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ABSTRACT

This unit of instruction deals with building models of light with emphasis on the particle theory, the wave theory, and the theory of possible duality. Successful completion of Algebra I and Plane Geometry is strongly recommended as indicators of success. The booklet lists the relevant state-adopted texts and provides a list of the performance objectives. It provides the course outline and experiments, demonstrations, projects, reports, field trips, innovative activities and related solved problems. Also listed are films available from the Dade County Audiovisual Center. Film loops and relevant transparencies are listed, as well as suggested discussion questions. Reference books are recommended, and a master sheet is provided relating each suggested activity to the specific performance objectives. (EB)

SYNCHRONIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

LIGHT THEORY

5318.05

SCIENCE

(Experimental)

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

LIGHT THEORY

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Written by Ralph E. Petit
for the
DIVISION OF INSTRUCTION
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1972

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LIGHT THEORY

COURSE DESCRIPTION

Building models of light

1. Particle theory
2. Wave theory
3. Theory of possible duality (open ended)

ENROLLMENT GUIDELINES

1. Successful completion of Algebra I and Plane Geometry is strongly recommended as an indicator of success in Light Theory.
2. Strongly recommended for the serious physics student.

STATE ADOPTED TEXTS

1. Genzer, Irwin and Youngner, Philip. Physics. Morristown, New Jersey: Silver Burdett Company. 1969.
2. Miller, Franklin, Jr., et al. Concepts in Physics. Atlanta, Georgia: Harcourt, Brace and World, Inc., 1969.
3. Rutherford, F. James, et al. The Project Physics Course Text. New York: Holt, Rinehart and Winston, Inc., 1970.
4. Williams, John E., et al. Modern Physics. New York: Holt, Rinehart and Winston, Inc., 1968.

PERFORMANCE OBJECTIVES

1. Given certain demonstrations, the student will distinguish among luminous, non-luminous, transparent, translucent, opaque and colored objects.

2. Through demonstrations, the student will relate the formation of shadows to solar and lunar eclipses.

3. Given discussion opportunities, the student will suggest methods to measure the speed of light.

4. Through demonstrations, the student will prove that the intensity of light complies with the inverse square law.

5. As a result of illustrations and class discussions, the student will deduce the photoelectric effect of light.

6. Given laboratory opportunity, the student will investigate the reflection of light from plane and curved surfaces.

7. Using experimental results, the student will differentiate real and virtual images.

8. Given laboratory opportunity, the student will prove Snell's law by refraction of light through different media and applied mathematics.

9. Given various conditions of reflection and refraction, the student will become proficient in the process of problem solving after having completed the above objectives, 1 - 8.

10. Given the opportunity, the student will construct optical instruments such as the microscope and telescope.

11. Through demonstrations, the student will distinguish among transverse, longitudinal and torsion waves.

PERFORMANCE OBJECTIVES (Cont.)

12. Given laboratory opportunity, the student will measure the frequency, wave length and speed of waves.

13. As a result of teacher demonstrations and class room discussion, the student will investigate the superposition principle.

14. Given laboratory opportunity, the student will investigate interference, diffraction, reflection and refraction of waves.

15. Through illustrations and class discussion, the student will identify Huygens' principle as a basic aspect of wave behavior.

16. Given laboratory opportunity, the student will distinguish between the interference patterns of single and double slits.

17. Using data from previous experiments, the student will measure the wave length of various colors of light.

18. Given laboratory opportunity, the student will examine the interference patterns produced by thin films.

19. Given various conditions of frequency, wave length, speed and interference patterns, the student will become proficient in the process of problem solving involving the wave nature of light after having completed the preceding objectives, 10-18.

20. Given the opportunity, the student will compare optical radiation with the other forms of electromagnetic radiation.

PERFORMANCE OBJECTIVES (Cont.)

21. Given various conditions, the student will use Plank's constant and Einstein's photoelectric equation to calculate the energy and momentum of photons.

22. Using the results of all experiments and demonstrations, the student will defend reasons for the particle nature of light.

23. Using the results of all experiments and demonstrations, the student will defend reasons for the wave nature of light.

24. After class discussions, the student will propose reasons for a theory of light that could show the duality of the particle and wave nature of light.

