THE DESIGN AND USE OF A PHOTOELECTRIC PHOTOMETER

B. A. HOWLETT, Rose Polytechnic Institute

The author has found a modification of the instrument described by Morey[1] of such usefulness in the physical or chemical laboratory that a description of its construction, faults, and uses might be of use to his fellow workers.

The photocell used in the circuit is a highly sensitive caesium tube produced by the General Electric Research Laboratories. The bridge amplifying circuit to which the photocell is coupled is similar to one

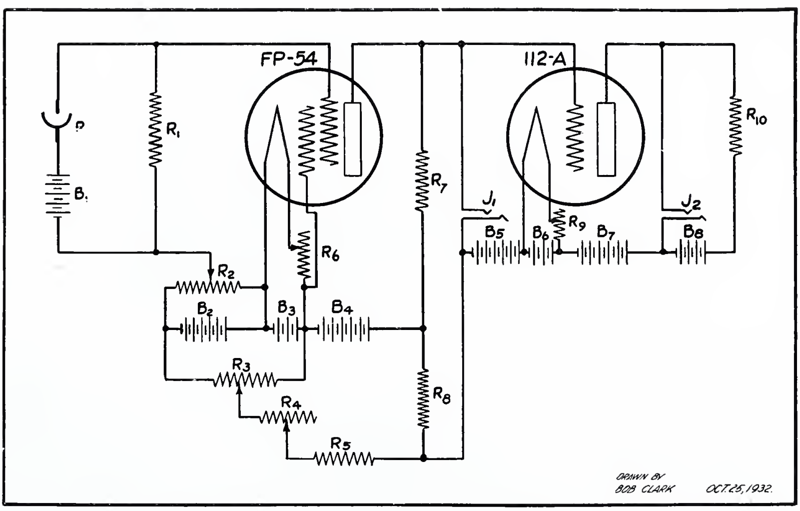

Fig. 1. Circuit Diagram. P, Photocell: R_1, 4.23 x 109 ohms; R_2 and R_3, 400 ohm potentiometers; R_4, 2500 ohm; R_5, 20,000 ohm fixed resistance; R_7 and R_8, 10,000 ohm fixed resistances; R_6, 50 ohm; R_9, 6 ohm; R_{10}, 2500 ohm variable. B_1, 90 volts; B_2, B_3, B_6, 6 volt storage batteries; B_4, 2 volt storage cell; B_5, 9 volts; B_7, 135 volts; B_8, 4.5 volts.

recommended by DuBridge[2]. Fig. 1 shows a diagram of the circuit used. The input resistance, R_1, was made from alundum cement, manganese dioxide and water glass as described by Morey[1]. The circuit consists essentially of an equal ratio arm Wheatstone bridge in which the impedance of the FP-54 tube is balanced by the resistances of R_4 and R_5. R_7 and R_8 are the two equal arms of 10,000 ohms each. The telephone jack J_1 makes it possible to plug in a meter for this preliminary balance.

[1] D. R. Morey, Rev. Sc. Inst., Vol. 3, No. 1, p. 24, Jan., 1932.

[2] Lee A. DuBridge, Phy. Rev., Vol. 37, No. 4, p. 392, Feb. 15, 1932.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

12—48585

A 112-A tube is used to amplify the unbalancing of the bridge due to light falling on the photocell, P. A second jack J_2 allows the connection of a microammeter or galvanometer to read any change in plate current of the 112-A tube, from which the steady current has been balanced by the battery B_8, and the variable resistance R_{10}. All of the circuit except the batteries is inclosed in a heavy brass box, mounted in a brass frame so that it may be rotated around the axis of the optical system. The knobs of R_2, R_3, R_4 and R_{10} extend through one side of the box to facilitate adjustment of the grid and plate voltage of the FP-54 tube, the balance of the bridge and the normal current balance of the plate circuit in the final tube. All batteries are inclosed in a copper box shown to the right in Fig. 2. A large brass tube shields the battery leads between the boxes. Fig. 2 shows the control knobs on the box containing the circuit. This box is slightly tilted to show how it can

