FURTHER LABORATORY AND WORKSHOP NOTES

A second selection reprinted from the
Journal of Scientific Instruments

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FOREWORD

The Laboratory and Workshop Notes here reprinted were selected mainly from those appearing originally in the Journal of Scientific Instruments from 1946 onwards, with the addition of several from the earlier years for which there was no room in the first volume. Since the first volume has been so favourably received, the Board of the Institute of Physics feels that laboratory workers would welcome a further selection and hopes that they will find in the following pages simple time-saving and elegant solutions of some of the many problems that they may have to resolve from time to time.

As before, the royalties from the sale of this volume will be placed to the credit of the Institute's Benevolent Fund, and the Board again wishes to record its grateful thanks both to the authors of these Notes for their kindness in allowing them to be reprinted, and to Dr. Ruth Lang for all the care she has taken to produce a second volume worthy of the first.

F. C. Toy.

President.

July, 1950

PREFACE

In presenting this second selection of Laboratory and Workshop Notes, the same general principles have been followed as in the previous volume. As before, some Notes have been slightly condensed, and introductory paragraphs, acknowledgments and so forth have been omitted. It has been thought best to omit the trade names of products, save in a few special instances, and the addresses of particular makers or suppliers of materials mentioned in the original Notes.

I should like to thank several authors who have willingly co-operated in bringing the information in their Notes up-to-date for the special purpose of this volume.

While every endeavour has been made to trace the authors to obtain their permission to reprint these Notes, this has been unsuccessful in a few cases; it is sincerely hoped that these authors will readily join with the others in agreeing to make their work more widely known by inclusion in this volume.

RUTH LANG.

CONTENTS

SECTION 1. GRAPHS AND DRAWINGS

1. Determination of Turning Values by Means of Logarithmic Graphs

By R. S. SILVER, M.A., D.Sc., Ph.D.

J. Sci. Instrum., **20**, p. 76 (1943)

In order to present data covering a wide range, it is frequently necessary to plot the logarithm of one variable against that of the other, rather than the variables themselves. Such graphs have a useful property to which attention may be drawn.

Consider the function of $f = uv^n$, where u is a function of v. Then f is a maximum or minimum when uv^n has turning values. At any such point $\log u + n \log v$ has a turning value.

Differentiating with respect to log v as variable and equating to zero, we obtain

$$\frac{d\,[\log u]}{d\,[\log v]} = -n \quad \text{as the condition for turning values.}$$

Hence if log u is plotted against log v, the values of u and v for which the product uv is a maximum or minimum are given by the point at which the slope of the curve is $-n$.

The theorem is true whether n is positive or negative, and obviously includes the important cases of uv and u/v. It is self-evident when $n = 0$.

The method is of value in practical work in two respects. First the calculations required to draw the log-log graph are very often easier and less numerous for cumbrous expressions than those needed to graph the function or solve the equation of the direct derivative to zero. The log-log graph can be used to represent the variables, and the turning values immediately spotted by laying a straight edge to the required slope. Secondly it may be helpful in interpretation of experimental results to consider turning values of simple products or quotients. If the experimental results are represented in a log-log graph such values can be obtained directly using the above proposition.

2. A Useful Method of Graph Plotting

By M. O'C. Horgan, M.Sc., M.I.E.E.

J. Sci. Instrum., **12,** p. 123 (1935)

To illustrate this method of graph plotting we may consider a series of calibration curves for a valve-voltmeter having a number of voltage ranges, on which the actual scale is divided into arbitrary divisions, and readings have to be converted to voltages by reference to the calibration chart. The actual voltmeter has five ranges requiring five calibration curves. In the normal way these curves are of similar shape, and when plotted on one sheet to the same axes with the most suitable scales from the point of view of accurate reading they overlap and cross one another, making conversions between scale readings and voltages very difficult and slow and causing a real possibility of error.

