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Title of Study: EXPERIMENTS AND DEMONSTRATIONS FOR AN EXPLORATORY COURSE IN GENERAL SCIENCE

Pages in Study: 61 Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: A collection of experiments and demonstrations that may be used in an Exploratory Course of Junior High School General Science. The experiments are of the type to show the relationship of subject matter taught in Junior and Senior High School Science to science professions and occupations. In most cases, simple equipment found in most any High School science laboratory may be used. To make this report more useful the experiments have been arranged with biology coming first, physics second and then chemistry. The report consists of one hundred eight experiments which have been divided into nine chapters, EXPERIMENTS WITH PLANTS, EXPERIMENTS WITH BACTERIA AND MOLDS, EXPERIMENTS WITH ANIMALS AND MAN, MECHANICS, EXPERIMENTS WITH HEAT, LIGHT AND SOUND, MAGNETISM AND ELECTRICITY, and EXPERIMENTS IN CHEMISTRY.

Use of the Study: To supplement daily classroom discussion and other activities; such as field trips, lectures, films and etc., which may constitute the curriculum of the Exploratory Course in General Science.

James H. Zant

EXPERIMENTS AND DEMONSTRATIONS FOR AN EXPLORATORY COURSE IN GENERAL SCIENCE

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EXPERIMENTS AND DEMONSTRATIONS FOR

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I am sincerely grateful to the members of this program who have helped so much during this year and to the instructors who have been so patient, and to the selection committee for making this year of graduate study possible.

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CHAPTER I

INTRODUCTION

The purpose of this report is to organize a group of experiments and demonstrations that may be used to aid the teacher of an exploratory course in science in conveying to the student, the purposes, the need, and the many other reasons for studying science, as a hobby or as a profession; to organize experiments and demonstrations that will help the student learn to reason critically, imaginatively and constructively; to make decisions for himself and to appreciate the values of science and what science has done for mankind; to organize materials of science that will be motivating to the student and cause him to continue his studies of science.

Laboratory problems may help the student discover interests that he could not discover elsewhere. Well planned and executed demonstrations and first hand experiences in the laboratory can make important principles and applications meaningful to the student.[1]

Laboratory study may help the student become better equipped to enter an occupation suitable to his abilities; to offer an opportunity for intellectual growth and social usefulness. It gives the student a chance to explore his interests and to satisfy his curiosity. It gives

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[1]John S. Richardson and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, New York, Toronto, and London, McGraw-Hill Book Company, Inc., (1951), p. 7.

him a chance to see and to do real things for himself.

These exercises may be used either as demonstrations or experiments as the teacher prefers to supplement other activities of the exploratory course, such as textbook readings, if a text is used; films, field trips, lectures by scientists of the community, etc.

It is believed that by using and observing these experiments and demonstrations that the student will receive a general idea of what is done in the various sciences, in higher education and in the professions. By having a knowledge of what the scientist do, the student will be encouraged to work harder to learn all he can about science as early as possible.

Many of the experiments of this paper may seem rather simple, while others may seem rather difficult for junior high students. However their value cannot be determined until after they have been tried.

It is believed that these experiments and demonstrations will greatly aid the teacher of an exploratory course in meeting his objectives.

CHAPTER II

EXPERIMENTS WITH PLANTS

2-1 A Useful Way to Grow Seeds[2]

Tie a piece of cloth over the mouth of an old potted meat jar. Allow extra cloth to hang down the sides and dip into about 2 cm. of water contained in a big mouthed jar. A sheet of glass placed over the top of the jar will keep the air moist. The seeds are placed on the cloth.

2-2 A Rag Doll Seed Tester[3]

Fold a square metre of muslin twice in the same direction. Near one end mark out eight or ten squares about 5 cm. by 5 cm. with a pencil. Number the squares and place ten seeds from each packet on each square. Fold the opposite end of the muslin over the seeds. Roll up the tester and tie it loosely with string. Keep it moist and in a warm place for several days. Unroll the muslin and see how many seeds of each kind have germinated.

2-3 To Study the Structure of Seeds[4]

Soak seeds of bean, pea, pumpkin, sunflower, corn and other

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[2]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956) p. 46.

[3]Ibid.

[4]Ibid., p. 47.

large forms. Remove the seed coats and carefully cut the seeds open. Discover the parts that make up the seed. There is little point in teaching the botanical names of these parts though pupils may enjoy learning them. It is of more importance that pupils learn to recognize the part of a seed that is the young plant and the part that is stored food.

2-4 To Test the Gas Given Off When Seeds Germinate[5]

Place some mustard seeds in a flask with some damp cotton wool. Stopper the flask with a two hole rubber stopper containing a thistle tube and a glass tubing leading into a test tube of lime water. Place a piece of rubber tubing in the middle of the glass tubing to allow for a pinch clamp. Place a stopper in the thistle tube and allow the seeds to germinate for a few days. Remove the cork and pour water down the thistle tube. Open the clip and allow the displaced air to bubble through lime water. This becomes cloudy showing the presence of carbon dioxide.

2-5 To Show The Direction of Sprout Growth in Seeds[6]

Soak pumpkin or other large seeds overnight and fasten three of them on needles and stand upright in a pan filled with paraffin. Fasten one with the tip pointing upward, one with the tip toward the side and the third with the tip pointing downward. Cover with a glass. Keep in moist air and note the direction in which the seed sprouts grow.

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[5]Ibid. p. 47.

[6]Ibid.

2-6 Germinating Seeds With or Without Oxygen[7]

In most living tissues free oxygen is necessary before respiration can occur. If respiration is prevented growth cannot take place. In general, if seeds are placed deep in soil or water, sufficient oxygen is not available for their germination.

The material needed are freshly soaked seeds or grains such as wheat; two bottles with stoppers; string; two small pieces of mosquito netting; about 40 cc. of freshly made potassium pyrogallate (made by mixing equal volumes of a six and two thirds per cent solution of pyrogallic acid and a thirty three and one third per cent solution of potassium hydroxide immediately before using).

Divide the number of soaked seeds equally. Bag each group of seeds in the mosquito netting. Tie each bag securely with string, leaving one end of the string long. Moisten each bag of seeds with water. Suspend a bag of seeds in each bottle from the bottom of the cork. A pin will attach the string to the cork. Prepare the potassium pyrogallate, pour it into one bottle and stopper immediately. Pour an equal quantity of water into the other bottle and stopper with the bag of seeds suspended from the cork. Allow the two bottles to stand for a few days and observe the grains. The bottle with potassium pyrogallate soon becomes oxygen free since this substance has a strong affinity for free oxygen. The other bottle still contains free oxygen since the water will dissolve but a small portion.

Seeds will germinate in atmosphere containing oxygen but will

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[7]David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences, New York and London: McGraw-Hill Book Company, (1938), p. 345.

not in oxygen deficient atmosphere. Ordinary garden peas may be used to show a seed type which does not require free oxygen for germination. Soak and suspend these over the potassium pyrogallate as in the experiment above. This type of respiration is known as intramolecular or anaerobic respiration.

2-7 Testing Whether Roots Absorb Water and Suspended Solids[8]

Three similar plants are inserted into test tubes containing 1, water; 2, red ink; 3, a suspension of congo red. After a few days 2 will be found to be colored; 1 and 3 uncolored, having absorbed only water.

2-8 How to Grow Root Hairs[9]

Hairs can easily be seen on the roots of mustard seed grown on damp flannel. Seeds placed on an earthenware dish standing in a soup plate containing water will produce very good specimens if covered by another plate to keep the air moist.

Study the root hairs with a hand lens and observe how they are constructed.

2-9 To Demonstrate Roots Grow From Their Tips[10]

From some germinating seeds, remove a corn seedling or a pumpkin seedling. With india ink and a fine pen, mark equidistant lines along the main roots of each seedling.

Put the seedlings back in the germinator for two or three days

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[8]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 39.

[9]Ibid.

[10]General Science Handbook, Part 1, Bureau of Curriculum Development of Secondary Education, (New York State Education Department, 1951), p. 172.

then examine the marked roots again. The lines should still be the same distant apart while the roots have grown longer at the tips.

2-10 To Demonstrate Root Pressure[11]

Active absorption results in the so called root pressure. The exudation of water from cut stems of woody plants in the spring is a result of this pressure. It is particularly noticeable when grape vines are cut during this period. When pigweeds (Amaranthus) are cut off at the soil level a wet spot of soil often appears surrounding the cut portion. This is caused by water exuding from the cut tissue.

