

Mackay

AMPLE

Thesis for
M.Sc. and Honours in
Electricity and Magnetism.

W.A. Mackay

PHYSICAL CONSTANTS OF KAURI GUM.

Kauri Gum is the fossilised resin of the Kauri Tree (*Agathis Australis*). The tree which often attains great size is found only in the Auckland Province, and the fossil gum is found embedded beneath the surface of the soil in open country on the sites of ancient forests.

The gum is located by probing with long spears, and is then dug out. It is largely used in the manufacture of high class varnishes and linoleums.

There is a large range of colour - from dark, almost black gum, that has evidently been subject in times gone by to the action of forest fires, to clear white, invaluable for certain descriptions of Varnishes.

The pieces collected vary from small "chips" to the size of large flint stones and very occasionally lumps up to 50 lbs are found. Most of the gum obtained to-day is of the chip variety and considerable labour is involved in separating it from its surrounding earth.

The gum used in these experiments was cut from a block weighing about three pounds, consisting of the best quality gum.

As far as could be ascertained only one previous attempt has been made to determine any of the physical constants of the gum and then not even approximate results were obtained.*

* J.S.S.Cooper Trans. N.Z. Institute Vol 36 p.490

This research was designed primarily to measure :

- (1) Resistivity
- (2) Surface Resistance
- (3) Dielectric Constant

These three are of importance in connection with the possible electrical separation of the chip gum from impurities.

Several methods are in use on the gum fields for separating the gum from clay and soils, but none give very good results.

Since this research was started an English company has patented an electrostatic method of separation and intends to use it on their gum fields in North Auckland.

The Refractive index and Specific Heat of the gum were also measured.

1 RESISTIVITY.

The method adopted was a leak one, the quantity of electricity passing through given volume of gum under a certain voltage being measured.

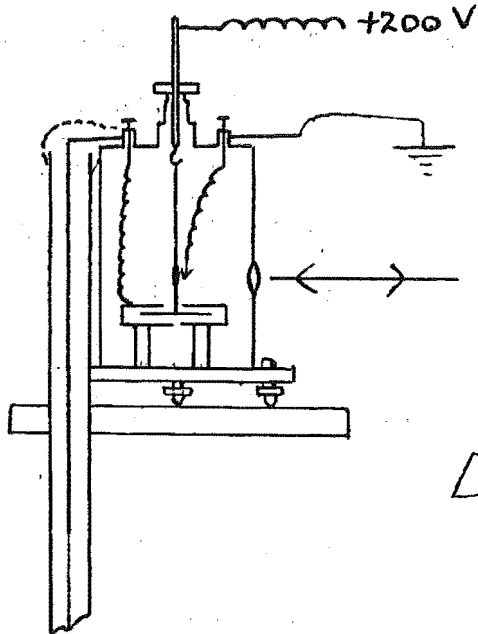
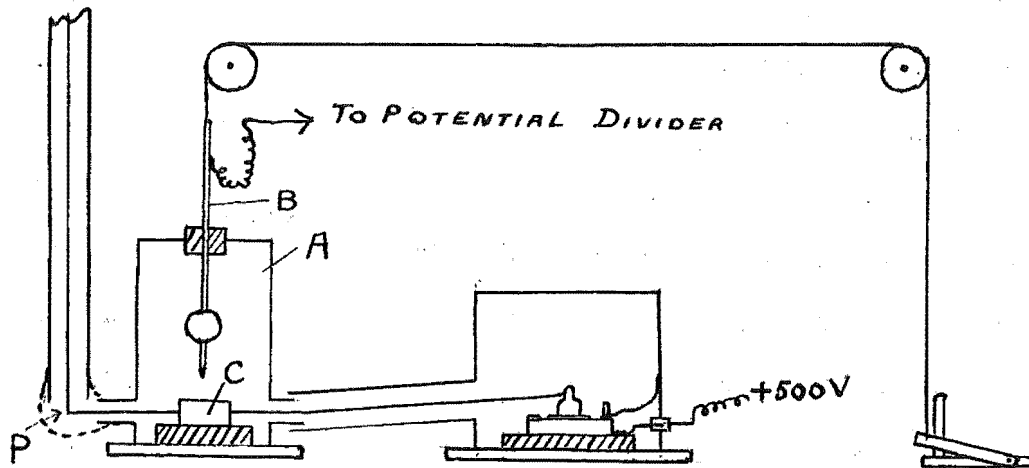


DIAGRAM OF APPARATUS
FIG. 1.



1. The Measuring Instrument consisted of a Dolezalek Quadrant Electrometer.

The instrument was mounted on a rigid base and a beam of light reflected on to a scale at a distance of 1 metre.

A scale deflection of 375 m.ms per volt was obtained.

One pair of quadrants was earthed and the needle maintained at a steady potential of + 200 Volts.

The other pair of quadrants was connected to one side of a key (A) as shown.

(C)

The key consisted of a piece of copper ⁶ m.m. thick 3 cms long and 1.5 cms wide mounted on a thick block of ebonite to ensure good insulation. The whole was contained in a brass case kept at zero potential. Two short pieces of thin brass rod were screwed into opposite ends of the copper and projecting through the sides of the case the wire connections were soldered to them. A long steel needle (B) with a sharp point passed through an ebonite bushing in the top of the case and was arranged to fall on the block of copper. It was weighted with a lump of lead, thus ensuring the point digging well into the copper, and could be raised or lowered at will by means of a cotton thread passing over a pulley.

