treated as a correction term of one or another value as circumstances may determine.

Let, then, the oceans become warmer (if cooler the method of calculation would be the same) than is their wont by 1° C. from the surface to the depth of 20 meters, a storage of 2,000, approximately, calories per square centimeter of surface, and let the previous temperatures remain unchanged below this level. In what times, under normal conditions, will half, three-fourths, and nine-tenths of this added heat be lost and the excess temperature have fallen to 0.5° C., 0.25° C., and 0.1° C. respectively?

Since the loss of heat by radiation per square centimeter of flat surface, or its equivalent, of a black body is $1.27 \times 10^{-12}\theta^4$ calories per second, in which θ is the absolute temperature, it follows that the net rate, calories per second, at which the stored up heat Q, is lost per square centimeter of ocean surface is the difference between the rates of total loss and total gain; that is, in symbols

$$dQ = \frac{1.27}{10^{12}} \left\{ \theta^4 - (260)^4 \right\} dt,$$

in which t is the time in seconds.

If m is the mass of water warmed, s its specific heat, then

$$dQ = msd\theta$$

but in this case $m = 2{,}000$ and $s = 1$. Hence, substituting

$$\frac{d\theta}{\theta^4 - (260)^4} = \frac{1.27}{2 \times 10^{15}} dt$$

If, as assumed, the initial planetary temperature is 261° absolute, then the time in seconds for the given mass of water to cool to θ_1 is found by the equation

$$\int_{\theta_1}^{261} \frac{d\theta}{\theta^4 - (260)^4} = \frac{1.27}{2 \times 10^{15}} \int_0^t dt$$

or

$$\left[\log_e \left(\frac{\theta - 260}{\theta + 260} \right)^{\frac{1}{4(260)^3}} \right]_{\theta_1}^{261} - \frac{1}{2(260)^3} \left[\tan^{-1} \frac{\theta}{260} \right]_{\theta_1}^{261} = \frac{1.27}{2 \times 10^{15}} t$$

in which t, as explained, is seconds, and the angle in radians.

The required times—time to lose, under normal conditions, half, three-fourths, and nine-tenths of the accumulated heat—are found by substituting for θ_1 in this last equation 260.5, 260.25, and 260.1, respectively. The results are

θ_1 =	260.5°	260.25°	260.1°
t, days =	178.958	358.287	595.625

Obviously, then, the temperature lags of the ocean incident to variations of incoming radiation are not very great, save for small and comparatively ineffective residuals.

GRAPHICAL METHOD OF COMPOUNDING VECTORS

551.501

By WILLIAM C. HAINES

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The composition of vector quantities may be accomplished by either one of two methods; namely, the analytical method or the graphical method.

The analytical method of compounding vector quantities is expressed by the formulae:

$$\tan \theta = \frac{Y}{X} = \frac{r_1 \sin \alpha_1, + r_2 \sin \alpha_2 + r_3 \sin \alpha_3 + \ . \ . \ .}{r_1 \cos \alpha_1, + r_2 \cos \alpha_2 + r_3 \cos \alpha_3 + \ . \ . \ .}$$

$$R = \sqrt{X^2 + Y^2}$$

where r_1, r_2, r_3 . . . are vectors, α_1, α_2, α_3, . . . are, respectively, the angles which the vectors make with the X axis and θ is the angle the resultant, R, makes with X axis. X and Y are $\Sigma r \cos \alpha$ and $\Sigma r \sin \alpha$, respectively. The composition of vectors by this general method is both tedious and laborious, but this is the proper method to use where mathematical accuracy is required.

The graphical method is accomplished by forming a parallelogram with two of the vectors as sides. The diagonal of this parallelogram and the third vector is taken as the sides of a second parallelogram, etc. The diagonal of the last parallelogram formed is the resultant. The accuracy of the result of this method depends entirely upon the precision with which the vectors are laid off. The writer has devised a simple graphical method by which vectors may be compounded quickly and with surprising accuracy. It is accomplished by means of a so-called plotting board somewhat similar to the one used in connection with our pilot balloon work, except that it is smaller in size.

The plotting board consists of an ordinary drawing board, over the central portion of which is glued a circular sheet of millimeter cross-section paper. Upon this board is mounted a circular celluloid protractor, fastened by a brass bearing at the center. The protractor is graduated in degrees; also, directions to 16 points of the compass are indicated to facilitate the compounding of wind vectors. The celluloid disc should be 50 or 60 cm. in diameter and frosted on one side so that it will take pencil marks readily and still be transparent. An initial line OR (see fig. 1) and scale are marked on the cross-section paper base. Other supplementary scales are indicated, the advantage of which will be explained later.

The use of this graphical method is made clear by the following simple example: Suppose we are to find the resultant direction and velocity of the vectors N–5, NE–6, and E–8.

