College Entrance Examination Board

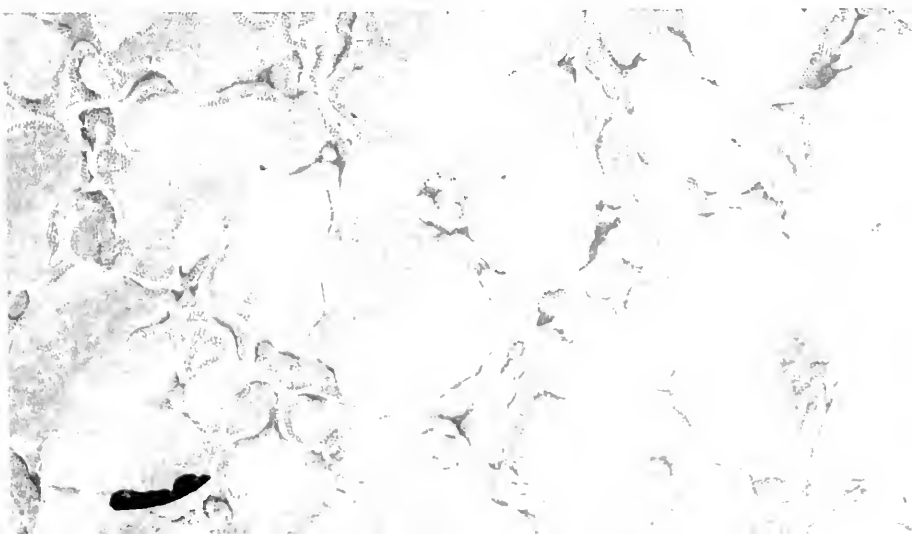
EXAMINATION QUESTIONS

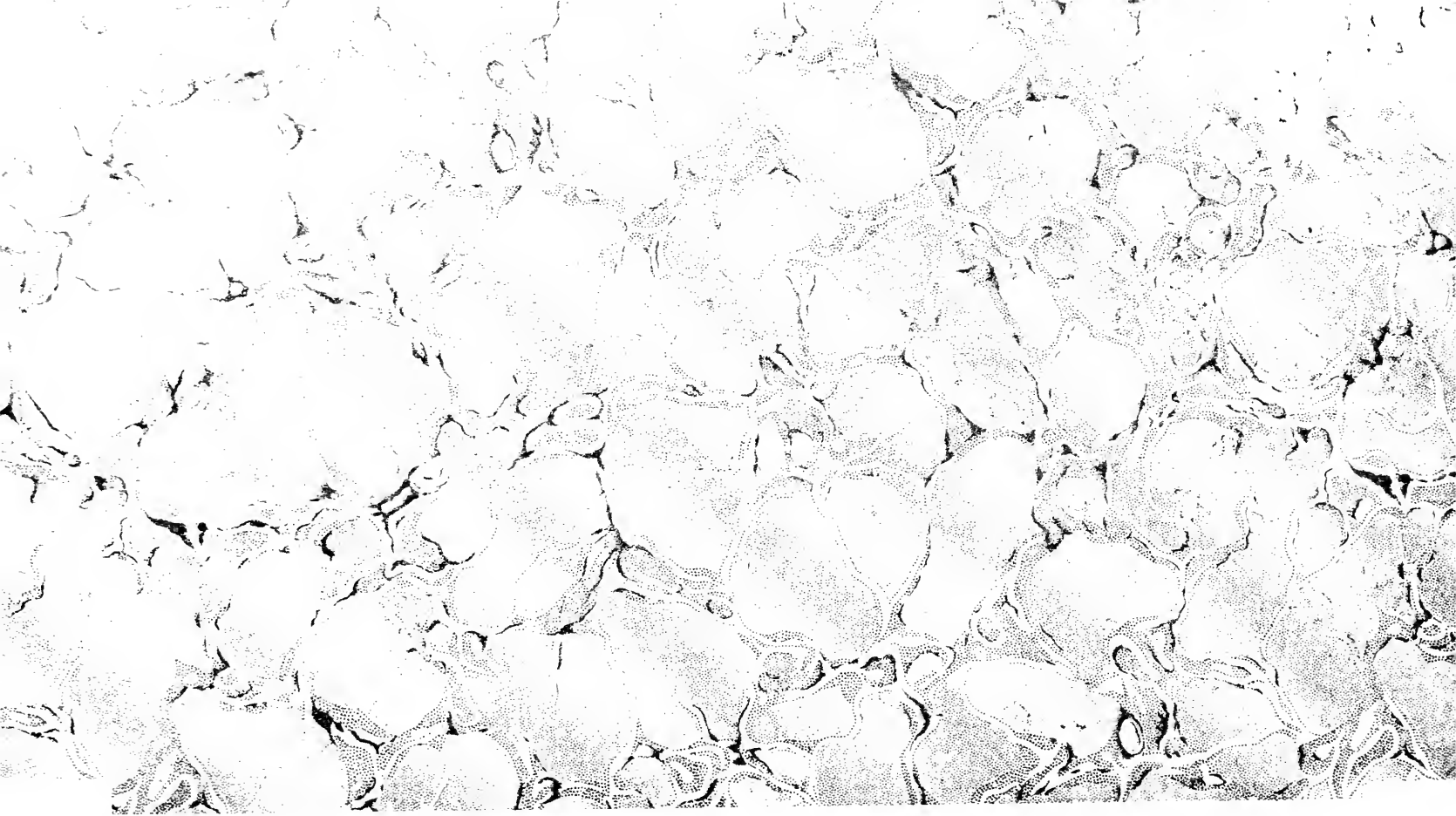
IN

OLOGY	BOTANY	CHEMISTRY
RAWING	GEOGRAPHY	PHYSICS
	ZOÖLOGY	

FOURTH SERIES

1916-1920





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PREFACE

While the annual volume of examination questions published by the College Entrance Examination Board has met the needs of many candidates for examination and their teachers, the Board is constantly in receipt of communications asking for the questions set in certain subjects in successive years. In order to meet this demand the Board has prepared pamphlets containing the questions in certain subjects from 1916 to 1920 inclusive. These pamphlets are as follows:

1. Examination questions in Latin and Greek, 1916–1920.
2. Examination questions in English and other modern languages, 1916–1920.
3. Examination questions in mathematics, 1916–1920.
4. Examination questions in history, 1916–1920.
5. Examination questions in the natural sciences and in drawing, 1916–1920.

Quite apart from meeting the needs of candidates for examination and their teachers, these publications ought to have a beneficial influence upon teaching for the reason that they illustrate in concrete form principles agreed upon by many leading teachers of the subjects represented.

CONTENTS

BIOLOGY

BIOLOGY

Friday 9:00 a.m. Two hours

A teacher's certificate covering the laboratory instruction must be presented as part of the examination.

Answer two questions from each group and four additional questions which may be selected from any group.

Group I

1. Describe a cell indicating—
   (*a*) the parts which are common to both plant and animal cells;
   (*b*) the parts peculiar to certain animal cells;
   (*c*) the parts peculiar to certain plant cells.
2. Explain in detail the structure of some seed.
3. Select a protozoan, a clam, a grasshopper, a frog, or a cat, and describe the organs by which it performs the following functions:
   (*a*) ingestion;
   (*b*) locomotion;
   (*c*) respiration;
   (*d*) sensation.
4. Describe the structure of the root of a plant and explain the various functions which it may perform.
5. Compare the organs of locomotion in—
   (*a*) ameba;
   (*b*) fish;
   (*c*) frog;
   (*d*) cat;
   (*e*) bird.

Group II

6. What similar functions does water perform in animals and plants?
7. Compare the metamorphosis of a grasshopper and of a butterfly.
8. Explain some of the adaptations of flowers to cross-pollination.
9. Why must plants and animals breathe in order to live?
10. Name the principal phyla, or large representative groups, of plants and animals, with an example from each group.

Group III

11. Explain what is meant by—
    (*a*) infection;
    (*b*) quarantine;
    (*c*) inoculation;
    (*d*) bacteria;
    (*e*) antitoxin.
12. Name 5 plants and 5 animals of considerable economic importance, each representing a different class. Show how each is useful or harmful.
13. Indicate four different ways in which food may be kept from spoiling, stating the biological principle involved in each case.
14. What part do soil bacteria play in agriculture?
15. For what are three of the following men famous: Linnaeus, Cuvier, Harvey, Pasteur, Darwin?

BIOLOGY

Friday 2 p.m. Two hours

Answer two questions from each group, and four additional questions which may be selected from any of the groups.

Group I

1. Describe the microscopic structure of the leaf of a flowering plant, indicating the function of each part.
2. Name and describe the reproductive organs in a flower and in a fish (or frog).
3. Describe fully three adaptations of plants for seed dispersal. Give illustrative examples.
4. Compare the circulatory system of man and some animal you have studied, pointing out the resemblances and differences.
5. Compare the sense organs of an insect and of a vertebrate.

Group II

6. Explain how the inorganic substances in the soil are absorbed and transported to the leaf.
7. What are the differences in the method of nutrition in a green plant and in man?
8. Show how each of the following organs contributes to the maintenance of life and health: salivary glands, pancreas, liver, kidneys, small intestine?
9. (*a*) Give the distinguishing characteristics of five general groups of animals.
   (*b*) Give the distinguishing characteristics of five general groups of plants.
10. Describe the life history of either a flowering plant or a frog.

Group III

11. Show how bacteria are essential to the life of man.
12. Explain fully the ways in which a knowledge of biology might be of importance to (*a*) the farmer, (*b*) the baker, (*c*) the butcher, (*d*) the doctor.
13. What is the economic importance of five of the following organisms: owl, flax, skunk, toad, yeast, white daisy, starfish?
14. (*a*) In what ways may the growth of bacteria be checked without killing them?
   (*b*) In what ways may bacteria be killed?
15. In what ways may plant or animal breeders improve their stock?

BIOLOGY

Friday, June 21 2 p.m. Two hours

Answer two questions from each group and four additional questions which may be selected from any of the groups.

Group I

1. Compare bacteria, yeasts, and molds.
2. (*a*) Name three tissues in the human body that have to do with the function of movement.
   (*b*) How is each tissue specially adapted for its work?
3. Describe the structure of some seed and explain the use of each part.
4. Compare the respiratory organs of a tadpole, a frog, and a man, stating precisely what occurs in the process of respiration.
5. Describe the principal appendages of an insect, stating the function of each, and naming the segment of the body to which each is attached.

Group II

6. Describe the process of reproduction of some alga which you have studied.
7. Distinguish between the terms phylum (or branch), class, genus, and species. Illustrate these terms by giving the classification of some animal or plant which you have studied.
8. Trace the modifications which a piece of meat undergoes in being incorporated into the tissues of the human body.
9. A bean seed was planted in May; from this seed a vigorous plant developed and reached full maturity before it was killed by frost in October. State the most important periods of development and the chief events in the life of this plant, noting what organs were most conspicuous at each period.
10. Describe the biological processes involved when an athlete starts to run at the sound of a pistol.

Group III

11. Show how molds affect human welfare.
12. (*a*) Distinguish between the processes of fermentation and decomposition.
    (*b*) Name the kind of organism that causes each.
    (*c*) State how each process is of use to man.
13. What is meant by Mendel's Law of Heredity?
14. Outline a dinner menu which is in accordance with war conditions and would at the same time supply adequate nutrition for a high-school student. (Give reasons for your choice.)
15. (*a*) Name the principal infectious diseases which may be obtained from (1) milk, (2) water, (3) dust of streets and public places.
    (*b*) Show how infection from these sources may be prevented by the individual and by the civic authorities.

1919

BIOLOGY

Friday, June 20 2 p.m. Two hours

Answer two questions from each group and four additional questions which may be selected from any of the groups. Number each answer to correspond with the question selected.

Group I

1. Make a labeled drawing of a typical plant cell.

2. Name a flower and an insect mutually adapted for insect pollination. Describe the structural adaptations in both flower and insect.

3. Name and locate the parts of a tooth shown in a drawing of a vertical section.

4. Describe the structure of some protozoan that you have studied. Explain how this organism moves, how it secures its food, and how it withstands adverse conditions.

5. (*a*) Describe the structure of your hand.
   (*b*) Name all the tissues of which it is composed.
   (*c*) What function does each tissue perform?
   (*d*) In what ways is the hand adapted for its work?

Group II

6. Explain the complete path, or cycle, by which a molecule of free nitrogen from the air may be incorporated into the living tissue of a man and may again reach the atmosphere.

7. Name five vital functions of a fish and briefly describe the mechanism by means of which each of these functions is accomplished.

8. Describe the development of the frog or toad from the time of egg-laying to the adult stage.

9. (*a*) Trace the course of soil water from its entrance into a living plant to its exit from the plant.
   (*b*) Name at least two ways in which the plant uses soil water.

10. Name the phylum (branch) and class of each of the following: fern, sunflower, shark, whale, bacteria, seal, frog, oak, turtle, grasshopper.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

11. (*a*) Name two diseases the germs of which may be transmitted through infected milk or water.
    (*b*) Explain fully the method of prevention for one of these diseases.

12. (*a*) Mention the principal organisms which may render each of the following foods unfit for human use: grain, milk, fruit, meat.
    (*b*) Explain the principles involved in the preservation of food by drying, by canning, by refrigerating, and by salting.

13. Describe the structure, growth, and reproduction, and the means of distribution of the bread mold.

14. (*a*) What is the probable cause of influenza?
    (*b*) How is the infection transmitted?
    (*c*) What precautions have scientific value?
    (*d*) What popular precautions are useless?
    (*e*) What should a person with the influenza do (1) for himself? (2) for the community?

15. Mention the principal organisms, living in a field, which are of service to the growing crops and explain why each is beneficial.

1920

BIOLOGY

Friday, June 25 2 p.m. Two hours

Answer two questions from each group and four additional questions which may be selected from any of the groups. Number each answer to correspond with the question selected.

Group I

1. Describe fundamental structural differences between a mold and a fern.

2. Make a labeled diagram of the digestive system of some animal.

3. Define the following terms and explain where each structure is to be found: stoma, nictitating membrane, cilium, stamen, chromosome, protoplasm, petiole, pulsating vacuole, tentacle, endosperm.

4. Describe the composition of the blood and explain what changes it undergoes in the lungs.

5. Make a diagram showing the structure of a root and explain the function of each part.

Group II

6. Explain how a frog or toad is adapted for living in its environment during each stage of its life-history.

7. Describe the process by means of which energy is stored up by a green plant.

8. Name three animals which reproduce in a strikingly different way and explain each method.

9. Distinguish between: (*a*) secretion and excretion; (*b*) absorption and digestion; (*c*) respiration and inhalation; (*d*) motion and locomotion; (*e*) saprophyte and parasite.

10. State the environmental conditions necessary for active life.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

11. (*a*) In what different ways are forests of importance to human welfare?

    (*b*) Name the most important enemies of forests.

    (*c*) Outline a plan by which forests may be conserved.

12. Explain the method by which an improved variety of plant or animal could be originated.

13. State different ways in which insects are beneficial to man.

14. (*a*) Criticize the following luncheon for a high-school pupil, giving scientific reasons for your answer: bread and butter; mashed potatoes; tapioca pudding; candy.

    (*b*) What changes, if any, would you make in the above?

    (*c*) Give the particular use to the body of each nutrient found in the revised menu.

15. Discuss the relations of the following birds to man: bobwhite, crow, robin, English sparrow, owl.

BOTANY

BOTANY

Friday 9:00 a.m. Two hours

A teacher's certificate covering the entire laboratory instruction must be presented as a part of the examination.

Answer three questions of each group, and one additional question which may be selected from any group.

Group I

1. (*a*) Represent the cross-section of a woody stem by a diagrammatic figure. (*b*) Label the various parts shown and give the function or functions of each.
2. Describe the epidermis and the green tissue of a typical leaf, giving the various functions of the parts described.
3. (*a*) Name and describe a seed with endosperm. (*b*) Describe the germination of this seed. (*c*) How are the solid foods stored up in a seed made available for the young plant?
4. Discuss the plants of deserts and of forests in relation to their environment.
5. (*a*) How do leaves maintain their rigidity? (*b*) Why does the loss of water by leaves cause them to wilt? (*c*) Why does a piece of wood remain rigid when dry?

Group II

6. (*a*) Name three plants in which motile asexual spores are found. (*b*) Name two plants in which non-motile asexual spores are found. (*c*) Assign each of the plants named to the great group or phylum to which it belongs.
7. Name a liverwort and outline its life-history.
8. (*a*) Distinguish between homospory and heterospory. (*b*) Name a homosporous plant; a heterosporous plant. (*c*) Describe briefly the gametophytic generation of the heterosporous plant you have named.
9. (*a*) Name an alga in which the sex organs are differentiated. (*b*) Describe the sex organs and the process of fertilization in the plant you have named.
10. (*a*) What is transpiration? (*b*) In what parts of the plant does it take place? (*c*) In what ways may transpiration be injurious to a plant? (*d*) How may excessive transpiration by plants be prevented?

Group III

11. Discuss the various ways in which agricultural field crops may be improved.
12. (*a*) Name two vegetable fibers of commercial importance. (*b*) Show how the fibers are obtained from the plants producing them. (*c*) What commercial uses are made of the fibers you have named?
13. (*a*) Give the names of two vegetable drugs and of the plants from which they are obtained. (*b*) Tell briefly how the drugs named are extracted.
14. Name three edible fungi, and show how they can be recognized.
15. (*a*) What are the characteristics of bacteria? (*b*) Discuss the part played by bacteria in processes of decay.

BOTANY

Friday 2 p.m. Two hours

Answer three questions of each group, and one additional question which may be selected from any group.

Group I

1. Make a drawing of one cell of an alga and label all the parts.
2. Enumerate the differences in structure between a woody dicotyledonous stem such as an oak and a monocotyledonous stem such as corn.
3. Compare by labeled drawings the following floral types: (*a*) hypogynous (superior) and epigynous (inferior); (*b*) regular and irregular. Give the name of the plant used to illustrate each.
4. (*a*) Name four different types of edible fruits. (*b*) What floral parts enter into each of them?
5. (*a*) In what different parts of a seed may its food supply be stored? (*b*) Name three foods found in seeds. (*c*) How would you detect the presence of each experimentally?

Group II

6. Describe fully with illustrations the life history and life processes of the yeast plant.
7. (*a*) Name two families of monocotyledons and three families of dicotyledons. Give a representative plant of each family. (*b*) Give one characteristic by reason of which you assign each plant named in answer to (*a*) to its particular family.
8. Explain fully what is meant by the expression "alternation of generations." In what group of plants is this phenomenon most obvious?
9. (*a*) Explain the use of the terms: species, genus, and family as used in botany. (*b*) Select a plant known to you and give its scientific name and the family to which it belongs.
10. Describe the process of photosynthesis, indicating (*a*) the substances used, (*b*) where each is obtained, (*c*) how each is obtained, (*d*) the conditions necessary for carrying on the process, and (*e*) the substances produced.

Group III

11. (*a*) Name four plants important because of their medicinal value. (*b*) In what part or parts of each plant does the medicinal material occur?
12. Give a brief discussion of forests, including (*a*) areas of greatest density in the United States, (*b*) uses of the forests, (*c*) dangers to the forests, (*d*) methods used in conserving the forests.
13. Describe briefly two methods by which plant breeders are improving plants.
14. Explain three ways in which soils may be improved for agricultural purposes.
15. From what plant and from what part of the plant is each of the following food and textile products obtained: cotton, linen, manila-hemp, flour, tapioca, cinnamon, sugar, and coffee?

BOTANY

Friday, June 21 2 p.m. Two hours

Answer three questions of each group, and one additional question which may be selected from any group.

Group I

1. The plant embryo: (*a*) Where found? (*b*) Of what parts composed? (*c*) How long may it stay in a dormant condition? (*d*) What are the conditions necessary for its growth? (*e*) Where is its food supply stored, and how is it rendered available for the growing embryo?
2. How do monocotyledons and dicotyledons differ: (*a*) In the external appearance of the plant? (*b*) In the internal structure of their stems? (*c*) In their leaf structure? (*d*) In their floral plan? (*e*) In their seed structure?
3. Name the principal ecological groups of plants, and briefly state how the structure of the plants of each group is fitted for the special environment.
4. Roots: (*a*) Describe the most conspicuous structural features and the manner of growth of a young root. (*b*) Name a plant which has aerial roots. (*c*) Name and describe a root especially fitted for storage. (*d*) Describe the roots of a parasite. (*e*) What is a mycorrhiza?
5. (*a*) What is a gametophyte? (*b*) What is a sporophyte? (*c*) Name a plant which has the gametophyte more highly developed than the sporophyte. (*d*) Name a plant which has the sporophyte dependent upon the gametophyte. (*e*) Name a plant which has the sporophyte more highly developed than the gametophyte.

Group II

6. (*a*) Give the distinctive features of the following plant families: (1) Pulse (Leguminosae), (2) Grass (Gramineae), (3) Nightshade (Solanaceae), (4) Mustard (Cruciferae), (5) Rose (Rosaceae), (*b*) Name two food-plants of each of these five families.
7. Explain the exact part which water plays in: (*a*) germination, (*b*) food manufacture, (*c*) growth, (*d*) movement, (*e*) maintenance of rigidity.
8. State how you would demonstrate the following facts giving clearly the essential points of your method, but not all the details: (*a*) carbon dioxide is a product of plant respiration; (*b*) germinating barley seeds contain diastase; (*c*) stomata are more abundant on the under side of most leaves than on the upper side; (*d*) plants require nitrates for their growth; (*e*) beans contain protein.
9. A bean seed was planted in May; from this seed a vigorous plant developed and reached full maturity before it was killed by frost in October. State the most important periods of development and the chief events in the life of this plant, noting what organs were most conspicuous at each period.
10. (*a*) Give the distinctive features of the following groups of fungi: (1) yeasts, (2) molds, (3) sac-fungi, (4) mildews, (5) mushrooms. (*b*) State briefly why each group is important economically.

(SEE NEXT PAGE)

Group III

11. What would be the necessary steps in the process of producing a hybrid fruit?
12. (*a*) Which of the algae may be the cause of the disagreeable odor and taste of reservoir water? How can this condition be remedied? (*b*) Why are the diatoms an interesting and important group? (*c*) What use is made of kelps at the present time?
13. Explain how in improving wheat or any other crop, by selection or breeding, (*a*) the demands of the market, (*b*) the farm or home needs, and (*c*) the climatic conditions must be considered.
14. (*a*) What is cellulose? (*b*) Name a substance which is almost pure cellulose. (*c*) What articles of commerce are made from cellulose? (*d*) Which of our foods contain a great deal of cellulose?
15. What is the United States government doing: (*a*) to conserve our forests; (*b*) to introduce new kinds of plants; (*c*) to control the spread of plant diseases?

1919

BOTANY

Friday, June 20 2 p.m. Two hours

Answer three questions of each group and one additional question which may be selected from any group. Candidates are advised to apportion the time wisely among the ten questions. Number each answer to correspond with the question selected.

Group I

1. State in regard to protoplasm: (*a*) its appearance, (*b*) its chemical composition, (*c*) its activities, (*d*) where it occurs. Make a fully labeled diagram of a typical cell.

2. Describe five different types of leaves and show how each is fitted for its special environment or function.

3. What is a fruit? Name definite examples of the following kinds of fruit: (*a*) a unipistillary, dry, dehiscent fruit; (*b*) a unipistillary, fleshy fruit; (*c*) a fruit formed from several pistils of *one* flower; (*d*) a fruit composed of several carpels; (*e*) a fruit formed from the pistils of *several* flowers.

4. As an example of your best scientific drawing and labeling illustrate one of the following: (*a*) two types of flowers which have special adaptations for insect pollination; (*b*) a fern sporophyll and an enlarged sporangium containing spores; (*c*) archegonium of a moss plant as seen in longitudinal section; (*d*) cross-section of a typical leaf.

5. State where the following structures occur and give their function: (*a*) lenticels, (*b*) stipules, (*c*) basidiospores, (*d*) asci, (*e*) endosperm.

Group II

6. State fully how you proved by experiments that more than one factor is involved in photosynthesis.

7. State how you would demonstrate experimentally: (*a*) the presence of oxygen as essential to growth; (*b*) the presence of starch; (*c*) the presence of mineral matter; (*d*) the transfer of water through ducts; (*e*) the presence of diastase in malt.

8. (*a*) Define osmosis. (*b*) How would you demonstrate it experimentally? (*c*) How are the conditions for osmosis fulfilled in the root hair? (*d*) Where else in plants does osmosis occur? (*e*) What is plasmolysis?

9. State briefly the life-history of *two* of the following plants: (*a*) White-pine blight, (*b*) a fern, (*c*) Fucus, (*d*) a beet plant, (*e*) a typical mold.

10. Name the most distinctive features which would enable you to identify the following: (*a*) a lichen, (*b*) a pine, (*c*) a liverwort, (*d*) a member of the mint family, (*e*) a horsetail, (*f*) a monocotyledonous plant, (*g*) an oak, (*h*) a cactus, (*i*) a member of the pulse family, (*j*) the sporophyte of a moss plant.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

11. Name five important crops of your state. Tell what has been done to improve each crop.

12. (*a*) What chemical compounds are found in a good commercial fertilizer for general garden or farm use? (*b*) Explain the rôle of bacteria in soils. (*c*) What weeds indicate the need of liming the soil? (*d*) Why is rotation of crops advisable? (*e*) When should fruit trees be pruned and why at the time specified?

13. (*a*) Name two industries which make use of plant enzymes. (*b*) Name two plants which furnish edible leaves. (*c*) Name two medicinal seeds. (*d*) Name two plants which furnish rope fibers. (*e*) Name two plants which have useful latex.

14. (*a*) Name four valuable forest trees, stating what constitutes their special value. (*b*) Name four trees used for street planting, giving their good and bad points.

15. Write a clear, well-arranged topical *outline*, giving at least three main topics and several subtopics under each main topic, on *one* of the following subjects: (*a*) the importance of the Department of Agriculture; (*b*) the making of new varieties of plants; (*c*) seed dispersal; (*d*) parasitic plants; (*e*) relations between plants and animals.

1920

BOTANY

Friday, June 25 2 p.m. Two hours

Answer three questions of each group and one additional question which may be selected from any group. Candidates are advised to apportion the time wisely among the ten questions answered. Number each answer to correspond with the question selected.

Group I

1. *a*) Trace the course of the fibrovascular bundles throughout an entire plant.
   b) Of what parts is the bundle composed?
   c) What is the use of each part?
   d) Of what is the heart-wood of a tree composed?
   e) Of what use are the medullary rays?

2. Describe a cell in a growing region of a plant. Make a properly labeled drawing of it. How may it be changed to make it a conducting cell? A storage cell? A supporting cell?

3. *a*) When a branch increases in size from one foot in length and a half-inch in diameter to five times these dimensions, what two types of growth have occurred?
   b) What external markings or features may be observed during the winter on a five-year-old branch?

4. *a*) Name a definite flower and describe its pistil, mentioning all the external and internal structures of the pistil which can *readily* be distinguished. State what the permanent parts of the flower develop into later.
   b) State the function of the following structures: (i) calyx, (ii) anther, (iii) receptacle, (iv) pollen, (v) corolla.

5. Briefly describe the following structures:
   a) The sporophyte of a moss plant.
   b) The reproductive organs of a mold.
   c) The prothallus of a fern.
   d) The thallus of a liverwort.
   e) The male flower of a pine tree.

Group II

6. Discuss chlorophyll, stating: (*a*) in what form and in what different plant organs it occurs; (*b*) the conditions necessary for its formation and activity; (*c*) its work in the plant; (*d*) how it may be extracted from plants; (*e*) what are the habits of plants that have no chlorophyll.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

7. *a*) If seedlings are grown in a water culture, what chemical compounds should the water contain to be a perfect nutrient solution?

   b) What chemical changes occur in a seed during germination?

   c) Why is clover planted to improve the soil for later crops?

   d) When fresh-water plants are placed in salt water, and salt-water plants put in fresh water, what changes occur in the cells of each? Explain why these changes occur.

   e) Give a chemical test for sugar.

8. Explain the relation of transpiration in the following instances: (*a*) Fall of leaves; (*b*) Adaptations in desert plants; (*c*) Distribution and position of leaf stomata; (*d*) Protection of winter buds; (*e*) Wilting of plants.

9. *a*) Explain the reasons for the following contrasted groups in the classification of plants: (i) Gymnosperm—Angiosperm, (ii) Monocotyledon—Dicotyledon, (iii) Annual—Perennial, (iv) Monoecious—Dioecious, (v) Polypetalous—Apetalous.

   b) Name a plant which is an example of each of these ten classes.

10. Name and briefly describe a representative of the following groups of plants: (*a*) a fern, (*b*) a blue-green alga, (*c*) a lichen, (*d*) a palm, (*e*) a mushroom.

Group III

11. Name five common weeds. State how you would identify each. Describe the seed dispersal of two especially successful weeds. Name two weeds that have other methods of propagation and describe the methods.

12. *a*) State upon what substances, and under what conditions, colonies of bacteria may be grown most favorably for examination.

    b) Discuss bacteria in relation to dairy products.

13. Name five new uses of plants, or plant products, called forth by the war. State the part or parts of the plant used in securing these products.

14. What measures are being taken to control the spread of the following plant diseases: (*a*) White pine blight, (*b*) potato wart, (*c*) wheat rust, (*d*) the smuts on oats, wheat, corn, and barley, (*e*) the grape mildew.

15. Name two useful plants of each of the five following families of plants, and state for what purpose each of the ten plants is used: (*a*) Grass family, (*b*) Solanum or Nightshade family, (*c*) Spurge family, (*d*) Rose family, (*e*) Parsley family.

CHEMISTRY

CHEMISTRY

Friday 9:00 a.m. Two hours

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination.

