A SUGGESTED LABORATORY COURSE IN ELECTRICITY FOR SECONDARY SCHOOLS.

By

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- OUTLINE -

An examination of the work given in electricity in connection with the Physics Laboratories in a number of the High Schools of the country and a study of the work planned by a number of the best Laboratory Manuals, shows such a wide difference that it has suggested a plan for a Laboratory course which should be a combination between theory and actual practice.

In collecting material for this thesis I first sent out letters to the nearest large city High Schools and to a number of county High Schools asking for the list of their experiments in Physics Laboratory to cover the work given in electricity. Of the seventeen letters sent out fourteen answers were received only ten of which contained the required lists, the others stating that they gave no work in electricity.

In tabulating these lists we find the widest divergence in the nature of the work done, from mere child's play to an imitation of the college Laboratory Course. The courses varied widely, probably as much with the competency of the instructors as with the available materials and the time offered for the course. The courses offered from the city high schools were in almost every case larger and more practical than those offered by the county high schools. This fact might be due to the lack of materials but is more likely due to the inefficiency of the teachers since in the small schools a specialist in one branch is forced to teach several. The work given by the city high schools was mostly on current electricity, that of the smaller county high schools on static electricity. The materials for the one course could be but little

above the other in price while the former gives to the student some idea of electricity, its uses and possibilities, the other nothing that is of any practical value the work being qualitative rather than quantitative.
The nature of the work given in the smaller schools suggested the idea that the apparatus was probabby handled by the instructors, the pupils merely taking down the data. This helps the student little more than text-book work and is very unsatisfactory.

Two of the lists which were received stated the numbers of the experiments which were used in two of the manuals which I have reviewed so they will not be taken into consideration. From the lists received I took those experiments which were given most generally and seemed the best and found out what percent of the lists gave those experiments, as is shown in the following data. I then took the same experiments and went through the lists of Laboratory manuals given below to see how the actual practice compared with what authors have given along that line.
The data is as follows.

	Lines of Force about a Magnet.	Cell Formation and effects.	Resistance by Substitution.	Resistance of Shunts.	Wheatstone Bridge.	Specific Resistance	Temperature Coeff. of Resistance.	Arrangement of Cell for largest current	Electrolysis as check for ammeter.	Tangent galvanometer	Induced Currents.	Electric Bells.	Small Motor and Dynamo study.
Experimental Physics. Stone.	x	x	x		x	x	x	x	x	x			
Lab. Manual Cheston-Dean & Timmerman.	x	x	x	x	x	x	x	x		x	x	x	x
Lab. Course in Physics. Sabine.	x		x	x	x	x	x	x	x	x	x		
Lab. Course in Physics. Milliken & Gale.	x	x	x		x	x		x	x		x	x	x
Lesson in Elementary Practical Physics. Stewart & Gee. Vol. I.	x	x	x	x	x	x	x	x	x	x	x		
Lab. Course in Physics. Dayton Clarence Miller.			x	x	x	x	x			x	x		
Man. of Ex. Physics. Nichols - Smith & Turton.	x	x			x	x	x	x	x	x	x		x

	Lines of Force about a magnet.	Cell Formation and Effects.	Resistance by substitution.	Resistance of Shunts.	Wheatstone Bridge.	Specific Resistance.	Temp. Coeff. of Resistance.	Arrangement of cells for largest C.	Electrolysis as check for ammeter.	Tangent Galvanometer.	Induced Currents.	Electric Bells.	Small Motor and Dynamo study.
Chicago High School.	x	x	x					x	x		x	x	
Topeka M. Training.	x	x	x	x	x	x		x			x		x
Olathe.	x										x		
Leavenworth.	x	x	x		x						x	x	x
Kansas City Kansas.	x	x	x		x	x							x
Indianapolis Ind.	x	x			x	x	x		x		x		
Wichita.		x	x								x	x	x
Manual Training K.C. Mo.	x	x		x	x			x			x	x	

From the above data is easily seen the wide difference between the laboratory manuals and the High School work. The experiments with the Wheatstone Bridge and the Specific Resistance were the only two given by all of the manuals and of the thirteen problems the Topeka Manual Training gave the highest number- nine. This suggested that a combination might be made and the idea which I tried to carry out in the following experiments was to give a course which could be carried on with as little outlay as possible for apparatus and still give to the student a thorough understanding of electrical currents and their uses.

Some allowance must be made for the time in the course in which this is to be given. The one planned would probably not be simple enough for anything less than third or fourth year High School pupils.

