 can be used to observe the diffraction of light through each color of cellophane to help explain results.*

Answer the following questions after you have observed plant growth and plant appearance for 3 weeks.

1. Describe the color of light which passed through the clear cellophane.

   The light passing through the clear cellophane is white light, containing all the colors of visible light.

2. Which plant grew the most? Which color of light did it receive?

   Answers will vary. Probably the plant receiving the white light, growing under clear cellophane, will have grown the most.

3. Which plant grew next to the most? Which color of light did it receive?

   Answers will vary, but probably the plant receiving the red light would have next to the most growth.

4. Which plant grew the least? Which color of light did it receive?

   Answers will vary, but the plant growing under the green cellophane will probably grow the least.

5. What color of light is reflected by chlorophyll in the plant?

   The green chlorophyll reflects most of the green light that it receives.

6. What wavelengths of light should artificial lights used for growing plants give off?

   Answers will vary, but should indicate red light or white light.

Teaching Note:	*The students may use the Light--Part of the Electromagnetic Spectrum Study Guide Computer Program for individual study and review for this lesson.*

Day 4

Teaching Note:	*Discuss Part A of Student Activity - 2 Record Sheet. After Student Activity - 3, students may want to change their predictions.*
Teaching Note:	*The steps and procedures for the next activity are found in the Student Activity - 3 "Diffraction of Light through Different Colors of Cellophane". Students can take notes and record them on the Student Activity Note Sheet during the teacher demonstration. The activity and demonstration steps are summarized below:*
Activity Summary:	*Students can work in the same groups of 2 - 5 students as previous activity. The cardboard tube from paper towel, wrapping paper, toilet tissue, can be used when the activity calls for a cardboard tube. Demonstrate how to make a diffraction tube. Show students how to look through the diffraction tube. The teacher may want the student groups to use a different colored cellophane on their diffraction tube and switch tubes so students can observe light rays that have been filtered by all colors of cellophane. If this is not desired, the teacher can have students remove the colored cellophane from their tube and replace it with another color of cellophane to make observations.*
Teaching Note:	*Assign and discuss Student Activity - 3 Information Sheet, "Diffraction of Light through Different Colors of Cellophane". Provide the students with supplies for the student activity and answer any questions. Coordinate the Student Activity. The students can record their observations of Student Activity - 3 Record Sheet.*

STUDENT ACTIVITY - 3
INFORMATION SHEET

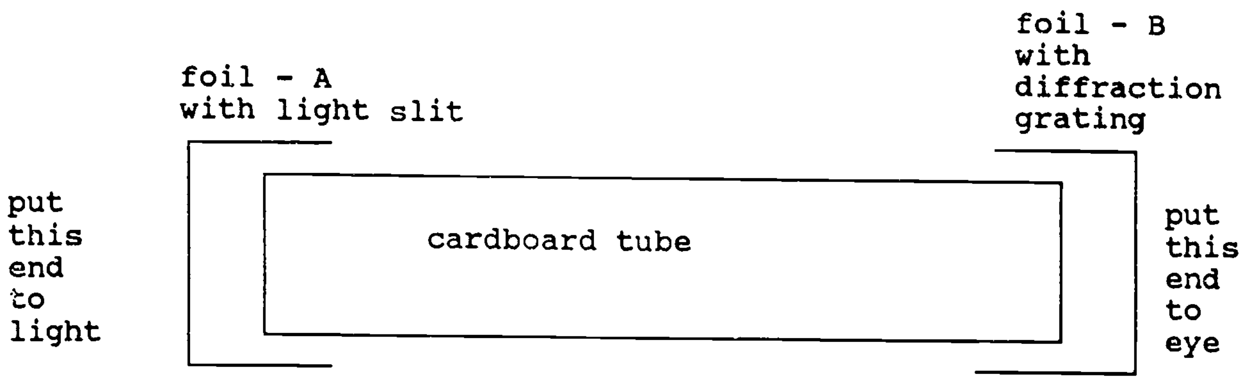
DIFFRACTION OF LIGHT THROUGH DIFFERENT COLORS OF CELLOPHANE

a. **Purpose:** To compare the diffraction spectrum of light after it has passed through the different colors of cellophane. This will provide us with information about the actual wavelength of light passing through the cellophane filters.

c. **What Each Group of Students Needs:**

diffraction grating
cardboard tube
masking tape
knife
scissors
aluminum foil
5 pieces of colored cellophane (green, blue, red, yellow, clear)

c. **Here's How:**



1. Get a cardboard tube from your instructor.

2. Cut 2 pieces of aluminum foil so they are large enough to fit over the ends of the cardboard tube.

3. Place 1 piece of aluminum foil (Piece A) over one of the ends of the tube and tape in place.

4. Use a knife to cut a slit in the piece of foil that covers the end of the cardboard tube. This is the light slit. Light will enter the tube through this slit.

5. Cut a piece of colored cellophane, so it is large enough to fit over the end of the cardboard tube. Tape the colored cellophane over the slit in the aluminum foil.

6. Place the other piece of aluminum foil (Piece B) on the other end of the cardboard tube. Tape in place.

7. In the center of the aluminum foil, (Piece B), cut a square shaped hole. The size of the hole will vary depending on the size of the tube, but a general recommendation is the hole in the foil should be approximately 1 cm^2.

8. Get a piece of diffraction grating from your instructor. A diffraction grating when held between the eye and light source will let us see the color bands in the spectrum of light.

8. Cut a piece of diffraction grating, a little larger than the square hole in the aluminum foil (Piece B).

9. Place the diffraction grating over the square hole in the aluminum foil (Piece B).

10. Turn the diffraction grating until the lines in the diffraction grating are parallel to the light slit on the other end of the tube.

11. Holding the diffraction grating in place, hold the diffraction tube up to the same light that you are using to grow the plants in Student Activity - 2. Point the light slit towards the light and look through the diffraction grating.

12. Observe the colors of light transmitted by the colored cellophane filter. Record your observations on Student Activity - 3 Record Sheet.

13. Now turn the diffraction grating so the lines in the diffraction grating are perpendicular to the light slit on the other end of the tube.

14. Hold the tube up to the light and observe the colors of light transmitted by the cellophane filter.

15. Remove the colored cellophane and replace with another color of cellophane. Observe and record your observations on the Student Activity - 3 Record Sheet and repeat this procedure until you have observed the colors transmitted by each cellophane filter.