Answer nine questions as indicated below. No extra credit will be given for more than nine questions.

Attach to the answer, in each case, the number and letter used in the printed paper.

PART I

(Answer all questions in this group. Each question counts 12.)

1. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be absolutely correct.
   (*a*) Silver nitrate+ferric chloride=
   (*b*) Sodium carbonate+nitric acid=
   (*c*) Ammonium chloride+calcium hydroxide=
   (*d*) Zinc hydroxide+hydrochloric acid=
   (*e*) Combustion of phosphorus in air=
   (*f*) Silver chloride+zinc=
2. (*a*) Describe in detail how you should determine experimentally either (1) the hydrogen equivalent of some metal, or (2) the weight of a liter of some gas.
   (*b*) What is meant by the relative activity of the metallic elements? Arrange in order of decreasing activity the following: gold, hydrogen, zinc, sodium, copper. (The arrangement must be correct throughout to receive credit.)
3. (*a*) Name each of the following compounds: the potassium salt of chlorplatinic acid, the sodium salt of tellurous acid, a compound containing magnesium and silicon only, the salt obtained by replacing half the hydrogen of carbonic acid with sodium.
   (*b*) If the percentages of calcium in two samples of limestone are 40 per cent and 38 per cent respectively, what conclusion should you draw in regard to the specimens? State the law upon which your conclusion is based. (Atomic weights: Ca 40, O 16, C 12.)
   (*c*) A body of air at constant pressure occupies a volume of 500 c.c. at 20° C. At what temperature will its volume become 1,000 c.c.?
4. How should you proceed to produce the first-mentioned substance from the second in four of the following cases? Describe each step in the process.
   (*a*) Nitrogen from the atmosphere;
   (*b*) Kerosene from crude petroleum;
   (*c*) Sulphuric acid from sulphur;
   (*d*) Lime water from marble;
   (*e*) Hydrochloric acid from sulphuric acid.
5. (*a*) How many grams of water of crystallization are there in the crystallized barium chloride ($BaCl_2 \cdot 2H_2O$) obtained from 10 grams of barium? (Atomic weights: Ba 137, Cl 35.5, O 16, H 1.)
   (*b*) How many cubic centimeters of ammonia gas, NH_3, under standard conditions, can be obtained from 5.00 grams of ammonium phosphate, $(NH_4)_3PO_4$, by treating it with sodium hydroxide in excess? $(NH_4)_3PO_4+3NaOH=Na_3PO_4+3H_2O+3NH_3$. (Atomic weights: P 31, Na 23, O 16, N 14, H 1.) One liter of ammonia weighs 0.77 gram.

(SEE NEXT PAGE)

Part II

(Omit one group. Each question counts 10.)

Group A

6. Answer five of the following: (*a*) How would you make ferrous chloride from ferric chloride? (*b*) Ferric chloride from ferrous chloride? (*c*) White lead from lead? (*d*) Sodium sulphite from sodium hydroxide? (*e*) Sodium hypochlorite from sodium hydroxide? (*f*) Alum crystals from aluminum sulphate?

7. Mention very briefly *any* means of identifying with certainty each of the following gases: hydrogen, nitrogen, carbon dioxide, sulphur dioxide, nitrous oxide, chlorine, carbon monoxide, hydrogen sulphide, oxygen, ozone.

Group B

8. (*a*) Ten liters of a gas whose formula is C_2H_6O are completely burned in oxygen. How many liters of oxygen gas are required for its complete combustion? How many liters of carbon dioxide should result? All volumes are measured under the same conditions of temperature and pressure.

   (*b*) If the temperature of a gas enclosed at an initial pressure of one atmosphere is decreased from 37° C. to 27° C. without change in volume, what will be the final value of the pressure?

9. (*a*) What classes of substances are electrolytically dissociated? What is the effect of dilution on the degree of dissociation of the substance? How may the degree of dissociation be diminished without changing materially the volume of the solution?

   (*b*) Show how the electric current is conveyed through a solution of $CuSO_4$, and indicate the reactions that take place at the poles.

Group C

10. (*a*) Mention one important industrial process depending on each of the following phenomena respectively: reduction, catalysis, crystallization, electrolysis.

    (*b*) State what impurities render water unfit for (1) drinking purposes, (2) steam boilers, (3) laundries; and outline a different practical method adapted to improving the water in each case.

11. Answer four of the following questions:

    (*a*) Explain the cleansing action of soaps. Of what substances are washing powders likely to be composed?

    (*b*) Describe one method of converting pig iron into steel.

    (*c*) Explain upon a chemical basis the use of ozone in the purification of water.

    (*d*) Name two products of commercial importance that can be obtained, by chemical change, from starch.

    (*e*) What rôle does each of the three general classes of foods play in nutrition?

CHEMISTRY

Friday 2 p.m. Two hours

Answer nine questions as indicated below. No extra credit will be given for more than nine questions.

Attach to the answer, in each case, the number and letter used in the printed paper.

PART I

(Answer all questions in this group. Each question counts 12.)

1. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be absolutely correct.
   (*a*) Sodium acid carbonate+sulphuric acid=
   (*b*) Carbon dioxide+heated carbon=
   (*c*) Silver sulphate+barium chloride=
   (*d*) Copper+hot concentrated sulphuric acid=
   (*e*) Hydrogen sulphide burned in excess of air=
   (*f*) Potassium chlorate heated with manganese dioxide=

2. Select three of the substances: chlorine, potassium nitrate, zinc, slaked lime, and give the following information in regard to each: (*a*) Name a naturally occurring material from which the substance is commonly made. (*b*) Write the equation or equations representing the preparation of the substance from this material. (*c*) Give one important commercial use.

3. (*a*) Given a soluble oxide, how could you determine whether or not it was the oxide of a metal?
   (*b*) What three tests could you make to distinguish between sodium chloride and finely divided paraffin?
   (*c*) Define the term "radical," and illustrate by an example.
   (*d*) Illustrate the law of multiple proportions by considering the composition by weight of two compounds containing the same elements.

4. (*a*) What forms of energy are manifest when a mixture of hydrogen and oxygen is exploded? From what source are these forms of energy derived? Apply the law of conservation of energy to this reaction.
   (*b*) Excess of phosphorus is allowed to act on air at atmospheric pressure in a sealed flask. When the reaction is complete, (1) What is the pressure (approximately) in the flask, the temperature remaining the same? (2) How does the weight of the flask and contents after the reaction compare with the weight before? State the law upon which the latter conclusion is based.

5. (*a*) If 50.0 grams of calcium carbonate, $CaCO_3$, are added to 50.0 grams of hydrochloric acid, HCl, in water solution; which substance remains in excess? What is the weight of this excess? (Atomic weights: Ca 40, Cl 35.5, O 16, C 12, H 1.)

(SEE NEXT PAGE)

(*b*) What volume of nitric oxide, NO, measured under standard conditions, can be obtained by adding 10.0 grams of copper to excess of dilute nitric acid according to the equation:

$$3Cu+8HNO_3=3Cu(NO_3)_2+4H_2O+2NO?$$

(Atomic weights: Cu 64, O 16, N 14, H 1. One liter of nitric oxide at 0° C. and 760 mm. weighs 1.34 grams.)

Part II

(Omit one group. Each question counts 10.)

Group A

6. Answer five parts of this question. How could you demonstrate experimentally that: (*a*) Nitric acid is an oxidizing agent? (*b*) Sulphur dioxide is a reducing agent? (*c*) Copper sulphate is a salt? (*d*) Alcohol contains carbon? (*e*) Kerosene is a mixture? (*f*) Litharge contains lead?

7. How could you make: (*a*) Zinc sulphate from zinc chloride? (*b*) Copper from copper sulphate? (*c*) Ferric oxide from ferric chloride? (*d*) Sodium sulphite solution from sulphur?

Group B

8. (*a*) What is meant by the term "reversible reaction"?
   (*b*) Under what three conditions will a reaction proceed to completion?
   (*c*) Illustrate each of these conditions separately by writing the equation of a suitable reaction, showing which condition is fulfilled in each case.

9. (*a*) State Gay-Lussac's law of combining volumes. What volume of oxygen is required for the complete combustion of five liters of acetylene, C_2H_2? All measurements are to be made under the same conditions of temperature and pressure.
   (*b*) One liter of gas A weighs 1.98 grams. One liter of gas B weighs 0.77 gram, under the same conditions. The molecular weight of A is 44. What is the molecular weight of B?

Group C

10. (*a*) Describe the electrolytic process for silver plating.
    (*b*) Of what chemical elements are ordinary fuels composed? What products are formed by their combustion? Aside from expense, what are the disadvantages of sulphur as a fuel?

11. (*a*) Show briefly the relation of four constituents of the atmosphere to the vital processes of plants and of animals.
    (*b*) Describe the chemical changes that occur in a blast-furnace for making pig-iron from an ore consisting of ferric oxide and sand.

CHEMISTRY

Friday, June 21 2 p.m. Two hours

Answer nine questions as indicated below. No extra credit will be given for more than nine questions.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(*Answer all questions in this part. Each question counts 12.*)

1. Write equations for the following reactions, using formulas throughout. The equations must be correct in every particular.

   (*a*) Ammonium nitrate (heated)=

   (*b*) Ferric chloride+zinc=

   (*c*) Methane (marsh gas)+oxygen (ignited)=

   (*d*) Hydrogen sulphide+silver nitrate=

   (*e*) Copper oxide (heated)+hydrogen=

   (*f*) Calcium oxide+sodium carbonate+water=

2. How would you prove, by chemical means, the presence (*a*) of carbon monoxide if mixed with sulphur dioxide? (*b*) of hydrogen if mixed with dry air (if the amount of hydrogen is too small to make the mixture explosive)? (*c*) of gold in copper? (*d*) of sulphuric acid in a solution of hydrochloric acid?

3. (*a*) What is the percentage of ammonia in cuprammonium sulphate, $CuSO_4 \cdot 4NH_3 \cdot H_2O$? (Atomic weights: Cu 64, S 32, O 16, N 14, H 1.)

   (*b*) What weight of pure sodium bicarbonate, $NaHCO_3$, must be treated with excess of acid to produce 250 liters of carbon dioxide measured at 0° C. and 1520 mm. pressure? (Atomic weights: Na 23, O 16, C 12, H 1. One liter of carbon dioxide at 0° C. and 760 mm. weighs 1.98 grams.)

4. (*a*) Given the valence of A as three, derive the probable valences of B, C, and D from the following formulas: A_2B_3, B_2C, B_5D_2. What would be the formula of a compound of A with C?

   (*b*) Prove that the law of definite proportions is a necessary consequence of the atomic theory.

5. Describe a method for the preparation of three of the following substances: (*a*) sodium, (*b*) nitric acid, (*c*) hydrogen sulphide, (*d*) calcium carbonate. How would you separate the desired product, in each case, from the reaction mixture?

(SEE NEXT PAGE)

Part II

(Omit one group. Each question counts 10.)

Group A

6. Arrange three metals in the order of decreasing activity. Describe in detail three experimental methods by which the correctness of the suggested order may be proved.

7. (*a*) State the physical and chemical characteristics of chlorine, bromine, and iodine as regards: physical state, color, solubility, tendency to combine with hydrogen.

   (*b*) How may bleaching powder be made? What are its properties?

Group B

8. (*a*) What weight of sulphur dioxide will occupy a volume equal to that of 42 grams of nitrogen at the same temperature and pressure? (Atomic weights: S 32, O 16, N 14.)

   (*b*) What volume of a solution of hydrochloric acid containing 73 grams per liter would suffice for the exact neutralization of the sodium hydroxide obtained by allowing 0.46 gram of metallic sodium to act upon water? (Atomic weights: Cl 35.5, Na 23, O 16, H 1.)

9. (*a*) What is a reversible reaction? Illustrate by means of an equation.
   (*b*) Under what three conditions will a reaction go to completion?
   (*c*) On the basis of the electrolytic dissociation theory, how would you explain (1) the neutralization of an acid by a base? (2) the changes that take place when a solution of copper sulphate is electrolyzed between copper electrodes?

Group C

10. (*a*) What substance burns with a blue flame on the top of a coal fire? Write two equations for the reactions involved in the formation of this substance; write an equation for the reaction involved in its combustion.

    (*b*) Define the term "by-product." Show how a valuable by-product is obtained in some chemical process of commercial importance.

11. Considering each of the following substances separately, name two important products made from it directly or by admixture or reaction with other substances: (*a*) lime, (*b*) salt, (*c*) crude petroleum, (*d*) coke, (*e*) sand.

1919

CHEMISTRY

Friday, June 20 — 2 p.m. Two hours

Answer nine questions as indicated below. No extra credit will be given for more than nine questions.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(*Answer all questions in this part. Each question counts 12.*)

1. Describe a method for the laboratory preparation of three of the following substances: (*a*) sodium nitrate, (*b*) ethyl alcohol, (*c*) barium sulphate, (*d*) hydrochloric acid. What property has the desired product in each case which makes it possible to separate it?

2. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be correct in every particular.
   (*a*) Chlorine (gas)+hydrogen (gas)=
   (*b*) Sodium carbonate+carbon dioxide+water=
   (*c*) Ammonium carbonate+copper (cupric) chloride=
   (*d*) Ferric oxide+carbon (heated)=
   (*e*) Ammonia completely burned in oxygen=
   (*f*) Silver sulphate+zinc=

3. (*a*) How many grams of sodium hydroxide will be required to neutralize 9.8 grams of sulphuric acid? Name the products formed and determine the weight of each product. (Atomic weights: H 1, O 16, Na 23, S 32.)
   (*b*) What volume will one liter of gas at 136.5° absolute have at 136.5° C., pressure remaining the same?

4. How could you show experimentally that—
   (*a*) fused calcium chloride is a deliquescent substance?
   (*b*) carbonic acid is unstable?
   (*c*) nitric acid is an oxidizing agent?
   (*d*) diamond is a form of carbon?
   (*e*) sugar is not an electrolyte?
   (*f*) a hydrocarbon contains hydrogen?

5. (*a*) Show by formulas how an anhydride is related to the corresponding acid or base.
   (*b*) Suggest, by writing appropriate equations, four different methods for making calcium sulphate from calcium, oxygen, sulphur trioxide, and water.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Part II

(Omit one group. Each question counts 10.)

Group A

6 (*a*) Outline a method by which pure silver nitrate could be obtained from a silver coin. What other metal is present in the coin, and how may it be identified?

(*b*) Give a method for the preparation of chlorine from common salt.

7. (*a*) Name two metals, each of which yields two oxides, and give the formulas of the oxides.

(*b*) Mention two elements that occur in allotropic forms, and name several allotropic forms in each case.

(*c*) Mention three metals fusible below red heat, and three fusible only above red heat.

(*d*) Mention three gases which are easily liquefied, and three which are liquefied with difficulty.

(*e*) Name an acid all of whose normal salts are soluble in water.

Group B

8. (*a*) Apply Avogadro's law in finding the volume of carbon dioxide formed from the burning of 4 liters of carbon monoxide in oxygen, provided all of the gases are measured at the same temperature and pressure.

(*b*) Name the components in a water solution of ammonia.

9. (*a*) Write an equation illustrating a reaction between two salts in solution, which does not go to completion. Explain why this reaction does not go to completion.

(*b*) How does a water solution of copper sulphate react with litmus? Explain.

Group C

10. (*a*) Explain the use of cream of tartar in baking powders.

(*b*) When a compressed mixture of air with gasoline is exploded in a confined space, what substances may be formed? What difference in the nature and relative amounts of the products may be expected (1) if the amount of gasoline is small in comparison with the air present? (2) if the proportion of gasoline is unduly large?

11. (*a*) State what you would do in each of the following emergencies respectively:

(1) Chlorine inhaled.
(2) Acid in the eye.
(3) Oil burning on the floor or desk.

(*b*) Distinguish between destructive, fractional, and ordinary distillation by giving a practical example of each.

1920

CHEMISTRY

Friday, June 25 2 p.m. Two hours

Answer nine questions as indicated below. No extra credit will be given for more than nine questions.

Number and letter your answers to correspond to the questions selected.

PART I

(*Answer all questions in this part. Each question counts 12.*)

1. Describe a method for the laboratory preparation of the following substances: (*a*) sodium chloride, (*b*) calcium carbonate, (*c*) nitric oxide. What property has sodium chloride which makes it possible to separate it? calcium carbonate? nitric oxide?

2. Illustrate by equations the action of dilute sulphuric acid on (*a*) zinc, (*b*) calcium oxide, (*c*) ammonium hydroxide, (*d*) sodium carbonate, (*e*) ferrous sulphide, (*f*) barium chloride. Name the type of reaction which occurs in each case. Formulas must be used throughout and the equations properly balanced to receive credit.

3. Describe an experiment illustrating the quantitative character of chemical action, including apparatus, method, and precautions. Show how the data found in the experiment warrant the conclusion reached The data may be represented by letters.

4. If 540 grams of silver react with an excess of concentrated sulphuric acid according to the equation $2\ Ag+2\ H_2SO_4=Ag_2SO_4+2\ H_2O+SO_2$, what weight of silver sulphate, and what volume of sulphur dioxide measured under standard conditions of temperature and pressure, will be formed? (Ag 108, S 32, O 16, H 1.)

   NOTE.—One liter of sulphur dioxide at 0° C. and 760 mm. weighs 2.9 grams.

5. (*a*) Which contains the more energy under the same conditions of temperature and pressure, a mixture of 1 gram of hydrogen and 8 grams of oxygen or 9 grams of water? Give the reason for your conclusion.

   (*b*) Name two elements having more than one valence. Illustrate each of the valences of these elements by constructing a formula containing also one element of constant valence. Write above the symbol of each element, in each formula, its valence.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Part II

(Omit one group. Each question counts 10.)

Group A

6. (*a*) Classify as oxidizing or reducing agents the following substances: hot concentrated H_2SO_4, H_2S, HOCl, H_2SO_3, concentrated HNO_3.

   (*b*) Make three pairs by combinations of the above which will react with each other to form new substances.

7. (*a*) Outline briefly a laboratory method for obtaining a pure sample of (1) sulphur crystals from powdered sulphur, (2) ferric hydroxide from iron.

   (*b*) Name two substances which in reacting upon each other can yield (1) an element by reduction of a compound of that element, (2) an element by oxidation of a compound of that element, (3) a soluble salt by direct combination, (4) an insoluble sulphide by precipitation.

Group B

8. Considering each of the following statements separately, explain why you consider it to be an experimental fact or an assumption: (*a*) The composition of a given compound does not vary. (*b*) Two atoms of iron have the same weight. (*c*) The materials composing foods cannot be put out of existence. (*d*) Some compounds ionize when dissolved in water. (*e*) Five grams of hydrogen may be found united with forty grams of oxygen or with eighty grams. Name the theory or law which applies in each case.

9. A dirigible balloon at sea-level contains 400,000 cubic feet of gas measured at a pressure of 774 mm. of mercury and at a temperature of 27° C. It rises to an elevation at which the pressure is reduced to 430 mm. and the temperature to −23° C. What is the volume of the gas under the latter conditions, assuming that none is allowed to escape from the containers?

Group C

10. (*a*) What component do rice, tapioca, and potatoes have in common? How could this component be identified?

    (*b*) What are the products of the fermentation of glucose? Why do the bubbles of gas not appear at once in this fermentation?

    (*c*) Describe the preparation of water gas and write an equation for the reaction involved.

11. How could it be determined by chemical means if a sample of (*a*) water were hard or soft? (*b*) hard water had temporary or permanent hardness? (*c*) washing powder contained sodium carbonate? (*d*) metal was gold or brass? (*e*) beverage contained alcohol?

COMPREHENSIVE CHEMISTRY

Comprehensive Examination

CHEMISTRY

Friday, June 23 — 9:00 a.m.–12:00 m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. Discuss concisely the important classes of compounds—acids, bases, and salts—from the standpoint of: (*a*) their composition, (*b*) their preparation, (*c*) their properties. Illustrate your answer fully with formulas and with equations for reactions.

2. *a*) Give a concise statement of the constitution of matter according to the atomic theory.

   b) State any two laws fundamental to the theory, and show how this theory explains these laws.

3. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:

   a) Sodium acid carbonate+hydrochloric acid = ?
   b) Calcium phosphate+sulphuric acid (in excess) = ?
   c) Copper+nitric acid (dilute) = ?
   d) Ferric nitrate+ammonium hydroxide = ?
   e) Silica+sodium carbonate (fused) = ?

4. A certain quantity of magnesium dissolved in acid gave exactly 100 c.c. of dry hydrogen at a temperature of 22° C. and a pressure of 780 mm. How many grams of metal were used? Compute the result to three significant figures (Mg = 24.3).

   Note.—A liter of hydrogen at 0°C. and 760 mm. weighs 0.09 gm.

5. Chlorine and nitric acid often act as oxidizing agents, sulphur dioxide and carbon as reducing agents. Explain these statements and give examples, with equations, illustrating these actions. State any necessary conditions of dilution or of temperature.

Part II

SUPPLEMENTARY REQUIREMENTS

Group A

(Answer two questions from this group.)

6. Give the names and formulas of five common minerals of industrial importance. State what commercial use may be made of each of them.

(SEE NEXT PAGE)

7. Classify in natural groups the following elements: carbon, calcium, chlorine, barium, bromine, iodine, and silicon. Indicate the relations of those within each group by comparing the formulas and the properties of their oxides or hydrides or both.

8. Answer any two of the following questions:
   a) Why does a water solution of ferric chloride give an acid reaction, while one of sodium carbonate gives an alkaline reaction?
   b) Account for the fact that a solution of common salt in water conducts the electric current, while one of sugar does not.
   c) Which exhibits the greater osmotic pressure, a gram-molecular solution of salt or one of cane sugar? Why? Sketch an apparatus for demonstrating osmotic pressure.

9. *a*) How would you proceed in order to get large crystals from a solution? Small ones?
   b) Why do certain crystalline substances on exposure to the air crumble while others do not?

GROUP B

(*Answer one question from this group.*)

10. At standard temperature and pressure, one liter of the gaseous element, *A*, unites with three liters of the gaseous element, *B*, to make two liters of the gas, *C*. If each molecule of *C* contains one atom of *A*, what is the simplest formula for a molecule of the element *A*? Show clearly how you arrive at your conclusion.

11. One gram of pure iron forms 1.43 gm. of an oxide. Find (*a*) the percentage composition for this oxide of iron, (*b*) its simplest formula, and (*c*) the equivalent weight of iron in the compound. (Fe = 56, O = 16.)

GROUP C

(*Answer two questions from this group.*)

12. How would you determine by chemical tests whether (*a*) "woolen" goods contained cotton, (*b*) baking powder contained ammonium compounds, (*c*) water contained chlorides?

13. *a*) State the composition of two kinds of baking powder.
   b) Write an equation for the reaction which occurs when one of these powders is moistened with water.
   c) Explain the action of yeast in bread-making.

14. *a*) Mention two compounds of nitrogen that are used as fertilizers.
   b) What natural provision is there for converting the nitrogen of the air into plant food?
   c) Outline one artificial process for the fixation of atmospheric nitrogen.

15. Give the method of keeping and the necessary precautions in the storage of each of the following substances: (*a*) sodium, (*b*) gasoline, (*c*) yellow (white) phosphorus, (*d*) bromine, (*e*) hydrofluoric acid.

Comprehensive Examination

CHEMISTRY

Monday, September 18 — 2:00–5:00 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. *a*) Define the terms "molecule," "atom," and "ion."
   b) State Avogadro's hypothesis, and show how it guides the chemist in determining molecular weights.
2. *a*) What takes place when steam is passed over heated zinc or iron?
   b) How would you identify the products?
   c) What do you learn about the composition of water from this experiment?
3. Describe the action, if any, and represent by equations the chemical changes taking place when dilute hydrochloric acid and nitric acid are added separately to each of the following substances: (*a*) ferric hydroxide, (*b*) zinc oxide, (*c*) calcium carbonate, (*d*) silver.
4. *a*) Calculate the percentage of oxygen in crystallized copper nitrate, $Cu(NO_3)_2 \cdot 6H_2O$. (Cu = 64, N = 14, O = 16, H = 1.)
   b) What weight, and volume at 0° C. and 760 mm., of carbon dioxide can be obtained by treating an excess of sodium acid carbonate with 490 gm. of sulphuric acid containing 20 per cent of H_2SO_4? (Na = 23, C = 12, O = 16, H = 1, S = 32.)
   NOTE.—A liter of carbon dioxide at 0°C. and 760 mm. weighs 1.97 gm.
5. Define and illustrate with an example each of the following: (*a*) acid anhydride, (*b*) catalytic agent, (*c*) saturated solution, (*d*) sublimation, (*e*) either destructive distillation or fractional distillation.

Part II

SUPPLEMENTARY REQUIREMENTS

Group A

(Answer two questions from this group.)

6. Two rods of copper are placed in a solution of copper sulphate. What takes place when a current of electricity is passed from one rod to the other through the solution? How might you prove what happens to each of the copper rods?

(SEE NEXT PAGE)

7. State in words and by writing equations how you would obtain: (*a*) Ferric chloride from ferrous chloride; (*b*) ferrous chloride from ferric chloride; (*c*) sodium carbonate from sodium hydroxide; (*d*) sodium hydroxide from sodium carbonate; (*e*) oxygen from ozone; (*f*) ozone from oxygen.

8. How would you prove, by chemical means, the presence in air of each of the following components: (*a*) water, (*b*) carbon dioxide, (*c*) oxygen, (*d*) nitrogen?

9. *a*) Arrange the names of ten common elements in natural groups.
   b) Write the formula for one oxide of each and state what acid or base can be formed from each of these oxides.

Group B

(*Answer two questions from this group.*)

10. *a*) A compound has the following composition: carbon, 54.67 per cent; hydrogen, 9.11 per cent; oxygen, 36.22 per cent. Find the simplest formula for the substance. (C = 12, O = 16, H = 1.)
    b) A body of air at constant pressure occupies a volume of 500 c.c. at 20° C. At what temperature will its volume become 1,000 c.c.?

11. How many liters of ammonia gas, measured under standard conditions, can be obtained when 20 gm. of sodium hydroxide react with an excess of ammonium sulphate? (Na = 23, O = 16, H = 1, N = 14, S = 32.)

    Note.—A liter of ammonia gas at 0°C. and 760 mm. weighs 0.772 gm.

12. What experimental evidence can be cited to show (*a*) that chloride ions are not molecules of chlorine? (*b*) that chloride ions are charged with negative electricity?

13. Write a reversible chemical reaction and explain how it may be made to go to completion in either direction.

Group C

(*Answer one question from this group.*)

14. *a*) Make a diagram of an acetylene generator. With the aid of an equation, explain its operation.
    b) Write the equation for the complete combustion of acetylene.
    c) Why does acetylene burn with a flame which is more luminous than that of methane?

15. Answer any two of the following questions:
    a) Mention a necessary property that must be possessed by an oil (1) for soap-making, (2) for mixing with paint, (3) for a lubricant. Name as an example some particular oil for each use.
    b) What are the physical and chemical differences between cast iron and steel?
    c) Why does iron, in the course of time, turn completely into rust, while aluminium and zinc tarnish only slightly?

Comprehensive Examination

CHEMISTRY

Friday, June 22 — 2–5 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. *a*) Name and define four different types of chemical action, and illustrate each by an experiment which you have performed in the laboratory, stating the object of the experiment, together with the names of the substances used and of the products formed.

   b) What is meant by a radical? Give an example to show how a radical may be decomposed in a chemical change.

2. *a*) State the Law of Multiple Proportions, and illustrate it by the consideration of two compounds of carbon and hydrogen containing respectively 75 per cent and 92.3 per cent of carbon.

   b) How does this law support the hypothesis that the elements are composed of atoms having definite weights?

3. *a*) How many grams of hydrochloric acid gas can be obtained by heating ten grams of crystallized ferric chloride, $FeCl_3 \cdot 6H_2O$, with concentrated sulphuric acid? (H=1, O=16, Cl=35.5, Fe=56.)

   b) What is the percentage of sulphur in iron alum, $K_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$? (K=39, S=32, O=16, Fe=56, H=1.)

4. Give a detailed account of a good laboratory method for preparing and collecting chlorine in quantity; write the chemical equations involved; make a diagram of the apparatus.

5. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit.

   a) Calcium hydroxide and sulphurous acid = ?

   b) Steam and magnesium (heated) = ?

   c) Hydrogen sulphide burned in excess of oxygen = ?

   d) Nitric acid and ammonia gas = ?

   e) Aluminium sulphate and ammonium hydroxide = ?

(SEE NEXT PAGE)

Part II

(*Answer five questions from Part II. Extra questions will receive no credit.*)

6. Indicate the basic oxides in the following list, and write the names of the compounds formed by heating them with the acid anhydrides in the list: phosphorus pentoxide, calcium oxide, silicon dioxide, sulphur trioxide, and aluminium oxide.

7. Compare and contrast the properties and uses of the two chlorides of mercury. Give the scientific and the common names; also the formulas of these compounds.

8. *a*) What volume would be occupied by 14 grams of carbon monoxide under standard conditions? (O=16, C=12.)
   b) If ten liters of carbon monoxide under standard conditions are heated to 27.3° C., without change in pressure, what volume will the gas occupy?
   c) What volume of oxygen is necessary to combine with five liters of carbon monoxide under the same conditions of temperature and pressure? Show how you arrive at your conclusion.

9. A certain chemical compound is found by analysis to contain 92.3 per cent of carbon and 7.7 per cent of hydrogen. What is the simplest formula which can express its composition? If the molecular weight is 78, what is the formula? (C=12, H=1.)

10. *a*) If steam is passed over heated iron, iron oxide and hydrogen are formed; if hydrogen is passed over heated iron oxide, metallic iron and steam are formed. Why are the products of reaction different in the two cases?
    b) Under what conditions will a chemical reaction reach equilibrium? Under what conditions will it run to an end?