Materials needed are a potted, vigorously growing plant of Dahlia, Bryoghyllum, tomato or pigweed; a piece of glass tubing about one foot in length; and a short piece of gum tube.

With a sharp knife cut the top from the plant selected so that about four centimeters of the stem remain above the soil. Connect the glass tube to the cut end of the stem by means of the gum tube. The connection must be made watertight. Care must be taken not to injure the stem. It may be necessary to use grafting wax or some other sealing compound in making this connection. Support the glass tubing in an upright position in some convenient way. Add water to the glass tube until the water is just visible above the connection with the gum tube. Saturate the soil above the roots. Place the setup in some convenient location and observe for a rise of the water column in the glass tube. Observations should be made at intervals over a period of two or three hours.

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[11]Ibid.

2-11 How Roots are Affected By Water[12]

Grow some seedlings in one end of a glass dish or pan. When they are about 5 cm. tall begin watering them on one side only and a little distance away from the nearest plants. Continue the watering daily for about a week and then dig away the soil and see if the watering has had any affect on the direction of growth of the roots.

2-12 Growing Roots From Different Parts of Plants[13]

Secure a box of sand and place it away from sunlight. Wet the sand thoroughly and keep it moist. Plant the following things in the sand.

a. Various bulbs.

b. Cutting of begonia and geranium stems.

c. A section of sugar cane stem with a joint buried in the sand.

d. A section of bamboo stem with a joint buried in the sand.

e. Carrot, radish and beet tops each with a small piece of root attached.

f. An onion.

g. An iris stem.

h. Pieces of potato containing eyes.

i. A branch of willow.

2-13 The Effect of Gravity on Roots[14]

Cut several pieces of blotting paper about 8 cm. square. Place

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[12]UNESCO, UNESCO Source Book For Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 40.

[13]Ibid.

[14]Ibid.

these between two squares of glass. Place several radish or mustard seed between the blotting paper and glass on each side and secure with rubber bands. Wet the blotting paper and when the seeds have sprouted and the rootlets are about 1.5 cm. long turn the square through 90 degrees and allow them to remain undisturbed. Repeat the turning and observe the effects on the roots.

Another way to study the effects of gravity on roots is to sprout some seeds and select one that is straight. Pierce the seed with a long pin or needle and stick this into a cork. Place some damp cotton or blotting paper in a bottle. Put the cork and seedling in the bottle. Place the bottle in a dark cupboard and look at it every hour or so.

2-14 Response of Roots to Light[15]

Make up about 500 cc. of very dilute erythrosin in water (1 part erythrosin to 50,000 parts water). Place this in a cylinder. Tie a piece of muslin over the mouth of the cylinder. The liquid should come almost to the top of the cylinder and just touch the cloth. Place wheat grains on the muslin covering them with sand to keep them moist. Set the apparatus in a warm dark situation until germination occurs and roots one inch or more in length have developed and are growing straight down. Then place the cylinder in a window so that the roots will be brightly illuminated from one side. This exposure should continue for 12 to 24 hours. Usually by this time the root tips will have bent at right angles and toward the bright

[15]David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences, New York and London: McGraw-Hill Book Company, (1938), p. 377.

light. The erthyrosin in some way causes the roots to become sensitive to light.

This should be checked by a similar setup in which no erythrosin is used.

2-15 Why Liquids Rise in Plants[16]

Wipe your hands on a towel and the towel dries them; put the stems of flowers in water and the blossoms revive; immerse the lower end of a lampwick in oil and the oil climbs to the top.

To determine why this happens, fasten two sheets of clean glass with cellulose tape, first separating them slightly at one edge with a strip of thin cardboard. Then stand the sheets of glass on edge in a dish of water.

Immediately because of the combined force of adhesion and surface tension, the water climbs between the glass sheets--rising highest where the surfaces are closest together.

Water climbs thus in the capillary, or "hairlike" tubes in the fibers of plants.

2-16 Different Types of Stems[17]

a. Monocots; Secure stems of several plants such as bamboo, sugar cane and corn. Cut each of the stems crosswise with a very sharp knive or razor blade. Observe the similarities in the cut across sections. Especially notice that the tubes or fibrovascular bundles are scattered throughout the pith on the inside of the stem.

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[16] Ibid., p. 355.

[17] UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 41.

b. Dicots: Secure the stems of several plants or small trees such as willow, geranium, tomato, etc. Cut across each of these stems with a sharp knife or razor blade. Observe that just under the outside layer of the stem there is a bright green layer. This is the cambium layer. Also observe that the tubes are fibrovascular bundles are arranged in a ring about the central, or woody portion of the stem.

2-17 Leaves Give Off Water Vapor[18]

Use two similar pots of soil, one with a small plant and the other without. Cover the soil in each pot with cardboard after watering. Invert glass jars over each pot. Place the pots side by side in the sun and examine from time to time during the day.

2-18 The Structure of Leaves[19]

With a microscope examine the underside of leaves and locate their breathing pores or stomata with the two little guard cells on either side.

Cut a very thin cross section of the leaf with a razor blade and look at the edge through a microscope. Locate the palaside layer, the epidermis and the spongy layer. You may be able to see a vein and a stomata opening into the spongy layer.

2-19 Green Leaves Make Food for Plants[20]

Heat some alcohol in a jar over boiling water until it boils. Break several green leaves from a geranium or other plant which has

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[18]Ibid., p. 43.

[19]Ibid.

[20]Ibid.

been in the sun for several hours and place them in the boiling alcohol until the chlorophyll has been removed. Quickly remove the leaves from the alcohol and put them in a basin of hot water. Remove a leaf from the water and spread it out on a piece of glass or tile. Cover the leaf with tincture of iodine and leave for several minutes. The deep blue color is the test for starch which has been made by the leaf in the sunlight.

2-20 Green Leaves Give Off Oxygen[21]

Place some water weed under a funnel in a beaker of water. Invert a test tube full of water over the tube of the funnel. Leave the apparatus in strong sunlight. Bubbles of gas will be liberated from the weed and rise to the top of the test tube. In a short time the tube can be removed and the gas tested with a glowing splint.

2-21 To Show The Respiration of a Plant[22]

Place a plant in a test tube in a weighted wooden block. Put this in a bowl containing lime water and cover the plant with a jar. Keep the plant in a dark place for several hours and examine next day.

The lime water will be milky showing that carbon dioxide was given off and the rise in the level shows that a considerable amount of oxygen was taken in.

2-22 Germinating Pollen Grains[23]

Make a strong sugar solution and place it in a shallow dish

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[21]Ibid., p. 44.

[22]Ibid.

[23]Ibid., p. 45

like a saucer. Shake pollen from several kinds of flowers onto the surface of the sugar solution. Cover with a sheet of glass and let it stand in a warm place for several hours. If the experiment is successful little tubes growing from the pollen grains can be seen with the use of a hand lens.

2-23 Observing the Development of Flowers into Fruit[24]

Collect specimens of flowers in different stages of maturity, from newly opened buds to specimens in which the petals have fallen. Cut the ovary open and note the changes that have taken place during seed development.

Look over a quart of freshly picked peas or string beans and pick out the pods that are not completely filled. Open these and compare them with fully filled specimens. The abortive seeds are the remains of ovules that were not fertilized by pollen.

2-24 Phototropism in Plants[25]

Select two flower pots that contain young seedlings of similar sizes. Wrap a desk blotter or piece of black paper around one of the pots and fasten it with rubber bands or string so as to form a cylinder that shuts out the light. Cut a small hole near the top of the cylinder then cover the top of the cylinder so as to shut out the light entering from that source allowing light to enter only through the small hole. After a few days remove the cylinder and compare the two seedlings.

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[24]Ibid.

[25]General Science Handbook, Part 1, Bureau of Curriculum Development, Division of Secondary Education (New York State Education Department, 1951) p. 170.

CHAPTER III

EXPERIMENTS WITH BACTERIA AND MOLDS

3-1 Where Can Bacteria Be Found[26]

Materials needed are agar-agar, beef extract, salt, soda, petri dishes, forceps, pans, burner, ring stand, cotton, funnel, balance and weights.

Boil the petri dishes and forceps for at least 30 minutes. Put 3 grams of agar, 1 gram of beef extract, a pinch of salt, and a pinch of soda into 200 cc. of water. Boil the mixture until the agar is dissolved. Strain through cotton in funnel. Sterlize the mixture by boiling it for thirty minutes. Pour some of the hot liquid into each of the sterlized dishes and cover them immediately. Set them aside to cool, and label each one A, B, C, etc.

