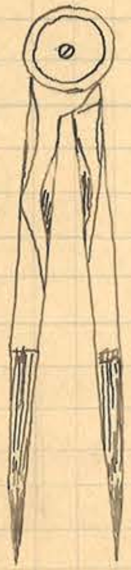
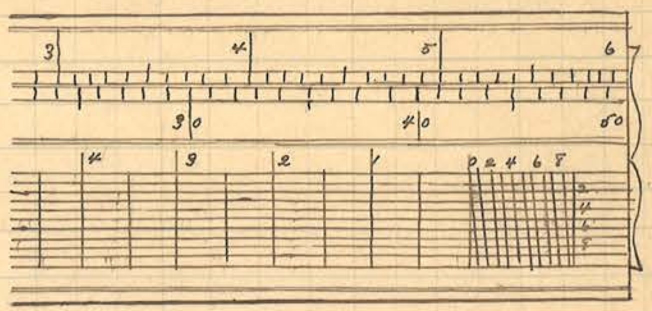




A Diagonal Scale.

A pair of dividers is merely a pair of compasses with fine steel points.

A pair of Dividers.

A diagonal scale is a scale of equal parts, having eleven equidistant parallel lines running lengthwise of the scale, and divided into a number of equal parts by perpendicular lines. The distance between two consecutive perpendicular line is the unit of the scale, and is usually $\frac{1}{2}$ in., 1 in., 1 cm., or 2 cm. This unit at one end of the scale, on both the first and the eleventh horizontal line, is subdivided into ten equal parts, and these points of division are joined by diagonal lines. These slanting lines are $\frac{1}{10}$ of the scale unit apart; and each one intersects a horizontal line at a point nearer to or farther from any perpendicular line than the adjacent line by $\frac{1}{100}$ of the scale unit. The diagonal scale, therefore, reads to hundredths of the scale unit.

Sept 11, 1900. Ex. 1.

Card - 5.

Problem 10.

Apparatus: – A pair of Dividers, A diagonal Scale.

To measure the distance between two points formed by intersecting lines.

Method: – Open the dividers and place one of its points exactly on one of the given points, and the other point on the second given point. Then place one of points of the dividers on one of the divisions of the scale so that the other point of the dividers will fall on 0 or between 0 and the vertical line bounding the scale. The scale-reading multiplied by the value of the scale unit, will give the distance.

1st measurement.	2.54
2d. " " "	2.55
3d. " " "	2.64
4th. " " "	2.54
5th. " " "	2.54.
Mean.	2.562.

Value of scale unit $\frac{1}{4}$ inch.

Distance between the points – 1.6268 cm.

Sept 13, 1900. Ex. 2.

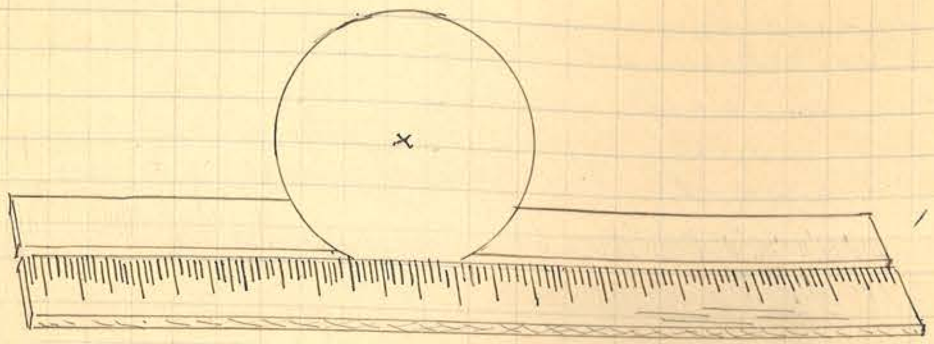
Problem 11.–

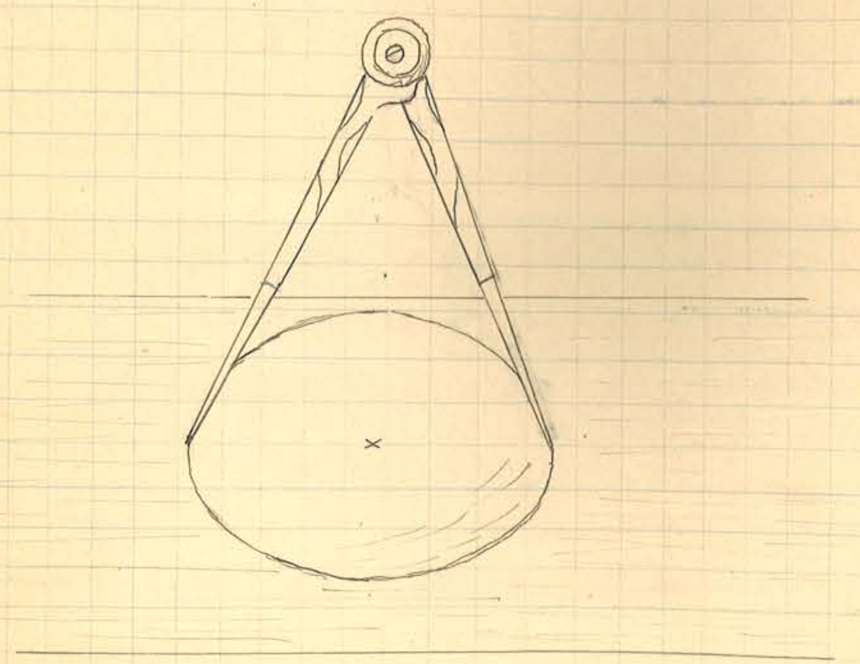
Apparatus: – A Metre-rod, a needle, and a plane faced block of wood.

To measure the length and the breadth of table, employing both the English and the metric measure.

Method: – Apply the scale to the object to be measured. The face of the wooden block, held against the edge of the table, will indicate the point at which the measurement should begin and terminate. The needle marks the intermediate points.

	Length,		Breadth.	
1st measurement.	244 cm	96 in.	90.3 cm	$35\frac{1}{2}$ in.
2d.	243.9 "	$95\frac{3}{4}$ "	90.2 "	$35\frac{3}{8}$ "
3d.	243.8 "	96 "	90.1 "	$35\frac{1}{2}$ "
4th.	244.	96 "	90.3 "	$35\frac{3}{8}$ "
Mean.	243.925 cm,	95.937 in,	90.225 cm,	35.437 in
Reduced.	243.68 cm,	96.003 in,	90.01 cm,	35.52 in
Difference	.243 cm	.046 in	.213 cm	.043 –





Sept 18 20 Ex. 3.

Problem 12.- Cards - 5 - 8.

Apparatus, - A pair of dividers, a linear scale, two metre-rods, a sharp knife-blade, and cardboard.

To find the ratio of the circumference of a circle to its diameter.

Method:- Measure the distance of the diameter with the dividers as in Problem 10. Make a mark on the circumference, hold the disk vertically with the mark exactly on a known division of the metre rod, and roll it along on the rod till the mark is again in contact with it. The difference between the two positions of this mark will be the circumference. A second metre-rod should be used as a guide in rolling the disk along a straight line.

Card 5.

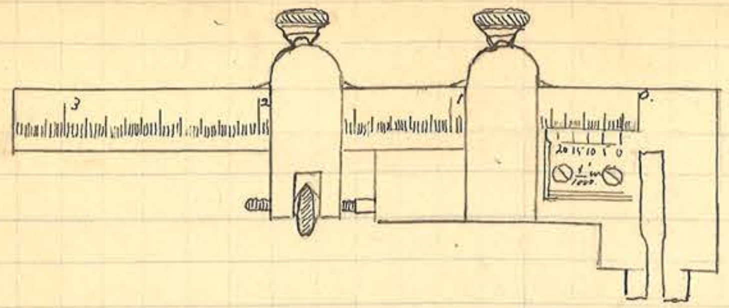
	Circumference		Diameter.	
First Measurement	38.2 cm	14 5/8 in	12.5 cm	4 7/8 in
Second " "	37.9 cm	14 15/16 "	12.4 "	4 15/16 "
Third " "	38.3 "	14 11/16 "	12.5 "	4 15/16 "
Mean.	38.13 cm	14.75 in	12.46 cm	4.91 in

Computed ratio 3.061 cm, 3.0081 in. True Ratio - 3.1416.
Amount of error .0815 cm, .1335 in. Per cent of error = .022, .042

Card 8.

	Circumference.		Diameter.	
First Measurement.	33.5 cm.	13 3/16 in	11 cm	4 3/16 in
Second " "	33.8 "	13 1/4 "	10.9 "	4 1/4 "
Third " "	33.8 "	13 5/16 "	10.9 "	4 5/16 "
Mean.	33.89 cm.	13.33 in	10.93 cm	4.29 in

Computed ratio 3.1006 cm, 3.1095 in. True ratio 3.1416.
Amount of error .0410 cm, .0325 in. Per cent of error. .013, .012.



The Verniered Steel Caliper.

This caliper is provided with a slow-motion screw. The movable scale or vernier is usually constructed so that n of its divisions equal n-1 divisions of the limb or bar. In that case, each vernier division is $\frac{1}{n}$ of a limb division shorter than each limb division. If each limb division is $\frac{1}{50}$ of an inch and 19 limb divisions equal 20 vernier divisions, then each vernier division is $\frac{1}{20}$ of a limb division shorter than each limb division, or $\frac{1}{20}$ of $\frac{1}{50} = \frac{1}{1000}$ of an inch.

Sept 25, 1900. Ex. 4.

Problem 13. Tube No. 2.

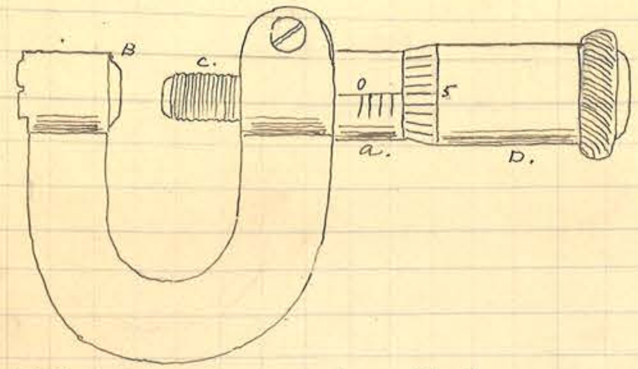
Apparatus :- The Verniered Steel Caliper.

To find the volume of the metal in a piece of brass tubing.

Method :- Place the tube between the jaws of the caliper with its axis parallel to the limb of the caliper. Clamp A and move jaw C. till the tube is just held between the jaws C. and D. Read the instrument by writing down decimally the number of limb divisions up to the zero line of the vernier scale. If the zero of the scale does not register exactly with the division on the limb, see which one of the vernier divisions coincides with a division on the limb and this gives the small space between the zero of the vernier and the limb division that is nearest to it on the side towards the tube. The outside diameter is measured the same as the length. To obtain the inside diameter, insert the rounded ends of the jaws within the cylinder, adjust and read as before directed. This reading must be increased by the width of the jaws. The volume is the difference between the volumes of the two cylinder, whose diameters are the outside and inside diameters of the tube. The volume is computed by the formulas $\pi R^2 H$, in which $\pi = 3.1416$, R = radius, H = length.

	Length.		Outside Diam.		Inside Diam.	
First Meas.	1.7 cm	.71 in	1.3 cm.	.506 in	.85 cm.	.112 in
Second "	1.75 "	.7 "	1.3 "	.506 "	.85 "	.109 "
Third "	1.7 "	.709 "	1.3 "	.506 "	.85 "	.112 "
Mean	1.716 cm,	.706 in,	1.3 cm,	.506 in,	.85 cm,	.111 in

Volume of brass = 1.307 cu cm. , .2369 cu. in.

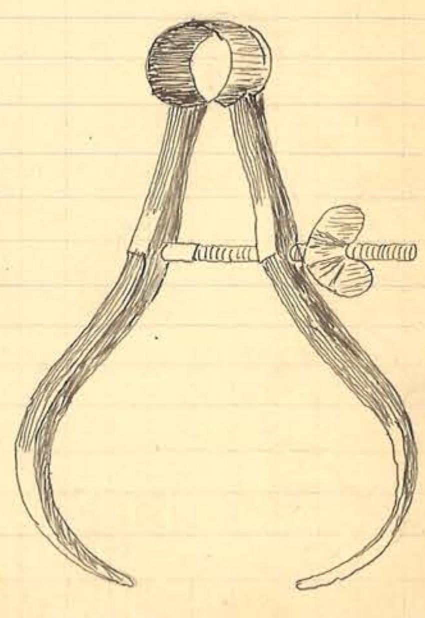


The Micrometer Caliper

This instrument consists of a stout, curved steel frame carrying two screws, B. and C.; the latter of which moves freely by means of the head D. The pitch of the screw C. can be obtained by observing the value of the space on the linear scale a. The circular scale on D usually consists of 25 parts when the pitch of the screw is $\frac{1}{40}$ of an inch, 20 parts when $\frac{1}{50}$ of an inch, and 100 parts when 1 mm. Hence one circular division represents $\frac{1}{25} \times \frac{1}{40} = .001$ in., $\frac{1}{20} \times \frac{1}{50} = .001$ in., or $\frac{1}{100} \times 1 = .01$ mm.

When the screw C. is in contact with B, the zero of the scale on D should be at the zero of the linear scale a.

The outside calipers are a kind of compass with curved legs. The distance between the inner faces of the points can be adjusted by means of a screw and nut.



Outside Calipers.

Sept 27, 1900. Ex 5.

Problem 14.

Apparatus:– The Micrometer Caliper.

To measure the diameter of a wire.

Method:– Place the wire between B. and C. and and turn D. until the wire is held. To get the diameter, observe how many spaces on the linear scale (a) are exposed and what division of the circular scale on D. coincides with the line running lengthwise of the cylinder having the linear scale.

First Trial.

Limb Reading	1.5	
Head "	.17	1.67 mm.

Second Trial.

Limb Reading	1.5	
Head "	.06	1.56 mm.

Third Trial.

Limb Reading	1.5	
Head "	.21	1.71 mm.
Mean		1.646 mm.

Problem 15. Ex. 6.–

Apparatus:– Two square cut blocks, a metre rod, Outside Calipers.

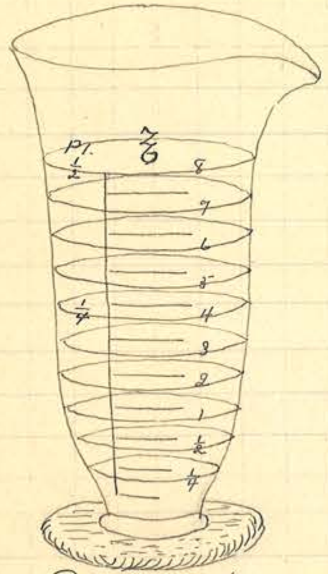
To measure the diameter of a ball.

1st Method:– Place blocks firmly against the edge of a metre-rod. Between the inner faces of the blocks place the ball. With the blocks touching the ball, read on the scale the distance between them. This will be the diameter.

First measurement.	3.8 cm.
Second " "	3.75 "
Third " "	3.8 "
Mean.	3.783 cm.

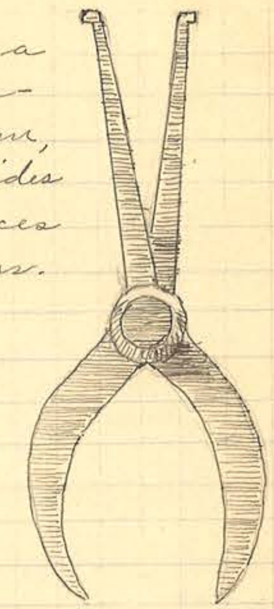
2d Method:– Adjust the distance between the points of the outside calipers, so that the ball at its thickest part just passes between them. Apply the calipers to a linear scale, like a pair of dividers, to ascertain the distance between the inner faces of the points.

First Measurement.	3.73 cm
Second " "	3.8 "
Third " "	3.75 "
Mean	3.733 cm.



Graduate.

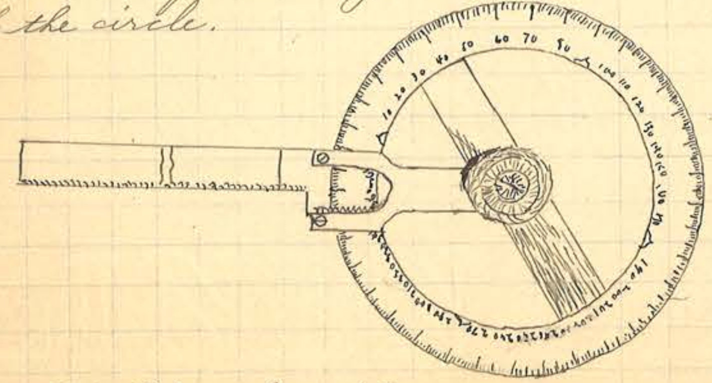
The graduate is a glass vessel of cylindrical or conical form, showing on opposite sides the volume in ounces and cubic centimeters.



Inside Calipers.

The inside calipers are merely compasses. Outside calipers having no adjusting screw may be converted into inside calipers by sliding the points by each other till the inner faces of the points become the outer ones.

The circular protractor is a brass, German-silver or translucent horn circle or semi-circle, having its circular edge divided into degrees or half-degrees. It is sometimes provided with an arm turning about the centre of the circle, and arranged in a manner to keep one of its edges a radius of the circle.



The Circular Protractor.

Oct 2. 1900. Ex. 7.

Problem 16.

Apparatus:— A metre-rod, a Graduate, and Inside Calipers.

To measure the depth and the diameter of a cylindrical jar, compute its volume, and compare the volume with that obtained by the use of a graduated measure.

Method:— Find the depth of the jar by standing the metre-rod vertically within it, and taking the reading on it at the point opposite the lower surface of a straight edge resting across the edge of the jar. Find inside diameter by opening inside calipers within the jar as far as possible, keeping the line of the points normal to the sides of the jar, and applying the points to a linear scale to ascertain the distance between the outer faces. Compute the volume by formula $V = \pi R^2 H$. To measure volume, ascertain by means of graduate, how much water it takes to fill the jar.

	Depth.	Diam.	Volume.
First Meas.	17.2 cm.	8.6 cm	999.113 c.cm.
Second "	17.25 "	8.6 "	1002.018 "
Third "	17.2 "	8.6 "	999.113 "
Mean.	17.216 cm.	8.6 cm.	1000.081 c.cm.

Computed volume 1000.043 c.cm.

True volume = 1000 c.cm. Diff = .043.

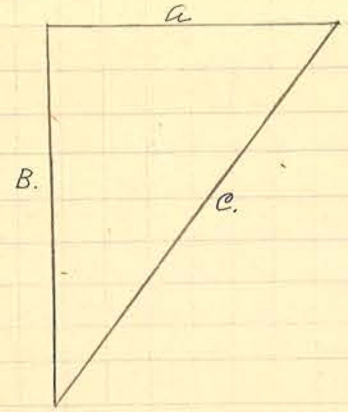
Problem 17. Ex. 8.

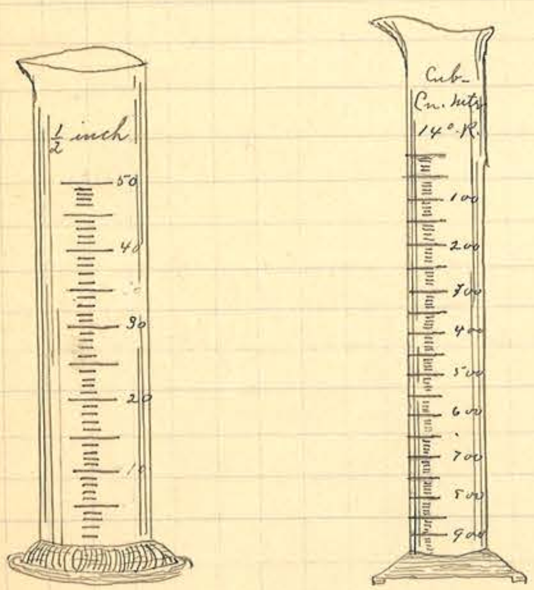
Apparatus:— The Circular Protractor.

To measure the angle formed by two intersecting straight lines.

Method:— Place protractor on the angle, with its centre exactly over the vertex of the angle, and the diameter of the protractor on one side of the angle. Then the point where the other side of the angle crosses the circular scale will mark the size of angle.

First Measurement.	43°
Second " "	43.5°
Third "	43.5°
Mean.	43.3⅓°





An Erdmann's Float.

A Cylindrical Graduate. The graduate is made of glass, and usually graduated to cubic centimeters.

The float is a short, hollow glass cylinder, closed at both ends, and weighted with mercury to make it keep an upright position when floating. A line is etched around it about midway between the ends, to serve as an index.

Oct 4.- 1900. Ex. 9.

Problem 18.-

Apparatus:- A pair of dividers, a linear scale, and a piece of cross-section paper.

To find the area of a triangle formed by lines drawn on a page of the note-book.

Method:- Find the length of each side of the triangle as in Problem 10. Compute the area by the formula $A = \sqrt{p(p-a)(p-b)(p-c)}$, in which p. is the semi-perimeter of the triangle, and a, b and c are the sides. Use also the formula $A = \frac{1}{2}$ base x altitude.

	a.		B.		C.	
First Meas.-	3.9 cm.,	$1\frac{1}{2}$ in,	5.1 cm;	2 in,	6.3 cm.,	$2\frac{1}{2}$ in
Second ..	3.8 cm.,	$1\frac{1}{2}$ .. ,	5.1 .. ,	2 .. ,	6.3 .. ,	$2\frac{1}{2}$ ..
Third .. -	3.85 .. ,	$1\frac{1}{2}$ in.,	5.1 .. ,	2 .. ,	6.3 .. ,	$2\frac{1}{2}$ ..
Mean.	3.85 cm.,	$1\frac{1}{2}$ in,	5.1 cm,	2 in,	6.3 cm,	$2\frac{1}{2}$ in.

Computed Area.- 1st formula 9.813 cm, 1.5 sq in.
2d. .. 9.8165 .., 1.5 sq in.

