AN ELEMENTARY EXPERIMENT IN INSOLATION[1]

John D. Boon

Meterology, the neglected science, is coming into its own. This new interest is due to the rapid development of airplane transportation, the radio, and the Second World War. Slowly we are beginning to learn that while our feet may be upon the solid earth, we live in the atmosphere, and this atmosphere is influencing and often controlling our lives.

Unfortunately experimental methods for teaching meteorology have not advanced so rapidly as have those for teaching other physical sciences. This defect is due to the fact that there has been little interest in the subject. Recently, in trying to explain why the earth has seasons, the writer worked out some experiments that proved of great value to some seventy-five students. It is the purpose of this paper to describe the apparatus, to illustrate the records obtained, and to call attention to some new units that were introduced because they were needed in graphing and discussing the data. In the use of these new units, students were told that the terms were not recognized in science, that the only excuse for their introduction was the fact that they were *needed.*

Terms and Units Used

Insolation. In meteorology this term has come to mean the energy of all wave lengths received from the sun. This is not new.

Insol. The insolation unit of *intensity.* It is that intensity which would deliver to one square centimenter of surface 1.93 calories of energy per minute. Or it may be

[1]The graphs and some of the data found in this paper were taken from a student report by Henrietta Hymes.

defined as the maximum intensity of solar radiation at the top of the atmosphere.[2]

Insol-hour. A unit used in measuring the *quantity* of insolation. It is the quantity of energy received by one square centimeter of surface exposed to one insol for one hour of time. It is equal to 115.8 calories.

Apparatus Used

Celestial Globe. This globe should be large so that angles can be measured to one-half degree. A good terrestrial globe may be used provided its axis is adjustable for all latitudes and it has a plate fixed to represent the horizon.

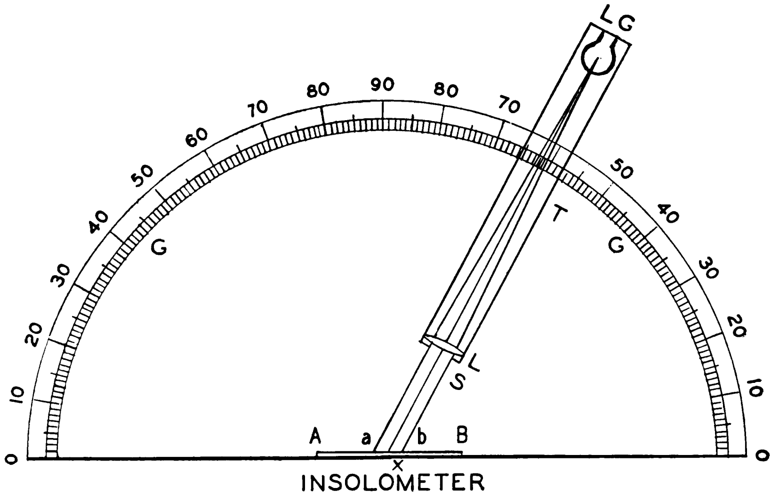
Spherical Protractor. This may be cut from thin stiff cardboard, or better still, celluloid. It should be made to fit the globe, and should be accurate to one-half degree.

Insolometer. This instrument is very important. It is used to illustrate and to measure the variations in intensity as the sunlight falls at different angles of obliquity. Its construction is illustrated.

The Experiment

Insolation for the Latitude of Dallas. The axis of the globe is set so that the altitude of the north pole is equal to the latitude of Dallas, and a ball of wax, the size of a pinhead, is placed on the ecliptic at June 21 (hereafter the ball of wax will be called the sun). With the sun on the eastern horizon the globe is turned westward to determine the number of hours between sunrise and sunset. Once more the sun is set on the eastern horizon, the globe is turned fifteen degrees at a time, and the altitude of the sun is measured with the protractor for each setting up to the time it is on the meridian. Having found the altitude of the sun for each hour in the morning the insolometer is set for these altitudes and

[2]This is the Solar Constant. It is the amount of solar energy received per minute per square centimeter at the top of the atmosphere when the sun is shining vertical. Its value has been found, by C. G. Abbott of the Smithsonian Institution, to be 1.93 calories. All insolation figures used in this paper are for the top of the atmosphere.