When the dishes are cool, set A aside for a control. Expose the other dishes to conditions as air of the room, a powder puff, a finger of a member of the class, or a piece of money. Recover all dishes immediately.

Set the dishes aside in a place where the temperature will not go below 70 degrees F.

Without removing the covers, observe the white, yellow, or other

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[26]Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, New York, J. B. Lippincott Company, (1955), p. 195.

colored spots that develop in a day or two. These are colonies of bacteria or molds.

3-2 Controlling Bacteria By Chemicals[27]

Materials needed are sterile dishes of agar, sterile needle, various antiseptics and germicides (alcohol, mercurochrome, tincture of iodine, and any trade name antiseptics).

Use the sterile needle to transfer a tiny quantity of bacteria from a colony to each of the sterile dishes. Put a couple of drops of each of the antiseptics or germicides into the spot where the bacteria was placed. Label each dish A, B, C, etc. Cover the dishes and put them in a warm place. Observe them daily.

3-3 Does Milk Contain Bacteria[28]

Materials needed are sterile petri dishes of agar, raw milk, pasteurized milk, sterile distilled water, sterile test tubes, and glass dropping tube.

Dilute about 1 cc. of a sample of the raw milk with about 10 cc. of sterile distilled water. Use a sterile test tube for mixing. Be sure to shake well. Put two drops of the mixture on the surface of the agar in one of the dishes. Repeat the process for a sample of the pasteurized milk. Put two drops of the sterile water on the agar in the third dish. This is a control. Label the dishes A, B, C, and cover and place the dishes in a warm place for two days.

How many colonies of bacteria developed in each dish? Did they develop at places where the milk mixture did not touch?

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[27] Ibid., p. 200.

[28] Ibid., p. 205.

3-4 To Study if Bacteria Grow Better Where It Is Dark or Light[29]

Inoculate two sterile dishes. Label one dark and the other light. Place the first dish in a dark warm place and the other in bright sunlight or where an electric bulb can shine on it all the time. Examine the dishes daily for a period of several days.

3-5 Observing Where Soil Bacteria Live[30]

Dig up a clover, alfalfa or soy bean plant. Carefully rinse all the soil from the roots and see if you can find the little white nodules on the roots. These are where the nitrogen fixing bacteria so important to soil fertility are found.

3-6 How Drinking Water is Tested[31]

Materials needed are water samples from various places, including water fountain, streams, pumps and wells. One fermentation tube of lactose broth and one fermentation tube of brilliant green bile, two per cent for each water sample to be tested.

Shake the water sample and place one ml. of each sample in a 10 ml. lactose broth fermentation tube. Label each tube.

Inoculate the tubes at about 37 degrees Centigrade for 24 hours. If 10 per cent or more gas is formed, as measured by the inner inverted tube, the water may be presumed contaminated and recorded as "Positive Presumptive".

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[29]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 48.

[30]Ibid., p. 49.

[31]Kaye Hutchinson Martin, "Bacteriology Experiments Designed for Use in A Course of High School Biology," (unpub. report, Oklahoma State University, 1957), p. 25.

Inoculate one tube of brilliant green broth from each positive presumptive lactose tube by placint one ml. or less in the brilliant green bile tubes.

Inoculate and store these tubes in a dark place at about 37 degrees Centigrade. Inspect after 19 to 24 hours. If fermentation has occured, it is confirmed that colon bacteria are present in the water sample.

To confirm that E Coli and not soil bacteria is present or absent in the brilliant green bile, a confirmation test may be run using E. M. B. and Endo agar plates. These media may be purchased at any biological supply house.

3-7 How To Obtain Molds[32]

a. Secure an orange which has green mold on it and keep it in a jar in a dark warm place.

b. Place a piece of moist bread in a jar and expose it to air. Leave for a few days in a dark warm place.

c. Secure a piece of blue or Roquefort cheese in which there is mold. Place in a jar and keep in a dark warm place.

d. Place a few dead flies in some stagnant water. In a few days they will become surrounded with a whitish growth of mold.

3-8 The Structure of Molds[33]

With cultures of different types of mold which has reached a vigorous state of growth examine each one with a hand lens. See if

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[32]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 49.

[33]Ibid.

you can see the strands which appear like spider webs. See if you can find little stalks with tiny black knobs on them. These are the spore cases. Thousands of spores are produced in each spore case which bursts when ripe. A new mold can develop from each spore if the conditions are right.

3-9 Do Molds Need Water for Growth[34]

Place a spoonful of dry cereal such as rice or oatmeal in a sterile culture dish. Place a like amount of the same cereal cooked in another culture dish. Using a sterile transfer needle inoculate each sample with mold from a growing culture. Cover the dishes and label them. Set the dishes aside in a dark, warm place and observe each one after a few days.

3-10 To Show the Effects of Yeast on Dough[35]

Mix together some sugar, water and flour in the proportions to make a good bread dough. Divide the dough into two equal parts. Stir a half yeast cake in some water and mix this with one of the samples of dough. Put each sample of dough in a dish which has a label and set aside in a warm place. Observe after a few hours.

3-11 To Study The Gas Produced When Yeast Acts on Sugar[36]

Place some clear lime water in a test tube and have a pupil exhale through a soda straw placed in the lime water. Soon the lime water will become milky which is a test for the gas carbon dioxide. Next place some yeast in a solution of sugar water in a test tube.

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[34]Ibid.

[35]Ibid., p. 50.

[36]Ibid.

Fit a one hole stopper to the tube and put a glass tube through the hole. Connect a rubber tube and another glass tube about 15 cm. long to the stopper. Place the long glass tube in a solution of clear lime water. Let the tubes stand in a warm place for a while. Observe the lime water.

CHAPTER IV

EXPERIMENTS WITH ANIMALS AND MAN

4-1 Making an Insect Collection

Obtain a cigar box or some other sturdy box with a lid and some straight pins for mounting. Place a piece of cardboard in the bottom of the box and cover it with white paper. Catch several insects, kill them in a killing jar and mount them in the box. Stick the pin through the thorax of soft insects and through the wing of hard winged insects.

Print the common name and order of the insect on a tab and paste near the posterior end of the insect.

4-2 Studying Life Histories of Insects[37]

Cut large rectangular holes in the sides of a large cardboard container and cover them with muslin folded over at the edges and gummed or pasted into place. Make a large door by cutting along three sides of a rectangle and bending along the fourth side. Stick a tab of folded paper or cardboard to the front edge of the door to act as a handle. Leave the original bottom of the box intact, to give rigidity. (If cellophane is available a window can be made in the door or in one side of the box.) Put a loose piece of paper on

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[37]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 53.

the floor to facilitate cleaning. Put moist soil into meat paste pots and put cut flowers into it, and stems and leaves of food plants. This is better than pots of water in which the insects may drown.

This cage is suitable for all stages of the life-histories of butterflies, and for moths if larger pots of soil are added for pupation. The insects can be handled by means of a brush or small stick.

4-3 Observing Spiders[38]

Many spiders cannot travel over water or a polished surface. Stand a plant in a pot in a bowl of water, or on a polished table. Put two or three sticks or strips of cardboard together, tie them into some sort of polygonal shape and lean this structure against the plant. Put an orb spinner on the plant and it will make a web.

If a few shelves can be removed from a cupboard a large spider such as Epeira diademata (female) can be persuaded to spin a web in it. Put some plants in pots in the cupboard with the spider, and close the door. After a few hours open the door. This will probably break the web, but if the door is now left open the spider will show no desire to escape but will spin another web. If enough insects are not caught give her daddy-long-legs, caterpillars, moths or flies.

The process of web spinning may be watched, and dated and timed observations made on feeding and other habits.

A 'cobweb spider' can be kept in a large jam jar. A gauze over the top serves to keep in a fly which can be introduced occasionally. Eggs which are laid can be easily observed, as well as the interesting feeding habits.

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[38]Ibid., p. 54.

4-4 An Aquarium for Larger Water Animals[39]

A glass aquarium 50 cm. by 25 cm. is of useful size.

To prepare an aquarium procure some fine silt from the bottom of a clear stream or pond and wash it carefully in running water. Cover the floor of the aquarium with it to a depth of about 2 cm. Plant a few reeds in this weighting the roots with a stone or some other weight. Then put in a layer of coarse sand or gravel and some large stones to serve as hiding places for the water insects. Fill with a slow stream of water and allow to stand for a day or two until clear. Clean water plants should be introduced. There is no need for elaborate aerating arrangements if plenty of water weeds are present.

