

**3. Quaternions in undergraduate physics.** J. G. WINANS, *University of Wisconsin*.—A quaternion or scalar plus vector ( $Q=S+V$ ) results from the multiplication or division of arbitrary vectors. One vector  $\mathbf{a}$  is replaced by the sum of two components, one parallel and one perpendicular to the other vector  $\mathbf{b}$ . Thus  $\mathbf{a}=\mathbf{a}_1+\mathbf{a}_2$ , and  $\mathbf{a}\mathbf{b}=\mathbf{a}_1\mathbf{b}+\mathbf{a}_2\mathbf{b}$ , or  $\mathbf{a}\mathbf{b}=S+V$ , since  $\mathbf{a}_1$  is parallel to  $\mathbf{b}$  and  $\mathbf{a}_2$  is perpendicular to  $\mathbf{b}$ . Now  $\mathbf{a}_1\mathbf{b}=\mathbf{a}\mathbf{b}\cos\theta=(\mathbf{a}\cdot\mathbf{b})$ , and  $\mathbf{a}_2\mathbf{b}=\mathbf{a}\mathbf{b}\sin\theta=[\mathbf{a}\times\mathbf{b}]$ ; so  $\mathbf{a}\mathbf{b}=(\mathbf{a}\cdot\mathbf{b})+[\mathbf{a}\times\mathbf{b}]$ . Also  $\mathbf{a}/\mathbf{b}=\mathbf{a}_1/\mathbf{b}+\mathbf{a}_2/\mathbf{b}=S_2+V_2$ . Distributiveness has been assumed.  $\cos\theta$ =adjacent side/hypotenuse is a quaternion as is also  $\sin\theta$  but  $\tan\theta$ =opposite side/adjacent side is a vector. Since  $\sin^2\theta+\cos^2\theta=1$ , we have  $Q_1^2+Q_2^2=1$ , and the square of a quaternion is a scalar.  $(S+V)^2=Q^2$ , or  $S^2+SV+VS+V^2=Q^2$ . Separating scalars and vectors leaves  $S^2+V^2=Q^2$ , and  $SV+VS=0$ . Thus multiplication of scalar and vector is not commutative.

**4. A simple method for obtaining numerical solutions to problems governed by the one-dimensional wave equation.** WALTER P. REID, *Naval Ordnance Test Station, China Lake, California*.—If  $y(x, t)$  is the general solution to the one-dimensional wave equation, then

$$y(x+vh, t+H)=y(x+vH, t+h) \\ +y(x-vH, t-h)-y(x-vh, t-H).$$

This formula may be new, although it is so simple that one would expect it to be well-known. At any rate, it can be shown that its use will frequently enable one to calculate very easily numerical results of problems governed by the one-dimensional wave equation.

**5. Film-loops for physics teaching.** JOHN J. HELLMAN, *Ursinus College, Collegeville, Pennsylvania*.—Continuous film-loops with running times of 20 to 120 seconds were shown illustrating phenomena in vibratory motion, wave motion, and impact. These loops may be used either as animated lantern slides in lecturing or by the students to make quantitative studies of the phenomena.

**6. A simple high frequency demonstration oscillator.** RICHARD H. HOWE, *Denison University*.—A high frequency demonstration oscillator of simple construction was exhibited and briefly described. The oscillator was used to demonstrate several of the fundamental uses of electromagnetic radiation with particular application to high frequency arrays.

The power output of the oscillator is sufficient to provide ample visual display of the effects to a large group. It operates at a frequency which permits the demonstration equipment to be of dimensions convenient for classroom use.

**7. Echo ranging with audiofrequencies.** GEORGE BRADLEY, *Western Michigan College of Education*.—A device has been constructed which detects objects in a room by means of a reflected sound signal. The sound pulse is made up of very few cycles of audiofrequencies, and therefore the amplifiers and detectors operate in the audio range. The device, in using only a few cycles in each pulse, gives graphic demonstration to the student that not all sound waves are periodic.

This apparatus was primarily designed for a demonstration piece for the classroom. It has been utilized successfully (a) to measure the speed of sound in free air, (b) to illustrate the reflection of sound waves, (c) to measure the reverberation time of enclosures, and (d) to illustrate the principle of sonar and radar detection in the classroom.

Aside from a standard power supply, the apparatus utilizes 8 tubes in the electronic circuits, mounted on a 7 in.  $\times$  7 in. chassis. A small permanent magnet speaker acts as the transducer and a dynamic microphone as the detector. Data were presented on a standard oscilloscope.

**8. Preparation of pictorial material for classroom use.** Z. V. HARVALIK, IST, *University of Arkansas*.—Photographic methods are employed to assemble pictorial material. Emphasis is given to the use of 35-mm film because of the easy handling, low costs, and the small storage space required for the slides.

Material was demonstrated which dealt with tables, graphs, apparatus layouts, experimental records, and microfilming.

A simple apparatus was described and shown which enabled almost routine-type speed in taking photographs of material useful in lectures, demonstrations, and reference.

**9. Color demonstration with a small projection lantern.** V. E. EATON, *Wesleyan University*.—A Model MC Delineascope and a transmission grating were used to project the continuous spectrum of a lamp source and the band spectra of various filters. By substituting a rutile prism for the grating, two large brilliant spectra were produced. The same lantern was used to demonstrate the subtractive method of color photography.

For other color experiments the light from the lantern was reflected onto the screen from three mirrors, mounted on universal joints and separately controlled. When three primary filters were properly mounted in the lantern the arrangement could be used as a color mixer and the intensity of each component could be controlled by means of Polaroids. This arrangement could be used also to demonstrate the additive method of color photography and to project the Maxwell color triangle.

**10. Individual projects on the intermediate level as a training aid and as an economy measure.** O. B. YOUNG, *Southern Illinois University*.—An outline of advantages of individual projects performed by undergraduate physics students on the intermediate level was presented. The method is highly adaptable and flexible, meeting different types of student needs and departmental circumstances. Twenty-three different points were considered. Special emphasis was given to student motivation, development of interest in physics, economy of teacher time, of departmental equipment, and application to students of varying abilities.

