colours were just distinguishable. The three colours 2.5G5/8, 2.5BG5/6 and 5B5/6, similarly mounted, appeared identical.

A second observer, completely unacquainted with the Munsell colour system, obtained results similar to those shown in the figure, though with more scatter. Apparatus is being constructed to check these findings by methods less open to objection on psychophysical grounds; but of the general picture there seems no doubt.

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Ottawa. April 13.

[1] Hartridge, H., *Phil. Trans.*, B, 592, 519 (1947).
[2] König, A., "Physiologische Optik", 396 (Leipzig, 1903), quoted in Wright, W. D., "Researches on Normal and Defective Colour Vision", 333 (London, 1946).

Electronic Digital Computers

A SMALL electronic digital computing machine has been operating successfully for some weeks in the Royal Society Computing Machine Laboratory, which is at present housed in the Electrical Engineering Department of the University of Manchester. The machine is purely experimental, and is on too small a scale to be of mathematical value. It was built primarily to test the soundness of the storage principle employed and to permit experience to be gained with this type of machine before embarking on the design of a full-size machine. However, apart from its small size, the machine is, in principle, 'universal' in the sense that it can be used to solve any problem that can be reduced to a programme of elementary instructions; the programme can be changed without any mechanical or electro-mechanical circuit changes.

The essential parts of such a machine are: (1) a store for information and orders; (2) various arithmetical organs (for example, adders, multipliers); (3) a control unit[1].

The present machine contains the minimum set of facilities for a universal machine, namely: (*a*) If x is any number in the store, $-x$ can be written into a central 'accumulator' A; or x can be subtracted from what is in A. (*b*) The number A can be written in an assigned address in the store. (By means of (*a*) and (*b*) addition or direct writing into A can be programmed.) (*c*) The content of A can be tested for whether $x \geqslant 0$, or $x < 0$; if $x < 0$ the order standing next in the store is passed over. This gives the essential power of branching routines. (*d*) Control can be shifted to an assigned order in the table. (*e*) The machine can be ordered to stop.

The capacity of the store is at present only 32 'words', each of 31 binary digits, to hold instructions, data and working. Hence only simple arithmetic routines devised to test the machine can be run. Examples of problems that have been carried out are: (1) Long division by the standard process. (For $(2^{30} - 1)/31$, this took $1\frac{1}{2}$ seconds, the quotient being given to 39 significant binary figures of which the 13 least significant, to the left of the binary point, were zero, since 31 is a factor of $2^{30} - 1$.) (2) H.C.F. by the standard process. (For 314,159,265 and 271,828,183, which are co-prime, approximately 0·5 second.) (3) Factorizing an integer. For (3) the method was deliberately chosen to give a long run the result of which could be easily checked. Thus the highest proper factor of 2^{18} was found by trying in a single routine every integer from $2^{18} - 1$ downward, the necessary divisions being done not by long division, but by the primitive process of repeated subtraction of the divisor. Thus about 130,000 numbers were tested, involving some 3·5 million operations. The correct answer was obtained in a 52-minute run. The instruction table in the machine contained 17 entries.

It will, of course, be understood that it is intended to have other arithmetical facilities, as well as a much larger store, in a full-sized machine; and that even on the present machine quicker routines could have been used. At present routines are chosen with the sole object of testing the machine as thoroughly as possible.

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[1] For a fuller discussion see, for example, the Royal Society discussion on computing machines, summary in *Nature*, 161, 712 (1948).

Excitation Probability Functions of Atomic and Molecular Energy-Levels

IN the correlation of the electrical and spectroscopic properties of a glow discharge in a molecular or atomic gas, the need for a rough quantitative analysis of the kinetics of the excitation of the gas soon becomes apparent. In all but the simplest cases, no more than a rough analysis can be attempted with the present scanty experimental and theoretical knowledge of the interaction of slow electrons with atoms and molecules. It is the purpose of this communication to present an empirical form for the excitation probability functions of the atomic and molecular levels which seems to fit the few experimental curves fairly closely, and at least provides a basis for calculation where previously only generalized discussion was possible.

In principle, the excitation probability functions of atomic or molecular levels may be calculated from quantum mechanics. However, in actual fact, very few atoms and molecules have been considered[1]. In any event, serious theoretical difficulties exist in calculating the excitation probabilities for collisions with slow electrons—the interesting case from the point of view of glow discharge—where the Born approximation becomes invalid. Apart from these difficulties, it is necessary that the wave functions of the ground and excited states should be known. The wave functions of very few of the energy states of atoms and molecules have, in fact, been calculated. The quantum-mechanical method does not express the excitation probability function in a form which is readily applicable to discharge problems. Blackett[2] made an interesting semi-classical approach to the subject using the principles of conservation of energy and momentum. This, however, was limited and exploratory.

The shapes of excitation functions observed experimentally for singlet and triplet atomic levels from a singlet ground state are different[3]. The singlet excitation function rises from zero at the energy of the level concerned to a broad maximum somewhat above it, while the triplet excitation function rises from zero at the energy of the level concerned to a