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# THE STATUS OF PHYSICS IN THE HIGH SCHOOLS OF OKLAHOMA.

## I. INTRODUCTION.

"We haven't taught physics for over six years. There is no demand for it."

I was somewhat surprised at that statement made by the science instructor of one of the large high schools which had belonged to the North Central High Schools as early as 1918.

"Why," I asked, "with an enrollment of nearly two hundred students is there no interest in physics?"

The word "why" is always easier to ask than to answer. However, during the course of our conversation I discovered one or two reasons for this lack of interest.

The science instructor had been an engineering student in Alabama and while there he devoted much of his time to athletics. Although he taught botany and other sciences, he said that the real enjoyment he found in his work was while coaching students in football and other athletics. Science was merely a sideline for him. In the botany class which I visited, the students conducted themselves and the recitation nearly as they pleased in spite of the fact that the instructor repeatedly reproved them for talking. The recitation was conducted by the question and answer method. The question s were taken from paragraphs in the same order in which they appeared in the text. One little girl, a daughter of an official of the city, enjoyed asking questions which were often left unanswered. I was later informed that she and several other students owned automobiles of their own, and that they had their own way at home; therefore they had to have their own way in school.

At my request I was shown the remains of the physics apparatus. After several minutes of sticking the latch yielded to the persistent efforts of the instructor. As I entered a small closet, a light was switched on revealing shelves loaded with relays and sounders to telegraph sets, electric bells, and other laboratory apparatus. I was informed that quite a few pieces were scattered over the building and were used in other sciences as general science. As I glanced at the various pieces which were lying there, I felt that I had entered a tomb and was looking at the relics of an age that had passed. These questions continued to bother me. Why had physics passed from the curriculum? Would it ever be resurrected, if so, in what form?

After considering the last question from all sides I offer the following suggestions:

1. To awaken students' interest in a subject, like physics, requires an instructor whose chief interest does not rest in athletics.

2. The question method alone in physics closely following the material in the text will discourage the average student.

3. The pupils' originality is dampened when their questions are dropped without answering or

investigating their possible answers later.

4. There is a great opportunity for teachers and parents to gain the deepest interest among boys and girls for physics. An automobile is a storehouse for physical investigation as well as an object of pleasure. Why not teach pupils the simple principles of mechanics with real machines that they use every day? Surely this would gain their enthusiasm and they would acquire ideals of careful observation.

5. I believe that if the enthusiasm of youth were directed toward investigation of common, every-day phenomena of actual life, the students would have more respect for their instructors.

As the physics problem in this city is not a local one, but a general problem, it will be well to discuss these suggestions after considering the data submitted by other schools of the state. A sketch of the growth of physics into its present form will help in the understanding of its tendencies to-day, and will show why physics is no longer taught in some high schools.

## II. HISTORY OF PHYSICS.

Almost from the foundation of European Universities physics was one of the subjects studied. However, the ancient physics did not resemble the present subject in the least. The students of the Middle Ages memorized Aristotle's speculations and they spent much time in discussing their possible meaning. In 1276 Roger Bacon, one of the greatest men in history, fought against such methods of instruction and preached experiment, experiment to a world that turned only a deaf ear to him.[1]

Modern physics began its growth at the end of the eighteenth century due to the efforts of Galileo. Its growth has been continuous and closely related to the development of mathematics.[2] Physics was not taught as early in the common schools as in the universities. The earliest date of its record in the common schools of England was in 1729.[3] In America it was taught under the name of Natural Philosophy in 1754. It differed from the physics as taught in the universities in this respect that it presented those things which were most useful instead of mathematical forms and interrelations. In some texts 62 pages were devoted to machines and 40 pages to pumps. The diagrams were pictures of real things, as levers with a hand pushing on one end, or a pulley with a hand operating the rope.[4] It was taught for the purpose of supplying common people with the information concerning everyday physical occurrences.

It was not until 1872 that natural philosophy gave way to physics. It was then first accepted as credit for entrance into colleges.[5] Its purpose, to teach those things that were most useful, changed into the ideal, to give mental training. The laboratory work was outlined by college men and apparatus dealers offered complete outfits for all the experiments in the list. With such treatment physics could not progress. Without growth the presentation fell far behind the commercial strides of the science.

There were two ways open to physics in the high schools; death from a lack of demand for a science which had become divorced from the daily life of the pupils, or a change in the method of teaching the subject. Which path has physics taken in the high schools of Oklahoma?

## III. PRESENT CONDITION OF PHYSICS IN HIGH SCHOOLS OF OKLAHOMA.

Upon investigation I found that it has taken both paths and is still following both courses. In ten schools it has died an easy death. In a few schools it is being taught to two, three or four students, while in some schools there is wide interest and a large attendance. Table I, on the next page, shows the size of the physics class and of the respective high schools, and the electives which may be chosen in place of physics.

### (a) General Information Obtained From Questionaires To Instructors.

This information is taken from questionnaires received from forty-eight schools. I sent them to 160 schools in all, fifty of which were fully accredited. I received 15 replies from the accredited high schools and 33 from the others, or in both cases thirty percent of the instructors answered the questions. This is a low percentage as the questions could be answered easily in half an hours time with little writing. A self-addressed, stamped envelope was included and a letter, asking for the co-operation of the instructors in working out the possibilities of high school physics by supplying the facts, accompanied each set of questions. Furthermore, I sent over one hundred postcards later, as a reminder to those who had forgotten my questions. Most of the instructors who answered my questions were anxious to make their department as efficient as possible. They were eager for suggestions for improvements. I asked 64 questions of each instructor. The questions dealt chiefly with the following topics: (a) physics instructors. (b) physics theory. (c) physics laboratory. (d) physics pupils.

TABLE I. Attendance of schools that answered questionnaires, with size of physics classes and electives for physics.

| school | students taking phys. | | | % of H.S. taking it. | electives for physics |
|---|---|---|---|---|---|
| | boys | girls | total | no. in H.S. | |
| 1. Alva | 13 | 3 | 16 | 270---6 | Any science |
| 2. Atoka | 4 | 0 | 4 | 140---3 % | all senior boys must take it. |
| 3. Beggs | 1 | 1 | 2 | 120---2 % | any science |
| 4. Boswell | 9 | 0 | 9 | 110---8 " | gen. sc. or domestic sc. |
| 5. Canadian | 1 | 6 | 7 | 30--23 " | general sc. |
| 6. Checotah | 8 | 7 | 15 | 273---5 " | gen. sc. zool. bot. agi. |
| 7. Chickasha | 15 | 25 | 40 | 365--11 " | chemistry |
| 8. Claremore | 9 | 5 | 14 | 260---5 " | any subject |
| 9. Clinton | 13 | 3 | 16 | 215---7 " | gen. sc. agriculture. |
| 10. Collinsville | 3 | 0 | 3 | 109---3 " | agi. domestic sc. |
| 11. Custer | 6 | 9 | 15 | 126---12 | any subject |
| 12. Dewey | 11 | 5 | 16 | 150--11 " | gen sc. agi. |
| 13. Elk City | 6 | 8 | 14 | 243---6 " | any subject |
| 14. Fort Gibson | 5 | 2 | 7 | 75--10 " | all musttake it. |
| 15. Frederick | 17 | 4 | 21 | 305---7 " | boys must take it. |
| 16. Geary | 6 | 11 | 17 | 150--11 " | agi. domestic sc. |
| 17. Grandfield | 7 | 6 | 13 | 126--10 " | any science |
| 18. Granite | 3 | 5 | 8 | 95---8 " | all must take it. |
| 19. Guymon | 7 | 4 | 11 | 170---6 " | gen. science |
| 20. Guthrie | 10 | 16 | 26 | 490---5 " | chemistry. |
| 21. Haskell | 4 | 6 | 10 | 104--10 " | any subject |
| 22. Hollis | 9 | 7 | 16 | 175---9 " | agriculture. dom, sc |
| 23. Kingfisher | 13 | 20 | 33 | 291--11 " | all must take it. |
| 24. Lawton | 15 | 21 | 36 | 570---6 " | chem and botany. |
| 25. Luther | 5 | 10 | 15 | 62--25 " | gen. sc. and adv. math. |
| 26. Madill | 6 | 7 | 13 | 152---8 " | agriculture. dom. sc. |
| 27. Mangum | 24 | 3 | 27 | 225--12 " | all boys must take it. |
| 28. Maysville | 9 | 9 | 18 | 82--22 " | any subject |
| 29. Mill Creek | 4 | 5 | 9 | 52--17 " | physical geo. gen. sc. |
| 30. Minco | 6 | 3 | 9 | 60---15 " | domestic sc. gen. sc. |
| 31. Mooreland | 6 | 5 | 11 | 89--12 " | general science. |
| 32. Mt. View | 12 | 10 | 22 | 126--17 " | all must take it. |
| 33. Muskogee | 64 | 36 | 100 | 1400---7 " | chemistry. |
| 34. Perry | 8 | 5 | 13 | 254---5 " | chem. agi. physiology. gen. sc. |
| 35. Pond Creek | 10 | 5 | 15 | 131--11 " | any subject. |
| 36. Stillwater | 9 | 8 | 17 | 320---5 " | any science |
| 37. Poteau | 7 | 14 | 21 | 194--11 " | all must take it. |
| 38. Prague | 6 | 4 | 10 | 102--10 " | any subject. |
| 39. Okla City | 82 | 22 | 104 | 2000---5 " | any science. |
| 40. Ringling | 4 | 4 | 8 | 125---6 " | gen. science |
| 41. Sallisaw | 3 | 13 | 16 | 125--13 " | any subject |
| 42. Seminole | 6 | 2 | 8 | 114---7 " | will be required next yr. |
| 43. Shawnee | 27 | 4 | 31 | 600---5 " | chem. biology. agi. physiol. |
| 44. Wakita | 8 | 6 | 14 | 87--16 " | gen. sc. normal training. |
| 45. Waurika | 9 | 3 | 12 | 125--10 " | normal training |
| 46. Waukomis | 1 | 5 | 6 | 70---8 " | all must take it. |
| 47. Waynoka | 10 | 2 | 12 | 109--11 " | any science. |
| 48. Yale | 9 | 3 | 12 | 365---3 " | any subject. |
| TOTAL----- | 531 | 362 | 893 | | |