A thin wire was soldered to the top of the needle and after being supported so as not to retard the movement of the needle was connected to a potential divider which had its

centre point earthed and gave from +1 to -1 Volt.

Thus the whole system could be put at any required voltage and then by raising the key was left isolated.

The other end of the copper was connected to the upper plate of the gum specimen.

At first the electrometer was used with a small wire attached beneath the needle and dipping in oil, the object being to make the instrument dead beat. It was found however, that the needle moved irregularly and considerable variations were obtained. This was probably due to the wire not entering the oil normally and consequent irregular surface tension effects. The wire was removed and then the instrument was quite consistent.

The level of the instrument and position of the needle between the quadrants were adjusted until the electrical and mechanical zeros coincided i.e. there was no movement of the needle on charging it up with all the quadrants earthed.

In damp weather, the electrometer developed a small insulation leak but this was removed by placing a small radiator 4-5 feet from the instrument

2. Capacity of Electrometer System.

This was determined by the method of mixtures using a

standard cylindrical condenser whose capacity could be calculated. The electrometer itself was used to measure the potentials.

(84) The Standard Condenser was constructed of two brass tubes the inner diameter of the one being greater than the outer diameter of the other by about 2 m.m.

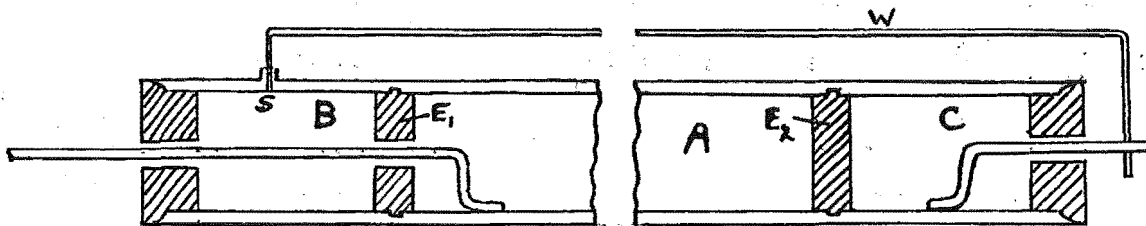


FIG 2. STANDARD CONDENSER.

The inner tube consisted of a middle portion (A) 25 cms long separated by small pieces of ebonite E1 and E2 from the two end portions B & C, the ebonite being screwed into both and thus the whole tube was perfectly rigid.

This tube was supported inside the outer by two pieces of ebonite screwed in at either end and having a small flange to support the tube away from the outer.

A thin brass rod was soldered to the inside of one end

portion (c) of the inner tube and passed through a hole in the ebonite.

A screw (s) was fitted into the other end portion and passed through an ebonite bushing in the outer tube. The two ends were then connected by an external wire (w)

A thin rod was soldered to the inside of the tube (A) and passing out through openings in the ebonite plugs served as terminal for the centre tube.

Dimensions.

(a) The outer diameter of the inner tube was measured by means of accurate sliding callipers.

Results :

Readings of diameter in cms. =	3.184,	3.178
	3.184	3.180
	3.182	3.178
	3.182	3.180
	3.182	3.180
	3.184	

Mean diameter = $\frac{34.994}{11}$ = 3.18127 cms.

∴ Radius of inner cylinder = 1.5906 cms.

(b) The inner diameter of the outer cylinder was found by waxing a plane sheet of metal to one end and then weighing the water required to fill it.

Length of outer tube	= 38.78 cms
(a) Weight of beaker and water	= 604.56 grams
Weight of beaker and water after filling tube	= <u>255.27</u> grams
∴ Weight of water required to fill tube	= 349.29 grams
(b) Weight of beaker and water	= 613.49 grams
Weight of beaker and water after filling tube	= <u>264.35</u> grams
Weight of water required to fill tube	= 349.14 grams
∴ Mean weight of water required	= 349.215 grams
Temperature of water	= 13.4° C
Density of water at 13.4° C	= .99935 grams per c.c.
	<u>349.215</u>
∴ Volume of water = .99935	= 349.44 c.c.
∴ Cross section of tube = $\frac{349.44}{38.78}$	= 9.0109 sq. cms
∴ Radius of tube = $\left(\frac{9.0109}{\pi} \right)^{\frac{1}{2}}$	= 1.6936 cms

(c) It was found that although the inner tube was parallel to the outer it was slightly excentric

The displacement of the axis was calculated by rolling the inner tube, with its end ebonite pieces fitted, on a plate glass surface and measuring with a travelling microscope the maximum

and the minimum distance of the bottom of the tube from the plate.

Difference between ^{and minimum} maximum distances from plate = .076 cms

∴ Distance between axes of inner and of outer cylinder = .038 cm

(d) The length of the inner central cylinder was measured and allowance made for the two ebonite pieces separating it from the ends.