COURSE OUTLINE

I. Investigation of the Phenomenon of Light on the Basis of a Particle Theory.

A. Luminous vs. non-luminous bodies

B. Formation of shadows

C. Color of objects

D. Transparent, translucent and opaque bodies

E. Speed of light

F. Photometry

1. Luminous intensity
2. Luminous flux
3. Illustration

a. Inverse square law
b. Photometers

G. Reflection from plane and curved surfaces with the formation of real and virtual images

H. Snell's law and refraction of light through different media

I. Optical instruments and light

J. Diffraction and interference (open ended)

K. The photoelectric effect

1. The laws of photoelectric emission
2. Cut-off potential of the photoelectric current

II. Characteristics of Waves

A. Propagation

B. Transverse, longitudinal and torsion waves

C. Frequency, wave length, amplitude and speed

D. Superposition

E. Interference and diffraction

F. Reflection and refraction

III. Investigation of the Phenomenon of Light on the Basis of a Wave Theory

A. Huygens' principle

B. Luminous vs. non-luminous bodies

C. Color vs. frequency and wave length

D. Transparent, translucent and opaque bodies

E. Photometry

1. Luminous intensity
2. Luminous flux
3. Illumination

a. Inverse square law
b. Photometers

F. Reflection from plane and curved surfaces

G. Refraction and speed through different media

H. Diffraction and interference

1. Shadows
2. Single slits
3. Double slits
4. Thin films

COURSE OUTLINE (Cont.)

I. The electromagnetic spectrum

J. Polarization of transverse waves

IV. The Quantum Theory

A. Photons

B. Plank's constant

C. Einstein's photoelectric equation

D. Photon energy

E. Photon momentum

EXPERIMENTS

Dillon, Thomas J., and Smith, Malcolm K. Concepts in Physics Laboratory Manual. Atlanta: Harcourt, Brace and World, Inc., 1969.

1. Lenses and the Location of Images (Ex. 42, p. 81)
2. The Nature of Images - Magnification (Ex. 43, p. 83)
3. Interference of Water Waves (Ex. 44, p. 86)
4. Interference of Light (Ex. 45, p. 88)

Holton, Gerald, et al. The Project Physics Course Handbook. New York: Holt, Rinehart and Winston, Inc. 1970.

5. Introduction to Waves (Ex. 30, p. 209)
6. Refraction of a light beam (Ex. 32, p. 234)

EXPERIMENTS (Cont.)

7. Young's Experiment-the Wave Nature of Light (Ex. 33, p. 236)
8. The Photoelectric Effect (Ex. 43, p. 295)
9. Spectroscopy (Ex. 44, p. 302)

Physical Science Study Committee. Physics Laboratory Guide. Atlanta: D. C. Heath and Co., 1965.

10. Reflection From a Plane Mirror (Ex. II-1, p. 13)
11. Images Formed by a Concave Mirror (Ex. II-2, p. 14)
12. Refraction (Ex. II-3, p. 15)
13. Images Formed By a Converging Lens (Ex. II-4, p.17)
14. The Refraction of Particles (Ex. II-5, p. 19)
15. Waves on a Coil Spring (Ex. II-6, p. 20)
16. Pulses in a Ripple Tank (Ex. II-7, p. 23)
17. Periodic Waves (Ex. II-8, p. 25)
18. Refraction of Waves (Ex. II-9, p. 26)
19. Waves and Obstacles (Ex. II-10, p. 27)
20. Waves From Two Point Sources (Ex. II-11, p. 28)
21. Interference and Phase (Ex. II-12, p. 29)
22. Young's Experiment (Ex. II-13, p. 31)
23. Diffraction of Light by a Single Slit (Ex. II-14, p. 31)
24. The Spectrum of Hydrogen and Plank's Constant (Ex. IV-15, p. 84)

Williams, John E., et al. Laboratory Experiments in Physics, New York: Holt, Rinehart and Winston, Inc. 1968.