Note that in table I out of 893 students 531 are boys and 362 are girls. For different schools the number of girls range from 0 to 36, the number of boys from 1 to 82. The greatest number of physics students is in Oklahoma City which has 104, and the least number which has only 2 although the high school has 120 pupils. The instructor of Beggs thought it would be best to eliminate physics because there were too few who wanted it. There are twenty-five percent of the schools which have less than 10 students in their physics classes. Twelve percent require physics of all their graduates, while 6 percent require it of their boys. Table I shows that the percent of physics students in the high schools which require physics of all seniors is higher for only a few cases than in schools which do not. The rest have electives varying from agriculture to chemistry.

From figures not shown in the table 45 percent of the schools report more students taking physics this year than last and 27 percent report a decrease. Sixty percent offer physics in the senior year, 5 percent in the junior year alone and 35 percent in both the junior and senior years. The maximum number of hours that students may take when studying physics is 5 hours for 45 percent of the schools and 4 hours for the rest of the high schools. The minimum varied from 2 to 4 hours. Most of the schools require one year of algebra and one of geometry as prerequisites to physics. Three schools had one and one-half years of both. Twenty-five percent of the schools which reported said that their students used algebra well. However, one of these schools made the lowest average over test problems and questions of any school. The pupils did not apply their algebra in working the simple physics problems. Thirty-seven percent of the schools reported that their students had a fair knowledge of algebra and 35 percent wrote that their students did not use the subject as well as they should. This shows that some of the instructors have to teach their pupils the fundamentals of algebra along with physics. I noticed in the tests I sent to the students and in the work I receive from my students, that the great tendency of to-day is to use proportion instead of algebraic equations. Mathematics and physics instructors should work together in order to connect the two subjects,or both courses will prove inefficient. Seventy percent of the instructors said that their students asked a great many questions during the recitation period, and the rest reported only a few or none asked questions.

The conclusions to table I and to the additional facts stated above are:

1.There are nearly 1.5 more boys taking physics than girls.

2.Most of the students when they study physics are seniors, hence their foundation is as good as it could possibly be in high school, but in one third of the schools algebra is poorly used.

3. There is a decrease in the physics classes in over one-fourth of the schools; an increase in one-half.

4.Physics is an elective in 82 percent of the schools.

5.Most students ask questions in physics;they are anxious to learn.

### (b) Results From Tests Sent To Pupils.

In order to determine how well the students were retaining the material as taken up in their textbook, "A First Course in Physics" by Millikan and Gale, I sent a test to each of the students whose schools were mentioned in table I. As these high schools are located in 41 different counties, students from practically all the sections of the state received questions.

I requested the instructor not to help his students with the tests in any way. At the top of the sets for each student were written the following instructions: Do not ask any questions. If you do not understand a question in list go to the next one. If any question includes work which has never been assigned you write "omit" after it.

I believe all the teachers carried out my instructions but one. The lists from one superintendent were practically identical whether right or wrong answers were given. The answers were bookish and very similar, and the grades were much higher than those of other schools. I have had sufficient experience in grading papers to know that students differ very much in their answers, so

I omitted those sets from my report. I received good sets from 310 students who represented 22 schools. An individual student could make as high as 34 points,but since most students omitted one of the questions, I counted 33 as 100 percent. The highest grade was made by Lloyd Moody of Shawnee. He was 17 years old. He answered 29 parts correctly which gives a grade of 87.9. Miss Lola Harris aged eighteen of Luther made 74 percent, the highest grade received by a girl. The lowest grade was made by a boy 21 years old. He answered only one question(3 percent) correctly.

Table II shows the percent that answered each question from each school, the number of papers, and the average percent correct for each question. From the table it may be noted that the average of all students amounted to 38.5 percent. The highest average grade from one school was made by Waynoka. By referring to other data I find that Waynoka had a class of nine boys and seven girls. The grades varied from 39 percent to 79 percent and averaged 60 percent. The instructor was twenty-six years of age. He taught algebra besides physics making fifteen hours of teaching.

He had majored in mathematics and physics while at Oklahoma University and had taught physics three years in the same place. Part of these facts, no doubt, contributed to the success in teaching physics. The lowest average was made by a school whose class ~~class~~ consisted of 8 boys and 7 girls. Their average was 21 percent. The high school had three times as many students as Waynoka. The instructor was tenty-four years of age. He taught arithmetic, general science, zoology and athletics besides physics. He taught 30 hours altogether and had not taught physics before. Nothing was expended on the upkeep of the apparatus which was poor at the beginning. Most of these facts would point toward poor results.

From figures not obtained from the table, I found that the average of the lowest grades from the boys taking one from each school was 21 percent, the girls was 24 percent, the average of the highest grades from the boys was 57 percent, and the girls was 50 percent. These tests, like most tests made with boys and girls, showed that the girls did not reach the extreme in grades either way.