Length of central inner cylinder = 25.15 cms

Half of total width of the two gaps = .16 cms

∴ Effective length of central cylinder = 25.15 + .16 cms
= 25.31 cms

(e) The capacity was now calculated using Thomson's formula*

$$C = \frac{1}{2} \frac{l}{\log_e \frac{a}{b} - \frac{c^2}{a^2 - b^2}}$$

where l = length

a & b = inner and outer radii respectively

c = distance between axes of cylinders

In our case

$$l = 25.31 \text{ cms}$$

$$a = 1.6936 \text{ cms}$$

$$b = 1.5906 \text{ cms}$$

$$c = .038 \text{ cms}$$

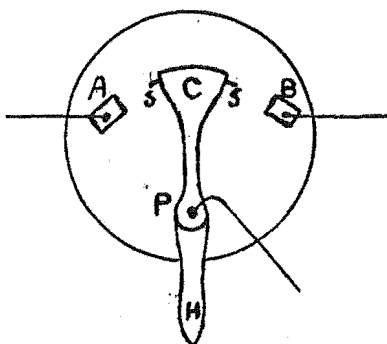
* P.T.R.S. Pt 111 1883

$$\therefore C = \frac{1}{2} \log_e \frac{25.31}{1.6936} - \frac{.0382}{1.6936^2} = 216.4$$

i.e. Capacity of standard condenser = 216.4 cms

(B) The central inner tube was now connected to the electrometer system at the point P (Fig.1) through a small key.

Some trouble was experienced with this key and the type finally adopted is shown in plan



The base was made of ebonite and the two terminals A and B consisted of small pieces of copper screwed to the base.

The part C was of copper about

3 m.m. thick and pivoted at P. Two

steel points S served to give good contact with A or B when C was moved by the ebonite handle H. The standard condenser was connected in to C, the electrometer to A, and B earthed. A small spring attached to H tended to keep C in close contact with A and a small chock outside was used to stretch the spring and put C in contact with B when required. Thus by having the chock in position the standard was earthed and on removing

the chock was connected to the electrometer. The whole key was contained in a small earthed tin with openings for the handle and terminals.

The electrometer system was connected immediately to the key but a short length of wire was necessary to join the standard to the key and was surrounded by an earthed tube. The capacity of this was calculated and added to that for the standard.

$$\begin{aligned}
 \text{Length of tube from standard to key} &= 12 \text{ cms} \\
 \text{Radius outer cylinder} &= 1.0 \text{ cms} \\
 \text{Radius inner wire} &= .1 \text{ cms} \\
 \therefore \text{Capacity} &= \frac{12}{2 \times 2.3026 \times \log_{10} \frac{1.0}{.1}} = 2.6 \text{ cms} \\
 \text{Capacity of standard (above)} &= 216.4 \text{ cms}
 \end{aligned}$$

\therefore Total capacity of standard condenser as used = 219 cms

(X) Measuring capacity of electrometer.

The key was put to earth the standard, and the guard ring of the standard was also earthed.

The electrometer system was charged up to a given potential then isolated and the charge shared with the standard. The resulting potential was measured.

The guard ring of the standard was now connected to a potential divider and arranged so that at the instant of sharing the charge from the electrometer the guard ring could

be put at the potential to which the centre tube was raised by the shared charge.

It was found that using the guard ring in this way gave a small though measureable difference in the resultant potential.

The procedure was now

1. Earth guard ring and centre of standard
2. Charge up electrometer and isolate
3. Make connection between centre tube and electrometer and at same instant switch round potential divider and put guard ring at approximate final value found above.

A series of readings were thus taken working with both +ve and -ve potentials. The mean value was taken and from it the capacity of the electrometer calculated. The resultant potential on sharing any charge was found to be quite constant when several readings were taken.

(a) Electrometer initially put at +.4 Volt

Final potential after sharing = +.134 Volt

(b) Original potential of electrometer = -.4 Volt

Final potential after sharing = -.132 Volt

(c) Mean final voltage on charging to $\pm .4$ volt = $\pm .133$ Volt

(d) Original voltage of electrometer = .4 volt

Voltage after sharing with standard = .133 volt

Capacity of standard = 219 cms

$$C \times .4 = (C + 219) \times .133$$

$$\therefore C = 109.1$$

i.e. Capacity of Electrometer and connections as used in experiment = 109.1 cms

3. The Specimens.

The Specimens were cut from a block of best quality gum about 12" X 6" X 4". The block which was the largest obtainable was unfortunately cracked in several places. The gum is exceedingly brittle and difficult to work.

The specimens were cut out approximately by means of ^ahack saw under running water and were then worked down to the required size by means of a rotating glass-paper buff. They were finally finished with fine paper on a plane metal surface.

The largest specimens obtainable were approximately 8 cms X 8 cms and it was not possible to work a specimen to a thickness of less than 8 mms without cracking.

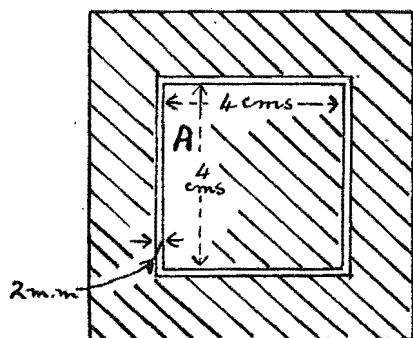
Several specimens developed small cracks at later periods and the surface leak being very much greater than the resistance leak these specimens were useless and had to be rejected.

Electrodes. The specimens were provided with electrodes of thin tin foil.

Aluminium paint was tried but rejected since the liquid gum in which the aluminium is suspended, makes it even when dry a fair insulator.

In using gloy to fasten on the foil it was found impossible to prevent some spreading over the surface and spoiling the insulation. The foil was finally fastened on by means of ether which had been made adhesive by placing some Kauri Gum in it and leaving for 2 to 3 weeks. This has the advantage that the ether evaporates and leaves nothing but gum.

The lower surface was completely covered with tin foil and rested upon a sheet of very thin copper connected by a wire to a source of high potential. The copper rested upon a slab of ebonite.