25. Wave Properties (Ex. 28, p. 52)
26. Photometry (Ex. 31, p.60)
27. Plane Mirrors (Ex . 32, p. 62)
28. Concave Mirrors (Ex. 33, p. 64)
29. Index of Refraction of Glass (Ex. 34, p. 65)
30. Converging lenses (Ex. 36, p. 69)
31. Color (Ex. 41, p. 82)
32. Diffraction and Interference (Ex. 42, p. 83)
33. Wave Length by Diffraction (Ex. 43, p. 85)
34. The Polarization of Light (Ex. 44, p. 88)

DEMONSTRATIONS

See Innovative Activities.

PROJECTS

1. Design and build apparatus to show that solar and lunar eclipses are caused by shadows.
2. Design and construct apparatus that could be used to measure the speed of light.
3. Design and construct apparatus to show that the intensity of light complies with the inverse square law.
4. Design and construct a photocell that may be used to open and close a door by the interruption of a light beam.
5. Construct and calibrate a photometer for measuring light intensities.
6. Design and construct apparatus to illustrate the laws of reflection and refraction.
7. Design and construct a microscope with various magnifications.
8. Design and construct an astronomical telescope.
9. Design and construct a refracting telescope.
10. Design and construct a periscope.
11. Design and construct a prism binocular.
12. Design and construct a pin-hole camera.

PROJECTS (Cont.)

13. Design and construct apparatus to show the interference patterns of single and double slit diffraction.

14. Design and construct a small searchlight for producing parallel beams of light.

15. Design and construct a slide projector.

16. Design and construct apparatus to show the difference between a primary and secondary rainbow.

17. Design and construct a polarimeter for measuring strengths of chemical solutions.

18. Design and construct a wave machine for illustrating the properties of waves.

REPORTS

1. The Study of Light by Scientists.

   A. (B.C. - 1000 A.D.)

   B. (1000 A.D. - 1500 A.D.)

   C. (1500 A.D. - 1800 A.D.)

   D. (1800 A.D. - 1900 A.D.)

   E. (1900 A.D. - 1971 A.D.)

   F. (1971 A.D. - 2000 A.D.)

REPORTS (Cont.)

2. Invisible Light.
3. Methods of Artificial Lighting.
4. Laser Beam. What is It and What is Its Usefulness?
5. Photons and the Atom.
6. Light Pressure and Its Effect.
7. Photometry.
8. The Electromagnetic Theory and Its Spectrum.
9. Spherical Aberration and Its Disadvantages.
10. Primary and Complementary Colors vs. Color Mixing.
11. Polarization of Light and Its Usefulness.

FIELD TRIPS

1. Observatory (Museum of Science).
2. Optometrist (See yellow pages of telephone directory.)
3. Optical laboratory (See yellow pages of telephone directory).
4. Fun houses at carnivals.
5. Photoelectric cells (See yellow pages of telephone directory).
6. Lighting consultants (See yellow pages of telephone directory).
7. Audio-visual center at school.
8. University of Miami optical laboratory.
9. Dade Junior College optical laboratory.

RELATED SOLVED PROBLEMS

1. Castka, Joseph F. and Lefler, Ralph W. Physics Problems. New York: Holt, Rinehart and Winston, Inc., 1961. (pp. 259-279).
2. Dillon, Thomas J. and Smith, Malcolm K. Concepts in Physics, Teachers' Manual and Answer Key. Atlanta: Harcourt, Brace Jovanovich, 1970. (pp. 104-108, 198 - 203, 206-234).
3. Genzer, Irwin and Youngner, Philip. Physics, Teachers Edition. Morristown: Silver Burdett Company, 1969. (pp. 509-511, 538-541, 571-527, 617-619).

RELATED SOLVED PROBLEMS (CONT.)

4. Physical Science Study Committee. P.S.S.C. Physics Teachers' Resource Book and Guide. Boston: D.C. Heath and Co., 1965. (Part 2)

5. Williams, John E., et al. Modern Physics-Teachers' Edition. New York: Holt, Rinehart and Winston, Inc. 1968. (pp. T83-T85, T95-T96, T99-T101, T105-T106).