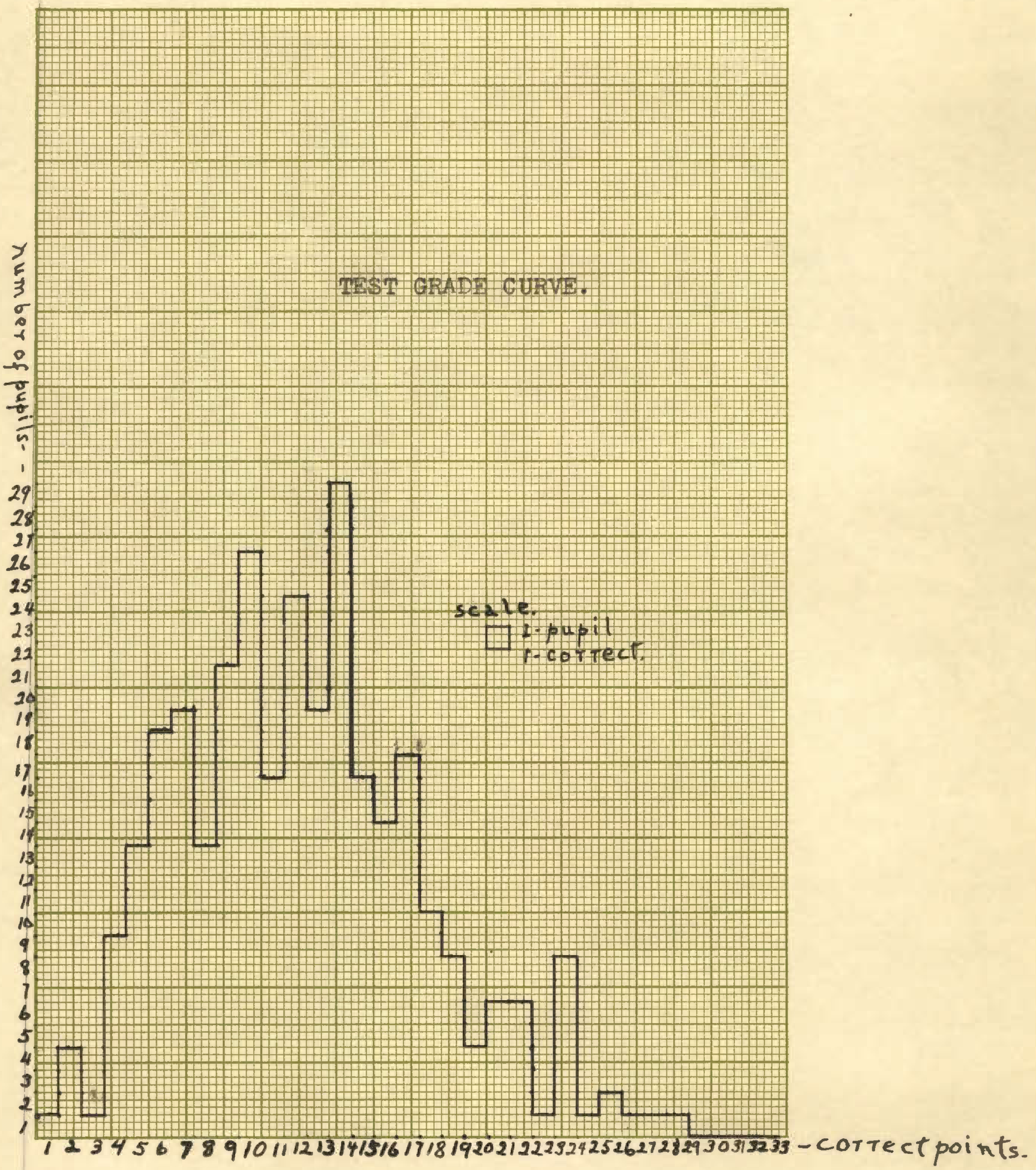


Fig. I.

SURFACE CURVE showing the number of students with number of correct points which they answered.

TABLE FOR FIGURE 1. The Number of Students Making the Different Correct Points.

| no.of correct points made | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| no.of pupils making them | 1 | 4 | 1 | 9 | 13 | 18 | 19 | 13 | 21 | 26 | 21 | 24 | 17 | 29 | 16 | 14 | 17 |

(continuation from above)

| 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 8 | 4 | 6 | 6 | 1 | 8 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The curve shows that 29 students made a grade of 14 points(52 percent). The next highest number of students made 9 (27 percent).

A brief discussion of each question will now be given in order to show the nature of the test and the common errors.

Question 1. A boy exerts a force of 75 pounds. How much work does he do in pushing a truck a distance of 100 feet on a level road if the truck weighs 3000 pounds? This is a simple problem in work and closely connected with the students' experience. The weight of the truck does not enter into the problem but most of the errors were made by multiplying it with the other numbers.

Question 2. A metal ball weighs 100 grams in air and 90 grams when suspended in water. What is the specific gravity of the ball? As five pages in the text is devoted to the principle by which this problem is worked I wished to see how it had impressed the students. The term specific gravity confused many. As shown in Table II only forty-four percent worked it correctly.

Question 3. The area of the large piston in a certain hydraulic press is 50 square inches, that of the small piston is two square inches. What weight can be supported on the large piston if a force of 100 pounds is applied to the small one? Slightly less than half of the students worked it right. It is a practical problem and applies Pascal's Law which has a five-page discussion in the text.

Question 4. A ball rolls down an inclined plane with an acceleration of 20 cm. per second per second. If it starts from rest how far does it travel in 7 seconds? I asked for the equation and answer. Thirty percent got the right equation and 27 percent worked the problem correctly. Many took 980 cm.per sec.per second as the acceleration. The equations varied from $d = a/t$ to $s = gt$.

As over 4 pages are devoted to examples of this nature and as the subject is a practical one the percent who worked it is low.

Question 5. What force is necessary at A in figure to balance the weights on the other side of pivot, neglecting the weight of the bar. All the details were shown by a diagram of a lever and weights. Many tried this problem but only 30 percent worked it right.

Question 6. A cylinder contains 1000 cubic inches of oxygen at a pressure of 50 pounds per square inch. What would be the pressure in the cylinder if the gas were compressed to 250 cubic inches at constant temperature? I asked for the equation and solution. Most of the 25 percent who got the right letters in the problem used proportion as their equation. 39 percent worked the problem correctly,but some got a smaller pressure when the volume was decreased although their reasoning should have told them that the smaller the volume the greater the pressure.

Question 7. Define moment of force. This subject is discussed in one page of their text. The name is misleading. "Moment of force is the energy it takes to move one gram one cm. in one second", wrote one student.

Similar answers show that the term is most vague in the minds of the average boy and girl and should be omitted.

Question 8. Could you exert a force of 10,000,000 dynes without using any machine? This is a good problem at which to guess. Fifty-eight percent answered it correctly. The dyne is a very small unit of force and a term new to students who have not studied physics.

Question 9. Define inertia. It was answered correctly by 52 percent. Answers as the following show that inertia is a thing set off by itself in the minds of many students: "Inertia is the position an object has when not in motion." "It is that which keeps things going in the world." "It is the density of a body that can support its own weight."

Question 10. Name at least one discovery each of the following men gave to the world: Sir Isaac Newton. Michael Faraday. The first part received the highest correct number of any question. Seventy-nine percent of the students remembered Newton by the laws of motion and the falling apple. Faraday who was a more recent scientist and who made the most important scientific discovery of any age received only 17 percent correct answers. Faraday's life is one of the most inspiring in science. Why is there this great ignorance of his life and works? Too much time is spent on unimportant details to study biographies.

Question 11. What does "g" stand for in this equation: $T = 2\pi\sqrt{L/g}$ ? Students experiment with pendulums and prove this equation but they frequently do not know what the letters mean. Only 16 percent answered this correctly. Most said that g stood for grams or gravity.

Question 12. What makes water rise in pumps? Everyone has pumped water but only 41 percent of the pupils knew why the water rose in the pump. These erroneous answers make one wish that more time were devoted to pumps and less time to molecular physics: "Water wets the walls of the pipes and adhering to them is drawn in at the middle as the surface seeks to straighten out, it is pushed constantly upward, aided by suction." "Capillary action causes water to rise in the pump." "The water in the earth is compressed." "Suction caused by the vacuum causes water to rise, for nature abhores a vacuum." This last thought originated with the early Greeks and still persists in clinging to man's mind.

Question 13. Why is it difficult to cook on top of a mountain? The following answers indicate that common occurrences are not stressed enough in the text and in class: "It is hard,because of the enormous pressure." "It is difficult to cook, because of the high boiling temperature." "The air is so dense it is mostly vapor." "The temperature is so dense."

Question 14. Why do water pitchers sweat in summer? Seventy-one percent answered this correctly although there were some very bad mistakes as: "Hot air brings the frost out of the pitcher." "Cold water causes molecules of heat to go to the outside of the pitcher, they are cooled by the time they do this and form on the outside." "The walls of the pitcher allow the water to seep through."

Question 15. Define a calorie. Sixty percent got this alright and there were not many outstanding errors.

Question 16. State briefly how a radiometer works. Most of the students omitted this question. Two percent answered it correctly. Since most of the students who tried to answer it had such wrong ideas concerning the wave theory it would have been better if the theory had never been discussed. A typical answer is: "A radiometer works because heat strikes the polished faces of the vanes which reflect it to the dark side causing the wheel to rotate."

Question 17. How many grams of water at 80° will be required to just melt 5 grams of ice at freezing temperature? This is a simple problem in heat which was solved by one fourth the students.

Question 18. Why does a compass needle point in a northern direction? It, with question 10-a, received the largest correct answers.

Question 19. Define an ampere. Nineteen percent defined it correctly. The definition that they gave, however, does not mean much. "An ampere is that amount of current necessary to deposit .001118 grams of silver per second." What picture can this definition bring to anyone?

Question 20. What is meant by electrical capacity? No one answered this one correctly although it occupies one page in the text. Most of the students answered what the term seems to imply: "The amount of electricity that a wire will hold before sparks will fly from it."

Question 21. When you talk into a telephone transmitter does the sound travel down the wire to the receiver? Fifty-nine percent answered "no", the rest answered it wrong or not at all.

