THE RAILWAY EDUCATIONAL BUREAU

STOP! THINK!

STUDY CLEARS THE ROAD TO PROGRESS

INSTRUCTION PAPER

UNIT C. 1

SUBJECT:

ELECTRICITY & MAGNETISM

ELECTRICAL ACTION

OMAHA—POSTAL ZONE 2—NEBRASKA

ELECTRICITY & MAGNETISM

ELECTRICAL ACTION

Introduction

1. This is the first craft text for those railroad employes who are engaged in electrical work. Electrical apprentices, shop electricians, Diesel maintainers, signal men of all classes, etc., must understand the principles of electricity and magnetism.

2. A working knowledge of arithmetic and formulas and some knowledge of certain of the principles of mechanics, physics, and chemistry are required in order to make practical shop use of the principles of electricity and magnetism. This additional training is available to all students of this series.

3. Electrical craftsmen, also, should have sufficient training so that they can read construction blueprints, circuit diagrams, and wiring plans. Instruction in these subjects is a part of this training service.

4. With this explanation, students of this service will realize that the fundamental training offered them in Mathematics, Reading Blueprints, Sketching, Principles of Mechanical Drawing, and the Elements of Mechanics are essential steps in their training.

5. As a student advances to the study of more difficult subjects, it becomes increasingly necessary for him to plan his study work systematically. It is far better to plan to study from one-half hour to an hour *each day* than to try to devote several hours to study one day and then skip several days before proceeding. An hour each day gives a better chance to think over what is absorbed the day before and, as a consequence, the knowledge gained will be retained. Irregular study is likely to cause the student to lose interest in his subject.

6. The adage, "Make haste slowly," applies to this work. Each paragraph should be read carefully; *then reread thinkingly.* Each rereading may bring out some point that escaped attention previously. Reading alone is not sufficient. In order to obtain real knowledge from the instruction, the student must stop after each paragraph or sentence and think about what he has read. The instruction is carefully planned, so that the student should be able to understand each step in succession, after he has mastered the information in preceding paragraphs or texts.

7. Failure to understand explanations in any part of a text usually indicates that the student has failed to understand thoroughly some explanation that has preceded the one that gives trouble. In such a case, a review of preceding paragraphs usually will clear up the difficulty. In any event, should the student fail to understand any part of any of the texts after careful study and thought, he is free to write the Bureau for additional helpful explanation.

8. The first series of texts on electricity and magnetism relates entirely to DIRECT CURRENTS. An entirely separate series of texts gives instruction on ALTERNATING CURRENTS.

9. Where texts of the series contain practical formulas and problems pertaining to the subjects under discussion, explanatory problems are worked out to demonstrate the application of the formulas. Carefully selected problems are given in the examination questions required for qualification on each text. The student should not turn to the examination questions and endeavor to work the problems before he has really mastered the text. If he does, he will find that he has failed to obtain proper benefit from his study. Lack of ability to solve an examination question is a sure proof of failure to have understood some portion of the instruction, and indicates the necessity for a more thorough review of the subject.

Sources of Electricity

10. The most useful sources of electricity are GENERATORS and BATTERIES. Electricity is produced by chemical action in ordinary batteries and by a combination of mechanical and magnetic action in generators. When produced it always has a certain amount of voltage.

ELECTRICITY

FOR MOST PRACTICAL PURPOSES ELECTRICITY MAY BE CONSIDERED AS A DEFINITE SOMETHING WHICH CAN BE GENERATED BY CHEMICAL ACTION OR BY A COMBINATION OF MECHANICAL AND MAGNETIC ACTION.

WHEN GENERATED, ELECTRICITY HAS DEFINITE PRESSURE, THAT IS, IT HAS THE POTENTIAL POWER TO DO WORK.

ELECTRICITY CAN BE MOVED FROM PLACE TO PLACE; IT CAN FLOW AS A CURRENT THROUGH A WIRE OR OTHER CONDUCTOR. ITS POTENTIAL POWER CAN BE CONVERTED INTO WORK IN MOTORS OR OTHER ELECTRICAL APPARATUS OR ITS POTENTIAL POWER CAN BE CONVERTED INTO HEAT, AS IN AN ELECTRIC IRON.

ELECTRICITY HAS MANY OTHER PRACTICAL APPLICATIONS.

11. VOLTAGE in a source of electricity is a great deal similar to pressure in a steam boiler; it represents the potential power of the electricity. However, no electrical work is produced except when the electricity flows through a circuit. Similarly, steam does not accomplish any work until it flows to the cylinders of an engine or a pump or some other device where its potential power can be changed into work.

12. A storage battery is not a primary *source* of

electricity. Electrical energy from an outside source is used to "charge" a storage battery. This produces a chemical change in the battery. This chemical action can be reversed after charging so that a large percentage of the electrical energy put into the battery during charging can be reclaimed for use later as desired.