INNOVATIVE ACTIVITIES

1. Design trick mirrors to show images that are tall and thin or short and fat.
2. "Kiddie" pools? Large ripple tanks.
3. Skindiving? Refraction and total reflection.
4. Gigging? Bring home the fish, if you can.
5. Single slit vs. small hole interference patterns.
6. Measure the thickness of air-wedges by using their interference pattern.
7. Try photographing the diffraction of light as it passes by a needle or through a wire screen.
8. Infrared and ultraviolet photograpy? Try it.
9. Air lenses in a liquid or solid? See how it works.
10. Bell telephone science kits: (a) Crystals and light (b) energy from the sun; (c) from sun to sound.

FILMS

Available from Dade County Audio-Visual Center

1. Atomic Radiation
   1-01921 11 min. B/W (EBEC)
2. Color and Light
   1-01857 11 min. Color (EBEC)
3. Cosmic Rays
   1-30330 29 min. Color (McGraw-Hill)
4. Elementary Optics
   1-11698 19 min. B/W (UW)
5. Interference of Photons
   (0419) 1-10791 18. min. B/W (MLA)
6. Introduction to Optics
   1-13043 17 min. B/W (UW)
7. Introduction to Optics
   (0201) 1- 30288 23 min. Color (MLA)
8. Light: Refraction
   1-10730 14 min. B/W (Coronet)
9. Light Sensitive Materials
   1-13061 22 min. Color (UW)
10. Light Waves and Their Uses
    1-01851 11 min. B/W (EBEC)
11. Matter Waves
    (0423) 1-30279 28 min. B/W (MLA)
12. Nature of Color, The
    1-01858 11 min. Color (Coronet)
13. Photo-Electric Effect
    (0417) 1-30317 28 min. Color (MLA)
14. Photons
    (0418) 1-10794 25 min. B/W (MLA)
15. Pressure of Light
    (0202) 21 min. B/W (MLA) 1-10731
16. Radio Waves
    1-30208 29 min. Color (McGraw-Hill)
17. Simple Waves
    (0204) 1-30282 27 min. B/W (MLA)
18. Speed of Light
    1-10734 23 min. B/W (MLA)
19. Speed of Light, The
    1-10727 14 min. B/W (EBEC)

LMS (CONT.)

20. Understanding Color: Color by Addition
    1-10738 14 min. Color (Academy)
21. Waves on Water
    1-10987 16 min. Color (EBEC)

The Project Physics Course Materials. New York: Holt, Rinehart and Winston, Inc., 1970.

22. Experiments of Microwaves
    (Cost of film is $87.00)
23. Waves, Modulations and Communications
    (Cost of film is $83.00)
24. Waves
    (Cost of film is $96.00)

NOTE: (Cost to rent each film is $12.50)

FILM LOOPS

The Project Physics Course Materials. New York: Holt, Rinehart, and Winston, Inc., 1970. Super 8.

1. Superposition.
2. Standing Waves on a String.
3. Standing Waves in a Gas.
4. Vibrations of a Rubber Hose
5. Vibrations of a Wire.
6. Vibrations of a Drum.
7. Vibrations of a Metal Plate.
8. Standing Electromagnetic Theory.

NOTE: (All loops @ $24.95 each)

TRANSPARENCIES

Available from Dade County Audio-Visual Center

1. Behavior of Light
   2-00087 B/W (Ideal)
2. Light: Double-Slit Interference
   2-00194 Color (Drago)
3. Light: Law of Inverse Squares
   2-00191 Color (Drago)
4. Light: The Additive Process
   2-00192 Color (Drago)
5. Refraction of Light: Converging and Diverging Lenses
   2-00149 Color (Tolsen)
6. Light: The Subtractive Process
   2-00193 Color (Drago)

The Project Physics Course Materials. New York: Holt, Rinehart and Winston, Inc., 1970.

7. Superposition
8. Square Wave Analysis
9. Standing Waves
10. Two-Slit Interference
11. Interference Analysis

R.C.A. "Educator-Aides". Camden, 8, New Jersey: R.C.A. Educational Services, R.C.A. Service Company, 1962.

12. S1-Sound Waves of Oscilloscopes
13. S4-Longitudinal Waves
14. S5-Tranverse Waves
15. S6-Relationship Between Wave Length, Amplitude and Frequency
16. S10-Wave Length, Frequency and Velocity Relationship
17. S19-Interference
18. S20-Superposition of Waves
19. S21-Examples of Superposition of Waves of Same Frequency and Amplitude

TRANSPARENCIES (CONT.)