Questions 22, 23, 25 consisted of diagrams of a galvanometer, induction coil and dynamo. The student was to draw an arrow indicating the motion of coil or direction of the induced current. The percentage of correct answers were 25, 37, and 19. The text devotes 14 pages to the discussion of these subjects with complex dynamos, yet only 19 percent could determine which direction the current was flowing in the diagram of the simplest dynamo. If they do not understand the first principles of the simplest dynamo, a coil rotating between two magnetic poles, how can they understand the multipolar alternator and other types discussed in the text?

Question 24. Draw a diagram of an electric bell. Tell why bell rings. Only 13 percent drew plain diagrams; the rest drew meaningless pictures, or none at all. The principles of the electric bell are simple. As most schools have bells for their students to use, more than

36 percent should have known how it worked.

Question 26 and 27 are simple problems in electricity. Sixty-two percent solved the resistance of wires in series alright, 11 percent for wires in parallel, 39 percent knew the equation for Ohm's Law and 24 percent applied it correctly in solving the problem.

Question 28. Give briefly the principles involved in any electrostatic machine. Although 70 percent of the schools owned electrostatic machines, only 10 percent of the pupils answered this correctly. The rest of the answers were vague and meaningless.

Most of the students who answered these tests were in the fourth year of high school; their errors point to one conclusive fact. They are studying too many principles and subjects to learn any well. All of the schools except one used the state-adopted text "First Course in Physics" by Millikan and Gale. Millikan and Gale have chopped up the work into 614 paragraphs. Within these paragraphs are innumerable topics discussed. There are over two hundred and fifty problems and many questions. I found that thirty percent of the schools required the pupils to work 90 percent or more of these problems. Moreover, over 50 percent have only 3-45 minute theory periods per week. Several of these periods are used for tests each month. Even if all the time were devoted to recitations and lectures over the 614 paragraphs and 250 problems, it would be too short for the students to get the work thoroughly. Is it any wonder that the average test grade from 310 papers is as low as 38.5 percent?

The tests from the three hundred and ten students representing twenty-two high schools in the state point to the follwoing conclusions.

1. The students did not use algebraic equations readily.

2. Very bad errors were made in the explanation of simple everyday occurrences. Therefore, more time should be spent on these topics.

3. The average student could not define terms like moment of force and electrical capacity. They have no meaning for the student, and should be omitted from the text.

4. The principles involved in electrostatic machines and radiometers are too complex for high school students to see and remember.

5. The students knew very little about great scientists of the 19th century. Therefore, more time should be spent on inspiring lives.

6. The highes t and lowest grades were made by boys. As a whole they did better than the girls.

7. The high school text covers far too many topics, for the students to get any of the material well in the short school year.

### (e) The Physics Instructors (Personal Interviews).

I will now consider the qualifications of the physics instructors and the conditions under which they were teaching.

I visited the schools at Guthrie, Edmond, Oklahoma City, Cushing, Yale, Stillwater and Pawnee, and had personal interviews with the science instructors of those schools. I found two instructors who like the teaching of physics better than any other work. One was the physics instructor of Oklahoma City and the other was the instructor of preparatory physics at Edmond State Normal.

Mr. Lippincott of Oklahoma City has taught physics for twenty years. He is in the prime of his life being 57 years old. I could catch the enthusiastic ring in his voice as he showed his equipment and explained how he had collected specimens such as ball bearings, or electric light globes that had been used on too high voltages; how he had improved certain pieces of apparatus by ingenious methods; how he had found certain experiments as determining the heat of vaporization unsatisfactory and how he had made substitutions for them. His laboratory was his work-shop for which he gathered materials from every walk of life. He had written parts of his own laboratory notes. He said, "Whenever I find the work not proving satisfactory, I change it."

The instructor at Guthrie was middle-aged too. He was greatly handicapped in his teaching of physics by lack of good equipment, convenient store room, and laboratory rooms. Moreover, besides physics he was teaching chemistry and general science to large classes of students. He had to teach 28 hours per week and tend to the combination store room for physics and chemistry. The physics instructor had previously worked in commercial chemistry and he told me he liked commercial work better than teaching. As Guthrie was planning on a new high school with good equipment, the difficulties under which the teaching staff were working will be removed in the near future.

The physics instructor at Pawnee had taught in the high school there for several years. He liked agriculture better than other subjects, and had specialized in it at college. He said that he cared less for physics than any of his subjects. As he had failed to fill out my questionnaire which I had sent him, I gave him a second one.

However, he neglected to send it to me so Pawnee is not represented in the general report of the schools. During my interview he said, "I suppose you found the laboratory work in the state a joke."

At Yale the instructor had recently been a student in engineering at Oklahoma University. He had taken up the work which Miss Jones had left several months before the close of the school. He showed me the apparatus but was not familiar with many of the pieces. He had been unable to locate complete experimenting sets, and pieces to different machines. He used his handbook in engineering to change dynes into pounds and to make similar transformations. He said that he always liked to explain laws by graphs but he found that the pupils could not follow him. I learned from my visit to Yale that a new instructor must spend much of his time with the apparatus at first, in order to become familiar with all of the pieces. Also, if the instructor does not expect to stay at one place long, he will probably not construct simple pieces nor mend broken ones. As a result valuable pieces of apparatus will often be put away for lack of repair.

The world has produced comparatively few women scientists , but this fact should not cast a shadow upon women's ability as instructors in high school science. I was well pleased with the work Miss Arnold is doing in the physics department at Stillwater. Just two years ago physics was added to the high school's curriculum. During those years Miss Arnold has taught the subject, and under her supervision the department has progressed to what it now is. Miss Arnold is young and progressive. She continues her study of science throughout the summer months. She gave me favorable reports about her science club and about different projects which her students took up during the year. Though she liked chemistry and mathematics better than physics, her attitude toward the latter was optimistic and enthusiastic.

My visit to these schools impressed me with these facts concerning the instructors of physics:

1. Most of the instructors who teach physics prefer other work. If new and successful changes in physics are to be worked out, they will be worked out by the minority who have made physics their life work and who find pleasure in teaching it.

2. Instructors can not do their best work in physics when they teach large sections of other sciences, when they teach over twenty-five hours of mixed subjects, when the equipment and laboratories are inadequate or when they are not interested in the subject.

3. Science instructors should not change schools very often, for time will be wasted and apparatus will wear out rapidly for lack of repair.

## PHYSICS INSTRUCTORS RESULTS FROM QUESTIONNAIRES.

I will now pass from the individual instructor to the group as a whole. The data that follow were taken from the forty-eight questionnaires which I have referred to in previous pages.

TABLE III. SALARY AND POSITION OF PHYSICS INSTRUCTORS.

| | Women instructors | Men (a) superintendents | (b) others |
|---|---|---|---|
| number | 7 | 9 | 32 |
| av.salary | 160 per mo. | 240 per mo. | 187 per/Mo. |
| lowest | 125 " " | 175 " " | 125 " |
| highest | 225 " " | 389 " " | 278 " |

Table 3 shows that the salary is lower for women than it is for men. As a whole the salary is good.

TABLE IV. MAJORS OF INSTRUCTORS AND SUBJECTS THEY ARE TEACHING.

| Major subject | number who majored | subjects taught besides physics |
|---|---|---|
| engineering | 2 | general science; manual training. |
| history | 3 | general science, history; geometry; English,history; gen.sc,mathematics. |
| economics | 2 | chemistry; chemistry. |
| mathematics with some science. | 11 | gen.sc,civics,algebra;history,alg; general sc,agi; normal tr; arith; gen.sc,agi;geometry,algebra,gen.sc; algebra,gensc;gen.sc; manual tr; gen.sc;gen.sc,algebra,geom; algebra. |
| science alone | 4 | gen.sc,zoology,botany,arith;gen.sc, agi,history;gen.sc,history;commercial geo,general science. |
| chemistry and some physics | 7 | chemistry;general sc; botany,gen.sc; algebra,geometry;chem,gen.sc;algebra, geom,gensc; chemistry,geometry. |
| physics | 2 | geom,geography; chemistry. |
| English | 4 | botany;gen.sc;algebra,trig;history, bookkeeping. |
| education | 7 | geom; math; economics; sociology; history; gen.sc,typewriting;gen.sc. |
| language | 1 | natural science,astronomy. |
| law | 1 | gen.sc, history. |
| biology | 1 | biology. |

The subjects which each instructor teaches are separated by semicolons.

All the instructors had college preparation for teaching. Table IV shows what their majors were at college, and what they are new teaching besides physics.