The Insolometer. G is a semicircular scale graduated in degrees. T is a tube with six volt light globe at one end and a lens at the other end. The tube rotates about X. A B is a celluloid ruler that may be shifted in a position so that the length of the light intercept, a b, may be measured. S is a slot one centimeter in width and three centimeters in length. The ratio of the intercept a b, for vertical setting of the tube, to its value for other settings, is the relative intensities of the light. This ratio gives the intensities for solar insulations in terms of insols. Obviously this ratio is also the sine of the altitude of the sun. The use of the insolometer has the advantage of showing the student the variation in intensity as the distribution changes.

the length of the intercepts obtained are divided into the number three. This gives the relative intensities for each hour. The average of these measurements will be the intensity, at Dallas, for June 21 in insols. These measurements are repeated for Dallas on December 22. The record of these data are found in Table A.

Insolation for the North Pole June 21. This measurement is simple. The north pole is set at an altitude of 90 degrees. With this setting the sun moves round and round at an altitude of 23.5 degrees above the horizon, and the sunshine day is 24 hours long. One measurement of the intensity is all that is required, and this multiplied by 24 gives the energy in insol-hours per day. It is of interest to note that the number of insol-hours received at the poles on June 21 is greater than for any other latitude at any other time of the year.

Table A. Insolation for the Latitude of Dallas (32.66 degrees)

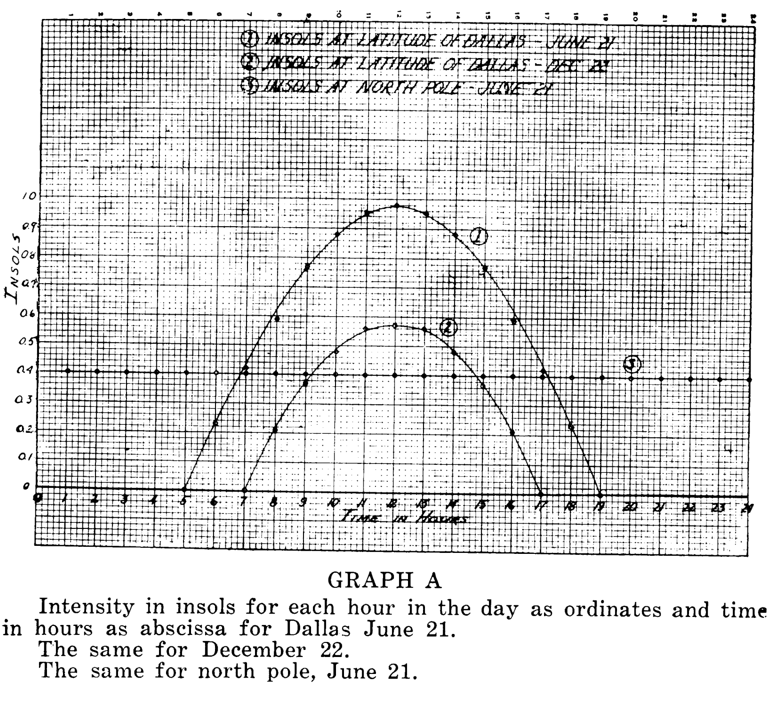
Time	Altitude of Sun Degrees		Distribution of Energy		Intensity in Insols	
	June 21	Dec. 22	June 21	Dec. 22	June 21	Dec. 22
5:00	0	0	0	0	0	0
6:00	12.0	0	13.2cm	0	.23	0
7:00	25.0	0	7.1cm	0	.42	0
8.00	36.0	11.0	5.1cm	14.5cm	.59	.21
9.00	55.5	21.0	3.9cm	8.2cm	.77	.37
10:00	63.5	29.0	3.4cm	6.2cm	.88	.48
11.00	75.0	34.0	3.15cm	5.4cm	.95	.56
12:00	81.0	35.0	3.05cm	5.3cm	.98	.57
			Average		.60	.365

Data for the Latitude of Dallas

Hours of sunshine June 21 14
Average intensity June 21 .... .60 insols
Energy received June 21 .... 8.4 insol-hours
Hours of sunshine December 22 10
Average intensity December 22 .... .365 insols
Energy received December 22 .... 3.65 insol-hours