11. Define the term "molecular weight," and give one method for determining a molecular weight.

12. How may ozone be prepared? What are its properties? How is its formula written? How would you demonstrate its chemical composition (not its formula)?

13. *a*) Give the names and formulas of two alcohols, together with the name and formula of the acid derived from each.
    b) Outline a process for the commercial production of grain alcohol and state some of its industrial uses. What is denatured alcohol?

14. *a*) Outline a method for the manufacture of nitric acid from atmospheric nitrogen or from ammonia. (*b*) Enumerate at least two of the important commercial uses of nitric acid.

15. *a*) Name three classes of food substances and list several food substances which are typical in each class.
    b) Describe tests by which the nature of a simple food substance may be determined.

Comprehensive Examination

CHEMISTRY

Monday, September 17 2-5 p.m.

A teacher's certificate covering laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. Define, and give at least one example of (1) diacid base, (2) acid salt, (3) reducing agent, (4) anion, (5) atom, (6) molecule.

2. *a*) Define and give three examples, of neutralization, describing the ionic changes involved in the reactions.

   b) Define and give an example of hydrolysis. How can the litmus reaction of the water solution of a normal salt be predicted from its composition? Illustrate your answer by an example of a salt having an acid reaction and of another having a basic reaction.

3. *a*) State Gay-Lussac's law of combining gas volumes, and illustrate with an example. State the hypothesis which serves to explain the facts generalized by this law.

   b) 30 grams of chlorine are to be united with hydrogen. What volume of hydrogen is required at 0° C. and 760 mm., and what volume of hydrogen chloride results under the same conditions? (Cl=35.5, H=1.)

Note.—A liter of chlorine at 0° C. and 760 mm. weighs 3.22 grams, and a liter of hydrogen 0.09 gram.

4. *a*) Name and describe three allotropic forms of sulphur, and tell how each is prepared.

   b) Give the names and formulas of the two most important oxides of sulphur, and show by means of chemical equations what occurs when each of these oxides is treated with water.

5. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:

   a) Lead nitrate and hydrogen sulphide= ?
   b) Copper and sulphuric acid (hot, concentrated)= ?
   c) Phosphoric acid and barium hydroxide= ?
   d) Sodium carbonate and acetic acid= ?
   e) Ammonium chloride and calcium hydroxide= ?

(SEE NEXT PAGE)

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. *a*) State how you would prove whether a certain salt solution is unsaturated, saturated, or supersaturated.

   b) How do changes in temperature and pressure respectively change the solubility in liquids of gases and of solids?

7. *a*) Mention three important differences between the water solutions of electrolytes and those of non-electrolytes. How are these differences explained?

   b) Explain fully in terms of the ionization theory the electrolysis of a solution of copper sulphate.

8. A balloon requires for adequate inflation 5,000 gram-molecular volumes (or an equal number of gram-molecules) of hydrogen, measured at normal temperature and pressure. What is the cost of inflating such a balloon if scrap iron at 1 cent per kilogram and sulphuric acid, containing 20 per cent of H_2SO_4, at 4 cents per kilogram, are used for generating the hydrogen? (Fe = 56, H = 1, S = 32, O = 16.)

9. *a*) Describe the production of ammonia either by the Haber process, or from calcium cyanamide. (All equations are required.)

   b) Write down in parallel columns five specific physical properties of ammonia, and three specific chemical properties.

10. *a*) Describe a test or tests to distinguish (1) between oxygen and nitrous oxide, (2) between hydrogen and carbon monoxide, (3) between nitrogen and carbon dioxide.

    b) State briefly the effect of inhaling each of these gases in the pure state.

11. *a*) How would you determine whether a given sample of ammonia gas contained air?

    b) Give tests for free chlorine, bromine, and iodine respectively; give also a test for the ions of the same elements.

12. Describe two important chemical industries depending directly or indirectly on electrical energy.

13. *a*) Describe the "burning" of limestone. Make a diagram of a kiln, and indicate its operation.

    b) Distinguish between quicklime, slaked lime, air-slaked lime, lime water, and milk of lime.

    c) What is meant by "destructive distillation"? By applying this process to soft coal, what products are obtained? What products are obtained by applying the process to wood?

14. *a*) What is "sterling" silver, and what acid should be used to dissolve it? (*b*) How may pure silver be obtained from this solution? (*c*) State how articles of baser metal are plated with silver, and how mirrors are silvered. (*d*) What compound of silver is used in indelible ink? Explain the chemical changes involved in its use.

15. 1.0085 grams of pure tin foil were oxidized with nitric acid, and the final weight of the highly ignited oxide was 1.2790 grams. From the data submitted, find the percentage composition and the simplest formula of this oxide of tin. (Sn = 119, O = 16.)

Comprehensive Examination

CHEMISTRY

Wednesday, June 19 2–5 p.m.

A teacher's certificate covering laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. Give (*a*) exact statement, (*b*) experimental proof, and (*c*) a practical application of one of the fundamental laws of chemistry.

2. *a*) Outline three different methods for obtaining oxygen; give some idea of their relative cost.

   b) Write equations, using formulas, to show how each of three metals may be obtained from ores or artificial compounds. Each method involved should be different from the others.

3. *a*) Calculate the weight of manganese dioxide required to produce chlorine enough to fill a flask of 4 liters capacity when the barometer stands at 760 mm. and the temperature is 0° C. (Mn. = 54.9, O = 16, Cl = 35.5.)

   Note—A liter of chlorine at 0° C. and 760 mm. weighs 3.22 grams.

   b) What weight of manganese dioxide would be required if the flask were filled at 760 mm. and 273° C.?

4. Give the formulas of two oxides of sulphur, one oxide of nitrogen, and one oxide of carbon, that are acid anhydrides. Show by equations how an acid may be made from each of these, and give the name of the acid in each case.

5. Write equations for *any five* of the following reactions, using formulas throughout: (The equations must be properly balanced to receive credit.)

   a) Solid sodium nitrate heated with solid ammonium chloride = ?
   b) Hydrogen sulphide and ammonia = ?
   c) Phosphoric acid and aluminium hydroxide = ?
   d) Sodium iodide and chlorine = ?
   e) Zinc oxide heated with hydrogen sulphide = ?
   f) Sodium acid carbonate and calcium hydroxide = ?

(SEE NEXT PAGE)

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. *a*) What is a normal solution of an acid? of an alkali?

   b) 10 c.c. of ordinary household ammonia are neutralized by the addition of 40 c.c. of a normal solution of hydrochloric acid. What weight of ammonia gas, NH_3, is contained in each cubic centimeter of the original solution?

7. Discuss (*a*) the extraction of sulphur in the United States and abroad; (*b*) its physical and chemical properties; (*c*) its uses.

8. *a*) Give an example of a chemical change brought about by heat, another by light, and a third by electricity. Mention three chemical reactions the first of which produces heat, the second light, and the third electricity.

   b) Distinguish between exothermic and endothermic reactions and illustrate each by means of an example.

9. 1.8 grams of magnesium displace from acid 1820 c.c. of hydrogen, measured dry at 740 mm. pressure and 20° C. Find the volume of this gas under standard conditions and determine the valence of magnesium. (Mg. = 24.3, H = 1.008.) What is your definition of valence?

   Note—The weight of one liter of hydrogen under standard conditions is 0.09 gram.

10. *a*) What is an electrolyte? Distinguish between electrolysis and electrolytic dissociation.

    b) If a strong (active) acid is added to the salt of a weak acid in water solution, what becomes of the four different ions involved? Illustrate by an example.

11. Describe the manufacture of *any one* of the following substances, giving a diagram, and equations whenever possible: (*a*) Ethyl alcohol; (*b*) water gas; (*c*) open-hearth steel.

12. *a*) What danger is there in a long-continued scarcity of potassium compounds? Why has there recently been such a scarcity in this country?

    b) Make a list of the sources of potassium compounds. Suggest a method for extracting a potassium compound from two of the raw materials mentioned.

13. *a*) Outline a commercial method for producing metallic aluminium. (*b*) How is aluminium used to produce other metals from their oxides? (*c*) Explain the fact that aluminium retains its bright appearance in the air. (*d*) Mention one industrial use for alum.

(SEE NEXT PAGE)

14. *a*) Name three military explosives and state from what substances each is made.

b) To what element does each of these owe its explosive character?

c) State briefly how two of the following substances are made: (1) Celluloid; (2) mercerized cotton; (3) collodion; (4) artificial silk.

15. *a*) Given unlabeled bottles which severally contain hydrochloric acid, nitric acid, and sulphuric acid, how would you identify each, using a chemical test in each case?

b) Give one test by which you would determine in each case whether the acid is dilute or concentrated.

Comprehensive Examination

CHEMISTRY

Monday, September 16 2–5 p.m.

A teacher's certificate covering laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions as indicated below.

Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(Answer all questions in Part I.)

1. Define, and also illustrate by means of at least one example in each case, the following terms: (*a*) element; (*b*) synthesis; (*c*) cation; (*d*) catalyzer; (*e*) hydrolysis.

2. Write equations for *any five* of the following reactions, using formulas throughout: (The equations must be properly balanced to receive credit.)
   a) Iron and dilute sulphuric acid = ?
   b) Lead acetate and hydrochloric acid = ?
   c) Aluminium hydroxide and sulphuric acid = ?
   d) Ferrous chloride and chlorine water = ?
   e) Copper sulphate and barium hydroxide = ?
   f) Manganese dioxide and concentrated hydrochloric acid = ?

3. 10 grams of crystallized ammonium carbonate, $(NH_4)_2\ CO_3 \cdot H_2O$, are heated until completely decomposed into ammonia, carbon dioxide, and steam. What will be the total volume of these products at 273° C. and 760 mm. pressure? (O = 16, N = 14, C = 12, H = 1.)

Note—Under the conditions above, liter volumes of ammonia, carbon dioxide, and steam weigh 0.38 gram, 0.98 gram, and 0.40 gram, respectively.

4. State Avogadro's law and show in detail how this law guides the chemist in determining the molecular weights of gases or vapors.

5. *a*) Name and describe one important commercial process for manufacturing sodium carbonate, giving all the equations involved.
   b) How may sodium acid carbonate be distinguished from sodium carbonate?

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. Two grams of finely divided metallic nickel are heated with a quantity of sulphur slightly in excess of that needed for complete combination until the chemical action is completed and the excess of sulphur is vaporized. The weight of the product formed is 3.09 grams. Give the name of the product, find its percentage composition and also the simplest formula by which its composition may be expressed. (Ni = 58.7, S = 32.)

(SEE NEXT PAGE)

7. *a*) Name two elements which are liquid at ordinary temperatures. (*b*) Name the common allotropic forms of each of four elements. (*c*) Name two elements having exceptionally high melting-points, and state how this property is put to practical use in case of each.

8. *a*) Describe briefly an experiment to determine the percentage of oxygen in air. (*b*) State as fully as possible the composition of air. (*c*) Give three proofs that air is a mixture and not a compound.

9. *a*) State one point of resemblance and one point of difference between solutions and compounds.

   b) Define precipitation and crystallization; illustrate each by means of an example.

   c) How are the freezing-point and the boiling-point of a solvent affected by dissolved substances? Give a practical application of one of these facts.

10. *a*) Distinguish between chemically pure water and spring water. (*b*) How may water be purified on a small scale for household use? How is it purified on a large scale for a city supply? (*c*) Name one impurity which renders water unfit for use in laundries and outline a practical method for removing it.

11. *a*) Define the terms hydroxide, anhydrous, and water of hydration (crystallization).

    b) Show that hydration is a reversible reaction by discussing the commercial manufacture and use of plaster of Paris.

12. *a*) Describe the manufacture of sulphuric acid by the contact process.

    b) Show how sulphuric acid is used to produce another acid, and state the principle involved.

    c) Write the ionic equation for neutralizing barium hydroxide with sulphuric acid.

13. Make a list of five gases which would be dangerous to life if contained in air to the extent of a small per cent, and suggest a method of eliminating each gas. Only a single impurity is assumed present in any one of the given samples of air.

14. *a*) How may crude copper be refined? (*b*) State the physical and chemical properties of copper. Write an equation showing the action of hot, concentrated sulphuric acid upon the metal. (*c*) Name the elements present in important alloys of copper.

15. State one locality in which each of the following substances, respectively, is found in relative abundance: iron ore, diamond, petroleum, sodium nitrate, sulphur, gold, copper ores, phosphate rock, coal, radium compounds.

1919

Comprehensive Examination

CHEMISTRY

Wednesday, June 18 2–5 p.m.

Answer ten questions as indicated below.
Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(*Answer all questions in Part I.*)

1. Define and give an example of (*a*) catalysis, (*b*) equivalent of an element, (*c*) allotropy, (*d*) molecular weight, (*e*) carbohydrate.

2. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit.

   a) Sodium chloride+manganese dioxide+concentrated sulphuric acid=

   b) Ferric chloride+calcium hydroxide=

   c) Lead nitrate+hydrogen sulphide (solutions)=

   d) Ammonium sulphate+sodium hydroxide=

   e) Concentrated nitric acid heated=

3. *a*) How many cubic centimeters of oxygen, measured at 0° C. and 760 mm. can be obtained by the complete decomposition of one kilogram of 3 per cent solution of hydrogen peroxide, H_2O_2, into water and oxygen? (H 1, O 16.)

   Note.—A liter of oxygen at 0° and 760 mm. weighs 1.43 grams.

   b) What is the percentage of silica, SiO_2, in the mineral analcite, $Na_2SiO_3 \cdot Al_2(SiO_3)_3 \cdot 2H_2O$? (Si 28, Al 27, Na 23, O 16, H 1.)

4. Explain each of the following experimental facts:

   a) A dilute solution of potassium chloride has a lower freezing-point than one of sugar of the same concentration measured in gram molecules per liter.

   b) A drop of concentrated sulphuric acid on a wooden table makes a black spot.

   c) Many minute gas bubbles appear on the inside of a glass of cold water standing in a warm room.

   d) Copper does not liberate hydrogen from nitric acid.

   e) Concentrated hydrochloric acid, if added to a saturated solution of sodium chloride, gives a white precipitate.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

5. *a*) Given pure samples of sodium carbonate, chloride, nitrate, sulphite, and sulphate, give one test by which the negative (acid) radical in each may be identified.

   b) Write equations for the reaction of each of the above substances with concentrated sulphuric acid at room temperature.

Part II

(*Answer five questions from Part II. Extra questions will receive no credit.*)

6. *a*) Using the ionization theory, explain the equilibrium in a dilute solution of sodium chloride. If two platinum electrodes are introduced and a current of electricity passed, explain in detail the changes at the cathode.

   b) Compare the degree of ionization of (1) hydrochloric acid and acetic acid, (2) ammonium hydroxide and potassium hydroxide, in water solutions of the same concentration.

7. *a*) What is a saturated solution of a solid in a liquid?

   b) How does increasing the temperature affect the solubility of solids in liquids?

   c) In what two ways could a saturated solution of sodium chloride in water be prepared? How could you satisfy yourself that the solution is just saturated in both cases?

8. *a*) State the Law of Multiple Proportions.

   b) Give two substances to illustrate the above law with the percentage composition in each case.

9. One hundred liters of dry air at 20° C. and at 760 mm. contain 0.078 gram of carbon dioxide. What is the proportion by volume of carbon dioxide present in the air?

   Note—One liter of carbon dioxide at 0° C and 760 mm. weighs 1.98 grams.

10. *a*) A small flask contains ferric chloride (yellow) strongly acidified with hydrochloric acid. A quantity of iron tacks is added, and the flask is closed in such a manner as to permit the escape of gas and to prevent the entrance of air. How do you explain the loss of color? Write an equation for the reaction.

    b) On exposure to air the yellow color of the solution is gradually restored. Account for the result. Write an equation for the reaction.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

11. *a*) State the action of yeast on sugar.
    b) Describe the function of baking powder in cooking.
    c) Give one process for softening hard water.
    d) Why does the flame of a gas stove sometimes "strike back"? How can this difficulty be remedied?

12. *a*) In the smelting of iron ore, what materials enter the blast furnace, and what is the function of each?
    b) What name is given to the metal produced by the blast furnace, and how does it differ in physical properties and in chemical composition from the product of the Bessemer converter?

13. *a*) Outline the manufacture of sulphuric acid by the contact process.
    b) Indicate the importance of this acid in the manufacture of military explosives by citing two processes in which it is necessary.

14. Barium carbonate is treated with a quantity of boiling dilute sulphuric acid just sufficient for complete reaction. Using the language and symbols of the ionization theory wherever pertinent, describe what takes place.

15. What experiment would you make to distinguish between:
    a) Sodium chloride and ammonium chloride?
    b) Potassium iodide and potassium bromide?
    c) Glucose and cane sugar?
    d) Copper oxide and manganese dioxide?
    e) Chlorine water and bromine water?

1919

CHEMISTRY

Monday, September 15 2–5 p.m.

Answer ten questions as indicated below.
Attach to the answer, in each case, the number and letter used in the printed paper.

Part I

(*Answer all questions in Part I.*)

1. *a*) Distinguish between a chemical law and a chemical theory.

   b) Name three laws dealing with weights; three dealing with gases.

   c) Name two important theories in chemistry.

2. Discuss sulphuric acid with reference to:

   a) Its physical and chemical properties.

   b) Four of its important uses.

   c) One process of manufacture.

3. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:

   a) Ethyl alcohol burned completely in oxygen=

   b) Hydrogen sulphide+chlorine (in solution)=

   c) Silver nitrate+calcium chloride=

   d) Nitric oxide+oxygen gas=

   e) Ferric chloride+sulphuric acid (concentrated)=

4. *a*) How many cubic centimeters of carbon dioxide, CO_2, measured at 0° and 760 mm., will be absorbed by a solution containing 2 grams of sodium hydroxide, to form sodium carbonate and water? (Na 23, O 16, C 12, H 1.)

   Note.—One liter of carbon dioxide at 0° C. and 760 mm. weighs 1.98 grams.

   b) The formula of a gaseous compound is C_2H_2. Calculate its percentage composition and its vapor density.

5. *a*) Why does wood burn with a flame while charcoal merely glows?

   b) Can you light a jet of oxygen in an atmosphere of (1) air, (2) hydrogen? Explain.

   c) Describe and explain the successive effects observed when a thin strip of copper is passed very slowly through a Bunsen flame.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. *a*) Give directions for making a normal solution of sulphuric acid and one of sodium hydroxide.

   b) Ten cubic centimeters of a normal solution of sulphuric acid requires 2.5 cc. of a solution of sodium hydroxide for complete neutralization. Find the concentration of the solution of sodium hydroxide in grams per liter. (S 32, Na 23, O 16, H 1.)

7. The water solutions of certain substances give the following tests: What may be the dissolved substance in each case?

   a) The solution turns blue litmus red and forms with silver nitrate solution a white precipitate insoluble in nitric acid.

   b) The solution gives a deep-red color with ammonium or potassium thiocyanate (NH_4CNS or $KCNS$), and with barium chloride solution a white precipitate insoluble in hydrochloric acid.

   c) The solution gives a blue coloration with iodine.

   d) The solution colors the Bunsen flame violet and forms a brown ring when it is mixed with concentrated sulphuric acid and ferrous sulphate solution is added.

   e) The solution colors the Bunsen flame yellow and turns red litmus blue.

8. Calculate the molecular weight of carbon-dioxide gas from the following data, showing clearly every step of the calculation:

Weight of flask filled with CO_2, dry	= 102.38 grams
Weight of flask filled with air, dry	= 101.56 grams
Temperature of measured gases	= 0° C.
Pressure of measured gases	= 770 mm.
Volume of flask	= 1200 cc.

   Note.—One liter of air at 0° C. and 760 mm. weighs 1.29 grams.

9. Outline one practical method for the preparation of each of the following substances: (*a*) nitrogen from the air, (*b*) carbon monoxide, (*c*) calcium oxide, (*d*) glucose. Mention one industrial use for each of the above-mentioned substances.

10. *a*) What do the following terminations indicate, *-ite, -ic, -ide, -ate, -ous?*

    b) What relation does the combining weight of an element bear to its atomic weight?

11. *a*) Describe the laboratory preparation of ammonia and mention its most important properties.

    b) How can ammonia be made commercially from the elements?

    c) In what way can ammonia be used in the manufacture of explosives?

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

12. *a*) Outline a simple process for making soap and explain the chemical reaction which takes place in its formation (without equation).

    b) Account for the action upon litmus paper of a solution of a soap which contains no free alkali.

13. Five liters of carbon monoxide are mixed with just enough oxygen for complete combustion and the mixture is ignited. If the original gases are measured at 20° C., at what temperature will the product occupy the same volume, the pressure remaining the same?

14. State the reason for each of the following precautions:

    a) Potassium chlorate and manganese dioxide, for making oxygen, must not be ground too finely together.

    b) A hot object should be cooled before weighing.

    c) Concentrated solutions of acid and alkali should not be mixed without previous dilution.

    d) Phosphorus should not be handled with the fingers.

15. *a*) Write equations illustrating three different methods for making sodium sulphate.

    b) Select any two of these equations and tell why the reaction goes to completion in each case.

1920

Comprehensive Examination

CHEMISTRY

Wednesday, June 23 2–5 p.m.

Answer ten questions as indicated below.
Number and letter your answers to correspond to the questions selected.

PART I

(*Answer all questions in Part I.*)

1. Classify the following compounds into (*a*) acids, (*b*) bases, (*c*) salts, (*d*) acid anhyrides, (*e*) substances belonging to none of the foregoing four classifications: sulphur dioxide, calcium oxide, ammonium carbonate, iron sulphide, sodium hydroxide, phosphorus pentoxide, barium chloride, hydrogen sulphide.

2. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit. Indicate by reversed arrows those reactions which do not go almost to completion.
   a) Silver+hot concentrated sulphuric acid=(sulphur dioxide is formed).
   b) Ammonium sulphate heated with sodium chloride=
   c) Carbon disulphide burned in an excess of oxygen=
   d) Sodium chloride, carbon dioxide, ammonia, and water=
   e) Hydrogen+nitrogen, heated with a catalyzer=

3. Baking powder can be made by mixing baking soda, $NaHCO_3$, and cream of tartar, $HKC_4H_4O_6$. These substances react according to the following equation:

$$NaHCO_3+HKC_4H_4O_6=H_2O+CO_2+NaKC_4H_4O_6$$

   a) How much cream of tartar should be mixed with one kilogram of baking soda so that neither ingredient will be in excess?
   b) What volume of carbon dioxide at 0° C. and 760 mm. may be obtained from the baking powder thus made? (K 39, Na 23, O 16, C 12, H 1.)

   NOTE.—One liter of CO_2 at 0° C and 760 mm. weighs 1.98 grams.

4. *a*) What is the relation between volume and pressure of a gas when the temperature is constant? between volume and temperature when the pressure is constant? between temperature and pressure when volume is constant?
   b) From the standpoint of the molecular hypothesis explain the fact that (1) 40 gallons of oxygen may be forced into a small steel cylinder, (2) gas escapes from a glass of soda water, (3) chlorine gas, although heavier than air, escapes from an upright vessel.

5. Tell how you would determine experimentally (*a*) either the equivalent of some element or the molecular weight of some gas; (*b*) either the percentage of carbon dioxide in exhaled air or of oxygen in ordinary air. Indicate the method of computing the result in each case.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. Explain each of the following facts:
   a) Painters' rags sometimes take fire spontaneously.
   b) Concentrated rather than dilute sulphuric acid is used in making hydrochloric acid.
   c) Acetic and nitric acid solutions of the same concentration in gram molecules per liter do not conduct electricity equally well.
   d) When the stopper is removed from a bottle containing concentrated hydrochloric acid, white fumes are sometimes observed.
   e) A solution of sodium carbonate has an alkaline reaction.

7. Indicate the difference in meaning between (*a*) ion and radical, (*b*) electrolysis and ionization, (*c*) equivalent and atomic weight of an element, (*d*) hydrate and hydroxide, (*e*) monobasic and dibasic acid. Give an example of each.

8. A portable gas stove used in heating a room burns natural gas (assumed to be pure methane, CH_4) and consumes in one hour 10 cubic feet of gas measured at a pressure of 30 inches of mercury and at a temperature of 60° F. What volume of oxygen is consumed and what space is occupied by the carbon dioxide which is produced, when measured under conditions of pressure and temperature previously specified? If 1 cubic foot of methane under these conditions weighs 0.04225 lbs., what weight of water vapor is formed during the combustion? (O 16, C 12, H 1.)

9. State one practical use for each of the following substances, suggested by the property mentioned. Give in each case an example of such a substance. (*a*) A metal having a very high melting-point, (*b*) a substance from which a water solution having a very low freezing-point may be made, (*c*) an acid having a high boiling-point, (*d*) a solid or liquid capable of sudden conversion into gases at high temperature, (*e*) a volatile, non-inflammable liquid.

10. How could you obtain (*a*) sulphur from hydrogen sulphide, (*b*) metallic copper from copper oxide, (*c*) potassium nitrate crystals from potassium chloride, (*d*) ferric oxide from ferric chloride?

11. Two gram molecules of the oxide RO combine with 44.8 liters of oxygen at 0° and 380 mm. pressure. The volume of the product, under the same conditions, is nearly equal to that of the oxygen taken. Calculate the formula of the product.

12. *a*) Name the products when: silica is fused with sodium carbonate; when dilute sulphuric acid acts on magnesium.
   b) Give two uses for each of the following substances: ammonium hydroxide, borax.
   c) Why is nitric acid a better solvent for silver, lead, and mercury than hydrochloric acid?

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

13. Why should sulphur compounds be removed from illuminating gas? phosphorus from steel? dust from sulphur dioxide in the contact process for making sulphuric acid? moisture from materials for making baking powders? calcium and magnesium chlorides from table salt?

14. *a*) Why does the admission of air at the base of the Bunsen burner make the flame non-luminous?

b) Why is the temperature of a flame of hydrogen burning in oxygen higher than that of hydrogen burning in air?

c) Why is a mixture of fine coal dust and air explosive?

15. *a*) What property has helium which makes it better than hydrogen for filling balloons?

b) How does commercial copper compare in purity with other metals as commercially supplied? Describe briefly the refining of copper.

c) Mention three substances commonly used for extinguishing fire. Indicate the one that you consider best adapted to extinguishing burning gasoline.

1920

CHEMISTRY

Monday, September 20 2–5 p.m.

Answer ten questions as indicated below.
Number and letter your answers to correspond to the questions selected.

Part I

(*Answer all questions in Part I.*)

1. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit.
   a) Nitric acid on ammonium carbonate =
   b) Silver nitrate solution and magnesium chloride solution =
   c) Hydrochloric acid and oxygen (with a catalytic agent) =
   d) Calcium phosphate and sulphuric acid =
   e) Hydrogen sulphide on lead nitrate solution =

2. *a*) What particular properties are used in recovering the sulphur from a solution in carbon disulphide?
   b) What chemical tests are used in recognizing sulphuric acid? a chloride? nitrous oxide?

3. *a*) Fifty cubic centimeters of a solution containing 40 grams of sodium hydroxide per liter neutralize 40 cc. of a solution of hydrochloric acid. What is the concentration of the acid solution in grams per liter? (Cl 35.5, Na 23, O 16, H 1.)
   b) How many grams of potash alum ($K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24\ H_2O$) can be made from 69 grams of bauxite ($Al_2O_3 \cdot 2\ H_2O$)? (K 39, S 32, Al 27, O 16, H 1.)

4. Carbon dioxide gas in excess is passed into a water solution of sodium carbonate. Write an equation to express the chemical change which takes place. The resulting solution is boiled vigorously for some time. Write an equation to represent the reaction and name the substance which is left in the solution. Explain why these reactions proceed in opposite directions.

5. *a*) Why is sulphuric rather than hydrochloric acid used in making nitric acid?
   b) Why is hydrochloric rather than nitric acid used in making hydrogen sulphide?
   c) Why is hydrochloric rather than sulphuric acid used in making carbon dioxide from marble?
   d) Why is sulphuric rather than hydrochloric acid used in preparing oxygen from water by electrolysis?
   e) Why is nitric rather than hydrochloric acid used to dissolve a silver coin?
   f) Why is dilute rather than concentrated sulphuric acid used in making hydrogen?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Part II

(Answer five questions from Part II. Extra questions will receive no credit.)

6. A liter of a certain elementary gas weighs 7.50 grams, while a liter of hydrogen gas under the same conditions weighs 0.050 gram. The atomic weight of the element composing the gas is 75. How many atoms are there in one molecule of the gas?

7. *a*) Mention three methods of increasing the speed of a reaction and give a practical illustration of the application of each method.
   b) If sodium is exposed to air, what product is finally obtained? How is sodium usually preserved in the laboratory or stockroom?

8. What experiment would demonstrate that (*a*) silver nitrate contains a metal? (*b*) sodium carbonate is a salt? (*c*) bromine is more active chemically than iodine but less so than chlorine? (*d*) iron is a reducing agent? (*e*) chlorine bleaches only indirectly?

9. *a*) In what two ways can ammonium chloride, without reacting chemically with any other substance, be split up into two parts? Specify in each case the conditions under which complete recombination will take place.
   b) Why is hydrogen more rapidly evolved by zinc reacting with hydrochloric acid than with acetic acid of the same concentration?

10. *a*) A certain weight of potassium carbonate, heated with 10 grams of sand, gives 25.6 grams of potassium silicate according to the equation $K_2CO_3 + SiO_2 = K_2SiO_3 + CO_2$. Calculate the weight of the potassium carbonate. (K 39, Si 28, O 16, C 12.)
    b) What is the percentage of sulphur trioxide in white vitriol ($ZnSO_4 \cdot 7H_2O$)? (Zn 65, S 32, O 16, H 1.)