Oct. 9, 1900. Ex. 10

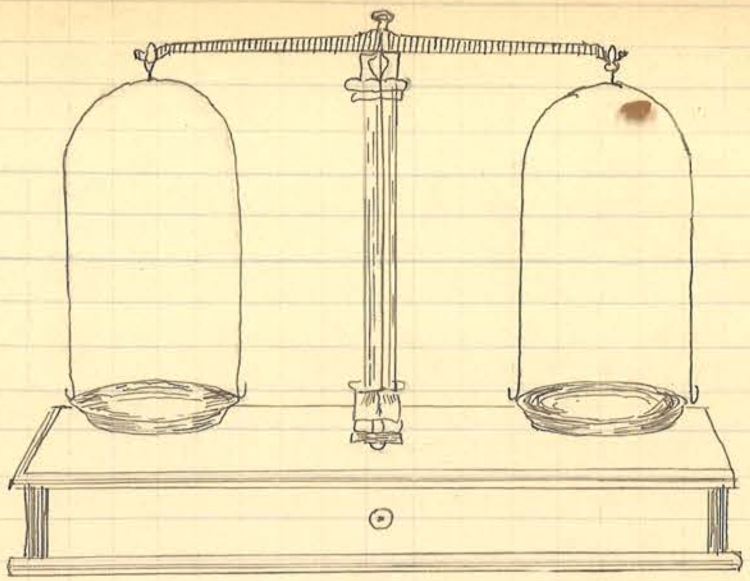
Problem 19.

Apparatus:- Cylindrical Graduate, an Erdmann's Float, and a liquid in which the solid is not soluble.

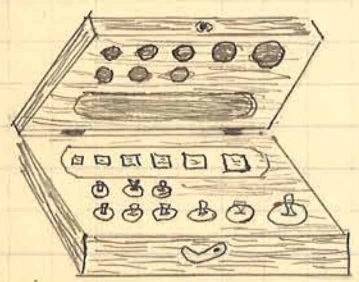
To find the volume of a small irregular body.

Method:- Partly fill the graduate with water, introduce the float by means of a wire hook and record the reading on the graduate scale that is exactly opposite the line on the float. Then remove the float and introduce the object to be measured; then introduce the float, and obtain the reading as before. The difference between the two readings is the volume of the object.

	1st Float Reading.	2d Float Reading.	Volume.
1st, 2d, 3d, - - -	410 ccm.	418 ccm.	8. ccm.
.. .. .. - - -	$415\frac{1}{2}$ ccm.	$420\frac{1}{2}$ ..	5. ..
.. .. .. - - -	$415\frac{1}{3}$ ccm.	$420\frac{1}{2}$ ..	5.167 ..



A Beam Balance.



Box of Weights.

The balance consists of a metal beam supported on a V-shaped axis, about which it is free to vibrate in a vertical plane. Pans of horn or metal are attached by cords or metal bails to the ends of the beam. A long pointer is fastened to the centre of the beam, and moves in front of a gradicated arc as the beam vibrates. The weights smaller than a gramme are made either of aluminium or of platinum; the others are made of brass. Each weight has its value stamped upon it, and has its special place in the box. A small pair of pincers is provided for handling the weights.

Oct. 11, 1900. Ex 11.

Problem 22.

Apparatus :- A Beam Balance, and Box of Weights.

To find the mass of a body.

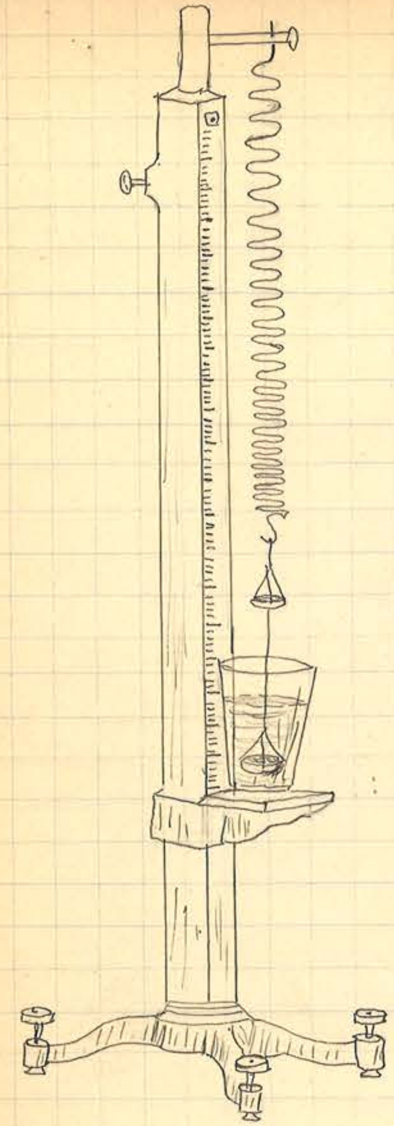
1st.- Method. Balance the scale. Place the weight in left-hand scale-pan in the centre. In the other pan place weights until the pointer swings equal distances each side of the middle of the ivory scale. Then count the weights.

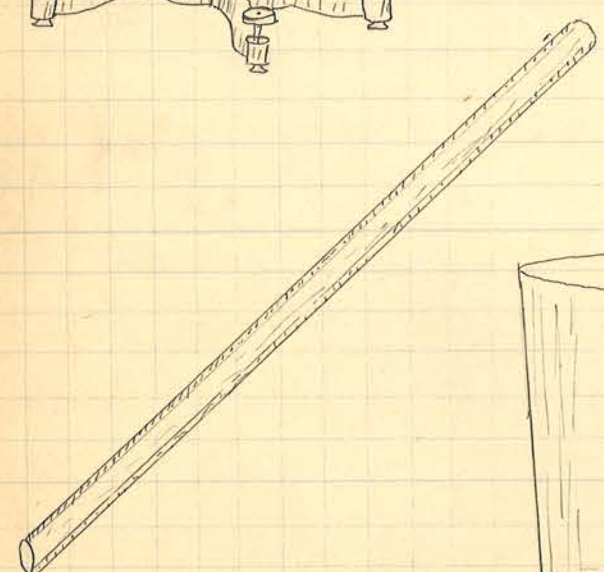
	Weight :- 2 oz.		Mass.
1st Measurement.	$50 + 5 + 2 + 5$ deci.	=	57.5 grams.
2d. " " "	$50 + 5 + 2 + 5$ "	=	57.5 "
3d. " " "	$50 + 5 + 2 + 5\frac{1}{2}$ "	=	57.55. "
	Mean		57.51 grams

2d.- Method. Use fine balances - protected by glass case. Balance the scale then procede as before by placing the weight to be weighed on the left-hand pan, and the other weights on the other pan. When it balances, count the weights.

Weight :- 2 oz. in both methods.

			Mass.
1st Measurement :	$50 + 5 + 2 + 5\frac{1}{2}$ deci.	=	57.55 gr.
2d. " " " :	$50 + 5 + 2 + 5$ "	=	57.5
3d " " " :	$50 + 5 + 2 + 5\frac{1}{2}$ "	=	57.55
	Mean. - -		57.53 grams





Nov. 6 - 1900. Ex. 12.

Problem 23.

Apparatus:- Jolly's Balance, and a set of weights.

To find the weight of a body by means of Jolly's balance.

Method:- Place the body in the pan and record the reading of the index. Then remove the body, and add weights till the same reading is obtained. The sum of the weights is the weight of the body.

19.9 cu cm.

First Measurement	- - - - -	30.8 grams.
Second " "	- - - - - -	31.
Third " "	- - - - - -	30.2
	Mean. - - -	30.6 grams.

Oct. 15. 1900. Ex. 13.

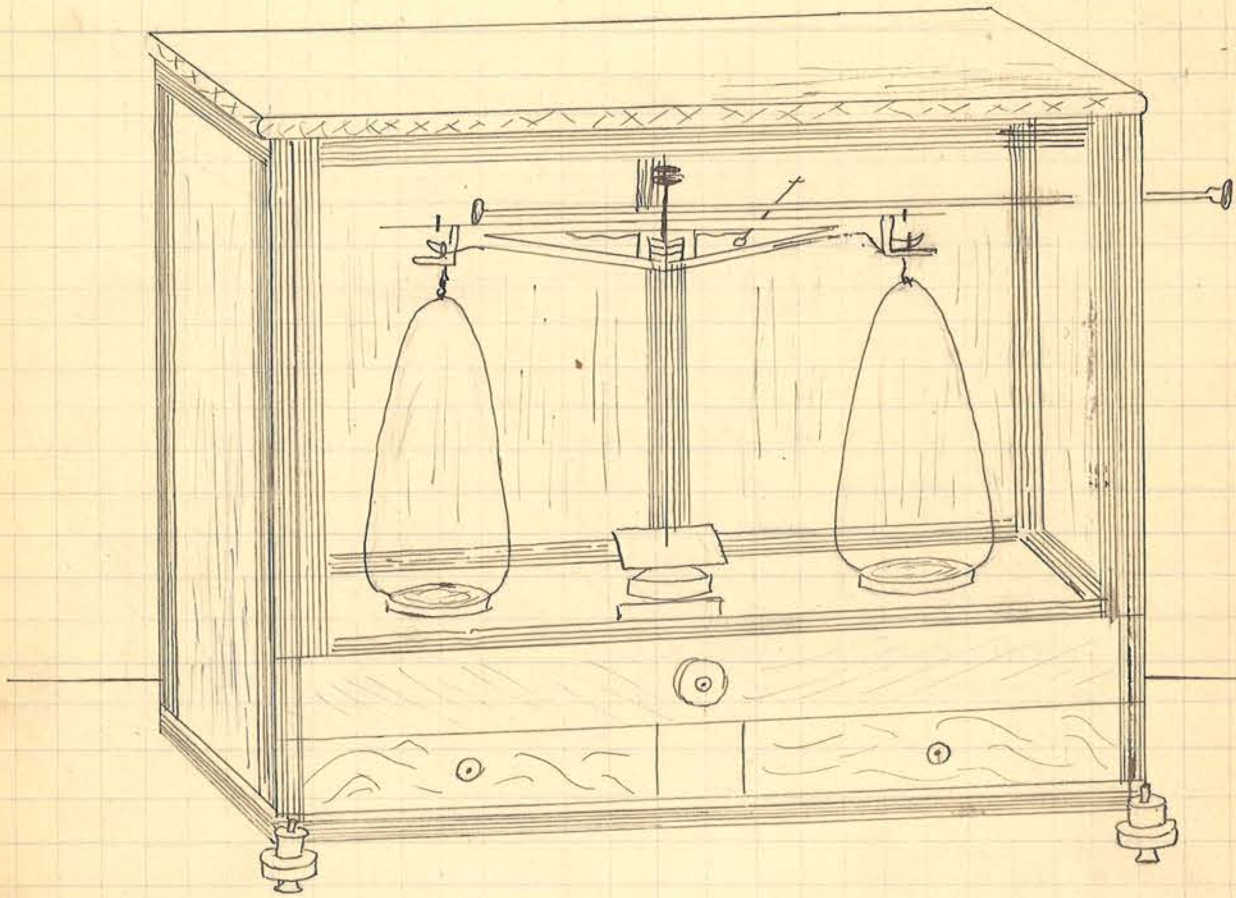
Problem 24.

Apparatus:- Micrometer caliper, balance, linear scale, mercury, dropper-bulb, and rubber tubing.

First Method:- Accurately fit to one end of the tube a stopper or plug of soft pine. Gently crowd the wooden plug into the tube so that it will conform to the opening and give its size. By using the micrometer caliper find the diameter of this stopper and this will be very nearly the diameter of the tube.

Glass tube - No. 1.		Glass tube. - No 2.	
1st meas. - -	.85 mm.	1st meas. - -	1.75 mm.
2d. " - -	.9 "	2d. " - -	1.80
3d. " - -	.85 "	3d. " - -	1.75
Mean. - -	.866 mm.	Mean.	1.766. mm.

Glass tube. - No. 3		Glass tube. - No. 4.	
1st. meas. - -	2.04 mm.	1st meas.	2.45 mm.
2d. " - -	2.05 "	2d. "	2.45 "
3d. " - -	2.05	3d. "	2.45 "
Mean.	2.045 m.m.	Mean.	2.45 m.m.



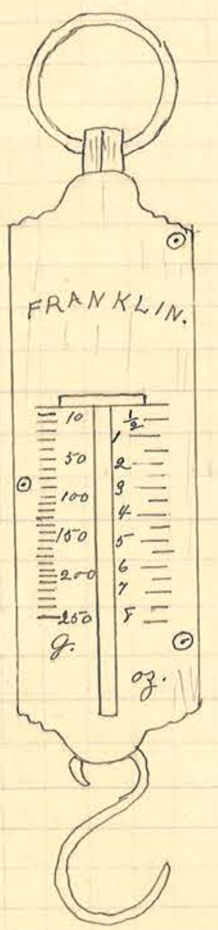
Oct 23 and 25. - 1900. Tube - no. 3.

Problem 24. -

Second Method: - Clean the apparatus before using. By means of alcohol evaporate the water inside and also have the tube perfectly dry. First strain the mercury through a cloth of four thicknesses; then keeping one end of the tube closed, hold the tube in a vertical position and by means of a dropper pour in enough mercury to fill it to a depth of about five cm. Find the exact length of this mercury column, then pour the mercury into a small glass of known weight and find its weight. The difference between the weight of the glass alone and the mercury and glass will be the weight of the mercury. A cubic centimetre of mercury weighs 13.6 grammes, then the weight of the mercury in grammes, divided by 13.6, will give the volume of the mercury cylinder in cubic centimetres. This volume divided by the length of the cylinder, will be the area of the cross-section. Divide this cross-section by .7854, and extract the square root of the quotient to ascertain the diameter of the cylinder or tube.

Measurement of mercury column = 6.4 cm.
Weight of vessel and mercury . . . . . . 10.74 grammes
" " " alone . . . . = 7.595 " "
Weight of mercury alone . . . . = 3.145 " "
1 cubic centimetre of mercury weighs = 13.6 " "
Volume of tube in cu. cm. = 3.145 ÷ 13.6 = .231
Length of mercury column . . . . . = 6.4 cm.
Area of cross-section of tube . . . . .036+ sq. cm.
Cross-section divided by .7854 . . . . .0458 = D^2
Square-root of .0458 = .211 cu. cm or. —
diameter of the tube.

Problem - 25. - (omitted).



Problem. - 26.

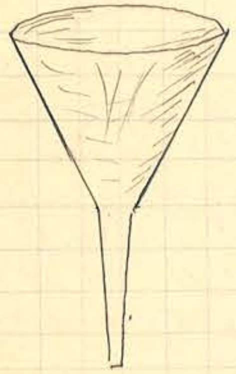
Apparatus: - A draw-scale or spring balance of 50 lbs capacity, and a wire micrometer.

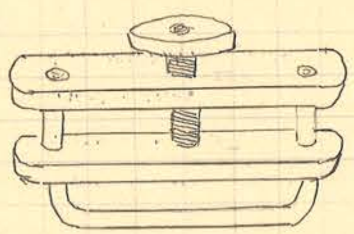
To measure the tenacity of a wire.

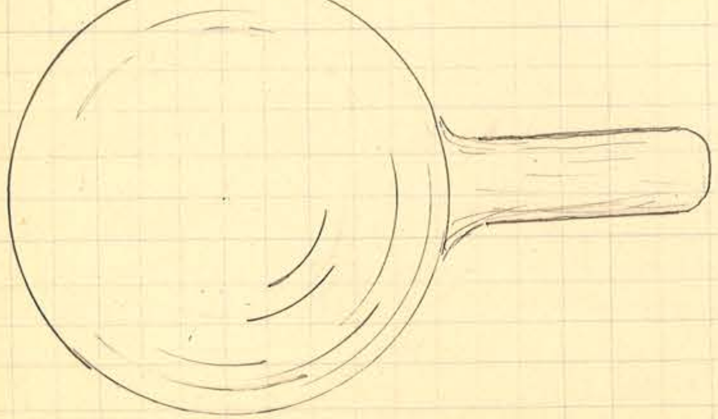
Method: - By means of the micrometer, measure the diameter of the wire. Attach one end of the wire to a hook in the wall and the other end to the hook of the draw-scale; then pull on the ring of the draw-scale till the wire breaks. Record the reading of the scale-index at the moment of rupture. The breaking-weight divided by the area of the cross-section of the wire, expressed in square millimetres is the measure of its tenacity. The area of the cross-section equals $.7854\ d^2$, in which d is the diameter of the wire.

Kind of wire	Diam.	Cross-section.
Copper	.18 ml	.0254+ smm.
Iron	.28½ "	.0636+ "

Breaking-strain	Tenacity.
2.5 lbs	98.42 lbs.
8.5 "	133.64 "







Oct 30. and Nov 1. - 1900.

Problem 27.-

Apparatus:— A balance, two or three glass bulbs or round-bottomed flasks of different sizes, a Funnel with a short piece of rubber tubing attached to its stem, an adjustable Pinch-cock, an Iron stand, and a Retort stand.

To ascertain how the size of a drop of a liquid is affected by the cohesion of the liquid, the shape of the surface on which the drop forms, and the rate of drop-forming.

Method:— Support one of the glass bulbs in the retort stand, and above it the funnel in the ring of the iron stand. Close the rubber tube on the stem of the funnel by means of the pinch-cock. Fill the funnel partly full of water. Adjust the pinch-cock so that the liquid flows from the funnel upon the spherical surface, and falls in drops from the lower surface. Catch 100 drops in a vessel of known weight and find their weight. Divide the volume by 100 to obtain the volume of a single drop. Also count the number of drops formed in one minute. In using the large and small sphere ascertain the difference in drop size.

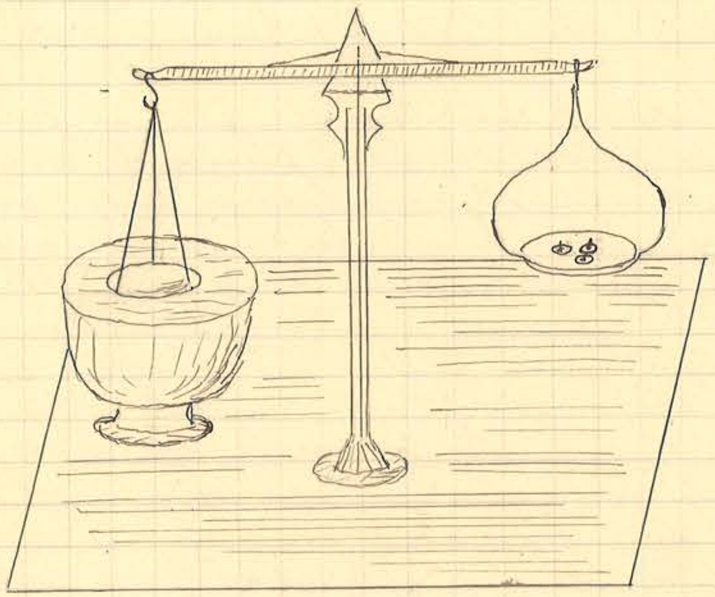
Liquid used.	Size of sphere.	No. of drops in 1 min.
Water	small.	70.

Weight of vessel plus 100 drops equals 33.7439. gr.
" " " " alone is 14.673gr.
" " water = 33.7439 − 14.673 = 19.0709+ gr.
" " 1 drop = .190708 gr.

Liquid used.	Size of sphere	No. of drops in 1 min
Water	large.	70.

Weight of vessel plus 100 drops = 37.5039 gr.
" " " alone = 14.673 gr.
" " water = 37.5039 − 14.673 = 22.830+
" " 1 drop = .22830+ gr.

Diff in drop size = 22.830 − 19.0708+ = 3.760 grams



Problem 28.-

Apparatus :- A glass and a copper disk, each 5cm in diameter, a stout hand-balance, a box of clean dry sand and a box of weights.

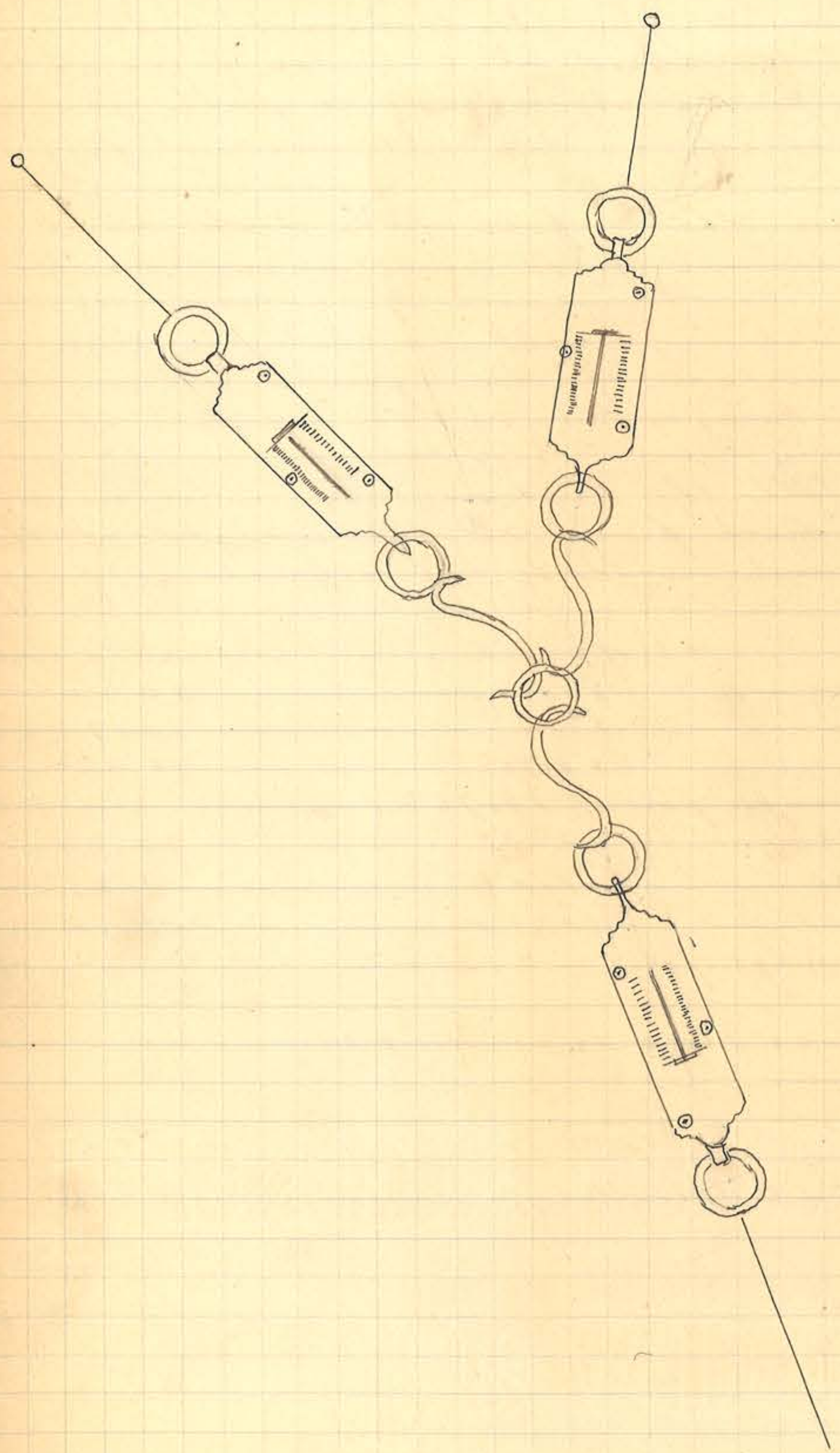
To compare the forces necessary to pull glass and copper disks of equal diameter, away from water.