**11. A most unusual solar phenomenon witnessed at Cedar Falls, Iowa, February 27, 1952.** R. A. ROGERS, *Iowa State Teachers College*.—From about 11:00 A.M. until 2:00 P.M. on February 27, 1952, conditions ap-

tion with this furnace are part of the back-reflection component of a General Electric X.R.D. unit; however, any one of a number of types of back-reflection arrangements may be used. With the G. E. film holder and sector mask, three separate exposures of opposing 60° sectors can be made on a five-inch circular film, providing a diffraction record at three different temperatures and thus reducing film shrinkage error in comparing the patterns for different temperatures.

The results obtained during more than a year of using this system have shown it to be more nearly accurate in temperature determination and control than furnaces suitable for use in cylindrical powder cameras, and to be more suitable for use by relatively inexperienced personnel.

### A Modified Cotton Balance\*

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**T**EACHERS of general physics laboratory courses often have felt that an experiment demonstrating the interaction of a magnetostatic field with a conductor through which an electric current flows would be desirable. The author constructed a simple apparatus demonstrating quantitatively the interaction of a permanent magnetic field and a magnetic field produced by an electric current using Cotton's<sup>1</sup> approach. The apparatus consists of a permanent magnet of large-area pole shoes and narrow air gap, and a conductor movably located in the air gap. It uses a damping magnet of a watt-hour meter as permanent magnet and a wire as conductor bent into a rectangular loop.

Assuming that a direct current  $I$  passes through the wire loop, a part of which is located inside of the magnetic field of the permanent magnet and having a length of  $l$ , a force will develop of the intensity

$$F = IlB, \quad (1)$$

where  $l$  is the length in centimeter of the wire inside of the magnetic field,  $B$  the flux density of the magnetic field in maxwell, and  $I$  the current intensity in abampere. According to the direction of the current and considering that the conductor wire is horizontally mounted, the wire will be pushed upward or downward when the current is permitted to flow. If one connects the conductor to a battery in such a way that the force acting upon the wire causes the wire to move upward against the gravitational field of the earth, the lifting force can be compensated by attaching weights to the wire. These weights represent a force

$$F = gm, \quad (2)$$

where  $g$  is the acceleration due to gravity (980 cm sec<sup>-2</sup>) and  $m$  the mass of the attached weights. Therefore, one can establish the equation

$$gm = IlB. \quad (3)$$

If  $I$  is known, the equation can be solved for

$$B = gm/Il. \quad (4)$$

### Description of the Instrument

A wooden block  $WB$  is mounted on a 6×12-inch base plate  $BB$  (Fig. 1), and carries two binding posts  $BP$  to

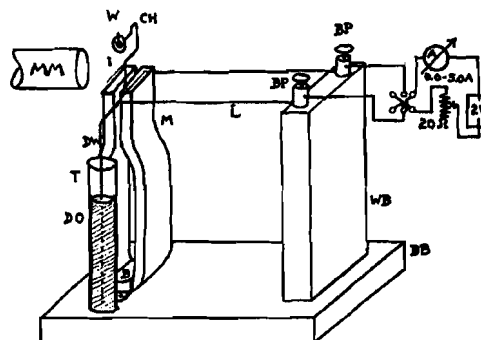


FIG. 1. Modified cotton balance.

which the wire loop  $L$  is attached. The wire loop  $L$  is of rectangular shape, the shorter side of which is placed into the air gap of the permanent magnet  $M$ . At the center of the smaller side of the wire loop, a carrying hook  $CH$  is soldered as well as an indicator wire. The carrying hook  $CH$  is of the same gauge as the wire loop (24 gauge, 0.51-mm diameter). The indicator wire is of 38 gauge (0.1-mm diameter), and serves in connection with a measuring microscope as compensation indicator. The weights added to the carrying hook  $WC$  are fiber washers  $W$  whose masses must be determined with an analytical balance. The permanent magnet  $M$  is mounted on the board by a brace  $B$  of appropriate shape.

Owing to the fact that undesired vibrations of the wire loop  $L$  occur, a damping device is introduced. The damping device consists of a damping wire  $DW$  soldered onto the loop  $L$ . The damping wire dips into a test tube  $T$  filled with oil of viscosity 10 as damping liquid  $DO$ .

### Experimental Procedure

After the student wires the circuit according to the diagram (Fig. 1), and establishes the zero position of the loop by observation through the measuring microscope  $MM$ , he tests the upward direction of the force on the loop by switching on the current. A weight washer  $W$  is then placed upon  $CH$  and the electric current is regulated with the resistor (20 ohm, 5 amp) till the zero position of the indicator  $I$  is established, using the measuring microscope. The current read on the ammeter is recorded. A 2nd, 3rd, 4th, etc., weight washer  $W$  is added and the procedure is repeated. A graph indicating the proportional relationship between the current and the compensating weights is prepared (Fig. 2) and the flux density within the air gap of the magnet is calculated by formula 4.

Students will have no difficulty in performing the measurements which are accurate to one percent if an ammeter

## An Electronic Magnifier for Observation of Infra-Red and Ultraviolet\*

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**I**N the early 1930's, many investigators applied image tubes to the study of infra-red reflecting and absorbing properties of materials.<sup>1-3</sup> They attached an image tube to a microscope or telescope and observed the object when illuminated with infra-red light.

During World War II, the image tube was considerably improved in its physical and electronic performance and was used as an infra-red-visible light transforming device in different types of snooperscopes and sniperscopes. These instruments enabled the observation of the enemy illuminated by an infra-red search light without the observer being seen.<sup>4,5</sup>

In 1947, Z. V. Harvalik<sup>6</sup> described an electronic eyepiece attached to a spectroscope that enabled the direct observation of the infra-red portion of the spectrum. In 1948, R. Bailly<sup>7</sup> showed how to use the image tube in connection with the microscope, and applied it to petrographic research.

After declassification of the improved image tubes,<sup>8</sup> the author attempted to find uses for these in physical and chemical research. Stimulated by the fact that some substances display special properties in filtered ultraviolet light, he felt that similar procedures could be followed by using filtered light in the infra-red region of the spectrum. Because the infra-red light is not visible to the human eye, certain converting devices have to be used. Originally, only photo-

graphic plates and bolometers were utilized. However, with the development of the image tube a significant improvement in such converting devices was made.