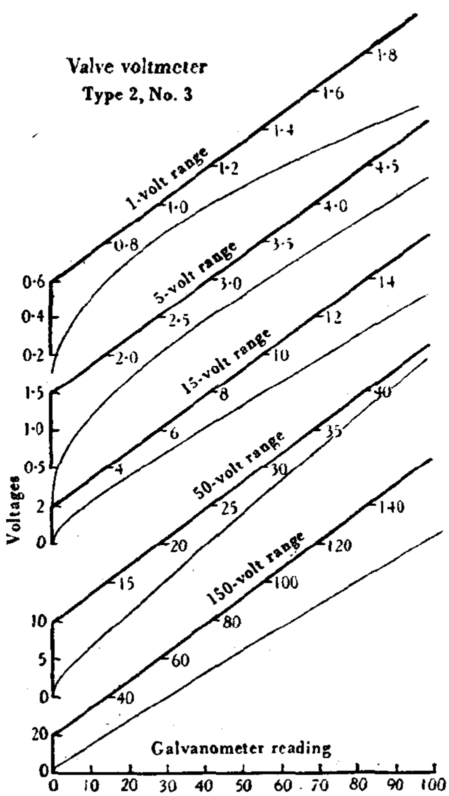

Fig. 1.—A useful method of graph plotting.

It was to overcome the need for five separate calibration sheets that the method of plotting was first developed.

The axis common to all curves (in this case the meter scale-reading) is taken as a base for all graphs. The ordinate scales are then drawn as shown in Fig. 1, firstly along the ordinate graph lines and then as a diagonal line to fit the general slope of the curves themselves. In the present case it has been possible to have all five "axes" at the same slope and equally spaced, which considerably improves the symmetry and appearance of the calibration. In the actual chart, the axes are all drawn in thick black lines, whereas the curves themselves are thin red ones, thereby adding greatly to the ease of reading.

The method of using the curves is the same as in the case where the scale lines are at right angles. Thus to evaluate a reading of 50 on the 5V range, a line is drawn parallel to the X-axis through the point on the 5V range calibration curve, to meet the sloping ordinate scale at 2·77V.

The minor initial difficulty in evaluating readings on a sloping axis is soon overcome after a little use, and the benefit accruing from having the scale always in close proximity of the curve is then fully appreciated. It is, of course, equally feasible to draw separate sloping X-axes for each curve parallel to the corresponding Y-axes, thereby bringing both axes close to the graph line itself. In cases where the base scale is not common to all curves this would be a distinct advantage, but in the particular example considered here it is found to be easier to read the calibration with one axis drawn in the direction of the normal graph paper lines.

3. Linear Scale for the Direct Measurement of Slopes of Curves

By L. V. CHILTON, M.A., F.Inst.P.

J. Sci. Instrum., **12**, p. 199 (1935)

The construction of this scale and its mode of use are shown simply in Fig. 2. On a rectangle of stout celluloid $ABDC$ are engraved a line EF parallel to the edge AB and a a line GH perpendicular to EF and intersecting it at P. Uniform scales GB, G'B', etc. are engraved along the edge AB and along parallel lines $A'B'$, etc., the units of graduation in each case being the perpendicular distance PG, PG', etc., of the line from the point P, and the zeros of the scales lying on the line GH.