On the upper face there was a central "island" of foil (A) 4 cms X 4 cms separated by a gap of 2 mm from the outer part which acted as a guard ring.

A 20 gram weight resting upon the central "island" was connected by a wire to the key (Fig. 1) and these thus served to lead to the electrometer any electricity leaking through the gum.

The outer guard ring was connected to earth and thus prevented any charge leaking over the surface of the gum to the instrument.

4. Connections.

All the wires connecting different parts of the apparatus, e.g. from the key to the electrometer, were surrounded by brass tubes kept at zero potentials, and all junctions and bends were shielded with tin foil also kept at zero potential. The specimen of gum was contained in an earthed tin.

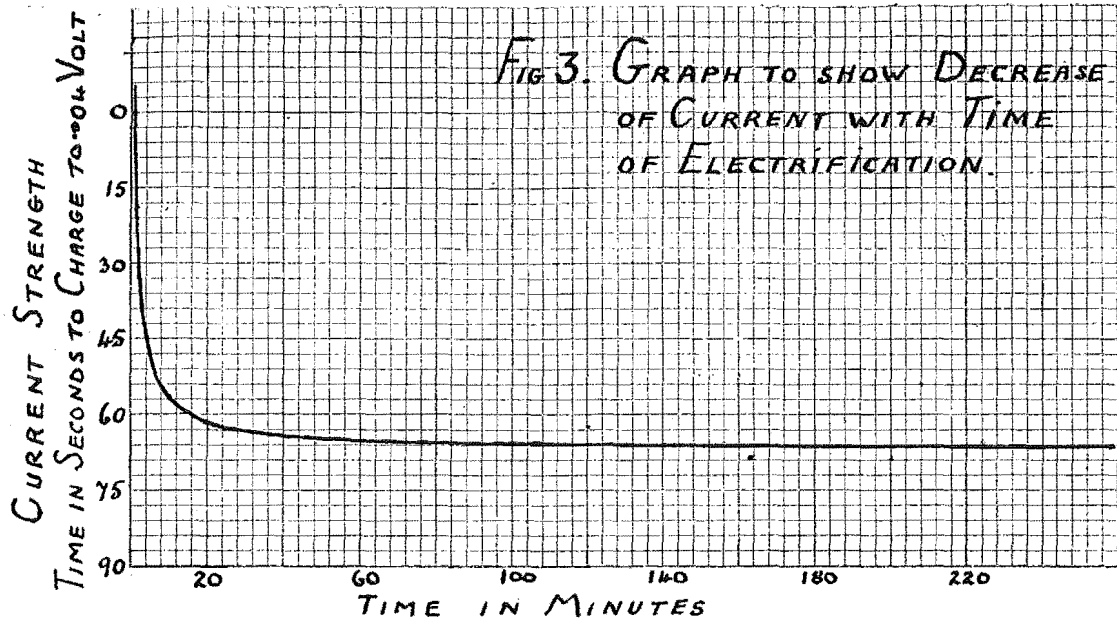
All connections were carefully soldered and special care was taken with the connections to earth.

5. The Potential.

The voltage required to drive the current through the gum was obtained from banks of small secondary cells giving up to 500 volts. The highest potential available was used.

If the leakage current through the gum was observed immediately after putting the voltage on the lower electrode, it was

found to be too great to be measured. It decreased rapidly for 10 minutes and then more and more slowly becoming constant after about two hours.



This steady current was the true resistance current, the earlier larger currents being due to the soakage effect in the gum.

This variation is shown in the graph where the reciprocal of the time taken to charge to a given potential is plotted against the time from the applying of the voltage to the specimen

If after being at a high voltage for some time, the voltage applied to the gum was reduced to zero, the effect of the soakage in the gum was to drive a current in ^{the} opposite direction to the charging current. This gradually decreased and became zero after 3 or 4 hours.*

* Compare G.L. Addenbrooke . Nature 1911

This effect was so great that it drove a current in the reverse direction if the applied voltage was reduced to less than $3/4$ of its previous value.

6. Method of Carrying out Experiment

(a) Making an observation.

1. By means of the potential divider connected to the key (A. Fig 1) the scale readings were calibrated in voltages.

2. The potential divider was now put at its earth position and the system thus at zero potential

3. When the electrometer needle became steady the key was raised, system isolated and at the same time a stop watch started.

4. The isolated quadrants immediately began to charge up and the needle to be deflected. The time to charge up to some definite voltage was measured.

(b) Natural charging current of electrometer.

It was found that with the lower electrode of the gum earthed, the instrument was charging up at a very small although quite definite rate. This was probably due to radio activity as the instrument had been frequently used in experiments with radium compounds.

Readings were taken of the time required for this current to charge the electrometer up to a given potential and hence the charge received per second calculated.

Original potential of electrometer = 0

Final potential of electrometer = .04 Volt

Times to charge up (a) 8 mins 30 secs.

(b) 9 mins 10 secs

∴ Mean time to charge = 8 mins 50 secs

∴ Rise in Potential per second

$$= \frac{.04}{530} \text{ Volts}$$

C. Resistance of the gum.

A high potential (+500 volts) was applied to the lower electrode of the gum and the charging current measured. Care was taken to see that the outer guard ring was connected to earth and well insulated from the centre "island".

Measurements were taken of the time for the charging current to charge the instrument from -.02 Volt to + .02 Volt

Readings were taken at intervals until the current became constant and then a series of readings was taken and the mean found.