The techniques involved in the transformation of infra-red light into visible light by the use of the image tube are as follows: The sample or specimen, illuminated by an infra-red light source (150-w projector bulb inserted into a light-tight box (Fig. 1, left) and equipped with an infra-red (Corning No. 254) filter will reflect a certain amount of infra-red light. The infra-red light reflected from the sample reaches the electronic magnifier (Fig. 1, center) where an optical (infra-red) image is focused upon the photo-cathode *PC* of the image tube (Fig. 2). The electrons released by the photo-cathode are electron-optically focused by the rings *R*<sub>1</sub>, *R*<sub>2</sub>, *R*<sub>3</sub>, *R*<sub>4</sub> upon a fluorescent screen which is covered with a phosphor of a composition similar to that of the phosphor used in cathode-ray tubes. When the electrons reach the phosphor of the screen *SC*, they activate it to a greenish luminescence characteristic of the phosphor. The electron image formed on the screen *SC* is observed through a magnifying eyepiece. This image can be photographed by a camera attached to the lens system *M*.

The electronic magnifier for observation of infra-red images (Fig. 2) consists of the image tube 1-P-25, the magnifying lens *CL* and the magnifying eyepiece *M*. The 1-P-25 tube is

\* The electronic magnifier was exhibited at the Colloquium of College Physicists in Iowa City, Iowa, June 16, 1949. The infra-red spectroscope (Fig. 6) at the Colloquium of the College Physicists in Iowa City, in June, 1948.

† Research Paper No. 876, Journal Series, University of Arkansas.

<sup>1</sup> E. Brüche and O. Scherzer, *Geometrische Elektronenoptik* (Verlag Julius Springer, Berlin, Germany, 1934).

<sup>2</sup> W. Schaffernicht, *Zeitsch. f. Techn. Physik* 17, 12 (1936).

<sup>3</sup> V. K. Zworykin and G. A. Morton, *J. Opt. Soc. Am.* 26, 181 (1936).

<sup>4</sup> G. A. Morton and L. E. Flory, *Electronics* 19, 112 (1946).

<sup>5</sup> G. A. Morton and L. E. Flory, *RCA Review* 7, 385 (1946).

<sup>6</sup> Z. V. Harvalik, *Rev. Sci. Instr.* 19, 254 (1948); *Bulletin APS* 22, No. 6, 23 (1947).

<sup>7</sup> R. Bailly, *Science* 108, 143 (1948).

<sup>8</sup> RCA Data Sheet on 1-P-25, 1944-7 (restriction removed).

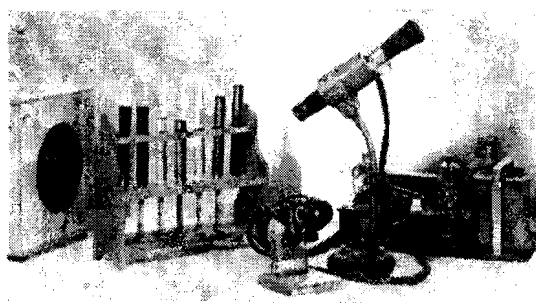


FIG. 1. Electronic magnifier.

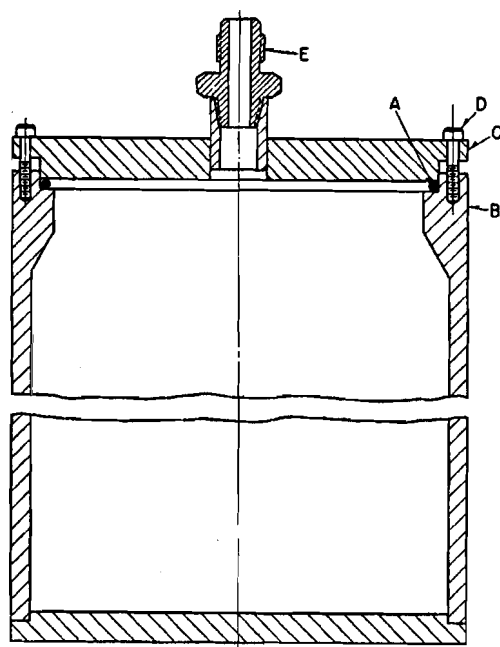


FIG. 1. Low temperature gasket.

container is indicated in Fig. 1. The gold wire, *A*, 0.020 in. in diameter, sealed the copper container, *B*, which in this application happened to be 8×4 in. (diameter), when the copper cap, *C*, was forced down onto it by twenty-two 4-40 Allen-head screws. The initial tightening of the cap caused the gold to flow and to take up any irregularities in the sealing surfaces. At the same time it became work-hardened and elastic. The gasket adhered well to the container and was not removed during subsequent disassembly operations. In the application in which this arrangement was used, the presence of magnetic bodies was not objectionable; hence standard steel screws were used. For experiments in which this is a consideration, strong, non-magnetic screws will be employed; beryllium copper screws appear to be a good choice for this purpose.

The arrangement was checked for tightness with a helium mass spectrometer leak detector.<sup>4</sup> Preliminary measurements, made with the leak detector operating in routine fashion, that is, with the diffusion pump associated with the device open to the system under test, gave a conservative lower limit to the size of leak detectable equal to  $5 \times 10^{-9}$  (micron-liter)/sec., measured at room temperature. Within this limit, no leak was detectable with the apparatus exposed to helium gas at one atmosphere in the temperature range room temperature to ca. 4.2°K, or to liquid helium between ca. 4.2° and 1.92°K.

Because of the general interest in the tightness of the gasket when the seal is exposed to superfluid helium, the test method was elaborated so as to decrease the lower limit to  $5 \times 10^{-9}$  (micron-liter)/sec. with the apparatus immersed in liquid helium below the  $\lambda$ -point. The container was filled with a machined piece of aluminum which decreased the gas space in the container practically to zero. The container communicated with a 1.5-liter volume at room temperature by way of the pumping line. When the liquid helium in which the container was immersed reached the  $\lambda$ -point, the container was isolated from the pumping system of the leak detector, and any helium leaking in was allowed to collect in the room temperature volume. The collection time was 100 min., during which time the liquid helium, whose vapor was being pumped away continually, reached a vapor pressure of 18.2 mm, corresponding to 1.92°K. At the end of the collection time, the system was quickly opened to the mass spectrometer, and, from independent calibrations, the lower limit already noted could be

deduced. There exists the possibility that the actual leakage rate is higher than the value given because of the adsorption of helium gas on the low temperature surfaces of the container. No further work was done on this possibility.