16. Clean up your work area when finished.

17. Study your observations that you recorded on Activity - 3 Record Sheet. Are the results as you expected?

STUDENT ACTIVITY - 3
RECORD SHEET

1. Record your observations from looking at light through the 5 colored cellophane filters.

FILTER COLOR	PARALLEL TO LIGHT SLIT	PERPENDICULAR TO LIGHT SLIT
1. GREEN		
2. BLUE		
3. RED		
4. YELLOW		
5. CLEAR		

Teaching Note: *Review information about Light and the Electromagnetic Spectrum with students. Some key facts are listed below:*

Teacher Review:

ELECTROMAGNETIC SPECTRUM

The sun's energy travels through space to the earth as electromagnetic radiation waves. Any energy that moves through empty space at the speed of light is called electromagnetic radiation.

Electromagnetic waves are classified as transverse waves. The transfer of energy by electromagnetic waves is called radiation.

Two properties that differ from one type of electromagnetic waves to another are frequency and wavelengths. Electromagnetic waves that have long wavelengths and low frequency are less energetic than wavelengths that have short wavelengths and high frequency.

The energy of electromagnetic wavelengths depend on wavelength. Waves with shorter wavelengths have greater energy than those with longer wavelengths. The electromagnetic spectrum is the arrangement of electromagnetic waves according to their wavelength.

THE VISIBLE SPECTRUM

Since visible light is part of the electromagnetic spectrum it can be measured by its frequency and wavelength. It can also be measured by its intensity. Visible light waves are the light waves we can see with our eyes and are between 400 and 760 billionth of a meter long. They are found near the middle of the electromagnetic spectrum.

Sunlight appears white to our eyes, even though it is made up of all the colors of the visible spectrum. Each color of light has a different frequency.

The wavelength of light varies from one color of light to another. Each color of light corresponds to a different wavelength.

Light is transmitted when it passes through matter such as air, water, glass, or clear plastic. When light rays move from one substance into another (such as from air into paper) its speed changes. The change in speed causes the ray of light to be refracted or bent into a new path. The degree of refraction depends on the frequency of light. Light rays with the highest frequencies have the largest angle of refraction, or are bent the most.

Most objects reflect some light. We can see things that are not luminous because they reflect some of the light that strikes them. This light is reflected back to our eyes.

Light-colored objects reflect more light than dark-colored objects. The colors of a substance depends on both the substances and the colors of light striking the substance.

Matter can also absorb light. Dark-colored objects absorb more light than light-colored objects do.

THE IMPORTANCE OF LIGHT TO PLANTS

Almost all plants and animals depend on plant's ability to use photosynthesis to create food. Plants use light energy along with water and carbon dioxide to make the food. Plants need the green material called chlorophyll to carry on photosynthesis. Chlorophyll is green because it reflects green light. It is found in the chloroplasts in plant cells.

Several factors affect the rate that photosynthesis occurs in plants. However, light accounts for several of the factors. Some of the factors that affect the rate of photosynthesis are:

1. Wavelength of Light (Light Quality)
2. Light Intensity (Brightness of Light)
3. Daylength
4. Concentration of Carbon Dioxide in the Atmosphere
5. Temperature
6. Amount of water available to the plant
7. Developmental Stage of the Plant

Sunlight appears white to our eyes, but remember that it is made up of rays of different wavelengths and different colors of light. The wavelengths of light are also known as light quality. Since each different color of light has a different wavelength, the energy level of different colors of light is different.

The quality of light effects plant growth, by determining how well it carries on photosynthesis. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the red and blue portions of the visible spectrum, and reflect the green portion.

Light intensity or the brightness of light also affects plant growth. The intensity of light influences the amount of photosynthesis taking place.

Each species of plants has a light intensity range that they grow best. The intensity of light directly effects the size and shape of leaves and the type of growth of a plant. Plants that are grown at higher intensities of light (within the normal light intensity range for that species) generally have thicker and larger leaves than plants that are grown at lower light intensities. Also higher light intensities (within the normal light intensity range of that species) generally result in plants having a good green color, strong & thick stem with short internodes, and large normal root systems. Plants grown at low light intensities, may have a more yellowish-green color, weak spindly stem with long internodes, and fine hairlike roots.

Since sunlight is needed for photosynthesis to occur, the length of day directly effects photosynthesis. Generally, plants will grow faster under long days than short ones because the plants can make food for a longer period of time during long days.

Teaching Note: *The students may use the Light--Part of the Electromagnetic Spectrum Computer Quiz for individual evaluation.*

Day 5:

Teaching Note: *Students should complete Work Sheet D: Student Review during class time.*

WORK SHEET D: STUDENT REVIEW

1. What is electromagnetic radiation?

   Energy that moves through empty space at the speed of light is called electromagnetic radiation.

2. What two properties differ from one type of electromagnetic radiation to another?

   Two properties that differ from one type of electromagnetic waves to another is frequency and wavelengths.

3. How does wavelength effect the energy of electromagnetic waves?

   The energy of electromagnetic wavelengths depend on wavelength. Waves with shorter wavelengths have greater energy than those with longer wavelengths.

4. What is the electromagnetic spectrum?

   The electromagnetic spectrum is the arrangement of electromagnetic waves according to their wavelength.

5. Where is visible light found on the electromagnetic spectrum?

   Visible light is found near the middle of the electromagnetic spectrum.

6. How do the colors of the visible spectrum differ from one another?

   Each color of light has a different frequency and wavelength.

7. Which color of light has the most energy?

   Violet light waves have the highest frequency and shortest wavelength of visible light and is refracted at the largest angle. Shorter wavelengths have a higher frequency and more energy.

8. What color is sunlight?

Sunlight appears white to our eyes, even though it is made up of many different colors of light.

9. What causes light to refract as it moves from one substance to another substance?

The refraction is due to the change in the speed of light waves as it moves from one object to another.

10. What determines the color of a substance?

The color of a substance depends on both the substances and the colors of light striking the substance.

11. Why is light energy important to our food supply?

Our food supply, plants, need light energy to carry on photosynthesis. Plants create food during photosynthesis.

12. How does light quality affect photosynthesis?

When plants are grown under light that contains all visible wavelengths, they absorb mostly from the red and blue portions of the visible spectrum and reflect the green portion.

13. How does light intensity affect photosynthesis?

The intensity of light directly affects the size and shape of leaves and the type of growth of a plant.

14. How does daylength affect photosynthesis?

Plants will grow faster under long days than short ones because the plants can make food for a longer period of time during long days.

Teaching Note: *Students should check their plants daily for 10 days. Measurements and observations should be recorded on the Student Activity Record Sheet. Students should complete Part C of the Student Activity Record Sheet at the termination of the activity. The results from the activity, "Growing plants under different colors of light" should be discussed by the class after Part C of the Student Activity Record Sheet is completed.*

Teaching Note: *The students may use the Light--Part of the Electromagnetic Spectrum Computer Quiz for individual evaluation.*

Teaching Note: *Quiz 1 can be used to evaluate student's knowledge of Light--Part of the Electromagnetic Spectrum.*

QUIZ 1

A: MATCHING:

d. 1. Object that transmits light — a. light bulb

b. 2. Object that reflects most of the light — b. white cloth

c. 3. Object that absorbs light — c. black plastic

a. 4. Luminous object — d. clear glass

B. TRUE OR FALSE:

TRUE 5. Dark-colored objects absorb more light than light colored objects.

