

**A STUDY OF THE CONTENT OF THE LABORATORY
COURSE IN HIGH SCHOOL PHYSICS.**

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PROBLEM.

The purpose of this investigation is to ascertain (1) the relative frequency with which various laboratory exercises in high school physics appear in widely used laboratory manuals, and (2) the relative importance of these experiments as indicated by judgments of competent experts—teachers of physics in high schools, colleges, normal schools, and universities, and teachers of college, normal school and university courses in the teaching of science and in the teaching of physics.

METHOD.

All the laboratory exercises found in the following eight laboratory manuals in high school physics were listed with the number of manuals in which each exercise appeared. The eight manuals were:

1. Fuller, Brownlee. *Laboratory Exercises*. New York. Allyn and Bacon, 1913.
2. Conrad, H. E. *Physics Manual and Laboratory Notebook*. New York, Mentzer, Bush and Co.
3. Black, N. Henry. *Laboratory Manual in Physics*. New York, The Macmillan Co., 1923.
4. Good, Frederick. *Laboratory Projects in Physics*. New York, The Macmillan Co., 1920.
5. Chute, Horatio N. *A Laboratory Guide to Accompany Carhart and Chutes Physics*. New York, Allyn and Bacon, 1913.
6. Millikan, Robert A.; Gale, Henry Gordon; Bishop, Edwin Sherwood. *A First Course in Laboratory Physics for Secondary Schools*. New York. Ginn and Company, 1914.
7. Dull, Charles E. *Laboratory Exercises in Physics*. New York, Henry Holt and Co.
8. Henderson, W. D. *Laboratory Exercises in Physics*. Chicago, Lyons and Carnahan, 1924.

The complete list of experiments grouped into the five familiar classifications; mechanics, heat, light, sound, electricity and magnetism, but without the numbers indicating their frequency of appearance in the eight manuals, was sent to several hundred experts for evaluation. Through the cordial cooperation of

professors conducting courses in the teaching of science and in the teaching of physics in the summer sessions of a number of the great universities and teachers colleges, a sampling was secured of individuals representing all parts of the country.

Following an explanation of the nature and purpose of the investigation, these instructions were given for marking the exercises:

Please mark each exercise 1, 2, or 3, respectively, to indicate whether you consider that exercise to be (1) essential in a one-year high school course in physics, (2) merely desirable if time permits its inclusion, or (3) undesirable in such a course.

At the end of each group, spaces are provided in which you may write the titles of other exercises which are not in the list but which you think should be included in a high school course in physics.

The marker was asked to indicate whether he was a teacher in high school, college, university, or normal school. The failure of many to do this, makes it impossible to indicate the number of judgments contributed by the various groups of teachers.

Judgments were received from ninety-one different individuals.

FINDINGS.

1. There is considerable diversity of opinion both among the authors of the laboratory manuals and these teachers of physics, regarding what exercises should constitute the laboratory course in high school physics. Of the 175 exercises included in the complete list, none were considered *essential* to the course by all the evaluators, and only 4 appeared in all 8 laboratory manuals. Table I, however, lists 25 exercises which appeared in more than half the manuals analyzed and which were considered essential by more than half the evaluators. To this list, moreover, may be added the 11 exercises of Table II, all of which appeared in more than half the manuals and only one of which has an average rating value of more than 2.00; and also the 20 exercises in Table III, which were considered essential by more than half the evaluators. A rich laboratory course could be selected from the 56 exercises in these three tables. Further choice of selection is offered from the exercises having the highest average rating values in Table IV.

2. Since only two exercises were added by the evaluators to the list secured from the analysis of the laboratory manuals, it seems reasonable to conclude that the combined list of exercises from all the manuals contains the laboratory exercises which are

appropriate to the subject and which are acceptable to these evaluators.

3. Seventy-three exercises appeared in not more than one of the eight manuals. Tables III and IV indicate, however, that 6 of these were considered *essential* by more than half the evaluators, and that 35 were considered *desirable* by more than half the evaluators.

4. Only one exercise, *Latent heat of fusion*, was evaluated by all 91 evaluators. It is interesting to note in Tables III and IV, that in general those exercises which appeared in few of the manuals were evaluated by relatively few of the evaluators.