The animals can now be introduced with a few snails to keep the grass clean. Very little feeding will be necessary. Fish will eat the snails' eggs and enough small water organisms can be found in the average pond to supply other needs. If worms are used as food they should only be given once a week cut in pieces small enough to be eaten. Any unconsumed food should be removed immediately or fungi will grow and will infect the fish.

A perforated zinc cover will prevent the escape of newts and frogs.

4-5 Observing the Life Cycle of Fruit Flies[40]

Small glass jars make excellent habitats for fruit flies. Place a bit of ripe fruit in the bottom of the jar and make a paper funnel

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[39]Ibid., p. 56.

[40]Ibid.

with a hole in the end to fit the mouth of the bottle. Place the bottle in the open; and when six or eight fruit flies have entered, remove the funnel and plug loosely with cotton wool. With this number of flies there should be both males and females. The females are larger with a broader abdomen. The males are smaller and have a black-tipped abdomen.

Soon eggs will be deposited, and in two or three days the larvae will hatch. A piece of paper may be placed in the jar for the larvae to crawl on when they are ready to pupate. The adult insects will come from the pupae. By adding newly hatched flies to another jar a new generation can be started.

4-6 A Class Project With Frogs' Eggs[41]

Collect a few frog or toad eggs and keep them in a jar or an aquarium filled with water from the same source as that from which the eggs were taken. Keep a day by day record of the development of the eggs and note all the changes that are observed.

4-7 What is a Cell Like[42]

What to use: Knife, alcohol, microscope slide and cover glass, stain, microscope.

Dip in alcohol the blade of a dull knife or other blunt instrument. Wash off the aldohol. Gently scrape inside the cheek with the back of the blade. A white material can be seen on the back of the blade. Touch this to the slide. Put a drop of iodine solution

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[41]David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences, McGraw-Hill Book Company, Inc., (1938), p. 401.

[42]Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, New York, J. B. Lippincott Company, (1955), p. 171.

on the material. Examine it under the microscope.

Do the cells have a definite shape? Do they have parts you can see?

4-8 To Demonstrate Permeable Membranes[43]

Materials: One recently killed frog; sirup of sugar solution; piece of small bore glass tubing; tumbler, can, or beaker; short piece of string.

Cut the skin around the frogs leg just below the hip. Peal this skin down toward the knee and then toward the ankle just as in removing a stocking. Stop at the ankle. Cut the foot off, leaving it inside the skin, since it is impossible to remove the skin from the foot without tearing it. Into the boot just made pour some concentrated sirup or sugar and water. Tie the top of the boot around the end of a glass tube, so that it will not leak, by winding the string around several times before tying. Submerge the boot in a can or glass of water up to the level of the string, but not above it. If the sirup stands up in the glass tube, mark the level to observe the rise of level after several hours.

4-9 Circulation in the Tail of a Fish or Tadpole[44]

Saturate a piece of cloth with water and wrap it loosely around the body of a small fish. Spread the tail fin over a hole in a board and fasten it with thumbtacks. Then fasten the cloth to the board in the same way. Pour a little water on the head end of the fish.

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[43]David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences, New York and London, McGraw-Hill Book Company, Inc., (1938), p. 331.

[44]Ibid., p. 337.

Examine the tail under a microscope to see the blood vessels running along the rays of the tail fin and capillaries running between the larger vessels. Keep the spread tail damp at all times. This may require dropping a little water on it every few minutes. If the fish is not used more than 20 minutes and is kept wet it may be returned to the aquarium and will be in good condition.

4-10 Response to Light[45]

Place enough culture of paramecium in a test tube to nearly fill it. Cork tightly and place in a horizontal position. Cover one-half of the tube with dark paper or cloth, or by inserting it into a paper tube. This must be opaque so as to exclude light. The cover must be loose enough to remove easily. After 20 to 30 minutes carefully remove the cover without shaking the tube and note the distribution of organisms.

4-11 Response to Food[46]

If material from an active paramecium culture is poured into a flat glass dish such as a watch glass or petri dish and allowed to stand for 5 or 10 minutes and is then examined under a microscope or strong hand lens, clusters of paramecia may be seen around the particles of decomposing food material or bits of bacterial scum.

4-12 Response to Electric Current[47]

Place paramecia culture in a small paraffin trough. Place a wire lead from one pole of a $1\frac{1}{2}$ to 3 volt dry cell in one end of the

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[45]Ibid., p. 364.

[46]Ibid.

[47]Ibid.

trough. Watch carefully what happens in the culture as the other electrode is applied to the opposite end of the trough. The animals quickly orient toward the negative pole and accumulate near it. If the poles are reversed, the response is repeated. This reversing may be accomplished by changing the positions of the wires or by the use of a reversing switch. With a good light and a dark background the results can be seen without a microscope.

4-13 Tactile Response[48]

To show that all parts of the body surface are not equally sensitive to contact. Thrust two ordinary needles through a cork or piece of very soft wood. If properly adjusted the points may be placed extremely close together, or by partially withdrawing the pins the points will separate. Using this instrument with the points very close, explore the back of the hand and forearm. If the pins are close enough together they give the sensation of a single contact on the skin. Separate the points a little at a time until just wide enough to give the impression of two contacts. Repeat these tests for the palm of the hand, fingertips, forehead, or other regions and compare the results. Do not press hard enough to cause pain, as pain and pressure are separate senses.

4-14 Reproduction of Paradise Fish[49]

Several kinds of fish reproduce in aquaria. The paradise fish which makes a bubble nest is very interesting if the temperature of the aquarium can be controlled at 80 or 85 degrees F. The embryo-

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[48]Ibid., p. 373.

[49]Ibid., p. 401.

logical development may be watched since both the eggs and embryos are so transparent that such things as heart beat and circulation are easily seen.

CHAPTER V

MECHANICS

5-1 <u>How a Lever Works</u>[50]

Support a meter stick or long ruler by tying a string around it at the middle. Hang a fairly large weight at a distance of 10 cm. from the center support. This center support is called the fulcrum and is the point around which the lever turns. Hang another weight 50 cm. from the fulcrum. Find how much weight is needed to balance the lever. "Teeter" the lever up and down, measuring the distance each weight moves.

Remove the small weight from the ruller. Use the spring balance, with a loop of string around the stick, and lift up on the stick in such a way that you support the weight with the balance. Pay no attention to the weight of the lever or to the part of the stick on the side which has no weights. Now measure the distance from the fulcrum to the resisting weight, and from the fulcrum to the spring balance.

What is the relation between the forces and distances moved when a simple lever is used?

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[50]Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, New York, J. B. Lippincott Company, (1955), p. 322.

5-2 A Simple Wheel and Axle[51]

Remove the cover from a pencil sharpener and tie a string tightly around the end of the shaft. Tie a weight of several grams to the end of the string and turn the handle. Note that the force needed to turn the handle is much less than the force of gravity on the weight. The pencil sharpener is used as a wheel and axle in this demonstration.

5-3 How to Overcome Resistance[52]

Tie a string around a brick and weigh the brick. Make a written record of all measurements.

Test the strength of several strings by tying one end to a strong support, such as a pipe, and pulling with a large spring balance until the string breaks. Then starting with the weakest string, tie each string in turn to the brick. Jerk forcibly to see if the string can be broken without lifting the brick.

Drag the brick along a board, noting the amount of force required. Then put rollers under the brick and repeat the experiment.

Raise one end of a board by putting one end on a pile of books. Make the height just one fourth of the length. Drag the brick up the board with and without the rollers. Compare the force required with the weight of the brick.

5-4 The Block and Tackle[53]

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[51] UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 109.

[52] Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, New York, J. B. Lippincott Company, (1955), p. 325.

[53] UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 110.

Let each of two pupils grasp a round stick, such as a broomstick and stand several feet apart. Tie a length of clothesline cord to one of the sticks and wrap it several times around both sticks so as to form a combination of pulleys. Ask a third pupil, smaller than the other two to pull on the rope. He can easily pull the two sticks together despite the efforts of the pupils holding the sticks.

5-5 How Speed is Increased by the Use of Machines[54]

Using nails for axles fasten a large spool and a smaller spool to a block of wood. Slip a rubber band over both spools. Turn the larger spool one turn and note whether the smaller spool makes more or less than one full turn.

5-6 Using a Bicycle to Show How Speed is Increased By Machines[55]

Turn a bicycle upside down so that it rests on the seat and handlebars. Turn the pedal wheel exactly one turn and note the number of turns made by the rear wheel.