Method :- Clean the surface of the disk and suspend it beneath one of the scale pans and find its weight. Place the vessel of water beneath the disk, and adjust its height so that the disk just touches the surface of the liquid when the balance-beam is horizontal. The surface of the disk must be horizontal. Pour sand slowly into the opposite pan till the disk is broken loose. Weigh the sand and deduct from it the weight of the disk. The difference will be the seperating force.

Disk		Weight	Wt. of sand used.	Seperating force
Copper.	1st meas.	30.86 gr.	51.4 gr.	20.54
	2d ..	31.7.	51.4	19.7
	3d ..	31.7.	50.75	19.05
		Average force = 19.763.		
Glass	1st meas.	40.13	62.37	22.24
	2d. ..	40.20	61.59	21.39
	3d. ..	40.20	61.54	21.34
		Average force = 21.657.		

As compared = 21.657 : 19.763 :: 1.09 : 1.

Problem 29. (omitted).



Nov. 15.- 1900.- Ex. 17.

Problem. 30.-

Apparatus:- Three draw-scales reading to grammes, a sheet of paper, a metre of cord, and a protractor.

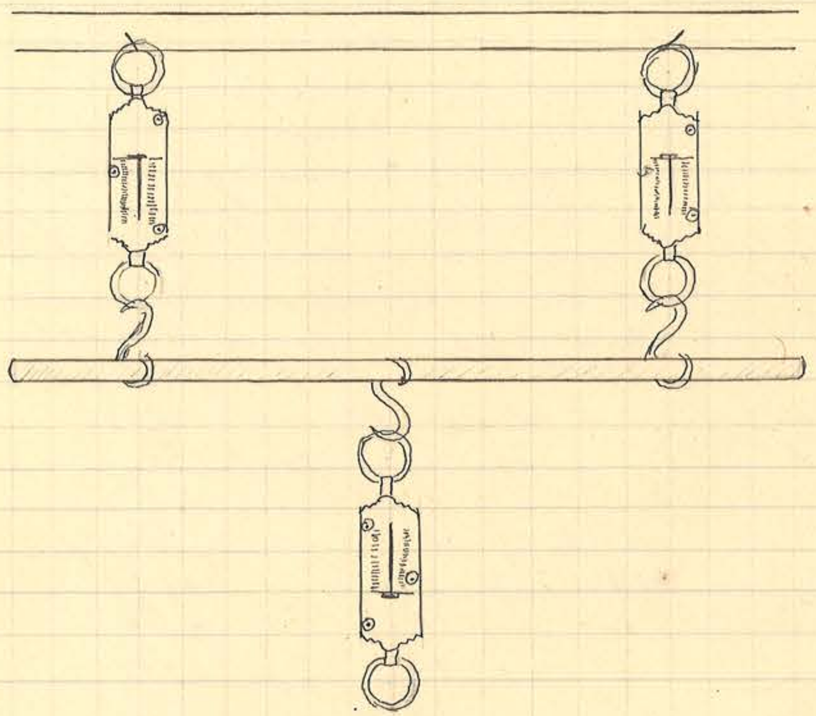
To test the rule for finding the resultant of two concurring forces.

Method:- Tie together at one end three stout cords and fasten the free ends to the hooks of three balances respectively. Fix two screws some distance apart, near the edge of the table and over each place a ring of a balance. Now pull on the third balance in a direction toward the opposite side of the table, till each balance registers several divisions of the scale and fasten it securely. There are three forces in equilibrium and acting at the centre and anyone of them is equal and opposite to the resultant of the other two. Place a sheet of paper beneath the cords and mark on it their directions. Lay off on each line as many units of length as there are units of force indicated by the respective balance. Complete the parallelogram and draw the diagonal which will equal the greater force. With a protractor, measure the angles.

	Bal. a.	Bal. b.	Bal. c.	Angle a, & c.	Resultant a & B.
1st trial.	$16\frac{1}{2}$	13	28	$36\frac{1}{2}^{\circ}$	28
2d. "	6	3	9	25°	9
3d. "	$4\frac{3}{4}$	4	$8\frac{1}{4}$	37°	$8\frac{1}{4}$.

Error (none).

Problem 31. (omitted).



Nov. 20.- 1900. Ex. 18.

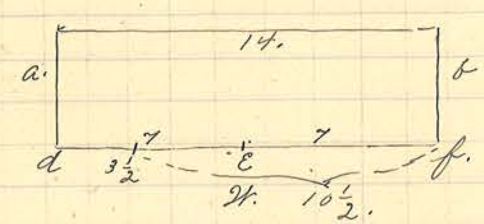
Problem. 32.-

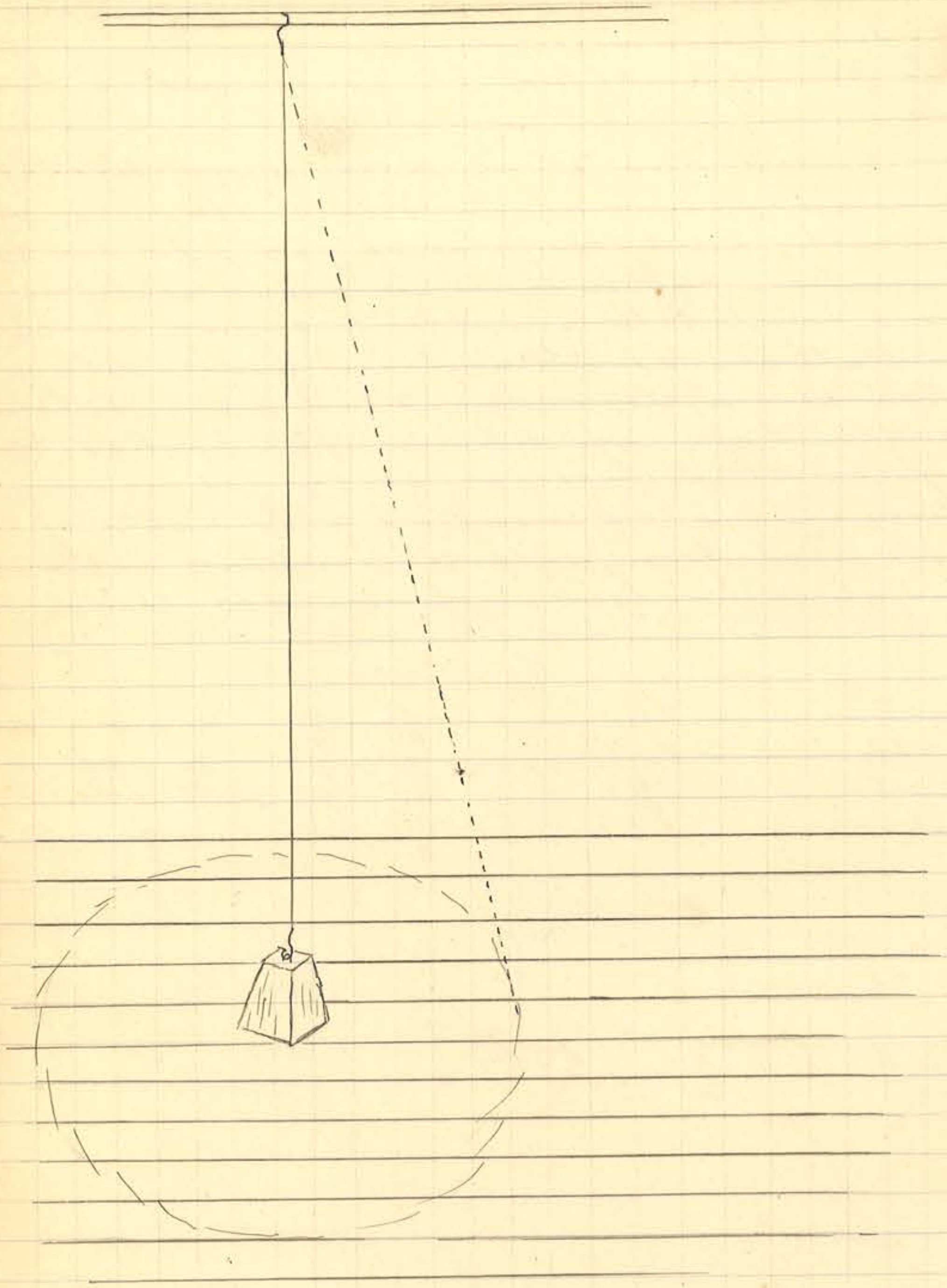
Apparatus :- A piece of gas-pipe 1 m. long, a metre-rod, and three draw-scales.

To test the principle applied in compounding two parallel forces.

Method :- Insert two stout screws in the table near its edge and 90 cm. apart. Place the ring of a draw-scale over each, and the piece of gas-pipe in the hooks of these scales. Hook the third draw-scale on the gas-pipe at some point between the two and on the opposite side. Pull on the third draw-scale till each balance registers several pounds. Read each balance and measure the distance between the hooks. Compare the reading of the third balance with the readings of the other two; and also compare the ratio of the readings of the first two with the inverse ratio of the distances of their hooks from the third hook.

$4 + 4 = 8$	7 in	$\frac{4}{4} = \frac{7}{7}$	$a + b = w.$
$6 + 6 = 12$	7 ..	$\frac{6}{6} = \frac{7}{7}$	$\frac{a}{b} = \frac{ef}{de}.$
$6 + 2 = 8$	$3\frac{1}{2}$ ..	$\frac{6}{2} = \frac{10.5}{3.5}$	$3 = 3.$
$8\frac{1}{2} + 3\frac{1}{2} = 12$	$3\frac{1}{2}$ "		





Problem 33.

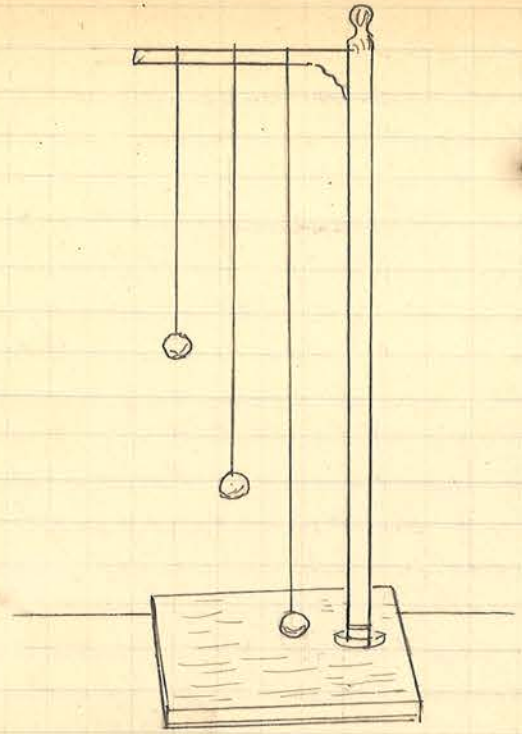
Apparatus. A heavy ball weighing several pounds, a draw-scale reading to ounces, a clock marking seconds, and a brass wire 3 m. long.

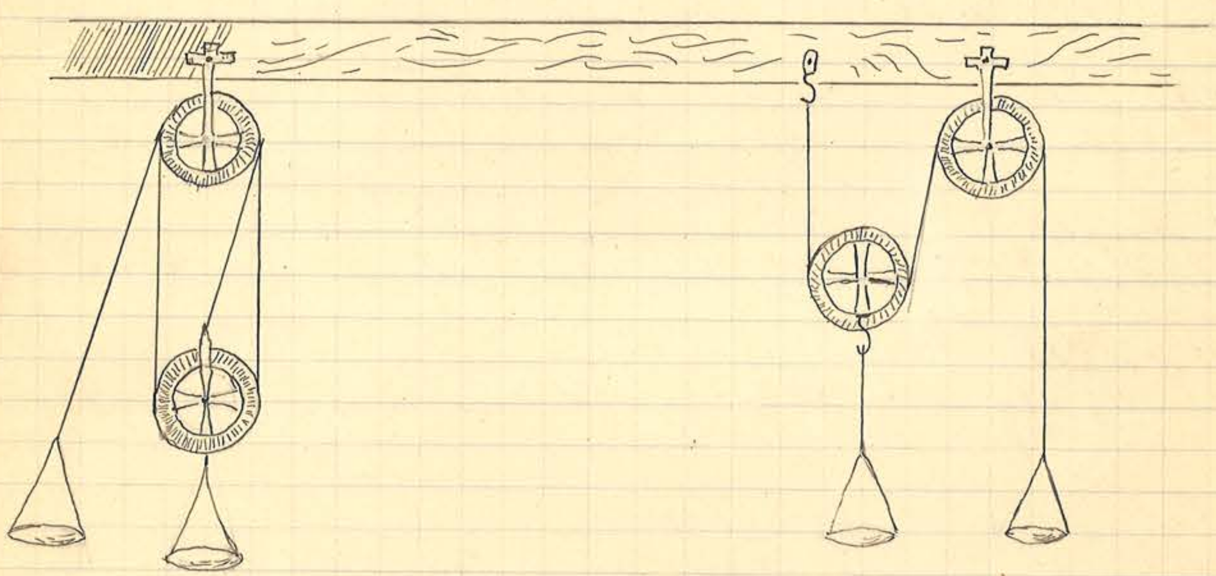
To test the laws of curvilinear motion.

Method:- Suspend the weight by the wire from a hook in the ceiling and set it swinging in a horizontal circle. Measure the diameter of the circle described by the ball, and also measure the time t, occupied in completing the orbit. Find by the draw-scale what force is necessary to hold the ball deflected from the vertical, a distance equal to the radius of the path described by it when, t, was measured. The laws of curvilinear motion are expressed in the formula $F = \underline{Wv^2}$. W = weight of body, v is its velocity, r is the radius of the circular path. g = gravity and may be taken as 32.16 ft. To obtain v, divide the circumference of circular path by the time. Compare F as computed by the formula with F as obtained by the draw-scale

	Radius	Revolutions	velocity
1st Weight 19 lbs	$28\frac{1}{2}$ in	2 in 5 sec.	71.62.
2d. Weight. 10 lbs	$28\frac{1}{2}$ in	9 in 10 sec.	53.72
3d. Weight. $5\frac{1}{2}$ lbs	$28\frac{1}{2}$ in	5 in 10 sec.	113.0976

F. as observed.	F. as computed	Error.
$5\frac{1}{2}$ lbs	5.69 lbs	.19 lbs.
3 lbs	3.01 "	.01 lbs.
2 lbs.	1.76 "	.24 lbs.





Nov 26. - 1900. Ex. 20.

Problem 35.

Apparatus :- A lead or iron ball suspended by a thread from a firm frame.

To test the laws of the pendulum and find the value of g.

Method :- Set the pendulum swinging through a small arc for a certain length of time (300 seconds) and find the time of a single vibration. Measure the length of the pendulum. Extract the square root of the length and see if it is proportionate with the time. Try three lengths. Compute g. by the formula $g. = \frac{\pi^2 l}{t^2}$.

	No. of Vibrations,	No. of Ticks,	Time of one vib.	Length.	$\sqrt{l}$.	Gravity.
1st.-	299.	300.	1.003	100 cm	10 cm	981.67.
2d.-	344	300	.872	75 cm	8.6 cm	981.24
3d.-	508	360	.709	50 "	7.06 "	981.07.

Nov 27. 1900. Ex. 21.-

Problem 37.

Apparatus :- Several pulleys, two scale-pans, cord, and a set of weights.

To test the law of equilibrium for any given combination of pulleys.

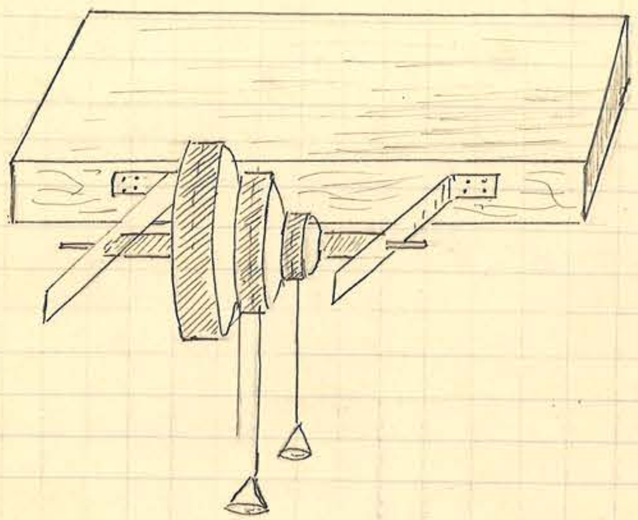
Method :- Counterbalance the weight of the pulleys. Then place known weights in the pans, and ascertain their ratio whenever equilibrium is secured. Compare this ratio with the inverse ratio of the distance that the weights pass through when displaced vertically. Try other combinations of pulleys.

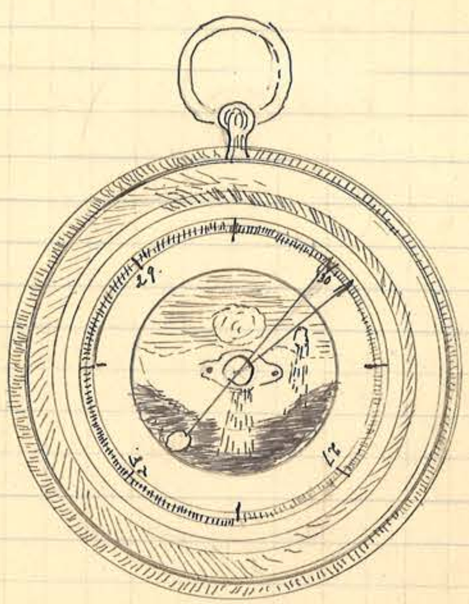
With 3 parts to the cord.

	W.	W'	D.	D'	W ÷ W'	D' ÷ D.	Error.
1st.-	17 g.	50 g.	31 cm.	10 cm.	.34	.322+	.03
2d.-	13.3 g.	40 "	30 "	10 "	.3325	.333+	.02.
3d.-	15 g.	45 "	31 "	10 "	.333+	.322	.03

With 2 parts to the cord.

	W.	W'	D.	D'	W ÷ W'	D' ÷ D.	Error.
1st.-	25 g.	50 g.	20 cm.	10 cm.	.5	.5	0.
2d.-	50 "	100 "	20 "	10 "	.5	.5	0.
3d.-	35 "	70 "	20 "	10 "	.5	.5	0.





Dec 6.- 1900. Ex. 22.

Problem 38.-

Apparatus :- A number of cylinders differing in diameter and turning on a common axis, and a set of weights. To each cylinder is attached a cord to support a scale-pan.

To test the law of equilibrium of the wheel and axle.

Method :- Attach scale-pans to two of the cords and place weights in one until equilibrium is secured. Now place known weights in the pans, and ascertain their ratio whenever equilibrium is secured. Compare this ratio with the inverse ratio of the diameters of the cylinders used. Trial should be made with several combinations.

D^1	D^2	W^1	W^2	$D^2 \div D^1$	$W^1 \div W^2$	Error.
15	$7\frac{1}{2}$	50	100	$\frac{1}{2}$ or .5	2.	0.
$7\frac{1}{2}$	$2\frac{1}{2}$	20	60	$\frac{1}{3}$ or $.33\frac{1}{3}$	3.	0.
15	$2\frac{1}{2}$	20	120	$\frac{1}{6}$ or $.16\frac{2}{3}$	6.	0.

Dec 10.- 1900. Ex. 23.

Problem 42.

Apparatus :- An Aneroid Barometer and ball of cord.

To measure the vertical distance between the floor of the basement of a building and that of the top story.

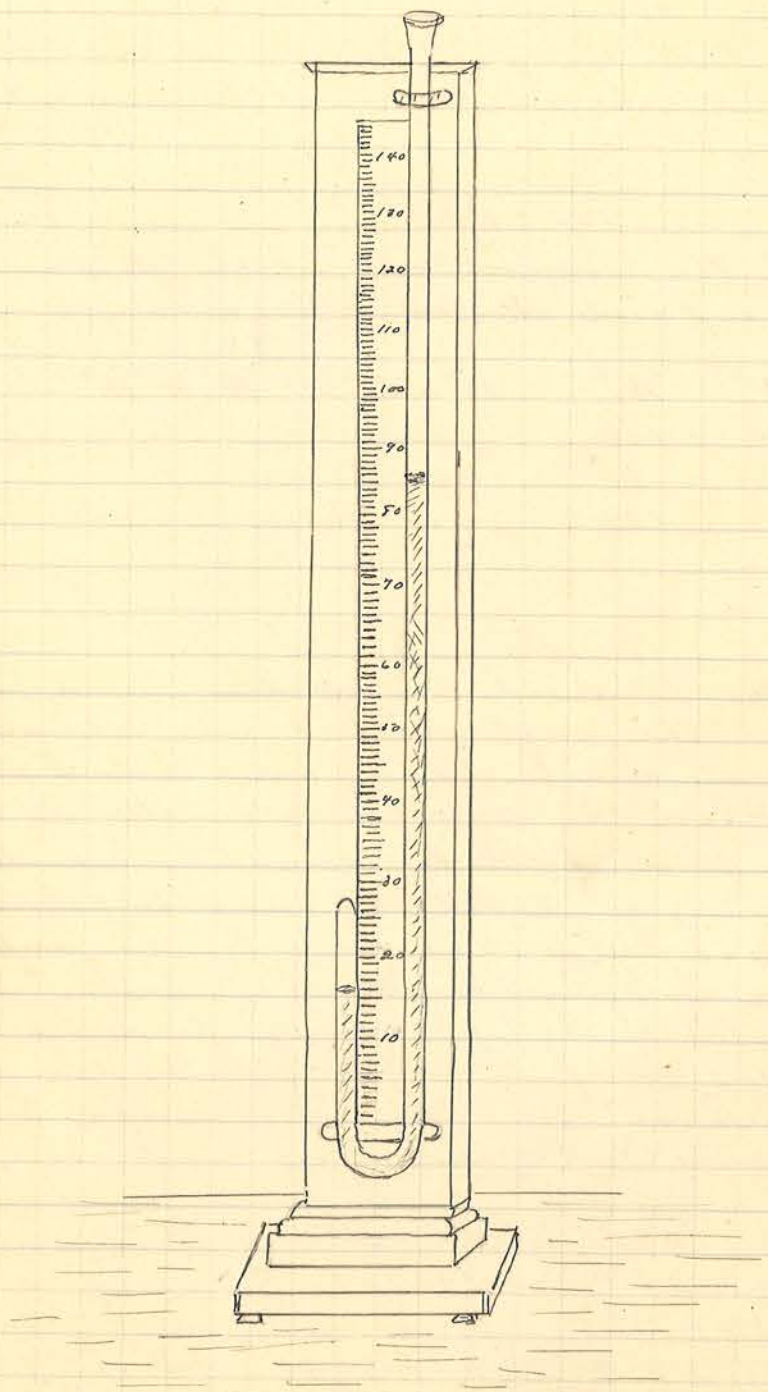
Method :- Place the aneriod barometer in a horizontal position on the floor of the basement. Tap the instrument gently with the finger in order to bring the pointer into equilibrium. Read the position of the pointer, expressing the result in inches and hundredths of an inch. Now take the barometer to the floor of the top story, and make similar observations there. Compute the height by the rule that a barometer changes .01 inch for a change of a level of 8.7 feet. With a cord measure the distance and compute the error.