11. *a*) Assume X to be a gaseous element having a valence of three and containing two atoms per molecule. To make two volumes of its gaseous compound with hydrogen, how many volumes of each constituent are required? State the law upon which your conclusion is based.
    b) From the standpoint of the electrolytic dissociation theory, what takes place when dilute solutions of an acid and a base are mixed?

12. Which is the more specific term in each of the following pairs: (*a*) dissociation or ionization, (*b*) carbohydrates or sugars, (*c*) fermentation or decomposition, (*d*) halogen acids or binary acids? Considering each of the foregoing pairs separately, cite a particular case illustrating the more general term which is not included by the more specific.

13. *a*) Give two different general methods for the formation of an acid. Illustrate each by an example giving equations for the reactions involved. Are there analogous methods for the formation of bases? Illustrate by equations.
    b) Sodium sulphate and copper sulphate are dissolved in separate portions of pure water. Do the two solutions affect litmus alike? Explain.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

14. Name or describe one useful property of each of the following substances, and give one use made of it because of this property: slaked lime, distilled water, charcoal, sulphur dioxide, aluminium, sodium nitrate, cast iron, copper sulphate, coke, lead.

15. *a*) How can decomposed organic matter be removed from water without distillation?

b) How can bacteria in drinking-water be destroyed without raising its temperature?

c) How can temporary hardness in water be removed without raising its temperature?

d) How can water be freed from dissolved ammonia?

DRAWING — FREEHAND

DRAWING—FREE-HAND

Saturday 9:00 a.m. Two hours

Candidates must do both exercises, including both *a* and *b* in exercise 1.

No more than forty-five minutes should be devoted to the first exercise. If this is not completed by 9:45 a.m., it should be left unfinished and work should be begun on the second exercise. If this should be finished before 11 a.m., the candidate is at liberty to devote the remaining time to the completion of the first exercise.

An incomplete drawing, correctly laid out and executed by correct method, is better evidence of proficiency than a completed drawing incorrect in construction and slovenly in execution.

Use a soft pencil, with a light touch.

All work must be strictly free-hand work without assistance from measuring slips, instruments, or artificial aids of any kind.

Accuracy of form is of more account than finished execution.

Students must not erase the construction lines.

1. *a*) Make a line drawing in perspective of a hollow cylinder lying on a horizontal plane with its axis turned at an angle of about 60° to the picture plane. Make the length of the cylinder equal to its diameter.

Make the greatest dimension of the drawing about 4 inches. Show all construction lines which indicate the position of vanishing points, drawing them with a light touch.

b) Make a line drawing in perspective of the bench shown in Fig. 1 turned at an angle of about 45° to the picture plane.

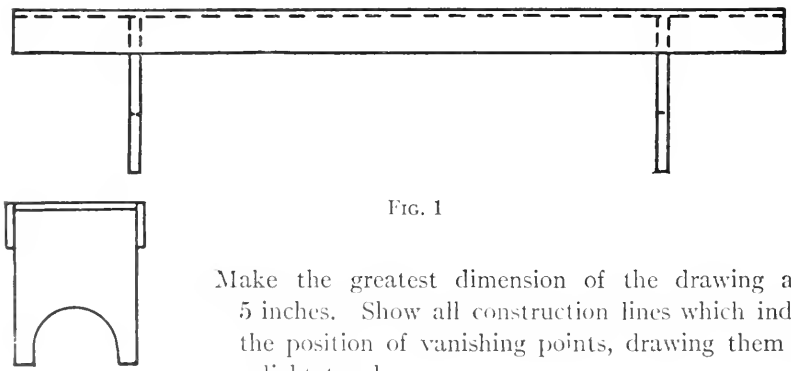


FIG. 1

Make the greatest dimension of the drawing about 5 inches. Show all construction lines which indicate the position of vanishing points, drawing them with a light touch.

(SEE NEXT PAGE)

2. Make a drawing in light and shade, without regard to color value, of Fig. 2 or Fig. 3.

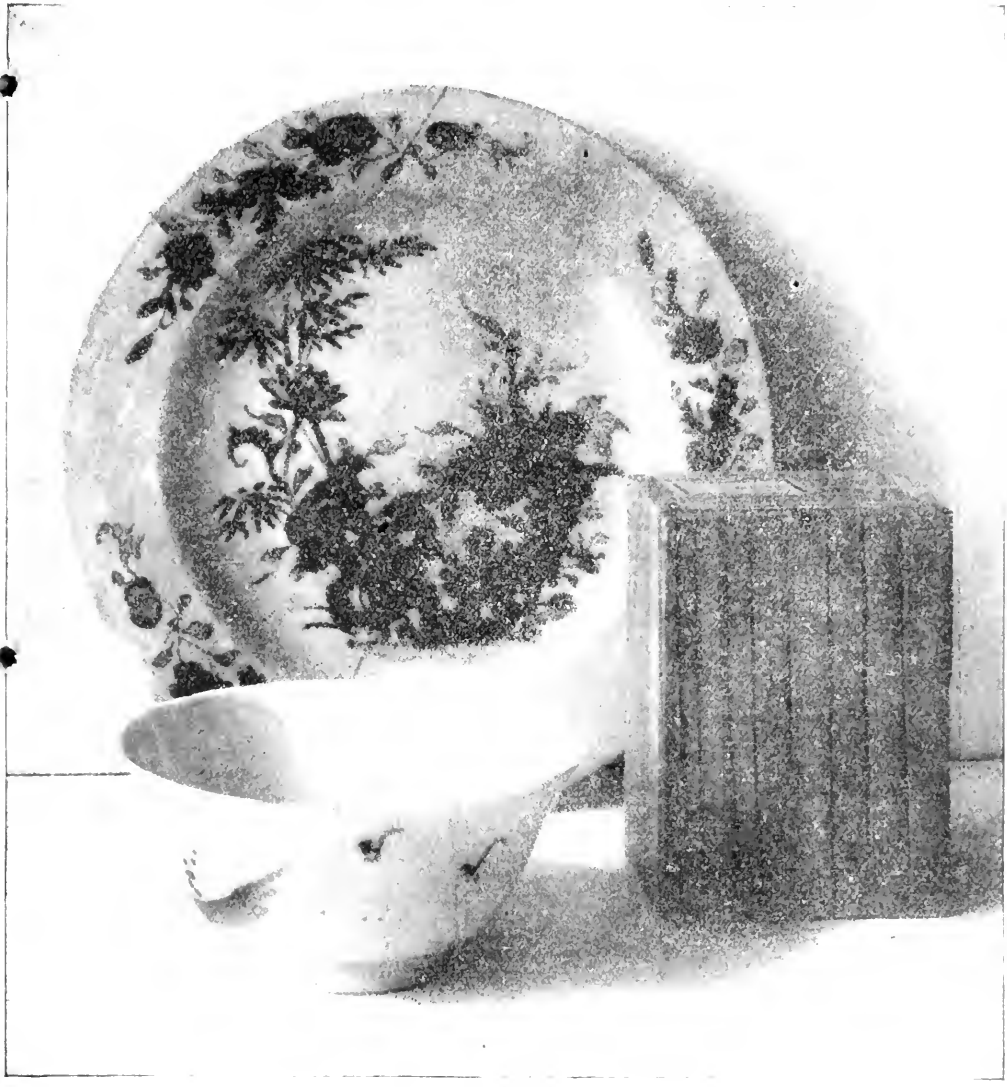


Fig. 2

In Fig. 2 the decoration on the plate and bowl shown by distinctions of color value should be omitted or indicated only in line. In Fig. 3 the background should be omitted.

Make the drawing the same size as the figure.

(SEE NEXT PAGE)

FIG. 3

DRAWING—FREE-HAND

Saturday 9 a.m. Two hours

Candidates must do both exercises, including both (*a*) and (*b*) in exercise 1.

An incomplete drawing, correctly laid out and executed by correct method, is better evidence of proficiency than a completed drawing incorrect in construction or slovenly in execution.

Use a soft pencil, with a light touch.

All work must be strictly free-hand work without assistance from measuring slips, instruments, or artificial aids of any kind.

Accuracy of form is of more account than finished execution.

Students must not erase the construction lines.

1. *a*) Represent a jelly layer cake, circular in plan, with a wedge-shaped slice cut from it, the cut going to the center. The cake is placed on a horizontal plane below the level of the eye. Show the slice lying near the cake.

   Make the drawing not less than 4 inches in width.

   b) What is the difference between perspective projection and geometric projection?

   Answer this question in writing, illustrating by diagrams.

2. Make a drawing in light and shade, without regard to color value, of Fig. 1 or Fig. 2.

   In Fig. 1 the painted decoration on the cup, shown by distinctions of color value, should be omitted, or indicated only in line.

   Make the drawing the same size as the figure.

(SEE NEXT PAGE)

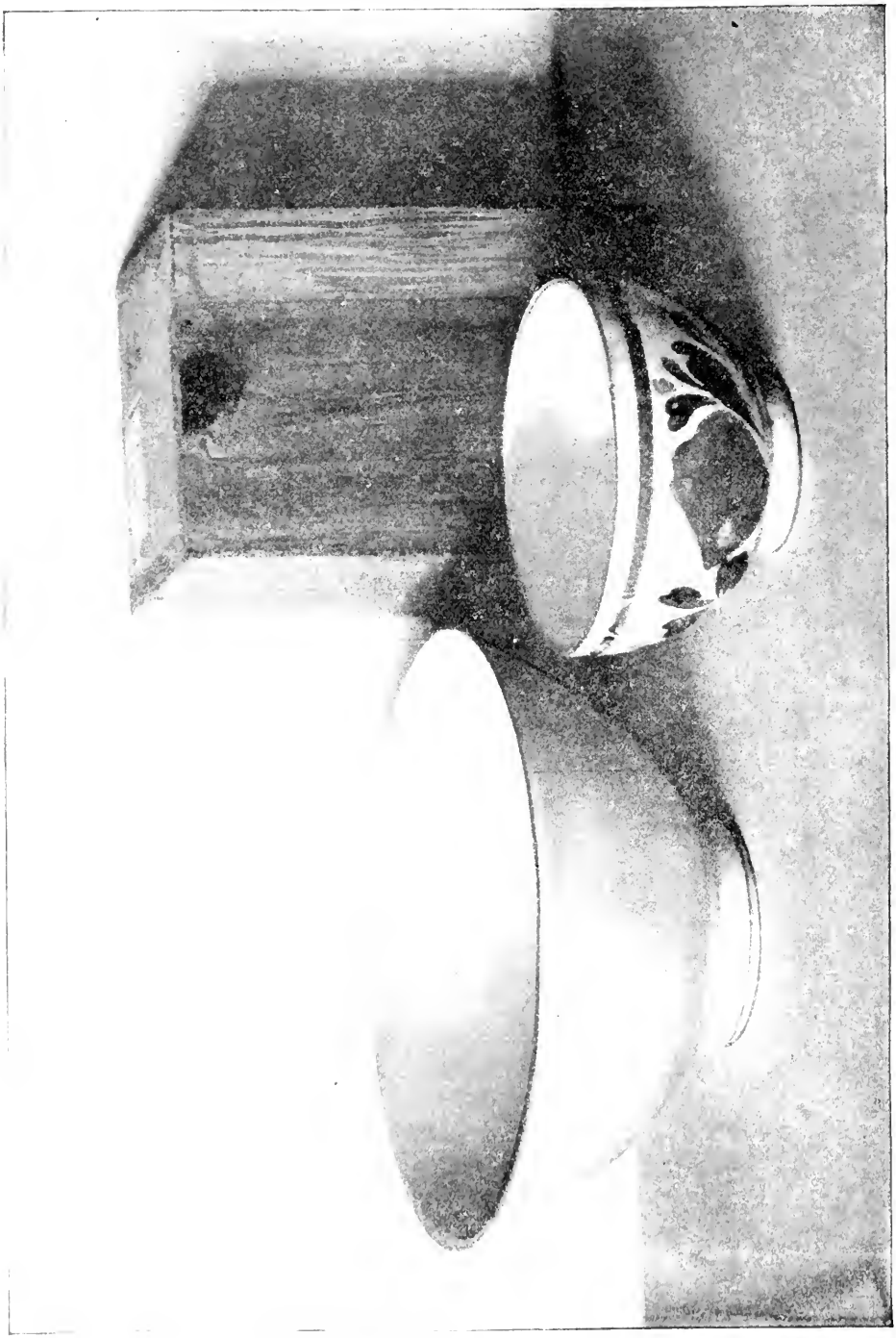


FIG. 1

(SEE NEXT PAGE)

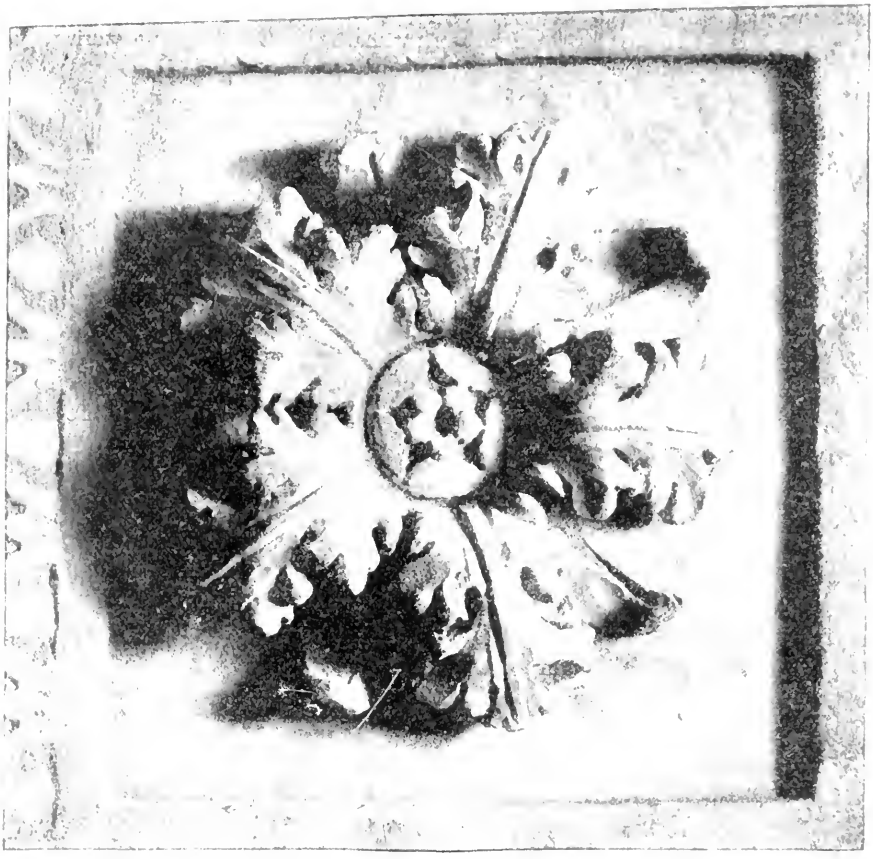


Fig. 2

DRAWING—FREE-HAND

Saturday, June 22 9 a.m. Two hours

Candidates must do all exercises.

An incomplete drawing, correctly laid out and executed by correct method, is better evidence of proficiency than a completed drawing incorrect in construction or slovenly in execution.

All work must be strictly free-hand work without assistance from measuring slips, instruments, or artificial aids of any kind.

1. *a*) A cylinder stands on one end.

Make three perspective drawings of equal dimensions to represent the cylinder under the following conditions:

(1) Eye level even with top surface;

(2) Eye level half-way between upper and lower surfaces;

(3) Eye level a little above top of cylinder.

The axis of the cylinder should be about double its diameter.

Make each drawing about 4 inches in its largest dimension.

b) Make a line drawing in perspective of a bureau, turned at an angle to the observer. Let there be at least three drawers in the bureau, the lowest one being open half-way. Do not show thicknesses.

Show all construction lines which indicate the position of vanishing points, drawing them with a light touch.

c) Define: (1) Vanishing Point;
(2) Vanishing Line.

2. Make a drawing in light and shade, without regard to color value,[1] of the subject shown in the figure.

Make the drawing the same size as the figure.

[1] By color value is meant the degree of lightness or darkness due to the actual color (the local tone) of the object.

(SEE NEXT PAGE)

1919

DRAWING—FREE-HAND

Saturday, June 21 9 a.m. Two hours

Candidates must do all exercises.

An incomplete drawing, correctly laid out and executed by correct method, is better evidence of proficiency than a completed drawing, incorrect in construction or slovenly in execution.

All work must be strictly free-hand work without assistance from measuring slips, instruments, or artificial aids of any kind.

1. Make a line drawing in perspective of the following subject:

   A rectangular box standing in the corner of a room, with a side of the box touching each wall; a cylindrical box standing on the top of the rectangular box.

   The top of the cylindrical box is slightly below the eye level.

   Draw lines to indicate the walls, the floor, and the ceiling of the corner of the room.

   Do not show thicknesses.

   Using light lines, draw the horizon line and all construction lines which indicate the position of vanishing points.

2. What is perspective projection as distinguished from geometric projection?

3. Make *either* a drawing in line only from Fig. 1, *or* a drawing in light and shade, without regard to color value,[1] from Fig. 2.

   Make the drawing the same size as the figure.

[1] By color value is meant the degree of lightness or darkness due to the actual color (the local tone) of the object. If students are at all uncertain of the meaning of this, they are advised to choose the line drawing from Fig. 1.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Fig. 1

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

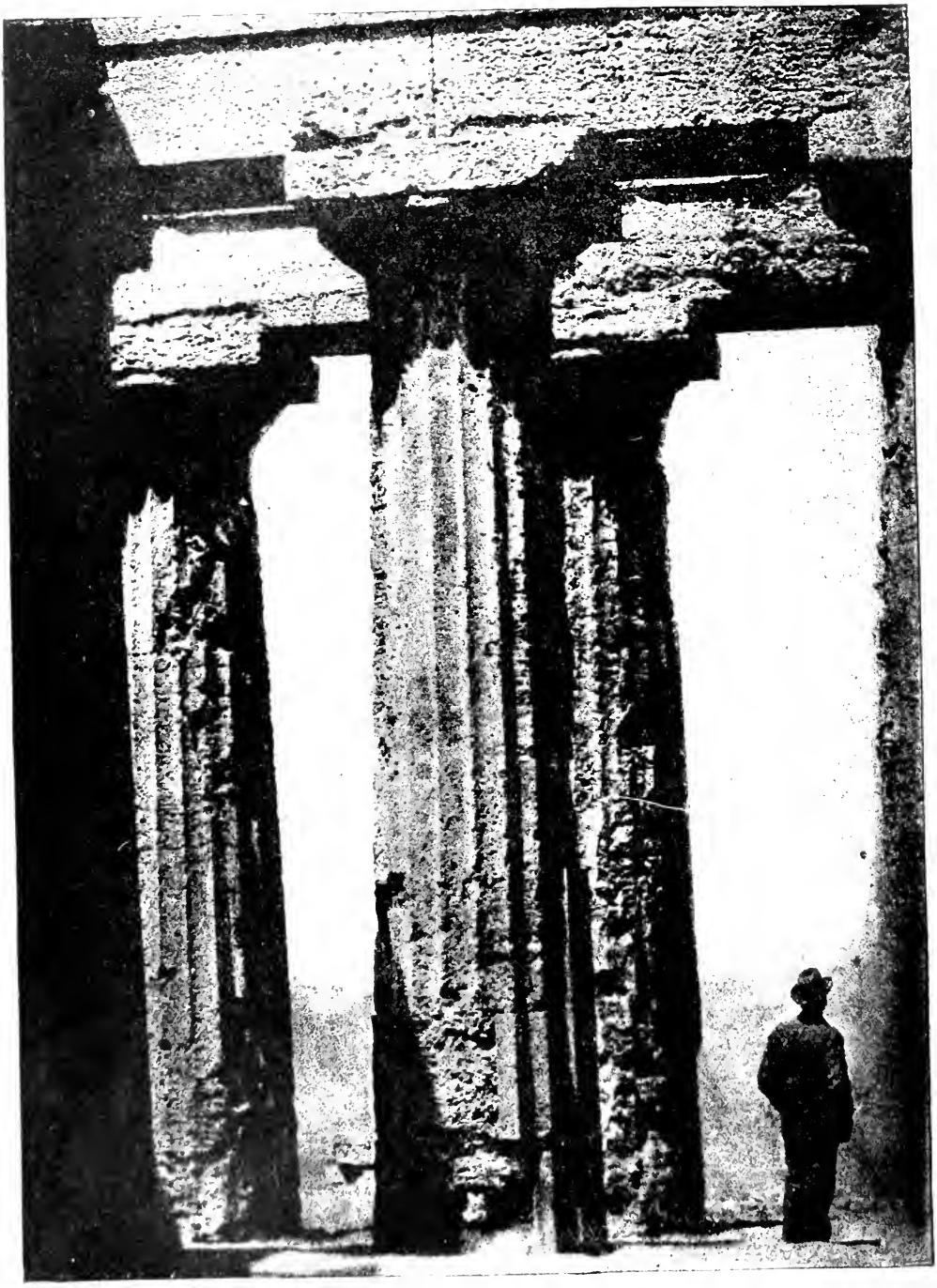


Fig. 2

DRAWING—FREE-HAND 1920

Saturday, June 26 9 a.m. Two hours

Candidates must do all exercises.

An incomplete drawing, correctly laid out and executed by correct method, is better evidence of proficiency than a completed drawing, incorrect in construction or slovenly in execution.

All work must be strictly free-hand work without assistance from measuring slips, instruments, or artificial aids of any kind.

1. *a*) At what institution did you receive your training in drawing for this examination?
   b) Over how many years did this training extend?

2. Make a line drawing in perspective of the bench and the cylindrical barrel shown in elevation in Fig. 1, arranged as shown in plan in Fig. 2.

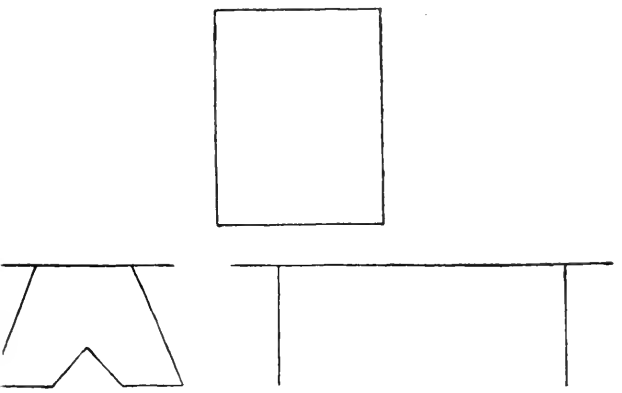


FIG. 1

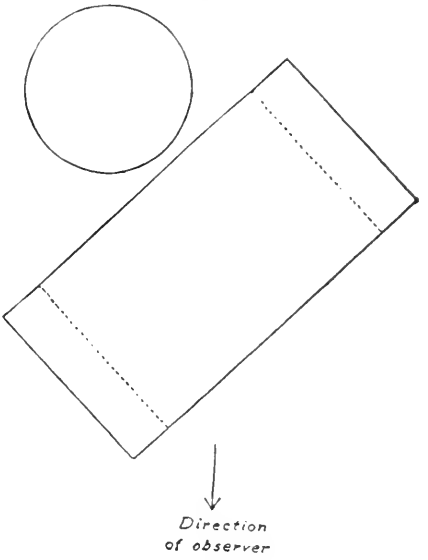


FIG. 2

Have the eye level slightly above the top of the barrel.
Do not show thicknesses.
Using light lines, draw the horizon line and all construction lines which indicate the positions of vanishing points.
Make the drawing not less than four inches in width.

3. What is meant in perspective by the terms *picture plane* and *horizon line?*

4. Make *either* a drawing in line only from Fig. 4, *or* a drawing in light and shade, without regard to color value, from Fig. 3.
   Make the drawing the same size as the figure.

(THIS EXMINATION IS CONTINUED ON PAGES 2, 3, AND 4)

FIG. 3

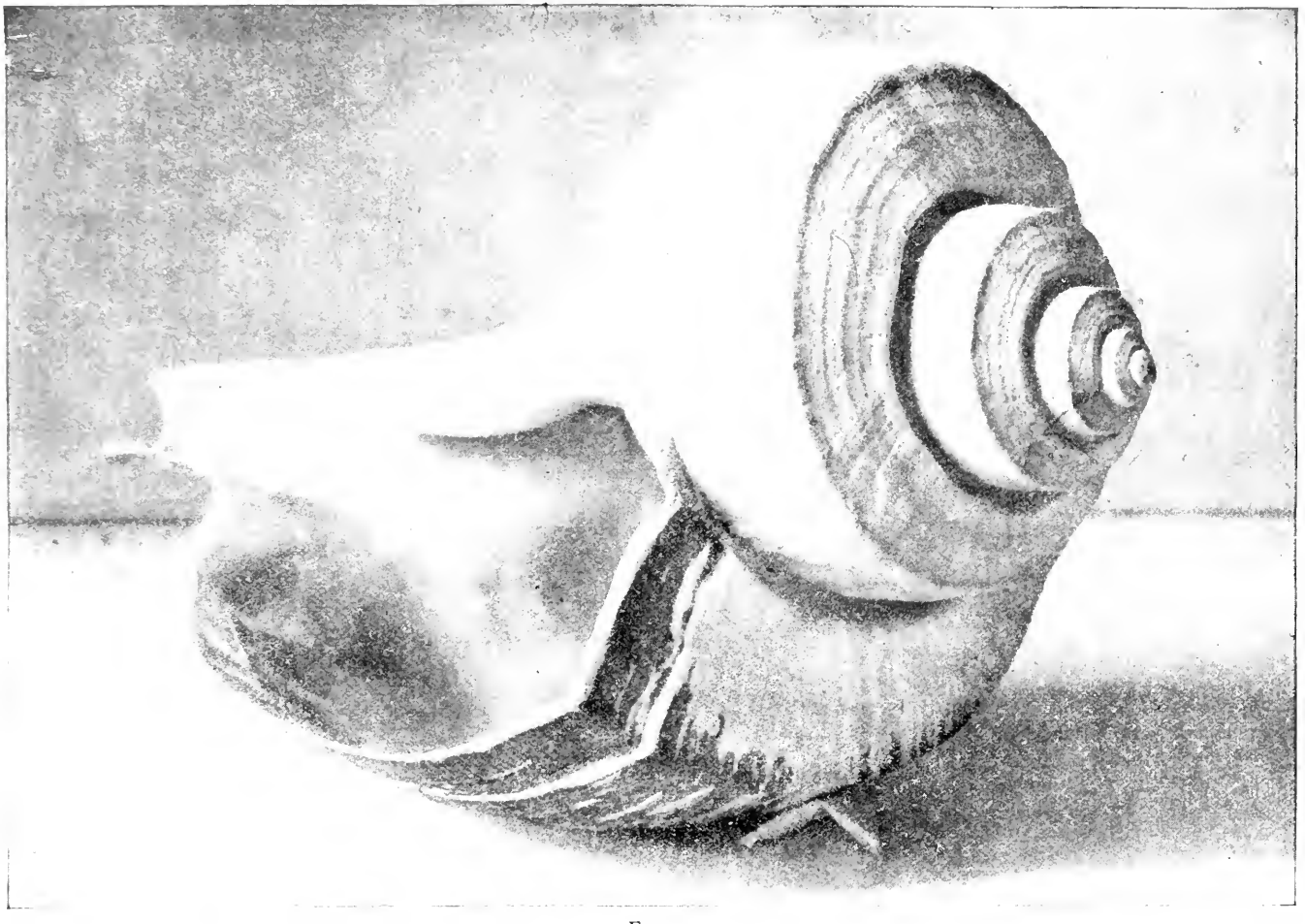
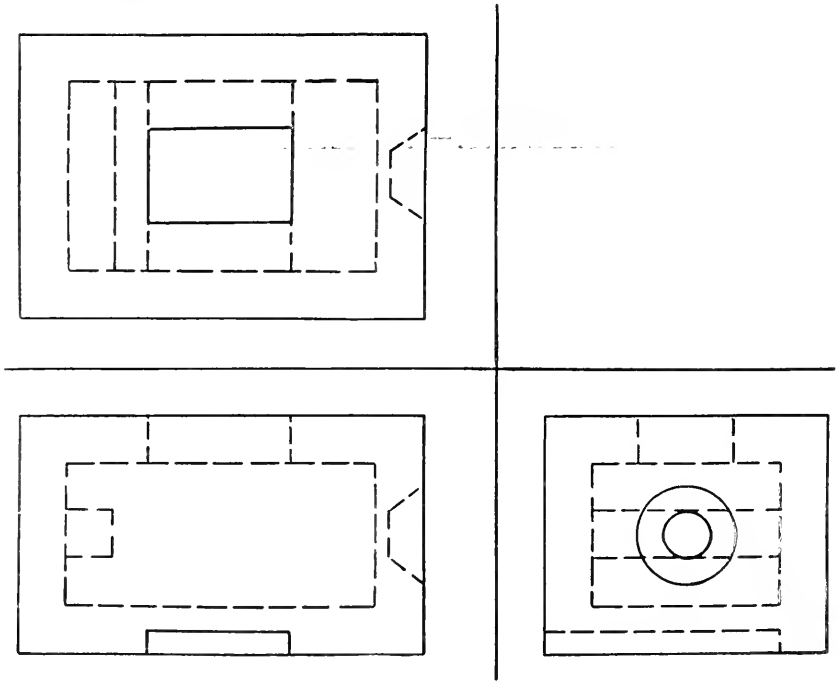


FIG. 4

DRAWING — MECHANICAL

DRAWING—MECHANICAL

Saturday 9:00 a.m. Two hours

1. Draw accurately the figures for the following constructions, and in each case indicate clearly on the figure or explain briefly the method used:
   a) *To draw two intersecting lines making with each other an angle equal to that formed by two given intersecting lines.* Draw at random any two intersecting lines forming an angle ABC, with the side BC horizontal. Elsewhere on the paper lay off an angle $A'B'C'$ equal to ABC, with the side $B'C'$ (drawn at random) inclined at any unknown angle to the horizontal.
   b) *To draw a tangent to a circle from a point outside the circle by geometric construction.*
   c) *To divide a right angle into six equal parts, using only the triangles and* T*-square.*
2. Draw a parabola passing through the ends of a vertical line $3\frac{1}{2}$ inches long and having for its vertex a point distant 2 inches horizontally from the middle point of the line.
3. 