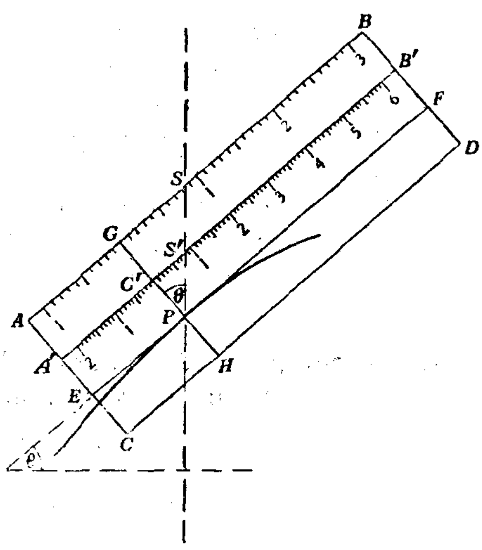

FIG. 2.—A linear scale for the direct measurement of slopes of curves

The scale is applied to a curve (assumed to be drawn on squared paper) with the point P coincident with the point at which the slope is to be measured and the line EF tangential to the curve at this point. The slope of the curve at this point is then given by the reading S (or S', etc.) of the scale GB (or $G'B'$, etc.) at which the ordinate line through P intersects these scales (slope at $P = 0{\cdot}85$ in the example shown). It is evident that the slope of the curve at $P = \tan\theta = \tan \angle GPS = GS/PG = G'S'/PG' =$ etc.

The additional scales $G'B'$, etc. are useful in the reading of high slope values where the point S may be outside the graph paper. In measuring slopes of curves at points near the upper margin of the graph paper, when all the points S, S', etc. may lie outside the paper, the whole scale may be inverted and the intersections S, S', etc. noted on carrying the eye down the ordinate line through P. The scale as described is arranged for reading positive slopes; negative slopes could be provided for by continuing the scales GB, etc. in the negative direction (*i.e.* to the left of GH) or more compactly, by the use of subsidiary parallel scales engraved at appropriate depths below the line EF. All lines and figures (reversed) are engraved on the under surface of the celluloid, to provide perfect register with the plane of the graph paper and so avoid parallax errors. With a scale 18×6 cm., employing a unit of 5 cm. for the scale GB (reading to slope 3·0) and of 2·5 cm. for the scale $G'B'$ (reading to slope 6·0), an accuracy of 1 per cent. is readily attainable over the whole range. It is to be noted that although slope readings might apparently be read to greater accuracy at the high slope values, the limiting factor is the accuracy of adjusting the line EF to tangency, which is probably constant for all slopes.

Should the curve be drawn on plain paper, the scale could be used in conjunction with a tee-square bearing on the upper or lower edge of a drawing board upon which the paper was mounted, or with a set-square registered with the X-axis of the curve. The scale has been found very useful in work on sensitometric curves for photographic materials and may well prove of service in other directions, such as the computation of thermionic valve characteristics.

4. A Simple and Accurate Method of Deriving the Slope of a Graphed Function

By E. RAMSAY WIGAN, D.F.H., B.Sc.(Eng.)

J. Sci. Instrum., **26**, p. 162 (1949)

The following method has been developed to obtain the tangents to a curve accurately and rapidly with no more than a $\frac{1}{4}$–$\frac{3}{8}$ in. diameter cylindrical rod of Perspex or glass used as a lens.

The rod is laid roughly tangentially to the curve near to the point P at which the slope is required. It is then rolled over the paper till the image of P appears on the axis of the rod. The rod is twisted in the plane of the paper until the image of the part of the curve near P lies exactly along the axis of the rod. The magnification of the cylindrical lens ($\times 5$ or 6) increases the accuracy with which this can be done. But a further check is obtained if a short pencil stroke is made across the curve at P: this, viewed through the rod, will appear as a line almost exactly normal to the rod axis, however carelessly the stroke is drawn. This line, therefore, gives a secondary criterion for setting the slope of the rod: the image of the stroke must appear to cut the image of the curve at right angles. The rod is then located over the tangent at P, as in Fig. 3.

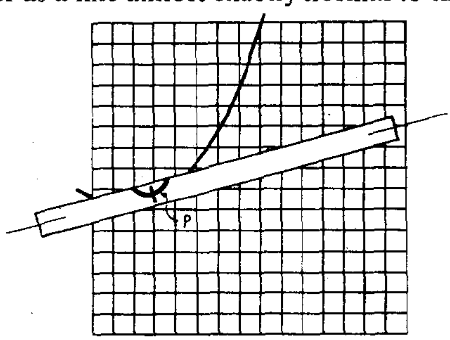

FIG. 3.—Locating the rod over the tangent at P.