1st Reading.-

lower floor. $29\frac{37}{50}$ or 29.74. Measurement with
upper floor $29\frac{35\frac{1}{2}}{50}$ or 29.707. cord = 28 ft.
Diff. .033.
8.7 X 3.3 = 28.71 feet length. Error = .71.

2d Reading.

lower floor. $29\frac{36}{50}$ or 29.72. Measurement with
upper " $29\frac{34\frac{1}{3}}{50}$ or $29.68\frac{2}{3}$ cord = 28.25 ft.
Diff. $.03\frac{1}{3}$
8.7 X $3\frac{1}{3}$ = 29 feet. height. Error = .75.



Drawing for problem 44.

Dec. 11. - 1900. Ex. 24.-

Problem 41.-

Apparatus :- A heavy glass tube about 80 cm. long and closed at one end, mercury, a small glass funnel, a rubber connector, a linear scale, a shallow glass beaker, and a wooden support.

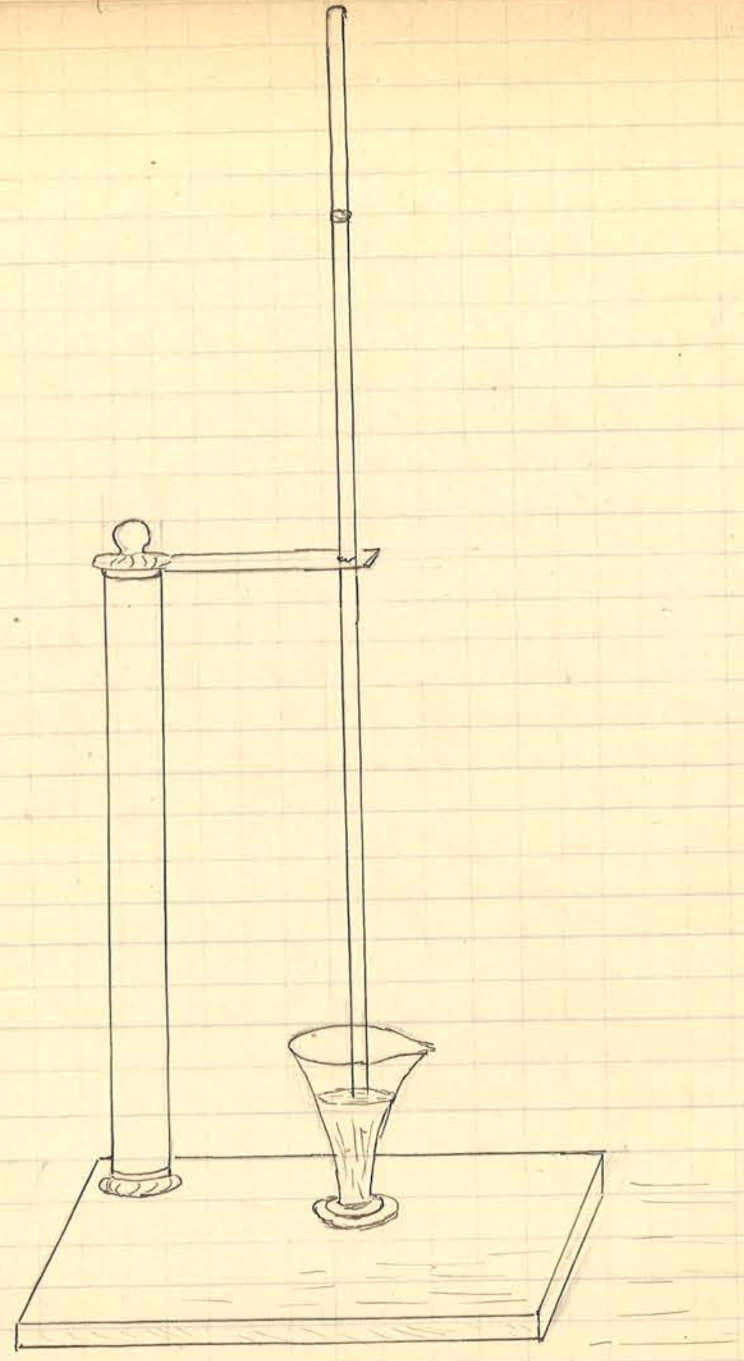
Method :- Measure the bore of the tube. Fill the tube with mercury. Close the open end with the finger, invert the tube, place the end in the dish of mercury, and remove the finger. Support the tube in a vertical position and measure in cm. the height of the mercury in the tube above that in the dish. Compute the area of the cross-section of the tube in sq. cm.; and multiply this by the height of the mercury. The product will be the volume of mercury sustained by the atmospheric pressure. Since 1 c cm of mercury weighs 13.6 grammes, then the product of 13.6 by the volume will be the atmospheric pressure on an area equal to the cross-section of the tube. This pressure divided by the area will be the pressure per square centimetre.

	Diam.	Area.	Height of. mercury	Volume of. mercury	Weight of Mercury.
1st.-	.7 m m.	.3848	74 cm.	28.416	386.45
2d.-	.7 m. m.	"	"	"	"

	Pressure per sq. cm.
1st.-	1004.3
2d.-	"

Barometer Reading = 74.3 cm.

Problem :- To measure the atmospheric pressure.



Drawing for problem 41.

Problem 44.-

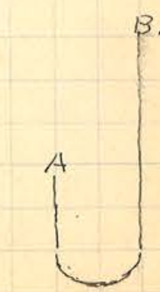
Apparatus:- A stout glass tube more than a meter long, bent; the short arm being closed. A scale graduated to milli-meters is fastened to the side of the tubes which are in turn fastened to an upright wooden support.

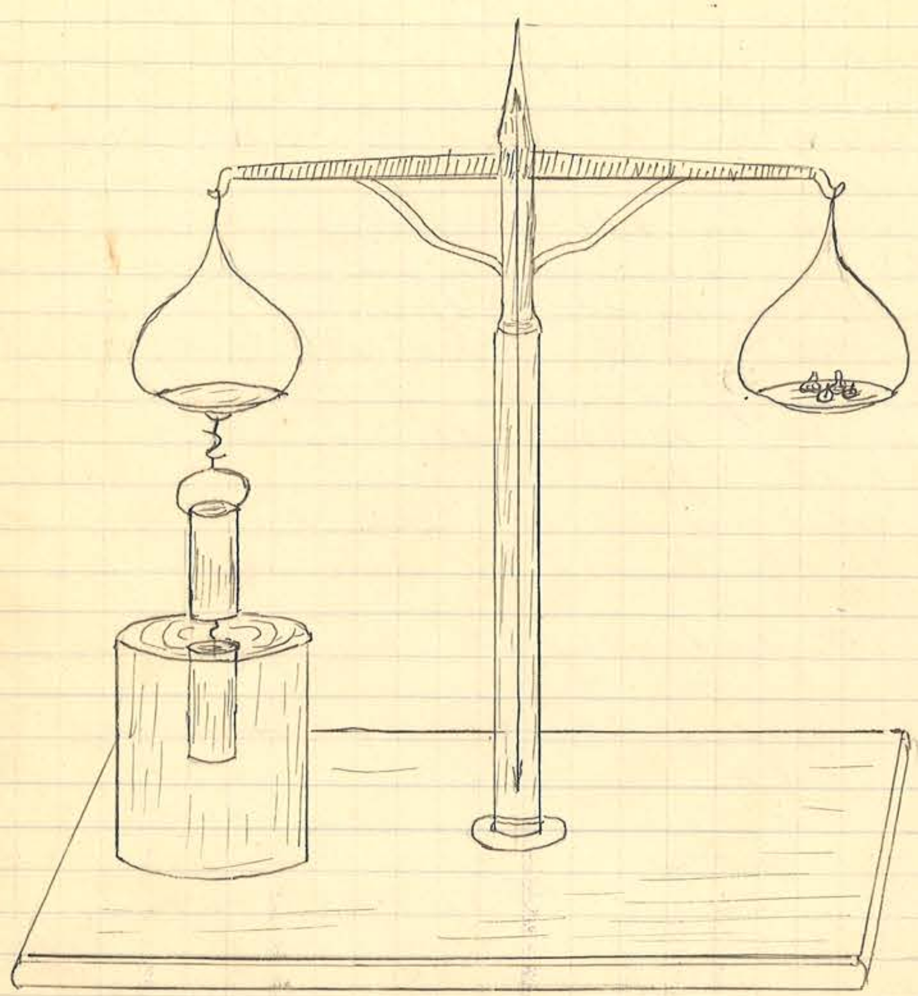
Method:- Pour a small quantity of mercury into the tube so that its surfaces in the two arms or tubes are in the same horizontal line. The air in the short arm will then be under a pressure of one atmosphere. Pour mercury into the long arm of the tube and as the mercury column B, moves above A, the pressure on the air in A exceeds that of the atmosphere by the difference of mercury level. For each position of B record the length of the air column in A, the position of the mercury in A, and also in B. Record the barometer reading. To this add the difference of mercury level, to obtain the total pressure. Compute the volume according to the law and determine the error.

Problem — To test Boyle's law for pressure.

	Length of air column or V.	Reading of A.	Reading of B.	Barometer reading.	Total Pressure.
	13 cm.	$2\frac{1}{2}$ cm	$2\frac{1}{2}$ cm.	29.2 in	
1st trial-	10.7 "	4.8 "	20 "	or	89.36
2d "	9.1 "	6.4 "	35.8 "	74.16 cm.	103.56
	$12\frac{1}{2}$ cm.	3 cm	3 cm.	29.548 in	
3d. "	12	$3\frac{1}{2}$ "	6.8 "	or	78.35
4th "	11.3 "	4.2 "	12.2 "	75.05 cm.	83.05
5th "	9.8 "	4.5 "	16.7 "		87.25

V X P.	Computed air column.	Error.
956.152	10.78	.08
942.396	9.3	.2
940.02	11.97	.03
938.465	11.29	.01
752.110.	10.7	.9





Dec. 20, - 1900. Ex. 26.

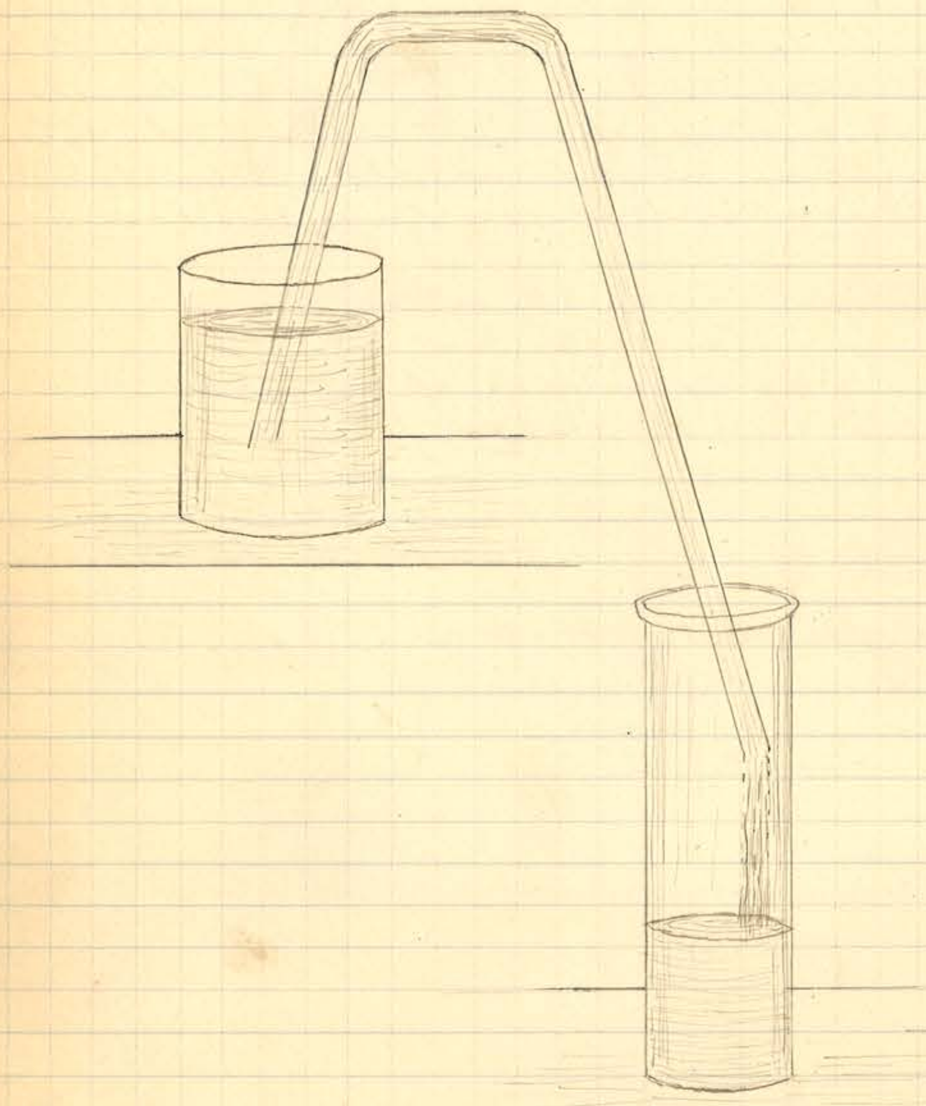
Problem 46.

Apparatus. — Balance, weights, verniered caliper, and a brass cylinder.

To find the measure of the buoyant force.

Method: — Measure the length and the diameter of the cylinder with the verniered caliper. Compute the volume of the cylinder in cubic centimetres. Find the weight of the cylinder in grammes. Tie a fine thread to the cylinder, and suspend it from the small hook usually found at the top of the bail of the balance-pan. The cylinder should be submerged in a dish of water when the balance beam is in action. Now find the weight of the cylinder in water, and compute the loss.

Diameter of cylinder = 2.32 cm.
Altitude " " = 3.3 "
Volume " " equals area of base × altitude.
Area of base = πR^2. R = 1.175.
Area " " = 4.335 sq. cm.
Volume of cylinder = 14.3055 cu cm. or 14.3055 g.
It is buoyed up by a force equal to the liquid it displaces.
Wt. of water and cylinder = 44.64 grams.
" " cylinder = 30.33
" " water = 14.31 "
14.31 − 14.30 = .01 Error.



Jan. 8. Ex. 27. -1904-

Problem 45.

To prove that the rate of flow of a liquid from a siphon is proportional to the difference of length of the arms.

Apparatus:– A siphon, a large vessel of water, and a graduate.

Method:– Clamp the siphon so that one branch is in the vessel of water, the part connecting the arms horizontal, and about 10 cm. above the water. Measure the length of the arms, the short one being the vertical distance of the highest part of the siphon above the water, and the long one being the vertical distance of the highest point above the outlet. Start the siphon by suction, and measure the amount of flow in 20 sec. Change the lengths of the arms by raising the siphon and repeat the measurements. Divide the amount of flow per minute in each case by the corresponding difference of the arms.

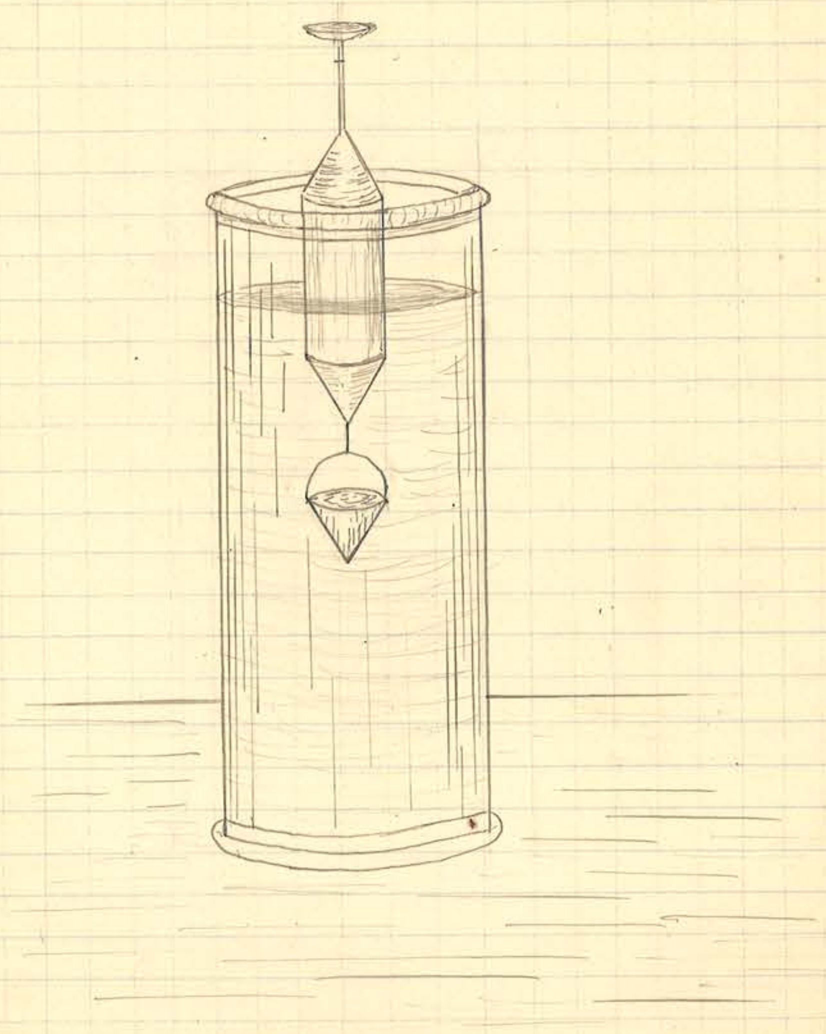
Long Arm	Short Arm.	Difference D.	Flow in 20 sec.	Flow in 1 minute V.
5.7 cm.	30 cm.	27 cm.	1250 cu. cm.	3750 cu cm.
5.8 "	32 "	26 "	1200 " "	3600 " " .
5.2 "	24 "	28 "	1290 " "	3870 " " .

V ÷ D.

3750 ÷ 27 = 138.8

3600 ÷ 26 = 138.4

3870 ÷ 28 = 138.2



Jan 10.- 1901.-

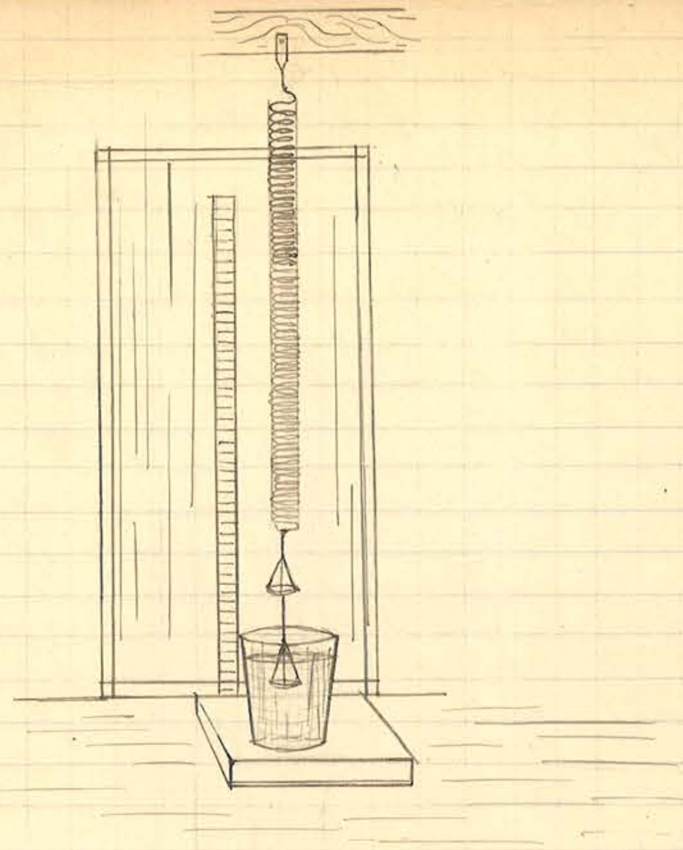
Problem 48 a.