TRUE 6. Visible light is found near the middle of the electromagnetic spectrum.

FALSE 7. The only difference between visible light and other electromagnetic radiation is that we can see visible light.

TRUE 8. Refraction of light waves occurs when the speed of the light waves is changed

C: SHORT ANSWER:

9. How are light waves similar to radio waves?

   BOTH TRAVEL AT THE SPEED OF LIGHT.

10. How are we able to see objects that are not luminous?

   WE SEE THEM FROM THE LIGHT THESE OBJECTS REFLECT.

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E: AUDIO VISUAL MATERIALS:

1. ELECTROMAGNETIC RADIATION
2. TRANSVERSE WAVES
3. COMPARING TWO WAVE MODELS
4. ELECTROMAGNETIC SPECTRUM
5. VISIBLE SPECTRUM/ELECTROMAGNETIC SPECTRUM
6. VISIBLE SPECTRUM
7. A FEW SOURCES OF LIGHT
8. TRANSMITTING LIGHT
9. REFLECTING LIGHT
10. ABSORBING LIGHT
11. IMPORTANCE OF LIGHT TO PLANTS
12. FACTORS THAT EFFECT PHOTOSYNTHESIS
13. HOW LIGHT QUALITY EFFECTS PLANTS
14. HOW LIGHT INTENSITY EFFECTS PLANTS
15. HOW DAYLENGTH EFFECTS PHOTOSYNTHESIS

OH1

ELECTROMAGNETIC RADIATION:

1. ENERGY THAT MOVES AT THE SPEED OF LIGHT - 300,000 KILOMETERS PER SECOND

3. EXAMPLES:

   COSMIC WAVES

   GAMMA WAVES

   X-RAYS

   ULTRAVIOLET LIGHT

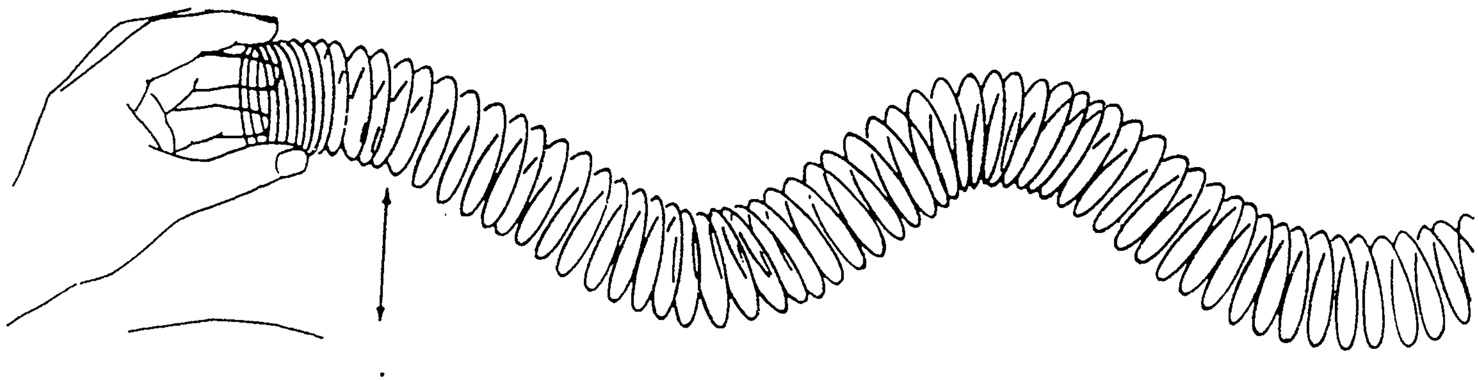
   VISIBLE LIGHT

   INFRARED RADIATION

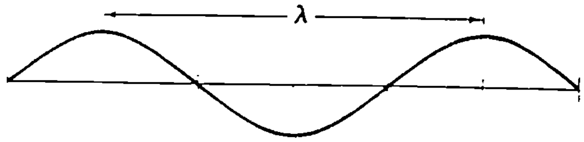
   MICROWAVES

   RADIO WAVES

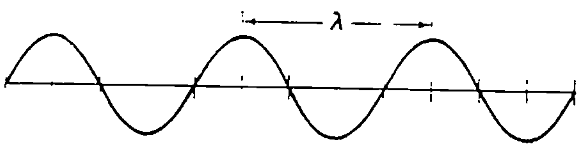
TRANSVERSE WAVES



COMPARING TWO WAVE MODELS

1. 

LONG WAVELENGTH
LOW FREQUENCY
LESS ENERGETIC

2. 