First step: Set the north point of the protractor on the initial line OR, and with a pencil mark the point A on the protractor at a distance of 5 from the center, as shown by the scale along the line OR. Next turn the protractor to set NE on the line OR, then take the length of the second vector, or 6 from the point A parallel to the line OR, marking the point B on the protractor as the end point of the second vector. In reality a parallelogram OABN is thus formed with the N–5 and NE–6 vectors as sides; therefore the diagonal OB is the resultant of these two vectors. Second step: Turn the protractor and set E on the line OR, and mark the point C on the protractor at a distance of 8 (length of third vector) from the point B parallel to the line OR. By this step parallelogram OBCM is formed with OB and BC as sides and OC as the diagonal. Keeping in mind the parallelogram law, it is obvious that OC is the resultant of the vectors N-5, NE-6, and E-8. Perhaps this may be seen more readily by referring to the polygon law. Considering the polygon OABC, it is clear that OC is the resultant.

When the protractor is turned so that point C is on the initial OR, the length and direction of the resultant is indicated on the scale and the protractor, respectively.

In short, the procedure of compounding vectors by this method amounts to setting the protractor so that the angle or direction of the vector to be considered lies on the initial line of the scale. The length of the vector is then laid off on the protractor from the end point of the preceding vector parallel to the initial line, and its end is indicated by a point, from which the next vector is laid off. The first vector is laid off from the center along the initial line of course. The resultant vector is the line from the origin or center to the end point of the last vector. Both its direction and magnitude are readily determined by placing the end point of the last vector over the initial line.

The millimeter cross-section paper and supplementary scales referred to above enable the operator to determine quickly and accurately the end points of the various vectors when they are far removed from the initial line OR. In this way results of considerable accuracy may be obtained without any computation.

This method of compounding vectors has been in use for the past two years and found to be especially advantageous in determining the mean wind direction; that is, the resultant direction where the strength of the wind is not considered, the various directions being considered as unit vectors.

For obtaining resultant winds, the aerological division has adopted a system suggested by Mr. H. P. Parker, of the aerological station at Broken Arrow, Okla., In this system the sums of the north and west components are obtained by the analytical method, and from these components the resultant direction and velocity of the wind are obtained graphically.

In compounding vectors by either the analytical or the graphical method, opposite directions should be canceled, thereby reducing the number of vectors to be considered.

WHY AN OAK IS OFTEN STRUCK BY LIGHTNING: A METHOD OF PROTECTING TREES AGAINST LIGHTNING

551.594: 634

By ROY N. COVERT

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It is desired to consider first what the factors are which determine the relative liability to lightning damage of trees, as determined by their location, the character of the soil in which they grow and its moisture condition, the electrical conductivity of the wood itself, etc.

As a general statement the tree which is a relatively good electrical conductor, and has a root system which is widespread, or which reaches deep into moist soil, is the one which is in most danger of being struck by lightning. No tree is immune, however.

Following are the factors which govern, as determined by careful studies made in western Europe of the effects of lightning on trees:[1]

(a) Among trees of the same kind the one which stands well above its neighbors is in most danger, even in a dense forest. This dominant position may be due to the greater height of the tree or be the result of the configuration of the ground.

(b) Trees growing in the open, either singly or in small groups, are in more danger than those in the dense forest or other thick stand of timber.

(c) Trees growing along avenues or in the border of a wood are also struck by lightning more often than those in thick woods.

(d) A tree growing in moist soil—that is, along the banks of a stream or a lake, or close to some other source of moisture—is a better conductor for lightning than one growing in drier soil.

(e) Trees growing in loam and sandy soils are struck much more frequently than those in clay, marl, and calcareous soils. Oaks grow mostly in loam and sandy soils.

(f) Sound trees in general are less likely to be seriously damaged than those with rotten wood. If the sound tree is also a relatively good conductor, lightning will go to earth easily, but rotten wood is a poor conductor of electricity so that the passage of the lightning current through this nearly nonconducting portion often results in a shattering of the tree and when dry the tree may be set on fire.

(g) Starchy trees, of which the oak is a good example, are better conductors of electricity than oily trees like the beech. The conifers are intermediate. Experiments made by Jonesco of the Württemburg Society of Natural Science gave the following results:

One turn of a Holz's electric machine passed the spark through oak wood, five turns through poplars and willows, and 12 to 20 turns through beech.

From the foregoing we learn that an oak is decidedly a good conductor of electricity, so far as trees go; that it grows in loam and sandy soils where trees are most frequently struck by lightning; and, furthermore, it is an excellent example of a tap-rooted tree with its root system extending deep into the soil, all of which qualities place the oak in great danger of lightning damage as compared with other trees. The following question is therefore pertinent:

What do statistical studies of the damage of trees by lightning show with regard to the relative frequency with which oaks are struck as compared with other trees?

The following figures were taken from Schlich's Manual of Forestry, Volume IV, entitled Forest Protection, by W. R. Fisher:

Trees struck in the Lippe-Detmold forest, Germany, from 1874–1890:

	Oak	Beech	Spruce	Pine	Others
Percentage of trees	11	70	13	6	----------
Trees struck	310	33	39	110	30
Relative frequency [1]	60	1	6	37	----------

[1] A previous discussion on kind of trees struck by lightning will be found on pp. 64–69 of Wea. Bu. Bull. No. 26, Lightning and the Electricity of the Air, McAdie and Henry, Washington, 1899.