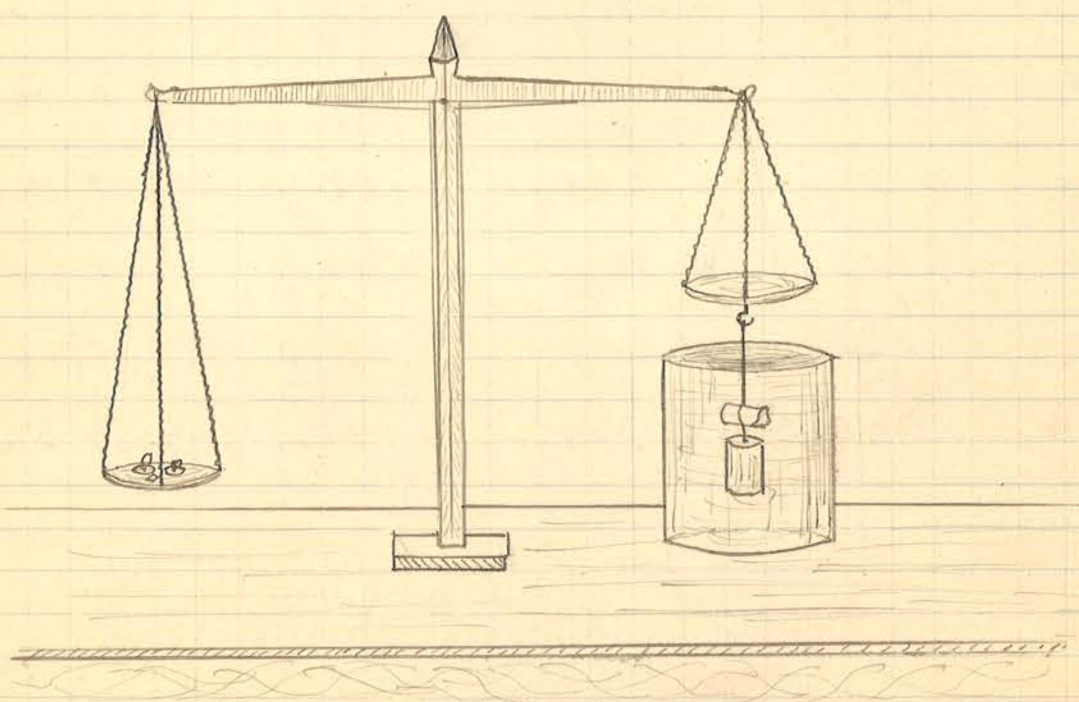
To find the density of a substance by means of the Nicholson Hydrometer.

Apparatus:- Hydrometer, a box of weights, and a tall glass beaker of water.

Method:- The whole apparatus must be lighter than water, so that a certain weight (W.) must be put into the pan to sink the apparatus to a fixed point marked on the rod. The given body, which must weigh less than W, is placed in the pan and enough weights (w) added to sink the point, (e), to the water line. Then the weight of the body is W-w. The given body is now taken from the pan and placed in the basket, when additional weights, x, must be added to sink the point, e, to the water line. Find the density by means of the formula- $D = \frac{W-w}{x}$.

	W.	w.	W.-w.	x.	Density.
Glass.-	10.3g.	5.02g.	5.1g.	2.1g.	2.514
Sulphur.	10.3g.	5.725g.	4.575g	2.24g.	2.042
Marble.	10.3g.	1.8g.	8.5g.	3.1g.	2.74.
Iron.	10.3g.	4.035g.	6.265g.	.875g.	7.16
Coal.	10.3g.	3.35g.	6.95g.	5.365g.	1.29.
Copper.	10.3g.	2.06g.	8.24g.	.93g.	8.86
Tin.	17.555g.	12.612g.	4.943g	.68g.	7.26





Jan. 14.-1901. Ex.-29.-

Problem 50.

To find the density of a solid insoluble in water by means of Jolly's balance.

Apparatus:- Jolly's balance, and a beaker of ice-water.

Method:- Solid used was copper. First place the body in the pan and record the reading of the index. Then remove the body and add weights till the same reading is obtained. The sum of the weights is the weight of the body in air (w.). Now place the body in water and find its weight (w'.); then the loss of weight in water would be w-w'. The density is found by means of the formula - $D = \frac{w}{w-w'}$ that is :- density equals the weight in air divided by the loss of weight in water.

	w.	w'.	w-w'	D.
	W. in air.	W. in water	Loss of W. in water.	Density.
1st trial	2.02 g.	1.792 g.	.228 g.	5.86
2d. "	2.015 g.	1.788 g.	.227 g.	5.87

Jan. 16.-1901. Ex.-30.

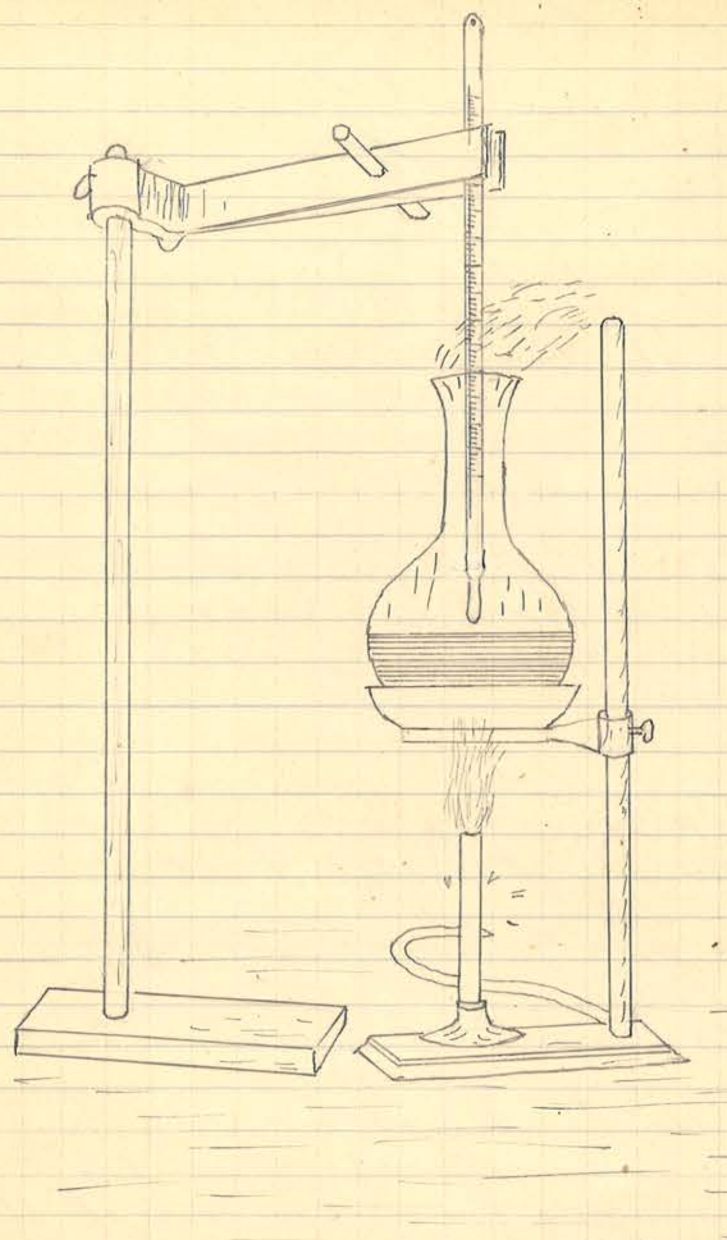
Problem 49.-

To find the density of a solid lighter than water and insoluble therein.

Apparatus:- Balance, set of weights, thread, beaker, wooden bench, ice-water.

Method:- The given solid is cork. Fasten to it another body heavy enough to sink it in water. Find the loss of weight for the combined mass when weighed in the water. Do the same for the heavy body. Subtract the loss of the heavy body from the loss of the combined mass. Divide the weight of the given body by this difference.

	1st. trial.	2d. trial.	3d. trial.
Wt. of body in air.	7.4 g	7.3 g.	7.5 g
" " solid " "	115.2 g.	115.3 g.	115.3 g
" " sinker in water	97.9 g.	98.1 g	98.5 g
Combined wt. " " .	73.4 g.	74.3 g.	74.9 g.
Density	.232	.236.	.241.



Jan 22. - 1901. - Ex. 31

Problem 58. -

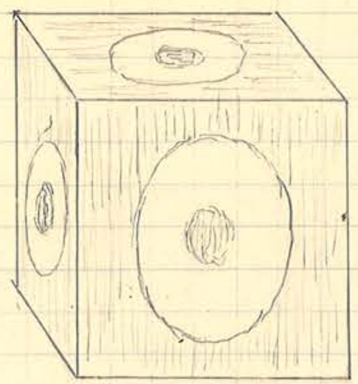
To test the accuracy of the location of the fixed points on the stem of a mercurial thermometer.

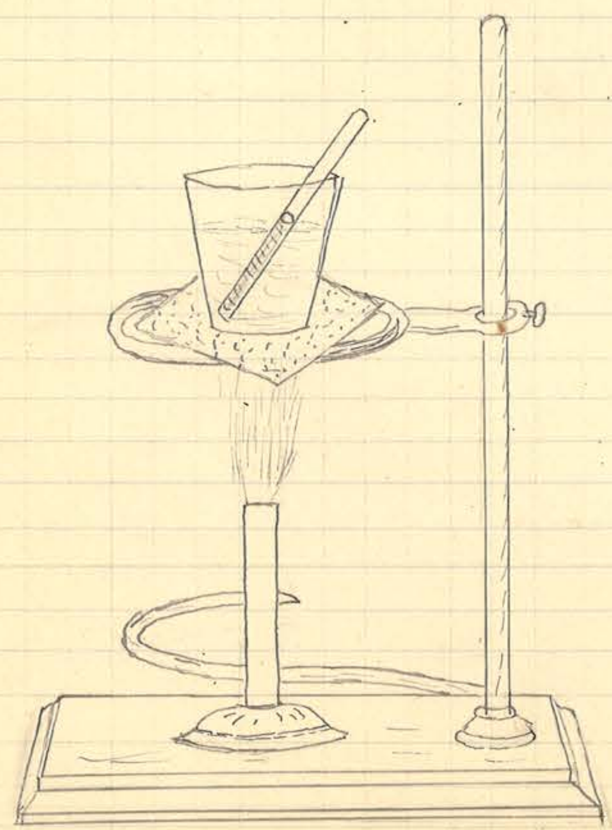
Apparatus: - A mercurial thermometer, a 4-in funnel, a quart Florence flask, an iron stand, and clean ice.

Method: - To test the freezing point, support the thermometer in a clamp, and pack snow around the bulb as far up the stem as the zero point. After about ten minutes, observe the reading of the thermometer. To test the boiling point, fill a Florence flask a little more than half full of water; support it on the iron stand, and apply heat. Hang the thermometer within the neck of the flask, with its bulb not more than 3 cm. above the water. After steam has been escaping freely from the flask for several minutes, read the thermometer, and also the barometer in the room. Since the boiling-point is affected by the barometric pressure, the true boiling point can be computed by the following formula, $t = 100° - 0°.0375 (760 - b)$ in which b is the observed barometric reading expressed in millimetres. The error will be the difference between the observed and the computed boiling point.

Observed freezing-point = 32° F and 0° C.
Barometer Reading = 29.05 in. or 737.87 m.m.
Observed boiling-point of distilled water = $93\frac{2}{3}$° C and $212\frac{1}{3}$° F.
" " " " hydrant " = $99\frac{1}{2}$° C " $212\frac{1}{3}$° F.

Computed boiling point at the time of experiment by formula — $t = 100° - 0°.0375 (760 - b.)$
b = 29.05 in. or 737.87 m.m.
760 - 737.87 = 22.13
22.13 × .0375 = .829+
100° - .829 = 99.171 = computed boiling-point.





Jan. 23. - 1901. - Ex. 32.

Problem 60. -

To compare the thermal conductivity of wood with the grain with that across the grain.

Apparatus: - A cube of wood about 5 cm. on the edge, a smooth metal ball 2.5 cm. in diameter provided with a handle of stout wire.

Method: - Coat uniformly with beeswax three of the faces about one corner of the wooden cube. Heat the metal ball and place it as quickly as possible on the centre of one of the waxed faces of the cube. After the wax has ceased to melt, measure two diameters of the spot taken at right angles to each other, one of them to be the longest diameter of the spot. Observe the direction of this diameter with reference to the grain of the wood. In like manner try the other two faces.

Diam of circle.	with grain	across.
1st meas.	2.8 cm.	2.3 cm.
2d. "	2.4 "	2.2 "
3d. "	2.5 "	2.3 "

Jan. 13. - 1901 Ex. 33. -

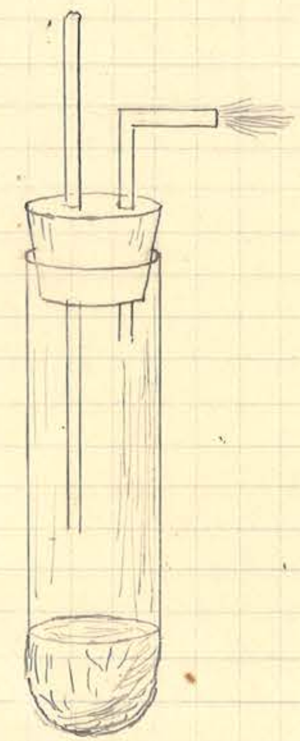
Problem 66. -

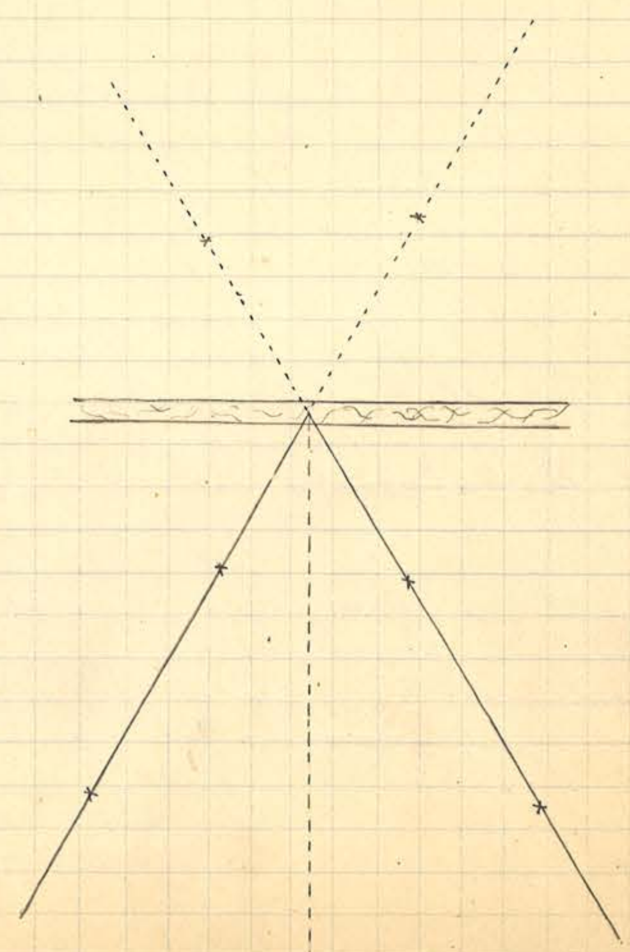
To determine the melting-points of such substances as tallow, lard, beeswax, etc.

Apparatus: - A chemical thermometer, glass beaker, ironstand, Bunsen burner, and capillary glass tubes.

Method: - Melt some of the substance and fill the capillary tube by suction. Close one end of the tube by fusion in a gas flame. On cooling, there should be a fine opaque thread of the substance in the tube. Tie this to the thermometer with the bulb and substance side by side. Place a small glass beaker nearly full of water on the sand-bath over the Bunsen flame. When the temperature of the water is near the melting-point of the substance, stir it gently with the thermometer; at the moment the substance begins to melt, the reading of the thermometer must be noted. Record the temperature at which opacity returns.

Substance.	Melting Point	Congealing-Point.	Mean.
Beeswax	63°	62°.5	62°.75
Sugar.	97°.5	97°	97°.25





Jan. 17. 1901. Ex. 34.

Problem 67.

To find the boiling-point of a liquid.

Apparatus:- A test-tube about 25 m.m. in diameter, a double perforated cork, a thermometer, beaker, iron-stand, and Bunsen burner.

Method:- Insert the thermometer in one of the holes of the cork, and a glass tube bent at right angles in the other to serve as an escape for the vapor. Pour about 15 ccm of the liquid to be tested into the test-tube, insert the cork, and adjust the thermometer so that its bulb is at least two centimetres above the liquid. Hold the tube in a beaker of hot water. The temperature of the heating-bath should not be many degrees above the boiling-point of the liquid. The test-tube should be submerged in the bath as far as the liquid reaches up the tube. When the vapor escapes freely from the bent tube, note the reading of the thermometer and also that of the barometer. Since the boiling-point of a liquid increases 0°.0375 C. for an increase of one millimetre in the atmospheric pressure, hence, to obtain the boiling-point at a pressure of 76 cm., the observed boiling-point must be increased by 0°.0375 (760-b) in which b. is the barometric pressure.

Liquid	Observed B.P.	Bar Pres.	B.P. at 76 cm.	Error.
Water	99°	25.904 mm	98°.031	.96
Distilled Water	100°	29.68 ..	99°.78.	.22

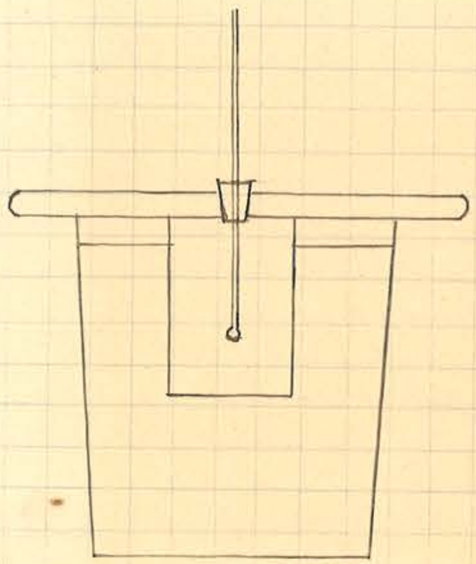
Problem 117. Ex. 35.

To investigate the law for the reflection of light.

Apparatus:- A plane mirror, a protractor, four darning-needles.

Method:- Place the mirror in an upright position and before it, on the table, tack a sheet of manilla paper. Draw a perpendicular line normal to the paper, place two needles, as far from the mirror as they are distance apart. Place two more needles in line with the first two and their reflections in the mirror. Now remove the mirror and draw lines intersecting the points. Measure the angles and subtract them from 90° and we have the angle of incidence and reflection.

	Angle of incidence.	Angle of reflection.
1st. trial.	21.5°	22°
2d. "	23°	22.5°
3d. "	30°	29.5°



Problem 61.-

To test the accuracy of Newton's law of cooling, the rate at which the temperature of a cooling body falls by radiation is proportional to the excess of its temperature over that of the surrounding medium.

Apparatus:- A tin can, a large vessel of water, and a thermometer with a very large bulb.

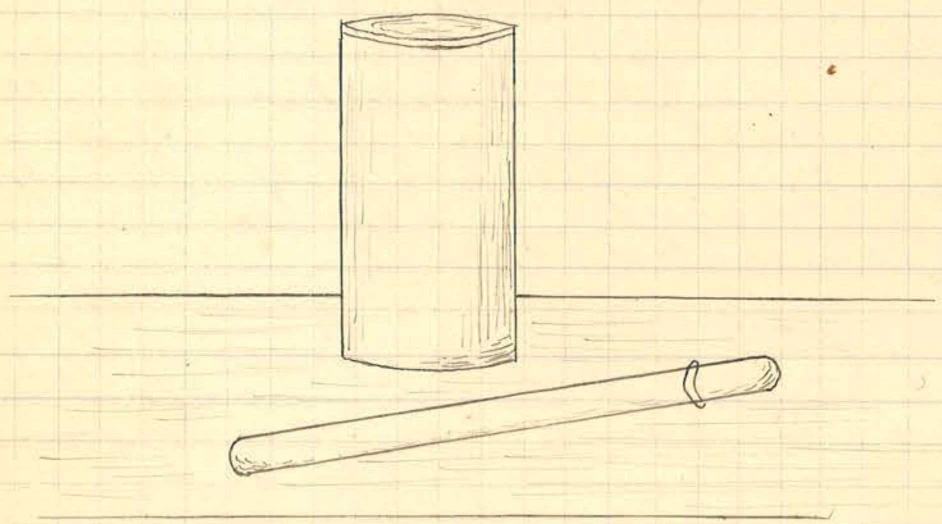
Method:- Fit a perforated cork to the cover of the can and through it pass the stem of the thermometer. The bulb should hang at the centre of the can. To maintain the enclosed air in the can, at a partially constant temperature sink the vessel, nearly to the top in a large vessel of water. Leave it in the water several minutes and then take the temperature of the water. Now heat the thermometer bulb to about 80°C. and as quickly as possible introduce it into the chamber. Then record the readings for every half-minute. In a parallel column write the difference between these readings and the temperature of the water. These differences will be the excess of the temperature of the bulb or object over that of the surrounding air for each half-minute. In a third parallel column, write the number of degrees that the temperature of the bulb has fallen each half-minute. In a fourth column, place the ratio of the excess to the fall of temperature for each half-minute. If the numbers comprising column four differ but very little, it will show that Newton's law is substantially true.

Temperature of water = 12°

Reading at ½ sec.	Diff. between Temp and Reading.	Time fallen every minute	Ratio
80°	68		
64°	52	16	52 : 16 = 3¼
52°	40	12	40 : 12 = 3⅓
43°	31	9	31 : 9 = 3 4/9
36°	24	7	24 : 7 = 3 3/7
31°	19	5	19 : 5 = 3 4/5

Temperature of water = 10°

Reading at ½ sec.	Diff. between Temp and Reading.	Time fallen every minute	Ratio
78°	68		
62°	52	16	52 : 16 = 3¼
50°	40	12	40 : 12 = 3⅓
41°	31	9	31 : 9 = 3 4/9
34°	24	7	24 : 7 = 3 3/7
29°	19	5	19 : 5 = 3 4/5



Problem 69.-

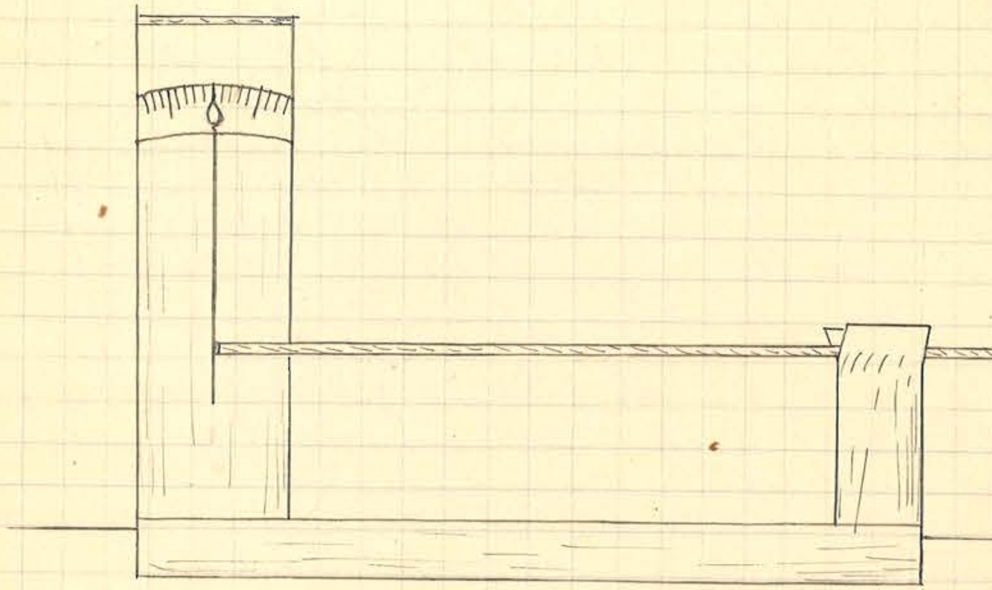
To determine the water equivalent of a vessel; that is, to find how much water will equal it in capacity for heat.