5-7 A Model Elevator to Show Change in the Direction of Forces[56]

A working model of an elevator can easily be made from simple materials. For the rotating drums or sheaves, metal coffee tins will do. With a hammer and large nails punch holes in the exact center of the bottoms and lids. Replace the lids and mount the tins on opposite ends of a board, taking care that they both turn easily.

For the elevator car use a small cardboard or wood box. Attach

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[54]Ibid., p. 112.

[55]Ibid.

[56]Ibid.

pieces of string to both ends of the box and wind them around the sheaves. A piece of modeling clay can be used for a counterweight and should just balance the weight of the car. Operate the elevator by turning the sheave that has the double turn of cord. A model of this kind is very similar to real elevators, but the sheave of real elevators are turned by electric motors.

5-8 The Principle of Two Kinds of Machines[57]

Fill a test tube about one fourth full of water, and hold it with the clamp on a ring stand. Point the test tube away from the class. Wet the stopper and put it loosely in the test tube. Put the burner beneath the test tube. For safety all people in the room should be well away from the test tube for there is a possibility that it might explode. Observe what happens when the water boils. Repeat the experiment, but insert the stopper more tightly, but do not drive it in.

What makes the stopper move?

Inflate a balloon and release it in the air. How far does the balloon travel before it is empty? What makes the balloon move?

5-9 Effect of Air Pressure [58]

a. Heat a gallon can (rectangular shaped) containing approximately 100 ml. of water to boiling. When the steam issues freely, remove the flame and stopper the can. Pour cold water over the can which

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[57]Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, New York, J. B. Lippincott Company, (1955), p. 340.

[58]John S. Richardson and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, New York, Toronto, London, McGraw-Hill Book Company, Inc., (1951), p. 192.

will collapse as the steam on the inside of the can condenses and reduces the pressure.

b. Fill a bottle or tumbler completely full with water, cover the bottle with a card, and invert it, one hand holding the card in place. After inversion, the hand supporting the card is removed. The effect of atmospheric pressure prevents the water from flowing from the bottle.

5-10 Falling Bodies[59]

Find a building that is about 20 m. high to study how gravity makes bodies fall faster the longer it acts on them. Get a piece of string long enough to reach from a point at least 20 m. high to the ground. Fasten the cord so that it forms a tight straight line. Opposite a window 20 m. from the ground tie a piece of colored cloth or yarn to the string. At about 5 m. below this point tie another piece of colored cloth. Have someone stand on the ground with a watch and call out the seconds. A good way is to beat seconds with the arm and call out 'a thousand and one--a thousand and two--a thousand and three'. This will beat seconds approximately.

Now station someone at the 5 m. mark below the starting point and someone on the ground. Drop heavy stones and light stones. Drop small objects and large objects. See how far they have fallen at the end of one second and how far at the end of two seconds.

5-11 Feeling Centrifugal Force[60]

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[59]UNESCO, UNESCO Source Book for Teaching Science, Amsterdam: Drukkerij Holland N. V., (1956), p. 116.

[60]Ibid., p. 117.

Tie a weight to a string about a meter in length and then whirl the weight at arm's length. Observe the outward pull of the string. This is centrifugal force.

Replace the string with a strong rubber band. Cautiously whirl the weight on the rubber band. Observe the stretch in the rubber. This is caused by centrifugal force.

5-12 <u>How A Centrifugal Clothes Dryer Works</u>[61]

Punch the sides of a tin can full of holes with a nail. Punch three holes equidistant from each other around the top of the can. Suspend with three cords and attach these to the screw eye of a drill chuck. Make a cylinder out of cardboard or secure a pail a little deeper than the can and considerable wider. Place a piece of wet cloth in the can attached to the drill. Lower the can into the cylinder or pail and spin it rapidly with the drill. The water is thrown out of the cloth and can by centrifugal force.

5-13 <u>Action and Reaction in Pushing Forces</u>[62]

Forces work in pairs. If one pushes against a wall, the wall pushes back. Secure two kitchen spring balances with square platform tops. Put the tops together with the dial faces up. Have someone push on one of the scales while someone else pushes on the other. Observe that when they are pushed together each balance reads the same.

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[61] Ibid., p. 118.

[62] Ibid., p. 120.

CHAPTER VI

EXPERIENCES WITH HEAT

6-1 To Show That Metals Expand[63]

a. Find a board about 7 feet long, 6 inches wide, and 1 inch thick and drive two 4 inch spikes into it exactly 6 feet apart.

b. Cut a wire exactly 6 feet long.

c. Twist exactly 3 inches at each end into a loop.

d. Put one loop over the lower spike near its head, and attach the other loop to the upper spike near its head by means of four stretched rubber bands.

e. Slit one end of a soda straw for 1 inch and slide this end into the end of another soda straw, to make a light pointer.

f. Drive in a third 4 inch spike in such a position that it touches the upper loop and its under side is at the middle of the loop. Insert the soda-straw pointer into the loop with the inserted end under the spike.

g. Cut a three inch strip of newspaper about 3 feet long and fold it lengthwise.

h. Pin the paper around the lower end of the wire and light it at its lower end.

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[63]Carleton John Lynde, Science Experiences with Inexpensive Equipment, Toronto, New York, London, D. Van Nostrand Company, Inc., (1939, 1950), p. 110.

You will see the outer end of the pointer rise when the wire is heated and sink when it cools.

6-2 A Bimetallic Strip to show the Difference of Expansion in Metals[64]

Two strips, of iron and brass, riveted together will bend when heated because of the difference of expansion. Make holes in the metal with a nail and use small tacks as rivets to fasten the pieces together. Heat the metal pieces and observe.

6-3 Temperature Sense[65]

Fill three pans with water. Have one at the highest temperature that you can bear your hand in. Have a second one with ice cold water. Have the third one lukewarm. Put both hands in the lukewarm water and hold them there for about half a minute. Does the water seem the same temperature for both hands? Does it feel hot, cold or neither?

Next place the left hand in the hot water and the right hand in the cold water for a minute. Quickly dry the hands and plunge both into the lukewarm water again. How does the right hand feel? How does the left hand feel? Do they feel the same as when in the lukewarm water before?

6-4 How A Thermometer Works[66]

Fill a flask made from a used electric light bulb with water that has been colored with ink. Insert a one hole stopper carrying

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[64]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 132.

[65]Ibid., p. 133.

[66]Ibid., p. 134.

a 30 cm. length of glass tubing until the water rises in the tubing a distance of 5 or 6 cm. Place the flask on an alcohol burner and observe the water level as the water is heated. The water expands at a more rapid rate than the glass and rises up the tube. A keen observer may see that just at the moment heating is begun, the water level drops then begins to rise again. This is caused by the expanding of the glass bulb before the water inside has reached the same temperature as the glass.

6-5 Heat and Temperature-the Idea of a Calorie[67]

Suspend a tin with a thermometer in it over a bunsen or a candle flame and record the time taken to raise different measured masses of water by 10 degrees C. It is sufficiently accurate to measure the water in the cylinder and count cubic centimeters as grams. The number of calories absorbed is, of course, mass times change in temperature.

6-6 To make Cresote, Wood Gas, and Charcoal[68]

Cut wood into short narrow sticks, put a handful or two into a can and heat the can over the fire in a range.

After the water vapor has been driven off, light the wood gas which issues from the hole in the cover.

After the gas has all burned, let the can cool and examine the charcoal left in the can. This is excellent for charcoal drawing, if hard wood was used.

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[67] Ibid.

[68] Carleton John Lynde, Science Experiences with Home Equipment, Princeton, New Jersey, Toronto, London and New York, D. Van Nostrand Company, Inc., (1937, 1949), p. 186.

Smell the inside of the cover. The odor is that of cresote.

Charcoal will burn with little flame or smoke.

6-7 To Make a Steam Turbine[69]

Find a can with a tight cover, and punch a small nail hole in the cover $\frac{1}{2}$ inch from the edge.

To make the turbine, cut a round slice of cork about 3/4 inch thick, insert four 1 inch by 3/4 inch cardboard paddles in $\frac{1}{4}$-inch slits in the cork, and use two pins for axles.

To make a support for the turbine, cut a piece of cardboard $7\frac{1}{2}$ by $1\frac{1}{2}$ inches, bend in a horseshoe shape and cut two notches one at each end to hold the pin axles.

Boil water in the covered can, and arrange the turbine and its support above the hole in the top of the can so steam can hit the turbine. The steam will spin the turbine very rapidly.

6-8 Heat Feat[70]

Place a penny on an asbestos sheet and heat. Periodically touch the penny and asbestos sheet. The penny will seem hotter.

Check the temperature with a thermometer and both will be found to be the same.