Conclusions from table IV are as follows:

1. High school instructors teach many subjects not related to their major in college.

2. Fifty percent are not teaching their major at all.

3. Fifty percent majored in subjects which are not related to physics.

4. Four percent majored in physics, and 46 percent in some science or mathematics.

From figures not shown in the tables I found the following important information:-
The number of teaching hours for physics instructors vary from 10 to 32. The number of years during which instructors have taught physics vary from 1 to 20, the average being 3.2 years. Fifty percent of instructors taught physics last year and only 86 percent taught it the same place this year as they did last. The number of instructors who teach more than 25 hours per week was 13 or 27 percent. Thirty years was the average age for the physics instructors. There were four who were 22 years old, and the oldest was 57. Twenty percent

were superintendents, 25 percent were athletic coaches, forty-three percent were principals, 29 percent were instructors alone and 4 percent taught nothing but physics. The last ones were the instructors at Oklahoma City and Muskogee.

In regard to the physics preparation, I found that three had not studied physics in any school and that three instructors had studied only high school physics, and that the rest had studied physics in college. The college work varied from one summer course to eighteen or more hours in winter sessions. Forty of the instructors were college graduates. Two of these had M.S. degrees. Twenty-two were graduates from Oklahoma colleges.

In a report of a committee by the National Education Association, the following statement is made: "To give good instruction in the sciences requires of the teacher more work than to give good instruction in mathematics or the languages, and the sooner this fact is recognized by those who have the management of schools, the better for all concerned. The science teacher must regularly spend much time in collecting material, preparing experiments and keeping collections in order, and this indispensable labor should be allowed for in programs and salaries."

As I have stated before, 28 percent of the physics instructors teach more than 25 hours per week. This number of hours should be lessened in order that they can have time to experiment and to carry out all the numerous details which befalls a physics instructor. As a rule the physics instructor should be relieved of coaching duties and administrative work. Since 25 percent were athletic coaches and 20 percent were superintendents, 55 percent should have been quite free to devote considerable attention to physics. However, at least half of these teach more than 25 hours of mixed subjects, and therefore the physics instructor in general has little time to work out better methods of presenting physics. Again I wish to call attention to the fact that the instructor whose school stood lowest in the tests taught five subjects and a total of 30 hours, and that the instructor whose school stood the highest taught two subjects and 15 hours.

The college preparation of instructors is quite good, as was indicated in prededing paragraphs. Although the 12 percent who had studied no physics or high school physics alone should not attempt to teach the subject. Prof. Mather[7] emphasizes this fact, when he wrote the following: "Except in rare instances it is not practicable for one to conduct physics when the only instruction that one has received is of the grade required for a permanent state teacher's certificate. For it is easy to secure the additional training necessary through summer courses from good universities." However, he further adds, "The fact remains that the developments of physical science and the methods of teaching it have been and continue to be so rapid, involving so much detailed knowledge and experience, that it is not practicable or desirable to demand of every teacher specific training in these directions." Although only 4 percent majored in physics 46 percent majored in work closely connected to physics; hence half of the instructors of the state ought to have a good foundation for teaching the subject. To my mind one of the most lamentable facts from the data which followed table IV is that only 36 percent taught physics at the same place this year as last. As long as physics instructors change around so rapidly no systematic laboratory equipment can be built up in many schools.

### (d) Presentation of Physics Theory as Shown by Questionnaires.

I will now present the points which indicate how the theory is taught to the students of the state. As most of the schools attempted to follow all of the discussions as given in their text by Millikan and Gale I found that they had not any time to devote to physics outside of the classroom.

I asked the instructors how many lectures with demonstrations they gave to their class each week. Sixty percent of the instructors stated that they gave from one to three lectures and demonstrations per week. Briefly stated, the following are the outstanding methods of procedure in the different classrooms: Lectures with demonstrations are given each week and these are followed by oral quizzes. The study of the working and operating of simple machines is stressed. Physics is applied as far as possible to farm work. All of the students from one school engage in a free discussion over the material in the text. Problems and projects are worked out to some extent in another class. In two schools demonstrations were given, but the students were not enthusiastic over the work and could not reason well. In one the pupils discussed everything as astronomy. Another instructor had his students make board drawings and report once a month on modern inventions. At Prague the instructor applied physics to everyday experiences in the classroom and had round table discussions with his pupils. Still another school had the pupils demonstrate the material in the text. At Oklahoma City the pupils made short talks on different principles, and they took up a systematic study of the practical problems.

Without a doubt the lecture room and laboratory should form the backbone to physics instruction. All the methods given above show that much time is spent in the lecture room. The one general plan seemed to be to discuss the topics as given in the text. Since students are not getting these topics well as indicated by their test grades, I question the advisability in spending all of the time in classroom discussions and demonstrations. I found that only five schools spent any time in the project method in which the students constructed box kodaks or other simple apparatus, or took trips to industrial centers. Scientific magazines contain many articles advising the instructors in physics to take their classes on visits to see how physics is applied to the industrial world,[8] or to encourage the students in definite projects outside the classroom.[9]

I found that the following had science clubs: Oklahoma City, Chickasha, Waukomis, Stillwater and Lawton. Lawton's club consisted of wireless work.

Most of the schools thought that a science club would be fine to stimulate interest and enthusiasm among the students. Four percent objected on the grounds that there was not time enough, for there were too many dances and theaters for the children to attend, and that the students wanted credit for everything they did. It is my opinion that these objections would vanish if credit was given for faithful work in the club for those who desire credit. Why could not a science club take the place in part of so much light entertainment? Right here is a big opportunity for instructors to help provide other interesting outlets for youth's enthusiasm.

The science club at Stillwater had 30 members. Most of the time they met once every two weeks. Once a month they met in the day time. Two students usually conducted the meeting during one session. The programs in general were lively and entertaining as well as instructive. At one meeting a boy who owned a motorcycle brought it along and showed its important parts and explained how it worked. This one illustration is sufficient to show the nature of the programs. Miss Arnold, the instructor, found the students very enthusiastic in the club.

With the hope that more clubs will be started I will outline briefly "A Science Club in the High School" by Louis C. Feldman.[10]

(a) The benefits derived from a club are: 1. A help to boys and girls to associate with good companions. 2. It instills love for nature and the great outdoors. 3. It furnishes wholesome recreation.

(b) The suggestions for the programs are: 1.Do not make the club a second class by having students read many papers. 2. Have talks by men who are expert in their line. 3.Plan visits to local industrial plants. 4.Take up different projects as the observation of stars, plants, birds and bugs.

(c) The requirements for membership are: 1. A grade of 85 in one subject. 2. An interst in science. 3.Readiness to attend all the meetings. 4. Willingness to take part in programs. Dues of 15 or 25 cents a semester to meet ordinary expenses and to pay for several socials should be collected from the members.

## (e)Physics Laboratory as Shown by Questionnaires.

Reports from the various schools showed that the methods in the laboratory were nearly as rigid as the methods in the classroom. Seventy percent of the schools used Millikan and Gale's Manual. Fourteen percent supplemented the manual with notes of their own. The number of experiments in mechanics, heat, sound and electricity with light and magnetism performed in one year varied from 20 to 44. I stated experiments in these topics which were approved by university men." The number performed by the schools varied as indicated in table V.

TABLE V. VARIATION IN STANDARD EXPERIMENTS.

| Mechanics | Heat | Light | Electricity | Sound |
|---|---|---|---|---|
| 65 to 100°/° | 50-100 | 30-100 | 60 to 100 | 33 to 100 °/° |

The nature of the experiments will be seen by a few of the typical ones below:-

1.Verification of Boyle's law for air. $PV = K$.

2.Verification of the laws of the lever: the law of moments.

3. Verification of Hooke's law of elasticity.

4. Determination of the latent heat of ice.

5. Determination of the conjugate foci of a concave spherical mirror.

6. Measurement of the resistance of two wires by voltmeter and ammeter.

7. Study of the electric bell and dynamo.

Many of the instructors reported that they were hindered by lack of equipment. Some of the instructors took their class on field trips in sound and some studied the Delco lighting system while others constructed radio sets. These last projects in laboratory work show that some schools are taking steps away from theoretical to practical physics.

The table below shows the length of the laboratory periods each week.

TABLE VI. LABORATORY PERIODS.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| length of periods | 2-45 min. | 4-45 | 5-45 | 3-70 | 2-70 | 2-90 | 1-90 | 2-65 or60 |
| °/°taking that no. | 10 °/° | 2 | 2 | 2 | 4 | 58 | 4 | 8 |

The majority give 2-90 minute periods per week which is sufficient time in which to do excellent work.