The slope of the rod can now be measured by rolling it over the paper until it reaches a position where two major reference lines (x_1x_1 and y_1y_1) intersect near one end of the rod as indicated in Fig. 4. This intersection can be viewed through the rod and the rod rolled till the image of the intersection lies on the

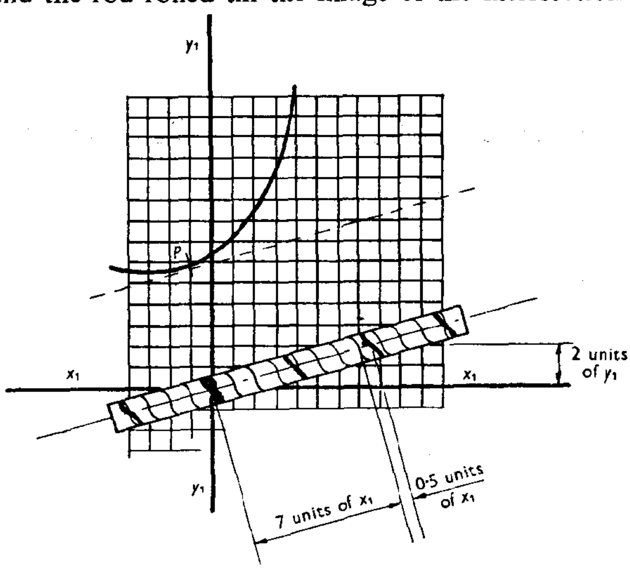

FIG. 4.—Measuring the slope of the rod.

axis as shown. Other x and y reference lines on the graph-paper appear as indicated in Fig. 4: those to which the rod is nearest in slope (x axis) are the thicker and the more obliquely distorted by the lens. The slope can now be read off directly: in the case illustrated the slope is 2/7·5, the derivation of this being obvious from Fig. 4.

5. A Graph or Chart Stylus

By L. G. Young

J. Sci. Instrum., **26**, p. 248 (1949)

A graph or chart embodying a series of recorded observations is rendered neat, legible and more capable of clear reproduction if the points representing individual readings be clearly indicated. This result is secured by use of a simple gadget which was made up from common materials in a small lathe in two hours. It has proved very useful in the preparation of curves expressing results of spectrographic and absorptiometric analyses.

Fig. 5 indicates the principle and construction of the stylus. A short pulled-out length of typewriter spring has the light resilience necessary to operate the plunger, which should be a nice sliding fit in the body.

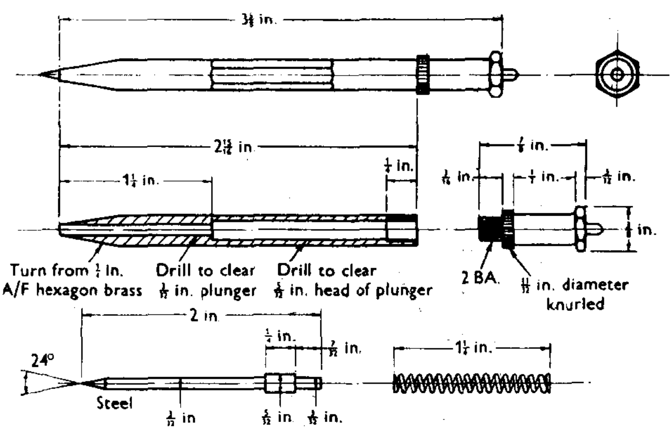

Fig. 5.—Principle and construction of stylus.

In operation the stylus is inked by pressing lightly on a stamp pad of the appropriate colour. The point is directed over the paper to explore and find the exact location of the desired marking, and when this is found the stylus is brought vertical, pressed and twirled. A neat ○ results. Between changes of colour the stylus may be cleaned by simply pressing on blotting paper.

