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ABSTRACT

This unit of instruction presents a laboratory-oriented course which relates the sources and behaviors of light to man's control and uses of light. Successful completion of Algebra I and Plane Geometry is strongly recommended as indicators of success. The course is recommended if the student plans further studies in science, optical technology, or medicine. It is not recommended for physics or engineering majors. The booklet provides performance objectives and lists the relevant state-adopted texts. It provides a course outline and suggests experiments, projects, reports, field trips, speakers or resource people, discussion questions, and innovative activities. Also listed are relevant films available from the Dade County Audiovisual Center. Transparencies are also listed. Reference books are recommended, and a master sheet is provided relating each suggested activity to the specific performance objectives. (EB)

AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

GEOMETRIC AND APPLIED OPTICS

5318.04

SCIENCE

(Experimental)

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

GEOMETRIC AND APPLIED OPTICS

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(Experimental)

Written by Robert C. Sanderson
for the
DIVISION OF INSTRUCTION
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GEOMETRIC AND APPLIED OPTICS

COURSE DESCRIPTION

A laboratory-oriented course which relates the sources and behavior of light to man's control and uses of light.

ENROLLMENT GUIDELINES

1. Recommended if the student plans further studies in science, optical technology, or medicine.

2. Not recommended for the physics or engineering major. See Light Theory.

3. Elective.

4. Successful completion of Algebra I and Plane Geometry is strongly recommended as indicators of success.

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 the opportunity for group discussion, the student will integrate his ideas of light.

2. As a result of teacher demonstration and discussion, the student will identify the sources of light.

3. Given laboratory experience, the student will discover how light behaves.

4. Given laboratory experience with plane mirrors, the student will identify the laws of specular reflection.

5. Using his laboratory data, the student will generalize the rules governing the location of a virtual image relative to its object.

6. Given teacher demonstration and discussion time, the student will discover the relation of rough surfaces to diffuse reflection.

7. Having completed objectives 1-6, the student will infer why some surfaces appear colored.

8. Given laboratory experience and teacher demonstration, the student will discover the phenomena of specular reflection from concave and convex parabolic reflectors.

9. Using his experimental data, the student will analyze the relative positions of object, image, and mirror.

10. Through his analysis and class discussion, the student will identify real and virtual images.

11. Using his experimental data of varying conditions, the student will compare the images to the objects.

12. As a result of prior comparison, the student will develop equations for parabolic specular reflection.

PERFORMANCE OBJECTIVES (CONT.)

13. Given selected data, the student will be proficient in problem solving involving parabolic and plane specular reflection after having completed objectives 8 -12.

14. Given laboratory opportunities, the student will discover the geometry of refraction through different media.

15. Using his experimental data, the student will discover Snell's Law.

16. Given teacher demonstration, the student will formulate his idea of critical angle and total internal reflection.

17. Using his experimental data, the student will discover the critical angle for three media relative to air.

18. Given selected data, the student will be proficient in solving total internal reflection problems after having completed objectives 14-18.

19. Given demonstration and laboratory experiments, the student will recognize diffraction.

20. As a result of class discussion, the student will identify the basic causes of diffraction.

21. As a result of demonstration and informal observations, the student will observe dispersion.

22. Given class observations, the student will hypothesize the reasons for dispersion.

23. As a result of class discussion, the student will discover the importance of infrared and ultraviolet.

24. Given simple demonstrations, the student will analyze the major parts of shadows.

PERFORMANCE OBJECTIVES (CONT.)

25. Using his data from the refraction experiments and assigned reading, the student will compare the relative speeds of light.

26. Given laboratory opportunity, the student will develop two general classifications of thin lenses.

27. Given laboratory opportunity, the student will discover the problems of chromatic aberration and dispersion.

28. Using his experimental data, the student will formulate equations for object and image size and location.

29. Given the lensmaker's equation, the student will be proficient in solving basic lens problems after having completed objectives 26 - 28.

30. Given laboratory opportunity, the student will contribute to the construction of a microscope, telescope or similar optical instrument.

31. Given teacher demonstration and class discussion, the student will discover the concept and technique of light intensity measurement.

32. Given laboratory opportunity, the student will develop the inverse square law for light intensity.

33. Given laboratory opportunity, the student will trace the path of light encountering a thin film.

34. Given a class discussion, the student will synthesize his new ideas of light.

COURSE OUTLINE

I. Student Developed Theories of Light

II. Sources of Light

III. General Behavior of Light

IV. Specular Reflection

V. Diffuse Reflection

VI. Reflected Color

VII. Transmitted Color

VIII. Parabolic Reflection

- A. Concave
- B. Convex

IX. Light Refraction

- A. Air-Water-Air
- B. Air-Glass-Air
- C. Air-?-Air

X. Snell's Law

XI. Total Internal Reflection and Critical Angle

XII. Diffraction

XIII. Young's Experiment

- A. Nodal Lines - Minima
- B. Bright Lines - Maxima
- C. Color Discoveries

COURSE OUTLINE (CONT.)