The top, front, and end views (horizontal, vertical, and profile projections) of a box are shown above, drawn to full scale (or actual size).
a) Does the hole in the top face extend through the face into the interior of the box? If not, how deep is it?
b) Answer the same question as to the hole in the right-hand end.
c) What are the dimensions of the groove in the bottom?
d) What are the dimensions of the cleat inside the box at the left-hand side?

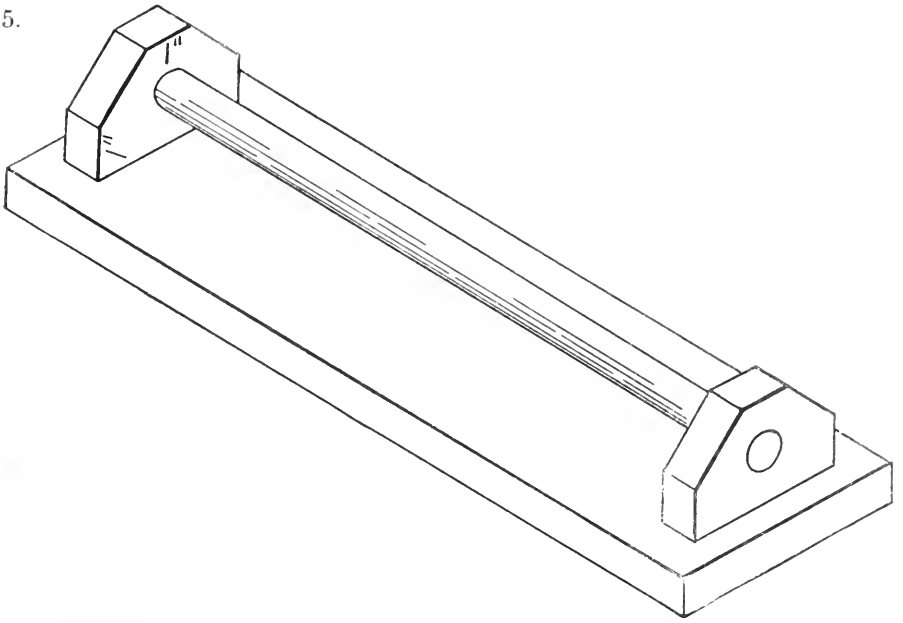
(SEE NEXT PAGE)

4. A right pyramid, whose altitude is 3 inches, has for its base a $1\frac{1}{4}$-inch square, two opposite sides of which are parallel to the vertical plane. The apex is 1 inch behind the vertical plane and $\frac{1}{2}$ inch below the horizontal plane. The axis is parallel to the vertical plane and inclined at an angle of 60 degrees to the horizontal.

   a) Draw the horizontal and vertical projections of the pyramid.

   b) Find the true size and shape of the section cut from the pyramid by a plane parallel to the vertical plane and $\frac{5}{8}$ inch behind it.

5.



Description.—The material of the rack shown above is all $\frac{3}{4}$ inch thick and the rod is $\frac{3}{4}$ inch in diameter. The board is 15 inches long and $4\frac{1}{2}$ inches wide. Each bracket is made from a piece 3 inches long and 2 inches wide, by cutting off the two corners at 45 degrees, as shown. The hole is in the center of the bracket. Each bracket is screwed to the board symmetrically, the nearest edge being $\frac{1}{2}$ inch from the end of the board.

Problem.—Make a working drawing of the rack shown above. Include a top view, a front view, and an end view, using a scale of $\frac{1}{4}$ inch to 1 inch ($\frac{1}{4}$ actual size). Put on all necessary dimensions. Using some simple single-stroke free-hand lettering, print carefully a title (Towel Rack), and such brief notes as will inform the workman what materials are to be used, how they are to be fastened together, and what finish you would suggest for the surfaces.

6. A right cylinder, $1\frac{1}{4}$ inches in diameter, whose axis is 2 inches long and vertical, stands at the center of the upper face of a block $1\frac{1}{2}$ inches wide, $1\frac{1}{2}$ inches deep, and 2 inches high. The cylinder is cut by a plane which passes through its axis parallel to the front face of the block and the half of the cylinder in front of the plane is removed. Make an isometric drawing of the block and the remaining half of the cylinder.

DRAWING—MECHANICAL

Saturday 9 a.m. Two hours

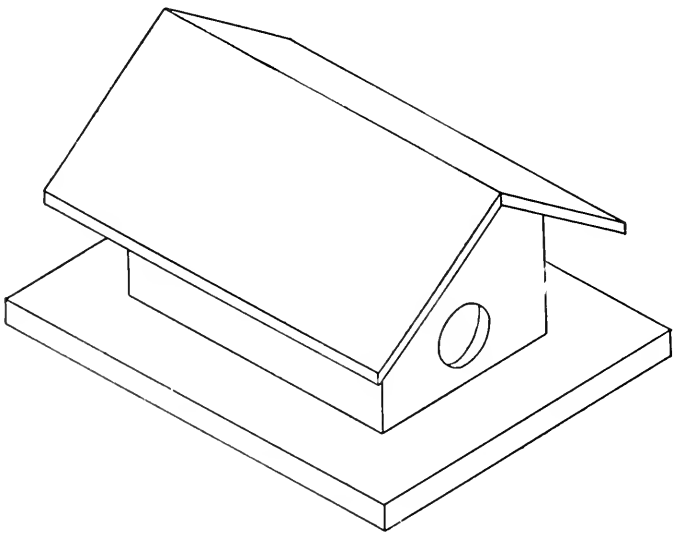
1. Illustrate the following geometric constructions by means of accurately drawn figures. Where the method is not clearly evident from the figure, add a brief explanation.

   a) To bisect a given arc.

   b) To construct half of a true ellipse whose axes are 3 inches and 4 inches respectively. Sketch the curve neatly free-hand through the points obtained.

2. Make an isometric drawing of a rectangular block 3 inches long, 2 inches wide and $1\frac{1}{2}$ inches high, with a right pyramid $1\frac{1}{2}$ inches high resting centrally on the top face of the block. The base of the pyramid is a hexagon each side of which is $\frac{3}{4}$ inch long; two sides of the hexagon are parallel to the long edges of the prism. Lengthwise through the center of the block there is a circular hole $1\frac{1}{4}$ inches in diameter.

3. *Description.*—The material of the bird house shown below is all $\frac{1}{2}$ inch thick. The house is 8 inches by 12 inches. The vertical side walls are 6 inches high. The highest point of the roof is 9 inches above the floor. There is



no interior framework. The roof overhangs at the sides and ends 2 inches (measured horizontally). A circular hole $2\frac{1}{2}$ inches in diameter extends through each end half-way between the sides. The center of each hole is 2 inches above the floor. The interior is divided into two equal compartments by a vertical partition wall parallel to the ends of the house.

(SEE NEXT PAGE)

The house rests centrally on a plank 1 inch thick, 14 inches wide by 18 inches long, in such a position as to leave a space 3 inches wide entirely around it.

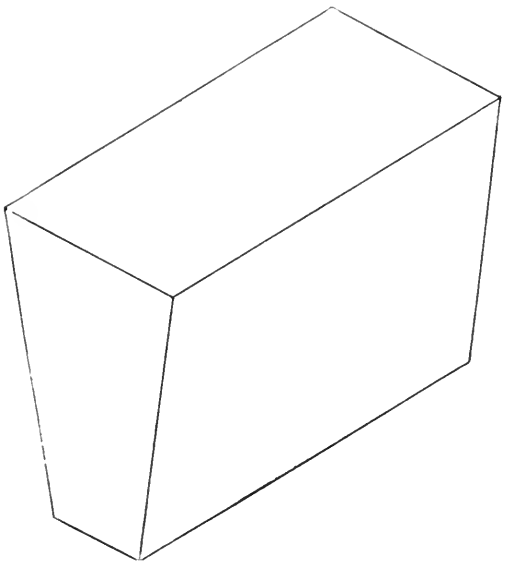
Problem.—Make a working drawing of the bird house shown on page 1. Include:

a) A top view, a front view, and an end view, drawn to a scale of $\frac{1}{4}$ inch to 1 inch (one-fourth actual size).

b) The necessary dimensions.

c) A simple title (Bird House), and such brief notes as will inform the workman what materials are to be used, how they are to be fastened together, and what finish you would suggest for the surfaces. Print carefully, using some simple single-stroke free-hand lettering.

4. The dimensions of the wedge shown below (in isometric projection) are as follows: The larger base is a rectangle 1 inch by 2 inches; the smaller base is a rectangle $\frac{1}{2}$ inch by 2 inches; the vertical distance between the bases is $1\frac{1}{2}$ inches. The ends are equal and parallel trapezoids, and the side faces slope equally.



a) Draw the horizontal and vertical projections (top and front views) of the wedge (actual size) in the following position: its larger base is uppermost and $\frac{1}{2}$ inch below the horizontal plane of projection; one corner of this base is in the vertical plane of projection, and the longer edges of the base make 30 degrees with the vertical plane of projection.

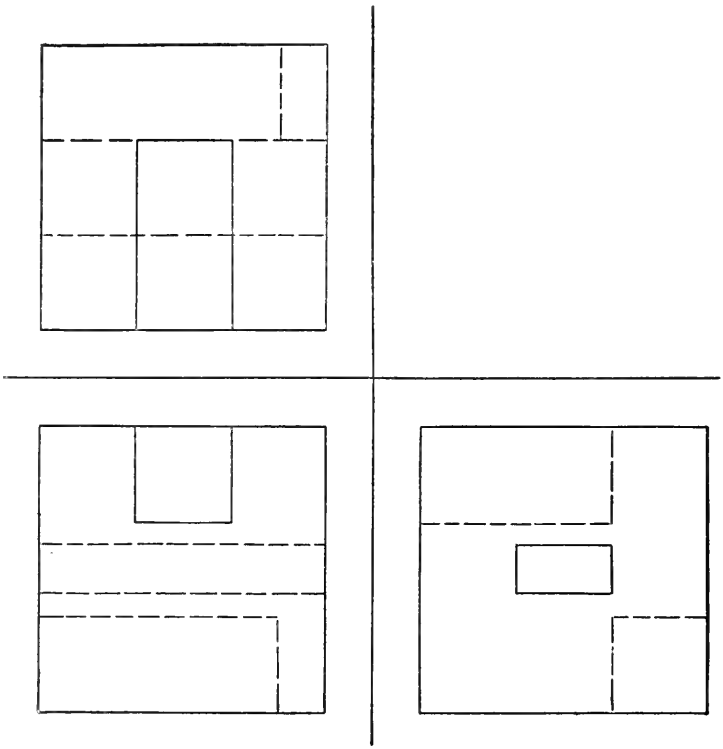
b) Find the true shape of the section cut from the wedge by a plane which passes through its exact center. The cutting plane is perpendicular to the horizontal plane, but makes 60 degrees with the longer edges of the base of the wedge (30 degrees with the vertical plane).

(SEE NEXT PAGE)

5. *a*) Enumerate briefly the precautions to be observed in the use of the ruling pen.

   b) How would you test a triangle for accuracy?

6. The accompanying full-size drawing shows three projections of a $1\frac{1}{2}$ inch cube from which three cavities have been cut. State the length, width, and depth of each cavity, as determined by direct measurement from the drawing.



DRAWING—MECHANICAL

Saturday, June 22 9 a.m. Two hours

The more important problems have been placed near the beginning of the paper, but if the two-hour period allowed for the examination is apportioned properly between the six problems, there should be no necessity for omitting any.

1. Make a working drawing of the book-rack shown below. Include:

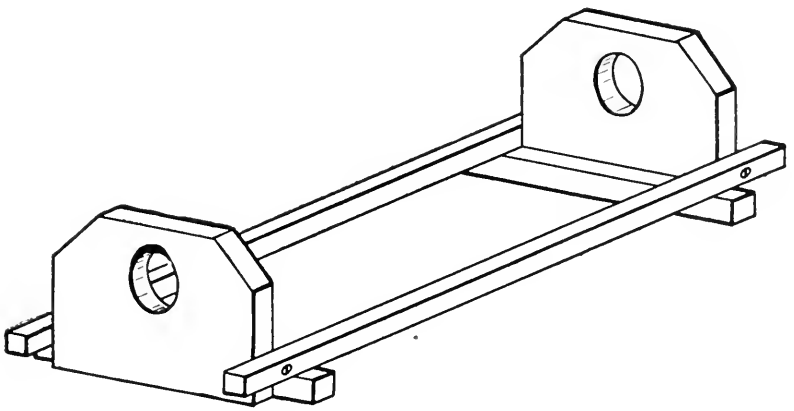
   (*a*) Three views, drawn to a scale of one-eighth actual size.

   (*b*) The necessary dimensions.

   (*c*) Enough brief notes to describe fully the materials, fastenings, and finish.

   (*d*) A title, such as "Design for a Wooden Book-rack."

   Description: The upright ends are 1 inch thick, 10 inches wide, and 8 inches high, with upper corners beveled 2 inches in each direction; the hole, $2\frac{1}{2}$ inches in diameter, is centered with its upper edge 1 inch below the upper edge of the end piece. The distance in the clear between the inner surfaces of the two upright ends is 23 inches. The rest of the material is 1 inch square; the two long side pieces are each 28 inches long, and the two short cross pieces are each 14 inches long. The ends fold down flat.



2. Make an isometric drawing of a right prism; its axis is vertical and 2 inches long; its upper and lower bases are equilateral triangles whose sides are 3 inches long. A cylindrical hole $1\frac{1}{2}$ inches in diameter extends through the prism from top to bottom; the axis of the hole coincides with the axis of the prism. (The isometric drawing of the circle may be sketched freehand after four or more of its points have been determined accurately.)

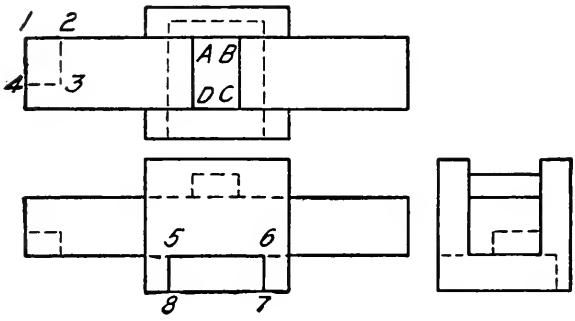
(SEE NEXT PAGE)

3. Three views of an object are drawn below.

(*a*) Is *1–2–3–4* an opening or a raised part? What are its dimensions?

(*b*) Answer the same two questions with respect to *5–6–7–8*.

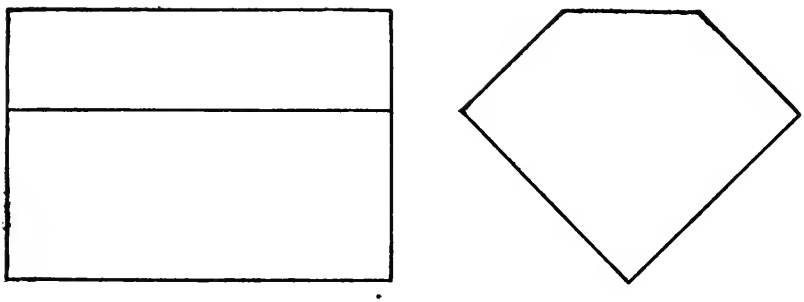
(*c*) Answer the same two questions with respect to *A–B–C–D*.



4. The front view and the end view of a solid are shown below. Copy these views and

(*a*) Draw the top view.

(*b*) Show the true shape of the section cut from the solid by a vertical plane which intersects the axis of the solid at a point equidistant from the ends of the solid, and is inclined at 60° to that axis.



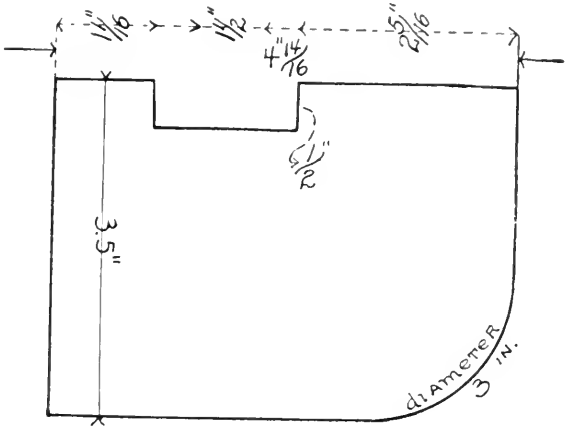
5. [Solve either (*a*) or (*b*)]

(*a*) Draw two regular hexagons each $1\frac{1}{2}$ inches on a side. Use a different method for each. One method must be that in which only the T-square, triangles, and scale are used.

(*b*) Draw the end view and the front view of a helix whose axis is horizontal. The diameter of the helix is 2 inches and the pitch is 3 inches. Sketch the curve neatly freehand after the necessary points have been accurately determined.

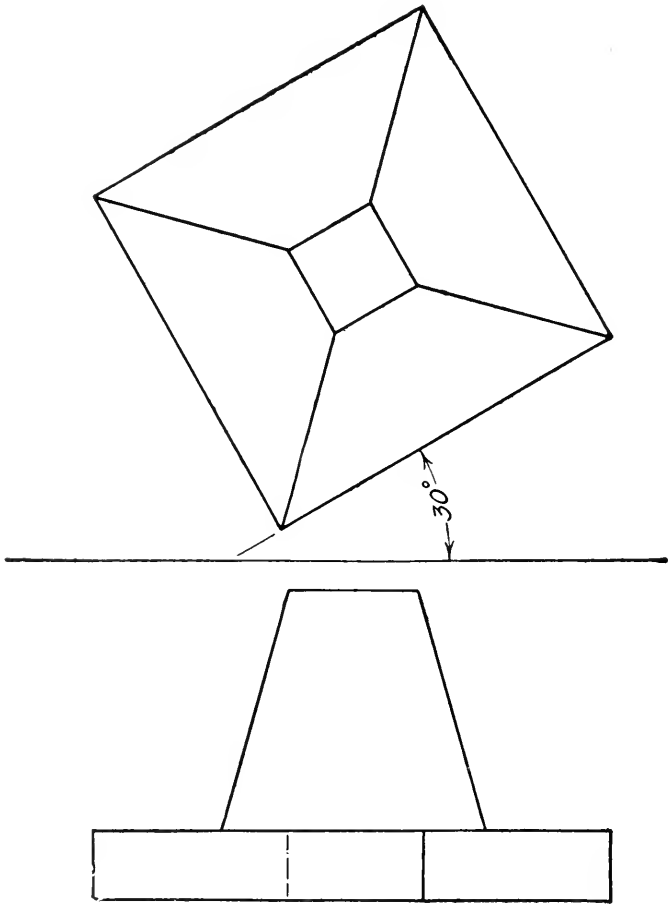
(SEE NEXT PAGE)

6. (*a*) One view of an object is shown below; no other views need be considered. The dimensions given are numerically correct. Required to copy the view, and to place the dimensions on it in a manner that will conform to standard practice.



(SEE NEXT PAGE)

(*b*) The frustum of a right pyramid rests centrally on a block which is 2 inches square and $\frac{3}{8}$ inch high. Two side faces of the block are inclined at 30° to the vertical plane of projection as is shown in the accompanying views. The lower base of the frustum is 1 inch square, with each side parallel to the corresponding edge of the block; the upper base is $\frac{1}{2}$ inch square; the height of the frustum is $1\frac{1}{4}$ inches. In each of the views as shown there are mistakes and omissions. Required to make a correct sketch of each view.

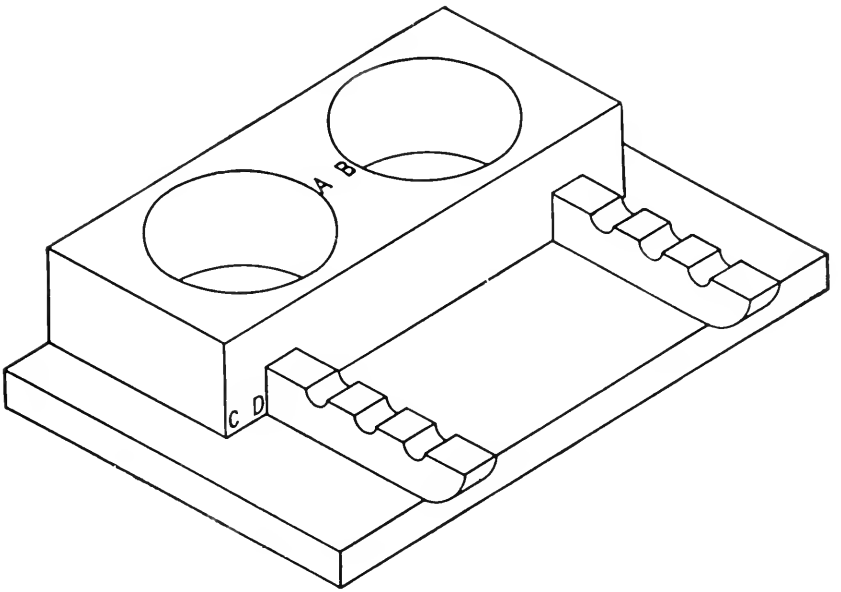


1919

DRAWING—MECHANICAL

Saturday, June 21 9 a.m. Two hours

Candidates taking the examination in Mechanical Drawing are requested to write their names in addition to their examination numbers on the answer book and sheets of drawing paper used in the examination.



1. Make a working drawing of the ink-bottle holder. Include
   (*a*) Three views drawn to a scale of one-half size.
   (*b*) The necessary dimensions.
   (*c*) A brief title, giving name of object, scale, date, and name.
   (*d*) Complete notes describing materials, fastenings, finish, etc.

Data:

Base: of $\frac{3}{8}$-inch stock, 4 by 6 inches.

Bottle block: 1 inch thick, $2\frac{1}{8}$ by $4\frac{7}{8}$ inches. Holes $1\frac{3}{4}$ inches in diameter and 1 inch deep. Space $AB=\frac{1}{2}$ inch.

Penholder strips: $\frac{3}{8}$ inch wide, $\frac{1}{2}$ inch deep, $2\frac{3}{8}$ inches long; $\frac{1}{2}$-inch radius at end. $CD=\frac{1}{2}$ inch. Diameter of semicircular grooves $\frac{1}{4}$ inch, spaced evenly.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

2. [*Answer four of the five*]

(*a*) How should drawing pencils be sharpened?

(*b*) Name four common causes of blots in inking due to improper handling of the drawing instruments.

(*c*) Describe fully, with a sketch, the method of drawing a line inclined at 75 degrees to the horizontal.

(*d*) In what order should the lines of a drawing be inked?

(*e*) Why and when and how much should the legs of the compasses be bent?

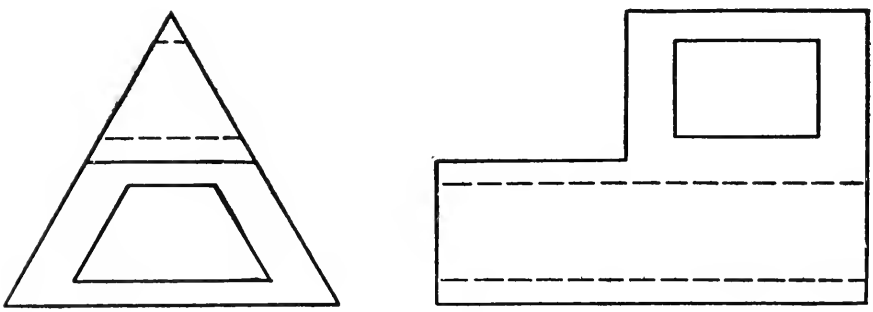
3. (*a*) Draw the top, front, and side views of the frustum of a right square pyramid. Axis vertical. Sides of upper base $\frac{3}{4}$ inch, of lower base 2 inches; vertical distance between bases $2\frac{1}{2}$ inches; two edges of each base parallel to *V*.

(*b*) Show the true shape of the section cut from the above-mentioned solid by a plane which is perpendicular to *V*, makes 45 degrees with *H*, and passes through the middle point of the axis.

4. Make an isometric drawing of the following block:

Front vertical face a regular hexagon, sides 1 inch, two sides horizontal. Rear vertical face a regular hexagon, sides 2 inches. Axis horizontal and $2\frac{1}{2}$ inches long. Side faces all equally inclined to the axis. A round hole $1\frac{1}{2}$ inches in diameter extends through the block; the axis of the hole coincides with the axis of the block.

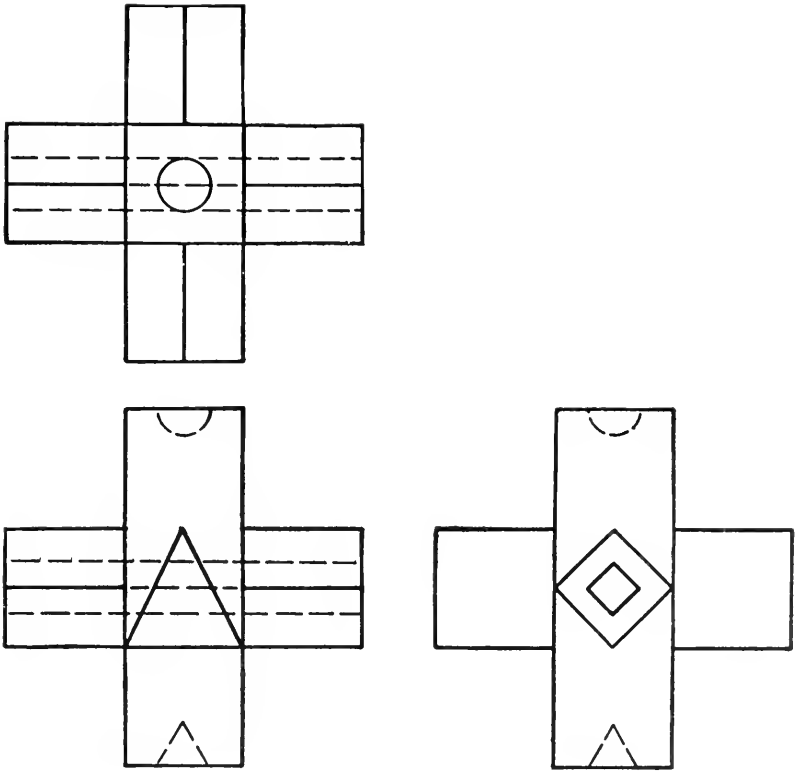
5.



The front and end views are given. Copy these and draw the top view.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

6.



The object represented above is composed of several blocks.

(*a*) Give the length of each block and the shape of its cross-section.

(*b*) What is represented, by the dashed lines at the top, and what at the bottom of the vertical block?

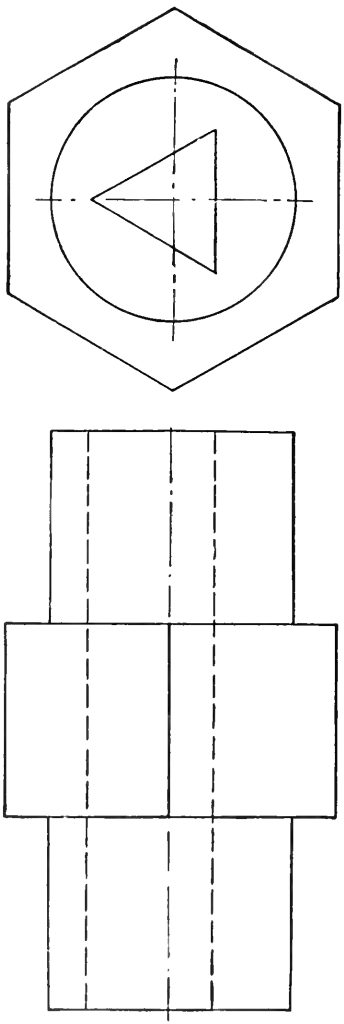
1920

DRAWING—MECHANICAL

Saturday, June 26 9 a.m. Two hours

Candidates taking the examination in Mechanical Drawing are requested to write their names in addition to their examination numbers on the answer book and sheets of drawing paper used in the examination.

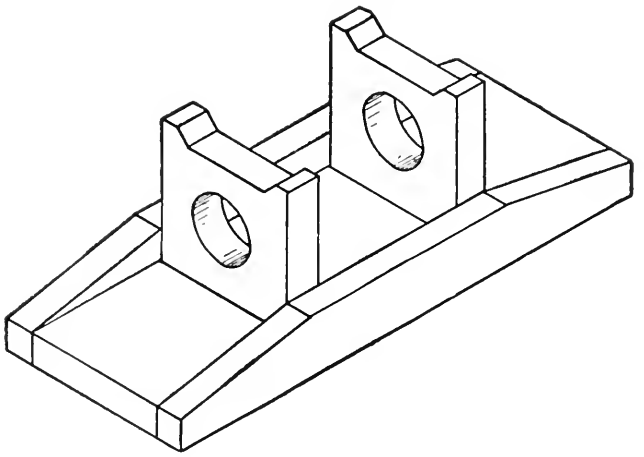
1. Make a full-size isometric drawing of the solid shown below.