The difference is in conduction. Metal conducts heat rapidly to the fingers; asbestos conducts slowly. Metals consequently, make good heat radiators and conductors; asbestos, good insulators.

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[69]Ibid., p. 188.

[70]D. Herbert, "Mr. Wizard Science Secrets", Science Digest, Vol. 33, (Jan. 1953), p. 71-4.

6-9 Heat That Will Not Burn[71]

Stretch a handkerchief across a coin and tighten by twisting it. Touch this spot with a cigarette or incense stick and it will refuse to burn.

The coin conducts heat to all parts of the coin; as a result the kindling temperature is kept below the burning point.

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[71]D. Herbert, "Mr. Wizards Science Secrets", Science Digest, Vol. 32, (Nov. 1952), pp. 1-6.

CHAPTER VII

LIGHT AND SOUND

7-1 Fluorescent Lighting [72]

Fluorescent paint can be made by mixing a paste of quinine sulfate and dilute sulfuric acid.

Coat half the tube and allow it to dry.

The coated side gives off more light because it is being bombarded by ultra-violet rays from the plates in the tubes; giving off visible rays of great intensity.

In a commercial tube the coating is on the inside, so as to protect it and at the same time utilize those ultra-violet rays that cannot pass through the glass. Mercury and argon vapor are the two gases used most often in fluorescent lights. The electric current is started by the low pressure argon present, but later most of the ultra-violet light is changed to visible light by the phosphor powders on the walls of the glass.

7-2 Reflection With A Mirror[73]

Place a plane mirror on the floor where a beam of sunlight will strike it and be reflected. Stand a drinking straw upright at the

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[72] "Home Experiments", Popular Science, Vol. 142, (Apr. 1943), p. 109.

[73] UNESCO, UNESCO Source Book for Science Teaching, Amsterdam; Drukkerij Holland N. V., (1956), p. 174.

place where the beam strikes the mirror. Compare the angle made by the incident beam and the straw with the angle made by the reflected beam and the straw.

7-3 Making a Smoke Box to Study Light Rays[74]

Secure or construct a wood box about 30 cm. wide and about 60 cm. in length. Fit panes of window glass in the top and front of the box. Leave the back open, and cover with loosely hung black cloth which drapes like a curtain. Hang the curtain in two sections making about a 10 cm. overlap at the center of the box. Paint the inside of the box with dull black paint. About midway between the top and bottom of one end about 8 or 10 cm. from the glass front, cut a window 10 cm. long and 5 cm. wide. This is to let in light rays. The window can be covered with different kinds of openings cut from cardboard and fastened with thumb tacks.

For the first experiment cut a piece of black cardboard with three equidistant holes about 5 mm in diameter. Place over the window with thumb tacks. Fill the box with smoke. This can be done with punk, incense candles or smouldering cigarettes placed in a dish and set in one corner of the box. Next set up a flash light about one meter from the window. Focus the light down to a parallel beam and direct it at the holes in the window. Observe the light rays in the box made visible by the smoke. Does this experiment show that light travels in a straight line?

7-4 Making Reflected Beams of Light[75]

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[74]Ibid., p. 173.

[75]Ibid., p. 174.

Hold a comb in a sunbeam falling on a piece of white cardboard. Tilt the cardboard so that the beams of light are several centimeters long. Place a mirror diagonally in the path. Observe that the beams which strike the mirror are reflected at the same angle. Turn the mirror and observe how the reflected beams turn.

7-5 Refraction in a Beam of Light[76]

Place a few drops of milk in a glass of water in order to cloud the water. Punch a small hole in a piece of dark paper or cardboard. Place the glass in the direct sunlight. Hold the card in front of the glass. A beam of sunlight will pass through the hole. Hold the card so that the hole is just below the water level and observe the direction of the beam in the water. Now raise the beam until the beam strikes the surface. Observe the direction of the beam of light. Experiment to find out how the angle at which the beam strikes the water affects the direction of the beam in water.

7-6 What is the Color of Sunlight[77]

Darken a room into which the sun has been shining. Punch a small hole in the window shade to admit a beam of light. Hold a glass prism in the beam of light and observe the band of colors, called a spectrum, on the opposite wall or ceiling.

7-7 The Color of Opaque Objects[78]

Get a good spectrum on a wall or a sheet of white paper in a darkened room. Place a piece of red cloth in the blue light of the

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[76]Ibid., p. 178.

[77]Ibid., p. 183.

[78]Ibid., p. 184.

spectrum. What color is it? Place it in the green and in the yellow. How does it appear? Place it in the red light. How does it appear? Repeat using blue, green, and yellow colored cloth. They will appear black except when placed in the same colored light. Thus opaque objects have color because of the light they reflect; they absorb the other colors of the spectrum.

7-8 Famous Lissajous Curves[79]

Cut a string six feet long and tie both ends about a foot apart, to a horizontal support.

Tie a string to a paper cup and fasten it to the other string to form a "Y".

Fill the cup with salt and after cutting a small hole in the bottom of the cup, start it to swinging.

By substituting this two way pendulum for a tuning fork , and salt for the light rays, a beautiful pattern, which is similar to the tuning fork waves can be seen.

7-9 Resonance Gives Sound of Sea[80]

The reason for the sound and it's pitch is resonance. The air within any enclosed space of moderate size vibrates more easily at one definite pitch than another; the bigger the space, the lower the pitch, and vice versa. The air around us is full of a mixture of sounds of different pitch. When we press a container to our ear we merely hear an amplification of any sound that corresponds to the

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[79]K. M. Swezey, Science Magic, New York: McGraw-Hill Book Company, (1952), p. 72.

[80]K. M. Swezey, After Dinner Science, New York; McGraw-Hill Book Company, (1948), p. 84.

shell's own natural pitch. Auto industries take advantage of this when test running a car for noises. The car is driven very close to a wall where any noise is picked up and amplified. Resonance is defined as the reinforcement of one sound wave by another.

7-10 Sound Cannot Travel in A Vacuum[81]

Tie a bell loosely to one end of a pencil by means of a rubber band. Push the other end of the pencil through a one hole stopper that fits snugly on a flask. Add a little water to the flask and boil until all air has been expelled.

Remove from the flame and put the stopper on instantly.

After the steam has condensed, a partial vacuum results, which makes the bell almost inaudible when the flask is shaken.

In 1660 Robert Boyle first proved that sound could not penetrate a vacuum in an experiment very similar to that above. It will be more dramatic if the flask is shaken at different intervals as the steam is condensing. Sound has its origin in a vibrating body and is transmitted to the ear through some medium. Solids are the best media for sound transmission; liquids and gases follow in the order named, but sound will not travel in a vacuum. The velocity of sound in air at zero degrees centigrade is 1090 feet per second. The velocity increases 2 feet per second for every 1 degree centigrade rise in temperature.

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[81] Ibid., p. 78.

CHAPTER VIII

MAGNETISM AND ELECTRICITY

8-1 Effects of the Earths Magnetic Field[82]

Suspend a bar magnet by a thread to demonstrate the compass. The poles should be clearly marked.

Use a sensitive compass to establish north in the laboratory. (This may not be feasible if there were magnetic materials used in the structure of the building.) If the variation from true north is sufficiently great, the difference may be shown by two sets of lines on the north and south walls, one set to show magnetic north; another set adjacent to show true north. Lines may be painted on the floor to show true and magnetic north. True north may be determined from magnetic north for a given locality by reference to a map of magnetic variations.

Show inclination by sliding an encased compass along a bar magnet, noting the effect. A dipping needle may be used instead.

Determine the inclination for a given locality by placing a dipping needle in a N-S direction and noting the position of the compass.

Magnetize a soft iron bar (shown to be free from magnetism by

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[82] John S. Richardson and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, New York, Toronto, and London, McGraw-Hill Book Company, Inc., (1951), p. 214.

testing with a sensitive compass) by tapping it on the end as it is held in the direction of the earth's magnetic field (parallel to the dipping needle). The compass registers its magnetization.

8-2 The Attraction of a Magnet[83]

a. A magnet attracts iron and steel.

Touch a magnet to a silver coin, copper coin, gold ring, pins, needles, tacks, nails, aluminum ware, glass ware, china ware, etc. The magnet attracts only things made of iron and steel.

b. The attraction of a magnet passes through every thing except iron and steel.

File an iron nail and collect the filings. Put the filings on cardboard and move a magnet against the under side. The filings will move with the magnet.

Repeat the test with paper, glass, china, aluminum, tin, and iron. Observe that the attraction of the magnet passes through all except those made of fairly thick iron or steel.

