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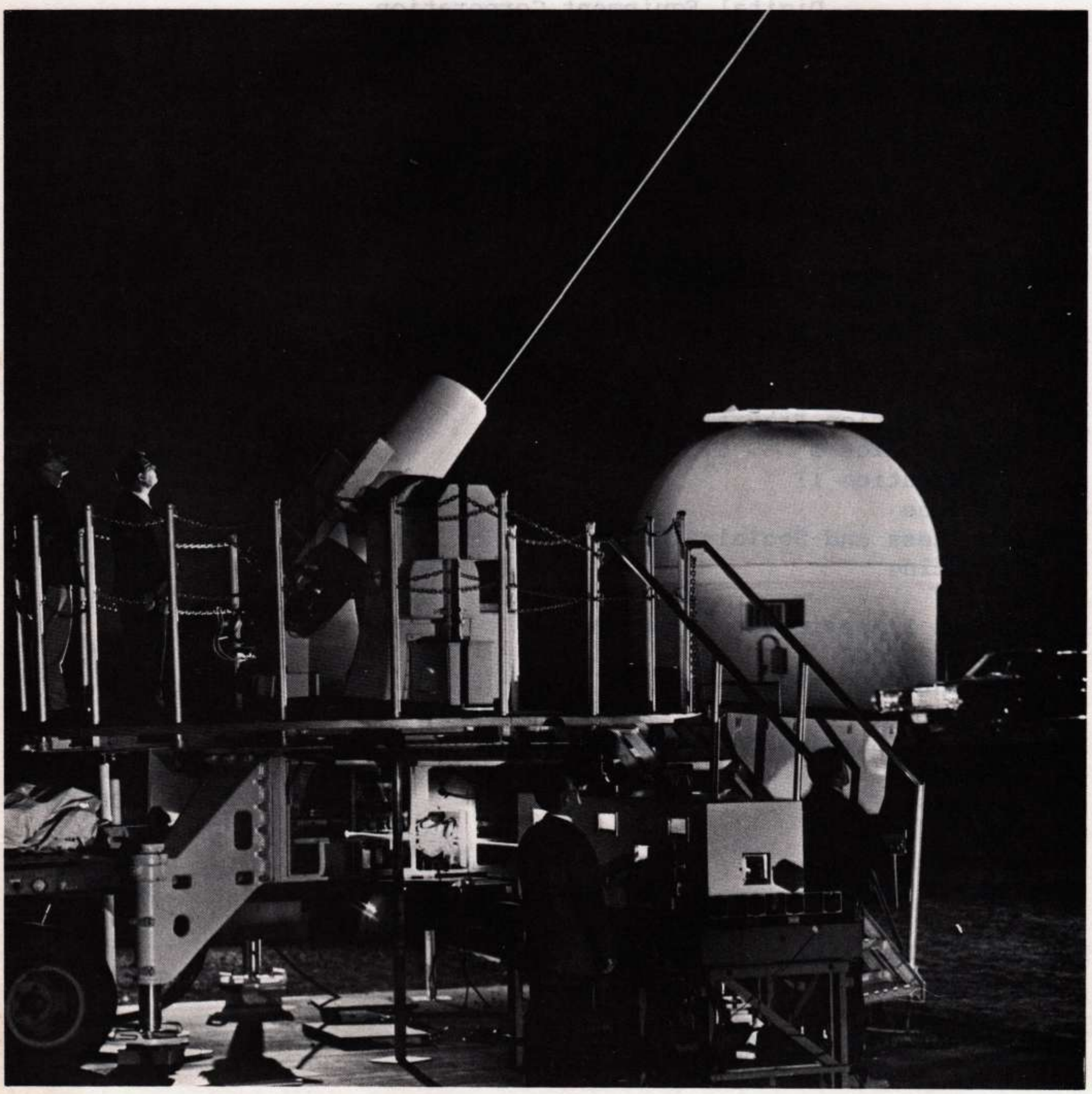
HUNTINGTON II Simulation Program–SLITS



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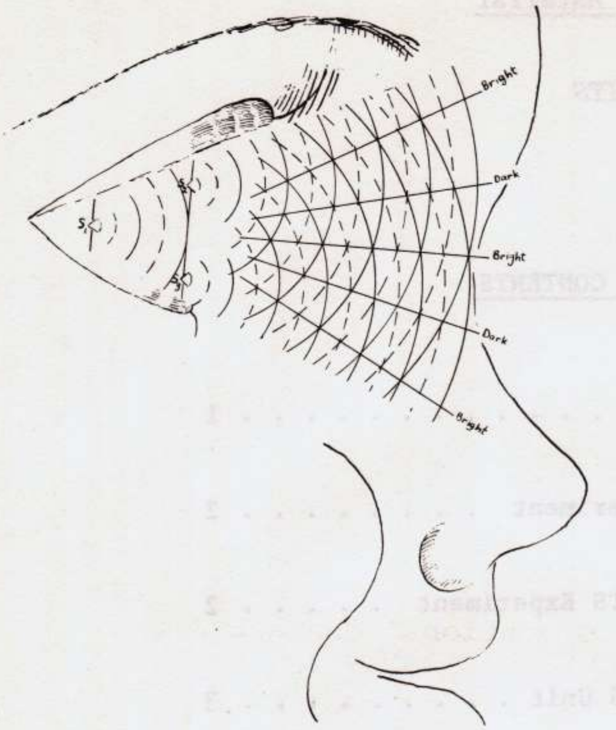

