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Earl F.R.S.

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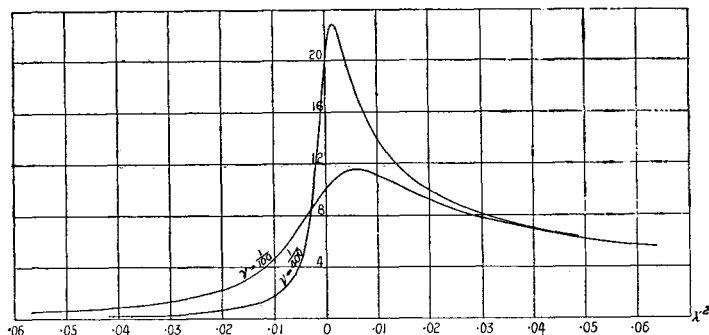


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the free period. The more abrupt descent on this side of the figure, of the curve for which ν has the smaller value,



shows how the discontinuity which occurs in the case of no friction is approached as the friction diminishes.

It is to be noted that the maximum value of the expression (46) does not occur when the forced period exactly coincides with the free period, but for a slightly smaller value, the difference between the two values diminishing as the friction is diminished.

LXIV. *Note on a Ruler for Drawing Curves.*

By The Earl of BERKELEY, F.R.S.*

IT is well known that by bending a steel ruler so as to cover five experimental points, a fair approximation to the true curve may be obtained, thereby affording a ready means of interpolation. Should high accuracy be required, it is often best to plot the known points on an extended scale, the steel ruler then becomes extremely difficult to manipulate: to obviate this, some two or three years ago I devised the ruler here described. Fig. 1 gives a plan of the apparatus as set up to draw a curve through the five points marked with a cross—the dimensions of the parts are to the scale given on the plan, but it may be mentioned that for the highest accuracy a curve on a larger scale is advisable.

A and B are two metal T squares cut out of sheet "duralumin." The two claws C and D (shown in plan and

* Communicated by the Author.

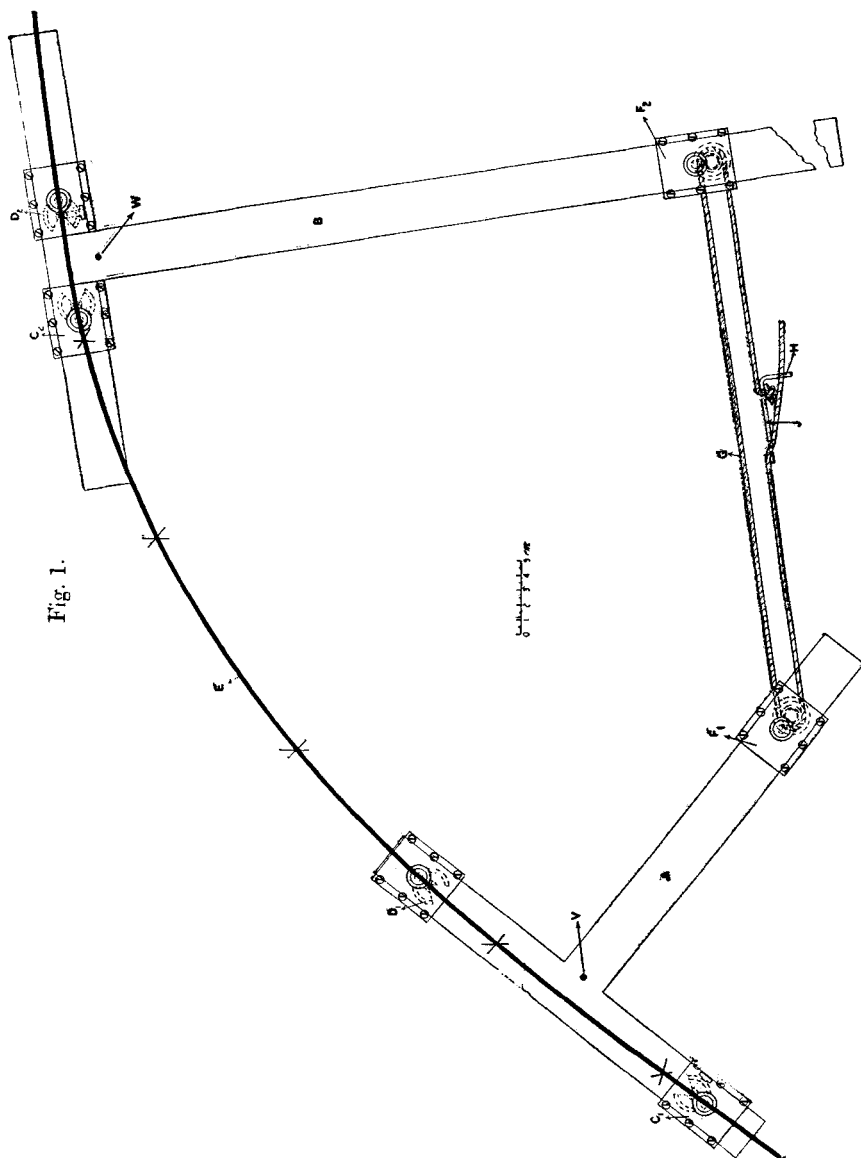
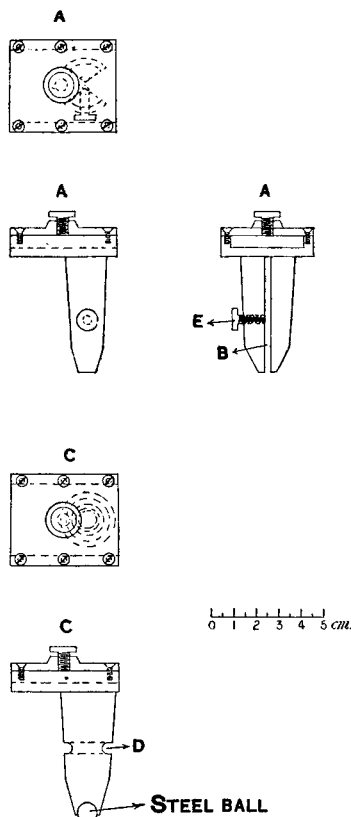