SHORT WAVELENGTH
HIGH FREQUENCY
MORE ENERGETIC

OH4

ELECTROMAGNETIC SPECTRUM

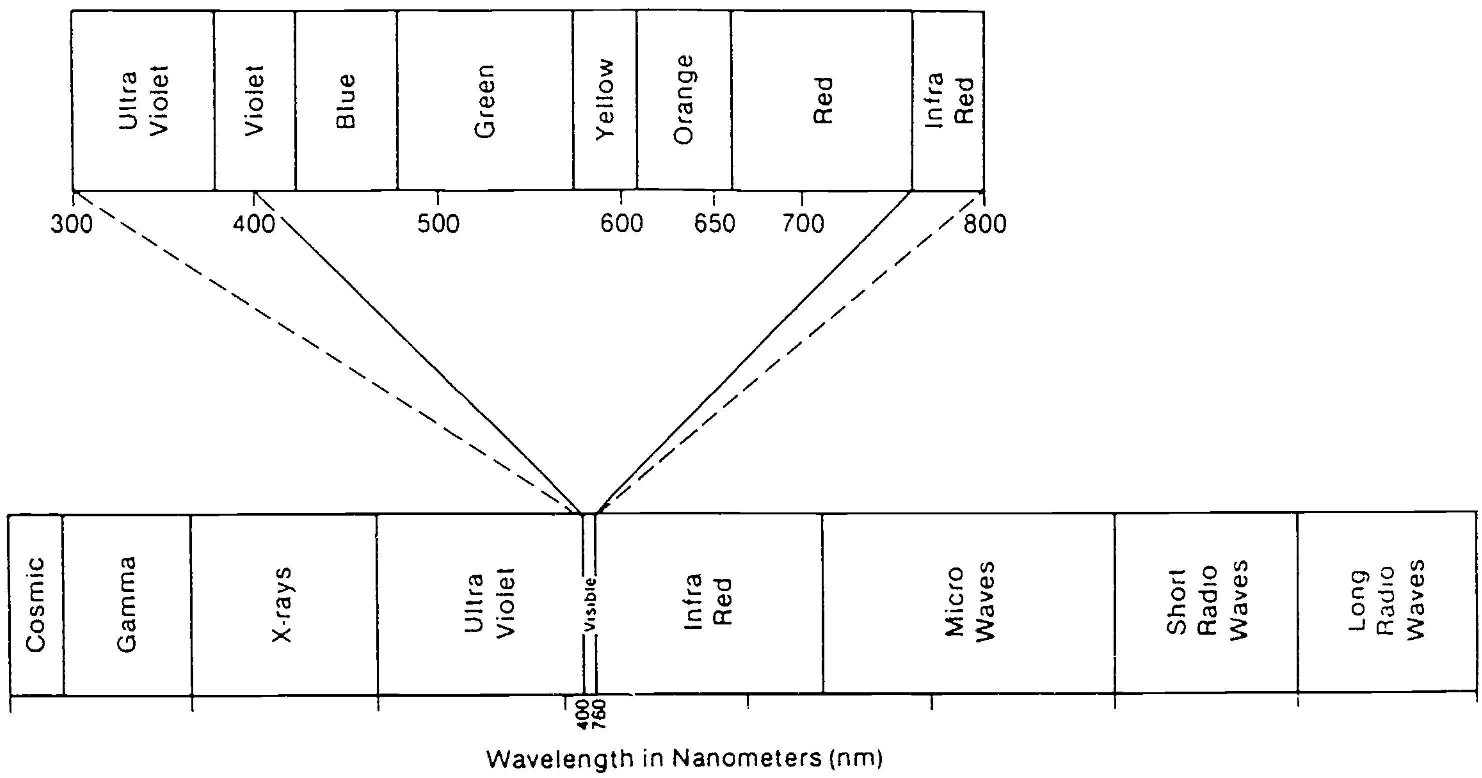
SHORTER WAVELENGTH & HIGHER FREQUENCY = MORE ENERGY

SHORT WAVES	10^{24} hertz	GAMMA RAYS
	10^{20} hertz	X - RAYS
	10^{18} hertz	ULTRAVIOLET LIGHT
	10^{15} Hertz	**VISIBLE LIGHT**
	10^{14} hertz	INFRARED RADIATION
	10^{11} hertz	MICROWAVES
LONG WAVES	10^{8} hertz	RADIO WAVES

LONGER WAVELENGTH & LOWER FREQUENCY = LESS ENERGY

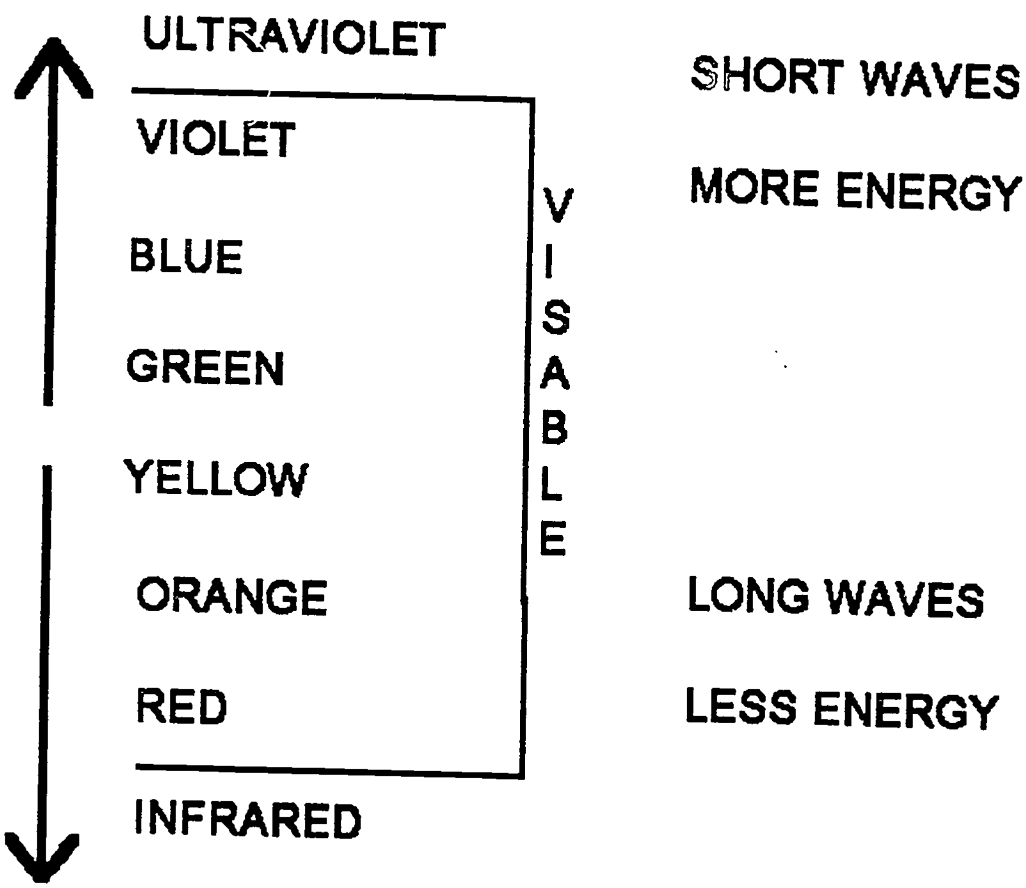
OH5

VISIBLE SPECTRUM / ELECTROMAGNETIC SPECTRUM



OH6

VISIBLE SPECTRUM



OH7

A FEW SOURCES OF LIGHT:

1. SUN

2. FIRE

3. LIGHT BULBS

OH8

TRANSMITTING LIGHT

1. LIGHT MAY BE TRANSMITTED THROUGH MATTER:

2. SPEED OF LIGHT CHANGES WHEN TRANSMITTED

3. SPEED CHANGE CAUSES LIGHT WAVES TO REFRACT

4. DEGREE OF REFRACTION DEPENDS ON FREQUENCY OF LIGHT

5. THE HIGHER THE FREQUENCY, THE LARGER THE ANGLE OF REFRACTION

OH9

REFLECTING LIGHT:

A. MOST OBJECTS REFLECT SOME LIGHT.

B. REFLECTED LIGHT GIVES PEOPLE THE ABILITY TO SEE OBJECTS THAT ARE NOT LUMINOUS.

C. LIGHT-COLORED OBJECTS REFLECT MORE LIGHT THAN DARK-COLORED OBJECTS.

D. COLOR OF A SUBSTANCE DEPENDS ON THE SUBSTANCE AND THE LIGHT STRIKING IT

OH10

ABSORBING LIGHT:

DARK-COLORED OBJECTS ABSORB MORE LIGHT THAN LIGHT-COLORED OBJECTS.