20. S27-Inverse Law
21. L1-The Electromagnetic Spectrum
22. L2-Michelson's Octagonal Mirror Method of Measuring the Speed of Light
23. L3-Law of Inverse Squares
24. L4-Bunsen Photometer
25. L5-Transmission of Light Through Plate Glass
26. L6-Regular and Irregular Reflection of Light
27. L7-Is Image Real or Virtual
28. L8-Image Formed by Plane Mirror
29. L9-Reflection From a Back Silvered Mirror
30. L10-Plane Diagram for Defining Terms Used With a Curved Mirror.
31. L11-Locating the Principal Focus of Spherical Mirrors
32. L12-Image Formation in Concave Mirror, Case 1
33. L13- Image Formation in Concave Mirror, Case 2
34. L14- Image Formation in Concave Mirror, Case 3
35. L15- Image Formation in Concave Mirror, Case 4
36. L16- Image Formation in Concave Mirror, Case 5
37. L17-Image Formation in Concave Mirror, Case 6
38. L18-Image Formation in Convex Mirror
39. L19-Spherical Aberration
40. L20-Derivation of the Mirror Formula for Curved Mirrors
41. L21-Dispersion by a Prism
42. L22-The Continuous Spectrum
43. L23-The Additive Process
44. L24-Complementary Colors
45. L25-The Subtractive Process
46. L26-Subtraction of Light by Color Filters
47. L27-Bright-Line Spectrum
48. L28-Absorption Spectrum
49. L29-Chromatic Aberration
50. L30-Double Slit Interference
51. L31-Diffraction
52. L32-Polarization
53. L33-Normal Ray Refraction
54. L34-Oblique Ray Refraction
55. L35-Reflection and Refraction
56. L36-Snell's Law
57. L37-Reflection and Refraction

TRANSPARENCIES (CONT.)

58. L38-Refraction by Double Convex Lens, Case 1
59. L39-Refraction by Double Convex Lens, Case 2
60. L40-Refraction by Double Convex Lens, Case 3
61. L41-Refraction by Double Convex Lens, Case 4
62. L42-Refraction by Double Convex Lens, Case 5
63. L43-Refraction by Double Convex Lens, Case 6
64. L44-Refraction by Double Concave Lens
65. L45-Atmospheric Refraction
66. L46-Mirage
67. L47-Illumination
68. L48-Luminous Flux
69. L49-Periscopes
70. L50-The Rainbow
71. L51-Huygens' Principle
72. L52-Defects of the Eye and Corrections
73. L53-The Microscope
74. L54-Refracting Telescope
75. L55-Reflecting Telescope
76. L56-Prism Binoculars

SUGGESTED DISCUSSION QUESTIONS

1. What is light?

2. Distinguish between luminous and illuminated objects.

3. Define and illustrate the following: (a) transparent; (b) translucent; (c) opaque; (d) color of an object.

4. Distinguish among reflection, refraction and diffraction.

5. What are the laws of reflection?

6. Describe the image you see of yourself in a plane mirror. In a curved mirror. What causes the differences?

7. What is meant by the index of refraction?

SUGGESTED DISCUSSION QUESTIONS (CONT.)

8. Can reflection occur when light falls on a transparent body? Give examples.

9. What are the laws of refraction?

10. What causes total internal reflection of light?

11. If no light reflects from a black object, how can it be seen?

12. Explain the lens system and images formed in a compound microscope.

13. What causes light to change speed when entering a new medium?

14. Is there a change of frequency or of wave length when a change of speed occurs?

15. Could particles of light diffract?

16. Why do containers of clear water not appear as deep as they actually are when viewed from above?

17. What causes the coloration on soap bubbles?

18. What is the purpose of using polaroid sunglasses?

19. What causes the sun to appear red when first appearing in the east or setting in the west?

20. Distinguish among frequency, wave length and amplitude.

21. Does the inverse square law apply to light coming from a searchlight? From a flashlight? From a light bulb?

22. Describe the standard candle.

23. Using a compound microscope, as the slide is moved away from you, the image moves toward you. Why?

SUGGESTED DISCUSSION QUESTIONS (CONT.)