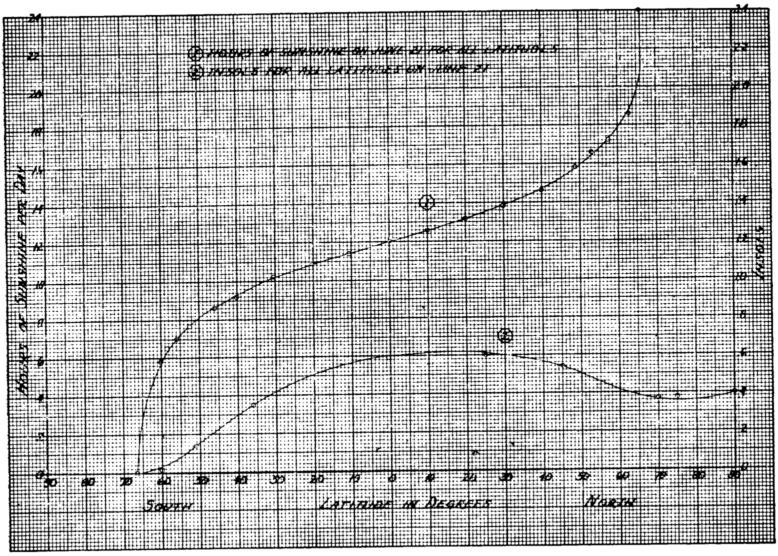
Data for the North Pole

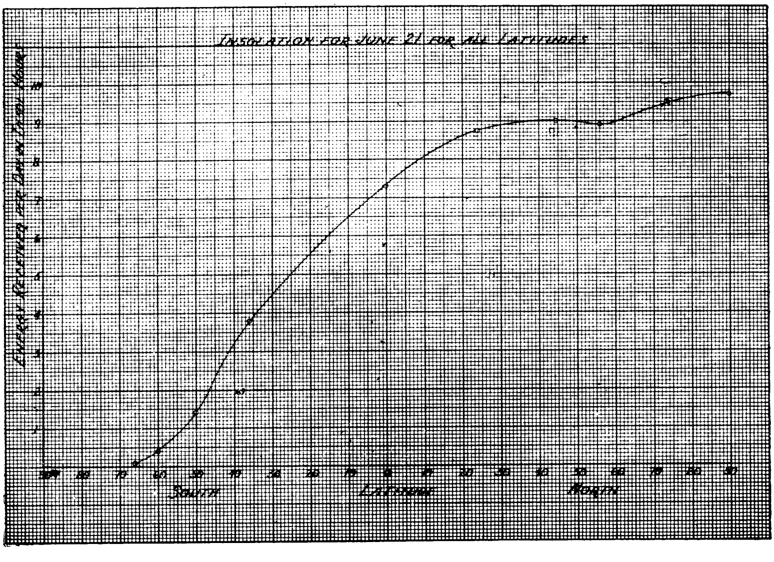
Hours of sunshine June 21 24
Average intensity June 21 .... .398 insols
Energy received June 21 .... 9.56 insol-hours



GRAPH A

Intensity in insols for each hour in the day as ordinates and time in hours as abscissa for Dallas June 21.
The same for December 22.
The same for north pole, June 21.





GRAPH B

Insolation for June 21 for all latitudes. 1. Hours of sunshine on June 21 for all latitudes. 2. Insols for all latitudes on June 21.

Insolation for All Latitudes June 21. The sun is placed at June 21, and the altitude of the north pole at 66.5 degrees. At this setting the sunshine day begins to be 24 hours long. The altitude of the sun is measured for each hour in the day and these figures are used in setting the insolometer and measuring the intensity. The average of these intensities are recorded in column 3 of table B. The measurements are repeated for sunshine days of 22, 20, 18, 16, 14, 12, 10, 8, 6, 4, 2, 0 hours. The average intensities are recorded in column 3 and the altitudes in column 2 of Table B. When the north pole was below the horizon its altitude is marked S (South).

Table B.

1. Sunshine Hours Per Day	2. Latitude (Altitude North Pole)	3. Insols. Average Per Day	4. Insol-Hours Per Day (1 x 3)
24	66.5 N	.391	9.36
22	65.0 N	.406	8.94
20	62.0 N	.440	8.80
18	57.0 N	.475	8.51
16	47.0 N	.546	8.74
14	32.0 N	.610	8.54
12	0.0	.581	6.97
10	32.0 S	.361	3.61
8	47.0 S	.201	1.61
6	57.0 S	.084	.50
4	62 0 S	.052	.20
2	65.0 S	.011	.02
0	66.5 S	.000	0.00