IMPORTANCE OF LIGHT TO PLANTS

1. PEOPLE, ANIMALS, & PLANTS DEPEND ON PLANTS TO MAKE FOOD
2. LIGHT ENERGY IS NEEDED FOR PLANTS TO MAKE FOOD (PHOTOSYNTHESIS)
3. THE GREEN CHLOROPHYLL NEEDED TO MAKE FOOD IS FOUND MAINLY IN PLANT LEAVES
4. CHLOROPHYLL IS GREEN BECAUSE IT REFLECTS GREEN LIGHT

FACTORS THAT EFFECT PHOTOSYNTHESIS

1. Wavelength of Light (Light Quality)
2. Light Intensity (Brightness of Light)
3. Daylength
4. Concentration of Carbon Dioxide in the Atmosphere
5. Temperature
6. Amount of water available to the plant
7. Developmental Stage of the Plant

OH13

HOW LIGHT QUALITY EFFECTS PLANTS

1. PLANTS ABSORB MAINLY RED & BLUE LIGHT WAVES

2. PLANTS REFLECT THE GREEN LIGHT WAVES

HOW LIGHT INTENSITY EFFECTS PLANTS

1. EACH PLANT SPECIES HAS A LIGHT INTENSITY RANGE BEST SUITED FOR THEM (Full-Sun to Full-Shade)

2. HIGH LIGHT INTENSITIES YIELD PLANTS WITH:
   THICKER LEAVES
   LARGER LEAVES
   GOOD, GREEN COLOR
   STRONG, THICK STEMS
   SHORT INTERNODES ON STEM
   LARGE NORMAL ROOT SYSTEMS

3. LOW LIGHT INTENSITIES YIELD PLANTS WITH:
   THINNER LEAVES
   SMALLER LEAVES
   YELLOWISH GREEN COLOR
   WEAK SPINDLY STEMS
   LONG INTERNODES ON STEMS
   FINE HAIRLIKE ROOTS

OH15

HOW DAYLENGTH EFFECTS PHOTOSYNTHESIS

1. PLANTS HAVE MORE SUNLIGHT TO MAKE FOOD ON LONG DAYS THAN SHORT DAYS

2. PLANTS GROW QUICKER DURING LONG DAYS THAN SHORT DAYS

F. STUDENT HANDOUTS AND QUIZZES

Student Information Guide

Work Sheet A

Work Sheet B

Work Sheet C

Work Sheet D

Student Activity Note Sheet

Student Activity Information Sheets

Student Activity Record Sheets

Quiz 1

STUDENT INFORMATION GUIDE

LIGHT--
PART OF THE ELECTROMAGNETIC SPECTRUM

ELECTROMAGNETIC SPECTRUM
The sun's energy travels through space to the earth as electromagnetic radiation waves. Any energy that moves through empty space at the speed of light is called electromagnetic radiation. Electromagnetic waves travel at the speed of 300,000 kilometers per second (186,000 miles per second.

Some examples of electromagnetic radiation are cosmic waves, gamma waves, x-rays, ultraviolet light, visible light, infrared radiation, microwaves, and radio waves. The cosmic and gamma wavelengths are very short when compared to radio waves.

Electromagnetic waves are classified as transverse waves. They travel like the waves on a rope or waves of water on a lake. The transfer of energy by electromagnetic waves is called radiation.

Two properties that differ from one type of electromagnetic waves to another are frequency and wavelengths. For example, visible light waves are different from other electromagnetic waves by their frequency and wavelengths. The frequency of electromagnetic waves is defined as the number of waves that pass a given point per second. Electromagnetic wavelength is defined as the distance between two neighboring crests in a wave. Electromagnetic waves that have long wavelengths and low frequency are less energetic than wavelengths that have short wavelengths and high frequency.

The energy of electromagnetic wavelengths depend on wavelength. Waves with shorter wavelengths have greater energy than those with longer wavelengths. The electromagnetic spectrum is the arrangement of electromagnetic waves according to their wavelength. The electromagnetic spectrum includes gamma rays, x-rays, ultraviolet light, light, infrared radiation, microwaves, and radio waves. Gamma radiation waves are the shortest wavelengths and have the greatest energy. Radio waves are the longest wavelengths and have the least energy.

THE VISIBLE SPECTRUM

Since visible light is part of the electromagnetic spectrum it can be measured by its frequency and wavelength. It can also be measured by its intensity.

Visible light waves are the light waves we can see with our eyes and are between 400 and 760 billionth of a meter long. They are found near the middle of the electromagnetic spectrum. Light's wavelengths are shorter than infrared radiation, but longer than ultraviolet light. This results in visible light waves having more energy than infrared radiation and less energy than ultraviolet light waves.

Light is energy that we can see with our eyes. Sunlight appears white to our eyes, even though it is made up of all the colors of the visible spectrum. White light can be divided into all the colors of the visible spectrum (colors of the rainbow), by using a prism. When a prism is held up to bright sunlight, so that sunlight passes through it, part of a rainbow will appear. Just like a rainbow that appears in the sky after a rain, the band of colors always appear in the following order: violet, blue, green, yellow, orange, and red. Each color of light has a different frequency. Because our eyes are sensitive to the frequencies of visible light, it is special to us. Sunlight contains a nearly equal mixture of all the colors and frequencies of light.

The wavelength of light varies from one color of light to another. Each color of light corresponds to a different wavelength. Violet light waves have the highest frequency and shortest wavelength of visible light and is refracted at the largest angle. Red light waves have the lowest frequency and longest wavelength of visible light and is refracted at the smallest angle. Yellow, green, and blue light are found in the middle of the visible spectrum.

Objects can be a source of light or they may transmit, reflect, or absorb light. The sun, fire, and light bulbs are all sources of light and are called luminous. Some materials give off light when they are heated. These materials are called incandescent.

Light is transmitted when it passes through matter such as air, water, glass, or clear plastic. When light rays move from one substance into another (such as from air into paper) its speed changes. The change in speed causes the ray of light to be refracted or bent into a new path. The degree of refraction depends on the frequency of light. Light rays with the highest frequencies have the largest angle of refraction, or are bent the most. This is why only 70 - 90 % of available light is transmitted through the covering of a greenhouse. The rest of the light is refracted away from the greenhouse.

Most objects reflect some light. We can see things that are not luminous because they reflect some of the light that strikes them. This light is reflected back to our eyes.