No day current of electricity is required for these experiments as the current from dry or storage cells is sufficient for all. This takes away the danger from allowing students to handle a high current, Also of their running delicate instruments. The first half of the experiments are mostly on the theoretical part of the work, the last half on practical experiments based upon principles of which every boy and girl should have a knowledge, such as the wiring of a door-bell, the use of electric lights and the cost of such, and the study of the parts of a small motor and dynamo. Any work with a tangent galvanometer was not introduced on account of the Trigonometry involved in its solution.

Since one instructor could scarcely oversee the work of more than twenty four pupils at a time, the apparatus planned is for that number. The experiments could not of course be given to all twenty four pupils in the order as arranged but it would be best to give the first half to all before beginning on the last problems.

The methods given for the work on the various experiments were those which seemed the most practical and give the best results in the quickest time. The apparatus for the experiments should all be grouped in the Laboratory but arranged and data taken by the pupil, being worked out with the methods given in the instruction sheets, so that the student, not the instructor, does the work. The instruction sheets should either be furnished by the school on each Laboratory day in a type-written form or should be printed so that the students could purchase at a low price. They should be on paper the same size as used in the number six loose fly note books. The instruction sheets as given could be so used

The following list of apparatus is one which includes all things required for the course excluding that apparatus which would be found in any experimental laboratory. The prises were taken from the catalogues of two Chicago Supply houses and could probably be duplicated by any good company.

Apparatus.

2 Dynamos	$ 8.75
2 Motors	8.75
2 Detecting Galvanomoters	30.00
1 D' Arsonval Galvanomoter	25.00
2 Resistance Boxes	16.00
2 Wheatstone Bridge	12.00
2 Voltmeters	62.00
2 Ammeters	42.00
4 Storage Cells	20.00
12 Gravity Cells	10.80
6 Dry Cells	.90
2 Horseshoe Magnets	4.00
2 Electric Bells	4.00

2 Keys	$ 3.00
6 4 c.p. Lamps	.40
2 Push Buttons	.24
1 Bar Magnet	.80
2 Small Jars	.50
1 Oil Bath	.50
1 doz. Glass Sheets	.15
Blue print paper	.50
Iron Filings	.05
Connectors and Binding Posts	2.40
WIRE.	
1/4 lb. No. 30- Copper Cotton wound	.55
2 lbs. No. 24- " " "	2.50
2 lbs. No. 16- " " "	1.80
1 lb. No. 8- Unwound	.37
	$ 257.46

Discount 1/4 off makes the cost of apparatus $193.10. If the funds were low a combination **voltmeter** and ammeter might be used bringing the cost down to about $175.00

The outline of experiments which follows was written after having collected the apparatus, set up the experiment by the method given and taken the data so that the experiments are all practical and can easily be performed by the average high school student. The experiments would require an average of two hours for their solution as is generally **allowed for all** Laboratory periods.

Experiment I.

OBJECT.