From other figures I found that 70 perdent of the instructors had their students write up the experiments in the laboratory. The rest had the students take notes or sketches and allowed them to write them up later. I have found by experience that it is best for students to write up their notes immediately after performing the experiments, for the material is fresh in their minds. Moreover, they cannot hand in notes not performed in class nor change the figures to fit the experiment.

Seventy percent expected their pupils to read over the notes before class time. The advantage of this is that the students will work less mechanically and see the experiment as a whole.

The frequency of handing the experiments to the instructors varied with the schools. Eighteen percent of the instructors required the experiments to be handed to them every period, 30 percent once a week, the rest once a month or once every 6 weeks. A few instructors had no set time but called for them at irregular intervals. The first or second method is best but requires more work for the instructors.

Seventy-five percent of the instructors had their students perform the experiments. The rest had the following methods: The aggressive students performed the experiments. The boys did the experimenting. The instructor alone did it all. The instructor aided by the students performed the experiments.

The first method is the only satisfactory method for the real value of the laboratory work lies in the student performing the experiment himself. He should obtain the data with as small an amount of assistance as possible.

In table VII. the number stands for the schools as indicated in table I with the addition of 49 which is Pawnee. Note that where few experiments are run at one time, as a rule, the number of students working in groups is large. Only 30 percent of these schools have students work in pairs, the rest have as high as eleven. This is unfortunate, for even when only two students are working together there is a tendency for one to let the other do more work. The schools that have few students working in groups, run as many as 10 experiments together. While this method is better than the first, too many experiments confuse the instructor.

TABLE VII. Comparison of number of students working in 1 group to number of experiments run at same time for 49 schools.

| School | No.exp.run at 1 time | No. of students in 1 group |
|---|---|---|
| 1 | 1 | 8 |
| 2 | 4 | 2 |
| 3 | -- | -- |
| 4 | 2 | 3 |
| 5 | -- | -- |
| 6 | 5 | 2 |
| 7 | 4 | 2 |
| 8 | 11 | 2 |
| 9 | 2 | 4 |
| 10 | 1 | 3 |
| 11 | 4 | 2 |
| 12 | 1 | 3 |
| 13 | 1 | 6 |
| 14 | 1 | 5 |
| 15 | 1 | 3 |
| 16 | 4 | 3 |
| 17 | 3 | 4 |
| 18 | 1 | 4 |
| 19 | 1 | 11 |
| 20 | 3 | 2 |
| 21 | 1 | 3 |
| 22 | 4 | 2 |
| 23 | 2 | 8 |
| 24 | 1 | 2 |
| 25 | 10 | 2 |
| 26 | 4 | 3 |
| 27 | 4 | 4 |
| 28 | 1 | 2 |
| 29 | 1 | 2 |
| 30 | 1 | 5 |
| 31 | 4 | 4 |
| 32 | 2 | 4 |
| 33 | 2 | 2 |
| 34 | 1 | 6 |
| 35 | 2 | 5 |
| 36 | 2 | 2 |
| 37 | 4 | 3 |
| 38 | 4 | 5 |
| 39 | 1 | 3 |
| 40 | 2 | 3 |
| 41 | -- | -- |
| 42 | 2 | 4 |
| 43 | 3 | 2 |
| 44 | 2 | 5 |
| 45 | 10 | 2 |
| 46 | 4 | 2 |
| 47 | 1 | 6 |
| 48 | 1 | 6 |
| 49 | 5 | 3 |

TABLE VIII. VALUE OF APPARATUS WITH ANNUAL EXPENDITURE.

| schools | annual expenditure | value of app. | °/° lecture app.alone. |
|---|---|---|---|
| 1 | 125 dollars | 250 | 20 |
| 2 | 100 this year | 150 | 10 |
| 3 | ---------- | --- | -- |
| 4 | this yr.all in man | --- | -- |
| 5 | -------- | --- | -- |
| 6 | nothing | --- | -- |
| 7 | 200 dollars | 750 | 10 |
| 8 | 75 " | 250 | 41 |
| 9 | 25 " | 250 | 20 |
| 10 | no.regular am't. | 300 | -- |
| 11 | 100 dollars | 800 | 20 |
| 12 | 50 " | 600 | 33 |
| 13 | 25 for 3 yrs. | 350 | 15 |
| 14 | no def. amount | 150 | 25 |
| 15 | --- | 850 | -- |
| 16 | 50 | 500 | 20 |
| 17 | 150 | 350 | 20 |
| 18 | 40 | 200 | -- |
| 19 | -- | 320 | 10 |
| 20 | approaches zero | 150 | 90 |
| 21 | --- | 300 | -- |
| 22 | 100 this yr. | limited | -- |
| 23 | no definite a m't | 700 | 25 |
| 24 | 100 | 700 | 25 |
| 25 | 175 | 250 | 2 |
| 26 | 25 | 400 | 50 |
| 27 | -- | 900 | 22 |
| 28 | -- | --- | -- |
| 29 | 65 | 900 | 20 |
| 30 | 150 | 1350 | 25 |
| 31 | 50 | 300 | 75 |
| 32 | 500 | 1000 | 25 |
| 33 | 200 | --- | -- |
| 34 | 50 | 500 | 10 |
| 35 | little | 100 | 10 |
| 36 | 150 | 400 | small |
| 37 | 125 | 1000 | 30 |
| 38 | 10 to 100 | 500 | 10 |
| 39 | enough for upkeep | 5000 | small |
| 40 | 100 | 400 | 15 |
| 41 | 10 | 475 | 25 |
| 42 | 75 | 600 | 75 |
| 43 | 350 | 2500 | 50 |
| 44 | 90 | 425 | 20 |
| 45 | 200 | 175 | 25 |
| 46 | --- | 400 | 25 |
| 47 | 50 for 4 years | --- | -- |
| 48 | 300 | 600 | 25 |

Note in table VIII that the amount spent on equipment per year varied from zero to five hundred dollars. The average expenditure for those schools that had stated amounts was 100 dollars. The apparatus for lecture table alone varied from zero to ninety percent of all the apparatus. When only a small amount is available for apparatus, it should not be spent on demonstration apparatus but for laboratory equipment. Twelve percent state that practically nothing was spent for the upkeep of the apparatus.

Other information not found in the table is as follows: The board and superintendent,as a rule, determine how much shall be expended for apparatus. Usually the instructor buys the apparatus, except in a few cases the board or superintendent does the buying. Forty percent use gas in the laboratory work, 62 percent use electricity from the power plant. Twenty instructors wrote that they bought their apparatus from the Central Scientific Co.of Chicago and fourteen chose Welch and Company of Chicago.

I asked Mr. Mapes, the Oklahoma representative of the Welch Scientific Company, how much should be expended for apparatus for twelve students. He with other authorities[12] estimated 300 dollars for apparatus and other equipment. By combining the figures in table I and VIII it is seen that there are seven schools whose apparatus is valued at less than 300 dollars and whose physics class consists of twelve or more students. If 300 dollars is not available for apparatus it would be better not to offer physics as it is taught to-day. In order to see if schools were expending money on elaborate and costly pieces of equipment, I enquired if the schools possessed the following pieces as given in the table. The approximate cost is listed beneath the pieces.

TABLE IX. VARIATION IN ELABORATE DEMONSTRATION APPARATUS.

| wireless<br>20 up | static machine<br>30 to 60 dol. | gyroscope<br>10 to 20 | air pump<br>5 to 45 | proj. lantern<br>55 to 130 | spectroscope<br>12 to 50 |
|---|---|---|---|---|---|
| 17 °/° | 70 °/° | 32 °/° | 66 °/° | 26 °/° | 32 °/° |

Other pieces mentioned by separate schools were: X-ray machines, rectifiers, motion picture machines, microscopes, telescopes. One instructor said they had a projection lantern but no money to buy a Mazda bulb for it. One school had a cream separator, gas engine and electric motor. Seventy-five percent of the funds were expended in demonstration apparatus which is far too high. If the instructor wanted to teach his pupils the principles of the cream separator and dynamo, he could show them these principles by visits to private machines.

Mr. Mapes said that the tendency of high school instructors was to buy some elaborate piece of apparatus for demonstration and to neglect the simple but practical pieces for the students to use. His company was trying to discourage this tendency in order to raise the standard of physics in the country, even though the sales of their apparatus would not be effected either way.