Times taken by instrument to charge from

-02 Volt to + .02 Volt

= 63, 69, 53, 80, 66, 70, 67, 64, 67, seconds.

∴ Mean time required to charge up instrument = 66.5 seconds.

7. Calculation of Resistivity.

Area of specimen (centre "island") = 16 sq. cms.

Thickness = .878 cms

Mean time taken to charge from $-.02$ to $+.02$ Volt = 66.5 secs

Natural charge of instrument per second = $\frac{.04}{530}$ Volt

\therefore Natural charge of instrument in 66.5 secs = $\frac{.04}{530} \times 66.5$
= .005 Volt

\therefore Actual increase in potential due to current through the gum
= .04 - .005 = .035 Volt

Voltage applied to gum = 493 Volts

Capacity of electrometer system = 109.1 E.S.U.
= $\frac{109.1}{9 \times 10^{11}}$ farads

\therefore Quantity of electricity passing this gum in 66.5 seconds
= $\frac{109.1}{9 \times 10^{11}} \times .035$ Coulombs

\therefore Current through the gum

= $\frac{109.1}{9 \times 10^{11}} \times .035 \times \frac{1}{66.5}$ Amperes

\therefore Resistance = $493 / \left(\frac{109.1}{9 \times 10^{11}} \times .035 \times \frac{1}{66.5} \right)$ ohms

\therefore Specific Resistance = $\frac{493 \times 9 \times 10^{11} \times 66.5 \times 16}{109.1 \times .035 \times .878}$ per C.C. ohms
= 1.4×10^{17} ohms per C.C.

Error

In the foregoing calculation the only figure which may be inaccurate is the time taken by the instrument to charge up to the required potential.

From the observed times the probable error = 1 ± 1.6

$$\begin{aligned}\therefore \text{Time taken to charge} &= 66.5 \pm 1.6 \quad \text{secs.} \\ &= 66.5 \left(1 \pm \frac{1.6}{66.5} \right) \quad \text{secs.} \\ &= 66.5 \left(1 \pm .024 \right) \quad \text{secs.}\end{aligned}$$

$$\begin{aligned}\therefore \text{Resistivity} &= 1.4 \left(1 \pm .024 \right) \times 10^{17} \quad \text{ohms per c.c.} \\ &= \left(1.4 \pm .034 \right) \times 10^{17} \quad \text{ohms per c.c.}\end{aligned}$$

\therefore Result is probably accurate to within $2\frac{1}{2}\%$

11 SURFACE RESISTANCE

This was measured in exactly the same manner as the resistivity the only difference being in the specimen which had a continuous foil electrode on both upper and lower surfaces i.e. the guard ring was removed. Care was taken to see that the corners were sharp and that the two electrodes came exactly to the edges of the upper and lower surfaces of the specimen.

The surfaces over which the leak was taken were as smooth as possible and immediately before the experiment were washed with ether.

The surface leak was found to be so much greater than the true resistance leak that it was unnecessary to allow for the latter in calculating the value of the surface resistance.

Care was taken however to apply the potential to the gum for 2-3 hours, before any readings were taken in order to avoid complications due to the soakage effect.

Length of surface	= 23.8 cms
Width of surface	= .88 cms
Voltage applied	= 98.0 Volts
Charge	= .9 volt
Average time to charge	= 7 seconds
Capacity of electrometer	= 109.1 E.S.U.
	= <u>109.1</u>
	9 X 10 ¹¹ farads

∴ Quantity of electricity leaking across surface in 7 secs

$$= \frac{109.1}{9 \times 10^{11}} \times .9 \text{ coulombs}$$

$$\therefore \text{Current over surface} = \frac{109.1}{9 \times 10^4} \times .9 \times \frac{1}{7} \text{ amps}$$

$$\therefore \text{Resistance of surface} = \frac{98 \times 9 \times 10^4 \times 7}{109.1 \times .9} \text{ ohms}$$

$$\therefore \text{Resistance per sq. cm} = \frac{98 \times 9 \times 10^4 \times 7 \times 23.8}{109.1 \times .9 \times .88} \text{ ohms}$$

$$= 1.7 \times 10^{14} \text{ ohms}$$

$$\text{i.e. Surface Resistance of Kauri Gum} = \frac{1.7 \times 10^{14}}{\text{per sq. cm}} \text{ ohms}$$

Error.

From the above readings the probable error in the mean time to charge up the electrometer = $\pm .2$

$$\therefore \text{Mean time to charge} = 7 \pm .2$$

$$= 7(1 \pm .029) \text{ seconds}$$

$$\therefore \text{Resistance} = 1.7 (1 \pm .029) \times 10^{14}$$

$$= (1.7 \pm .05) \times 10^{14}$$

i.e. Result is probably accurate to within 3%

111 REFRACTIVE INDEX .

The refractive index was determined by grinding a prism and using the method of minimum deviation. The prism was made with a very acute angle to make absorption as small as possible.

It was not possible to make the surface very plane and hence the image of the slit obtained by reflection from the prism was only moderately defined but readings could be taken with reasonable accuracy.

The light from a Sodium burner was used and attempts were also made to obtain the refractive index for the Hydrogen lines but the reflection was too faint for them to be accurately observed.