24. Why are parabolic mirrors better than spherical mirrors?

25. How can a lens be used to ignite a piece of paper?

26. Compare the elements of a camera with the parts of the human eye.

27. Telescopes and microscopes use basically two convex lenses. What is the difference between these two optical instruments?

28. Can you photograph a virtual image? Explain.

29. What are the additive primaries? The subtractive primaries?

30. Did diffraction enter into Young's double slit experiment? Did interference?

REFERENCES

1. Baker, D. Lee, et al. Elements of Physics. Atlanta: Allyn and Bacon, Inc., 1956.

2. Bennett, Clarence E, Physics Without Mathematics. New York: Barnes and Noble, 1949.

3. Carman, Robert A. A Programmed Introduction to Vectors. New York: John Wylie and Sons, 1963.

4. Castka, Joseph F., and Leftler, Ralph W. Physics Problems. New York: Holt, Rinehart and Winston, Inc. 1961.

5. Fuchs, Walter R. Physics for the Modern Mind. New York: The Macmillan Company, 1967.

6. Genzer, Irwin and Youngner, Philip. Physics. Morristown, New Jersey: Silver Burdett Company, 1969.

REFERENCES (CONT.)

7. Halliday, David and Resnick, Robert. Physics, Parts I and II. New York: John Wylie and Sons, Inc.,1967.

8. Holton, Gerald and Roller, Duane H.D. Foundations of Modern Physical Science. Reading, Mass: Addison-Wesley Publishing Co., Inc., 1958.

9. I.P.S. Introductory Physical Science. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1967.

10. Lehrman, Robert L., and Swartz, Clifford, Foundations of Physics. New York: Holt, Rinehart and Winston, Inc., 1965.

11. Marantz, Samuel A. Physics. New York: Benziger Brothers, 1969.

12. Miller, Franklin Jr. College Physics. Atlanta: Harcourt, Brace and World, Inc., 1967.

13. Miller, Franklin, Jr., et al. Concepts in Physics. Atlanta: Harcourt, Brace and World, Inc., 1969.

14. Olivo, C. Thomas and Wayne, Allan. Fundamentals of Applied Physics. Albany: Delmar Publishers, Inc. 1957.

15. P.S.S.C., Physics. Atlanta: D.C. Heath and Company. 1965.

16. Ruchlis, Hyman and Lemon, Harvey B. Exploring Physics. New York: Harcourt, Brace and Co., 1952.

17. Rutherford, F. James, et al. The Project Physics Course Text. New York: Holt, Rinehart and Winston, 1970.

18. Schaum, Daniel. Theory and Problems of College Physics. New York: McGraw-Hill Book Co., 1961. Reprint 1967.

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19. Weisbruch, Fred T., et al. Patterns and Processes of Science. Boston: D.C. Heath and Company, 1967. 1967.

20. White, Harvey E., et al. Physics, An Experimental Science. Princeton: D. Van Nostrand Co., Inc., 1968.

21. Williams, John E., et al. Modern Physics. New York: Holt, Rinehart and Winston, Inc., 1968.

Laboratory Guides

22. Dillon, Smith. Concepts in Physics Laboratory Manual. Atlanta: Harcourt, Brace and World. Inc., 1969.

23. Holton, Gerald, et al. The Project Physics Course Handbook. New York: Holt, Rinehart and Winston, Inc., 1970.

24. P.S.S.C. Physics Laboratory Guide. Atlanta: D.C. Heath and Company, 1965.

25. Williams, John E., et al. Exercises and Laboratory Experiments in Physics. New York: Holt, Rinehart and Winston, Inc., 1968.