XIV. Dispersion

XV. Shadows

A. Umbra

B. Penumbra

XVI. Infrared, Ultraviolet and Their Applications

XVII. Speed of Light

XVIII. Thin Lenses

A. Positive, Convex, Converging

B. Negative, Concave, diverging

XIX. Technical Problems in Applied Optics

A. Chromatic Aberration

B. Diffraction

C. Dispersion

XX. The Geometry of Light and Lenses

XXI. The Practical Control of Light

XXII. Measuring Light Intensity

XXIII. Inverse Square Law

XXIV. Light and Thin Films

XXV. New Student Developed Theories of Light

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 (exp. 42, p. 81)
2. The Nature of Images - Magnification (exp. 43, p.83)
3. Interference of Light (exp. 45, p. 88)

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

4. Reflection from a Plane Mirror (exp. 18-I, p. 153)
5. Reflection and Multiple Images (exp. 18-II, p. 157)
6. Concave Mirrors (exp. 18-III, p. 163)
7. The Refraction of Light (exp. 19-I, p. 167)
8. Convex Lenses (exp. 19-II, p. 175)

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

9. Refraction of a Light Beam (exp. 32, p. 234)
10. Young's Experiment (exp. 33, p. 236)
11. Activities with Light (pp. 238-241)

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

12. Reflection From a Plane Mirror (exp. II-1, p. 13)
13. Images Formed by a Concave Mirror (exp. II-2, p. 14)
14. Refraction (exp. II-3, p. 15)
15. Images Formed by a Converging Lens (exp. II-4, p. 16)
16. Young's Experiment (exp. II-13, p. 29)
17. Diffraction of Light by a Single Slit (exp. II-14, p. 31)
18. Resolution (Exp. II-15, p. 32)
19. Measurement of Short Distances by Interference (exp. II-16, p. 33)

EXPERIMENTS (CONT.)

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

20. Photometry (exp. 31, p. 60)
21. Plane Mirrors (exp. 32, p. 62)
22. Concave Mirrors (exp. 33, p. 64)
23. Index of Refraction of Glass (exp. 34, p. 65)
24. Index of Refraction by a Microscope (exp. 35, p. 67)
25. Converging Lenses (exp. 36, p. 69)
26. Focal Length of a Lens (exp. 37, p. 72)
27. Lens Magnification (exp. 38, p. 73)
28. The Compound Microscope (exp. 39, p. 75)
29. The Refracting Telescope (exp. 40, p. 79)
30. Color (exp. 41, p. 82)
31. Diffraction and Interference (exp. 42, p. 83)
32. Wave Length by Diffraction (exp. 43, p. 85)
33. The Polarization of Light (exp. 44, p. 88)

PROJECTS

1. Design and construct a workable pinhole camera.

2. Design and construct a compound microscope.

3. Design and construct an apparatus that will produce a real image that is visible to the class.

4. Construct a simple overhead projector.

5. Construct a simple opaque projector.

6. Construct a refraction telescope.

7. Design and construct an apparatus for measuring light intensity.

PROJECTS (CONT.)

8. Design and construct apparatus that will enable a student to detect color by touch.

9. Draw and construct a light interferometer.

10. Design the best lighting system for your physics area.

11. Design and construct the "perfect" desk lamp.

12. Design and construct a reflecting telescope.

13. Design and construct a simple 8mm. strip or loop projector.

REPORTS

1. The Study of Light by Scientists

   A. (- 1600 A.D.)

   B. (1600 A.D. - 1800 A.D.)

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

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

2. Photosynthesis

3. Photoelectric Effect

4. Light and Astronomy

5. Infrared Light

REPORTS (CONT.)

6. Ultraviolet Light
7. Light, Twixt Radio and X-ray
8. Illumination as a Career
9. Holography
10. Lasers, What and How?
11. Colored Light vs. Colored Paint
12. Gravity vs. Light
13. What is Light?
14. Who Says It's $3(10^8)$ Meters Per Second?
15. More About Total Internal Reflection
16. Long Life vs. Standard Bulbs
17. Fluorescent Lighting, Its Limitations and Advantages
18. Black Light in Daily Living
19. Life Without Light
20. The "Boob Tube" and Its Relation to Light
21. A Study of the Relationship Between Light and Heat.
22. Why are there Different Colors of Emitted Light?
23. Lighting the Undersea World
24. Lighting in Space

FIELD TRIPS

1. Architects' Offices
2. Lighting Consultants
3. Opticians' Offices
4. Museum of Science
5. Optical Services
6. University of Miami Physics Laboratories
7. Lighting Fixture Stores

SPEAKERS OR RESOURCE PEOPLE

1. Optician
2. Southern Bell - Simulated Laser Presentation
3. Architect or Lighting Engineer
4. Highway Engineer
5. Astronomer
6. Photographer

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. 210- 215) (pp. 221- 224)

3. Physical Science Study Committee. P.S.S.C. Physics Teachers' Resource Book and Guide. Boston: D.C. Heath and Co., 1965.