6. Resistance-watts Computer and Curve Plotter

By A. HETHERINGTON, B.A., and C. J. MILNER, M.A., Ph.D., F.Inst.P.

J. Sci. Instrum., **26**, p. 278 (1949)

For devices such as bolometers for radiation and high-frequency power measurement, and for the filaments of lamps, valves, and Pirani gauges, it is often required to obtain graphs of resistance R against watts dissipation W. Usually the measurements give, directly, pairs of values of voltage V and current I. The computation of $R=V/I$ and $W=VI$ is simple enough, but tedious if often repeated.

Theory. The R–W curve may be directly plotted from the V–I values, if a double-logarithmic plot is used, in which $y=b+\log R$ and $x=a+\log W$, relative to Cartesian axes Oxy (see Fig. 6). For, if y' and x' are the co-ordinates of any point (y, x) relative to new axes, $Ox'y'$, rotated by 45° (clockwise) with respect to Oxy, one has

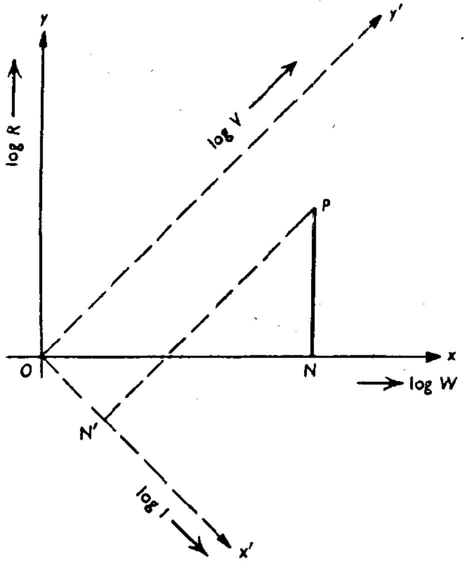

FIG. 6.—Principle of curve-plotting device.

$$y' = x \sin 45° + y \cos 45°,$$

or

$$\begin{aligned} y'\sqrt{2} &= x+y \\ &= (a+\log V+\log I) \\ &\quad +(b+\log V-\log I) \\ &= (a+b)+2\log V, \end{aligned}$$

and similarly

$$x'\sqrt{2}=(a-b)+2\log I.$$

That is, the point at which (R, W) is plotted as (y, x) with respect to Oxy is also, as (y', x'), a plot of (V, I) with respect to $Ox'y'$, provided that the logarithmic scales of V and I have a cycle length $\sqrt{2}$ times that of the R and W scales, and provided that the scale zeros ($\log V=0$, $\log I=0$) are chosen so as to represent correctly at $y'=(a+b)/\sqrt{2}$, $x'=(a-b)/\sqrt{2}$ the one point ($\log R=0$, $\log W=0$; $y=b$, $x=a$).

Such a plot, made on quadruple-logarithmic graph paper, with two sets of perpendicular co-ordinate lines oriented at 45° to each other, has been already used. However, this practice involves the use of specially printed paper and the large number of co-ordinate lines in four directions has been found rather confusing.

Set-square plotting device. The device to be described enables V and I to be plotted in relation to the diagonal axes $Ox'y'$ without these being printed, thus giving directly on standard double-logarithmic paper a plot of R against W. A 45° set-square, made from transparent material (Perspex), is engraved along the edges adjacent to the right-angle with logarithmic scales, $\sqrt{2}$ times larger than the graph-paper scales, both commencing from unity at the 90° corner and increasing towards the 45° corners. These are labelled 'voltage' and 'current' as indicated in Fig. 7. It is convenient to have one or more lines scribed across the under surface of the square parallel to the hypotenuse. One of these, as shown, may be marked to show the cycle-length of the paper with which the square is to be used.