Light-colored objects reflect more light than dark-colored objects. This is the reason light colored clothes are cooler to wear in the summer than dark colored clothing. It is also one reason plants are often grown in white hanging baskets on porches and decks during the summer. The white pot reflects more light than a dark pot. The soil in a white pot stays cooler than the soil in a green or black pot.

The colors of a substance depends on both the substances and the colors of light striking the substance. If white light strikes a violet object, all frequencies of light except violet are absorbed. Violet light is reflected.

Matter can also absorb light. Dark-colored objects absorb more light than light-colored objects do. This is apparent when you compare two cars that have been parked in the sun in the summer. Heat buildup occurs more rapidly in a car with dark interior than a car with light interior.

THE IMPORTANCE OF LIGHT TO PLANTS

Only about 2 or 3% of the light that reaches the earth from the sun is used by plants to make food for themselves. However, almost all plants and animals depend on plant's ability to use photosynthesis to create food. Plants use light energy along with water and carbon dioxide to make the food. Plants need the green material called chlorophyll to carry on photosynthesis. Chlorophyll is green because it reflects green light. It is found in the chloroplasts in plant cells. Chloroplasts can be found in many parts of a plant, however the leaves of the plant is the primary location of chloroplasts.

Several factors affect the rate that photosynthesis occurs in plants. However, light accounts for several of the factors. Some of the factors that affect the rate of photosynthesis are:

1. Wavelength of Light (Light Quality)
2. Light Intensity (Brightness of Light)
3. Daylength
4. Concentration of Carbon Dioxide in the Atmosphere
5. Temperature
6. Amount of water available to the plant
7. Developmental Stage of the Plant

Sunlight appears white to our eyes, but remember that it is made up of rays of different wavelengths and different colors of light. The wavelengths of light are also known as light quality. Since each different color of light has a different wavelength, the energy level of different colors of light is different. Blue light has a shorter wavelength and higher frequency than red light.

The quality of light effects plant growth, by determining how well it carries on photosynthesis. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the red and blue portions of the visible spectrum, and reflect the green portion. Light quality is especially important when plants are grown under fluorescent, incandescent, or other artificial lights such as HID (High intensity Discharge) lamps. In order for photosynthesis to occur, plants grown under artificial lighting must receive enough of the blue and red wavelengths. The amount of blue and red wavelengths vary with the different lighting systems. Incandescent lights have a high proportion of red and far-red light waves. Florescent lights have a high proportion of blue waves. Special Grow light florescent lights emit more of the red and far-red light waves. The differences in light quality is apparent when you observe the color of clothing under fluorescent lights, incandescent lights, & sunlight. The diffraction, or spreading out of electromagnetic waves as a result of its passing through an opening in a barrier, can be used to examine the wavelength of light waves of a particular source of light.

Light intensity or the brightness of light also effects plant growth. The intensity of light influences the amount of photosynthesis taking place. Light intensity can be measured in footcandles or luxes.

Each species of plants has a light intensity range that they grow best. Some plants require being grown in "full sun" because they require high intensities of light. Other plants are grown in "full-shade" because they grow best when exposed to very little light. The important thing to remember is to grow the plants with the light intensity that suits them the best. The intensity of light directly effects the size and shape of leaves and the type of growth of a plant. Plants that are grown at higher intensities of light (within the normal light intensity range for that species) generally have thicker and larger leaves than plants that are grown at lower light intensities. Also higher light intensities (within the normal light intensity range of that species) generally result in plants having a good green color, strong & thick stem with short internodes, and large normal root systems. Plants grown at low light intensities, may have a more yellowish-green color, weak spindly stem with long internodes, and fine hairlike roots.

Since sunlight is needed for photosynthesis to occur, the length of day directly effects photosynthesis. Generally, plants will grow faster under long days than short ones because the plants can make food for a longer period of time during long days.

WORK SHEET A

DIRECTIONS: Complete the following questions.

1. Energy that moves through empty space at the speed of light is called ______________________.

2. Electromagnetic waves are classified as ______________ waves because they move like waves on a rope or waves of water on a lake.

3. Radiation is the transfer of __________ by electromagnetic waves.

4. Two properties that differ from one type of electromagnetic waves to another are frequency and _______________.

5. Visible light waves are not any different from any other _________________________ except in frequency and wavelengths.

6. The _________ of electromagnetic wavelengths depend on their wavelength.

7. Waves with shorter wavelengths have __________ energy than those with longer wavelengths.

8. Visible light has ___________ wavelengths than radio wavelengths.

9. Sunlight appears ____________ to our eyes, even though it is made up of many different colors of light.

10. The ____________ of light varies from one color of light to another.

11. Violet light waves have the ___________ frequency of visible light and is refracted at the largest angle.

12. Violet light waves have the ____________ wavelength of visible light.

13. Red light waves have the __________ frequency of visible light and is refracted at the smallest angle.

14. Red light waves have the ___________ wavelength of visible light.

15. When light rays move from one substance into another its ______ changes.

16. The path of light waves refracts or ________ as it moves from one substance to another substance.

17. We area able to see objects which are not luminous because most objects ___________ some light.

18. Light-colored objects ___________ more light than dark-colored objects.

19. Dark-colored objects _________ more light than light-colored objects do.

20. The color of a substance depends on both the substance and the _____________ of light striking the substance.

WORK SHEET B

Directions:
The answers to the following fill-in-the blank questions are terms which have something to do with Light--Part of the Electromagnetic Spectrum. Choose the term from the word list below that best answers each question. Each term may be used only once.

Word List:

Diffraction
Electromagnetic spectrum
Electromagnetic waves
Energy
Frequency
Gamma rays
Hertz
Infrared radiation
Light Intensity
Light Quality
Luminous
Matter
Photosynthesis
Radiation
Refraction
Ultraviolet light
Visible light waves
Visible spectrum
Wavelength

Fill-in-the blank:

1. Anything that has mass and takes up space is called ________.

2. Objects that give off light are called ____________.

3. ________ is the unit of measure used for measuring the frequency of electromagnetic waves.

4. ____________________ are electromagnetic waves with frequencies just lower than visible red light.

5. The ____________________ is the band of colors that is produced when white light can is refracted into its separate colors.

6. The bending of waves, or ______________ occurs as light rays move from one substance to another because of a change in its speed.

7. ____________ are electromagnetic waves at the highest end of the spectrum, often from nuclear radiation in the form of energy without mass or electrical charge.

8 __________________ is invisible to the human eye and has frequencies just higher than visible violet light.

9. ________ is the capacity of moving matter from one place to another or changing matter from one substance to another.

10. ____________________________ are a form of energy that move through empty space at the speed of light.