4. Schaum, Daniel. Theory and Problems of College Physics, Sixth Edition. New York: Schaum Publishing Co., 1961, Reprint 1966. (p. 212), (pp. 215-217), (pp. 220-221), (pp. 223-225), (pp. 227-229), (pp. 233-236)

5. Williams, John E., et al. Modern Physics Teachers' Edition. New York: Holt, Rinehart and Winston, Inc., 1968. (T 91-T 109)

6. Williams, Stanley, et al. Physics, Student Study Guide with Programmed Problems. (To Accompany Physics, Part I and II, by Halliday and Resnick), New York: John Wiley and Sons, Inc., 1970. (pp. 455-459), (pp. 469-473), (pp. 479-482), (pp. 489-496), (pp. 507-511).

FILMS

Available From Dade County Audio-Visual Center

1. Demonstrations with Light
   1-10728, 11', C MIS

2. Interference of Photons
   1-10791, 18', B/W, MLA

3. Introduction to Optics (0201)
   1-30288, 23', C MLA

4. Light Refraction
   1-10730 14', B/W Coronet

5. Light Sensitive Materials
   1-13061 22', C UW

6. The Microscope
   1-02240 11' C McGraw Hill

7. Photoelectric Effect (0417)
   1-30317 28', C MLA

8. Photons (0418)
   1-10794 25' B/W MLA

9. Pressure of Light (0202)
   1-10731 21' B/W MLA

10. Speed of Light
    1-10734 23' B/W MLA

TRANSPARENCIES

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

1. Law of Inverse Squares
2. Bunsen Photometer
3. Transmission of Light Through Plate Glass
4. Regular and Irregular Reflection of Light
5. Is Image Real or Virtual?
6. Image Formed by Plane Mirror
7. Reflection From a Back Silvered Mirror
8. Plane Diagram for Defining Terms Used With a Curved Mirror
9. Locating the Principal Focus of Spherical Mirrors
10. Image Formation in Concave Mirror, Case 1
11. Image Formation in Concave Mirror, Case 2
12. Image Formation in Concave Mirror, Case 3
13. Image Formation in Concave Mirror, Case 4
14. Image Formation in Concave Mirror, Case 5
15. Image Formation in Concave Mirror, Case 6
16. Image Formation in Convex Mirror
17. Spherical Aberration
18. Derivation of the Mirror Formula for Curved Mirrors
19. Dispersion by a Prism
20. The Continuous Spectrum
21. The Additive Process
22. Complementary Colors
23. The Subtractive Process
24. Subtraction of Light by Color Filters
25. Bright-Line Spectrum
26. Absorption Spectrum
27. Chromatic Aberration
28. Double Slit Interference
29. Diffraction
30. Polarization
31. Normal Ray Refraction
32. Oblique Ray Refraction
33. Reflection and Refraction
34. Snell's Law

TRANSPARENCIES

35. Reflection and Refraction
36. Refraction by Double Convex Lens, Case 1
37. Refraction by Double Convex Lens, Case 2
38. Refraction by Double Convex Lens, Case 3
39. Refraction by Double Convex Lens, Case 4
40. Refraction by Double Convex Lens, Case 5
41. Refraction by Double Convex Lens, Case 6
42. Refraction by Double Concave Lens
43. Atmospheric Refraction
44. Mirage
45. Illuminance
46. Luminous Flux
47. Periscopes
48. The Rainbow
49. Huygens' Principle
50. Defects of the Eye and Corrections
51. The Microscope
52. Refracting Telescope
53. Reflecting Telescope
54. Prism Binoculars

SUGGESTED DISCUSSION QUESTIONS

1. When the lamp is turned off, what happens to the light that is on its way? Why?

2. What would happen if there were no more light?

3. What does a "color-blind" person see? Why?

4. Does a dog see what we see?

5. Do we all see the same thing?

6. Does light travel in straight lines? Can you prove it?

7. Why can't I see radio?

SUGGESTED DISCUSSION QUESTIONS (CONT.)

8. How many virtual images can we get with two plane mirrors? How few?

9. How smooth is a specular surface?

10. How small is light-- whatever it is?

11. Can we photograph a virtual image -- a real image?

12. Can you feel a real image?

13. Can we reflect 'cold' from a concave mirror?

14. Where do the movies go after they hit the screen?

15. At sunrise and sunset, do we really see the sun itself?

16. Why are sunsets pretty?

17. In total internal reflection, why doesn't the light leave the medium?

18. Could light be a thinking organism (globbie)? Can you prove it?

19. Why does light change direction when it refracts?

20. Why does light change speed when it refracts?

21. If nothing can travel as fast as light--how does light go this fast?

22. Could something be traveling faster than light?

23. Why does light disperse?

24. What is the Doppler effect? Does it relate to light?

25. Does gravitational force affect light?

SUGGESTED DISCUSSION QUESTIONS (CONT.)