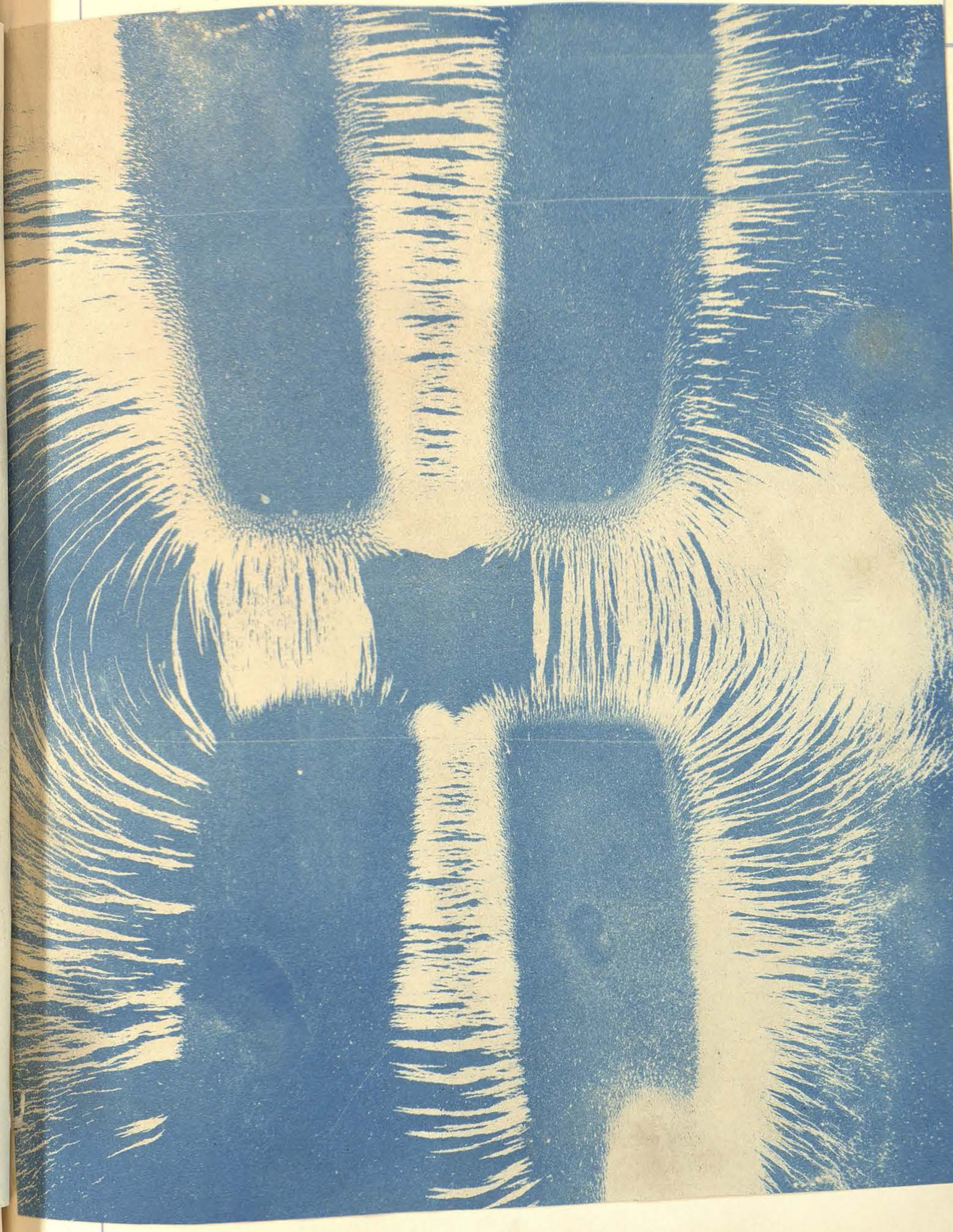
To map the magnetic lines of force about a horse-shoe magnet.

MATERIALS.

Two sheets of blue-print paper the size of the note books. A bottle containing iron-filings, which is covered with cheese cloth. Two sheets of glass the size of the paper, two horse-shoe magnets.

INSTRUCTIONS.

Arrange the magnets, pole to pole, and then cover with the glass and tap until they arrange themselves according to the lines of force. Reverse one magnet and repeat. Darken the room before exposing the blue print paper, sprinkle on filings, tap and cover with the other glass.. Expose 3 to 7 minutes to the sunlight, then shake off the filings and let lay in running water for 30 minutes.. Repeat reversing one magnet. When dry the prints should be put in file with the notes in which general facts and deduction should be stated.



Experiment II.

OBJECT.

To study one method of current production. To construct a cell which begins action quickly and gives practically a steady current.

MATERIALS.

One glass jar, a copper, and a zinc of the crow-foot type. A quantity of copper- sulphate and some zinc sulphate solution. A Voltmeter and an ammeter.

INSTRUCTIONS:

Unless new the jar and metals should be cleaned. Put the copper into the bottom of the jar and pack with copper-sulphate. Fill the jar two-thirds full of distilled water. Put in the zinc and carefully cover with the $ZnSO_4$ solution, being sure not to mix the liquids. Take the current and the voltage with the ammeter and voltmeter. Short circuit and let set over night, then take the drop and current. Cover the liquid with a slight film of oil. Explain the use of the oil, the two liquids, and of the short circuit.

Experiment III.

OBJECT.

To measure, by means of substitution, the resistance of several wires, Also to find the comparative resistance of wires connected in series and parallel.

APPARATUS.

A mil-ammeter, or a galvanometer, a resistance box, a gravity cell, several lengths of wire and double connectors.

DIRECTIONS.

Connect in series the cell, ammeter, resistance box, and unknown R. of wire. Take current. Make connections with double connectors without the unknown and remove until the current reads the same. Repeat. Try the same with a german silver wire. Which has the largest resistance per cm.? By removing plugs from the R. Box find the change in the current for each tenth of an ohm change in resistance. Connect the copper and german silver wires in series, take current and find R. by the Resistance Box. How might this be found from former data? Connect the two wires in parallel, take the drop across and the current. Solve for the R. of the two.