11. Electromagnetic waves are measured by their ____________, or number of crests that pass a point per second, as they travel.

12. The __________________________________ is the range of electromagnetic waves from highest to lowest frequency.

13. Light waves that we can see are called ______________________.

14. The transfer of energy by electromagnetic waves is called ______________.

15. _________________ is a plant's ability to make food from light, water, carbon dioxide.

16. _________________ is another way of describing the wavelengths of light.

17. ______________ is the spreading out of electromagnetic waves as a result of its passing through an opening in a barrier.

18. The distance between 2 neighboring crests in a wave is called ______________.

19. The brightness of light, or ___________________ is measured in footcandles or luxes.

WORK SHEET C

A. Fill-in-the blank:

1. Almost all plants and animals depend on plant's ability to use ________________ to create food.

2. Plants use _______________ along with water and carbon dioxide to make the food.

3. Plants need the green material called _______________, found in the chloroplasts of the leaves, to carry on photosynthesis.

4. Chlorophyll is _________ because it reflects green light.

5. Sunlight is made up of _________ colors of light.

6. Since each different color of light has a different wavelength, the ________ level of each color of light is different.

7. When plants are grown under light that contains all visible wavelengths, they absorb mostly from the _____ and _____ portion of the visible spectrum.

8. _______________ is especially important when plants are grown under artificial lights.

9. Each species of plants has a _________________ range they grow best.

10. Plants generally grow _________ during long days than short ones.

B. Short Answer:

11. What factors affect the rate of photosynthesis?

12. What are the characteristics of plants grown at higher light intensities?

13. What are the characteristics of plants grown at lower light intensities?

WORK SHEET D: STUDENT REVIEW

1. What is electromagnetic radiation?

2. What two properties differ from one type of electromagnetic radiation to another?

3. How does wavelength effect the energy of electromagnetic waves?

4. What is the electromagnetic spectrum?

5. Where is visible light found on the electromagnetic spectrum?

6. How do the colors of the visible spectrum differ from one another?

7. Which color of light has the most energy?

8. What color is sunlight?

9. What causes light to refract as it moves from one substance to another substance?

10. What determines the color of a substance?

11. Why is light energy important to our food supply?

12. How does light quality affect photosynthesis?

13. How does light intensity affect photosynthesis?

14. How does daylength affect photosynthesis?

STUDENT ACTIVITY NOTE SHEET

List steps to follow:

1. Writing information on pots

2. Planting Bean Seeds

3. Taping cellophane tent over pots

4. Measuring plants

5. Observing Plant Appearance

6. Observing light as it passes through the colored cellophane with a diffraction grating

STUDENT ACTIVITY - 1
INFORMATION SHEET

PLANTING CORN SEEDS

a. **Purpose:** To produce 5 uniform pots of corn seedlings.

b. **What Each Group of Students Needs:**

10 corn seeds
waterproof marker
5 plastic pots
5 labels
potting soil

c. **Here's How:**

1. Work in your assigned group.
2. Get 10 corn seeds and 5 pots from your teacher.
3. Write your names on the pots and number the pots 1 - 5 with a waterproof marker.
4. Fill the pots 2/3 full (about 1 1/4 ") with potting soil.
5. Put 2 corn seeds in each pot.
6. Cover the seeds with about 1/2" of potting soil. There should be about 1/2" of space left at the top of the pot.
7. Water media thoroughly.
8. Insert a plant label into the soil at the center of the pot.
9. Place all 5 plants together in a warm place where they will receive plenty of light. (Be careful not to place the pots in a location where they will get too hot.)
10. Water pots as needed to keep the soil moist but not soggy.
11. Clean up your work area.

STUDENT ACTIVITY - 2
INFORMATION SHEET

GROWING PLANTS UNDER DIFFERENT COLORS OF LIGHT.

a. **Introduction:** Research in the production of plants grown under artificial light is an ongoing area of plant production. Scientists need to understand how light quality affects plant growth in order to develop new and more efficient lighting systems for plant production.

b. **Purpose:** To determine which wavelengths of light (colors) have the greatest effect on plant growth.

c. **What Each Group of Students Needs:**

green cellophane	clear tape
blue cellophane	ruler
red cellophane	scissors
yellow cellophane	5 corn plants
clear cellophane	potting soil

d. **Here's How:**

1. Wait until a corn seedling emerges in each pot that was planted in Student Activity - 1, before starting this activity. After a seeding emerges in each pot, complete the following steps.

2. After seedlings in all 5 pots have emerged, thin plants so there is only 1 plant in each pot.

3. Measure the height of each plant in centimeters. (Measure from the bottom of the pot to the tip of the plant shoot.) Then measure the width of the stem in millimeters. This measurement should be taken at the same place on each of the corn plants.

4. Record the plant's measurements in Part B of the Student Activity Record Sheet.

5. Water plants, if needed so soil is moist but not soggy.

6. Get a green, blue, red, yellow, and clear piece of cellophane from your teacher.

7. Using a different color of cellophane for each pot, make a cellophane tent covering the corn plant in the pot. Make the tent large enough to allow for the corn plant to grow. Tape the cellophane tent together so it covers the corn plant in the pot. Tape the cellophane to the pot to hold it in place.

8. Place all 5 plants together in a place where they will receive plenty of light. (Be careful not to place the pots in a location where they will get too hot.)

9. Clean up your work area.

10. Make predictions about the outcome of this activity and record the predictions in Part A of your Student Activity Record Sheet.

11. Observe the plants for 3 weeks and record measurements and observations in Part B of the Student Activity Record Sheet. Measurements of the corn plant should be taken 3 times a week. The height of each plant should be recorded in centimeters. The stem width of each plant should be recorded in millimeters. Loosen the cellophane on the pot on one end if necessary to make the measurements. Remember to tape the cellophane back onto the pot when you are finished taking measurements.

12. Water the plants as needed, so soil is moist but not soggy.

13. Complete Part C & D of the Student Activity Record Sheet after you have observed the plants for 3 weeks.

STUDENT ACTIVITY - 2
RECORD SHEET

A. Predictions:

1. What do you predict will happen with the 5 plants?

2. Describe the color of light that will pass through the clear cellophane.

3. How will the color of light change as it passes through the colored cellophane?

4. Which plant will grow the most? Which color of light will it receive?

5. Which plant will grow the least? Which color of light will it receive?

6. Why will plant growth vary with the color of light that the plant receives?

B. Observations--Plant Growth:

Measure the height of each plant in centimeters & record measurements of each plant in the table below. (Measure from the bottom of the pot to the tip of the plant shoot.) Measurements of stem width (in mm) can be recorded in the table below also. Measurements should be taken 3 times a week for 3 weeks.