SLITS

A COMPUTER SIMULATION of YOUNG'S DOUBLE-SLIT EXPERIMENT

TEACHER'S GUIDE

Developed and programmed by:

Anthony Caggiano
Patchogue High School
Patchogue, New York

Teacher support material written by:

Elizabeth A. Williamson
Northwest Regional Educational Laboratory
Portland, Oregon

HUNTINGTON TWO COMPUTER PROJECT

15 January 1971

The work of the Huntington Two Computer Project is partially supported by the National Science Foundation, Grant GW-5883.

Teacher Material

SLITS

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COVER PHOTO

A continuous argon laser is being used by engineers of the Goodard Space Flight Center, Greenbelt, Maryland in experiments to send a message by laser to a satellite in orbit. This is an advanced application of monochromatic light used in young's light interference experiments. Photo courtesy of NASA.

SLITS

I. IDENTIFICATION

Subject Area: Physics

Specific Topic: Wave Theory of Light -- Young's Double-Slit Experiment

Grade Level: 11 - 12

Coordinated Computer Program: *SLITS*

Computer Language: BASIC

Special Language Features Used: RANDOMIZE; TAB

Abstract: The classic experiment demonstrating interference patterns for light is simulated on the computer allowing greater flexibility for variation and investigation of parameters.

Text References:

Halliday and Resnick, *PHYSICS*, New York: John Wiley & Sons, pp.976-988.

PSSC, *PHYSICS*, Boston: D. C. Heath, 2nd Ed., 1965.

Beiser, Arthur, *THE SCIENCE OF PHYSICS*, Reading, Mass.: Addison Wesley, 1964, pp.358-367.

II. DESCRIPTION OF THE EXPERIMENT

Young's double-slit experiment, first performed in 1801, demonstrated that diffraction and interference both occur in light. These conclusions gave substantial support to the theory that light has a wave nature.

In the experiment, a source of monochromatic light (light of a single wavelength) is placed behind a narrow slit S in an opaque screen (or, alternatively, a laser may be used in place of the light source and slits S). Another screen with two narrow slits, A and B, is placed on the other side of the one-slit screen. The light passes through slit S, and through slits A and B to the viewing screen. (See Figs. 1 and 2.)

III. DESCRIPTION OF THE *SLITS* PROGRAM

The computer program in this unit simulates Young's double-slit experiment. The program allows the user to manipulate three of the key variables in the experiment, one at a time. The three variables are:

1) W, the wavelength (in angstroms) of the light source

2) D, the distance (in millimeters) between slits A and B

3) L, the distance (in meters) between the double-slit screen and the viewing screen.

Each time the user specifies a value for W, D, or L, the computer will plot a graph of relative light intensity on the viewing screen vs. distance from the center of the viewing screen. On the computer's graph, the vertical axis is the distance axis, and the horizontal axis is the intensity axis. A "self test" for the user has been built into the program which helps him to determine his degree of understanding of the relationships between L, W, and D. The computer randomly selects a wavelength W for the light source which is not given to the user. The user must try to determine the selected wavelength by varying L and D. An estimate within 10% of the actual value is an acceptable approximation.