There was no ambiguity associated with the temperature measurement. It was determined from the vapor pressure as indicated by both an ordinary mercury manometer and a Dubrovin gauge having a ninefold amplification factor and readable to  $\pm 0.1$  mm Hg. The gauges were connected to a tube having an I.D. of 0.175 in. and immersed in the liquid helium. The attainment of the  $\lambda$ -point was indicated by a discontinuity in the slope of the vapor pressure, time relation for the evaporating liquid and corresponded accurately to the  $\lambda$ -point pressure as read on the gauges.

The assembly survived 12 cooling-heating cycles between room temperature and 77°K, as well as six separate openings and closures, with no evidence of leakage. Parenthetically, it is interesting to note that the leak test included any possible contribution by the S.A.E. brass to copper flare fitting which was therefore free of leaks to the limit and under the conditions described.

It is evident that the seals described here are sufficiently tight to permit the use of the practice widely employed in the case of glass Dewar vessels.<sup>5</sup> Thus it would be possible to rough pump a copper vacuum container using a gold gasket and to allow the pressure to drop to a negligible value when low temperatures are reached. In other words, no kinetic diffusion pump system need be used.

In conclusion, the authors are happy to acknowledge the cooperation of Dr. R. E. Fox and Mr. D. J. Grove in certain phases of the use of the mass spectrometer leak detector.

- <sup>1</sup> Giauque, Stout, and Barieau, *J. Am. Chem. Soc.* 61, 654 (1939).  
<sup>2</sup> Giauque, Fritz, and Lyon, *J. Am. Chem. Soc.* 71, 1657 (1949).  
<sup>3</sup> W. M. Hickam, *Rev. Sci. Inst.* 20, 472 (1949).  
<sup>4</sup> Thomas, Williams, and Hipple, *Rev. Sci. Inst.* 17, 368 (1946).  
<sup>5</sup> W. F. Giauque, *Rev. Sci. Inst.* 18, 852 (1947).

### Simple Method to Seal Liquids of High Vapor Pressure into Glass or Quartz Capillaries

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 August 1, 1949

A SIMPLE method of sealing a liquid of high vapor pressure (water, ethyl ether, ethyl alcohol, carbon disulphide) into heavy-walled glass or quartz tubes and capillaries is described as follows.

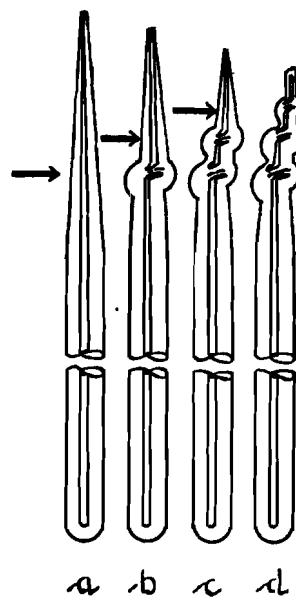


FIG. 1.

## Subjective Spectral Band Limits\* Under Controlled Conditions†‡

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AND

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(Received September 26, 1949)

Subjective spectral band limits have been established under controlled conditions as to dark adaptation of the eye, luminance of the spectrum (0.8 millilambert at 555  $m\mu$ ) at the eyepiece slit, small visual angle ( $2.2^\circ$ ) of the slit, and observed band width of 0.6  $m\mu$  at 400  $m\mu$  to 1.3  $m\mu$  at 700  $m\mu$ . One hundred and twenty-five students have been subjected to the test. Color-blind persons were excluded. The mean values of transition points established by these tests are as follows: Transition from infra-red to red, 744  $m\mu$ ; red to orange, 614  $m\mu$ ; orange to yellow, 597  $m\mu$ ; yellow to green, 582  $m\mu$ ; green to blue, 514  $m\mu$ ; blue to violet, 476  $m\mu$ ; and violet to ultraviolet, 419  $m\mu$ .

Color transitions of some color-blind subjects, exceptional subjects and subjects pre-exposed to various conventional light sources, are also given.

### I. INTRODUCTION

A LITERATURE study of subjective band limits<sup>1-10</sup> in the spectrum revealed a considerable discrepancy between various authors in regard to wave-lengths of color transitions (Table I). It was assumed that the data compiled by these authors are the results of

### II. APPARATUS

The instrument used was a Gaertner constant deviation spectrometer, which acted as a monochromator. As light source, an incandescent projection bulb (100 watt, 120 volt) operated at approximately 2800°K was used because of its convenience and reproducibility.<sup>11</sup> By

ionization potential making the process analogous to formation of  $Cs^+$  from  $Cs$  impacting on  $W$ . The sharp threshold voltage for the pitting process to be expected on this picture has been observed.

<sup>1</sup> L. H. Germer and F. E. Ifaworth, *Phys. Rev.* **73**, 1121 (1948).

### Optical Physics; Line-Spectroscopy; Nuclear Magnetic Resonance; Mass Spectrometry

**G1. The Establishment of Mean Points of Transition Between Spectral Bands.\*** ZABOJ V. HARVALIK AND JOHN H. BOWEN,<sup>1</sup> *University of Arkansas*.—A method for obtaining the mean spectral band transition points is outlined and the mean values are presented. Comparison is made between transition values of this study and the values given in contemporary literature. The spectral transition points for binocular vision of light adapted eyes are: red, 739–613; orange, 613–597; yellow, 597–585; green, 585–517; blue, 517–479; violet, 479–422, at the brightness of the eyepiece slit of 0.002 foot candles/cm<sup>2</sup>. The data were obtained from 125 individuals of the ages from 17 to 36 years of both sexes (42 women and 83 men). The selection of these subjects was made without selection with respect to eye deficiencies. Data on color ranges of monocular vision and binocular vision for the dark and light adapted eye are given.

\* Based on work performed under contract with the Office of Chief of Ordnance, Department of Army.

<sup>1</sup> Ordark Research Fellow in Psychology, Department of Psychology.