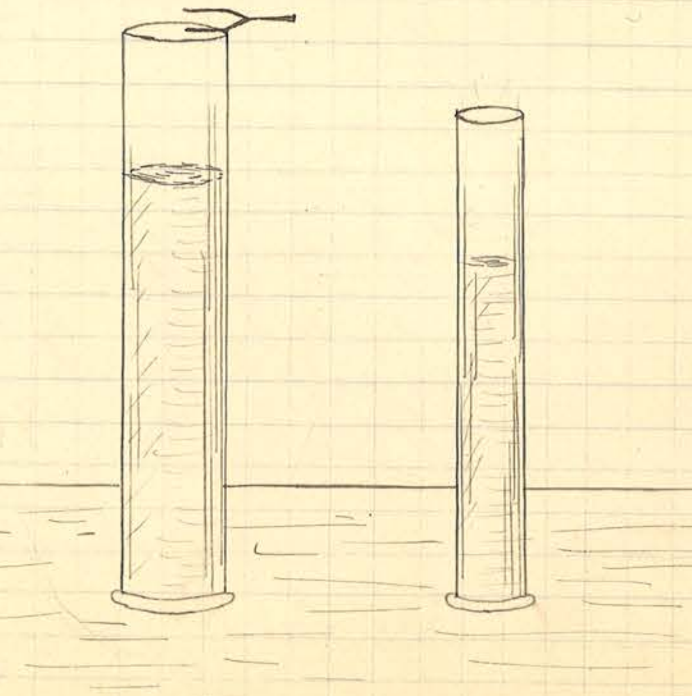
Apparatus:- A copper beaker, a thermometer, warm water, a heavy balance, and a set of metric weights.

Method:- Dry the beaker thoroughly, then let it come to the temperature of the room. Weigh out in another beaker about 600 g. of water whose temperature is about 60°C. Place this vessel on the table, ascertain its temperature, then wait exactly one minute and again note its temperature. Now as quickly as possible, pour the water into the beaker. Record the temperature at the end of thirty seconds and also at the end of the following minute. The fall of temperature during the first minute was due to radiation; that during the next thirty seconds was due to absorption by the vessel as well as to radiation; that during the last minute was due to radiation. The average of the fall in temperature for the first and last minute will be the radiation per minute. This multiplied by the time in minutes allowed for absorption, will be the correction to be added to the observed temperature at the end of the absorption period. The sum will be the temperature of the water and also of the containing beaker, if there has been no radiation. The number of calories of heat consumed by the beaker will be the product of the number of grammes of water by the difference between the temperature of the water when poured into the beaker and its temperature after absorption corrected for radiation. This product divided by the gain of temp. on the part of the beaker will be the number of calories necessary to heat the beaker 1° C., and will therefore be the number of grammes of water to which the beaker is equivalent.

a- Mass of beaker = 265 g.
b- Temp. of beaker at beginning = 26.5°
c- Mass of water used = 600 g.
d- Temp of water at beginning = 67°
e- " " " after 1 min = 64°
f. " " " at end of absorption = 61.5
g- Time allowed for absorption = .5 min.
h- Temp of water at the end of next min. = 59.5°
i- Corrected for radiation = 62.5°

k- calories absorbed by beaker 900
l- Temp gained by beaker = 35°
m- Thermal capacity of beaker = 25
True thermal capacity = 25.14
Error = .14.





Problem 63.

To determine the coefficient of linear expansion of a metallic rod:—

Apparatus:— A wooden frame, supporting a brass rod between two points.

Method:— Find the length of the rod with great accuracy. Then ascertain its temperature. Place the rod so that the needle will just touch it, and record the micrometer head. Now heat the rod for several minutes, and again read the micrometer. The difference between the two readings is the expansion of the rod. This expansion divided by the gain of temperature by the rod will be the expansion for one degree; and this quotient divided by the initial length will be the coefficient sought.

Length of rod	56½ cm	300° − 22° = 278°
Initial Temp	22°	2.9 ÷ 278 = .01043
Final "	300°	.01043 ÷ 56½ = .00001866
Accepted coefficient	.00001866	.00001866 − .00001842 =
Expansion	2.9 mm.	.00000024 = Error.

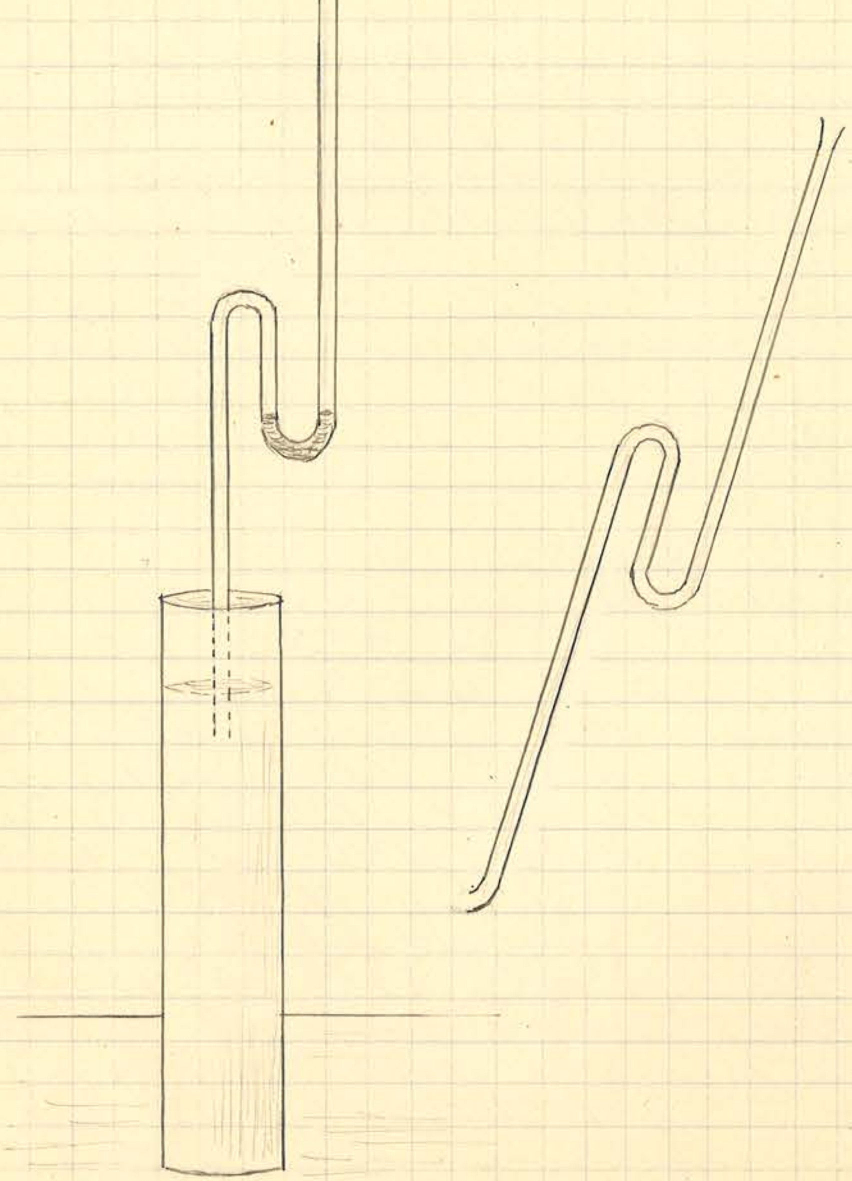
Problem 103. Ex. 39.

To find what correction must be made for diameter in the length of a cylindrical resonating air-column.

Apparatus:— A tuning fork, 3 glass cylinders, inside calipers, a thermometer, a linear scale.

Method:— Measure the inside diameter of each tube. Hold the prongs of the vibrating fork over the open end of the glass jar and gradually fill it with water until the shortest length of air-column is found which gives the loudest resonance. Find the length of the air-column and Temp. of the air. Velocity = 332 + .6t. Length = $\frac{v}{n}$ and $\frac{l'}{4}$ = length of shortest resonating column. The difference between the computed and measured lengths of the air column divided by the diam of tube will be that part of the diameter of a cylindrical resonator to be added to the observed length of the resonating column to give the true length.

	n.	Diam	Length of air col.	Temp.	Velocity of sound.	Theoretical l. of air col.	Difference	Ratio.
1st jar	512	6.4 cm	16.5	15.5	341.3	16.6	.1	.013
2d "	512	5.4 cm	16.4	15	341.	16.6	.2	.037
3d "	512	2.5 cm	16.6	22	340.2	16.8	.2	.07



Problem 40.-

To measure the pressure at any point within a vessel of water, and compare the pressures in different directions at that point.

Apparatus :- Several bent glass tubes, mercury, a pair of dividers, a linear scale, a deep vessel of water, and a rubber connector.

Method :- Pour mercury in the U shaped part of the tube till it rises about 1 cm in each arm. Fill the tube with water, connect it to the lower end of tube with a rubber connector, hold it vertically in the vessel of water, and measure the difference of level of mercury in the two limbs for various distances of the mouth of (b) below the surface of water. Try three tubes using same distances of their mouths below the surface. Find the ratio of depth of the submergence to the corresponding change in mercury level. These ratios should be constant.

Side Pressure.

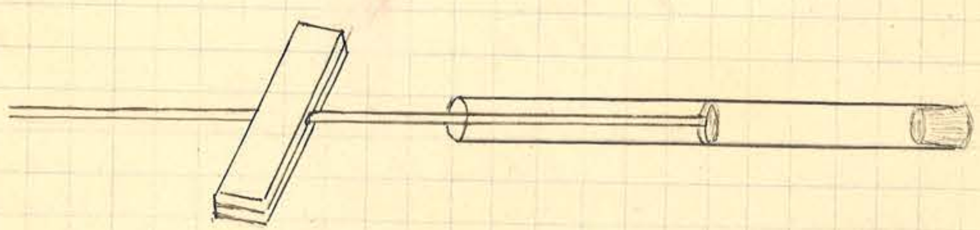
Height of mer. col. in tube a.		Distance of mouth of b. below water	Difference in mercury col.
2.5 cm	5 cm.	7.3 cm.	2.5 cm.
2.8 "	4.7 "	17.7 "	1.9 "
3 "	4.5 "	19.9 "	1.5 "
3.3 "	4.2 "	30.2 "	.9 "

Upward Pressure.

5.5 cm	8. cm.	7.3 cm.	2.5 cm.
5.8 "	7.7 "	17.7 "	1.9 "
6 "	7.5 "	19.9 "	1.5 "
6.3 "	7.2 "	30.2 "	.9 "

Downward Pressure.

4 cm	6.5 cm	7.3 cm.	2.5 cm.
4.3 "	6.2 "	17.7 "	1.9 "
4.5 "	6 "	19.9 "	1.5 "
4.8 "	5.7 "	30.2 "	.9 "



Problem - 111. - Ex. - 41 -

To investigate the laws of vibrating strings.

Apparatus :- Sonometer, wires stretched across the bridges at the ends, and over pulleys at one end to which tensions are attached.

Method :- Stretch two steel wires of the same diameter, giving them different tensions. By means of the movable bridge shorten the wire of lower pitch till it sounds in unison with the higher. Compare the ratio of the tensions with that of the lengths and thereby ascertain the effect of tension on pitch.

Tensions of wires = 25 lbs, 20 lbs.
Sq. root of tensions = .894.
Ratio of lengths of wires = .893.

Method :- Stretch two steel wires of different diameters, giving them the same tension. By means of the movable bridge shorten the wire of lower pitch until it is in unison with the other. In this case the lengths vary inversely as the diameters.

Lengths of wires - 39 in, 28 in. } 39 : 28 :: 1.13 : .812.
Diam of wires. - .812 cm, 1.13 cm. } 31.66 = 31.64 Error = .02

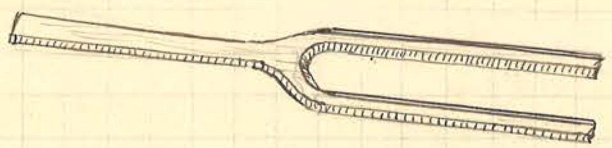
Problem 105. - Ex. - 42 -

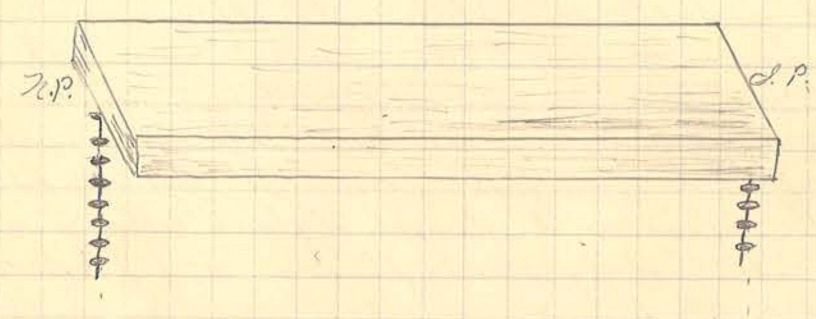
To determine the velocity of sound in steel.

Apparatus :- A glass tube 1 m. by 4 cm, a steel rod 1.5 m by 1.5 cm, an iron clamp, piece of soft leather, powdered rosin, cork, and thin rubber.

Method :- Place the steel rod in the clamp so that one end of it just touches the thin rubber at one end of glass tube. In the glass tube evenly scatter cork-dust and place a cork in the other end of glass tube. Now by using a piece of soft leather, dusted over with powdered rosin stroke the steel rod thus causing vibrations in the glass tube and disturbing the powder in the tube. This cork dust is thrown into clearly marked heaps of uniform length, subdivided into parallel ridges. Measure d, length of glass tube giving vibrations and also temperature of air at the place. - Substitute in the formula $V = \frac{d}{s}(332 + .6t)$ in which V = velocity of sound in glass, s = distance between two nodes, t = temperature.

1st trial.	2d trial.
Length of steel rod = 154 cm.	Length of rod = 154 cm.
Wave length = 10.20 cm.	Wave length = 10.2 cm.
Temperature = 20°	Temperature = 20.5°
by formula V = 5236.33	by formula V = 5236.8
true V = 5237	true V = 5237
Error = .77	Error = .2





Problem 108.- Ex. 43.

To find the vibration-rate of a tuning-fork by means of a sonometer.

Apparatus:- A tuning-fork, a sonometer, wire-micrometer, and metre-rod.-

Method:- Stretch a steel-wire on the sonometer, then by the movable bridge, make a portion of it vibrate in unison with the fork. Record length, diameter, and tension of the vibrating part. Substitute in the formula $n = \frac{1}{2lr}\sqrt{\frac{T}{\pi d}}$ in which l = length, r = radius, d = density, T = tension in absolute units, dynes, or poundals. Vibration number = 426.

1st trial.	2d trial	3d trial.
l = 26.5 cm	l = 26.1 cm	l = 26 cm.
d = .86 mm.	d = .086 cm	d = .086 cm
r = .043 cm.	r = .043 cm.	r = .043 "
T = 50 lbs.	T = 50 lbs.	T = 50 lbs
density = 7.816	density = 7.816.	density = 7.816.
$n = \frac{1}{2lr}\sqrt{\frac{T}{\pi d}}$.	$n = \frac{1}{2lr}\sqrt{\frac{T}{\pi d}}$.	$n = \frac{1}{2lr}\sqrt{\frac{T}{\pi d}}$.
$2lr$ = 2.2790	$2lr$ = 2.2446	$2lr$ = 2.236
T = 22234950.98	T = 22234950.98	T = 22234950.98
πd = 24.5547456	πd = 24.554744+	πd = 24.554744.
by formula n = 418.06	by formula n = 424.46	by formula n = 426.1
Error = 7.94 vib.	Error = 1.54 vib.	Error = .1 vib.

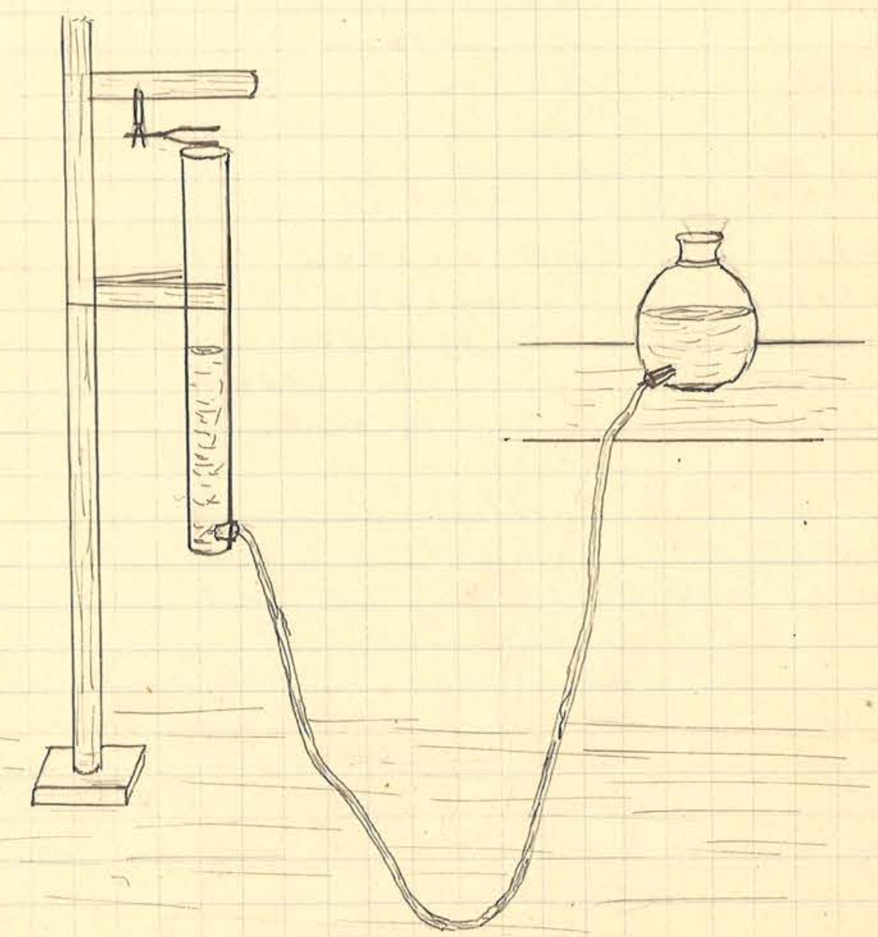
Problem 78.- Ex 44.

To compare the strength of the poles of a bar magnet.

Apparatus:- A bar-magnet and a box of iron carpet-tacks

Method:- Insert the magnet vertically into the box of tacks, and record the number lifted. Repeat several times, with as little variation of the conditions as possible. Try the other pole of the magnet in the same way. The ratio of the average of the number of tacks lifted by the two poles will represent approximately their relative strengths.

North Pole		South Pole.-	
1- trial	4	1- trial	4
2.- "	5	2- "	5
3- "	5	3- "	4
4- "	6	4- "	4
5- "	5	5- "	5
6- "	6	6- "	6
Mean.-	$5\frac{1}{6}$	Mean.-	$4\frac{2}{3}$



Problem 104.-

To determine the velocity of sound in air.

Apparatus :- A tuning fork, thermometer, 3 glass tubes closed at one end with a cork through which passes a small tube, a piece of rubber tubing, wooden clamps, a water beaker.

Method :- Place the tube in the frame and connect the water beaker and tube with the rubber tubing. Clamp the fork with the ends of its prongs over the open end of the glass tube. Water should now be poured in the beaker. Strike the fork with a rubber mallet. While the fork is sounding, vary the length of the air-column in the tube by raising the beaker or lowering it, till a strong re-enforcement of the sound of the fork is secured. Measure the length of this resonating air column, the diameter of the tube, and the temperature of the room. Find the value of the shortest resonating air-column in each case by dividing by the number of the multiple. Correct this value in each case by $\frac{2}{5}$ of the diam. of tube and compute the velocity by formula – $v = ln$, $l = 4(a + \frac{2}{5}d)$, or $v = 4n(a + \frac{2}{5}d)$. $v = 332 + .6T$.

1st. tube.

	Vib. No.	Length of air-col.	Length of air-col.	Diam of tube	Temp.
1.—	512	16.4	49	2.5	25°
2 —	"	16.2	51		
3. —	"	15.4	50		
	Mean =	16.	50.		

$a = 16$ cm.
$l = 4(a + \frac{2}{5}d) = 17 \times 4 = 68$.
$v = 347$ m.
Theoretical $v = 348.16$ m.
Error = 1.16 m.

2d tube.
$a = 16.4$ cm
$l = 68$
$v = 348.16$ m
Theo $v = 348.2$ m Error = .04

2d tube.

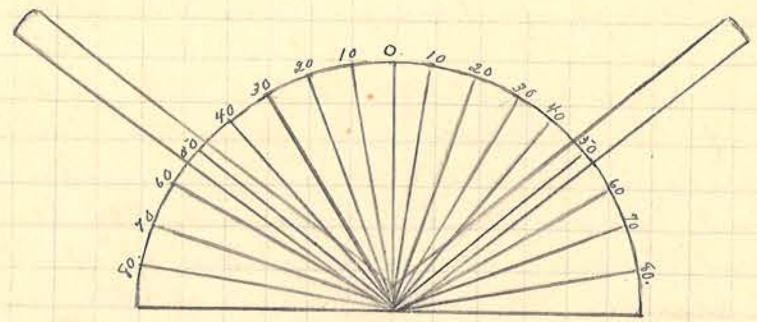
	Vib. No.	Length of air-col	Length of air col.	Diam of tube.	Temp.
1.–	512	16.4	50.25	1.5 cm.	27°
2.–	"	16.	49.25		
3.–	"	16.8	51.25		
	Mean =	16.4	50.25		

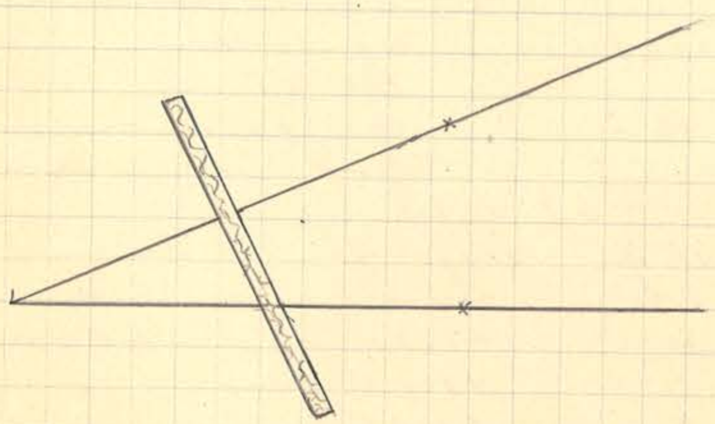
3d tube.–

	Vib. No.	Length of air-col	Length of air col.	Diam of tube.	Temp.
1.–	512	16.5	48.7	1 cm.	24°
2.–	"	16.2	49.		
3.–	"	16.53	50.1		
	Mean.	16.41	49.26		

$a = 16.416$ cm
$l = 67.64$
$v = 346.4$ m.
theo $v = 346.3$ m

Error = .1 m.