(a) Angle of Prism

$$1. \text{ Reading of reflection to right} = 41^{\circ} \quad 35'$$

$$\text{Reading of reflection to left} = 163^{\circ} \quad 8' \quad 20''$$

$$\therefore \text{Angle of prism} = \underline{180^{\circ} + 41^{\circ} \quad 35' - 163^{\circ} \quad 8' \quad 20''}$$

2

$$= 29^{\circ} \quad 13' \quad 20''$$

$$2 \text{ Reading of reflection to right} = 19^{\circ} \quad 18' \quad 40''$$

$$\text{Reading of reflection to left} = 141^{\circ} \quad 3' \quad 40''$$

$$\therefore \text{Angle of prism} = 29^{\circ} \quad 7' \quad 30''$$

$$3. \text{ Reading of reflection to right} = 11^{\circ} \quad 53' \quad 40''$$

$$\text{Reading of reflection to left} = 133^{\circ} \quad 33' \quad 20''$$

$$\therefore \text{Angle of prism} = 29^{\circ} \quad 10' \quad 10''$$

$$4. \therefore \text{Mean angle of prism} = 29^{\circ} \quad 10' \quad 20''$$

(b) Angle of Minimum Deviation

1. Position of minimum deviation to left = $163^{\circ} 23'$

Position of minimum deviation to right = $16^{\circ} 19' 40''$

$$\therefore \text{Angle of minimum deviation} = \frac{180^{\circ} + 16^{\circ} 19' 40'' - 163^{\circ} 23'}{2}$$

$$= 16^{\circ} 28' 20''$$

2. Repeated determinations gave

Angle of minimum deviation = (a) $16^{\circ} 29' 50''$

(b) $16^{\circ} 27' 20''$

3. Mean angle of minimum deviation = $16^{\circ} 28' 30''$

$$(c) \mu = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

Now $A = 29^{\circ} 10' 20''$
 $D = 16^{\circ} 28' 30''$

$$\therefore \mu = \frac{\sin 22^{\circ} 49' 25''}{\sin 14^{\circ} 35' 10''}$$

$$= 1.54$$

i.e. Refractive Index of Kauri Gum for Sodium Light = 1.54

Error.

Calculating from the observed angles by probabilities, we have

Angle of prism = $29^{\circ} 10' 20'' \pm 1' 7''$

Angle of Minimum Deviation = $16^{\circ} 28' 30'' \pm 30''$

These variations make no difference in the value of the refractive index calculated until the 4th decimal place.

\therefore Result is probably accurate to within .1%

IV SPECIFIC HEAT.

1. Method

The method used was Joly's steam calorimeter

2. Apparatus

Steam acts upon the gum and alters it considerably, hence in using this method the gum must be protected from the steam.

To do this a small packet was made of thin brass about 8 cms x 2 x $\frac{1}{2}$. This was filled with the powdered gum and then all crevices completely soldered up.

A large scale pan had to be made to hold this and was hung in the steam chamber from an arm of the balance.

3. Procedure

(a) The packet full of gum was weighed and then placed in the scale pan in the steam chamber. It was left here over night to allow it to come to the temperature of the room. Its temp was then taken as carefully as possible and the weight of the scale pan and packet measured.

The steam chamber was closed and a rapid stream of steam passed in. A large outlet was provided so there was no increase of pressure inside.

After about 20 minutes the weight of the pan and contents became constant but the passage of steam was continued for about 45 mins from the initial entry and then the weight of pan and condensed steam measured.

The Barometer height was taken and from it the temperature of the steam calculated.

(b) The packet containing the gum was now removed and a hole cut in the side. All the gum was scrapped out and the packet washed in kerosene and finally rinsed in ether. When dry it was weighed and hence the weight of gum it had contained determined.

(c) The steam calorimeter was now left for a day and then the packet replaced in the pan. When the two had come to a constant temperature the experiment was repeated.

Care was taken to pass the steam in for 45 mins. as in the first experiment. The water equivalent of the pan and packet was calculated from these figures.

(d) In the first determination made the weight of steam condensed did not become very constant.

The results of this experiment were therefore discarded.

The steam outlet was improved and in the other experiments the weight of pan and condensed steam became very constant.

4. Results

A Water - Equivalent of pan and packet empty

Weight of pan and packet	= 21.479 grams
Weight of pan and packet and condensed steam	= 21.760 "
∴ Weight of steam condensed	= .281 "
Original temp of pan	= 16.95° C
Barometer height	= 764.5 m.m
∴ Temperature of steam	= 100.17° C

Water equivalent of pan and packet

= W grams

Latent Heat of Steam

= 539 calories per gram

$$\therefore \text{Heat lost by steam} = .281 \times 539 \text{ calories}$$

$$\text{Heat gained by pan} = W \times (100.17 - 16.95)$$

$$\therefore W = \frac{.281 \times 539}{83.22}$$

$$= 1.820$$

$$\therefore \text{Water equivalent of pan and brass packet} = 1.820 \text{ grams}$$

B. Experiment with gum in packet

Weight of packet and gum

= 17.742 grams

Weight of packet empty

= 11.785 "

\therefore Weight of gum

= 5.957 "

Weight of scale pan, packet and gum

= 27.439 "

Weight of scale and contents + condensed steam = 28.137 "

\therefore Weight of steam condensed

= .698 "

Original temperature of pan

= 17.45° C

Barometer height

= 760.2 m.m.