**G2. The Use of "Exploding Wires" as a Light Source of Very High Intensity and Short Duration.** WILLIAM M. CONN, *Rockhurst College*.—The flash of light obtained in discharging a large condenser through a very thin wire has been used as a light source for obtaining high speed photographs and for making visual observations of rapidly moving objects. Copper wire was found most suitable for photographic exposures, while wires made of silver and chromel gave good results in visual work. Examples of some typical settings are presented using wires of silver, gold, aluminum, copper, steel, constantan, and chromel. Arrangements for increasing the intensity of single flashes of light and for multiple flashes are briefly discussed, as well as means for electrically exploding materials not available in the shape of thin wires.

**G3. Forbidden  $s-n_s$  Lines in Alkali Metal Atomic Absorption Spectra.** J. E. MACK, *University of Wisconsin*.—A re-examination of Kratz' long-path absorption spectrograms<sup>1</sup> shows that at least on the Rb plates there are, in addition to the series from the normal state to high  $d$ -,  $f$ -,  $g$ - . . . levels, transitions to  $s$ -levels in the neighborhood of  $50s$ . These levels were overlooked before because they are only barely or partly resolved from those in the  $f$  series, where the asymptotic quantum defect is less by almost 3 units. The significance of their presence lies in their evidence that the unusual transitions must arise from disturbances attributable to other atoms, since the  $0-0$  transition in  $l$  is strictly forbidden.

<sup>1</sup> H. R. Kratz and J. E. Mack, *Phys. Rev.* **76**, 193A (1949).

**G4. Isotope Shift in the  $2p^1S_0-3s^1P_1$  Line of Carbon.\*** JOHN R. HOLMES, *University of Southern California*.—A study has been made of appropriate methods of excitation of small samples of carbon in order to make a measurement of isotope shift in the atomic spectrum of carbon. It has been found that milligram amounts of carbon can be excited to give the  $2479 A$  ( $2p^1S_0-3s^1P_1$ ) line with good intensity and sharpness in a liquid nitrogen cooled electrodeless discharge tube of rectangular cross section, but that no other carbon lines appeared. The carrier gas was about 4 mm of helium but it is essential

that it contain about 0.5 mm of oxygen to make the carbon line appear. Using a mixture of  $C^{12}-C^{13}$  enriched to 52 percent  $C^{13}$ , a measurement of the isotope shift in this line was made with a Fabry-Perot interferometer crossed with a medium Hilger spectrograph. The normal mass effect, based simply on the change in the Rydberg constant, would predict an isotope shift in this line of plus  $0.142 \text{ cm}^{-1}$ . The observed shift, however, is minus  $0.156 \pm 0.002 \text{ cm}^{-1}$ , indicating a "specific mass effect"<sup>1</sup> of minus  $0.298 \text{ cm}^{-1}$ .

\* Supported by the ONR.

<sup>1</sup> D. S. Hughes and Carl Eckart, *Phys. Rev.* **36**, 694 (1930).

**G5. Departure of the Lamb Shift from the  $n^{-3}$  Law in  $He^+$ .** J. G. HIRSCHBERG, JR. AND J. E. MACK, *University of Wisconsin*.—Light of the Paschen line,  $\lambda 4686$ , from a liquid-air-cooled hollow-cathode discharge was diffracted from a 21-foot grating, and the extreme violet portion ( $3_1-4_{11}$ , in the notation  $n_1$ ), isolated by a knife-edge, was subjected to a Fabry-Perot interferometric examination with several spacers ranging from 16 to 21 mm. The separation of the two<sup>1</sup> components, which (neglecting any  $p$ - and  $d$ -shifts) is just the  $3s$ -shift, is  $0.1314 \left\{ \begin{array}{l} + \text{ about } 0.003 \\ - \text{ about } 0.006 \end{array} \right\} \text{ cm}^{-1}$ , and thus definitely smaller than the  $0.139 \pm 0.003$  which an  $n^{-3}$  extrapolation from the  $2s$ -shift<sup>2</sup> would yield. Other values to be compared, all based on the  $3_1-4_1$  component and incorporating the assumption ( $4s$ -shift)/( $3s$ -shift) =  $27/64$ , are our previous tentative grating value<sup>3</sup> of  $0.113 \pm 0.014 \text{ cm}^{-1}$  and Kopfermann's<sup>4</sup>  $0.137 \pm 0.015$  and<sup>5</sup>  $0.118 \pm 0.003 \text{ cm}^{-1}$ .

\* Supported by contract with the ONR.

<sup>1</sup> J. E. Mack and N. Austern, *Phys. Rev.* **74**, 1262A (1948).

<sup>2</sup> M. Skinner and W. E. Lamb, Jr., *Phys. Rev.* **75**, 1325A (1949).

<sup>3</sup> J. E. Mack and N. Austern, *Phys. Rev.* **72**, 972 (1947).

<sup>4</sup> H. Kopfermann and W. Paul, *Nature* **162**, 33 (1948).

<sup>5</sup> H. Kopfermann, *Zeits. f. Physik* manuscript sent to us in advance of publication.

**G6. Hyperfine Structure and Isotope Shift in Barium.** O. H. ARROE, *University of Wisconsin*.—Spectroscopic h.f.s. studies have been made with concentrated samples of the isotopes  $Ba^{137}$  and  $Ba^{138}$ .\*\* The resonance lines of  $Ba$  II show that both isotopes have the spin  $3/2$  and that the splittings from  $Ba^{137}$  are 12 percent larger than those from  $Ba^{138}$ . A small isotope shift, in which the even isotopes are displaced with respect to the odd, is found in these lines. Earlier studies with natural barium have indicated the values  $5/2$  or  $3/2$  for both odd isotopes; the current acceptance of  $3/2$  has come from a consistency test by Hay,<sup>1</sup> who found by a molecular beam resonance method that the nuclear magnetic moments have the ratio  $\mu_{137}/\mu_{138} = 1.1174 \pm 0.0010$ , although the structure of  $Ba^{138}$  had never been resolved from that of  $Ba^{137}$ . The disagreement among earlier investigations probably arose from the blending caused by the difference in the h.f.s. splittings of  $Ba^{137}$  and  $Ba^{138}$  (natural abundances respectively 11.32 and 6.59 percent).

\* Supported by contract with the ONR.

\*\* Produced by the Y-12 plant, Carbide and Carbon Chemicals Corporation, and obtained by allocation from the United States AEC.

<sup>1</sup> R. H. Hay, *Phys. Rev.* **60**, 75 (1941).