In using the square, one should choose, for the origin O, a point on the paper labelled with R and W values which are integral powers of 10, and which also correspond to V and I values which are the integral powers of 10 next below the smallest values to be plotted. (In the example shown, the point O is $R = 100\ \Omega$, $W = 10^{-2}$ W., which corresponds to $V = 1$ V., $I = 10^{-2}$A.) The square is laid with its hypotenuse towards the

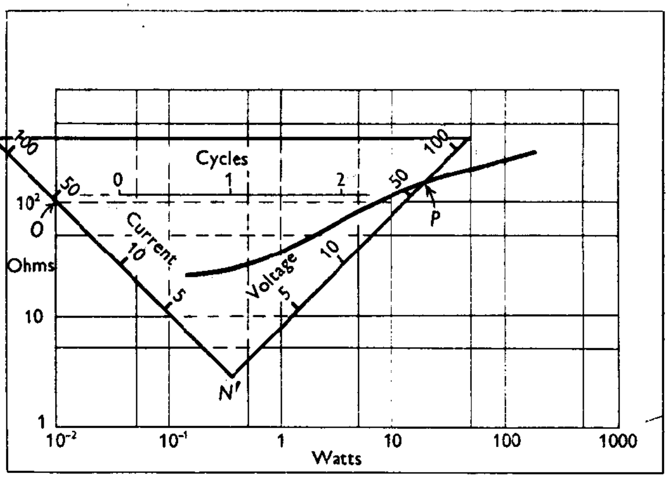

FIG. 7.—Diagram showing square applied to plot of lamp filament characteristic.

top edge of the paper and slid, keeping the hypotenuse parallel to the W axis, so that the I-value to be plotted (reckoned in the units indicated by the labelling of the chosen origin) is marked, by the origin, on the scale on the left, labelled 'current.' The point similarly marking the

V-value of the pair on the 'voltage' scale is then plotted on the paper, where it marks the corresponding R–W point. (Alternatively, with the hypotenuse facing the bottom of the paper, the V-value is set at the origin and the I-value is plotted, with the same result.)

The above procedure only serves to plot points in the right-hand quadrant of the four formed by the diagonals through the origin. If, as in the example, the origin is chosen near the middle of the left edge of the paper, this quadrant covers most of the paper. By rotating the square through $\pm 90°$, points in the upper and lower quadrants can be reached but: (*a*) in both quadrants the 'current' scale must be used for V and vice versa, and (*b*) in the upper quadrant the reciprocal of the I-value, and in the lower quadrant the reciprocal of the V-value, must be registered on the 'voltage' or 'current' scale respectively. To plot points in the left quadrant, the reciprocals of both V and I must be used, the 'current' and the 'voltage' labels now again being both correct.

The curve shown in Fig. 7 is the resistance-watts relation for a standard 200V., 150W. tungsten filament lamp plotted in the manner described. The set-square is indicated diagrammatically as replaced in position to show the plotting of the pair of values ($I = 0{\cdot}45$A., $V = 65$V.). The points O, N', P correspond functionally to O, N', P in Fig. 6.

7. Proportional Plotter

By F./Lt. W. M. BIELAK, Dipl.Eng.Chem.,

J. Sci. Instrum., **25**, p. 205 (1948)

This instrument, for facilitating the plotting of a curve representing the ratio between the ordinates of two other curves, is of general application but should be of particular interest in connexion with infra-red spectrography employing a single-beam system.

The principle involved is that of the properties of similar triangles, and a simple example is illustrated in Fig. 8. An L-shaped frame, the inner edge (13) of the vertical arm of which is set to coincide with the ordinates of the curves to be compared, carries a slide (2) moving in a vertical groove the side of which is graduated from 0 to 100. An extension of the slide carries a marker which moves over a sheet of paper (12) on which the diagram is to be plotted. The lower arm carries a guide (15) along which a slider moves, so that a point (1) in it is always over the base (11) or base produced of the curves (9) and (10) on the sheet of paper (8). Attached at this point (1) are two extensible cords, of which one (3) is joined to a fixed bracket (5) on the vertical arm over the 100