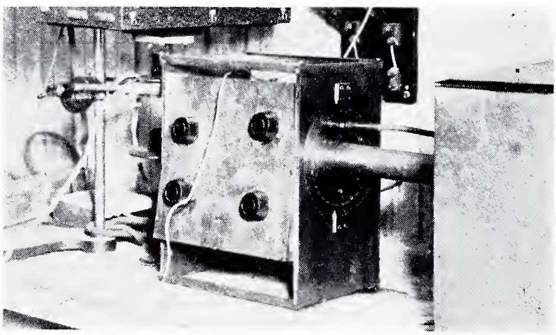

Fig. 2. A view of the instrument with battery box to the right.

be revolved around a horizontal axis. This view also shows a circular scale with verniers which show the angle of tilt to the nearest 5 minutes of arc. The two jacks are also mounted on the back of the scale plate. The figure shows the galvanometer plugged into J_2. Fig. 3 is a general view of the apparatus showing the tube on the left side which may contain a nicol prism or other optical parts between the source and the photocell. In the figure a solution cell is shown in front of the nicol for the study of perpendicular scattering from a vertical beam of polarized light.

In the construction of as sensitive an apparatus as this, great care must be given to high insulation of all grid connections and very careful shielding of all parts. The apparatus has about the same electrical sensitivity as a good quadrant electrometer and must be insulated accordingly. Slight changes in position or size of static charges on insulation or supports cause erratic disturbances. It was found necessary to rigidly support the tubes and make all wire connections rigid enough to maintain their positions when the apparatus was rotated. It was also found necessary to cover all individual battery leads with metal braid, and ground this, to prevent static accumulation on the insulation. The circuit box should be nearly air tight to prevent the drifting of ions on to exposed parts. With these precautions the circuit becomes stable enough to use a reflecting galvanometer with a sensitivity of 2.53×10^{-9} amperes per mm. The input resistance, R_1, as constructed has a poor temperature characteristic and for the maximum sensitivity of the apparatus should be mounted in a constant temperature box. Magnetic shielding of the box would also be advantageous as the rotation of the box across the earth's field gives noticeable difficulty when trying to find positions of maxima and minima in the study of polarized light.

The uses of such an instrument are many and varied as it combines the properties of a photometer and a polarimeter. Its optical sensitivity as a photometer is such that even with a nicol of only 1 cm. aperture in the optical tube a standard candle at a distance of 10 ft. gave a deflection of slightly over 5 micro amperes. Most photometric readings, even with color filters, could be readily made with a microammeter as the

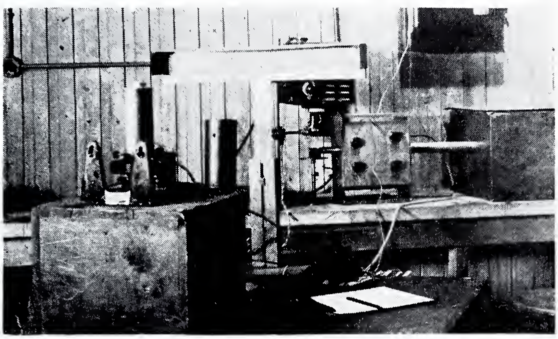

Fig. 3. A general view of the instrument with tube for optical system extending from the left of the box.

measuring instrument. Relatively low intensity spectral lines can be directly compared with the galvanometer in use. This, of course, involves the use of the spectral characteristic of the phototube and its accuracy is dependent on the accuracy of that characteristic. The instrument can be used to measure very minute rotation of the plane of polarization and so has a wide field in chemical research. The author has done considerable work with it in studying the intensity distribution of polarized light scattered from fluorescent and non-fluorescent solutions. It has also been used to measure percentage of polarization of light from such solutions. In this work with low intensities its high sensitivity is very essential.

For student work where the microammeter can be used in place of the galvanometer, the instrument is more simple to operate than an ordinary photometer or polarimeter. It has been used to check the cosine squared law of Malus and to measure the variation of per cent of polarization of light transmitted through a plate at different angles of incidence, besides the usual experiments in polarized light. Its widely variable sensitivity and general stability except under extreme conditions make it a very useful instrument in either a physical or chemical laboratory.