**G7. Nuclear Moments of  $Mg^{25}$ .** F. M. KELLY, A. L. SCHAWLOW, W. M. GRAY, AND M. F. CRAWFORD, *University of Toronto*.—The h.f.s. of the  $Mg$  I line 5167A ( $3s^2 3p^1 P_0-3s4s^2 S_1$ ) and the  $Mg$  II line 2796A ( $3s^2 S_{1/2}-3p^1 P_{1/2}$ ), excited in an atomic beam source, have been resolved with a Fabry-Perot etalon. 5167A shows two faint components due to  $Mg^{25}$  at  $+0.0303$  and  $-0.0341 \text{ cm}^{-1}$ , and a  $Mg^{26}$  component at  $-0.0138 \text{ cm}^{-1}$ , from the strong  $Mg^{26}$  component. If the  $Mg^{25}$  centroid is assumed midway between the  $Mg^{24}$  and  $Mg^{26}$  components, the interval rule gives  $I=5/2$  and the inverted structure of  $^2S_1$  shows that the magnetic moment is negative. The  $^2S_1$  splitting gives  $\mu(Mg^{25}) = -0.97 \pm 0.05 \text{ n.m.}$  2796A shows

# An Electronic Image Converter and Its Use in Chromatography

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An electronic image converter and its accessories, enabling observation of textures and color reactions of adsorption columns illuminated by an infrared light source, are described. The converter employs an image tube, Type CV-147, which converts infrared into visible light. The color sensitivity of the tube also permits observation of ultraviolet light. The color range of this device is 300 to 1400 milli-

microns and its magnification power is 2.5X. It is suggested that the converter be applied to medical, criminological, and industrial investigations as well as problems in analytical chemistry. The addition of this device to chromatographic techniques necessitates a new or broader definition of the term "ultrachromatography," and the introduction of the terms "infra-" and "fluorochromatography."

COLORLESS substances adsorbed in a chromatographic column are difficult to locate. Karrer and Schöpp (8) and Winterstein and Schön (17) used filtered ultraviolet light for identification of some colorless substances because of their fluorescence. This method of identification, erroneously called ultrachromatography, is limited in its use because not all colorless substances fluoresce in the region of visible light when activated with ultraviolet radiation.

Some colorless substances form fluorescent compounds after their adsorption in the chromatographic column when chemical reagents are added (3, 14-16). Strain (13) suggested forming fluorescent compounds of colorless samples before they are adsorbed in the chromatographic column, and identifying them after their adsorption.

Some adsorbents interfere with the fluorescence of the compounds; they fluoresce and make identification of chromatographic layers difficult.

The author investigated reflection, absorption, and fluorescence in the infrared region of the spectrum of some colorless compounds to study the possibility of chromatographic identification using infrared as a light source. Infrared light is invisible to the human eye, and can be observed only by devices for converting infrared to visible light. Electronic image converters permit the observation of infrared absorption and reflections from specimens illuminated by various light sources.

Electronic image converters use image tubes as elements for converting infrared to visible light. As early as 1934, image tubes were used to study the infrared-reflecting and absorbing properties of materials. An image tube was attached to a microscope or telescope and objects illuminated with infrared light were observed (2, 12, 18). The image tube was improved in its physical and electronic performance during World War II (9, 10). An electronic eyepiece attached to a spectroscope, permitting direct observation of the infrared and ultraviolet portion of the spectrum, was described by the author at the Chicago meeting of the American Physical Society in 1947 (6, 7). The use of the image tube attached to a microscope (previously reported, 18) was reported and applied to petrographic research in 1948 by Bailly (1). The importance of electronic image converters in analytical chemistry, and possible uses in criminology, medical sciences, and industry were pointed out by the author at the meeting of the AMERICAN CHEMICAL SOCIETY, September 1948 (5).

The transformation of infrared light into visible light by the use of the image tube is explained as follows:

The chromatographic column (Figure 1, center), illuminated by an infrared light source (150-watt projector bulb inserted into a light-tight box and equipped with an infrared filter, Corning No. 2540, Figure 1, left), reflects and absorbs a certain amount of infrared light. Infrared light reaches the electronic image con-

verter (Figure 1, center), where an optical, infrared image is focused upon the photocathode of the image tube (also Figure 2, P). The electrons released by the photocathode of the image tube, P, fall upon a fluorescent screen, W, covered with a phosphor of a composition similar to that of cathode-ray tubes. Electrons activate the phosphor, S, to a greenish luminescence and the electron image formed on the screen, S, is observed through a magnifying eyepiece, EP. The image on the screen can be photographed on any green-sensitive film.



Figure 1

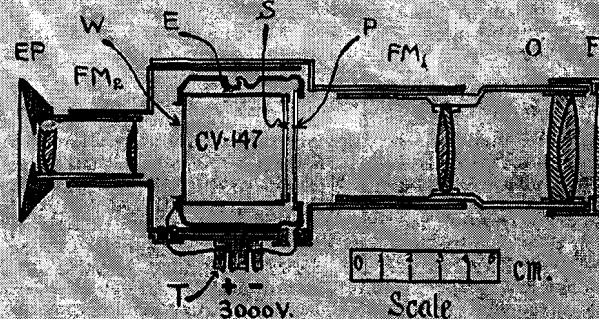


Figure 2

The electronic image converter, because of its simple construction, can be built by any individual familiar with electronic circuits. It (Figure 2) consists of the image tube CV-147 (11) (Figure 2, CV-147), the objective lens system, O, and the magnifying eyepiece, EP. The image tube is mounted in a brass shielding tube, the inside of which is lined with mica. An outer tube is slipped over the shielding tube. As a focusing mount, FM<sub>1</sub>, for the objective lens system, O, a tube of somewhat smaller diameter is attached to the outer tube. The objective lens system, O, has

**BA5. Theory of Electron Multiplication in Crystals.\***

FREDERICK SEITZ, *Carnegie Institute of Technology*.—The multiplication of free electrons in strong electrostatic fields is examined. This problem is related to that of dielectric breakdown if the latter problem is approached from von Hippel's viewpoint of ionization by impact. Let  $E_H$  be the electrostatic field for which an electron gains energy from the field more rapidly than it loses it in exciting lattice vibrations. The present work shows that avalanches sufficient to produce breakdown could occur at a field of about  $0.2E_H$  through statistical fluctuations. The size of the average avalanche grows by  $10^{12}$  as the field is increased by about 25 percent if the electrons ionized belong to the bulk material. It is concluded however that the avalanches observed by Haworth and Bozorth and others in the pre-breakdown region are probably connected with impact ionization of impurity atoms. It is also concluded that the interaction between electrons and non-polar lattice vibrations, hitherto ignored in ionic crystals though not in non-polar crystals, is important in polar crystals. This interaction makes von Hippel's and Fröhlich's criteria for breakdown nearly identical; however, both are too stringent.