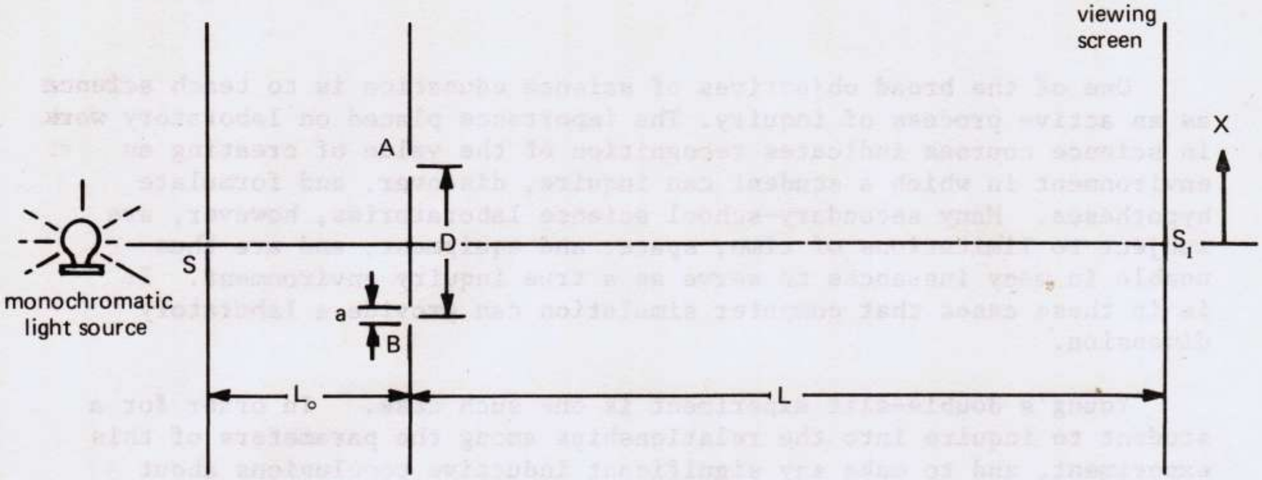

Fig. 1. Apparatus for Young's Double-Slit Experiment

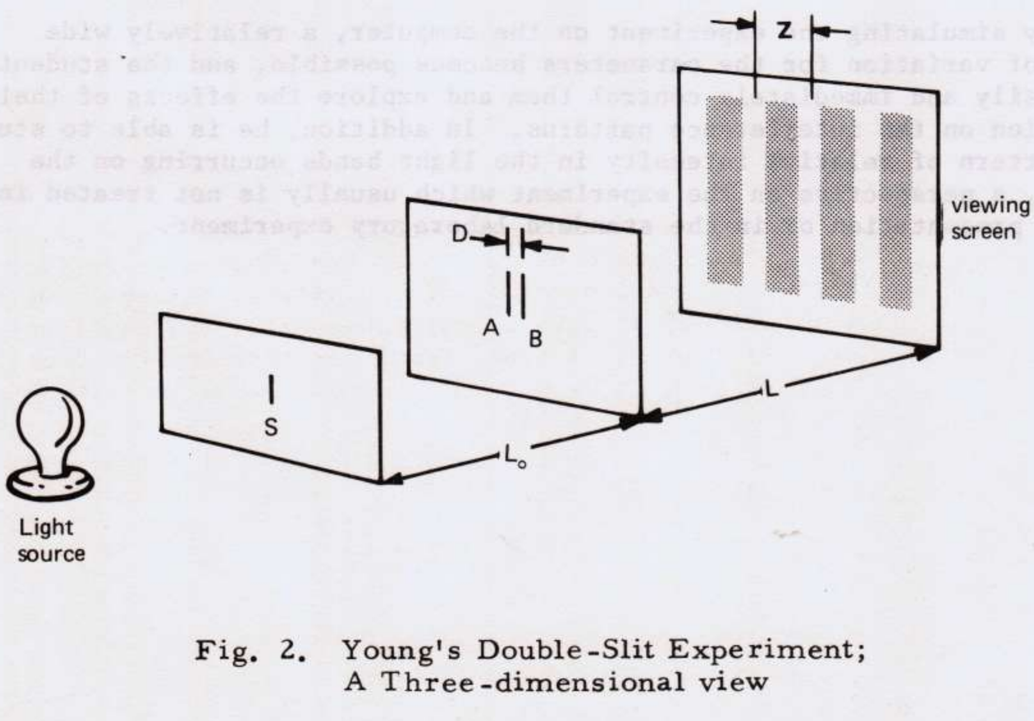

Fig. 2. Young's Double-Slit Experiment;
A Three-dimensional view

IV. RATIONALE FOR THE *SLITS* UNIT

One of the broad objectives of science education is to teach science as an active process of inquiry. The importance placed on laboratory work in science courses indicates recognition of the value of creating an environment in which a student can inquire, discover, and formulate hypotheses. Many secondary-school science laboratories, however, are subject to limitations of time, space, and equipment, and are thus unable in many instances to serve as a true inquiry environment. It is in these cases that computer simulation can provide a laboratory dimension.

Young's double-slit experiment is one such case. In order for a student to inquire into the relationships among the parameters of this experiment, and to make any significant inductive conclusions about their effect on the patterns on the viewing screen, he must collect a substantial amount of data. He must be able to vary the slit spacing by minute amounts; to measure the spacing of bright and dark bands accurately, and to vary and measure the wavelength of the light source. Because these procedures are difficult to control, the flexibility and scope of values available for study are limited. For example, if the slits are one millimeter apart and the viewing screen is at a distance of one meter from the double-slit screen, then for red light, the bright band would be only 0.6 millimeters apart!