8-3 How to Magnetize a Steel Rod[84]

Use a piece of magnetic iron ore or another magnet to magnetize a steel knitting needle, a darning needle, an iron nail, a piece of clock or watch spring. This may be done simply by stroking the bar several times with the magnetized substance. To make a bar magnet with opposite poles at either end, use an artificial magnet. Begin at the center of the unmagnetized bar and stroke toward the end of

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[83]Carelton John Lynde, Science Experiences With Ten-Cent Store Equipment, Princeton, New Jersey, Toronto, London and New York, D. Van Nostrand Company, Inc., (1941-1950), p. 174.

[84]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam: Drukkerij Holland N. V., (1956), p. 143.

the magnet. After several strokings turn the bar around and stroke from the center to the other end using the opposite pole of the magnet. Test the results by using the rod to pick up iron filings or by approaching it to a compass.

8-4 Magnetizing a Bar By Hammering[85]

Secure an iron rod about one meter in length. An iron curtain rod will do. Test it with a compass at each end to see if it is magnetized. Hold the bar in a north south direction and tilt. Strike the rod several times with a hammer while in this position and test it again with the compass. A bar can often be demagnetized by holding it in an east-west position and striking the end several times with the hammer.

8-5 Lines of Force[86]

A piece of plywood with two grooves cut in it to the depth of one ply is useful for holding magnets and magnetic materials while testing the patterns of their lines of force.

Permanent records can be made of such 'filing maps' if the paper used over the magnets is first dipped in hot candle grease and allowed to cool. Place it over the magnets under test, scatter filings on it from a height of 30 cm. and tap the paper. Fix the pattern formed by warming the waxed paper with the medium flame of a bunsen burner.

8-6 A Magic Magnetic Spinner[87]

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[85]Ibid., p. 145.

[86]Ibid.

[87]Ibid., p. 147.

Make a spinning top from a wooden spool which has been used for thread. The spool is first cut in two. One piece is then shaped into a top. Find a nail or other piece of iron rod that will fit tightly in the hole of the spool. Cut off a length that will go through the cone and stick out about 1 cm. above the top. Grind the lower end which just sticks out, to a very sharp and evenly rounded point to make a spinning peg. Magnetize the spindle and insert it in the wooden cone. Form a large S curve from a piece of soft iron wire. Place this on a smoothe surface. Set the top spinning near one of the cones and it will follow the wire to the end.

8-7 Static Electricity is Everywhere[88]

Rub a blown up balloon through the hair and then bring it near some fine particles of cork particles. Repeat using a comb and a plastic ruler. Rub a fountain pen on a coat and test it for static electricity. Hold two strips of newspaper, about 5 cm. wide and 30 cm. long, together. Stroke them lengthwise with the thumb and finger of your free hand. What happens?

8-8 How to Make an Electroscope[89]

To make a device for detecting charges of electricity, a jam jar, some wire, and pieces of light foil are needed.

A waxed cork is necessary to prevent the charge from leaking away. Push an L-shaped piece of brass or copper through it, and hang a piece of tissue paper or a strip of aluminum foil to the lower end.

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[88]Ibid., p. 150.

[89]Ibid., p. 152.

If a charged body is brought near the rod, the leaves of the paper fly apart because they have received the same kind of charge.

Insulating wax or Perspex are better insulaters and therefore more satisfactory than the waxed cork.

8-9 Electrical Heating Devices[90]

Wind iron wire around a pencil, making a coil. Connect the ends of this coil to two dry cells in series. Fill a water glass with cold water, and take a reading of its temperature. Put the coil into the water for three minutes, and note any changes in temperature. To be more scientific, take a reading of the current flowing, and find the number of watts used. Multiply the weight of the water in grams by the increase in temperature in centigrade degrees, and find the number of calories of heat produced.

8-10 A Model Fuse[91]

To demonstrate the purpose of fuses in circuits, one can construct and use this simple device.

Cut a very thin strip of metal foil from a candy bar or other wrapper and fasten it between the ends of two wires that have been forced through a cork. This will represent a model of a fuse that should work with dry cells. This can be connected into different circuits and its action under different loads can be observed. By changing the width of the metal foil one can adjust the fuse to carry different loads.

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[90]Victor C. Smith and W. E. Jones, General Science, Chicago, Philadelphia, and New York, J. B. Lippincott Company, (1955), p. 288.

[91]Ira C. Davis, John Burnett and E. Wayne Gross, Science, New York, Henry Holt and Company, (1952), p. 310.

8-11 How to Construct a Simple Electric Motor[92]

The essential parts of an electric motor are: a magnet, an armature, two brushes, and a source of current. A permanent horseshoe magnet may be used. It should be mounted in a firm position on a small board. The armature will be the most difficult part to make. A small piece of wood, cylinderical, may be used as the core. A piece of broomstick or a big piece of cork will do. Wind about 20 turns of no. 22 wire, insulated, lengthwise over the wood or cork. Each bare end of the wire is fastened to a copper nail (or heavy wire). Both of the nails are driven into one end of the wood or cork, one opposite the other. The brushes touch these nails as the armature revolves.

The armature must have an axis upon which it revolves. A knitting needle or small steel rod will do. This must be driven through the center of the wood or cork. Now the armature must be mounted between the poles of the magnet. Small blocks of wood may be used in which to fasten the knitting needle or rod. Brushes must be placed properly so that they will be in contact with the nails of the armature. These brushes may be pieces of copper wire fastened to nails driven into the board that supports the magnet.

When the motor is finished, connect it to two dry cells as a source of current. Use a switch if desired and make the motor run.

8-12 A Conducting Device[93]

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[92]Ibid.

[93]Carlton John Lynde, Science Experiments with Ten Cent Store Equipment, Princeton, New Jersey, Toronto, London, and New York, D. Van Nostrand Company, Inc., (1941-1950), p. 185.

A tester to demonstrate that some substances conduct electricity while others do not can be made from the following articles; two dry cell batteries, a push button switch, a socket and flashlight bulb, two pieces of tin, two by three inches, bent at a right angle, a jar and a two hole stopper to fit, four nails, a board about three feet long. In one of the wires connect the bulb and socket and the push button switch. Take the two pieces of tin and tack them to the board base about three inches apart, making a loop of the wire around the nails just before they become solid, then finish driving them in. Attach two fairly long nails to the ends of the wires at one end of the apparatus and drop these through the two holes in the stopper. Connect the batteries to the other end of the apparatus and it is ready to use.

Test the electric conductivity of solid objects by laying them across the metal strips and pressing the push buttons. Test liquids by placing them in the bottle and lowering the nails into it. If the bulb lights the liquid is a conductor.

8-13 How to Make a Simple Storage Battery[94]

Strip the lead covering from some electric cable. Cut it into pieces, 1.5 cm. by 3 cm. with a short projection or 'lug' on the short side of each.

Now prepare pieces of thin wood 1.5 cm. by 3 cm. from a matchbox to act as 'spacers' to separate the plates.

Arrange a pile of plated with lugs placed alternately and

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[94]UNESCO, UNESCO Source Book for Science Teaching, Amsterdam, Drukkerij Holland N. V., (1956), p. 156.

separate each plate with a spacer.

Connect the lugs on each side by a copper wire.

Immerse this arrangement in dilute sulphuric acid and pass a current to form the plates. Even with a few minutes the battery will light a small torch. Alternate charging and discharging will improve the condition of the plates.

8-14 How to Copper Plate With Electricity[95]

Dissolve enough copper sulphate (blue vitriol) in a jar of water to make it deep blue in color. You can usually secure copper sulphate at a hardware store or a drug store. Connect a wire from the positive post of a dry cell to a piece of copper and put it in the solution. Attach a wire from the negative pole of the dry cell to an iron nail which has been cleaned of rust and grease. Now place the nail in the solution so that it does not touch the piece of copper. In a short time you will have a coating of copper on the nail. Other metal objects may be plated by attaching them to the negative pole of the cell and placing them in the solution.

8-15 How to Make an Electromagnet[96]

Secure an iron bolt about 5 cm. long which has a nut and two washers. Place a washer at each end and screw the nut just on to the bolt. Wind layers of insulated bell wire on the bolt between the washers, making certain to leave 30 cm. of wire sticking out when you start winding the coil. When you have filled the bolt between the washers with several layers of turns of wire, cut the wire,

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[95] Ibid., p. 160.

