Some Experiments with a Simple Jolly Balance.

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In presenting a paper of this kind before the Academy of Science I think it is well to point out that the research work of the high school teacher must be "re"search work indeed—must be research work backward instead of forward. If I might be allowed to read you a parable I should remind you that some fifty, or perhaps sixty, years ago our grandfathers came to Indiana to do research work of a bread-winning character. But those grandparents had brothers, who, through necessity or lack of years, were compelled to stay at home and take care of the real little folks. I take it that the same thing is true of the members of this Academy. Some, usually those of the colleges, are able to do research work. Others, particularly those of the high schools, must expend their energies in the perfecting of details.

Those of us that remember our college course in Physics hold the old Jolly balance, with which we wrestled, in much awe. Certainly no piece of apparatus could be more perverse. The spring being stationary at the top and entirely free at the bottom would take its time in coming to rest and its distance from the meter stick gave parallax an excellent opportunity to do its worst. Further, as the spring stretched the table must be moved, and the table was usually stuck. It is easy to see *now* that the conversion of the Jolly balance from a rogue to a useful citizen depended upon some device for stretching the spring "up" from a stationary bottom instead of "down" from a stationary top. It is the purpose of this paper to explain one such device and to present data showing the accuracy that may be obtained by using it.

The base of the balance is a Sapolio box 6x9x12-in. mounted on leveling screws and weighted with a brick. To the front of the box is screwed an upright standard four feet long. This standard is made by nailing to the face of a piece of poplar ½x2-in. two strips ¼x1½-in. leaving a groove between them 1-in. wide and ¼-in. deep in which a meter stick may slide freely. To the upper end of the meter stick is fastened a string which runs over a pulley at the top of the standard. The other end of this string is tied to the end of a large horizontal screw which runs through the side of the box with sufficient friction to hold the meter stick in any desired position. From the top of the meter stick at right angles to it projects an arm two inches long to the end of which the spring is attached. From the lower end of the spring is suspended an indicator of the form shown in figure I, with the usual pans below. The shelf shown in figure I upon which the point of the indicator rests when not in use is made of sheet brass and is fastened to the column one foot from the lower end. Tacked to one of the side strips immediately below this shelf so that it projects over the meter stick slightly is a small metal plate

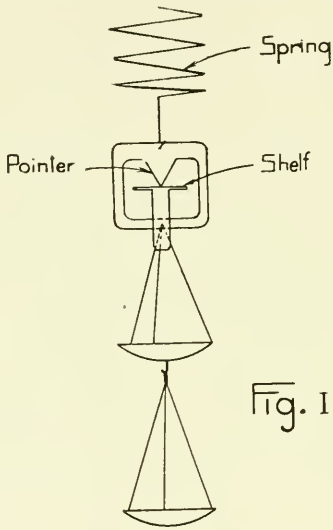

Fig. I

bearing a horizontal scratch. The distance from the top of the meter stick to this scratch can be read with considerable accuracy to the tenth part of a millimeter. Below this shelf slides a table upon which vessels of water, etc., can be placed. To use the apparatus the spring must first be calibrated. Incidentally, Hooke's law may be verified. To do this a reading of the distance from the top of the stick to the scratch is taken when the spring is so adjusted that the pointer barely swings clear of the shelf, no load being in the pans. A load of one gram is then added and the spring is stretched,—by raising the meter stick with the before mentioned cord and screw—until the pointer clears the platform again. The distance from the top of the meter stick to the scratch is again read. The difference between the two readings gives the elongation for a load of one gram. For ordinary work this elongation should be about five centimeters. With such a spring it is seen that a load of .002 grams will cause an elongation of .1 of a millimeter.

The following tables of data and results obtained by using this simple Jolly balance are self explanatory. They are given not because of any new principle contained in them, but because of the extreme accuracy shown—accuracy seemingly out of all proportion to the care with which the apparatus was constructed.

Hooke's Law and the Modulus of the Spring.

Load.	No Load Reading.	Reading with Load.	Elongation.	E/L.
1 g.	54.96 cm.	60.14 cm.	5.18 cm.	5.18
2	54.96	65.33	10.37	5.18(5)
3	54.96	70.51	15.55	5.18(3)
4	54.96	75.66	20.70	5.17(5)
5	55.00	80.90	25.90	5.18(0)
	Modulus = L E = .193.		Mean	5.180

Density of a Steel Bicycle Ball.

No Load.	Load.	Elongation.
54.97 cm.	83.95 cm.	28.98 cm.
54.97	83.93	28.96
55.00	83.97	28.97

Mean elongation = 28.97.

Mass = elongation × modulus = 5.591 g.

Diameter by micrometer screw caliper = 1.1115 cm.

Volume .7189 cc.

Density = M V = 7.78 g. per cc.

Principle of Archimedes.

Ball in Air.	Ball in Water.	Decrease.
82.98 cm.	79.32 cm.	3.66 cm.
82.99	79.30	3.69
83.00	79.34	3.66

Mean decrease in elongation = 3.67

Loss of weight in water .708 g.

Volume of ball from preceding experiment .718 cc.

Volume of water displaced by the ball .718 cc.

Weight of water displaced by the ball .718 g.

The weight of the water displaced by the ball differs from the loss of weight by 1.4 %. The accuracy may be increased by using aluminum instead of steel.

Specific Gravity of an Irregular Solid.

No Load.	Aluminum in Air.	Aluminum in Water.
54.07 cm.	88.36 cm.	75.70 cm.
54.07	88.38	75.69
54.08	88.38	75.69

Elongation in air 34.31 cm.
Elongation in water 21.62 cm.
Decrease in water 12.69 cm.
Specific gravity of aluminum 2.70.

Specific Gravity of Solids Lighter than Water.

No Load.	Paraffin in Air.	Paraffin and Aluminum in Water.
54.01	67.23	73.39
54.01	67.25	73.37
54.00	67.24	73.38

Elongation due to paraffin in air 13.23 cm.
Elongation due to both in water 19.37 cm
Elongation due to aluminum in water 21.61 cm.
Elongation due to paraffin in water —2.25 cm.
Loss by paraffin in water 15.48 cm.
Specific gravity of paraffin = .854.

Specific Gravity of Liquids.

No Load in Ether.	Aluminum in Ether.
54.26 cm.	79.01 cm.
54.26	79.00
54.27	79.00

Elongation due to aluminum in air 34.31 cm.
Elongation due to aluminum in ether 24.74 cm.
Decrease in ether 9.57 cm.
Decrease in water 12.69 cm.
Specific gravity of ether .754.

Besides these, two other experiments can be performed in a very satisfactory manner, namely, "The Surface Tension of Water" and "The Distribution of Magnetism in a Bar Magnet."