\therefore Temperature of steam

= 100.00° C

Water equivalent of pan and packet

= 1.820 grams

Latent Heat of steam

= 539 calories per gram

Specific Heat of gum

= S

$$\therefore \text{Heat given out by steam} = .698 \times 539 \text{ calories}$$

Heat gained by pan and contents

$$= (5.957S + 1.82) \times 82.55 \text{ calories}$$

$$\therefore S = \frac{.698 \times 539}{5.957 \times 82.55} - \frac{1.82}{5.957}$$

$$= .66$$

i.e. specific Heat of Kauri Gum = .46

C. The experiment was repeated using a larger amount of gum,
8.349 grams.

Value of specific Heat = .456

D ∴ Mean Specific Heat = .458

= .46

E. Accuracy of determination

Weights could be obtained to within 1 milligram but the initial temperature of the gum could not be read to nearer than $.05^{\circ}\text{C}$ and it was doubtful whether the temps recorded were actually those of the pan and contents.

Care was taken that the thermometer remained constant for some time before the temperature was read and hence the error due to bad contact between thermometer and pan is probably not more than $\pm .2^{\circ}\text{C}$

Assuming an error of this amount and recalculating from data in B above we have

Specific Heat = .458

Previous value = .460

∴ Error is 2 in 450

i.e. Result is probably accurate to within .5%

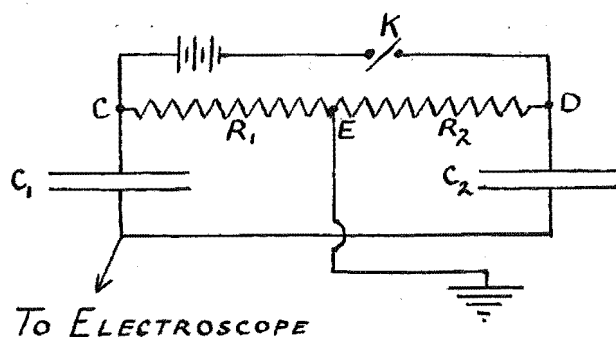
V DIELECTRIC CONSTANT

A. Method.

The method consisted in using a parallel plate condenser the distance between the plates being adjustable. A slab of gum was placed between the plates and the capacity measured. The gum was removed and the distance between the plates adjusted till the condenser had the same capacity as in the first case. The connections are the same in both cases and hence the only change in capacity is that between the plates. Now the capacity of a parallel plate air condenser is calculated from its dimensions and hence we know the capacity with the gum between the plates. Thus we can calculate the dielectric constant.

The method of inducing equal and opposite charges on two condensers was used to measure ^{the} capacity. If two condensers are connected to an electrometer there will be no deflection if the induced charges are equal and opposite.

Consider connections as shown.



One terminal of each condenser is connected to an electrometer. The other ends are connected to the ends C and D of adjustable resistances R_1 and R_2 , through

which a steady current can be maintained by a small battery. The point E is earthed. On inserting the key K the condensers will be charged to potentials V_1 and $-V_2$. The relation between these being

$$\frac{V_1}{V_2} = - \frac{R_1}{R_2}$$

Now if C_1 and C_2 are the capacities of the condensers, the quantity of electricity flowing into each while charging up will be $V_1 C_1$ and $V_2 C_2$. If these induce equal charges they must be equal.

$$\text{i.e.} \quad \frac{C_1}{C_2} = \frac{V_2}{V_1} = \frac{R_2}{R_1}$$

Hence by adjusting the resistances until there is no deflection on closing K, we can get the ratio of the capacities.

B. Apparatus

1. The detecting instrument used was a tilted gold-leaf electroscope. The plate was charged to +150 Volts and the distance between plate and leaf and the angle of tilt were adjusted to give a sensitivity of 50 eye-piece scale divisions per volt, near the zero mark.

2. A parallel plate condenser was constructed with a lower plate of 14 cms. diameter. This was at right angles to a vertical brass tube which slid with a friction fit inside another

fixed rigidly to the outer case.

Two scratches were made one on the outer and one on the inner of these tubes and by measuring the distance between them with a travelling microscope the position of the plate could be determined.

The upper plate was 6 cms. diameter and surrounded by an outer guard ring 4 cms wide the whole being the same diameter as the lower plate.

The maximum distance between the plates to be used in the experiment was approximately 1 cm. and hence the width of the guard ring was made 4 times this distance in order to ensure a straight field to the centre plate. The two parts were kept rigid by means of three arched strips of mica^(M) passing from one to the other and fastened into small clips by sealing wax. A small vertical rod soldered to the centre plate served as a terminal. The whole was encased in a stout metal box.

Three vertical metal rods were attached to the guard ring and passing through ebonite bushings in the roof of the case were supported by means of screw nuts resting upon the bushing. The height and level of the upper plate could thus be adjusted as required.

To ensure upper and lower plates being parallel the lower was pushed up until the upper rested upon it. The nuts were then screwed down until the upper plate and guard ring were just supported.

The distance between the marks on the friction tubes in this position gave the zero reading.