[96] Ibid., p. 162.

again leaving about 30 cm. sticking out. Twist the two ends of the wire close to the ends, then wind short lengths of tape at the ends of the bolt to keep the wire from unwinding. Remove the insulation from the two ends of wire. Connect two dry cells in series and attach the electromagnet to them. Pick up some tacks and nails. Disconnect one wire from the battery while the tacks are still attached. Pick up other objects made of iron or steel. Test the poles of each end of the magnet with a compass while the current is turned on.

CHAPTER IX

EXPERIMENTS IN CHEMISTRY

9-1 The Flame Test for Metals

One of the jobs of the chemist is to identify substances. Some metals can be identified by the color of the flame produced when they are burned.

Heat a 2 to 3-inch chromium wire until it is free from foreign substances. Dip the wire into the material to be tested and hold the wire in a bunsen burner. Note the color of the flame. Reheat the wire to clean it and repeat for other metals. Each material produces a different colored flame.

The following list of metals should produce a flame of the color listed opposite them.

Metal	Color of Flame
Potassium	Bluish Purple
Lithium Chloride	Pinkish Violet
Sodium	Yellow
Calcium Nitrate	Pale Orange
Strinthium Chloride	Bright Orange
Copper	Bluish Green

9-2 To Test for Radioactivity in Plants

With a Gieger counter, (if a Gieger counter is not available an electroscope may serve the purpose) check a tomato plant for radioactivity. Note the count or if an electroscope is used, how far the leaves stand out.

Place the roots of the plant in a container of water and place a piece of radioactive material in the water. Phosphorus is a good material for this experiment. Allow the plant to remain in the water for about 15 minutes. Remove the plant away from the container and recheck it for radioactivity. Is the count higher or lower than before? Are materials absorbed through the roots of plants?

9-3 How to Make a Disagreeable Odor[97]

Place four measures of sulfur in a dry test tube and add a piece of candle about one eighth inch long. Heat the test tube over a flame, and after a minute notice the disagreeable odor of the evolved gas. The gas is hydrogen sulfide, which has an odor resembling that encountered when rotten eggs are broken.

9-4 A Magic Odor That Will Revive Fainting Persons[98]

Place two measures of ammonium chloride and two measures of calcium oxide in a test tube. Heat this mixture over a flame for a few moments and smell the gas which is given off. This gas has the property of reviving persons that have fainted.

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[97] Chemcraft, Chemical Magic, 95 Mystifying Magical Demonstrations, The Porter Chemical Company, Hagerstown, Maryland, 1940, p. 10.

[98] Ibid.

9-5 How to Prepare Hydrogen[99]

Hydrogen can be prepared from a dilute acid, such as hydrochloric or sulphuric, when it reacts chemically with a metal such as zinc. The acid may be secured from a drug store. It should be handled carefully to avoid spilling on hands and clothing. Zinc can be secured from the outside container of an old dry cell. Clean the zinc thoroughly and cut into small pieces about 2.5 cm. square.

To make the hydrogen place the zinc in a flask or bottle filled with a two hole rubber stopper. Through one hole place a funnel tube that reaches nearly to the bottom. In the other hole place a tube with a right angle bend and attach it to a 30 to 40 cm. length of rubber tubing. Fill a pan about half full of water and invert bottles of water in the pan. Place the end of the delivery tube in one of the bottles to collect the hydrogen. Pour the dilute acid on the zinc through the funnel tube. Be sure to keep flames away from the generator; hydrogen mixed with air is very explosive. When the bottles are filled with hydrogen, put a glass plate over the mouth and stand them on the table, mouth down.

9-6 Relative Strength of Acids[100]

Prepare solutions of HCl, H_2SO_4, and $HC_2H_3O_4$, diluting each to a normality of 2. A quantity of 200 ml. of each of the acids is placed in each of three 500- ml. flasks. Magnesium ribbon cut into ½ inch lengths, such pieces being placed in each of three balloons

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[99]John S. Richardson and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, New York, Toronto and London, McGraw-Hill Book Company, Inc., (1951), p. 435.

[100]Ibid., p. 431.

which then have their necks stretched over the openings of the flasks. At a given time all balloons are raised and the pieces of metal fall into the acid. The relative expansion of the balloons indicate the relative activity of the acids in the flasks.

9-7 Iodine Clock Demonstration[101]

This demonstration was designed to show the different speeds of chemical reactions.

Two solutions are required. Solution A is made by dissolving one gram of potassium iodate in 500-ml. of water.

Solution B is made by dissolving 0.2 grams of sodium bisulfide in 450-ml. of water. Also add 50-ml. of starch suspension, made by dissolving 1 gram of starch in 50-ml. of hot water. Cool thoroughly before adding.

Now mix equal quantities of the two solutions. After about 20 to 30 seconds the liquid will suddenly turn blue-black without any apparent reason or cause.

9-8 A Test For Starch[102]

In your kitchen there are two white powders that look alike-- starch and baking powder. If these were in unlabeled boxes you still could tell which is starch. Take two glasses and into each one pour ½ cup of water. Then put one teaspoonful of one substance in one glass and one teaspoonful of the other substance in the other glass. Both liquids turn milky. You still can not tell which is starch.

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[101] Burton L. Hawk, Experimenting With Chemistry, Washington, Science Service, (1957), p. 72.

[102] Rose Wyler, The First Book of Science Experiments, New York, Franklin Watts Inc., (1952), p. 54.

Take the iodine solution from your medicine chest and with the dropper put one drop into each glass. The iodine gives a brownish tint to the baking powder, but the starch liquid turns deep purple. Starch is the only substance that has this color when tested with iodine.

Try the iodine test on different foods. Place a small sample of the food on the lid of a coffee can, then put a drop of iodine on it. Everything that turns purple contains starch.

9-9 Destructive Distillation of Coal[103]

Heat small pieces of bituminous coal in a pyrex test tube and collect the vapors in another tube which is submerged in a cold water bath. The gas from the jet is ignited. After the action is completed the coke residue may be recovered by breaking the glass tube.

The distillate in the tube may be studied by adding to it an equal volume of 3N NaOh solution. A piece of moist red litmus is placed over the mouth of the tube, which is then warmed. Other tests may be used to detect the presence of ammonia, if desired.

The chamber may be a piece of capped iron pipe rather than a pyrex tube. Such a chamber may be cleaned and reused.

9-10 A Test for Lead in Paints[104]

Test for lead in paint by treating 3 ml. of paint with 15 ml.

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[103]John S. Richardson and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, New York, Toronto, and London, McGraw-Hill Book Company, Inc., (1951), p. 446.

[104]Ibid., p. 450.

of CCl_4. This is then filtered and the precipiate dried. It is then placed in a hollow cup formed in a charcoal block and heated with the reducing flame of a blowpipe. If lead is present it is deposited in the cup. A further check for the presence of lead may be made by adding 0.5 ml. of ammonium polysulfide to 5 ml. of paint. A black color shows the presence of lead.

9-11 Making Paper From Wood[105]

Use a rasp to cut white pine into fine particles. These are sifted, and the finest particles are used. Fifty grams of wood are boiled for 15 minutes in a solution of KOH. This solution is made by adding 20 grams of the hydroxide to 100 ml. of water. After boiling, the liquid is poured off and the precipitate is washed several times with water. It is then bleached with a chlorine solution, the bleaching being repeated if necessary. The pulp is then spread out on a thin sheet of wire gauze to dry. A glossy paper may be made by adding a few grams of starch to the pulp after bleaching. The mixture is then stirred well and spread out and ironed smooth with a warm iron.

9-12 Formaldhyde-Aniline Hydrochloride Plastic[106]

A plastic may be made by mixing 50 ml. of 40 per cent formaldehyde and 150 ml. of a saturated solution of aniline hydrochloride. This mixture should be heated, with stirring. After it has become vixcous it should be poured into a mold.

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[105] Ibid., p. 452.

[106] Ibid., p. 453.

9-13 Tempering Steel[107]

Use a discarded screw driver and a discarded drill for testing. Each is tried with a file. It is noted that the screw-driver blade is somewhat softer than the drill and also that the screw-driver blade is tough. The screw driver and the drill are heated separately in the flame until they are red hot, then each is gradually withdrawn and permitted to cool. Each is tested with a file and found to be soft. They are then reheated and while red hot are plunged into cold water. Testing with the file shows that each is very hard and brittle. The screw driver is then reheated and one end moved in and out of the flame. The color is carefully noted. The color changes from dark yellow to light yellow, then to straw, brown, purple, and blue in succession. When the screw driver is purple it is plunged into cold water. Examination shows that it is hard but not brittle.

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[107]Ibid., p. 458.

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