By simulating the experiment on the computer, a relatively wide range of variation for the parameters becomes possible, and the student can easily and immediately control them and explore the effects of their variation on the interference patterns. In addition, he is able to study the pattern of relative intensity in the light bands occurring on the screen, a perspective on the experiment which usually is not treated in a text presentation or in the standard laboratory experiment.

V. GOALS FOR THE *SLITS* UNIT

A student who has completed a unit on the wave theory of light centered around the SLITS program should be able to:

1. Write a brief description of each of the following:

   a) wave theory of light
   b) diffraction
   c) constructive interference of waves
   d) destructive interference of waves
   e) monochromatic light

2. Write a detailed summary of Young's double-slit experiment including:

   a) a diagram and description of the apparatus
   b) a description of the observed phenomena
   c) an explanation of these phenomena in terms of the wave theory of light.

3. State that the variables

   Z, the distance on the viewing screen between bright bands

   L, the distance between the double-slit screen and the viewing screen

   D, the distance between the slits

   and W, the wavelength of the light source

   are related by the equation

$$Z = \frac{LW}{D}$$

   when all units are consistent.

If light were not a wave phenomenon, no light ray could reach the center of the viewing screen from its source along a straight line path. In fact, however, a regular pattern of alternate bright and dark bands appears on the viewing screen with a bright band appearing at S_1. A variation in either

W, the wavelength (in angstroms) of the light source

L, the distance (in meters) between the double-slit screen and the viewing screen

or D, the distance (in millimeters) between the slits will cause a change in the pattern of light bands on the viewing screen.

4. Determine any one of X, L, W, or D, given the other three, using the equation

$$X = \frac{LW}{D}$$

5. State that the pattern of relative light intensity on the viewing screen can be described by the equation

$$Y = \tfrac{1}{2}(1 + \cos RX)$$

VI. BASIC INSTRUCTIONAL USE OF *SLITS*

Activities Preparatory to the Use of the Program

1. Before the SLITS program is used, the following concepts relative to the unit on light should be explained:

   a) the wave theory of light
   b) diffraction
   c) monochromatic light
   d) constructive interference of waves
   e) destructive interference of waves

2. The teacher should ascertain that the students have a basic understanding of the mathematical notions of:

   a) direct variation
   b) inverse variation
   c) trigonometric functions of sine and cosine

3. If the apparatus for Young's experiment is available, it should be explained and set up. The class should make an hypothesis about the outcome of the experiment, and then a demonstration of the experiment should be made. The class should take and record measurements of the key variables in the demonstration. If the apparatus is not available, the teacher should give a complete description of the apparatus and the experiment, illustrated with diagrams. He should also describe the procedures for taking measurements of the various quantities.

4. The teacher should explain what a computer simulation of the experiment is, and how the SLITS program will be used. He should discuss:

   a) the assumptions underlying the SLITS program (in fairly simple terms; see *RESOURCE MATERIAL)*.

b) the format of the program

c) the procedures to be followed by the students while using the SLITS program (i.e., follow the guide sheets, etc.)

d) the fact that the graph generated by the computer is a graph of <u>relative</u> intensity of light on the viewing screen.

Use of the Program

The SLITS program is probably best used as an extension of the actual double-slit experiment. It can be used by individuals, teams of students, or entire classes (with appropriate viewing equipment). The guidelines in the student materials in this unit should be sufficient to suggest specific procedures for using the program. Students should be encouraged to vary one parameter at a time until they have diagnosed its effect, and also to write down any questions, hunches, or hypotheses that occur to them during the simulation. Following the use of the program, the students should have an opportunity to examine and analyze their data and investigate any questions or hunches they may have had. The simulation should be treated as a laboratory experiment, i.e., the experiment is done, the students analyze the data as an assignment, lab reports are turned in, and discussion follows.

Followup Discussion Questions

The following are some suggestions for discussion questions, which may be used in addition to those generated by the students and the teacher.

1) Explain why the light appears in bands on the viewing screen.

2) What effect does changing the distance between the slit screen and the viewing screen have on the intensity pattern?

3) What effect does changing the distance between the slits have on the intensity pattern?

4) What is the effect on the intensity pattern of changing the wavelength of the light source?

5) What equation may be used to describe the variation of light intensity with distance along the viewing screen? (Answer: $Y=\frac{1}{2}(1+\cos(RX))$.)

6) What is the function of the single-slit screen?

7) How would the outcome of the experiment differ if you removed the double-slit screen and used only the single-slit screen?

8) Why does the light source have to be monochromatic in this experiment?

VII. FURTHER INSTRUCTIONAL USES OF *SLITS*

The *SLITS* program could be used as the basis for a study of mathematical modelling in a physics context. Students could examine the anatomy of the program and try to explain and derive the defining equations used for the intensity curve.