26. What are some of the limiting problems in lens use?

27. Why can't we see an electron?

28. Will laser replace wires? Radio?

29. Can we earn a living making light of light?

30. Do you know any other inverse square relationships?

31. So...what is light?

INNOVATIVE ACTIVITIES

1. Demonstrate real images using a large concave spherical mirror and a light box.

2. Show examples or illustrations of specifically-ground bi-focal, tri-focal, quadri-focal lenses for special tasks.

3. Start an astronomy club.

4. Get students involved in stage lighting with drama class.

5. Collect as many types of light sources as possible. (Bulbs, tubes, etc.)

6. Study pigment properties, fabrics and dyes relative to light.

7. Study the effect of infrared, white and black light on detergents. Discuss result of detergent on clothes.

8. Construct thin film models using clear and colored

plastics.

9. Prove that light is really an intelligent community of organisms (globbies).

10. Use student locations to illustrate the inverse square law.

11. Discuss lenses of lesser density than the surrounding media.

12. Discuss the paths of light from outer space. (Straight? Speed? Color?)

13. Try to build a rainbow machine.

14. Have students design and paint a mural depicting the adventures of light on a class wall.

15. Coordinate with the Biology classes to have students measure refraction in a salt water aquarium relative to fresh water.

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.

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 Physics. New York: Holt, Rinehart and Winston, Inc., 1958.

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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.

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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, 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, Inc., 1970.

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

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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. Genzer, Irwin and Youngner, Philip. Laboratory Investigations in Physics. Morristown, New Jersey; Silver Burdett Company, 1969.

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

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

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

Objectives	Texts	Experiments	Projects	Reports	Field Trips	Transparencies	Films	Discussion Questions	Related Problems	Innovative Activities	References
1,2				12,13,19			9	1,2,6,10		5,9	
3,4, 5	#1 Ch. 13 #2 Ch. 21 #3 U. 4,- Ch. 13 #4 Ch. 16	4,5,6,12, 13,21,22	3,4,6	1	2,7	4,6,44	1,3	8,9	1-6	5	All
6,7	#1 Ch. 20 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 16	30		1,11		4		3,4,5,16	1-6	6	All
8-12	#1 Ch. 18 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 16	6,13,22	3,5,6,12	1,4	2,3,5	5,8-18		11,12,13	1-6	1	All
13											
14 15	#1 Ch. 19 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 17	1,2,7,8,9, 14,15, 23-30	4,6,8,12, 13	1,4,9,10	3,4,5, 6	3,7,19, 31-34,43, 50	4,6	5,15	1-6	15	All
16 17	#1 Ch. 19 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 17	7,9,14,23		1,15	6			17	1-6		All
18											
19 20	#1 Ch. 20 #2 Ch. 21, 22,23 #3 U. 4- Ch. 13 #4 Ch. 15	10,16,17, 18,31,32	6	1	3,6	28,29		19,20	1-6		All
21 22	#1 Ch. 19 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 17	1,2,7,8, 9,14,15, 23-30		1,22	3,5,6	19-27			1-6	13	All
23	#2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 15			1				23	1-6		All
24	#1 Ch. 25 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 15			1,5,6, 7,18	2,6			7	1-6		All

Objectives	Texts	Experiments	Projects	Reports	Field Trips	Transparencies	Films	Discussion Questions	Related Problems	Innovative Activities	References
25	#1 Ch. 20 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 17		9	1,14	6		10	20	1-6		All
26-28	#1 Ch. 19 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 17	1,2,8,15, 25,26,27	3,5,6,12, 13	1	3,5	36-42 51-54	6	11,12,14, 26,27	1-6	2,11	All
29											
30	#1 Ch. 19 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 16, 17,18	All	1,2,3,4, 5,6,10, 11	1,4	3,5,7	47, 51-54		29	1-6	2,3,13	All
31	#1 Ch. 18 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 15	20	7,10,11	1,8,16, 17	1,2,7	2,45,46		29	1-6	4	All
32	#1 Ch. 18 #2 Ch. 21 #3 U. 4- Ch. 13 #4 Ch. 15	20	10,11	1	1,2	1		30	1-6	4,10	All
33	#2 Ch. 23 #4 Ch. 18	11		1	6				1-6	8	All
34				2,3,13, 19,20,21, 23,24	6	30,48,49	2,5, 7,8	18,21,22, 24,25,28, 31		12,14	All