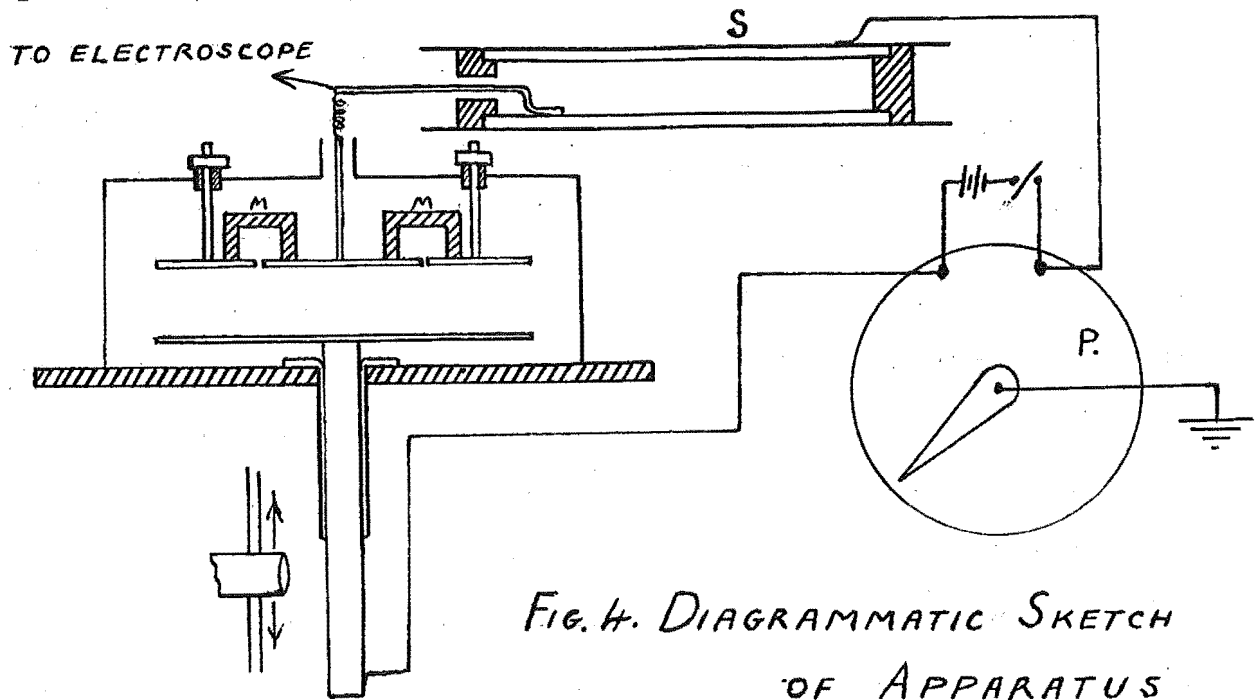


FIG. 4. DIAGRAMMATIC SKETCH
OF APPARATUS

3. A small cylindrical air condenser^(S) was made up, of capacity about 10 E.S.U. This was used for comparison with the adjustable condenser.

4. The apparatus was connected in as shown.

The upper plate of the variable and the inner tube of the cylindrical condenser were connected together and to the electrostatic meter. The outer lower plate and outer cylinder, both insulated, were connected to opposite ends of a potential divider (P) through which a current was sent by two cells.

C. Procedure.

1. The height of the lower plate is adjusted till it supports the top plate. The nuts are then screwed down until the upper plate is just held.

The distance between the marks on friction tubes is measured with a travelling microscope.

2. The lower plate is moved down and the specimen of gum placed in the condenser. Again the distance between marks on friction tubes is measured.

3. The position of the earthing key on the potential divider is adjusted until on closing or opening the switch in the battery circuit there is no movement of the electroscope leaf.

4. The gum is removed and the position of the earthing key left as found, in (3) The lower plate is now moved up or down until there is no kick of the electroscope on making or breaking the battery circuit. The capacity is now the same as in (3) with the gum in the condenser.

The distance between the marks on the two sliding tubes is again measured.

5. From this data and the thickness of the specimen the dielectric constant can be calculated.

D. Results

Distance between marks plates touching

$$= 5.344 - 4.664 = .68 \text{ cms}$$

Distance between marks with specimen between

$$= 5.344 - 3.714 = 1.63 \text{ cms}$$

Distance between marks air alone

$$= 5.344 - 4.416 = .928 \text{ cms.}$$

∴ Distance between plates with gum between

$$= 1.63 - .68 = .95 \text{ cms}$$

Distance between plates air alone

$$= .928 - .68 = .248 \text{ cms}$$

Thickness of specimen

$$= .887 \text{ cms}$$

Area of upper plate

$$= A \text{ sq cms}$$

∴ Capacity with air alone, - $\frac{A}{4\pi \times .248}$

$$4\pi \times .248$$

Capacity with gum in

$$= \frac{A}{4\pi \{ .950 - .887 (1 - \frac{1}{k}) \}}$$

These are equal

$$\therefore \frac{1}{4\pi \times .248} = \frac{1}{4\pi \{ .950 - .887(1 - \frac{1}{k}) \}}$$

$$\therefore k = 4.79$$

i.e. Dielectric Constant of Kauri Gum = 4.79

(3) Other determinations were made with different distances between the plates. From the calculation it is seen that determinations made with the plates as close as possible will be the most accurate. Hence a certain weight was attached to each value and the weighted mean ~~was~~ taken.

Value	Distance bet. plates	Weight Assigned	Value X Weight	. Weighted .. Mean
5.19	.99 cms	3	15.57	
4.79	.95 "	3	14.37	<u>51.78</u> 11
3.56	1.16 "	1	3.56	= 4.7
5.65	1.85 "	0		
4.28	.97 "	3	12.84	
5.44	1.11 "	1	5.44	
				<u>51.78</u>

Errors

It was impossible to detect any movement of the leaf for variations of less than .2 to .3 m.m. in the position of the plate and this error is sufficient to give the observed variations.

From the individual readings the probable error of the result is $\pm .2$

$$\therefore \text{Dielectric Constant} = 4.7 \pm .2$$

i.e. Result is probably accurate to within 5%