(THIS EXAMINATION IS CONTINUED ON PAGE 2)

2. Make a working drawing of the pen tray. Include three views drawn to one-half size; all necessary dimensions; brief printed notes describing materials, finish, and the necessary fastenings; a brief printed title, "Pen Tray," scale, name, and date.

Description. Over all dimensions—length 8 inches, width $3\frac{1}{4}$ inches, height $2\frac{3}{4}$ inches. *Material*—all $\frac{1}{2}$ inch thick. *Base*—8 inches by $2\frac{1}{4}$ inches. *Side pieces*—1 inch high; length on top $3\frac{1}{2}$ inches. *Upright supports*—$2\frac{1}{4}$ inches square; 45° bevels begin $\frac{1}{4}$ inch from each end and cut $\frac{1}{4}$ inch deep; holes 1 inch in diameter and at center of pieces; supports fold outward.



3. *a*) Write the following sentences and supply the missing expressions:

The scale should not be used as _____ because _____

_____.

In using the T-square for drawing horizontal lines, always place its head against the _____ side of the drawing board, hold its _____ with the _____ hand, and rule along its _____ edge in a direction from _____ to _____.

b) Circumscribe a circle about a triangle whose sides are 2, 3, and 4 inches long respectively. Show the construction lines.

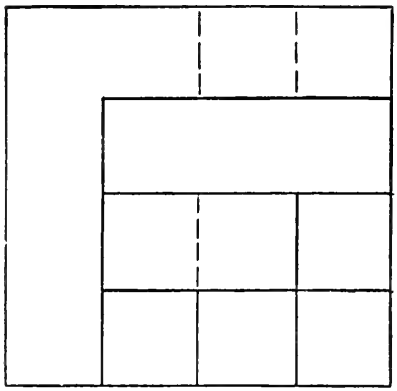
4. Given a 2-inch cube; two faces are horizontal; its vertical (side) faces make 45° with the vertical plane of projection (*V*); a central vertical opening 1 inch square extends entirely through it.

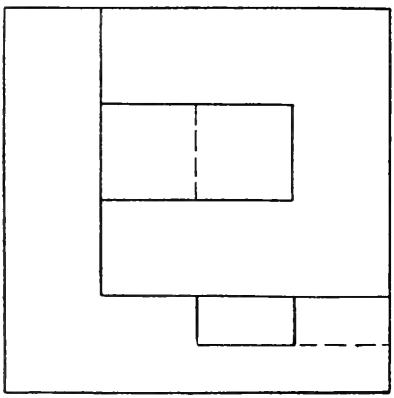
a) Draw the top view and the front view of the cube.

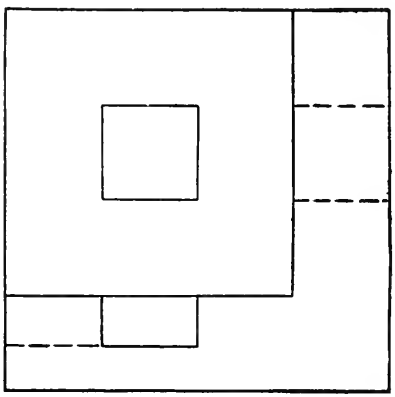
b) The cube is cut by a plane which passes through its center, is perpendicular to the vertical plane of projection (*V*); and is inclined at 30° with the horizontal plane of projection (*H*). Required the true shape of the section cut.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

5. Three full-size views of an object are shown below. Answer concisely the following:
   a) In which face is there an opening and how large is it?
   b) From which face does a projection extend? Give the dimensions of the projection.
   c) Which face contains a groove? What is the form of the groove and what are its dimensions?







GEOGRAPHY

GEOGRAPHY

Friday 9:00 a.m. Two hours

A teacher's certificate covering the laboratory instruction must be presented at the time of the examination.

No extra credit will be given for more than the required number of questions.

Group I

(Answer one question from this group.)

1. Explain the term *heat equator.* How does its position vary with the seasons? Why is it an irregular line?
2. Draw two diagrams showing the relations of the sun's rays to the Northern Hemisphere in summer and in winter.

Group II

(Answer one question from this group.)

3. Tropical driftwood is brought to the coast of Spain by ocean currents. From what land does it probably come, and what course does it follow?
4. A vessel was sunk owing to collision with an iceberg during a fog on the Newfoundland Banks. What caused the fog? Where did the iceberg come from, and how did it reach the Banks?

Group III

(Answer two questions from this group.)

5. Explain the difference in rainfall (*a*) between the east and west slopes of the Andes in Peru and northern Chile; (*b*) between the east and west slopes of the Sierra Nevadas in California; (*c*) between the northern and southern slopes of the Himalayas.
6. What facts make it possible to predict the weather in the eastern United States? Why do weather predictions sometimes fail?
7. Explain why lowlands under the trade wind belts are usually deserts. Name two such deserts.

Group IV

(Answer three questions from this group.)

8. Account for the saltness of Great Salt Lake. What change in natural conditions would make the lake fresh? What are the topographical evidences of past changes in the lake level?
9. What are glacial erratics (foreign boulders)? Name the states where you would expect to find them. With what peculiarities of topography are they commonly associated?

(SEE NEXT PAGE)

10. Draw a profile or cross-section of a plateau in a young stage of dissection. Draw a second profile or cross-section showing the same region maturely dissected; and a third showing the same region in old age.

11. Why does such a river as the lower Mississippi make a poor boundary line? If you owned a plantation bordering such a river, what dangers would threaten your property? Would you rather live on the inside or the outside of a bend in the river? Why?

12. Define ten of the following terms: horse latitudes, drumlin, talus, solstice, neap tide, isotherm, bore, fiord, monsoon, ox-bow lake, anticyclone, crevasse, fall-line, residual soil, cirque.

GEOGRAPHY

Friday 2 p.m. Two hours

No extra credit will be given for more than the required number of questions.

Group I

(Answer one question from this group.)

1. What differences would there be in the climate of the earth if its axis were perpendicular to the plane of its orbit?
2. Draw a diagram showing the relative positions of earth, moon, and sun at the times of spring and neap tides of one lunar month.

Group II

(Answer one question from this group.)

3. Coral reefs are absent from the shores of the Galapagos Islands which lie under the equator off the west coast of South America; but they occur around the shores of the Bermuda Islands 32° north of the equator off the east coast of North America. Explain this peculiarity of distribution.
4. Explain the chief differences between the topography of the ocean floor and the topography of the land. How do near-shore deposits differ from those of the deep sea?

Group III

(Answer two questions from this group.)

5. The eastern and western sides of Lake Michigan have unlike climates. Which side is the more favorable for fruit raising? Why?
6. Describe two types of barometers. Explain how each works. For what purposes are barometers used?
7. With the accompanying weather map for the morning of December 8, 1916, before you, predict the temperature, wind direction, and state of the sky at Columbus, Ohio (indicated by red star on the map), for the afternoon of the 8th and for the 9th.

Group IV

(Answer three questions from this group.)

8. In what different ways are lakes commonly produced? Name an example of each kind of lake. Through what processes do lakes usually become extinct?
9. How are alluvial fans formed? In what part of the United States are they most common? Why? What use does man make of them?
10. Describe 3 types of soils, each of which is characteristic of a particular region of the United States. Explain the origin of each type, and discuss its value for agriculture.
11. Describe the different types of land forms which you would expect to find in a maturely dissected volcanic region and explain the processes by which each form is produced.
12. Define ten of the following terms: humus, loam, eolian deposit, cumulus cloud, baselevel, moraine, water-table, atoll, playa, till, spit, stalagmite.

GEOGRAPHY

Friday, June 21 2 p.m. Two hours

No extra credit will be given for more than the required number of questions.

Group I

(*Answer one question from this group.*)

1. If the earth's axis were inclined 30 degrees away from a perpendicular to the plane of its orbit, what would be (*a*) the latitude of the Arctic Circle, (*b*) the width of the Temperate zones, (*c*) the width of the Torrid zone?

2. What difference is there in the positions of earth, sun, and moon during full moon and during a total eclipse of the moon? What phenomenon observable during every eclipse of the moon indicates the spherical form of the earth?

Group II

(*Answer one question from this group.*)

3. Account for the fact that the water at the bottom of the Gulf of Mexico has a temperature about 4° F. higher than the water of the adjacent open ocean in the same latitude *at the same depth.* Name another body of water connected with the ocean that exhibits a similar phenomenon.

4. Why is the harbor of Hammerfest, Norway, 76° N., not closed by ice in winter? Why would it probably be closed by ice if the continent of South America were shifted 8° farther north?

Group III

(*Answer two questions from this group.*)

5. State two places in the Northern Hemisphere where the isotherm of 40° F. bends distinctly to the north, and two places where it bends distinctly to the south, on the isothermal chart of the world for January. Give the reason in each case.

6. What atmospheric conditions are responsible for such disastrous inundations of low coasts as occurred at Galveston, Texas, in the fall of 1900?

7. What are the causes that determine the directions of (*a*) the trade winds, (*b*) the prevailing westerlies?

(SEE NEXT PAGE)

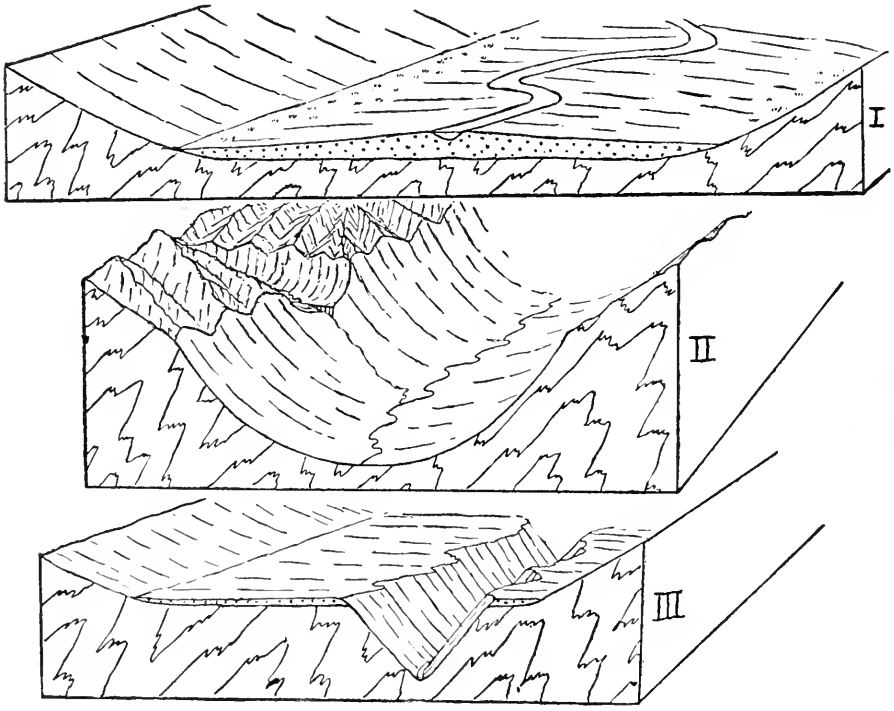
Group IV

(Answer three questions from this group.)

8. Name three cities the locations of which have been determined by distinctly different topographic features, and explain how these features were effective in each case.

9. Name the different types of moraines and explain how each is formed.

10. Describe the significant characteristics and give your understanding of the history of each of the valleys shown in the accompanying diagrams:



11. Draw a contour map of an alluvial fan, showing characteristic arrangement of channels on the surface of the fan. Draw a cross-section of the fan, showing location of coarsest and finest deposits.

12. Define ten of the following terms: loess, anticyclone, sink-hole, isobar, spring tide, cut-off, bad lands, nimbus cloud, wind-gap, peneplain, aggradation, atoll.

1919

GEOGRAPHY

Friday, June 20 2 p.m. Two hours

No extra credit will be given for more than the required number of questions.

Group I

(*Answer one question from this group.*)

1. (*a*) Define map projection. (*b*) Make a sketch of the parallels and meridians as they are in a Mercator's projection map of the world. (*c*) Mention the advantages and disadvantages of this kind of map.
2. In the South Temperate zone a farm on a hillside sloping north can grow earlier spring vegetables than a farm situated on level land at the base of the hill. Why is this true?
3. (*a*) How was the so-called "daylight-saving" in summer accomplished by the plan practised in 1918? (*b*) Why will this scheme not work in winter?

Group II

(*Answer one question from this group.*)

4. If the master of a sailing ship wished to take advantage of ocean currents and prevailing winds, what course would he take, and why, on voyages (*a*) from Liverpool to Rio de Janeiro and (*b*) from Cape Horn to Cape of Good Hope?
5. (*a*) Where and how do the icebergs encountered in the steamer lanes of the North Atlantic originate? (*b*) Why do these icebergs float so far south? (*c*) Why is it dangerous for a large ship to run into one of these bergs at high speed even if the berg rises only a few feet above the surface of the sea and is not apparently of great areal extent?

Group III

(*Answer two questions from this group.*)

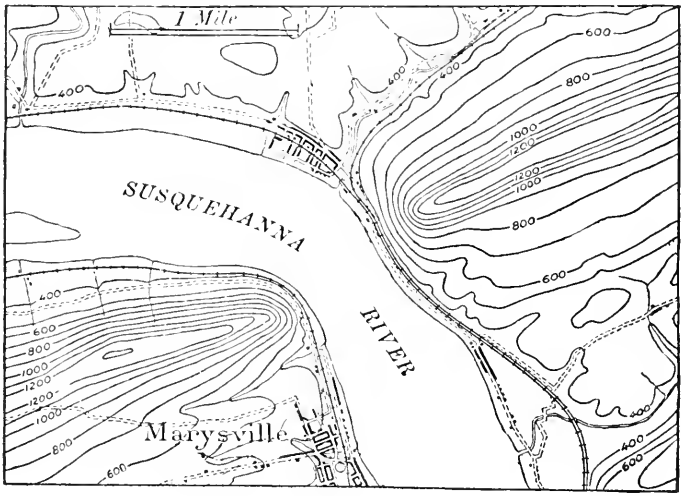
6. (*a*) Draw an outline map of the part of the earth's surface within the Tropics, and on it indicate and label: (1) the equator, (2) the heat equator in July, (3) the heat equator in January. (*b*) On the same map locate the Sahara Desert and account for its position.
7. The daily United States weather map for a certain day gave the pressure for Denver, Colorado, as 30.00 inches. Denver is one mile above sea-level. What was the actual reading of the barometer at Denver on that day? Show how you obtain your result.
8. Distinguish between a temperate-latitude cyclone and a temperate-latitude tornado as to (*a*) place of occurrence, (*b*) diameter, (*c*) destructiveness, (*d*) climatic effects.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group IV

(Answer three questions from this group.)

9. Describe as a whole the region represented on the accompanying contour map, mentioning especially the different forms of relief and the drainage. State (*a*) the greatest elevation, (*b*) the least elevation, (*c*) the location of the steepest slope. Name and locate the works of man indicated on this map and show how their location is related to topography.



10. Describe the coastal plain of Eastern United States as to (*a*) origin, (*b*) slope, (*c*) drainage, (*d*) soil, (*e*) industries and their location.

11. Give an account, in proper notebook form, of a class trip taken with your teacher, on which you studied (*a*) stream work, or (*b*) rock classes and structures, or (*c*) glaciation, or (*d*) wind work.

12. Give reasons why Iowa has become known as the typical agricultural state on account of (*a*) its topography, (*b*) its original vegetation cover, (*c*) origin, composition, texture, and depth of its soils, and (*d*) its location.

13. Define ten of the following: agonic line; mean solar time; chronometer; erratic bowlder; nunatak; monadnock; cirque; spit; isotherm; relief; hanging valley; rejuvenation; fault-scarp.

1920

GEOGRAPHY

Friday, June 25 2 p.m. Two hours

No extra credit will be given for more than the required number of questions.

Group I

(*Answer one question from this group.*)

1. How do the lengths (in miles) of the degrees of latitude and of longitude vary and why? Describe one method of determining latitude; one method of determining longitude.

2. If a man is standing on the equator at noon on June 21, in what part of the sky (compass direction) will he see the sun? How many degrees above the horizon will the sun appear at that time and place?

Group II

(*Answer one question from this group.*)

3. Name the important movements of the ocean waters and state the cause or causes of each.

4. Give five characteristics of naturally good harbors and explain how the lack of each might affect the use of a harbor.

Group III

(*Answer two questions from this group.*)

5. Distinguish between oceanic and continental climates, giving characteristics of each; and name important cities where each is typically developed.

6. Why are there two rainy seasons in the equatorial forests of Africa and no rainy season in the Sahara Desert?

7. Explain why low-pressure areas in the prevailing westerlies usually bring cloudy or rainy weather. Describe and explain the temperature changes which occur at a given point while the center of a low is passing north of it.

Group IV

(*Answer three questions from this group.*)

8. Write an essay of about one hundred words in which each of the following terms is used in its geographic sense: monadnock; entrenched (or incised) meanders; residual soil; peneplain; sluggish rivers; rejuvenation; base level.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

9. Describe and explain the geographic features observed by you while on a field trip with your geography teacher. State exactly when and where the trip was made.

10. A road having a west to east direction for three miles crosses over a north-south ridge which is one hundred feet high and steep near the top. The road then turns abruptly to the north and follows down a valley bottom for three miles beside a stream which falls 40 feet to the mile. Make a contour map of the road and region described, on a scale of one inch to the mile and with a contour interval of 20 feet.

11. Explain the relation of wells, lakes, permanent streams, and temporary streams to the water-table or ground-water level.

12. Define ten of the following: relative humidity; equinox; mesa; névé; geographic cycle; international date line; metamorphic rock; differential weathering; continental shelf; drumlin; fjord; feldspar.

PHYSICS

PHYSICS

Friday 9:00 a.m. Two hours

A teacher's certificate covering the laboratory instruction must be presented as part of the examination.

Answer ten questions as indicated below. No extra credit will be given for more than ten questions.

Group I

(Omit one question from this group.)

1. Define density and specific gravity. How do they compare in value in the metric system? How do they compare in value in the English system?
2. Upon a table stands a closed cubical box, measuring 15 cm. on each inside edge, above the top of which projects a tube 20 cm. high and 1 sq. cm. in area of inside cross-section. The box and tube weigh 200 gms. Both box and tube are filled with water. Find
   (*a*) the total force exerted upon the table;
   (*b*) the total force exerted by the water upon the bottom of the box.
3. When supplied with 100 cubic feet of water per second, at a head of 45 feet, what horse-power is developed by a turbine water wheel having an efficiency of 80 per cent? (One cubic foot of water weighs 62.4 pounds.)
4. A trolley car starting from rest experiences a uniform acceleration. At the end of 20 seconds its speed is 15 miles per hour.
   (*a*) What is its acceleration?
   (*b*) How far has it traveled?

Group II

(Omit one question from this group.)

5. Given a gun, a stop watch, and a thermometer, how could the width of a lake be determined? Show how the calculations should be performed.
6. If two musical tones, one of 68 vibrations per second and the other of 70 vibrations per second, are sounded at the same time, describe and explain the effect produced. What name is given to this phenomenon?

Group III

(Omit one question from this group.)

7. Describe an experiment, preferably one which you have personally performed, by which the heat changes occurring during a change of state, such as from a liquid to a solid, may be shown. Explain the results obtained.
8. A steel projectile is moving with a speed of 700 meters per second at the instant that it strikes a target. Assuming that all of the energy of motion is transformed into heat in the projectile, calculate its rise of temperature. Take the specific heat of steel as 0.12 and the mechanical equivalent of heat as 41,800,000 ergs.
9. The air in an automobile tire has a pressure of 80 pounds per square inch at a temperature of 15°C. If, after the car has been driven, the temperature of the air in the tire has risen to 32° C., what is the air pressure in the tire?

(SEE NEXT PAGE)

Group IV

(Omit one question from this group.)

10. Show, by means of a diagram, the least height of a vertical plane mirror which would enable a man 6 ft. tall to see a full length image of himself.
    Why does a shallow pond, when viewed from one side, appear to be less deep than it really is?
11. If the illumination necessary for reading is 2 foot-candles, how far away from a reader may a 16 candle-power lamp be placed? (One foot-candle is defined as the intensity of illumination produced by a source of light of one candle-power at a distance of one foot from that source, the light falling perpendicularly.)
12. An object 6 in. long is placed 20 in. in front of a concave mirror whose radius of curvature is 2 ft.
    (*a*) Where, and at what distance from the mirror, is the image?
    (*b*) What is the length of the image?

Group V

(Omit one question from this group.)

13. Why are high potential currents employed for the long distance transmission of electrical energy? Explain the use of transformers as employed on transmission circuits.
14. Given three 110-volt incandescent lamps, each requiring 0.5 ampere. Find the voltage required, the resistance of the circuit and the current in the circuit.
    (*a*) when the lamps are connected in series;
    (*b*) when the lamps are connected in parallel.
15. An electric heater connected to a 110-volt circuit takes 600 watts. How many calories of heat does it develop in 10 minutes?

PHYSICS

Friday 2 p.m. Two hours

Answer ten questions as indicated below. No extra credit will be given for more than ten questions. Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Group I

(Omit one question from this group.)

1. State Archimedes' principle. Describe an experimental proof of this principle. Good eggs sink and bad eggs float in pure water, though the dimensions of the eggs do not change. Explain.
2. A child weighing 75 pounds sits in a swing. The swing is drawn aside and held in equilibrium by a horizontal force of 30 pounds. Find the tension in each of the two ropes of the swing.
3. An automobile tire contains an inner tube, initially empty, the capacity of which is 750 cubic inches. A pump, which takes in at each stroke 30 cubic inches of air at a pressure of 15 pounds per square inch, is employed to pump up the tire. Assuming no change in temperature, what is the air pressure in the tire after 135 strokes of the pump?
4. A rifle weighing 8.7 pounds discharges a bullet weighing 0.32 ounce with a velocity of 2,700 feet per second.
   (*a*) What is the kinetic energy of the bullet?
   (*b*) With what velocity does the gun recoil?

Group II

(Omit one question from this group.)

5. What are the nature and the direction of the motions of a small portion of a medium which is transmitting sound?
   A vibrating tuning fork held vertically near the ear is slowly rotated about its shank as an axis. State and explain the effects observed.
6. What is the length of a pipe, closed at one end, which at 0°C. will give the greatest reinforcement to the sound of a tuning fork making 250 vibrations per second?

Group III

(Omit one question from this group.)

7. Describe two experiments which indicate that heat is a form of energy. What causes the draught of a chimney?
8. A 30-foot steel rail, when subjected to a change in temperature from −14°C. in winter to 36°C. in summer, changes 0.0195 foot in length. Find the coefficient of linear expansion of steel.

(SEE NEXT PAGE)

9. A glass pitcher weighing 1,500 grams contains 1,800 grams of tea at 40°C. Ice is used to cool the tea to 10°C. If the specific heat of tea is 1 and that of glass is 0.18, find how many grams of ice are needed.

GROUP IV

(Omit one question from this group.)

10. Draw a diagram of a compound microscope showing the lenses used, their focal points, and the locations of the images formed; also state the character (real or virtual) of each image.

The critical angle for water is 48.5 degrees. Show by a diagram what is meant by this statement.

11. The image of a post 12 feet high and 20 feet from a camera is 5 inches long.

(*a*) How far from the lens is the image?

(*b*) What is the focal length of the lens?

12. What is the cause of the apparent color of opaque objects?

Explain why a mixture of yellow and blue pigments appears green.

Why is it difficult to match certain colors by lamp-light so that they will agree by daylight?

GROUP V

(Omit one question from this group.)

13. A man holding a compass under the trolley wire of an electric railway running north and south observes that the compass needle deflects toward the northwest. What can you infer from this with regard to the current in the trolley wire?

A single loop of wire lies in a horizontal plane and through it is dropped a bar magnet whose north pole is pointing downward. What is the direction of the current induced in the wire while the magnet is approaching the loop? What factors determine the magnitude of this current?

Describe an experiment by which an induced current may be produced by moving a wire forming a part of a closed circuit in the earth's magnetic field.

14. In a copper refinery a current of 1,000 amperes is employed in a plating bath to deposit the metal by electrolysis. How much copper is deposited in 24 hours?

(The electrochemical equivalent of copper is 0.000329 grams per coulomb.)

15. An electric bell of resistance 4.2 ohms is connected by a wire of 1.2 ohms resistance to three dry cells, each of resistance 0.2 ohm and electromotive force 1.4 volts.

What current flows through the bell—

(*a*) When the cells are connected in series?

(*b*) When the cells are connected in parallel?

Show by a diagram how the cells are connected in each case.

PHYSICS

Friday, June 21 2 p.m. Two hours

Answer ten questions as indicated below. No extra credit will be given for more than ten questions. Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Group I

(Omit one question from this group.)

1. (*a*) Explain the meaning of the terms acceleration, work, power, momentum, moment of a force.
   (*b*) A balance has unequal arms, the left-hand arm having a length 99 per cent of that of the right-hand arm. A dealer has the habit of putting in the left-hand pan the articles which he sells. Who gains, the dealer or the customer? Why?

2. The water passing through the turbine water wheels at the Niagara power plant has fallen 136 feet. The average horse-power of the turbines is 5,000 and their efficiency is 85 per cent. How many cubic feet of water does each turbine discharge per minute? (One cubic foot of water weighs 62.4 pounds.)

3. A painter's platform is 18 feet long and weighs 100 pounds. Its center of gravity is 8.5 feet from the right-hand end. The platform is hung in a horizontal position by two ropes, one attached one foot from one end, the other one foot from the other end. When a painter weighing 150 pounds stands at a point 7 feet from the left-hand end of the platform, what weight does each rope support?

4. An aeroplane one mile above the earth is moving horizontally with a velocity of 60 miles per hour. A bomb is dropped from it in an attempt to hit a station. When the bomb is released, how far should the aeroplane be from the point ahead in its path which is directly over the station?

Group II

(Omit one question from this group.)

5. Describe an experiment, preferably one which you have personally performed, by which the wave-length of a musical sound may be determined.

6. A man is standing two miles in front of a cliff. A gun, located between the man and the cliff, is fired. The man hears the report of the gun and, four seconds later, hears the echo of the report from the cliff. Taking the temperature of the air as 0° C., find the distance from the gun to the cliff.

(SEE NEXT PAGE)

Group III

(Omit one question from this group.)

7. Describe an experimental method of determining the coefficient of expansion of a gas under constant pressure.

8. A Centigrade mercury thermometer contains in its bulb and capillary tube up to the 0° mark 0.15 cubic centimeter of mercury. If the diameter of the capillary tube is 0.012 centimeter, what is the length of the tube from the 0° mark to the 100° mark? (The coefficient of apparent expansion of mercury in glass is 0.000156.)

9. How many kilograms of coal would be needed in a boiler having an efficiency of 65 per cent to convert 50 kilograms of water at 10° C. into steam at 100° C.? Assume that the heat value of the coal is 7,000 calories per gram.

Group IV

(Omit one question from this group.)

10. (*a*) Explain in terms of the wave theory of light the production of a spectrum by means of a prism.
    (*b*) Describe the appearance of the solar spectrum.

11. (*a*) Describe an experimental method of determining the index of refraction of glass.
    (*b*) The index of refraction of glass being 1.5, find the speed of light in it.

12. The works of a watch are held 1.5 inches from a jeweler's eye-lens which has a focal length of 1.75 inches. How many times are the works magnified?

Group V

(Omit one question from this group.)

13. Using diagrams describe an electric telephone transmitter and an electric telephone receiver and explain the action of each.

14. A total current of 24 amperes flows through two branches of a divided circuit having resistances of 7 and 5 ohms, respectively. Find
    (*a*) The strength of current which flows through each branch.
    (*b*) The electromotive force required to maintain the current.

15. An electric motor having an efficiency of 85 per cent develops 3 horse-power when connected to a 220-volt circuit. How much current flows through the motor? (One horse power = 746 watts.)

1919

PHYSICS

Friday, June 20 — 2 p.m. Two hours

Answer ten questions as indicated below. No extra credit will be given for more than ten questions. Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Group I

(Omit one question from this group.)

1. A receiver contains 500 cubic centimeters of air under a pressure of 75 centimeters of mercury. What will be the pressure of the air if its volume is reduced to 200 cubic centimeters, the temperature remaining unchanged?

2. (*a*) State Pascal's principle.

   (*b*) A submarine weighs 1800 tons when its submerging tanks are empty, and in that condition 10 per cent by volume of the submarine is above water. What weight of water must be let into the tanks just to submerge the boat?

   (*c*) If the specific gravity of sea-water is 1.03, what volume of water is required to submerge the boat?

3. (*a*) Explain the meaning of these terms: moment of force; acceleration; a unit of force.

   (*b*) Show how to find by a graphical method the resultant of two forces acting at an angle to each other.

4. A uniform plank 20 feet long, weighing 200 pounds, rests on a flat roof with 8 feet of its length projecting beyond the edge of the roof. If a keg of nails weighing 50 pounds rests over a point 1 ft. from the inner end, how far out on the plank beyond the edge of the roof may a man weighing 180 pounds go without tipping the plank?

Group II

(Omit one question from this group.)

5. (*a*) State the physical difference between a noise and a musical sound.

   (*b*) Describe briefly an experiment that demonstrates which characteristic of a musical sound determines its pitch.

   (*c*) If the expansion of an organ pipe is ignored, what change, if any, is produced in the sound of the pipe by a rise in temperature? Give reason for your answer.

6. Describe some common form of resonator and explain resonance as illustrated by its action.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

(Omit one question from this group.)

7. A steel tape 100 feet long and correct at 60° F. is used for measuring a base line on a day when the temperature is 85° F. The observed length is 330 feet. If the coefficient of linear expansion of the tape is 0.0000058 per degree Fahrenheit, what is the true length of the base line?

8. (*a*) Distinguish between temperature and quantity of heat.
   (*b*) State some evidence in verification of the statement that heat is a form of energy.
   (*c*) Explain what is meant by the mechanical equivalent of heat.

