

Simple Arrangement for Educational Mössbauer-Effect Measurements

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Citation: *Am. J. Phys.* **41**, 127 (1973); doi: 10.1119/1.1987142

View online: <http://dx.doi.org/10.1119/1.1987142>

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buttons require 12- or 24-V, and draw more current than these outputs can provide, it was necessary to derive logic from these outputs and to drive the linear solenoids with a separate power supply. Figure 1 shows the circuit used for each line.

Transistor Q_2 was mounted on the rear of the analyzer and obtained its operating bias current from the analyzer power supply. It acts as an inverter and as a protective buffer to isolate the analyzer from the remainder of the output circuitry. The current in the connecting cable is quite small so that long leads of small gauge can be used. The capacitor serves to filter out any 60-Hz pickup in the cable. Transistors Q_3 and Q_4 form the driving circuit to provide the 0.25 A required for the operation of the solenoids used (Dormeyer Industries Model P10-22). Power at this end is supplied by a 24-V, 0.5 A power supply. Component selection is critical only so far as Q_2 must have a V_{CE} saturation voltage adequate to fully turn off Q_3 and Q_4 , and Q_4 should have V_{CE} low enough at saturation to prevent excessive power dissipation in the transistor while it is on. Diodes D_1 and D_2 are for negative transient protection.

The device was constructed on a piece of $\frac{5}{8}$ -in. Lucite. Solenoids were mounted to drive digits 0-9, the space bar, and card-control buttons. Since the 029 keyboard is curved, provision must be made for differential placement of the solenoids in the Lucite mounting piece above. A milling machine is definitely beneficial in this instance.

The solenoids used have a 40-oz thrust and a 6 mm stroke which is quite adequate to depress the keys. One must allow for the fact that thrust ratings are typically for maximum thrust during the stroke. Starting thrust is often much less than this. It was found, for example, that a solenoid delivering a maximum of 10 oz. during the stroke was unreliable and very sensitive to its location above the keys. The finished device was found to operate reliably at the speed established by the analyzer, although the end-of-line delay was initially increased to allow sufficient time for a new card to feed in.

From a teaching standpoint, this proved to be an excellent project for two students over a one-semester period. The students were impressed with the fact that they could make a significant addition to a device as complex as a multichannel analyzer. The total cost of the project was under \$220.

Simple Arrangement for Educational Mössbauer-Effect Measurements

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(Received 3 July 1972)

The usual, rather complicated and expensive way to obtain Mössbauer spectra needs a momentary correlation between count rate and relative velocity between source and absorber. A very simple way omitting the momentary correlation was described by Bryant.¹ In this method a sinusoidal motion is used which can be realized simply by a loudspeaker drive. The gamma-

detection system is a normal single channel analyzer. The number of counts during equal time intervals is recorded versus the amplitude of the velocity at constant driving frequency. The amplitude of the loudspeaker driving voltage can be used as a measure of the velocity.

Single line spectrum: In general, for a single line with resonance velocity $v_R=0$ the ratio of count rates at v and $v=\infty$ is given by²

$$Z(v)/Z(v=\infty) = 1 - A/(B^2 + v^2) \quad (1)$$

for a thin absorber and a Lorentzian line. A is a constant containing the efficiency and $2B$ is the linewidth.

Using $v = v_0 \sin(\omega t)$ and averaging the count rate over a period of motion one obtains

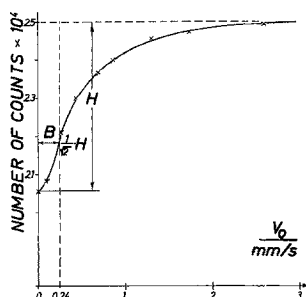


FIG. 1. Result of a measurement. Source: ^{57}Co in stainless steel. Absorber: stainless steel. Source activity is 0.25 mCi. Measurement time per point is 2 min. $\omega = 2\pi \cdot 25$ Hz. The determination of B is indicated.

$$N(v_0) = T^{-1} \int_0^T Z(v) dt$$

$$= N(v_0 = \infty) \left[1 - \frac{A}{B(B^2 + v_0^2)^{1/2}} \right] \quad (2)$$

where $N(v_0 = \infty) = Z(v = \infty)$ and $T =$ duration of a period.

In the experiment the measurement has to be extended over many periods of motion to minimize statistical fluctuations. Figure 1 shows the result of such a measurement, allowing a easy determination of B .

Six-line spectrum: As an example for more complex spectra the six-line pattern in the case of magnetic hyperfine interaction of ^{57}Fe nuclei in iron will be treated. In this case the integral

$$\frac{N(v_0)}{N(v_0 = \infty)}$$

$$= T^{-1} \int_0^T \left(1 - \sum_{i=1}^6 \frac{A_i}{B^2 + (v_{Ri} - v_0 \sin \omega t)^2} \right) dt \quad (3)$$

TABLE I. Resonance velocities and minima of calculated average count rates.

Resonance velocities v_R in mm/s	Result of calculation v_{0R} in mm/s	Shift in mm/s	Relative deviation (%)
0.839	0.93	0.09	10.7
3.084	3.19	0.11	3.2
5.329	5.43	0.10	1.9

has to be evaluated by a computer.