WEEK #	DATE		COLOR OF CELLOPHANE			
		GREEN	BLUE	RED	YELLOW	CLEAR
1						
1						
1						
2						
2						
2						
3						
3						
3						

B. Observations--Plant Appearance:

Observations about each plant's appearance should be recorded in the table below. Note plant color, size of leaves, stem diameter, and space between internodes when making your observations.

WEEK #	DATE		COLOR OF CELLOPHANE			
		GREEN	BLUE	RED	YELLOW	CLEAR
1						
1						
1						
2						
2						
2						
3						
3						
3						

C. Final Data:

1. Rank the plants by their height (from tallest to shortest) and record the final measurement of height.

2. Rank the plants by their stem diameter (from thickest to thinnest) and record the final measurement of stem diameter.

3. Rank the plants by their appearance (from healthiest to least healthy).

Complete Questions 4, 5, & 6 only if your instructor assigns them.

4. Rank the plants by plant mass.

5. Rank the plants by stem strength.

6. Rank the different colors of cellophane by the light intensity plants received (most to least).

D. Conclusions:

Answer the following questions after you have observed plant growth and plant appearance for 3 weeks.

1. Describe the color of light which passed through the clear cellophane.

2. Which plant grew the most? Which color of light did it receive?

3. Which plant grew next to the most? Which color of light did it receive?

4. Which plant grew the least? Which color of light did it receive?

5. What color of light is reflected by chlorophyll in the plant?

6. What wavelengths of light should artificial lights used for growing plants give off?

STUDENT ACTIVITY - 3
INFORMATION SHEET

DIFFRACTION OF LIGHT THROUGH DIFFERENT COLORS OF CELLOPHANE

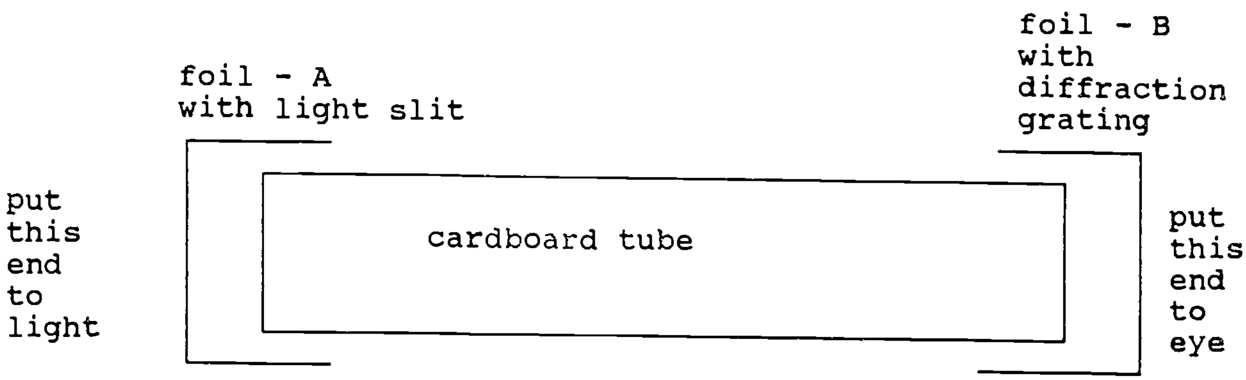
a. **Purpose:** To compare the diffraction spectrum of light after it has passed through the different colors of cellophane. This will provide us with information about the actual wavelength of light passing through the cellophane filters.

c. **What Each Group of Students Needs:**

diffraction grating	cardboard tube
masking tape	knife
scissors	aluminum foil

5 pieces of colored cellophane (green, blue, red, yellow, clear)

c. **Here's How:**



1. Get a cardboard tube from your instructor.

2. Cut 2 pieces of aluminum foil so they are large enough to fit over the ends of the cardboard tube.

3. Place 1 piece of aluminum foil (Piece A) over one of the ends of the tube and tape in place.

4. Use a knife to cut a slit in the piece of foil that covers the end of the cardboard tube. This is the light slit. Light will enter the tube through this slit.

5. Cut a piece of colored cellophane, so it is large enough to fit over the end of the cardboard tube. Tape the colored cellophane over the slit in the aluminum foil.

6. Place the other piece of aluminum foil (Piece B) on the other end of the cardboard tube. Tape in place.

7. In the center of the aluminum foil, (Piece B), cut a square shaped hole. The size of the hole will vary depending on the size of the tube, but a general recommendation is the hole in the foil should be approximately 1 cm^2.

8. Get a piece of diffraction grating from your instructor. A diffraction grating when held between the eye and light source will let us see the color bands in the spectrum of light.

8. Cut a piece of diffraction grating, a little larger than the square hole in the aluminum foil (Piece B).

9. Place the diffraction grating over the square hole in the aluminum foil (Piece B).

10. Turn the diffraction grating until the lines in the diffraction grating are parallel to the light slit on the other end of the tube.

11. Holding the diffraction grating in place, hold the diffraction tube up to the same light that you are using to grow the plants in Student Activity - 2. Point the light slit towards the light and look through the diffraction grating.

12. Observe the colors of light transmitted by the colored cellophane filter. Record your observations on Student Activity - 3 Record Sheet.

13. Now turn the diffraction grating so the lines in the diffraction grating are perpendicular to the light slit on the other end of the tube.

14. Hold the tube up to the light and observe the colors of light transmitted by the cellophane filter.

15. Remove the colored cellophane and replace with another color of cellophane. Observe and record your observations on the Student Activity - 3 Record Sheet and repeat this procedure until you have observed the colors transmitted by each cellophane filter.

16. Clean up your work area when finished.

17. Study your observations that you recorded on Activity - 3 Record Sheet. Are the results as you expected?

STUDENT ACTIVITY - 3
RECORD SHEET

1. Record your observations from looking at light through the 5 colored cellophane filters.

FILTER COLOR	PARALLEL TO LIGHT SLIT	PERPENDICULAR TO LIGHT SLIT
1. GREEN		
2. BLUE		
3. RED		
4. YELLOW		
5. CLEAR		

QUIZ 1

A: MATCHING:

______1.	Object that transmits light	a.	light bulb
______2.	Object that reflects most of the light	b.	white cloth
______3.	Object that absorbs light	c.	black plastic
______4.	Luminous object	d.	clear glass

B. TRUE OR FALSE:

______5. Dark-colored objects absorb more light than light colored objects.

______6. Visible light is found near the middle of the electromagnetic spectrum.

______7. The only difference between visible light and other electromagnetic radiation is that we can see visible light.

______8. Refraction of light waves occurs when the speed of the light waves is changed

C: SHORT ANSWER:

9. How are light waves similar to radio waves?

10. How are we able to see objects that are not luminous?