Objectives	Texts	Experiments	Projects	Report	Field Trips	Transparencies	Tables	Film Loops	Discussion Questions	Related Problems	Innovative Activities	References
1	#3 Ch. 14 #4 Ch. 15,17			1A,1B	8,9	1	4,6,7		1,2,3,11			All
2	#3 Ch. 14 #4 Ch. 15		1,12	1A,1B	1,8,9		4,6,7					All
3	#3 Ch. 13 #4 Ch. 15		2	1A,1B, 1C,1D, 1E	8,9	22	18,19		13,14			All
4	#1 Ch. 18 #4 Ch. 15	26	3,5	7	5,8,9	3,20,23, 21,67,66	4,6,7		21,22			All
5	#1 Ch. 25 #2 Ch. 24 #3 Ch. 16,18 #4 Ch. 15	8	4	1D,1E	8,9		9,13				10	All
6	#1 Ch. 18 #2 Ch. 21 #3 Ch. 13 #4 Ch. 16	2,10,11, 27,28	6,10, 14,16	3,9	4,8,9	26,27,28, 29,30,31, 39,40,69	4,6,7		5,6,8,24		1	All
7	#1 Ch. 18 #2 Ch. 21 #3 Ch. 13 #4 Ch. 16	11,13	6		2,3,7, 8,9	32,33,34, 35,36,37, 38			6,28		1	All
8	#1 Ch. 19 #2 Ch. 21 #3 Ch. 13 #4 Ch. 17	1,2,6, 13,15, 29,30	6,11, 15,16	1C,9	2,3,7, 8,9	5,25,41, 49,53, 54,56,65, 66	8		7,9,10,13, 16,19,35,36	All	3,4,9	All
9	#1 Ch. 18,19 #2 Ch. 22 #3 Ch. 13 #4 Ch. 15,16, 17					55,57,58, 59,60,61, 62,63,64, 70				All		All
10	#1 Ch. 19 #4 Ch. 17		7,8,9	1C,1D, 1E	1,5,7, 8,9	72,73,74, 75,76			12,25,27			All
11	#1 Ch. 20 #2 Ch. 9 #3 Ch. 12 #4 Ch. 15	5,15,25	18		8,9	13,14			18			All
12	#1 Ch. 20 #2 Ch. 9 #3 Ch. 12 #4 Ch. 15	5,15,17, 25	18		8,9	15,16	17,24		14,20		2	All

Objectives	Texts	Experiments	Projects	Reports	Field Trips	Transparencies	Films	Film Loops	Discussion Questions	Related Problems	Innovative Activities	Reference
13	#1 Ch. 21 #2 Ch. 9 #3 Ch. 12 #4 Ch. 13	5,15, 25	18		8,9	7,8,9,12, 18,19	17,24	1,2,3, 4,5,6,7			2	All
14	#1 Ch. 20 #2 Ch. 9 #3 Ch. 12 #4 Ch. 13	3,4,16, 18,19, 32		1C,1D, 1E	8,9	17,51	21		4,15		2,7	All
15	#1 Ch. 20 #2 Ch. 21 #3 Ch. 12 #4 Ch. 15			1C	8,9	21	10,22					All
16	#1 Ch. 16 #2 Ch. 22 #3 Ch. 12,13 #4 Ch. 18	7,17, 20,21, 22,23, 32	13		8,9	2,10,11, 50,51	21		30		5	All
17	#1 Ch. 16 #2 Ch. 22 #3 Ch. 13 #4 Ch. 17,18	9,31,53		10	8,9	4,6,43,44, 45,46	2,12,20		30		6	All
18	#2 Ch. 23 #4 Ch. 18			1C	8,9				17			All
19	#1 Ch. 20,21 #2 Ch. 9,21,22 #3 Ch. 12,13 #4 Ch. 13,17, 18									All		All
20	#1 Ch. 22 #2 Ch. 20 #3 Ch. 16 #4 Ch. 15	24		1D,1E, 1F,2, 8	8,9	21,47,47, 48	2,3,16, 25	8			8	All
21	#1 Ch. 25 #2 Ch. 24 #3 Ch. 20 #4 Ch. 15	24		1D,1E			5,14			All		All
22	#1 Ch. 18,19 #2 Ch. 21,22 #3 Ch. 13,20 #4 Ch. 15,16, 17	14		6	8,9		15					All
23	#1 Ch. 20,21, 25 #2 Ch. 22,23, 24 #3 Ch. 12,20 #4 Ch. 13,15, 16,17,18	31	17	31	8,9	52			18			All
24	#1 Ch. 25 #2 Ch. 24 #3 Ch. 20 #4 Ch. 15			1D,1E, 31,5	8,9		5,11, 13,14, 15					All