TABLE I. LABORATORY EXERCISES IN PHYSICS APPEARING IN MORE THAN HALF THE LABORATORY MANUALS AND CONSIDERED ESSENTIAL BY MORE THAN HALF THE EVALUATORS.¹

Title of Exercise	Number of Manuals	Number of Ratings	Average Rating Value
Mechanics			
1. Specific gravity of heavy solids.....	6	87	1.04
2. The lever.....	6	83	1.06
3. Inclined plane.....	8	86	1.11
4. Archimedes' principle.....	6	47	1.16
5. Specific gravity of light solids.....	6	86	1.19
6. Hooke's Law.....	6	87	1.21
7. Resultant of two forces at an angle.....	7	51	1.27
8. Boyle's law.....	6	87	1.28
9. Pendulum.....	7	87	1.39
10. Parallel forces.....	7	51	1.47
Sound			
1. Laws of vibrating strings.....	7	86	1.34
2. Velocity of sound.....	6	85	1.43
Light			
1. Image in plane mirror.....	7	87	1.08
2. Refraction (glass).....	7	87	1.23
Heat			
1. Specific heat.....	7	87	1.08
2. Latent heat of fusion.....	8	91	1.20
3. Humidity.....	5	84	1.25
4. Zero point of thermometer.....	7	82	1.36
5. Heat of vaporization.....	7	85	1.36
6. Boiling point on thermometer.....	7	50	1.42
7. Coefficient of expansion of solids.....	7	86	1.48
Electricity and Magnetism			
1. Lines of force about a magnet.....	6	87	1.16
2. Voltaic cell.....	5	86	1.17
3. Magnetic effect of a current.....	5	27	1.26
4. Dynamos and motors.....	5	69	1.33

¹It would be impossible for an exercise to have an *Average Rating Value* below 1.50 if fewer than half the evaluators rated it as essential (1.00)

TABLE II. LABORATORY EXERCISES IN PHYSICS APPEARING IN MORE THAN HALF THE MANUALS BUT CONSIDERED ESSENTIAL BY FEWER THAN HALF THE EVALUATORS.

Title of Exercise	Number of Manuals	Number of Ratings	Average Rating Value
Mechanics			
1. Pulley.....	7	82	1.62
2. Weight of lever (Principle of Moments).....	6	83	1.56
3. Specific gravity by hydrometer.....	5	85	1.58
4. Laws of friction.....	5	84	1.96
5. Area of a triangle.....	5	50	2.20
Sound			
1. Frequency of vibration of tuning fork.....	6	87	1.63
Light			
1. Photometer.....	8	85	1.58
2. Refraction (water).....	7	50	1.72
3. Telescope and microscope.....	7	86	1.67
4. Concave mirror.....	5	84	1.51
Electricity			
1. Resistance by Wheatstone bridge.....	8	51	1.88
2. The electroscope.....	7	70	1.74

TABLE III. THE LABORATORY EXERCISES IN PHYSICS APPEARING IN FEWER THAN HALF THE MANUALS BUT CONSIDERED ESSENTIAL BY MORE THAN HALF THE EVALUATORS.

Title of Exercise	Number of Manuals	Number of Ratings	Average Rating Value
Mechanics			
1. Efficiency of machines.....	1	51	1.21
2. Barometer.....	3	66	1.84
3. Comparison of English and metric units.....	3	51	1.43
4. Volume of irregular body.....	3	51	1.49
Sound			
1. Length of sound wave.....	3	87	1.43
2. Resonance.....	3	51	1.49
Light			
1. Images formed by lens.....	4	50	1.32
2. Laws of reflection.....	4	45	1.35
3. Dispersion of light by prism.....	3	51	1.39
4. Focal length of a lens.....	1	50	1.42
Electricity			
1. Induced currents.....	4	86	1.18
2. Electrolysis.....	1	52	1.21
3. Grouping of cells.....	3	51	1.33
4. Resistance by voltmeter-ammeter.....	3	84	1.34
5. Electrotyping.....	1	51	1.35
6. E. M. F.....	3	34	1.35
7. Ohm's law.....	1	86	1.38
8. Storage battery.....	2	51	1.39
9. Electric bell.....	1	51	1.39

TABLE IV. LABORATORY EXERCISES NOT INCLUDED IN TABLES I AND III, WHICH ARE GIVEN AN AVERAGE RATING VALUE BETWEEN "ESSENTIAL" AND "DESIRABLE."