I will conclude my discussion of demonstration apparatus with this statement[13] from Prof. Mather. "For demonstration simple apparatus, largely homemade, is desirable as it stimulates the student's interest and leads to independent thought and study. Highly finished and expensive apparatus is not essential in demonstration and it often distracts the student's attention from the purposes of the illustration and leads him to conclude that polished bras and mahogany are requisites to successful experimenting."

I investigated the possibilities of students making physics apparatus in their manual training work. Sixty percent of the schools taught manual training, 20 percent had the students make some physics apparatus and 54 percent thought the making of apparatus would be advisable. I will state the different reasons given for and against such procedure. The reasons underscored were given by instructors who have actually tried it out in school. The reasons why students should make apparatus in their manual training class are: The apparatus is needed; the students would be more careful with the apparatus in the laboratory; students' ability would be developed and the school helped; interest in physics would be created; pupils become more famaliar with the subject; originality in vocational work is promoted; practical side of physics would be seen; students make many good pieces of apparatus; students become acquainted with the text. The reasons against such methods were: The manual training classes would be overcrowded; apparatus would not be true, accurate nor systematic; time would be wasted and confusion would result.

I conclude that actual experimentation should be continued with the making of simple apparatus in the manual training shops.

Since it would take too much writing for the instructors to describe their laboratories and storerooms in the questionnaires, I can give only a report of this phase of physics from those schools I visited.

## Physics Laboratory as Seen in the Schools.

In one laboratory the students worked at high cement tables originally built for chemistry. They had to be very careful of all the glass articles in order not to break them on the hard stands. A small storeroom at the side contained apparatus for both chemistry and physics. Much of the apparatus was mixed together and was lying in piles on the floor. It reminded me of farm implements rusting under the open sky and rapidly deteriorating for lack of care. All of the balances were broken and the static machine was beyond repair. There was no system nor convenience to the laboratory or to the store room. The apparatus was poor to start with but it was made worse by unnecessary wear and tear.

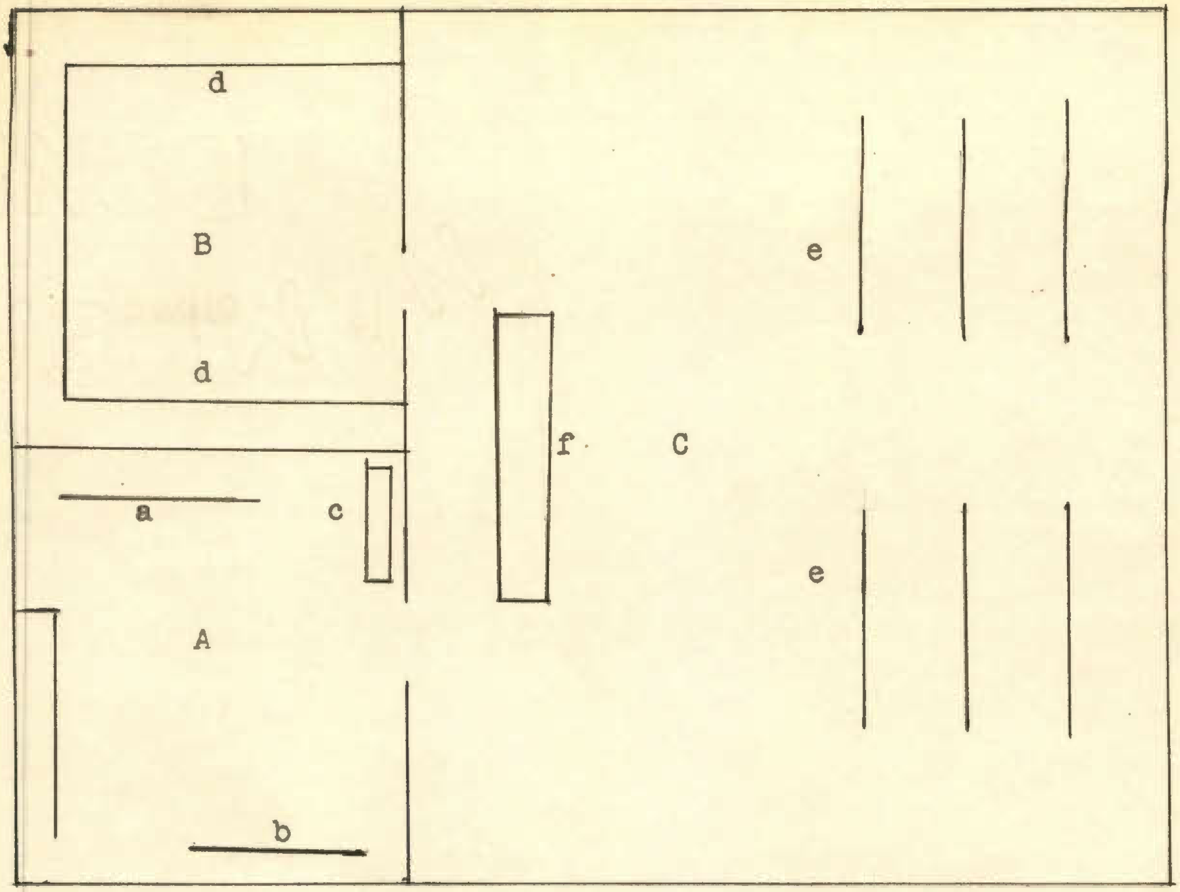
At a second place the apparatus was placed in glass covered shelves in the same room where the laboratory tables were located. The tables were low and arranged conveniently. One course which was stressed was photography. The students took all pictures of athletic events and campus scenes. The walls of one room were covered with the pictures which the students had taken and developed.

The third laboratory which I visited was very inconvenient. As physics was given alternately with other sciences, the instructor had improvised five tables, all different in appearance, for the laboratory work. The instructor appointed the brightest boys to watch the others do the experiments. One of these boys with three other students worked at each table. Usually five different experiments were carried on at the same time. These same boys put the apparatus away in a storeroom which was located over fifteen feet away from the experimenting room. In the storeroom the instructor took down a rubber disk from an electrostatic machine. The disk was badly warped by sunlight. This disk impressed me with two facts, namely, that rubber apparatus should be kept in a dark room and that fewer electrostatic machines should stand around in the physics rooms. Nearly every laboratory I visited contained broken electrostatic machines. Every broken machine means thirty or forty dollars wasted. At their best they are too complex to teach principles in electricity. The instructor was much dissatisfied with the adopted manual. He said that it did not fit his apparatus or the needs of his pupils.

The laboratory at Stillwater contained sufficient tables for sixteen students when they worked together in pairs. When the section was full no more students were permitted to enroll in the subject. The tables had supports above them for fastening pulleys and scales. They were of a convenient height and size for the students to sit at their work. The equipment was kept in two cases, one of glass and the other of opaque material. These stood near the laboratory tables. The instructor prepared the laboratory notes to fit the apparatus. When the students were through with their experiments they wrote their data in good form and drew sketches of the apparatus which they used. Since physics has been in the high school only three years the equipment is not complete. The plan which the instructor has been following is to add more sets each year and gradually build up the equipment. The value of the equipment is approximately 400 dollars and the school is allowed nearly 150 dollars per year. Last year the instructor bought a transformer and next year she wishes to buy a rectifier in order that the students can use electricity in their experiments from the city circuit. This will eliminate the buying of dry cells every year and will save money in the long run. I am sure that this systematic plan will not only build up a course of instruction of increasing strength and value, but it will stimulate the pupils with new interest in the subject.

I visited a new high school building with physics equipment valued at six hundred dollars. The laboratory should have been modern but it lacked every convenience. There was one experiment table for the pupils. Its dimensions were approximately four and onehalf feet in height by seven feet in length. It was so small that the twelve students could scarcely stand around it and see what was going on. Two groups of six worked at the table and they were in each others way. The table had no gas, water, nor electrical fixtures. It was placed in one corner of the classroom, and diagonally across the room from it was located the storeroom. The storeroom was on the side to receive all the sunlight possible.There may be some excuses for old high school buildings to have inconvenient laboratories but there are no excuses for new high schools.

I will end my descriptions of the laboratories after presenting a word picture of the best equipped laboratory which I found. Oklahoma City had one of the best electrically equipped laboratory of any high school in the country. Mr. Lippincott stated that physics instructors frequently wrote to him for the general plans of his storerooms and laboratory. The sketch on the following page shows the general plan of the rooms. Note how compact and convenient they are. Storeroom A contained shelves with glass covered doors. Apparatus for demonstration purposes like electric meters and gas meters. In one corner of this room was a large automatic switchboard. Wires conducted electricity from here to tables for each pair of students to use. If the student carelessly connected up his circuit with a small resistance, so that over six amperes would flow, the switbh would fly open and break the circuit. Near the switchboard was a dynamo with ammeter and changeable resistance.