Experiment IV.

OBJECT.

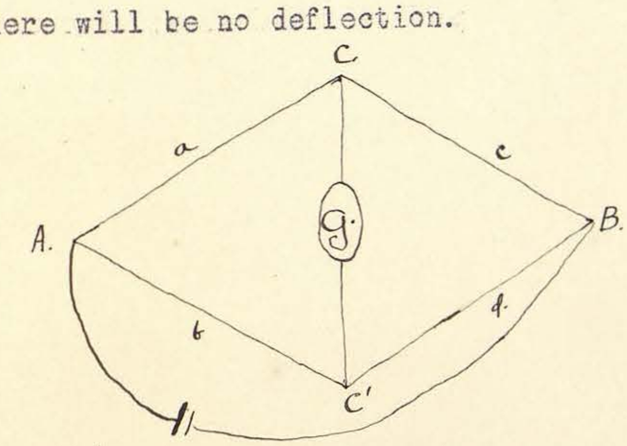
To measure, by means of a Wheatstone Bridge, the resistance of two coils of wire and to find the specific resistance of equal lengths of copper and german silver wire.

MATERIALS.

A slide-wire meter bridge, a gravity cell, a resistance box, two coils of wire, equal lengths of g. silver and Cu. wires and a sensitive galvanometer.

DISCUSSION.

The Wheatstone Bridge is an instrument for measuring unknown resistance by comparing it with a known. It is based on the fact that when the terminalsof a galvanometer are connected over points of equal potential there will be no deflection.



If the given circuit be divided at A to B the potential og any point on e either branch equals the resistance x the current. If the potential is higher on one branch than the other there will be a deflection of the needle. Then we have the ratio of the arms, a x d = c x b. Since the resistance of a wire is directly proportional to the length a wire fastened over meter stick is used as two arms, a known R. and an unknown as the other two.

INSTRUCTIONS.

Work out the connections for the bridge. Introduce as one Resistance, a coil of fine copper wire. Take several plugs out in the known resistance to establish a ratio between the arms. Find the Resistance of the coil. **Exchange position** of box and coil and repeat. Take an average. Repeat with equal lengths of german **silver** and copper wires. By means of the formulae $r = R \frac{l}{a}$ find the specific resistance, determining a from a table by measuring the diameter with the micrometer caliper.

Experiment V.

OBJECT.

To find the temperature coefficient of Resistance for copper wire.

APPARATUS. Wheatstone Bridge, gravity cell, galvanometer, resistance box, vessel of oil, gas burner, thermometer, and a coil of copper wire.

DISCUSSION. The Temperature coefficient of Resistance is the increase in the resistance per ohm. per degree change in temperature. Then we would have

$$K = \frac{r_2 - r_1}{r_1(t_2 - t_1)} \quad (1)$$

where r_1 and r_2 correspond to t_1 and t_2, The formulae then being the total change in resistance divided by the total change in temperature times the initial resistance.

INSTRUCTIONS.

Connect the cell, galvanometer and bridge using the coil immersed in oil, as one resistance and a Resistance Box as the other. Put the thermometer into oil bath, always stirring well before taking a reading. Take reading at room temperature. Start the burner and raise the T. by steps of about five degrees until it reaches 100°, taking the bridge readings each time. Solve the bridge readings for the total change in T. Then by means of (1) solve for K. Do the same with intermediate pairs of temperature and the corresponding pairs of resistances. Plot a ~~cotre~~ curve using temperature as the ordinate.

Experiment VI.

OBJECT.

To find what arrangement of cells will give the strongest current for a given external resistance.

APPARATUS.

Four gravity cells, ammeter, voltmeter,, wires and double connectors..

DIRECTIONS.

Take the drop across each of the four cells, also find what current each gives. Then join the cells in parallel. Take the entire drop and the current. Join the four cells in parallel. Take the drop and current. What proportion of the sum of the E.M.F's is the one just found? How does the current compare with the former one.. Join two sets of cells in parallel and then connect these in series. This is called banking. Take the drop and current. Which of the three methods gives the largest current? How does the E.M.F. vary in parallel and series arrangements?

Experiment VII.

OBJECT.

To test the accuracy of an ammeter by means of the amount of copper deposited by its recorded current in fifteen minutes on two copper coils immersed in $CuSo_4$ solution.

APPARATUS.

Six gravity cells which are connected in Arc. An ammeter, a stop watch, two copper coils, two small jars containing $CuSO_4$ solution. Two rough coils of wire.