9. Two hundred grams of snow at 0° C. are contained in a cup the thermal capacity of which equals that of 12 grams of water. Steam at a temperature of 100° C. is turned into the snow, melting it and raising the temperature of the resulting water to 40° C. Assuming no loss or gain of heat, find how much steam is used.

Group IV

(Omit one question from this group.)

10. (*a*) Explain carefully all that will happen to a ray of sunlight when passed through a triangular glass prism.
    (*b*) Why does a green leaf appear nearly black when seen in a red light?

11. (*a*) Describe the construction and use of some form of photometer.
    (*b*) A 16-candle-power lamp and a standard candle are placed 5 feet apart. At what position between them should a screen be placed that its two sides may be equally illuminated?

12. (*a*) A camera has a lens whose focal length is 15 centimeters. How far from the lens is the photographic plate when there is focused on it the image of an object 300 centimeters away from the lens?
    (*b*) If the image is 10 centimeters in height, what is the height of the object?

Group V

(Omit one question from this group.)

13. (*a*) A bar magnet is broken into three pieces of equal length. Describe the magnetic condition of these pieces. Illustrate by diagram.
    (*b*) Describe a method for determining the sign of the electrification on a charged body.

14. A small arc lamp requires a current of 5 amperes and a difference of potential between its terminals of 45 volts. What resistance must be connected in series with it in order to use it on a 110-volt circuit?

15. A current of electricity passed through a coil of wire having a resistance of 10 ohms heated 1000 grams of water from 15° C. to 61.08° C. in 5 minutes. What was the strength of the current?

1920

PHYSICS

Friday, June 25 2 p.m. Two hours

Answer ten questions as indicated below. No extra credit will be given for more than ten questions.

Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Number and letter each answer to correspond with the question selected.

Group I

(*Omit one question from this group.*)

1. *a*) Distinguish between mass and weight.

   b) Could the fact that the weight of a body changes if it is taken from the equatorial to the polar region of the earth be shown by either a spring balance or a beam balance? Explain.

2. A body having a volume of 100 cubic centimeters and a density of 2.5 is fastened to a block of wood having a volume of 200 cubic centimeters and a density of 0.5.

   a) What will the combination weigh when immersed in water?

   b) What will the combination weigh when immersed in oil of density 0.9?

3. *a*) Represent by a diagram a system of pulleys consisting of a double fixed block and a single movable block.

   b) If the efficiency of the above system is 70 per cent, how great a weight can be lifted by a force of 30 pounds applied to the free end of the rope?

4. What horse power is required to run an automobile on a level road at the rate of 30 miles per hour if the forces of friction amount to 125 pounds?

Group II

(*Omit one question from this group.*)

5. *a*) How are sounds produced and how are they transmitted to the ear?

   b) How does the intensity of sound vary with change of distance from the source?

6. *a*) If the lowest tone which the ear can recognize has a frequency of 16 vibrations per second what is the length of the longest wave the ear perceives in air at a temperature of 0° C.?

   b) What effect, if any, does change in temperature produce in the velocity of sound in air?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

(*Omit one question from this group.*)

7. *a*) Define dew point.

b) What is meant by the relative humidity of the air?

c) How may the relative humidity of the air be experimentally determined?

8. If gas costing $1.00 per 1,000 cubic feet furnishes 600 B.T.U. of heat per cubic foot of gas burned, how much would it cost to raise from 62° F. to 212° F. one quart (2 pounds) of water by means of a burner and kettle having a combined efficiency of 50 per cent?

9. *a*) Describe in detail an experimental method for determining the specific heat of a substance.

b) Explain how a numerical result may be secured from the data obtained.

Group IV

(*Omit one question from this group.*)

10. In a darkened room a spectrum of sunlight is thrown on a screen. A bouquet of red, yellow, and blue flowers with green foliage is placed in the red end of the spectrum and gradually moved toward the violet end. State and explain what would be observed.

11. *a*) Describe the construction and explain the operation of the so-called "pin-hole" camera.

b) If such a camera is 8 inches long and the image of a building 50 feet high appears as an image 3 inches high on the plate how far away is the building?

12. *a*) Represent by a diagram the path of the rays of light through the lenses of an astronomical telescope.

b) A telescope has an objective whose focal length is 30 feet and an eye-piece whose focal length is 1 inch. What is the magnifying power of the telescope?

Group V

(*Omit one question from this group.*)

13. *a*) Given one battery, one bell, two push buttons, and a quantity of wire, represent by a simple diagram a scheme for wiring a house so that the bell may be rung from either the front door or the back door.

b) Why is it advantageous to use a high voltage for the transmission of electric energy over long distances?

c) Why are alternating currents used for long distance electrical transmission?

14. A 17-candle-power carbon filament lamp takes 0.6 ampere at 110 volts. A 260-candle-power gas filled tungsten filament lamp takes 1.85 amperes at 110 volts. Compare the efficiencies of the two lamps.

15. The poles of a storage cell having an electromotive force of 2 volts and an internal resistance of 0.1 ohm are connected by two wires in parallel whose resistances are 12 ohms and 4 ohms respectively.

a) What current flows in each wire?

b) What current flows through the cell?

COMPREHENSIVE PHYSICS

Comprehensive Examination

PHYSICS

Friday, June 23 9:00 a.m.–12:00 m.

A teacher's certificate covering the laboratory instruction must be presented as part of the examination, unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten questions. Show clearly the method by which you obtain your answers, and state the units used in each case.

1. *a*) What is meant by potential energy? by kinetic energy? Give examples.
   b) A body whose mass is 50 gm. is raised to a height of 300 cm. What is its potential energy?
   c) If it is allowed to fall freely, what will be its potential energy after it has fallen through a distance of 100 cm.? What is its kinetic energy at this point? What is the sum of these two energies?
   d) After it has fallen through the whole distance, 300 cm., what is its kinetic energy?
   e) What principle do the combined answers to (*b*), (*c*), and (*d*) illustrate?
2. Define coefficient of friction; mechanical advantage.
   A boat weighing 1,800 lbs. is to be drawn to a point above high water level along a beach which rises 3 ft. in 10 ft. Make a sketch of a six-rope block and tackle adapted to the foregoing purpose, and calculate the force required, assuming the coefficient of friction between the boat and the beach to be 0.4.
3. Given a U-tube and some water: (*a*) explain how you would determine the pressure of the illuminating gas in the pipes of a house; (*b*) explain how the result may be reduced to pounds per square inch. (One cubic foot of water weighs 62.4 lbs.)
4. A standard life-preserver made of cork, the specific gravity of which is 0.14, measures 40 in.$\times$12 in.$\times$2 in.; what extra weight would the life-preserver support when completely immersed in sea-water of specific gravity 1.03. State the principle involved in the solution of the problem. (1 cu. ft. of fresh water weighs 62.4 lbs.)
5. The vibration frequency of two equal strings 5 ft. long is 236 vibrations per sec. How many beats per sec. will be heard when one of the strings has been shortened 1 inch?
6. Describe fully a laboratory experiment for determining the rate of vibration of some body emitting a sound.
7. What is the source of the heat which melts the ice in a tightly closed refrigerator? If it requires 3 lbs. of ice to cool a gallon of milk (8.3 lbs.) contained in a glass jar weighing 4 lbs., from 75° F. to 40° F., what is the efficiency of the refrigerator? Assume specific heat of milk to be 1.0, specific heat of glass to be 0.12, and the latent heat of melting of ice to be 147 in the units here used.

(SEE NEXT PAGE)

8. A mass of 100 kgm. falls 10 meters. All of its energy is employed in stirring 1,000 gm. of water contained in a calorimeter which weighs 150 gm. (Specific heat, 0.1.) The temperature is observed to rise 2°.3 C. Calculate the mechanical equivalent of heat.

9. Define coefficient of expansion. Describe a laboratory experiment by which the coefficient of expansion of some substance is determined.

10. What two classes of images are formed by a concave mirror? Show by diagrams the position of an image of each kind, and explain the principles underlying the construction of the diagrams.

11. How does the intensity of illumination at a point 2 ft. distant from a 32 candle-power lamp compare with the intensity of illumination at a point 3 ft. distant from the same lamp? How far away from the above lamp should one's book be placed to secure an illumination upon its pages of 2 foot-candles? (One foot-candle is the illumination produced by a standard candle at a distance of one foot.)

12. Glass-bottomed boats are frequently used in the observation of the life in the ocean. Draw approximately the path of a ray of light, coming from a point some distance below the boat bottom and in the water, as it passes up through the thick glass bottom (index of refraction of glass, 1.5; of water, 1.33) (1) when the direction of the ray is perpendicular to the glass; (2) when the direction of the ray is oblique to the glass. Give reasons for your answers.

13. Describe briefly some form of galvanometer or ammeter, with diagrams if necessary, and explain its action as a measuring instrument.

A galvanometer or ammeter having a resistance of 10 ohms is to be connected so as to take only one-tenth of the total current in the main circuit. Explain how this may be done.

14. If an electric flat-iron takes 5.3 amperes at 110 volts, what is the resistance of the heating element? How many watts of electric power are required to operate the apparatus? How many calories of heat should it develop in 10 minutes? How much does it cost per hour to run the flat-iron at 10 cents per kilowatt-hour? (1 watt-second = 0.24 calories.)

15. Discuss the principle and the details of construction of a commercial transformer.

Why is it impracticable to transmit electrical power over great distances, such as from Niagara to New York City? What changes in the older methods of installation have led to considerable extensions in the practical working distances during the last decade?

A commercial transformer was placed on the outside of a building to change 220 volts to 110 volts for laboratory use. By mistake the line wires were connected to the secondary terminals. What voltage was obtained in the laboratory?

Comprehensive Examination

PHYSICS

Monday, September 18 2:00–5:00 p.m.

A teacher's certificate covering the laboratory instruction must be presented as part of the examination, unless a laboratory notebook is to be presented at a laboratory examination.

Answer ten questions. Show clearly the method by which you obtain your answers, and state the units used in each case.

1. *a*) Define kinetic energy; potential energy.

   b) A shell weighing 6 lbs. fired from an anti-aircraft gun aimed vertically upward has a muzzle velocity of 1,200 ft. per sec. If the shell bursts beside an aeroplane 3 sec. after leaving the gun, how high is the aeroplane?

2. A boy weighing 110 pounds sits in a hammock whose ropes make angles of 60° and 30° respectively with the horizontal. Find the tension in each rope.

3. *a*) Draw a diagram of a force pump. Explain the action of the pump, referring as much as possible to your diagram in giving your explanation.

   b) A 1.5 horse-power gasoline engine is used to drive a force pump which pumps water from a spring to a 60-gallon tank 70 ft. higher than the spring. If the tank is filled in 2 minutes, what is the efficiency of the pump? (A gallon of water weighs 8.4 lbs.)

4. A bubble has a volume of 5 c.c. and is at a depth of 1 meter below the surface of water, the barometer reading 70 cm. of mercury. If the barometric pressure changes to 73 cm., what will be the resulting volume of the bubble? (Specific gravity of mercury = 13.6.)

5. Explain the action of a megaphone. Give a physical explanation of the reason that sound can be transmitted to greater distances through a speaking-tube than in the open. Why does the presence of a large number of people in an auditorium improve its acoustic properties, that is, make it easier to understand the speaker?

6. *a*) The sound of a fire-alarm is heard 3 sec. after the bell is struck by the hammer. If the temperature of the air is at 68° F., how far away is the bell?

   b) If the *A* above middle *C*, tuned to 435 vibrations per second, is the standard pitch for the orchestra, what is the vibration frequency of middle *C* upon the same scale?

(SEE NEXT PAGE)

7. What determines the magnitude of (*a*) 1° C.? (*b*) 1° F.? In what respects would a gas thermometer be (*a*) superior and (*b*) disadvantageous as compared with a mercury, or liquid thermometer? Explain.

8. How many grams of steam will be produced if 1,000 gm. of lead of specific heat 0.032 at a temperature of 300° C. are dropped into 100 gm. of water at 80° C. contained in a calorimeter of specific heat 0.1 and weight 90 gm.?

9. Why does hot air rise? Why does frost appear on the inside of a window pane in one's living-room before it appears on the outside of the pane? Why are hot-air registers placed near the ceiling and cold-air registers placed near the floor in mechanically ventilated schoolrooms? What is the cause of the loud hammering heard in certain steam radiators in the early morning and how may the trouble be remedied? Why are furnace pipes placed near the inner walls of a room heated by hot air and why are steam radiators placed near the outside walls of a room heated by steam?

10. Describe a laboratory experiment that you performed in which you used some form of mirror, either plane or curved. Do this very completely, drawing diagrams whenever possible. State not only what you did but also what you found to be true as the results of your experiment.

11. A camera with a lens whose principal focal distance is 4 in. permits the lens to be drawn out to a maximum distance of 5 in. from the plate.
    a) What is the shortest distance from the lens at which a flat object may be placed in order to secure a properly focussed image?
    b) If the object is 8 in. high, what will be the height of its image?

12. Why does one's face appear so ghastly and one's lips so purple when seen by the light of a mercury-vapor arc lamp? Would the addition of a colored shade to the lamp improve the situation? Explain.

13. Describe an experiment that you performed in the laboratory in which a voltmeter or ammeter or some form of galvanometer was one of the pieces of apparatus used. Draw diagrams where helpful, and state, not only what you did, but also the object of the experiment.

14. *a*) A battery, whose e.m.f. when delivering no current is 2 volts and whose internal resistance is 6 ohms, sends a current of $\frac{1}{4}$ ampere through an external resistance connected across its terminals. Find the value of the external resistance.
    b) How many watts are supplied to the external resistance?

15. *a*) Explain clearly what is meant by an alternating current.
    b) What are the advantages and disadvantages of an alternating current as compared with a direct current?

Comprehensive Examination

PHYSICS

Friday, June 22 2–5 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination, unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and one of the remaining questions.

The number in parenthesis before each question indicates the number of credits assigned to it.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer, in each case, the number and letter used in the printed paper.

Group I

1. If a 10-gram body should start from rest down a frictionless plane and gain in six seconds a velocity of 120 cm. per second, what would be:

a) (2) the total distance covered?

b) (2) the distance covered during the first second?

c) (2) the distance covered during the last second?

d) (2) the acceleration?

e) (2) the kinetic energy at the end of six seconds?

2. *a*) (2) Define horse-power.

b) (6) An automobile running at the constant rate of 30 miles per hour exerts a force of 200 lbs. in the direction of motion. What is the power supplied to the wheels of the automobile?

c) (2) If the efficiency of the transmitting mechanism is 75 per cent, what horse-power is the engine developing?

3. *a*) (7) A uniform plank, AB, 12 ft. long and weighing 80 lbs., is used as a "diving-board." End A is fastened to the floor of a float. Four ft. from A the plank rests on the slightly raised edge C of the float, so that 8 ft. of the plank projects over the water. A boy weighing 100 lbs. stands on end B and a second boy of 60 lbs. weight, 1 ft. from him. Under these conditions, how strong must the fastenings be at A?

b) (3) What is the direction and magnitude of the force exerted at C? Make a diagram.

4. *a*) (7) A building is being moved on rollers on a level road by means of a capstan (a form of the wheel-and-axle machine). Two horses, each exerting an effective pull of 125 lbs., are attached to the capstan bar (wheel) at a distance of 7 ft. from the center of the drum (axle). This drum, on which the rope attached to the house is wound, is 6 in. in diameter. If the coefficient of friction of the building on the rollers is 0.3, what is the weight of the building? Neglect other friction.

b) (3) If the horses make 5 circuits per minute, what is the rate of working of the team?

(SEE NEXT PAGE)

5. *a*) (7) A hollow sphere of glass weighs 500 gm. in air and requires a force of 1,000 gm. to hold it under water. If the density of the glass is 2.5 gm. per cu. cm., what is the volume of the space inside?

b) (3) Is it harder to lift a stone in air than when it is under water? Why?

Group II

6. (10) An automobile tire contains 1,500 cu. in. of air at 12° C. and a pressure of 90 lbs. per sq. in. Driving the car causes the air in the tire to be heated to 33° C. What is the pressure, assuming the air in the tire to have now a volume of 1,530 cu. in.?

7. *a*) (4) Describe the processes by which heat passes from the steam in a steam radiator to the objects in the room.

b) (6) Steam at 100° C. is passed into a 55-kg. iron radiator. Calculate the weight of steam condensed in heating the radiator from 5° C. to 100° C. (Specific heat of iron = 0.11.)

8. *a*) (4) Describe a laboratory experiment to determine the latent heat of vaporization of water.

b) (4) What quantities must be determined and how would you use these in calculating the result?

c) (2) Mention two important sources of error which must be guarded against.

Group III

9. *a*) (5) Name and define three characteristics by which different sounds are distinguished from each other.

b) (5) Explain how each of these characteristics may be altered in the case of a vibrating string.

Group IV

10. *a*) (4) Show how the intensity of a source of light may be measured.

b) (1) What is the unit of intensity of light?

c) (5) If a light 6 ft. away is illuminating your book, how far away should a light 16 times as bright be placed to produce the same illumination?

11. At what distance from a double convex lens of focal length 12 in. must an object be placed to cause a real image:

a) (4) of twice the length of the object?

b) (3) of half the length of the object?

c) (3) of the same length as the object?

12. *a*) (3) What is a spectrum and how is it produced?

b) (2) What are the Fraunhofer lines in the solar spectrum?

c) (2) What do these lines indicate?

d) (3) Explain the appearance of each color in the American flag when placed in pure blue light; when placed in pure red light.

(SEE NEXT PAGE)

13. *a*) (2) Describe a leaf electroscope.
    b) (3) Describe how the electroscope may be charged by the method of induction.
    c) (3) Explain the various steps of the process.
    d) (2) Explain how the electroscope is used to tell that a body is positively charged.

14. A 40-watt incandescent lamp is connected to a 100-volt circuit:
    a) (3) What current passes through the lamp?
    b) (2) If three such lamps are connected in parallel in the above circuit, what current passes through each lamp?
    c) (2) If the three lamps are connected in series, what current passes through each lamp?
    d) (3) If the three lamps are connected in parallel and used 10 hours each day for 4 weeks, and the cost is 8 cents per kilowatt-hour, what will be the total cost?

15. *a*) (1) Whose name is associated with the discovery of induced currents?
    b) (2) What is Lenz's Law for the direction of induced currents?
    c) (2) Name two machines or pieces of apparatus that depend upon induction for their usefulness.
    d) (1) In what other way are currents of electricity commonly produced?
    e) (1) Which was discovered first?
    f) (1) Which is the more important today?
    g) (2) Give some reasons for your last answer.

Comprehensive Examination

PHYSICS

Monday, September 17 2–5 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination, unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and one of the remaining questions.

The number in parenthesis before each question indicates the number of credits assigned to it.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer, in each case, the number and letter used in the printed paper.

Table of Constants

Acceleration of gravity = 980 cm. per sec. per sec.

1 horse-power = 746 watts.

Group I

1. *a*) (5) A 100-lb. child in a swing is pushed 9 ft. away from the vertical, the distance from the top of the swing to the center of gravity of the child being 15 ft. What horizontal force is necessary to hold him in his new position?

   b) (5) What is the strain on each of the swing ropes?

2. *a*) (6) A uniform plank 20 ft. long weighing 50 lbs. rests on a support 6 ft. from one end. The plank is held in a horizontal position by a vertical rope attached to the other end of the plank. What is the force on the support and the tension in the rope?

   b) (4) How far from the support can a boy of 80 lbs. walk before the plank tips? Make a diagram.

3. A box weighing 200 lbs. is pushed up a plank 10 ft. long into a wagon 4 ft. high. Disregarding friction:

   a) (3) What force is necessary to keep the box from sliding down the plank?

   b) (2) What work is done in pushing the box from the ground into the wagon?

   If a force of 30 lbs. is required to overcome friction:

   c) (3) What is now the total work done?

   d) (2) What is the efficiency in this case?

4. *a*) (3) State the principle of the conservation of energy.

   b) (7) A 142-gm. baseball is dropped from the Washington monument, a distance of 160 m. If this ball is caught and is stopped within a distance of 80 cm., what is the average force it will exert upon the catcher's hand? Neglect the resistance of the air.

(SEE NEXT PAGE)

5. *a*) (2) Define density; specific gravity.

b) (8) When a meter stick is made to float upright in pure water, 18.5 cm. of the stick projects above the water and when similarly floated in a second liquid, 24 cm. of the stick projects above. What are the specific gravities of the second liquid and the meter stick?

Group II

6. *a*) (6) A 50-ft. steel tape is correct at 20° C. How long would it be at a temperature of −10° C.? (Coefficient of linear expansion of steel =0.000012.)

b) (4) Describe two instances where the change of size of a solid with change of temperature is of practical use; and two instances where the change of size is not desired but has to be allowed for.

7. *a*) (4) Why does a person feel more comfortable on a hot dry day than on a humid day of the same temperature?

b) (6) 100 gm. of a liquid whose specific heat is 0.6 and temperature 80° C. are mixed with 300 gm. of water at 15° C. What will be the temperature of the mixture? Assume the interchange of heat to be confined to the two liquids.

8. *a*) (3) What is the essential feature in the construction of a "fireless cooker"?

b) (2) Is the cooking done entirely without a source of heat?

c) (2) Explain wherein its use is economical of heat.

d) (3) What is meant by conduction of heat; by convection; by radiation?

Group III

9. *a*) (3) What do the terms "frequency" and "wave-length" mean, as used in the study of sound?

b) (4) If low C has a frequency of 128, what is the frequency and wave-length at 0° C. of the note one octave higher?

c) (3) State and explain the effect on the pitch of increasing the speed of a phonograph.

Group IV

10. *a*) (2) State the law of reflection of light, making use of a diagram.

b) (5) A plane or convex mirror is often placed on an automobile to allow the driver to see in it the reflection of what is in the rear. What are the advantages of the convex mirror; of the plane?

c) (3) Why is not a concave mirror, which may form a magnified image, better than either of the others for the purpose?

11. *a*) (4) Describe in detail a laboratory method of determining the index of refraction of glass or of water.

b) (4) What measurements must be made and how is the index computed from them?

c) (2) What is the velocity of light through water? (Index of refraction of water=1.33.)

(SEE NEXT PAGE)

12. ***a)*** (2) Wherein does blue light differ from red light?

b) (2) If an object colored a pure red (such as a red rose) is illuminated by pure blue light only, what is the effect on its appearance?

c) (2) Explain the cause of this effect.

d) (2) What are infra-red rays; ultra-violet rays?

e) (2) How may each be detected?

Group V

13. *a)* (3) Make a sketch of an electromagnet, showing clearly the direction of the current through the wire, and the resulting polarity of each end of the magnet.

b) (2) Mention two important uses of the electromagnet.

c) (2) What are its advantages over a permanent steel magnet?

d) (3) Suppose you were presented with two steel bars exactly alike except that one was magnetized. How could you decide which was the magnet?

14. *a)* (4) A certain incandescent lamp of constant resistance takes 50 watts from a 100-volt circuit. How much power will it take from a 200-volt circuit?

b) (4) How much power will two such lamps in series take from the 200-volt line?

c) (2) What is the current flowing in each of the above three cases?

15. *a)* (6) A $\frac{1}{4}$ horse-power motor, a 750-watt electric stove, and an electric flat-iron using 5 amperes are connected in parallel on a 110-volt circuit. What is the total current?

b) (4) What would be the cost of using this current for half an hour at 3 cents per kilowatt-hour?

Comprehensive Examination

PHYSICS

Friday, June 21 2–5 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and one of the remaining questions.

The number in parenthesis before each question indicates the number of credits assigned to it.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer, in each case, the number and letter used in the printed paper.

Group I

1. A wooden cube 5 cm. on an edge weighs 100 g.
   a) (3) What is the density of the cube?
   b) (3) What force would be required to hold the cube submerged in a liquid having a density of 1.5 g. per cu. cm.?
   c) (4) How much of its volume would protrude above the surface if the cube were floated in a liquid having a density of 1.2 g. per cu. cm.?
2. *a*) (3) Define work; mechanical advantage of a machine; efficiency of a machine.
   b) (7) Two men raise a weight by means of a jackscrew. They push with a force of 100 lbs. each, at opposite ends of a bar 5 ft. long that passes through a hole at the top of the screw. If the pitch of the screw is $\frac{1}{2}$ inch and the efficiency of the machine is 30 per cent, how great is the weight?
3. An engine operates a pump which raises water to a height of 50 ft. at the rate of 1,000 gal. per min. (One gallon of water weighs 8.4 lbs.)
   a) (3) How much work is done upon the water per second?
   b) (7) If the efficiency of the pump is 90 per cent, how many horse-power is the engine developing?
4. A constant force acting on a mass of 40 grams for 5 seconds changes its velocity from 60 cm. per second to 100 cm. per second. What is:
   a) (2) the acceleration?
   b) (2) the magnitude of the force?
   c) (2) the total distance covered in the five seconds?
   d) (2) the final momentum?
   e) (2) the kinetic energy at the end of the first two seconds?

(SEE NEXT PAGE)

5. *a*) (8) A tank having a volume of 12 cu. ft. contains air under a pressure of 30 lbs. per sq. in. On connecting the tank to an exhausted recepticle the air pressure is reduced to 10 lbs. per sq. in. Find the volume of the recepticle.

b) (2) Describe two phenomena that are caused by surface tension.

GROUP II

6. *a*) (2) Define coefficient of linear expansion.

b) (8) Describe an experimental method of measuring the coefficient of linear expansion of a solid, describing the apparatus used, the measurements made, and the way in which these measurements are used to compute the coefficient.

7. *a*) (6) A balloon is filled on a cool night with 20,000 cu. ft. of gas at a temperature of 7° C. under a pressure of 15 lbs. per sq. in. In the sunshine of the day the gas becomes warmed. At what temperature will the pressure reach 16 lbs. per sq. in.? Assume that the gas bag does not stretch and that no gas escapes.

b) (2) Express 9° C. on the Fahrenheit scale.

c) (2) Compare the advantages of mercury and of air as thermometric substances.

8. *a*) (2) Name and define a unit quantity of heat.

b) (8) A copper calorimeter of mass 210 g. contains 85 g. of water and 100 g. of lead shot at 15° C. How much boiling water must be added to raise the temperature of the calorimeter and contents to 25° C.? (Sp. ht. of copper $=0.095$; of lead $=0.032$.)

GROUP III

9. *a*) (2) What conditions are necessary for the formation of an echo?

b) (2) What is the physical difference between a noise and a musical sound?

c) (2) Why is thunder usually heard some time after a lightning flash is seen?

d) (2) Upon what does the loudness of sound depend?

e) (2) Upon what does the pitch of a sound depend?

GROUP IV

10. *a*) (3) A more sharply defined shadow is cast by an opaque body when the source of light is an arc lamp than when it is a gas jet. Explain by the aid of diagrams.

b) (3) What should be the brightness of a single light in the ceiling 10 ft. from a book to give the same illumination as two candles placed one foot from the book?

c) (4) Explain what is meant by saying that the index of refraction of water is $\frac{4}{3}$. Make a careful, fully labeled diagram showing the passage of a ray of light obliquely from air into water.

(SEE NEXT PAGE)

11. *a*) (2) Define principal focus; conjugate foci.

A moving-picture machine is to be designed to project the picture on the film upon a screen 60 ft. from the film. If the image on the screen is to be 119 times the linear dimensions of the picture on the film:

b) (2) How far from the film must the projection lens be placed?

c) (4) What must be the focal length of the lens?

d) (2) How many times as intense will be the light passing through the film as that falling on the screen?

12. *a*) (4) Make a diagram to show the dispersion of a narrow beam of sunlight by a triangular glass prism.

b) (4) What is the explanation of refraction? of dispersion?

c) (2) Explain carefully why the same blue cloth may seem to be of a different color when viewed by gaslight and by sunlight.

Group V

13. *a*) (2) What type of cell is best adapted to the ringing of electric bells? Why?

b) (2) What is meant by the term local action as applied to voltaic cells?

c) (2) How may local action be reduced?

d) (2) What is meant by polarization of cells?

e) (2) How may polarization be reduced?

14. Two resistance coils of 10 and 30 ohms joined in parallel are connected in series with a key, an ammeter of negligible resistance, and a battery whose electromotive force is 21 volts and whose internal resistance is 3 ohms. A voltmeter of high resistance is connected in parallel with the battery.

a) (2) Draw a diagram of the connections.

b) (2) What will be the ammeter and voltmeter readings when the key is open?

c) (6) What will the readings be when the key is closed?

15. (10) Describe the construction and operation of two of the following: electric bell; telegraph key and sounder; telephone receiver. Illustrate by carefully drawn diagrams.

Comprehensive Examination

PHYSICS

Monday, September 16 2–5 p.m.

A teacher's certificate covering the laboratory instruction must be presented as a part of the examination unless the laboratory notebook is to be presented at a laboratory examination.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and one of the remaining questions.

The number in parenthesis before each question indicates the number of credits assigned to it.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer, in each case, the number and letter used in the printed paper.

Group I

1. A hollow box, 10×20×40 cm. on outside measurements, weighs 1,000 g. when empty. How many cu. cm. of stone of specific gravity 2.5 must be put into the box:
   a) (4) to sink it in water?
   b) (4) to cause it to float with $\frac{1}{10}$ of its volume above water?
   c) (2) A vessel is moving at the rate of 8 miles per hour. A boy drops a ball from the mast to the deck. The ball takes 2 seconds to fall. At what point will it strike the deck?

2. *a*) (3) How heavy a car can be drawn at a uniform rate along a horizontal track by a horse pulling parallel to the track with a force of 100 lbs. if the coefficient of friction between the car and the track is 0.08?
   b) (5) If the car moves at the rate of 4 miles per hour, at what rate does the horse work?
   c) (2) Why is the outer rail on a curved railway track placed higher than the inner rail?