Problem. 106.- Ex. 46.

To test the law for the reflection of sound-waves.

Apparatus:- Two tin tubes 5 cm by 1.5 m, a semi-circular protractor of cardboard, a plate of glass, and watch.

Method:- Place the tubes on the protractor, forming a V with the zero of the scale midway between the tubes. Support the plate of glass across the ends of the tubes at the V. in a plane normal to the zero line of the protractor. Suspend a watch close to the outer end of one of the tubes, and listen for the sound of the ticking at the free end of the other tube.

Distance from reflector to reflector. = 36 in. First Trial.
" " " " funnel = $3\frac{1}{2}$ in.
" " " " watch = $3\frac{1}{2}$ in.

Distance from reflector to reflector = 41 in Second Trial.
" " " " funnel = $4\frac{1}{2}$ "
" " " " watch = $4\frac{1}{2}$ "

Problem 119.- Ex 47.

To prove that the image of an object in a plane mirror is situated as far behind the mirror as the object is in front.

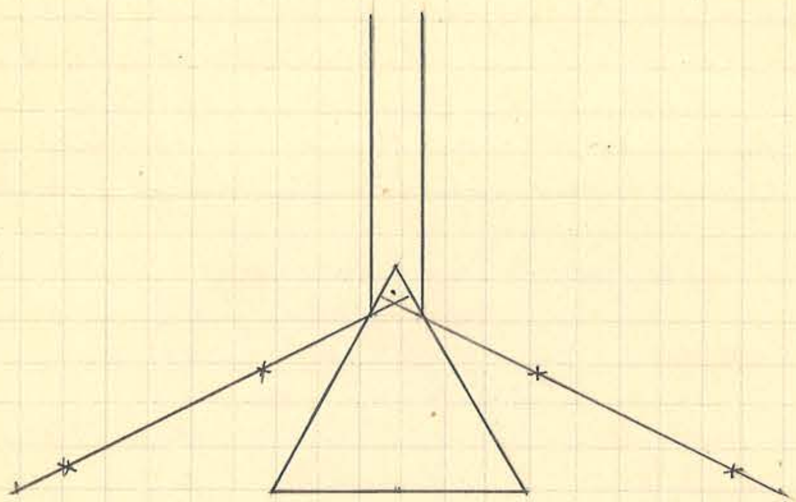
Apparatus:- A plane mirror, protractor, 4 darning-needles.

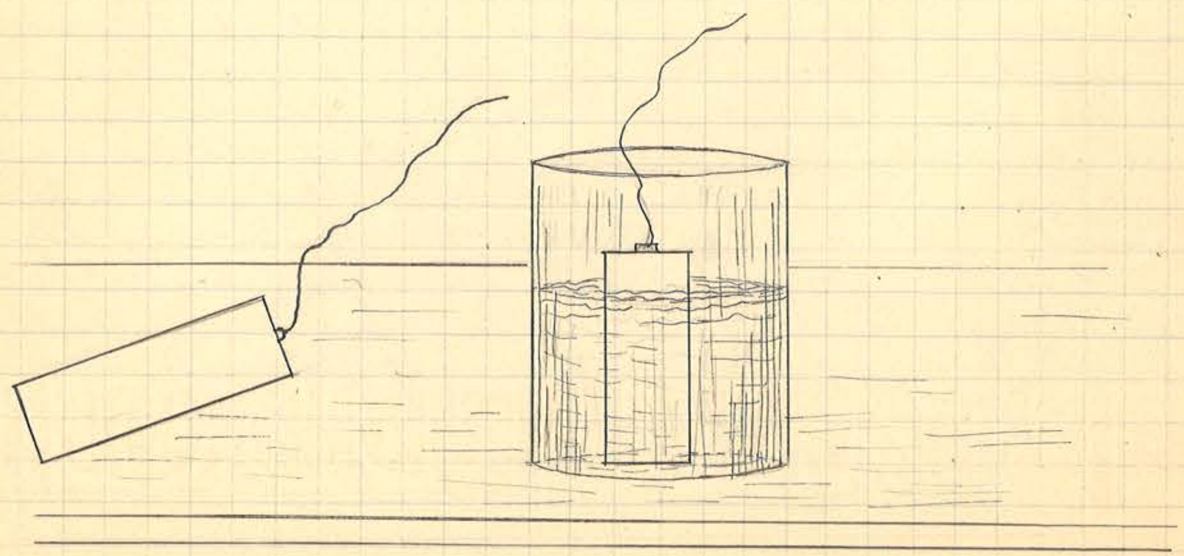
Method:- Tack a sheet of manilla paper on the table. Draw a straight line on it, and place the mirror in the normal plane containing this line. Set a darning needle, normally to the paper and about 15 cm in front of the mirror. Set a second one in an exact line with the first one and its image in the mirror. To one side of these set two more needles, so that the line of sight they mark out passes exactly through the image of the first needle. Now remove the mirror and draw straight lines through the points marked by the needles, producing them till they intersect. The point of intersection will be the position of the image of the first needle. Measure this distance from the mirror and compare with distance of object from mirror.

1st trial - Distance of object in front of mirror. - 15 cm.
Distance of image behind " - 15 "

2d trial - " of object in front of mirror - 13 cm
" of image behind. " - 13. "

3d trial - " of object in front of " - 10 cm.
" of image behind " - 10 "





Problem 115.- Ex. 48.-

To measure the angle of a glass prism.

Apparatus:- A prism, straight edge, protractor, and several darning-needles.

Method:- Tack a sheet of manilla paper on the table. Draw on the paper two parallel lines about 2 cm. apart. Place the prism with the angle to be measured between these lines. In each line set two needles, each normal to the paper. In line with the image of these needles place two other needles on each side of the prism. Now remove the prism, draw lines through the points marked by the needles. Measure the angle they form. Half of this angle is the angle of the prism.

Angle.-		Angle of prism.
120°	— 1st trial —	60°
120°	— 2d " —	60°
121°	— 3d " —	$60\frac{1}{2}$°.

Problem 84.- Ex - 49.

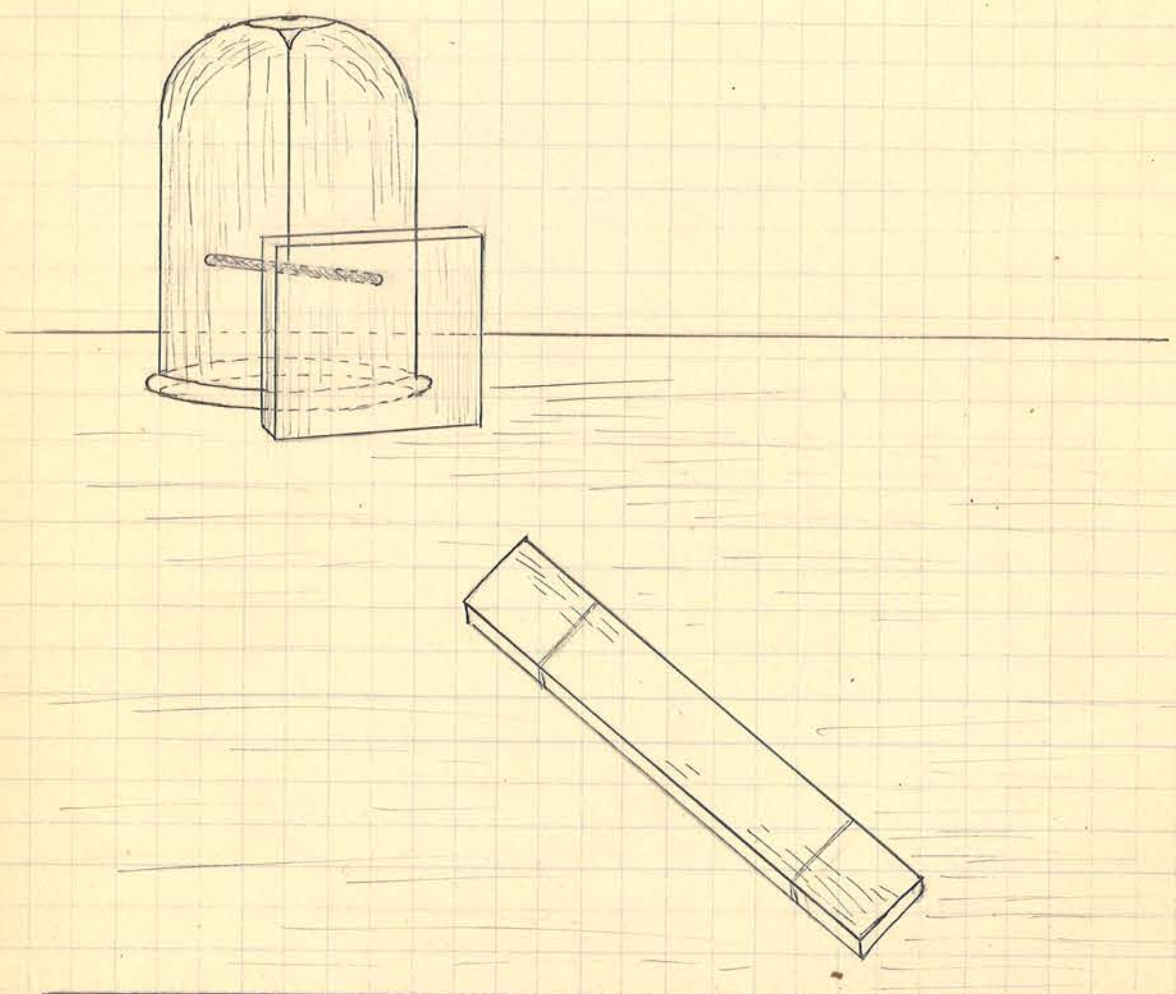
To show that local action is prevented by amalgamating the zinc.

Apparatus:- A strip of zinc and one of sheet copper, a glass tumbler three-fourths full of sulphuric acid diluted with 30 parts of water and amalgamating fluid.

Method:- Hold the strip of zinc vertically in the dilute acid and observe the surface of the zinc. Hold the copper in the acid without letting it touch the zinc and observe its surface. Then put in both zinc and copper and let the wire by which they are connected touch in one place only and notice the effect. Amalgamate the zinc and repeat the process noticing the effect.

Observations:- When zinc was put in alone, steam and bubbles arose. When copper was put in alone, there was no change. When zinc and copper were put in and the wire touched in one place only, there were changes in the previously observed action in both zinc and copper. When copper and amalgamented zinc were put in, the sulphuric acid action takes place on copper and not on zinc.

Inference:- An electric current is produced and the current in the solution runs from the zinc to copper; and in the air from the copper to the zinc.



Problem 77.

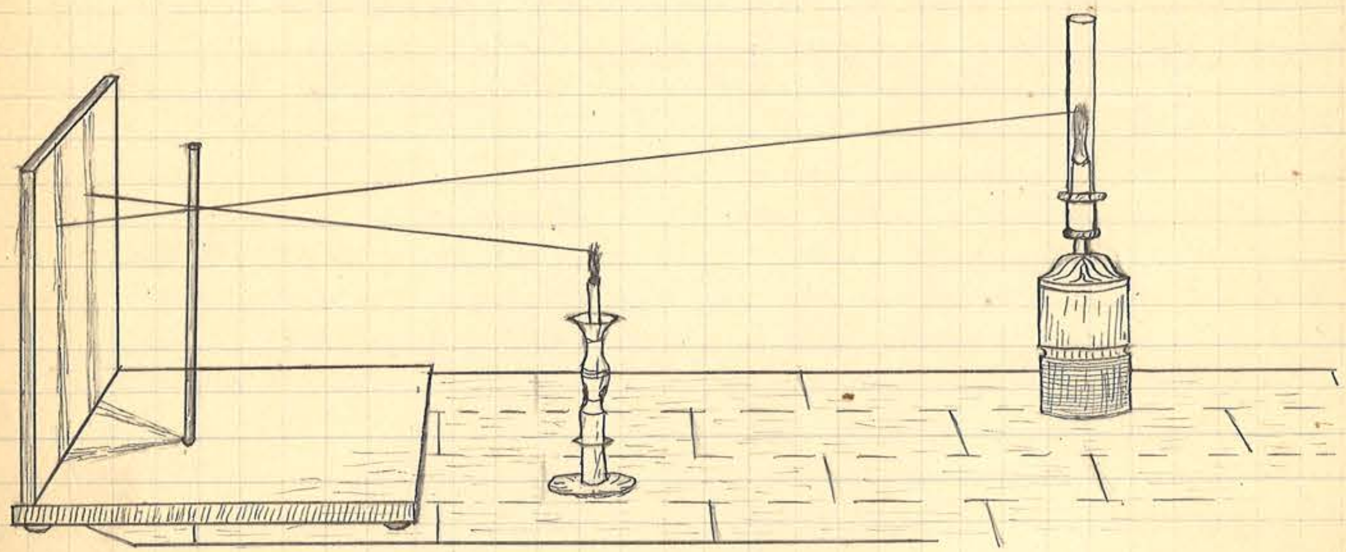
Ex. 50.

To compare the action of magnetic force through sheets or plates of various substances.

Apparatus:- Thin sheets of cardboard, wood, glass, etc, about ten cm. square, bar magnet, a Magnetoscope, and a watch.

Method:- Set the magnetoscope vibrating through a small arc by bringing a bar magnet near it, and count the number of vibrations it makes in a minute. Now support the N-seeking pole of a magnet near the S.-seeking pole of the needle, and count the number of vibrations as before. Count the number made when a sheet of cardboard is held between the magnet and the needle. Try also sheets of wood, glass, etc. The distance between the magnet and the vibrating needle should be the same for each trial. The vibrations that the needle made in the minute before the magnet was placed near and the sheets of wood glass, etc, were used is due to the magnetism of the earth.

Earth	Air	Glass.-	Wood.-	
8.	10	11.	$10\frac{1}{2}$	- 1st trial
8.	9	11.	11	- 2d. "
8.	10	11.	$10\frac{1}{2}$	- 3d "
8	$9\frac{2}{3}$	11	$10\frac{2}{3}$.	- Mean.



Problem 115.- Ex.: 51.

To measure the candle-power of a kerosene lamp by means of a Rumford photometer.

Apparatus:- A lamp, a sperm candle, a white paper screen, and a wooden rod about 1 cm. in diameter and 20 cm. long.

Method:- Support the white screen in a vertical plane. About 10 cm. in front of it support the wooden rod vertically and about 30 cm. from the screen place the lighted candle. On the same side of the screen also place the lamp giving it such a position that it casts a shadow of the rod by the side of that cast by the candle and equal to it in darkness. Measure the distance of each light from the shadow on the screen. Then the square of the ratio of the distance of the lamp to that of the candle is the candle-power of the lamp.

first trial:-

Dist to candle = 32 cm.

" " gas burner = 82 cm.

$1 : x :: 32^2 : 82^2$

$1 : x :: 6724 : 1004$

$x = 6.67.$

second trial:-

Dist. to candle = 19 cm.

" " gas-burner = 50 cm.

$1 : x :: 19^2 : 50^2$

$1 : x :: 361 : 2500$

$x = 6.92 +$

third trial:-

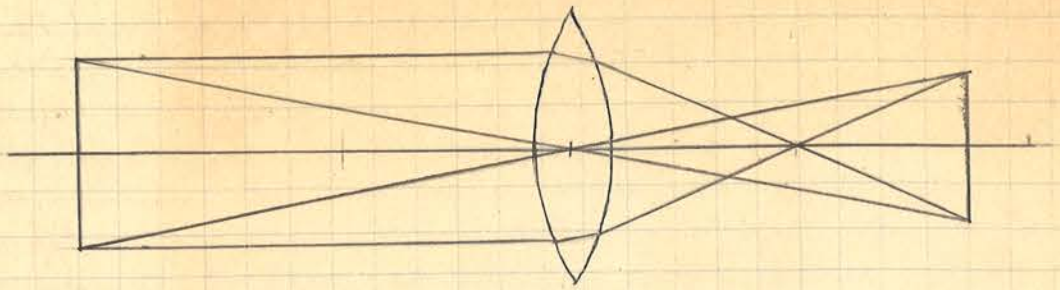
Dist to candle = 21 cm.

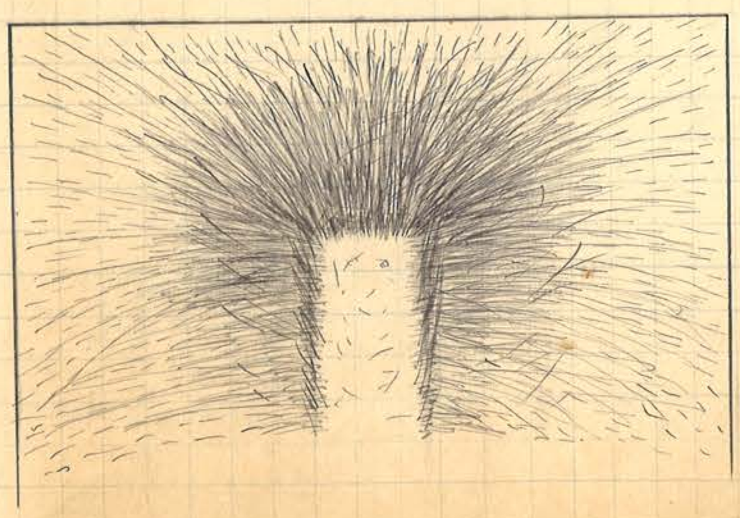
" " gas-burner = 56 cm.

$1 : x :: 21^2 : 56^2$

$1 : x :: 441 : 3006$

$x = 6.59 +$





Problem 128 Ex 52.

To measure the principal focal distance of a convex lens. First Method.

Apparatus :- A convex lens, a lamp, two screens, and a metre rod.

Method :- Support the lens in a vertical plane between the two screens. Place a lamp or candle behind the screen containing the aperture to illuminate the cross-threads. Adjust the lens so that the aperture and optical centre of the lens are in a horizontal line. Now find by trial a position for the lens between the screens where a sharply defined image of the threads is formed on the screen. Find the distances of the screens from the lens. These quantities will be the a and b. of the formula $f = \frac{ab}{a+b}$.

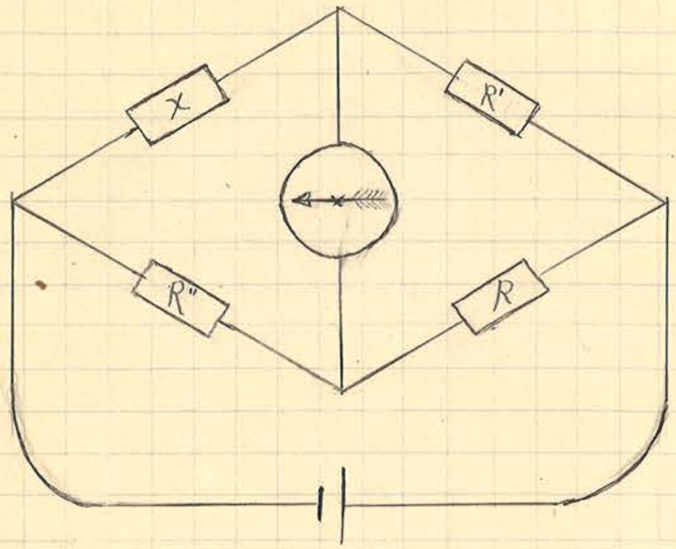
	Dist of Object. a.	Dist of Image. b.	Focal Dist. f.
1st. --	$41\frac{1}{2}$ cm.	$68\frac{1}{2}$ cm.	25.843 cm.
2d. --	36 cm.	$91\frac{1}{4}$ cm.	25.81 cm.
3d. --	$20\frac{3}{4}$ in	20 in	10.18 in or 25.837 cm

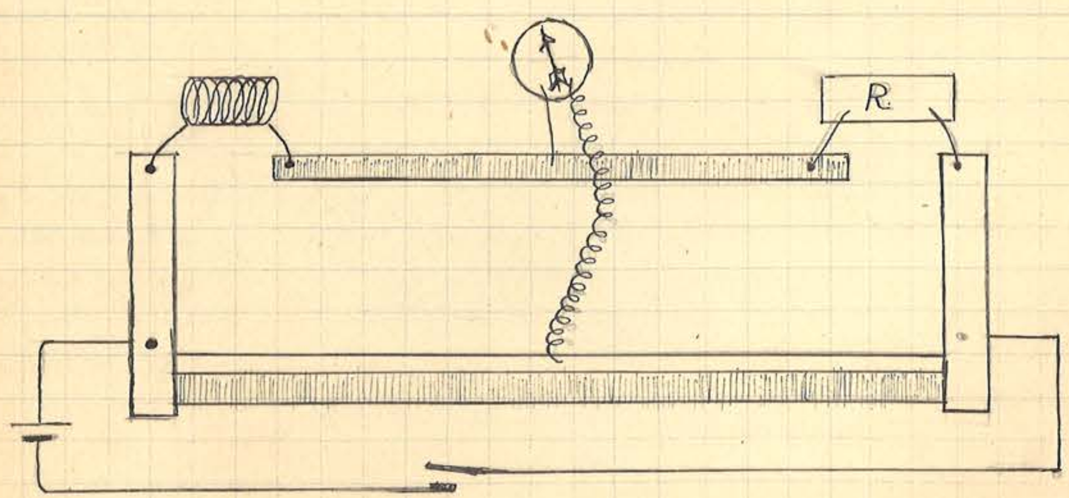
Problem 80.- Ex 53.

To map out the magnetic field of a magnet.