13. A dry cell furnishes electricity at a pressure of about $1\frac{1}{2}$ volts. A single cell of a storage battery furnishes electricity at a pressure of about 2 volts. Generators can be built to produce electricity of much higher voltages. The electrical pressure in the lighting circuits of most homes is about 110 volts. The pressure in long distance power lines may be as much as 50,000 volts or more.

14. As an example: The storage battery used on a Diesel locomotive usually has 32 cells and so operates at a pressure of 64 volts. The Diesel main generator can furnish electricity at pressures ranging up to 1,000 volts. The Diesel auxiliary generator supplies electricity at from 74 volts to 76 volts.

CIRCUITS

15. Electricity can be moved from place to place by setting up a CIRCUIT through which it can travel. The voltage of the electricity is what causes the movement. A copper wire provides one of the most practical paths through which to move or conduct electricity from place to place.

16. There are many metals beside copper through which electricity will travel readily. Electricity also will travel through a number of other substances which are not metals. Salt water is one example; carbon is another; moist earth—the ground—is another. All such substances are known as CONDUCTORS of electricity.

17. There are a number of substances through which electricity will not flow; slate, glass, mica, porcelain, some plastics, paper, shellac, and rubber are examples. Such substances are known as INSULATORS. Porcelain, glass, and plastic fittings are used to support power lines or other wires through which electricity is flowing. These supports prevent the electricity from leaking or short-cutting away from the path that it is desired to have it follow.

18. Air is a very good insulator. Bare wires that carry high voltages are strung in the open air. When bare wires are supported properly on insulators, very little electricity leaks or strays away from the path through the wires.

19. As long as wires which carry electricity can be separated by a sufficient AIR GAP, no insulation, other than the air, is required to keep the electricity from jumping from one wire to another. Where wires must be strung close together or there is danger of their swinging together in the wind or touching because of vibration, they must be insulated.

20. INSULATED WIRE is a wire that has been covered throughout its length with a coating of insulating material sufficient to prevent any straying or short circuiting of the electricity from the intended path or circuit. Many electrical connections are made by CABLES which contain as many separate conductors as are required for the different circuits. Each wire or conductor of a cable is covered with a sufficient coating of shellac, rubber, fabric, or other insulation to hold the electricity in its intended circuit.

21. To understand how electricity is moved or how it flows from one place to another, one first must imagine that there is a source of electricity, that is, a battery or generator where a supply of electricity at a certain pressure or voltage is available for use. Batteries and generators are provided with TERMINALS to which the wires that will form a circuit are connected. The terminals are marked + for POSITIVE and—for NEGATIVE. Electricity flows from its source through its circuit and

back to its source. It is considered that it flows from the plus or positive terminal through the circuit and back to the minus or negative terminal.

22. Electricity will not move or flow except through a *complete* circuit. This means that the wire or other conductor which will form the LEADS or connections of the circuit must lead from one terminal of the battery or generator through whatever path the electricity is to follow and back to the other terminal of the battery or generator so that there will be no break in the circuit. If a circuit through which electricity is moving is broken, the movement or flow simply stops.

QUESTIONS FOR SELF-EXAMINATION

QUESTIONS FOR SELF-EXAMINATION AID THE STUDENT TO DETERMINE WHETHER HE REALLY UNDERSTANDS THE MEANING OF WHAT HE HAS READ. SOMETIMES A PERSON *THINKS* HE UNDERSTANDS A SUBJECT FROM READING ABOUT IT. WHEN HE TRIES TO EXPLAIN IT TO SOMEONE ELSE, HE MAY FIND THAT HE DOES NOT UNDERSTAND IT WELL ENOUGH TO EXPRESS HIS IDEAS IN WORDS. IF THE STUDENT WILL TEST HIS KNOWLEDGE OF A SUBJECT BY ANSWERING QUESTIONS FOR SELF-EXAMINATION *OUT LOUD*, HE WILL DISCOVER WHETHER HE CAN EXPLAIN THE QUESTIONS TO SOMEONE ELSE. IF NOT, IT WILL INDICATE THE NEED FOR ADDITIONAL STUDY.

1........What is a conductor of electricity?

2........What is meant by an insulator?

3........What is insulated wire?

4........What is required in order to have an electric circuit?

5........Will there be any flow of electricity through a circuit if a swich in the circuit is open?

23. ELECTRICAL ENERGY is the potential power present in any source of electricity. Electrical energy can be used to produce either HEAT or WORK or MAGNETISM. The common way to use electrical energy is to pass electricity through a CIRCUIT. Heat or magnetism is produced or work is accomplished when the electricity overcomes a resistance to its passage through a circuit.