DIRECTIONS. If the $CuSO_4$ solutions have not been used before they must be filtered. Cleanse the two unwound copper coils by dipping in lye water, acid, then distilled water. Dry very carefully and weigh on Analytic Balances. Place one in each glass jar, inside a larger coil of rough wire, being careful that they do not touch. Connect the terminals of the battery, ammeter, and the two sets of coils all in series and as the last connection is made, turn on the stop watch. Let run fifteen minutes and then break the connections. Dry carefully and weigh. We know that copper deposits at the rate of .000329 gms. per sec. pr. amp.

Solve for the current and find how near it corresponds to the ammeter reading.

Experiment VIII.

OBJECT. To investigate a new method of producing electric currents, namely induction which illustrates the principles upon which the dynamo and telephone operate.

APPARATUS.

D'Arsonval Galvanometer, a bar magnet, a coil of wire on a hollow core, two dry or four gravity cells, large and small copper wires.

DIRECTIONS.

Connect the coil several feet from the galvanometer. Thrust in the N. pole of the bar magnet. Is there a deflection? Withdraw. In what direction is the deflection. Repeat more quickly. Reverse ends and repeat. What do you learn from the rate of change and direction of the lines of Force?

Around a bar already wound with heavy wire, wrap evenly, forty turns of fine copper wire. Attach the galvanometer to the fine wire and the four cells to the coarse. What is the deflection of the needle on the " make " of the circuit? Wind on forty more turns and read the deflection. How would you say the number of turns of wire influenced the amount of induced current?

Experiment IX.

OBJECT.

To study the windings and operation of an electric bell.

APPARATUS.

An electric bell, two push buttons, three Leclanebe or two dry cells.

DIRECTIONS.

Study the windings of the bell and make a diagram explaining the operation of the clapper, and showing the essential parts.

Set up the bell on a board. Connect in series with the two dry cells, putting in the push button so that pressure on it will ring the bell. Why is this fixed to break the connections? Next put in the second button so that the bell will ring from either.

Experiment X.

OBJECT.

To study the winding and operation of a small motor with the relative value of shunt, series, and compound windings.

MATERIALS.

A small motor, three storage cells, an ammeter and a voltmeter.

DIRECTIONS.

From the binding posts trace out the windings of the field and armature. Is it arranged for direct or alternating current? What is the present winding? Screw on to a long board. Connect to the storage cells and notice the direction of the motion. Does reversing the cell terminals reverse the motion? Why? Undo one of the terminals of the field wires, and attach the cells to one field and one armature terminal. Trace current. Put the ammeter in series with the motor and the voltmeter over the terminals of the motor. How does the amount of energy consumed compare with the other winding? By the use of binding posts introduce into the Field in series with the armature a short length of german silver wire. Thus varying the Field resistance. How does this effect the speed? Take the drop and amperes.

Experiment XI.

OBJECT.

To determine the efficiency of a system composed of a small motor and dynamo and to determine the cost of electric lighting.

APPARATUS.

A small motor and dynamo set up on a board, a key, three 4 candle power lamps, three storage cells, a pulley, voltmeter and ammeter.

DIRECTIONS.

See that the pulley wheels on dynamo and motor are in line then screw onto the board. Adjust the pulley. Put the voltmeter over the terminal of the dynamo. Attach the three storage cells to the motor by means of the key. Start the current by holding down key and take the voltage from the dynamo. Connect in series the ammeter and electric lights and attach to the dynamo terminals. Take the volts and amperes after it has run for a minute. Put the ammeter and voltmeter in so that they read the current and the voltage of the motor. Find the watts of energy put into the motor and out of the dynamo. Then the efficiency = what per cent the out-put is of the in-put.

If $\frac{\text{amperes x volts x seconds}}{1000}$ = Kilo-watt. hrs. find the cost of running the three 4 c.p. lamps for 24 hrs. at 15¢ per kilo-watt hour

The following list of laboratory rules would, if adopted, save both the instructor and student time and unneccessary work. It will force the student to be careful with the apparatus, and to be orderly. It also gives him an outline of the way in which the experiments should be written up.

Laboratory Rules.

I. Apparatus must be left in the same condition as found.

II. Experiments must be written up and handed in for correction at the next Laboratory period.

III. Order in Note Books.

1. Instruction sheet.

2. Name and number of experiment. Names of experimentors -Form of apparatus used- Sketch of the apparatus as adjusted- Theory on which experiment rests- Data and experimental results.

IV. If not accepted the experiment must be rewritten or if incorrect the data must be taken again.