3. A uniform horizontal bar 8 ft. long and weighing 9 lbs. is hinged at one end and carries a weight of 6 lbs. at the other end. The bar is supported by a vertical rope attached 3 ft. from the hinge. Draw a diagram.
   a) (4) What is the tension in the rope?
   b) (1) What is the direction of the force acting on the bar at the hinge?
   c) (3) What is the magnitude of the force acting on the bar at the hinge?
   d) (2) What is the mechanical advantage of the rope in raising the 6-lb. weight?

4. A 200-gram stone thrown along the surface of a horizontal sheet of ice has its speed reduced from 12 m. per sec. to 4 m. per sec. in 10 sec.
   a) (2) What is the acceleration (supposed to be uniform)?
   b) (2) What is the retarding force?
   c) (4) How much kinetic energy does the stone lose in these 10 sec.?
   d) (2) How much work is done against friction in that time?

(SEE NEXT PAGE)

5. *a*) (2) Draw a diagram showing the essential parts of a suction pump.

b) (4) Explain the action of the pump, referring to the diagram.

c) (2) What is the approximate height to which water can be raised by suction?

d) (2) What imposes a limit to the height to which water can be raised by suction?

GROUP II

6. *a*) (2) Describe two instances in which allowance has to be made for the change of size of bodies with change of temperature.

b) (2) Give an example of a practical use made of the fact that different solids do not all expand at the same rate.

c) (2) What use is made of the fact that platinum and glass have practically the same rate of expansion?

d) (4) An iron steampipe is 400 cm. long. Through how many degrees Centigrade must it be heated to increase its length 0.4 cm.? (Coefficient of linear expansion of iron = 0.000011 per degree C.)

7. *a*) (2) Explain clearly the distinction between quantity of heat and temperature.

b) (3) State a method of measuring temperature and state the facts on which it is based.

c) (3) State a method of measuring quantities of heat and state the principle involved.

d) (2) The normal temperature of the human body is $98\frac{2}{5}°$ F. Express this temperature on the Centigrade scale.

8. *a*) (3) What transformations of energy take place in generating electricity from coal by a steam engine?

b) (2) State two ways in which energy is "lost" during these transformations, and tell how such losses may be reduced.

c) (5) The heat value of a certain kind of coal is 8,000 calories per gram. How many grams of coal must be burned under a boiler of 60 per cent efficiency to heat 100,000 g. of water from 15° C. to the boiling-point and to change it to steam under normal pressure?

GROUP III

9. *a*) (2) What is the cause of beats in sound?

b) (2) How is it possible by means of beats to tune in unison two strings that differ slightly in pitch?

c) (1) What is the value of the sounding board on a musical instrument?

d) (1) What is a fundamental tone?

e) (1) What is a node?

f) (3) What is the relative loudness of the sound of the discharge of a gun as heard by A a mile from the gun and as heard by B a quarter of a mile from the gun?

(SEE NEXT PAGE)

GROUP IV

10. *a*) (2) State the modern theory of light.
    b) (2) How is the spectroscope used to help us in determining what chemical elements are present in a body?
    c) (2) What is the physical difference between blue light and red light?
    d) (4) A candle and an electric light 64 times as bright as the candle are 9 ft. apart in a (Bunsen) photometer. Where between them is the photometer screen when its opposite sides are equally illuminated?

11. *a*) (4) A lens is used to produce a picture 8 ft. high of a three-inch object. What focal length does the lens have if the screen on which the picture is formed is 24 ft. from the lens?
    b) (1) What kind of an image is formed in this case?
    c) (1) Is the image erect or inverted?
    d) (4) Make good-sized sketches of the essential optical parts of the eye and of the photographic camera. Show their optical similarity by indicating the corresponding parts and stating the function of each part.

12. *a*) (2) Define the term complementary colors.
    b) (3) Describe an experiment which may be performed to demonstrate such colors.
    c) (3) When pulverized blue and yellow crayons are mixed the resulting color is green. Explain.
    d) (2) Give the names of two men who have contributed to our knowledge of light. What were their contributions?

GROUP V

13. (10) State the function of each of the following electrical devices: fuse, storage battery, transformer, dynamo, motor, rheostat, Wheatstone bridge, induction coil, electroscope, galvanometer.

14. A 2-ohm coil and a 3-ohm coil joined in parallel are connected in series with a 5.5-ohm coil and a battery having an electromotive force of 15 volts and an internal resistance of 0.8 ohm.
    a) (3) What is the current in amperes flowing through the 5.5-ohm coil?
    b) (3) What fraction of this current flows through the 2-ohm coil?
    c) (2) At what rate in watts does the battery generate electrical energy?
    d) (2) How much power is being absorbed by the 3-ohm coil?

15. *a*) (3) How long would it take a current of 3 amperes to deposit 16.5 g. of copper by electrolysis? (Electrochemical equivalent of copper = 0.00033 g. per coulomb [ampere-sec.].)
    b) (4) To what phenomena do the terms "electrostatic induction" and "electromagnetic induction" refer? Describe an example of each.
    c) (3) A compass needle is placed above a wire running north and south. What may be inferred if the needle points north? northwest? northeast? if it vibrates?

1919

Comprehensive Examination

PHYSICS

Friday, June 20 2–5 p.m.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and any one of the remaining questions.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer in each case the number and letter used in the printed paper.

Group I

1. A submarine weighs 1800 tons when its submerging tanks are empty, and in that condition 10 per cent by volume of the submarine is above water.
   a) What weight of water must be let into the tanks just to submerge the boat?
   b) If the specific gravity of sea-water is 1.03, what volume of water is required to submerge the boat?
   c) What is the total force, due to water alone, against the hatch, 3 by 4 ft. in size, at a depth of 100 ft. in the ocean?

2. A uniform pole, AB, 10 ft. long and weighing 16 lbs., has a 10-lb. weight attached 4 ft. from the end A. The pole is carried by two men, one at the end B and the other 2 ft. from the end A.
   a) How much does each man carry when the pole is held in a horizontal position?
   b) What difference would it make if the end B were more elevated than the end A?

3. A bicycle tire contains 120 cu. in. of air at a pressure of 20 lbs. per square inch. How many strokes must be made on a pump whose cylinder has a volume of 5 cu. in. to increase the pressure in the tire to 30 lbs. per square inch? Consider the atmosphere as having a pressure of 15 lbs. per square inch and the volume of the tire and the temperature of the contained air to remain constant.

4. *a*) How long must a force of 2 lbs. act upon a mass of 10 lbs. to give it a velocity of 20 ft. per second?
   b) How much work will the force do in the time involved?

5. What is the force of the backward thrust of the propeller of an airplane driven by an engine developing 150 horse-power, when the airplane is traveling 120 miles per hour?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group II

6. *a*) Explain why pans of water in a greenhouse may prevent the freezing of plants.
   b) Discuss the effect of sprinkling the streets on a hot day with water having the same temperature as the air.
   c) Why are very hot days more unpleasant in moist than in dry climates?

7. *a*) Draw a diagram and explain the use of apparatus such as might be used in a laboratory for obtaining distilled water.
   b) In an apparatus for obtaining distilled water 800 grams of water are contained in a copper vessel weighing 300 grams. Both are at a temperature of 20° C. How many calories of heat will be used in heating the containing vessel and in distilling the water? (The specific heat of copper = 0.093.)

8. *a*) Explain what is meant by the mechanical equivalent of heat.
   b) In an apparatus for determining the mechanical equivalent of heat the work done in producing the heat was equivalent to the work done by a 200-gram weight falling a distance of 78,570 centimeters. If this heat raised the temperature of 28 grams of water, and of a brass receptacle weighing 190 grams which held the water, from 17° C. to 25° C., calculate the value of the mechanical equivalent of heat. (The specific heat of brass = 0.095.)

Group III

9. *a*) What characteristic of a note sounded by a violin distinguishes it from the same note sounded by a cornet?
   b) What is the vibration rate of an organ pipe which sends out sound waves 4.4 ft. long when the temperature is 20° C.?

Group IV

10. It is desired to project a real magnified image on a screen. Would it be possible to do this by means of:
   a) A plane mirror?
   b) A concave mirror?
   c) A convex mirror?
   Give reasons for your answers.

11. Given two converging lenses, one of 1-inch focus, the other of 8-inch focus. With the aid of diagrams indicating the manner in which the images are formed show:
   a) How the lenses should be used for a microscope.
   b) How the lenses should be used for a telescope.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

12. *a*) In making a photographic print by an electric light how will the illumination at a distance of 5 ft. compare with that from the same light at a distance of 15 ft.?

b) If an exposure of 10 seconds is correct at a distance of 5 ft. what should be the time of exposure at a distance of 15 ft.?

c) What is the physical difference between "red light" and "blue light"?

GROUP V

13. Describe in detail a method for determining the resistance of a piece of wire, representing the scheme of connections by a diagram.

14. In an apartment supplied with direct current at 110 volts there are two 40-watt lamps and a heating unit connected in parallel. In one week the lamps are burned 20 hours each and the heater is used 25 hours. The total use of energy is 7,100 watt hours.

a) How many watts are used by the heating unit?

b) How much current passes through the heating unit?

c) What is the resistance of the heating unit?

d) What current flows when both lamps and the heating unit are in use?

15. A direct-current dynamo furnishes a current of 50 amperes at 500 volts to a line having a resistance of 2 ohms.

a) How much power is generated by the dynamo?

b) How much power is delivered at the other end of the line?

1919

PHYSICS

Monday, September 15 2–5 p.m.

Answer ten numbered questions, distributed as follows: three from Group I, two from Group II, two from Group IV, two from Group V, and any one of the remaining questions.

Show clearly the method by which you obtained your answers to problems and state the units used in each case.

Attach to the answer, in each case, the number and letter used in the printed paper.

Group I

1. A stone of specific gravity 2.5, weighing 300 lbs. in air, rests on the bottom of a pond. What work will be done in raising the stone 10 ft. through the water?

2. A tapering telephone pole 24 ft. long is supported at each end in a horizontal position. The pressure on one support is 200 lbs., and on the other support 120 lbs.

   a) Locate the center of gravity of the pole.

   b) If it were supported at its center of length only, what would be the least force that might be applied to the pole that would keep the pole horizontal?

3. An automobile accelerates from rest to 45 miles an hour in 15 seconds.

   a) If this acceleration is uniform find its value in feet per second per second.

   b) What distance did the car go in the first 15 seconds?

4. What horse-power must be used to pull a body weighing 5 tons along a horizontal surface at the rate of 6 miles per hour, the coefficient of friction being 0.2?

5. Water is pumped into the bottom of an air-tight tank having a capacity of 1000 gals., compressing the air above it from a pressure of 15 lbs. per square inch to a pressure of 50 lbs. per square inch.

   a) How much water is pumped into the tank?

   b) If 200 gals. of water are now drawn off, what will be the air pressure in the tank?

Group II

6. *a*) Explain under what conditions frost will form on the inside surface of a window of a house and not on the outside surface.

   b) Explain the cooling of a liquid by evaporation.

   c) The volume of a mass of gas is 200 cu. cm. at 27° C. At what temperature will its volume be 250 cu. cm., if the pressure is maintained constant?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

7. A piece of glass (specific heat=0.19) weighing 3 kg. and at a temperature of −30° C. is placed in water at 0° C. Neglecting the heat effects upon the containing vessel find how much water will be converted into ice at 0° C.

8. Two kilograms of shot having specific heat of 0.031 are dropped 70 meters. The temperature of the shot is found to have risen 5.3° C. On the supposition that all the heat generated was retained by the shot, calculate the mechanical equivalent of heat.

Group III

9. On a day when the thermometer stood at 15° C. a projectile moving forward with an average velocity of 1700 ft. per sec. was heard by the gunner to strike its target 5 sec. after it left the gun. What was the distance from the gun to the target?

Group IV

10. Describe with the aid of a diagram a method for determining the position and size of the image of an object produced by a plane mirror.

11. *a*) What kind of a mirror will produce an erect image of an object one-half of its natural size when the object is 10 in. from the mirror?

    b) What is the radius of curvature of the mirror?

12. A candle is 8 in. from a lens. Its real image is 40 in. from the lens. Show from calculation and diagram the relative positions of lens image, and object and the relative sizes of the image and the object.

Group V

13. A single closed loop of wire lies in a horizontal plane, and through it is dropped a bar magnet whose north pole is pointing downward.

    a) Show by a diagram the direction of the current induced in the wire while the magnet is approaching the loop? State the law illustrated by this experiment.

    b) What factors determine the magnitude of this current?

14. A circuit consists of the following four parts joined in series: an ammeter of negligible resistance; a cell with an internal resistance of 0.8 ohms; a pair of wires, of 4 ohms and 6 ohms resistance respectively, joined in parallel; a 1-ohm coil. The connecting wires have a resistance of 0.2 ohm. Make a labeled diagram of the circuit.

    a) If the electromotive force of the cell is 1.4 volts, what is the reading of the ammeter?

    b) How much current flows through each of the two wires which are joined in parallel?

15. An incandescent lamp has a resistance of 275 ohms when connected with a 110-volt circuit.

    a) If the lamp takes 1.25 watts per candle power, what is its candle power?

    b) How much heat is developed in the lamp per minute?

1920

Comprehensive Examination

PHYSICS

Friday, June 25 2–5 p.m.

Answer ten questions as indicated below. No extra credit will be given for more than ten questions.

Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Number and letter each answer to correspond with the question selected.

Group I

(Omit one question from this group)

1. *a*) Explain the principle of the mercury barometer.
   b) What is the pressure in the mercury halfway up the barometer column?
   c) What effect does the diameter of the barometer tube have upon the height of the mercury column?

2. *a*) State Archimedes' principle.
   b) What application, if any, does this principle have in aeronautics?
   c) Since hydrogen is lighter than air, would pumping more and more hydrogen into a balloon increase its lifting power? Explain fully.

3. A truck weighing 4 tons changes its speed at a uniform rate from 10 miles per hour to 20 miles per hour in 2 minutes.
   a) What force is required to produce this change in speed?
   b) What distance does the truck go in the 2 minutes?

4. A cord 10 feet long has its ends fastened 8 feet apart on a ceiling and supports a weight of 20 pounds from its middle point. Find the tension in the cord.

Group II

(Omit one question from this group)

5. *a*) When musical instruments are not in exact unison one hears a throbbing called "beats." Explain.
   b) What is meant by resonance?

6. *a*) Describe a method for determining the velocity of sound in air.
   b) An open organ pipe is 3.5 feet long. What is the frequency of its fundamental tone?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

(Omit one question from this group)

7. *a*) Describe, by the aid of a diagram, the construction of a reciprocating steam engine and explain its operation.

   b) In what respects does the steam escaping from the cylinder of the engine differ from that entering it?

8. Three pounds of water at a temperature of 50° F. are contained in an aluminium kettle (specific heat = 0.22) weighing 2 pounds. If one cubic foot of gas when burned supplies 600 B.T.U. how many cubic feet of gas are needed to turn one-half the water in the kettle into steam, assuming no loss of heat? Consider the atmospheric pressure to be normal. The latent heat of vaporization of water = 972 B.T.U. per pound.

9. One thousand grams of liquid ammonia at 0° C. enters the pipes of an ice-making machine and leaves them as gas at 0° C. How much water at 10° C. will it change to ice at 0° C.? The heat of vaporization of ammonia is 450 calories per gram.

Group IV

(Omit one question from this group)

10. Explain the meaning of the following terms used in connection with light: refraction, index of refraction, critical angle, reflection, dispersion.

11. A tree 55 feet high stands on the edge of a pond. From the opposite bank a man whose eyes are 5.5 feet above the level of the pond, and who is standing 18 feet from the edge of the pond, sees the reflected image of the tree with the top appearing to just touch the edge of the pond nearest to him. How wide is the pond?

12. An image, 10 feet by 12 feet in size, of a lantern slide, 2.5 inches by 3 inches in size, is thrown upon a screen 40 feet from the lens of the lantern.

   a) What is the focal length of the lens?

   b) If a larger image were wanted, should a lens of greater or of less focal length be used? State reason for your answer.

Group V

(Omit one question from this group)

13. *a*) What are the essential parts of an alternating current generator?

   b) Describe its operation.

   c) Does it create electrical energy? Give reason for your answer.

(THIS EXAMINATION IS CONTINUED ON PAGE 3)

14. Electric power is supplied to a kitchen range from 110-volt mains.
    a) If the range takes a current of 9 amperes, what is the resistance of the heating coil?
    b) If power costs 3 cents per kilowatt-hour, how much does it cost per hour to run the range?
    c) If all the energy supplied were used in heating water, how long would it take to heat 4 kilograms of water from 20° C. to 100° C.?

15. In a certain experiment the current from two dry cells in series divides and one part goes through a wire 100 centimeters long having a resistance of 2.5 ohms, while the other part goes through two coils in series with each other, one of 4 ohms resistance and the other of 6 ohms resistance.
    a) Represent the scheme of connections by a diagram.
    b) If each of the dry cells has an electromotive force of 1.4 volts and an internal resistance of 0.2 ohm, find the current passing through the 100-centimeter wire and the current passing through the 6-ohm coil.

1920

PHYSICS

Monday, September 20 2–5 p.m.

Answer ten questions as indicated below. No extra credit will be given for more than ten questions. Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Number and letter each answer to correspond with the question selected.

Group I

(*Omit one question from this group.*)

1. Describe the construction and explain the operation of the piston air pump:
   a) As employed for exhausting a receiver.
   b) As employed for compressing air.
2. The density of a piece of metal is 165 pounds per cubic foot.
   a) What is its specific gravity?
   b) What will a cubic centimeter of the metal weigh?
   c) How much will a cubic foot of the metal weigh when immersed in alcohol of specific gravity 0.8?
3. A hill rises 50 feet in its length of 2,000 feet. What horse-power is needed to draw a load of 5 tons at a uniform rate up the hill in 10 minutes if 20 per cent of the total work is done against friction?
4. *a*) A boy weighing 50 pounds is seated in a swing supported by two parallel ropes 13 feet long. How great a horizontal force will be required to hold him 5 feet to one side of the vertical position?
   b) What will be the tension then on each of the swing ropes?

Group II

(*Omit one question from this group.*)

5. Given a tuning-fork making 256 vibrations per second, how could you determine the velocity of sound by means of a resonating column of air?
6. *a*) How would the intensity of the sound of a bell heard by a man 1,000 feet away compare with the intensity of the sound heard by a man 2,500 feet away?
   b) If the tone of a man's voice has a frequency of 160, how long are the waves which are produced when he speaks in air at a temperature of 20° C.?

Group III

(*Omit one question from this group.*)

7. *a*) How does change of pressure affect the melting-point of ice or the freezing-point of water?
   b) How do the boiling-point and the freezing-point of salt water differ from those of pure water?
   c) How is the boiling-point of water affected by change of pressure?

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

8. A stove burning 150 grams of alcohol changes 4,500 grams of ice at 0° C. into water at 100° C. in 10 minutes. If the heat of combustion of alcohol is 7,400 calories per gram, what per cent of the heat produced is utilized?

9. *a*) What is meant by the absolute zero?
   b) From what point on the Centigrade scale are absolute temperatures measured?
   c) Two liters of air at atmospheric pressure and at 20° C. are heated until the volume and the pressure are both doubled. What is the temperature of the air?

Group IV

(*Omit one question from this group.*)

10. *a*) Distinguish carefully between refraction and dispersion.
    b) Why does a very thin layer of oil on water produce colors?
    c) What is total reflection?
    d) What is the critical angle?

11. Two shadows of an upright rod are cast side by side upon a screen, one by a standard candle and the other by a Welsbach gas burner. The standard candle is placed 2 feet from the screen. When the gas burner is moved until the two shadows are of the same density the burner is found to be 14 feet from the screen. What is the candle-power of the gas burner?

12. An incandescent lamp is placed 8 feet from a concave spherical mirror. If the image of the lamp is seen 1 foot in front of the mirror:
    a) What is the radius of curvature of the mirror?
    b) Is the image real or virtual?
    c) What are the relative sizes of the image and of the object?

Group V

(*Omit one question from this group.*)

13. *a*) Explain how an electroscope might be given either a positive or a negative charge by means of a positively charged body.
    b) Describe the construction and explain the operation of a condenser as illustrated by a Leyden jar.

14. *a*) A motor takes 8 amperes from a 500-volt circuit and delivers 5 horse-power. What is its efficiency?
    b) An ammeter in circuit with a small motor indicates 7 amperes when the motor is starting and 3.5 amperes when the motor is running at full speed. Explain.

15. A resistance coil marked 10 ohms is found by careful measurement to have a resistance of 10.8 ohms. How much wire whose resistance is 1.35 ohms per foot would be needed and how should it be connected with the coil in order that the resistance of the combination should be 10 ohms?

ZOÖLOGY

ZOÖLOGY

Friday 9:00 a.m. Two hours

A teacher's certificate covering the laboratory instruction must be presented as part of the examination.

Answer three questions from each group, and one additional question which may be selected from any group.

Group I

1. What structures in addition to a backbone are characteristic of vertebrates as contrasted with invertebrates?
2. Describe as completely as you can the anatomy, external and internal, of an annelid worm.
3. Describe the component parts of the blood of any animal, stating the function of each part.
4. Compare the respiratory organs of an insect, fish, and mammal. Explain the function of these organs.
5. Compare the skeleton of the leg and pelvic girdle of a man and of a frog.

Group II

6. Name an animal belonging to each of the following groups: coelenterata, annelida, crustacea, insecta, amphibia. What is the food of each of the animals you have named, and how is the food secured?
7. Select some Protozoan and describe: (*a*) its habitat; (*b*) its manner of food-getting; (*c*) its method of locomotion; (*d*) its method of reproduction.
8. Distinguish between the inhaling process in the frog and in man.
9. Describe the circulation of blood in a fish.
10. Describe the life-cycle of a frog and show how this animal is adapted to its environment in each stage of its development.

Group III

11. Name three injurious insects with the methods for the control of each.
12. What is the actual evidence that certain birds are beneficial to the farmer?
13. Name some wild animal that it would be worth while to try to domesticate, and give the reasons why.
14. What can be done to prevent malaria and yellow fever? Explain the reasons for your answer.
15. What is being done to increase our supply of food fishes?

ZOÖLOGY

Friday 2 p.m. Two hours

Answer three questions from each group, and one additional question which may be selected from any group.

Group I

1. Describe the structure of any protozoan you have studied, stating the function of each of its parts.
2. (*a*) Name and locate the appendages of the crayfish or of the lobster and state the functions of *five* different appendages named, or (*b*) Draw and name the mouth parts of some insect.
3. Describe the structure of the eye of some vertebrate and explain how the phenomenon of sight occurs.
4. Compare the nervous system of man with that of some invertebrate.
5. Compare the organs of excretion of three of the following: (*a*) an annelid, (*b*) an insect, (*c*) a crustacean or mollusk, (*d*) a fish or frog, (*e*) a bird or mammal.

Group II

6. Describe the complete course of a molecule of oxygen from the external air to the brain of an animal.
7. Give the characteristics that assign:
   (*a*) a beetle to its order;
   (*b*) a crayfish to its class;
   (*c*) an ameba to its branch or phylum;
   (*d*) a spider to its class;
   (*e*) a fly to its branch or phylum.
8. Give the life history of an insect having complete metamorphosis.
9. Explain the process of fertilization and the first divisions of the egg in some animal.
10. Explain the process of digestion of food in a mixed diet.

Group III

11. Describe the economic importance of five of the following animals: mosquito, house fly, trichina, starfish, clam, earthworm, toad, cuckoo, weasel.
12. Mention two external and two internal animal parasites of man or of domestic animals, giving for each the source from which infestation occurs.
13. What steps are taken by the national, or your state government to protect and to increase the numbers of valuable fishes or birds?
14. (*a*) In what ways are the codling moth and the English sparrow pests?
    (*b*) How may each be controlled?
15. (*a*) Give an outline of the life history of the malarial parasite.
    (*b*) State the agency by means of which infection occurs.
    (*c*) What are the methods of preventing malaria?

ZOÖLOGY

Friday, June 21 2 p.m. Two hours

Answer three questions from each group, and one additional question which may be selected from any group.

Group I

1. Describe fully the organs used by some insect in the process of breathing, and explain how these organs work.
2. Compare the general plan of the body structure of a coelenterate, an annelid, and a vertebrate.
3. Describe the sense organs of (*a*) an annelid, (*b*) an insect, (*c*) a crayfish *or* a mollusk, and (*d*) a fish *or* a frog, explaining the function of each.
4. Explain with diagrams the cell structure of (*a*) bone, (*b*) muscle, and (*c*) blood.
5. Compare the characteristic method of locomotion and the organs concerned in a fish, a frog, and a bird.

Group II

6. Describe the processes or reproduction and regeneration in Hydra.
7. Define each of the following terms and give an example of its use: (*a*) parasitism, (*b*) protective resemblance, (*c*) segmentation, (*d*) specialization, (*e*) struggle for existence.
8. Illustrate by concrete example what is meant by Mendel's Law of Heredity.
9. (*a*) Describe the life cycle of the mosquito.
   (*b*) What is the food of this insect?
   (*c*) What are its enemies?
   (*d*) What is its importance to man?
10. Describe in detail the various steps that take place from the time that the egg cells and sperm cells of a fish, or a frog, are deposited in the water until the gastrula stage is formed.

Group III

11. Give the life-history of a protozoan that lives in human blood.
12. What is the principal food of five of the following birds and how does each secure it: woodpecker, owl, robin, quail, humming-bird, English sparrow, chickadee?
13. If you were a fruit farmer, what animals would you try to secure on your farm and what animals would you try to exterminate? Give reasons.
14. Name three animal parasites that cause human disease. Show in each instance the method of infection and the means of prevention.
15. Describe methods by which the supply of available animal food for man may be increased in the United States.

1919

ZOÖLOGY

Friday, June 20 2 p.m. Two hours

Answer three questions from each group, and one additional question which may be selected from any group. Number each answer to correspond with the question selected.

Group I

1. Make a labeled drawing of the alimentary canal of a bird or of a fish.

2. Describe, or illustrate by a carefully labeled diagram, the mouth parts of an insect, stating the function of each organ.

3. Explain the structure of the human stomach and describe the work which this organ performs, stating the effect on foodstuffs of each of its secretions

4. How are homologous structures adapted to diverse uses in the human hand and foot?

5. In connection with the frog name and locate: (*a*) two types of joints, (*b*) two types of muscles, (*c*) two ductless glands, (*d*) two kinds of nerves, (*e*) two digestive glands.

Group II

6. Account for five of the following facts and indicate in each instance the animal concerned:
   a) Larger number of sperms than eggs.
   b) Open valve in dead bivalve molluscs.
   c) Absence of gills in certain aquatic animals.
   d) Absence of mouth parts in certain adult animals.
   e) Dentition with cusps.
   f) Degenerate vermiform appendix.

7. Describe the reproduction of Paramecium.

8. Define each of the following terms: (*a*) natural selection, (*b*) Mendelism, (*c*) anesthetics, (*d*) trichinosis, (*e*) flagellum, (*f*) hermaphroditic, (*g*) reflex, (*h*) gastrula, (*i*) asexual, (*j*) respiration.

9. Describe the development of the frog or toad from the time of egg-laying to the adult stage.

10. (*a*) What nutrients are needed in a normal diet?
    (*b*) State the principal use to the organism of each nutrient mentioned.

(THIS EXAMINATION IS CONTINUED ON PAGE 2)

Group III

11. Indicate the important methods employed by the government for the protection and propagation of food fishes.

12. (*a*) Name three kinds of animals that have definitely aided man in the war, and show how each has been of service.

    (*b*) Name three kinds of animals which have been a hindrance to man in war time. Explain.

13. (*a*) Name two or more kinds of birds useful in each case in destroying (1) insects, (2) weeds, (3) rodents.

    (*b*) Give a general summary of methods of bird protection.

14. What was the wild ancestor of each of the following animals: (*a*) dog, (*b*) homing pigeon, (*c*) domestic hen, (*d*) pig?

15. How do the following insects affect man: (*a*) Anopheles mosquitoes, (*b*) lady-bird beetles, (*c*) house flies, (*d*) cabbage butterflies, (*e*) grasshoppers?

ZOÖLOGY

Friday, June 25 2 p.m. Two hours

Answer three questions from each group, and one additional question which may be selected from any group. Number each answer to correspond with the question selected.

Group I

1. Make a labeled drawing of the brain of some vertebrate and state the function of each part.
2. Compare the body-plan of coelenterate, annelid, insect, and vertebrate.
3. Describe the composition of the blood and explain what changes it undergoes in the lungs.
4. Describe with as much detail as possible some protozoan which you have studied in the laboratory.
5. Name and locate the different kinds of cells found in the human hand.

Group II

6. Indicate the location of each of the following and discuss its particular function in animals: haemoglobin, pepsin, leucocyte, dentine, epithelium.
7. Explain briefly Mendel's laws of heredity.
8. Describe the methods of reproduction and regeneration in Hydra.
9. Name two animals that meet winter conditions, (*a*) by hibernating; (*b*) by migrating; (*c*) by remaining active. Give reasons for each of these differences in behavior.
10. Name the great branches or phyla of the animal kingdom and the important classes under each.

Group III

11. Name the principal animal parasites of man, and explain how each is injurious.
12. Name some animal of economic importance in connection with each of the following articles of human use: cloth, varnish, leather, buttons, oil.
13. How may insect pests be controlled by the use of other insects?
14. Mention the principal food of each of the following: black snake, toad, pickerel, cicada, earthworm, bumblebee, starfish, skunk, gipsy moth, crow. Which of these animals should be protected and which should be exterminated?
15. Name eight animals, each belonging to a different order, that are of importance as human food.

This book