For the calculation the following assumptions have been made³:

$$A_1:A_2:A_3:A_4:A_5:A_6 = 3:2:1:1:2:3,$$

$$B = 0.2 \text{ mm/s},$$

$$|v_{R1}| = |v_{R6}| = 5.329 \text{ mm/s},$$

$$|v_{R2}| = |v_{R5}| = 3.084 \text{ mm/s},$$

$$|v_{R3}| = |v_{R4}| = 0.839 \text{ mm/s},$$

and isomer shift is zero.

The calculation shows that the minima of the averaged numbers of count are shifted relative to the values of the resonance velocities. The results of the calculation are given in Table I. It can be seen, that the absolute shifts are very small. They are negligible for many purposes especially in student demonstration experiments and rough determinations of internal magnetic field values.

In Figs. 2 and 3 the calculated and measured spectra are shown. During the measurements the source was ^{57}Co in stainless steel. For the "single line" stainless steel and for the "six-line pattern" natural iron were used as absorbers.

Absolute velocity calibration: If the loudspeaker is treated as a linear system, velocity and driving voltage are proportional. In this case the desired calibration can be done in two manners provided the oscillation frequency is known:

(1) Measuring the oscillation amplitude $s_0 = v_0/\omega$ at a given voltage.

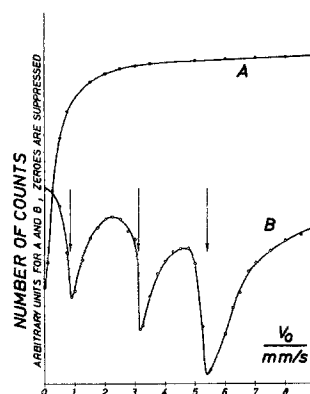


FIG. 2. Results of calculations. A: "single line" Mössbauer spectrum. B: "six-line" Mössbauer spectrum. The arrows indicate the positions of correct resonance velocities.

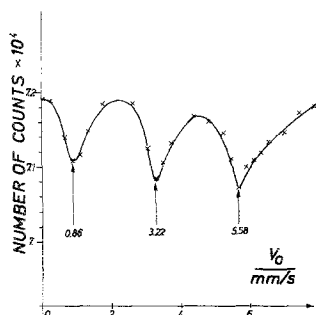


FIG. 3. Result of a measurement. Source: ^{57}Co in stainless steel. Absorber: natural iron. The arrows indicate experimentally determined resonance velocities. Measurement time per point is 5 min.

(2) Measuring the maximal acceleration $b_0 = v_0\omega$ during an oscillation period at a given driving voltage.

In case (1) it is easily possible to set mechanical stops and to measure the interval $2s_0$ by observing the onset of stopping noise with increasing driving voltage. In case (2) a small weight has to be put upon the moving part of the loudspeaker. The direction of motion has to be vertical. With increasing driving voltage the acceleration increases. If the maximal acceleration reaches the value of the gravitational acceleration g noise occurs, showing that the weight is no longer able to follow the motion of the loudspeaker.

Acknowledgments: I would like to express my thanks to Profs. H. Brömer and Ch. Schwink.

¹ H. C. Bryant, *Amer. J. Phys.* **35**, 1159 (1967).

² H. Wegener, *Der Mössbauer-Effekt* (Bibliographisches Institut, Mannheim, 1966), p. 26.

³ A. H. Muir Jr., K. J. Ando and H. M. Coogan, "Mössbauer Effect Data Index 1958-1965" (Wiley-Interscience, New York, 1966), p. 26.

Bragg Diffraction of Microwaves

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(Received 1 August 1972)

An experiment on the Bragg diffraction of 3 cm microwaves has been a part of the St. Olaf advanced laboratory for about 15 years. During this period several improvements have been incorporated into the apparatus, and we describe the current version which is capable of a high degree of precision.

The basic apparatus shown in Fig. 1 resembles that reported by Mareley.¹ Microwaves are generated by a 2K25 klystron and collimated by means of a large pyramidal horn and a converging lens of paraffin. A smaller horn attached to a long arm acts as a receiver. The klystron is switched on and off by applying a square wave of 1000 Hz to the reflector, and the audio signal from the crystal detector is amplified by a standing wave

meter (readily available from dealers in surplus electronics).

For "crystals" we have used the familiar arrays of metal balls inbedded in styrofoam blocks, but find a two-dimensional crystal constructed with vertical rods to be more satisfactory. Since the receiver moves in a single plane, a three-dimensional crystal is not necessary. Sheets of microwave-absorbing material (Goodrich Type H)

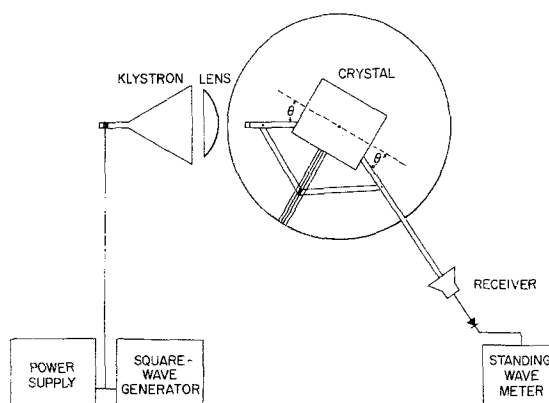


FIG. 1. Apparatus for Bragg diffraction of microwaves.