Apparatus :- Bar magnet, white paper, a dish of iron filings.

Method :- Place a magnet beneath a sheet of paper and sift iron filings evenly over it tapping the paper gently to facilitate the movements of the filings. Permanent copies of these figures may be obtained as follows :- Dampen a sheet of printing paper with a solution of tannin, and place it carefully on the figure after removing the magnet. Place on this a sheet of blotting paper, and apply a slight pressure.





Problem 90.- Ex 54

To measure the electrical resistance of a coil of wire by means of the Wheatstone Bridge.

Apparatus:- A battery, set of resistance coils, Wheatstone bridge, wire for connections, telegraph key, and galvanometer.

Method:- Connect the battery. A telegraph key should be placed in the battery circuit, and the galvanometer should be located where the smallest motion of the needle can be seen. Introduce through R. a resistance. Then close the battery circuit and slide B along the wire E. F. till a point is found at which the galvanometer is not affected; then X equals R multiplied by the ratio of E. B. to B. F. Vary the conditions by giving different values to R. successively.

Resistance	R'	R"	X.	Deflections
10 ohms	50	50	10 ohms.	3.
20 "	50	50	20 "	2.
40 "	50	50	40 "	1.

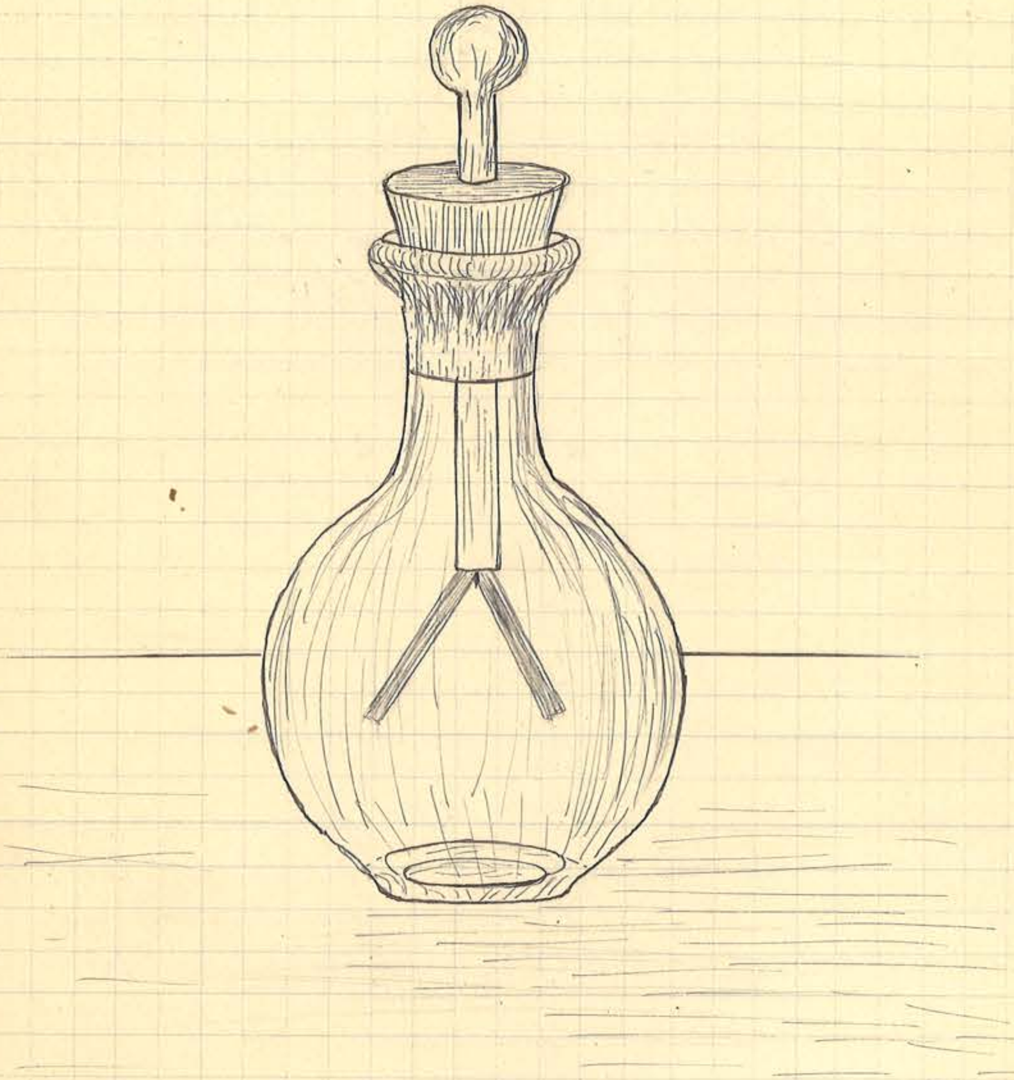
Problem 90. a. Ex 55.

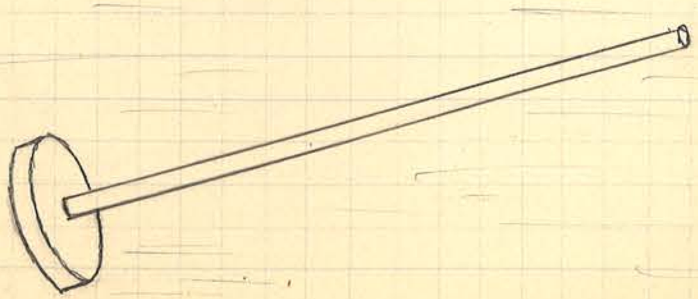
To find the resistance of the telephone.

Method:-

Connect the battery as in the preceding experiment and instead of the resistance box place the telephone. With R. of one box 84.6 ohms, there was no deflection which shows that the telephone has a Resistance of 84.6 ohms.

Resistance = 84.6 ohms.
X = 84.6 ohms.
Deflection = None.





Problem 82.- Ex 5 6.

To charge an electroscope.

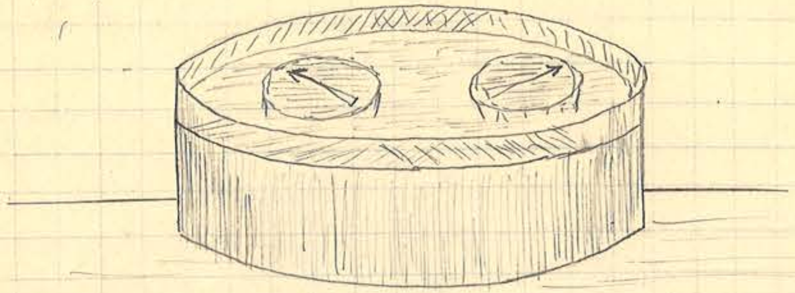
Apparatus:- An Electroscope and a Proof-plane.

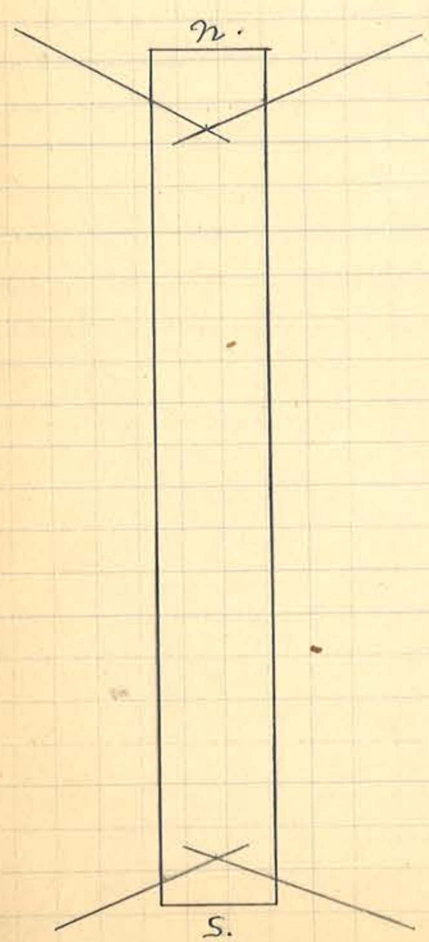
Method:- First. By Conduction. Excite a glass tube by friction. Slide the edge of the metal disk of the proof-plane along the surface, and then, without delay, touch it to the ball of the electroscope. Repeat the operation till a sufficient separation of the leaves is secured.

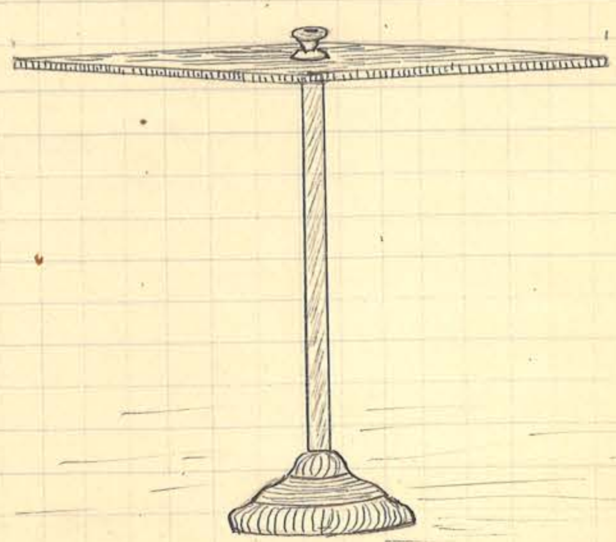
Second.- By Induction.- Hold a finger on the ball of the electroscope, and bring near the ball an electrified body, as a glass tube. Remove the finger before taking away the electrified body. The leaves of the electroscope will separate, and by the law of induction will be charged with the opposite kind of electrification to that of the body. The intensity of the electrical charge can be varied by varying the distance between the excited body and the ball of the electroscope during the act of charging.

Conduction:- The proof-plane was electrified by bringing it in contact with the glass rod which had also been electrified. It was then placed in contact with the ball of the electroscope and the leaves separated widely.

Induction:- Finger was placed on the ball of the electroscope and the electrified glass rod was held a short distance above the ball. Leaves did not separate until finger was removed.







Problem 75.- Ex.-57.

To study the action between magnetic poles.

Apparatus:- Two large needles, a magnet, a flat cork, and a dish of water.

Method:- Magnetize each needle by means of the magnet. Float each needle in succession on the cork and determine its N. seeking pole. While one needle is floating on the cork, bring the N. seeking pole of the other needle to its N. seeking pole, and record the effect; bring it to the S. seeking pole; bring its S. seeking pole to each pole of the floating magnet in succession.

	Effect on N. seeking pole.	Effect on S. seeking pole.
N. seeking pole bro't up.	repulses	attracts
S. " " " "	attracts	repulses.

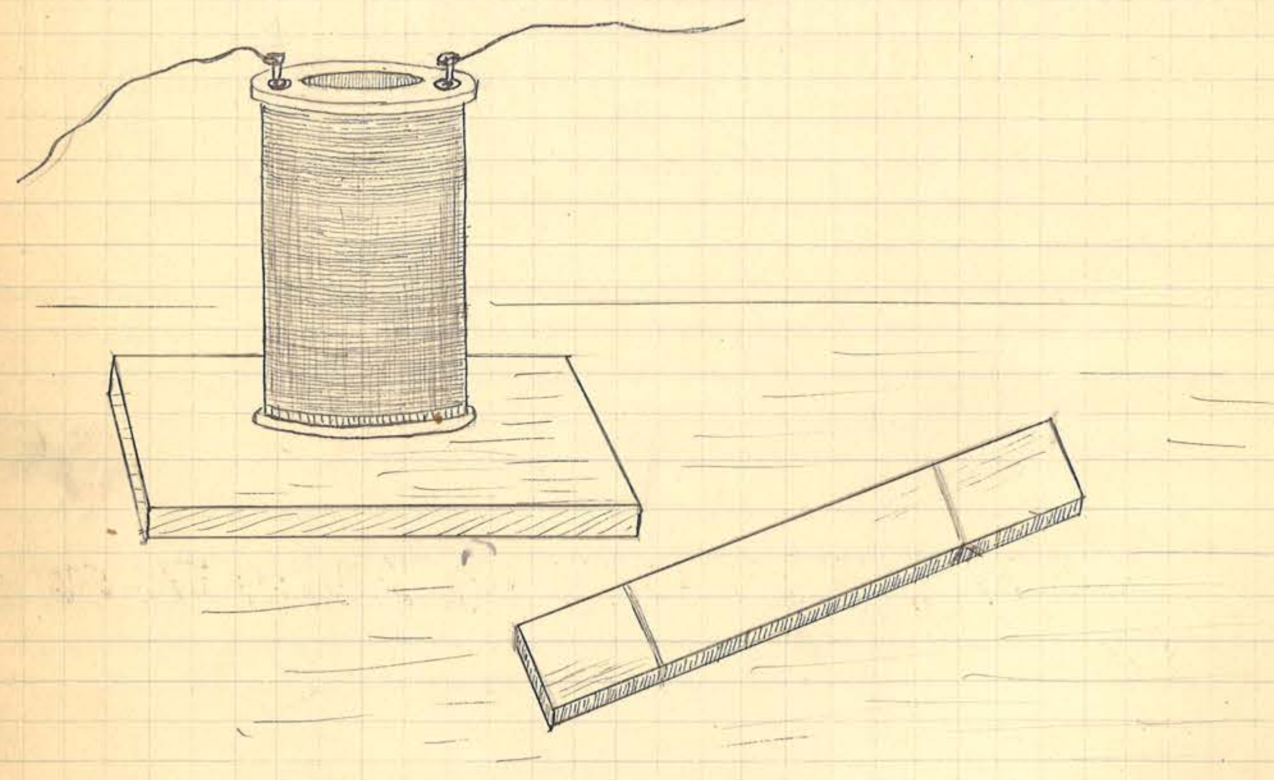
Problem 76. Ex 58.

To find the position of the poles of a bar-magnet.

Apparatus:- A bar magnet, a sheet of paper, a short magnetic needle, or pocket compass.

Method:- Lay the magnet on the sheet of paper and trace its outline. Place the magnetic needle near one corner of the magnet. Stick two pins vertically in the paper about three or four cm. apart and exactly in line with the two poles of the needle. Now move the needle to the other corner of the magnet, and locate two pins as before. Remove the magnet, and draw lines through each pair of points marked by the pins or in other words - draw lines from the needle through the outline of the magnet. The point where these lines cross will be situated very nearly under the pole of the magnet.

The distance from the N seeking pole is two times as far as from the south pole.



Problem 100. Ex 59.

To investigate the laws of magnetoelectric induction

Apparatus. — A sensitive galvanometer, a hollow spool of insulated wire, a strong bar magnet, and a battery.

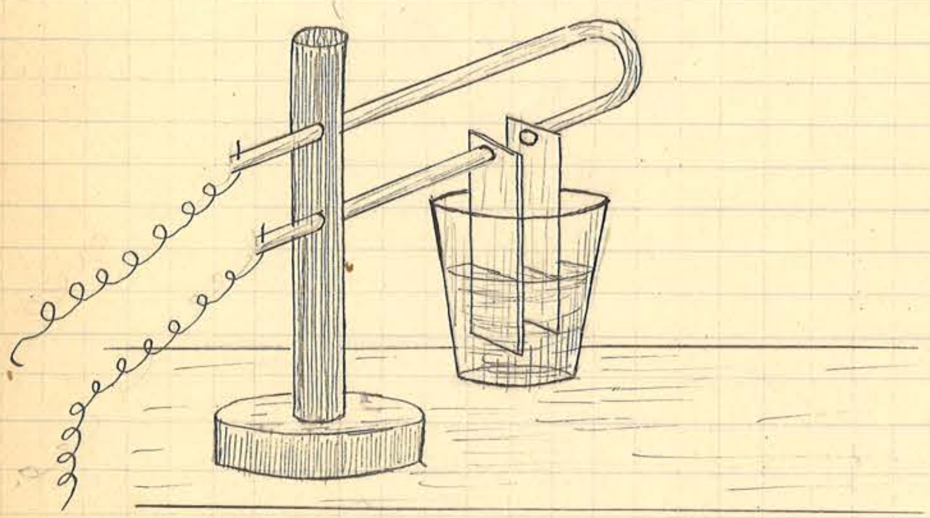
Method :— Connect the hollow helix by long wires to the galvanometer. Introduce suddenly into the helix the N-seeking pole of a strong bar magnet. Record the direction of the deflection of the needle. Place a battery in circuit with the helix and galvanometer so as to deflect the needle in the same direction as when the N-seeking pole of the magnet was inserted in the helix. Trace the direction of the current through the helix. Try the effect by using the S. seeking pole.

North pole :—
needle moves toward right — 5°
6°
6°

South pole. —
needle moves toward left. — 4°
$4\frac{1}{2}$°
4°

When battery is placed in circuit with helix and galvanometer, we find that when the N. seeking pole is put in the helix, the current goes around the helix in this direction ↻. but when the south pole is placed in the helix, the direction is ↺.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18



Problem. 83:- Ex 60.-

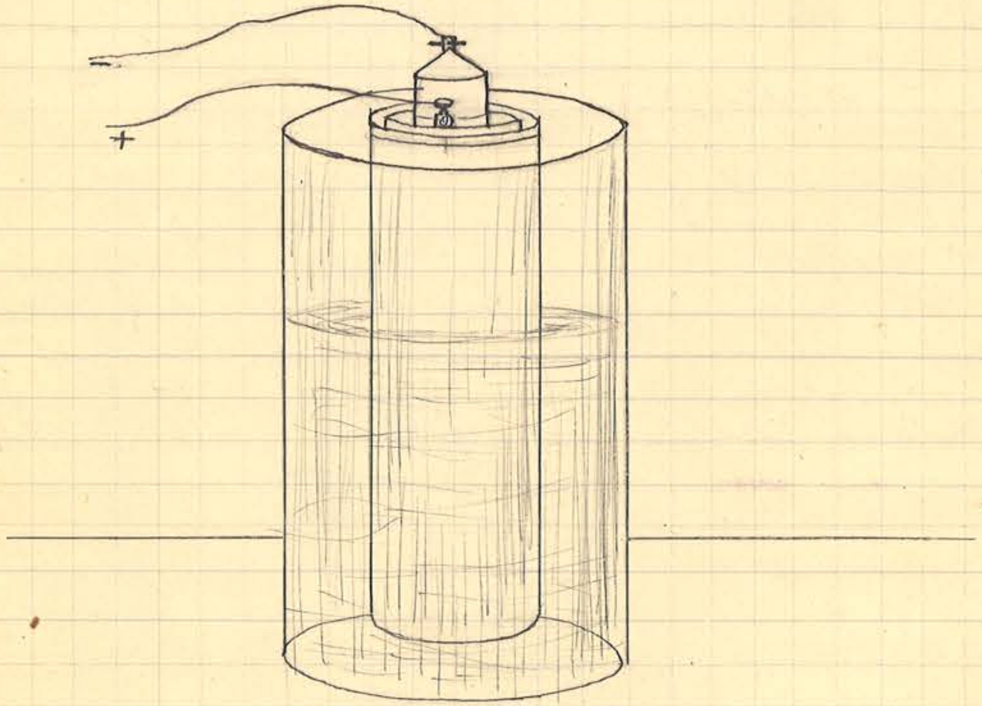
To ascertain the action of an electric current on a mounted magnetic needle.

Apparatus:- The voltaic cell, a stand for supporting the elements insulated copper wire and a magnetic needle, or pocket compass mounted in a grooved block.

Method:- Remove the insulation from the ends of the wire, and connect these ends to the plates of the simple voltaic cell by inserting them in slots cut in the ends of the brass rods of the supporting stand. Hold the wire above the needle, parallel to it, and with the current passing from north to south. Record the effect on the needle. Hold the wire so that the current passes from south to north and record the effect. Repeat the experiment with the wire below the needle.

When the current goes from south to north or from the positive to negative, the needle moves towards the right. Negative = zinc ; Positive = copper.

When the current goes from north to south - from negative to positive, the needles move toward the left. When two wires are connected and placed beneath the compass, it has no effect on the needles.



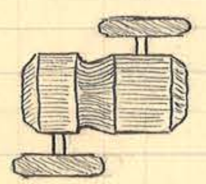
Problem, not in book. Ex 61.-

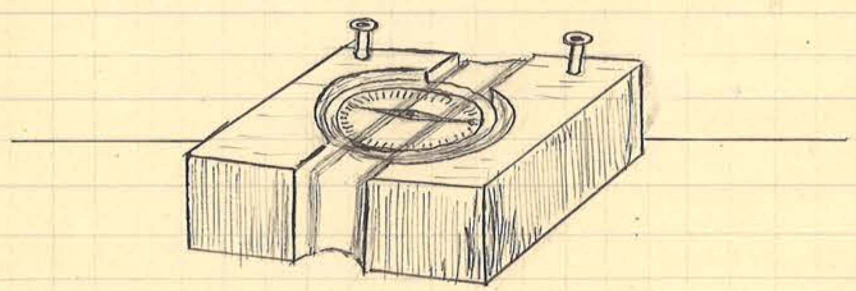
To connect batteries in series, parallel, and both together and find the current.

Apparatus:- Six similar cells, galvanoscope, key, wire, and Resistance box.

Method. Put the galvanoscope in circuit with a battery of six similar cells joined in parallel,- negative to negative; positive to positive. Notice the deflection of needle. Put the galvanoscope in circuit with a battery of the same cells joined in series - negative to positive - and record the deflection of needle. Then put the galvanoscope in circuit with the same cells joined in both series and parallel. - 2 sets of three cells joined in parallel and those 2 sets joined in series. Notice the deflection of needle. From the records, determine which method of joining cells is most effective with a high external resistance.

	Cells joined in Series	Cells joined in Parallel.	Cells joined in both.
1st. —	230°	172°	198°
2d —	234°	173°	200°
3d —	233°	171°	201°
Mean	233°	172°	$199\frac{2}{3}°$





Problem 89. Ex 62.

To measure the electrical resistance of a coil of wire by the method of substitution.

Apparatus:- Daniell battery, galvanometer, telegraph key, resistance coils, wire for connections and Double Connectors.

Method:- Form a circuit consisting of a constant battery, a galvanometer, a set of resistance coils, the conductor to be measured, and a telegraph key. Take the reading of the galvanometer when sufficient resistance has been introduced by means of the box to produce a deflection of about 45°. Drop the unknown conductor out of the circuit, connect the wires by a double connector, and introduce through the box sufficient resistance to produce the same reading of the galvanometer. The difference between the two readings of the resistance-box is the value of the unknown conductor.

Unknown R.	Known R.	X.
110	110	
110	109	3.3 ohms.
110	110	

"Finis."