\* Contribution to a program supported by the Bureau of Ships in cooperation with the Office of Naval Research.

**BA6. Measurement of the Piezoelectric Constants of Alpha- and Beta-Quartz.** RICHARD K. COOK AND PEARL G. WEISSLER, *National Bureau of Standards*.—The piezoelectric constants  $d_{11}$  and  $d_{14}$  of alpha-quartz have been measured between room temperature and about  $565^\circ\text{C}$ . At the latter temperature,  $d_{11}$  is about  $\frac{1}{3}$  of its room temperature value, whereas  $d_{14}$  has increased by a factor of approximately  $2\frac{1}{2}$ . At a temperature of  $573^\circ\text{C}$  (the inversion temperature), the crystal structure changes to that of beta-quartz, and  $d_{11}$  vanishes. The constant  $d_{14}$  for beta-quartz has been measured between about  $585^\circ\text{C}$  and  $620^\circ\text{C}$ .  $d_{14}$  appears to be substantially constant over this short range of temperature, and differs from  $d_{14}$  for alpha-quartz at  $565^\circ\text{C}$  by only a few percent. The piezoelectric constants were deduced from measurements of the equivalent circuits of long thin bars driven electrically at frequencies near the resonance frequency for the fundamental longitudinal mode. The bars were cut with flat faces perpendicular to the  $x$  axis, and the flat faces were gold plated and used as electrodes. The long dimensions of the bars lay in the  $yz$  plane, and made known angles with the  $y$  axis. The equivalent circuits were determined with a  $Q$ -meter technique, and the circuit constants needed for calculation of the piezoelectric constants depended only on the measurement of frequencies and of changes in capacitance.

✓ **BA7. Some Properties and X-Ray Diffraction Pattern of Some Inorganic Salts Crystallized by the Critical Temperature of Water as Solvent.** ZABOJ V. HARVALIK, *University of Arkansas*.—Certain inorganic salts as sodium chloride, sodium sulfate, barium chloride, and barium nitrate have been precipitated in an autoclave at the critical temperature of water as solvent. The precipitated salts were recovered by slow expansion of the solvent (water) while the autoclave temperature was held a few degrees above the critical temperature of water.<sup>1</sup> X-ray diffraction patterns were made on a North American Phillips recording x-ray diffraction unit and revealed that the crystals ob-

tained by this method are somewhat different from crystals obtained by conventional means of crystallization. Lattice calculations indicate that the salts crystallized at the critical temperature of water approach an x-ray diffraction pattern closer to the theoretical values and are without internal strain.<sup>2</sup> The crystals are about 3 to 5 microns in size, although larger aggregates have been observed. The crystals have been used as seeds for conventional crystallization at temperatures lower than the normal boiling point of water. Attempts have been made to obtain larger crystals at the critical temperature of water by using temperature pulsation, with and without mother liquor supply. The crystals thus obtained are larger (0.01 mm to 1.0 mm) and do not show any difference from crystals grown under conventional conditions, as far as the microscopic inspection is concerned. No x-ray diffraction patterns have been made yet.

<sup>1</sup> Paper presented by Z. V. Harvalik at the 112th meeting of Am. Chem. Soc., New York, 1947.  
<sup>2</sup> J. W. Buttrey, Thesis at University of Missouri, MSM (1948).

**BA8. The Vibrational Spectrum of Crystalline Benzene.**

R. D. MAIR AND D. F. HORNIG, *Brown University*.—The infra-red spectrum of crystalline benzene was studied at  $-12^\circ\text{C}$ ,  $-68^\circ\text{C}$ , and  $-170^\circ\text{C}$  and the liquid at  $28^\circ\text{C}$ . As predicted theoretically,<sup>1</sup> the lines are extremely sharp, the mean line width for fundamentals being but  $7\text{ cm}^{-1}$  in the crystal. In three cases it is less than the spectral slit width ( $4.5\text{ cm}^{-1}$ ). All out-of-plane degenerate modes are split by about  $10\text{ cm}^{-1}$ . Selection rules agree with the x-ray structure. All ungerade fundamentals are observed directly, some for the first time. The assignments of Ingold *et al.*<sup>2</sup> are confirmed except for the  $B_{2u}$  species. There is strong evidence for changing  $\nu_{16}$  by about 3 percent. Forty-one combination lines are observed. One of these, an extremely sharp line at  $1311\text{ cm}^{-1}$ , appears to violate selection rules. We suggest that it is  $\nu_{14}$  and that the Raman line observed at  $2618\text{ cm}^{-1}$  is its overtone. An allowed combination with  $\nu_8$  is observed at  $2907\text{ cm}^{-1}$ . Ingold's other data can also be satisfactorily accounted for on this basis. Combination lines involving torsional lattice modes are observed at  $-170^\circ\text{C}$ .

<sup>1</sup> D. F. Hornig, *J. Chem. Phys.* **16**, 1063 (1948).  
<sup>2</sup> N. Herzfeld, C. K. Ingold, and H. G. Poole, *J. Chem. Soc. Pt. 1*, 316 (1946).

**BA9. Symmetry Coordinates in Molecules and Crystals.\***

WILLIAM J. TAYLOR, *Ohio State University*.—In the treatment of the vibrations of a symmetrical molecule or crystal symmetry coordinates may be formed from sets of equivalent coordinates so as to reduce the point group of the molecule or the factor group of the space group of the crystal lattice. The reduced representations of a set of equivalent coordinates in the group may be found by general methods. A set of coordinates may be divided into equivalent subsets which are in one-to-one correspondence with a set of equivalent points (in the molecule or unit cell). There is a set of conjugate subgroups which leave the points invariant. The representation of the set of coordinates in the group is completely characterized by the nature of the set of points (and subgroups) and by the representation of a typical subset in the associated subgroup. Compact tables may be prepared showing the reduced representation in the group for each possible set of points and for





tion of a high negative voltage. The schematic of such a stabilizer is shown in Fig. 10. Here the unregulated negative high voltage is applied to the cathode of the series tube, and the grid-biasing signal is obtained as before from the r-f rectifier and filter in the cathode-grid circuit. Since the grid circuit, including the r-f transformer secondary, is insulated from the r-f primaries, that entire circuit can travel up and down with fluctuations in the unregulated high

voltage input; but the grid signal so controls the drop across the series tube that the plate of that tube remains at a quite constant potential.