24. RESISTANCE is anything in a circuit which retards the movement or flow of electricity through the circuit. The wire of a circuit offers some hindrance to the free movement or flow of electricity, consequently it offers some resistance. However, the principal resistance in a useful circuit is the electrical equipment which is to be operated or which produces heat or magnetism in performing its purpose.

25. One fundamental fact must be borne in mind about the flow of electricity through a resistance. No matter how much electricity at any certain voltage is available to flow through a circuit, only as much will actually flow as the voltage can force through the resistance of the circuit. If the voltage is increased, more electricity will be forced through the same resistance; if the voltage is reduced, less will flow.

26. An example of a resistance where electrical energy is changed into useful work is an electric motor. An electric iron is an example of a resistance where the electrical energy is made useful by producing heat. A similar example is the electric light, where the resistance of the filament is so great that the filament becomes heated to incandescence and produces the desired light. A relay is an example of a resistance where electrical energy is made useful by magnetic action.

27. After electricity has performed all of the required work in a circuit, it must be led back to the negative terminal of its source. The return portion of the circuit may be a wire which is used for just that one circuit or it may be a common wire which forms the return for a dozen or a hundred different circuits.

28. Since the earth or the ground is a fair conductor, it is used as the return path for some circuits. The bare end of the wire from the last resistance in the circuit is led to the ground. When the path of the return circuit is to be through the ground, one terminal of the *source* also

must be GROUNDED. The path for the flow of the electricity must be complete.

29. If there is a convenient metal path that can be used as a conductor for the return portion of a circuit, it will be more reliable than the ground alone. Any such return path is spoken of as a GROUND RETURN. For example, the rails of the track of electric streetcar lines are used this way. The metal frame of an automobile is used as the return for the circuits for headlights and horn. Similarly, a locomotive frame may be used as a ground return for some electrical circuits. One terminal of the source, that is, one terminal of the battery or the generator, must be connected with the ground return in each case.

30. All circuit wires must be insulated from a ground connection until the electricity has completed its useful work in the circuit. Otherwise, the electricity will short-circuit through the "ground" without performing the intended useful work.

31. When a wire is large in comparison with the amount of electricity flowing through it, very little heat will result from the friction of the passage of the electricity through the wire. What little heat is formed will radiate to the air without being apparent to the touch. Even if the wire is covered with insulaton, the small amount of heat developed will dissipate through the insulation without evidence of heating. However, if a large quantity of electricity is being forced by its voltage through a comparatively small wire, the electrical friction will be sufficient to heat the wire in proportion to the resistance. It may even heat it to incandescence, as is the case with an electric light bulb.

32. Electrical engineers know from experience how much heat each size of wire is able to dissipate without an appreciable increase in its temperature. Designers of electrical circuits, therefore, specify a size of wire for

each circuit that will carry the necessary amount of electricity without undue heating.

33. Even the smallest wire can carry the highest voltage. It is not the voltage which causes heating. The size of the wire must be in proportion to the *amount* of electricity that is to flow through it*

QUESTIONS FOR SELF-EXAMINATION

6........What is an electrical resistance?

7........How is the electric potential or power in a source of electricity used to perform work or produce heat?

8........What is meant by a short circuit?

9........Why must the size of wire used in a circuit be selected in accordance with the resistance of the circuit, that is, the amount of electricity that will flow through the circuit?

Kinds of Circuits

34. There are two principal kinds of circuits. They are known as SERIES CIRCUITS and PARALLEL CIRCUITS. A combination of these two circuits is called a SERIES-PARALLEL CIRCUIT. There are shunts in some circuits, also. SHUNTS will be discussed later.

35. If one terminal of a battery is connected through a series of light bulbs, as shown in Fig. 1, the light bulbs are said to be connected in SERIES. The total amount of electricity that flows through the circuit must pass through each one of the bulbs in turn in order to complete its circuit back to the battery. If any one of the four lamps in Fig. 1 is removed from its socket or burns

*Electrical charges of tremendous voltage form in the clouds during a storm. The voltage or pressure is so great that the charge overcomes the resistance of the air and jumps from the clouds to the earth as lightning. However, the amount of electricity in the charge is comparatively small. A lightning rod will carry a stroke of lightning from the top of a chimney or building to the ground. Such charges are called STATIC ELECTRICITY. They are the same as the electricity which forms in the body in cold weather when the feet are scuffed on the carpet. Static electricity is of very little practical use. Usually it is a disturbing element because, with few exceptions, there is no way in which it can be controlled.

out, the circuit will be broken and all the other lights will go out.