PLAN OF LABORATORY AND STOREROOMS

OKLAHOMA CITY

A---room for electrical apparatus.

a and b--shelves for electrical apparatus.

c---automatic switch board.

B---dark room.

d--cases for apparatus.

C---laboratory.

e--tables for students.

f--instructor's demonstration table.

It furnished the current for the students and the instructor. The dark room B contained cases with glass fronts. These held most of the experimenting apparatus. The dark room was practically dust proof. No sunlight could enter it and warp the apparatus made of rubber, The tables for instructor and students were in the laboratory

They were of convenient height and size. All of them were equipped with gas, water and electrical fixtures. Lockers in which the students kept their notebooks were in the hall leading from the doorway. In addition to the fine equipment and convenient arrangement of the room, I wish to call attention to the laboratory notes. As the state manual did not meet the requirements of the apparatus, Mr. Lippincott wrote the notes to fit his particular needs. He had the notes printed for his students. In addition to working inside the laboratury the students spend some time in a systematic study of the high school iceplant and of industrial plants.

Although few high schools in the state can afford to spend five thousand dollars on their physics apparatus or even one tenth of that amount, they can afford to have convenient laboratory rooms and good cases in which to keep apparatus.

So much is written about convenient kitchens to save steps for the busy housewife, but when a high school is built I wonder if much consideration is taken to save steps for the physics instructor?

## IV THE FUTURE PHYSICS.

Should physics be eliminated from the high school schedule? In answering this question the great majority answered "no". They gave the following reasons for their answers: Some good is obtained from physics. It is essential and practical. It may help some student to find his niche. It is needed for those students who never go further than the high schools. Students need the scientific knowledge in order to keep up with scientific progress. They need it as a finding course and for college. It furnishes enjoyment for the students. Since considerable money has been expended for the apparatus, physics should be taught. Physics teaches the students to work. It is a hard course but it is interesting and compensating.

The improvements for the course were given as follows: More laboratory room and equipment is needed. There should be more students in the course. There should be better teachers. The instructor should have fewer hours in order that he have time for the care of laboratory.

There should be a more teachable text. Too many topics are taken up in the course. There should be more individuality shown by the pupils in their experimenting. The text is too technical and the course too theoretical. Recitation periods should be longer. The students should have a better foundation for the course. Projects should be given to interest the pupils. The students should have more interest.

These suggestions which the different instructors gave for the improvement of physics in the high school are too brief to show what physics may become in the future. So I will paint a word picture of my dream class in physics. This dream class is based upon the successful efforts and bright hopes of physics instructors of to-day.

In my ideal school the material of the text book dealing with mechanics was based upon seven fundamental principles: (a) conservation of energy. (b) principle of Carnot or degradation of energy. (c) principle of Newton's action and reaction. (d) principle of conservation of mass. (e) least action. (f) relativity.[14]

These principles were illustrated by practical applications. As science progressed some of them were replaced by more important ones. The text book contained only as much material as the student could grasp and thoroughly learn. No more ground was covered in class than what would be of distinct advantage to the student. There was no sudden break in the pupils' experience with the physical world when he began his class work. The instructor touched the plain boy and girl, and not relativity and ether, nor the latest theory on atoms and gases.

Instead of beginning physics with a great number of definitions about cohesion and adhesion, or the meter and gram, the instructor demonstrated examples of work which were quite familiar to the average boy and girl. He attached a spring balance to a cart and pulled it up an inclined plane. He let the pupils take down the readings and compare them to lifting the cart in the air. Several lessons were given concerning the inclined plane dealing with the friction resulting, the use of pulley, and efficiency of the machine.[16] Some of the principles were illustrated with the pendulum, water motor, stoves and burners, model steam engine and Joule's experiment. As a result the student saw that energy is measured in foot-pounds or in British Thermal Units. This knowledge meant more to him than if he said energy is ability to do work. In all cases the problems which were set before the students were worth while. They helped him to acquire scientific methods of solving problems in later life.

The students had time to carry on some well planned projects. They constructed box kodaks[17] when they were studying light. Their wonder was aroused by pictures of outdoor scenes caught on a screen in a darkened room. In the study of electricity the students collected worn out bulbs, and constructed simple Leyden Jars. Definite projects cut down the expense for equipment. As moment of force and electrical capacity with many similar topics were not given in the text nor discussed in class, there was time to make visits to important industrial centers. Visits were made to iceplants, telephone offices, heating plants in school and homes, to farm houses that had water rams or other appliances. The students enjoyed the trips, and caught visions of scientific progress.[18] They saw that physics existed everywhere. Each student studied the refrigerators and electrical appliances in his home. The principles of sound were made plain by violins and flutes which the students brought to class.

The class work and laboratory were knit into a well coordinated, simple and unified course. The experiments furnished the student with concrete examples and helped him to utilize facts. The answers to his problems could not be obtained without measurements or experiments in the laboratory. Some of the problems were: 1. What kind of coal in your town gives the greatest number of heat units per pound? 2. Can you construct a telescope with spectacle lenses? 3. In your town is it cheaper to light houses by electricity or gas? 4. What is the dew point to-day? There were no problems to prove like $PV = K$.[19]

The instructor taught twenty hours of work. He had so many pupils in physics that he taught only one other subject and that was mathematics. The instructor knew the practical as well as the theoretical. He felt that his position was permanent so he built up a fine department and looked for all possible points of interest to show his pupils. The parents worked in the science club along with their children. They gave their youngsters pulleys and electric motors, and told them stories of drewdrops and water rising in pumps. It was not long before the instructor had to teach deeper subjects, therefore the problem which he had solved some years previous required his energies again, but he was not hampered by fixed customs nor by administration; hence he extended his research to new fields.

It is a dream but it is workable and holds untold possibilities.

When all is said and done, is it any wonder that students become bewildered and then discouraged when their introduction to physics consists of a ten page discussion of the meter, kilogram and liter, of density and specific gravity, followed by page after page of new terms and theories? To make this fact more impressive I will use a crude illustration.   I am going to take a trip around the world. I board a lightning express and whizz past scenes and cities. A guide stands at my side and continually points to important views, interesting and beautiful. From the Pacific coast I enter an aero-plane and fly to undreamt of heights. Dizziness and faintness overcome me, and I am glad when I land in Japan. Knowing no other language except English, I have difficulty in making myself understood or in understanding the natives. I catch onto the meaning of a few words but the time is up and I continue my groping through China, India and France. I catch glimpses of castles and cathedrals, of mountains and vast plains, but I have no time to visit any of these. My guide is too busy to explain anything in detail, and he is oftentimes hampered by lack of words and facts. I arrive home nearly exhausted wondering if it were worth the money and effort. I sit down to write of my impressions but they are vague and confused. My conclusion is, no more traveling like that for me.

The student takes a trip through a world of science which it has taken mankind 300 years to construct. His guide-book is written by explorers who have spent most of their lives in that world. He is confused with so many new terms and with the vastness of it all.

He is hurried past facts and theories. His imagination must follow the waves of the ether, and it must contract to fit molecules of matter. At the end of nine short months he has completed his trip. Has it been ~~worth-~~ worth while? Yes, if he has been filled with the wonder and beauty of science, and desires to continue to seek into its truths and hidden possibilities. No, if he is merely dazed and disgusted with the infinite number of apparently unrelated facts, and warns others not to try the venture.

The great question is *can the trip through science be made more worth while*. If this discussion will help some instructor to catch a vision of future possibilities in physics, and make him dissatisfied with inadequate methods of the present teaching of physics, so that he will devote some time to careful research work, it will have served its purpose.

## SUMMARY OF IMPORTANT CONCLUSIONS.

I. A text book should be adopted to fit the needs of the pupils, for they are not getting the material well in the present text.

II. The goal of physics instruction should be NOT HOW MUCH BUT HOW WELL.

III. Physics should be more practical and less theoretical.

IV. Demonstration work is fine in the state. It should be supplemented with projects and trips to industrial plants to awaken interest in physics.

V. More science clubs should be organized.

VI. More money is needed for laboratory equipment, cases, and convenient laboratories; and less for elaborate demonstration apparatus.

VII. Experiments should be continued in the manual training department with the construction of simple physics apparatus.

VIII. The teaching hours of many of the physics instructors should be lowered.

IX. Physics instructors should not change schools often.

X. More teachers are needed who are anxious to work out better methods for teaching physics.

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