#### ACKNOWLEDGMENT

The writers wish to express their gratitude to the Signal Corps Engineering Laboratories, Bradley Beach, New Jersey, for support of the program of which the development of the high voltage stabilizer is a part.

### An Electronic Eyepiece for Spectroscopy of Near Infra-Red\*

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(Received January 8, 1948)

An electronic eyepiece for the observation of near infra-red of the spectrum is described. It can be attached to any spectroscope and consists of an image tube of the type 1-P-25 which converts an infra-red image into a visible one. The spectrum is projected by the telescope system of the spectroscope upon the mosaic face of the image tube. The infra-red radiation releases photoelectrons from the mosaic face of the image tube which are focused electron-optically upon a fluorescent screen. The image appearing on the fluorescent screen can be observed directly or magnified optically. The visible range of a spectroscope equipped with an electronic eyepiece extends the visible range to approximately 1150  $m\mu$  into the infra-red and to 300  $m\mu$  into the ultraviolet.

**I**N spectroscopic work, when a photographic spectrogram is contemplated it is sometimes desirable to observe the infra-red or ultraviolet portion of the spectrum in order to identify the spectral lines without being forced to use photographic methods or to focus the spectroscope in the regions of the spectrum invisible to the human eye.

The declassification of certain war developments including the viewing tube 1-P-25<sup>1-3</sup> en-

ables the construction and general use of an electronic eyepiece. It can be attached to any conventional spectroscope and can be used to observe the infra-red and ultraviolet part of the spectrum. The observation of the visible part through the electronic eyepiece is also possible.

Long before the outbreak of the World War II Zworykin and Morton<sup>4</sup> reported on viewing tubes and on their use to observe infra-red light reflected from objects viewed through a telescope or microscope. Similar reports were given in foreign periodicals also, as well as monographs and textbooks.<sup>5-7</sup> All these reports agree on the

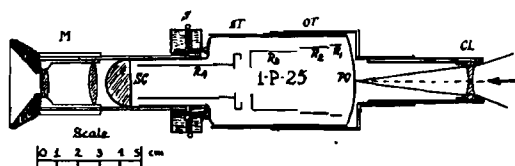


FIG. 1.

\* This paper was presented at the Chicago Meeting of the A.P.S., Dec. 1947.

<sup>1</sup> RCA Data Sheet on 1-P-25, 1944-7 (Restriction removed).

<sup>2</sup> G. A. Morton and L. E. Flory, *RCA Review* 7, 385 (1946).

<sup>3</sup> G. A. Morton and L. E. Flory, *Electronics* 19, 112 (1946).

<sup>4</sup> V. K. Zworykin and G. A. Morton, *J. Opt. Soc. Am.* 26, 181 (1936).

<sup>5</sup> E. Brüche and O. Scherzer, *Geometrische Elektronenoptik* (Verlag, Julius Springer, Berlin, Germany, 1934).

<sup>6</sup> B. Schaffernicht, *Zeits. f. Tech. Physik* 17, 12 (1936).

<sup>7</sup> Grimsehl-Tomaschek, *Lehrbuch der Physik* (B. G. Teubner, Leipzig, Germany, 1938), Vol. II, Part 1, p. 714.

# THE REVIEW OF SCIENTIFIC INSTRUMENTS

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## A Modified Fitch Thermal Conductivity Apparatus

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(Received July 21, 1947)

A thermal conductivity apparatus based upon the increase of temperature of a receiver by heat transferred through the sample is described, and its modification to samples inclined to the horizontal. The temperature changes of the receiver are measured with thermocouples, the reference junction of which is at room temperature.

A DEVICE described by A. L. Fitch<sup>1</sup> determines the thermal conductivity of poor conductors of heat by means of the relationship of the time necessary to change the temperature of a heat receiver when heat passes through a sample placed upon this receiver. The sample itself is exposed to the heat reservoir of a transmitter. The apparatus based upon this principle, which is commercially available (Central Scientific Company, Chicago, Illinois under Catalog No. 77 555), is very satisfactory in its performance when samples are tested in a horizontal position.

However, there are sometimes conditions to be investigated where horizontal positions of the sample are rather special cases. The investigation of thermal conductivities of liquid or gaseous layers, for instance, inclined to the horizontal, requires a modification of the apparatus. Under these conditions it is possible to measure not only the transfer of heat by conduction but also implicitly by convection.

The apparatus described in this paper gave excellent results with respect to thermal conductivities of gaseous and liquid layers under different inclinations of the sample to the hori-

<sup>1</sup> A. L. Fitch, *Am. Phys. T.* **3**, 135 (1935).

zontal.<sup>2</sup> Figure 1 shows a drawing of the modified Fitch thermal conductivity apparatus. It is pictured in an inclined position, indicating that the sample to be tested is a gaseous layer (air) confined between two glass plates, and inclined to the horizontal. Like Fitch's thermal conductivity apparatus it consists of a receiver and a transmitter between which the sample is placed. The transmitter which is filled with boiling water or melting ice, or any other system of phase equilibrium maintaining constant temperature, has a cover similar to an inverted funnel of asymmetrical shape. It is designed to insure proper action of the transmitter in all positions of inclination without spilling its content, or impeding the heat transfer through the bottom of the transmitter. A copper-constantan thermocouple is inserted in the bottom. The receiver consists of a copper block of cylindrical shape of the approximate mass of 300 grams. It is well insulated against heat loss. A copper-constantan thermocouple is placed into the copper block. If a defined pressure is to be applied upon the sample, a spring can be inserted into the lower end of the frame after blocking the

<sup>2</sup> Z. V. Harvalik, *Proc. Minn. Acad. Sci.* **15** (1947), in print.