Title of Exercise	Number of Manuals	Number of Ratings	Average Rating Value
Mechanics			
1. Wheel and axle.....	3	50	1.54
2. Specific gravity by bottle method.....	4	87	1.53
3. Specific gravity by loss of weight.....	3	51	1.58
4. Specific gravity of liquid by balancing columns.....	1	51	1.62
5. Acceleration of gravity.....	1	51	1.64
6. Capillary action.....	1	51	1.70
7. Centrifugal force.....	1	51	1.74
8. Protractor.....	3	82	1.74
9. Use of chemical balances.....	4	85	1.74
10. Vernier caliper.....	3	83	1.77
11. Micrometer caliper.....	3	86	1.79
12. Volume of regular solids.....	1	51	1.80
13. Acceleration of motion.....	1	62	1.80
14. Forces acting upon simple truss.....	1	50	1.84
15. Weight of 1 cc. of water.....	1	51	1.88
16. The linear scale.....	1	50	1.92
17. Force at center of gravity.....	1	50	1.92
18. Lift pump and force pump.....	2	51	1.92
19. Law of floating bodies.....	2	49	1.93
20. Weight by substitution and balancing.....	2	49	1.95
21. Relation of depth to pressure.....	3	51	1.96
22. Weight of a liter of air.....	2	51	1.98
23. Density of air.....	3	51	1.98
Sound			
1. Interference of sound waves.....	1	50	1.80
Light			
1. Color.....	1	51	1.66
2. Spectra.....	1	49	1.69
3. Illuminating and lighting.....	1	51	1.74
4. Optical disc.....	1	50	1.90
5. Conjugate foci.....	1	50	1.92
6. Total reflection.....	2	51	1.96
Heat			
1. Coefficient of expansion of a gas.....	4	51	1.70
2. Boiling and melting points.....	3	49	1.73
3. Effect of solution upon temperature.....	2	51	1.76
4. Steam engine.....	1	51	1.78
5. Conduction of heat.....	1	51	1.78
6. Gasoline engine.....	1	51	1.78
7. Mechanical equivalent of heat.....	1	67	1.80
8. Law of heat exchange.....	2	65	1.84
9. Effect of solids in solution upon boiling point.....	2	51	1.90
10. Increase in volume at constant pressure.....	1	51	1.94
11. Effect of heat upon density of water.....	1	51	1.94
12. Increase of pressure of gas at constant volume.....	3	51	1.96

13. Heat changes through solution and evaporation.....	1	50	1.96
14. Boiling phenomena.....	2	70	1.97
Electricity			
1. Heating effect of a current.....	4	85	1.51
2. The telephone.....	1	51	1.51
3. Rheostats and resistance.....	1	86	1.52
4. Electric light and power.....	2	48	1.58
5. Alternating current.....	1	51	1.60
6. Electroplating.....	1	51	1.62
7. Polarity of a magnet.....	3	51	1.64
8. Resistance of conductors in series and parallel.....	1	51	1.64
9. Telegraph instruments.....	1	51	1.68
10. First law of magnetism.....	1	50	1.68
11. Fall of potential along a conductor.....	2	51	1.70
12. The shunt.....	3	51	1.70
13. Efficiency of electric motor.....	3	52	1.72
14. Study of incandescent lamps.....	2	51	1.72
15. Internal resistance of a cell.....	3	87	1.78
16. Polarization and recovery.....	1	51	1.80
17. Molecular nature of magnetism.....	1	51	1.86
18. Static electric effects.....	1	52	1.86
19. Wireless.....	1	53	1.86
20. Magnetic strength.....	2	51	1.88
21. Effect of temperature on resistance.....	2	51	1.92
22. Magnetic substances.....	1	50	1.94

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

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In defense of accuracy we must be zealous, as it were, even to slaying.—*P. G. Tait.*

Extinguished theologians lie about the cradle of every science, as the strangled snakes besides that of Hercules.—*Thomas Henry Huxley.*

. . . behind all your practical applications, there is a region of intellectual action to which practical men have rarely contributed, but from which they draw all their supplies. Cut them off from this region, and they become eventually helpless.—*John Tyndall in "Lectures on Light."*

Why is an object seen erect when its image on the retina is inverted? In answer to this question the equally sensible question is sometimes asked: when one hears a baby cry with two ears, why does one not take it for twins?—*Wm. S. Franklin and Barry MacNutt in "A Calendar of Leading Experiments."*

Say first, of God above or man below,

What can we reason but from what we know?

—*Alexander Pope, "Essay on Man."*

"Sperrit? Well, maybe," he said. "But there's one thing not clear to me. There was an echo. Now, no man ever seen a sperrit with a shadow; well, then, what's he doing with an echo to him, I should like to know? That ain't in natur', surely?"—*Long John Silver, in Stevenson's "Treasure Island," attempting to quiet the fears of his superstitious accomplices, who think they hear the ghost of the terrible Captain Flint.*