Fig. 1.

two elevations under A in fig. 2) slide on either end of the short arms of the T's and hold a Chesterman steel ruler (1·5 metres long, 5·7 cm. wide. and 2·4 mm. thick) in the jaws* B of fig. 2. The pins F† (plan and elevation under D of fig. 2) slide on the long arms of the T's; they are pulled

Fig. 2.



towards each other by the cord G which passes round the grooves D of fig. 2—this cord is “belayed” by pulling it tight into a V-shaped slot cut at H in the brass right-angled piece J.

* It may be of use to mention that these jaws were made by putting two saw cuts, with a circular saw, through the solid pin at right angles to one another and parallel to the vertical axis.

† In actual construction the T with the longer arm has that arm set high so as to clear the other T should it be necessary for them to cross—hence one of the pins is made longer so as to avoid “wringing” the ruler.

It is evident that the slope of the tangent to the ruler at a point can be given almost any value by altering the tension on the cord, while the curvature can be altered both by varying the relative positions of the claws and pins on their arms and by bringing the heads of the T's closer together or further apart—in fact, the practical limit to the variation in curvature lies in the physical properties and thickness of the steel.

In general, if the curvature change sign, the ruler, as the apparatus is at present constructed, cannot be made to follow the curve—an exception to this is afforded by a point of inflexion near the end of the curve; here, as will readily be seen, if the pin F_1 (fig. 1) be slid towards the ruler to such a position that the line F_2F_1 , produced, cuts the T anywhere between the two claws, a movement in a clockwise direction is set up round C_1 , thus giving a point of inflexion.

If the curve begins as a straight line it may be necessary to substitute a hook in place of the set screw E (fig. 2), and pass the cord over this.

Theoretically the ruler should be so adjusted that the curve to be drawn comes between D_1 and C_2 , thus avoiding any slight changes of curvature that there may be at these points, but in practice I have found for curves of moderate curvature that this effect is not noticeable.

As a test, a curve of the natural sines plotted against the corresponding angles was drawn on a scale such that 1° of the abscissæ = 7.5 cm., while 0.1 of the ordinates = 5 cm. The following four points were taken as known— 0° , 18° , 72° , and 90° ; and a curve was drawn through them, giving for the values of the natural sines of 36° and 54° the number .595 instead of .588, and .813 instead of .809, respectively. An objection may be raised against this test in that a uniform steel ruler, when its ends are pulled together by a small force, must give a sine curve; the validity of this objection is greatly lessened when it is realized that the forces required to get the steel to give the curve, on the scale mentioned, were so great that the ruler was permanently and largely deformed.

Opportunity was taken to test this deformed ruler against a logarithmic curve, by passing it through the logs (to the base 10) of the numbers 1, 2, 4, 8, and 10, on a scale such that 7.5 cm. = .075 in the logs and 1 in the numbers. The interpolated value for the log of 6 was .7810, instead of .7782.

The actual value of the apparatus lies not so much in enabling one to draw curves such as these, but in getting smooth graphs on an extended scale. For instance, suppose we have obtained the densities (assumed correct to 1 in 50,000)

of five solutions of widely different concentrations, and these be plotted on squared paper 100 cm. by 75 cm.; on passing the ruler through the points, interpolation values will be obtained which, when tested by experiment, will be found to be only 1 or 2 parts in 10,000 out.

In a case such as this it would seem that theoretically the accuracy obtainable is limited chiefly by the unavoidable errors in the paper (errors of ruling and of "stretch") and in the quality of the ruler. It is found, however, that a practical limit is imposed by the weight of the apparatus; for, with the 1.5 metre ruler, the ease of adjustment is already interfered with by the friction between the steel edge and the paper. This difficulty may be overcome by attaching vertical rods to the T's underneath the points V and W (fig. 1), so that by the aid of springs the ruler is held a millimetre above the surface of the paper, but can be depressed into contact by pressure. The lower end of the rods terminates in a steel ball which slides on the polished surface of three others above it, but rolls on the paper; this device is found to be a very efficient unlubricated castor.

LXV. *Multiply-charged Atoms.*

By Sir J. J. THOMSON, O.M., F.R.S.*

[Plate XV.]

IN the photographs of the positive rays (see, for example, those given in the Phil. Mag. Aug. 1912) the mercury line is remarkable for the exceptionally small displacement of the head of its parabola. Even when the electric and magnetic fields are strong enough to produce deflexions of several millimetres in the heads of the parabolas corresponding to the other elements, the head of the mercury parabola is so little deflected that at first sight it seems to coincide with the origin. When, however, the electric field used to deflect the particles is made very large, in our experiments from 5000 to 10,000 volts per centimetre, the head of this parabola is distinctly displaced, and on measuring the electrostatic displacement it is found to be $1/8$ of the normal displacement of the heads of the parabolas corresponding to the other elements.

The displacement due to the electric field is inversely proportional to the kinetic energy of the particle displaced, so that the atoms which produce the head of the mercury

* Communicated by the Author. Read before the Mathematical Congress at Cambridge, August 26, 1912.