36. When four light bulbs are connected in a circuit, as shown in Fig. 2, they are said to be connected in PARALLEL. The electricity that enters the circuit di-

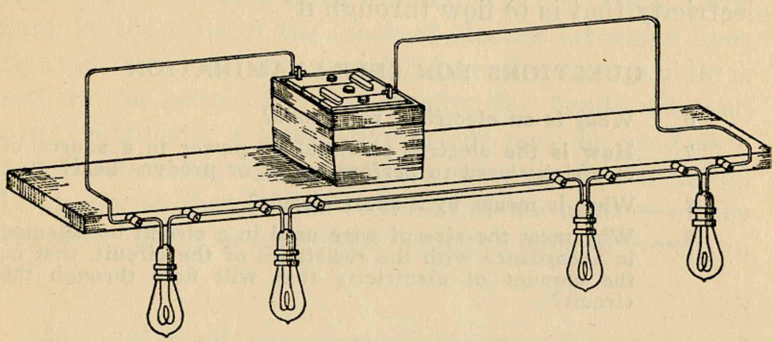

Fig. 1

vides. A part of it flows through each of the four lamps. The part of the electricity that flows through each lamp completes its circuit to the battery through the COMMON RETURN WIRE.

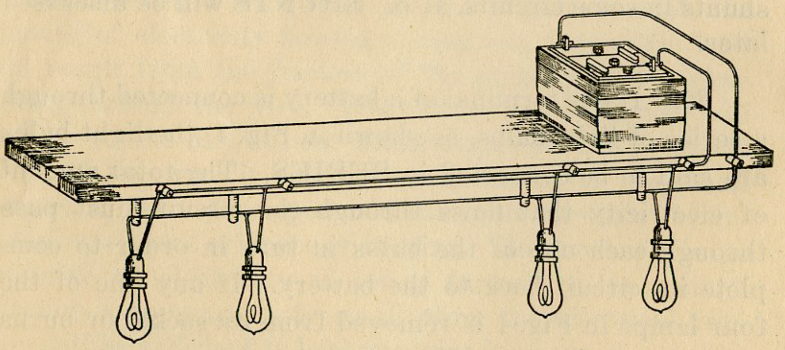

Fig. 2

37. With a plentiful supply of electricity at any certain voltage available to flow through each branch of a parallel circuit, the full voltage will act on each lamp or other apparatus in each branch of the parallel circuit. However, only as much electricity will flow through each branch as the resistance of the branch will allow to pass.

For example, in the parallel circuit shown in Fig. 2, each lamp will burn with the full voltage of the source, but only as much electricity will flow through each branch as can pass the resistance of the lamp in that branch. If three lamps are removed, the fourth lamp will use no more electricity than it did when all four were burning. The current that the other three lamps were using still is available, but that fact has no effect on the remaining lamp, its resistance is not changed, so it burns just as it did before.

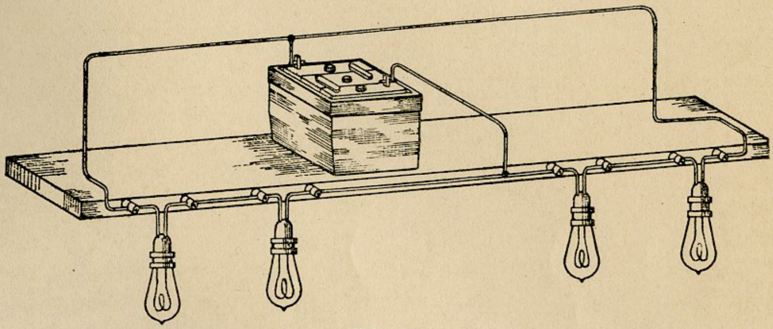

Fig. 3

38. Referring again to Figs. 1 and 2, the total resistance of the four similar lamps in series (Fig. 1) cuts down the voltage acting on any one lamp to one fourth of the voltage of the source, whereas, when the lamps are in parallel (Fig. 2), each lamp is acted upon by the full voltage of the source. On the other hand, in the series circuit, the total amount of electricity that flows through the circuit passes through each lamp just as though the four lamps were one big lamp having a resistance equal to that of the four. However, when the lamps are in parallel, only one fourth of the total flow of electricity passes through any one of the four lamps.

39. A combination of the two circuits shown in Figs. 1 and 2 is shown in Fig. 3. The first pair of lights is in series and the second pair of lights is in series, but the two *pairs* of lights are connected in parallel. This is an example of a SERIES-PARALLEL circuit. The total amount of electricity which enters the circuit will be

divided equally between each of the *two pairs* of lights that are in parallel. However, since the two lights of each pair are in series, each light of each pair will receive but half of the voltage of the main circuit.

QUESTIONS FOR SELF-EXAMINATION

10........What is a series circuit?

11........What is a parallel circuit?

12........What is a series-parallel circuit?

EXAMINATION QUESTIONS

The examination on this text consists of writing out answers to the twelve questions for self-examination that appear in this text. The questions are on pages 6, 9, and 12. These questions should be answered in the usual manner and the answers sent to the Bureau for checking.

R.E.B.—8-45-10.