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tions which appear when the system goes into oscillation, the parallel is evident. Here, as for the familiar oscillator, a threshold condition exists, and once it is satisfied the starting of the new oscillations, and their phases, are dependent on some disturbance, however small.

If, then, it were found possible to describe atomic transitions as the initiations of oscillations of this type in a Newtonian system, the associated disturbances might produce significant effects only at the transitions. Their effect could then be adequately taken into account by assigning probabilities to the transitions and treating the system as non-Newtonian. (This of course leaves open the question as to whether the behavior of the system between transitions can be described in Newtonian terms.)

Recently, however, it has been found desirable to assume the existence of a randomly fluctuating electromagnetic field in free space, of such magnitude as to produce a small but not negligible effect on the behavior of the elementary particles. Such a field would be precisely what was assumed in the previous paragraph, and should provide a mechanism for controlling the apparently random transitions.

We arrive then at the conclusion that the fact that it has been found convenient to describe atomic phenomena in terms of a non-Newtonian system characterized by certain probabilities of transitions does not in itself constitute evidence that the system in its detailed behavior does not conform to Newtonian laws.

#### References

1. HARTLEY, R. V. L. *Bell Sys. tech. J.*, 1936, **15**, 424.
2. HUSSEY, L. W. and WRATHALL, L. R. *Bell Sys. tech. J.*, 1936, **15**, 441.
3. WIENER, NORBERT. *Cybernetics*. New York: John Wiley, 1948.

## An Analysis of Multiple Counter Technique for the Measurement of Radioactive Sources Independent of Geometry

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This discussion is concerned with the mathematics of a system of multiple Geiger-Müller counters for the measurement of radiations from a point source within the area bounded by the counters. Graphs are presented from which an area giving any desired accuracy of measurement can be determined.

Similar multiple counter techniques (*1, 2*) have been used by others over the past several years and offer considerable promise for precise physical, medical, and biological measurement.

A sketch of the apparatus is given in Fig. 1.

For the purpose of analysis the following assumptions are made regarding the geometry, source, and counters.

[1] The authors wish to acknowledge the counsel, during discussions, of Dr. A. K. Solomon, Biophysics Laboratory, Harvard Medical School. They also wish to acknowledge the work of P. J. Edwards, who performed the computations.

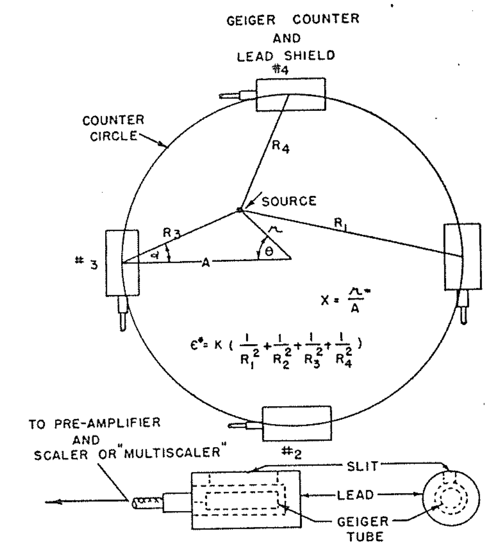


FIG. 1. Sketch of multicounter and lead shield.

1. The radiation is emitted uniformly in all directions about the source. There is no absorption in the medium between the source and counters; or the absorption is uniform in all directions.

2. The efficiency of the counter is proportional to the solid angle subtended at the source by the Geiger counter cathode, and the solid angle is inversely proportional to $R^2$, where $R$ is the distance from the source to the center of the counter cathode.

3. The efficiency of the counter is independent of angle $\alpha$ between the normal to the counter cathode and the line from the source to the center of the cathode.

4. All counters have identical counting characteristics (plateau and efficiency).

5. The source is a point.

6. The region of interest is limited to the plane containing the centers of the four counters.

Under these assumptions the analysis is reduced to eval-

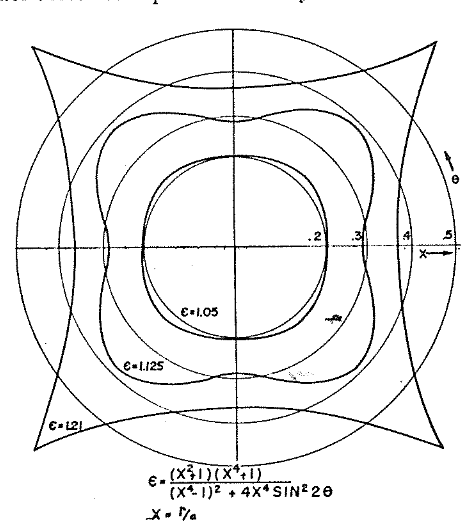


FIG. 2. Efficiency contours: $x$ versus $\theta$ for constant $\varepsilon$ (theoretical).

uating the sum of $1/R^2$ factors over all four counters for a source position within the circle passing through the four counters. This yields the following expression for the counting efficiency $\varepsilon^*$:

$$\varepsilon^* = \frac{K(x^2+1)(x^4+1)}{(x^4-1)^2+4x^4\sin^2(2\theta)} \quad (1)$$

where

$$x = \frac{\mu}{A} = \frac{\text{Distance of source from center of counter circle}}{\text{Radius of counter circle}}$$

and $K$ = a constant of proportionality containing such factors as the solid angle subtended at the center by the counters, and the energies of the gamma radiation emitted by the isotopes being measured. By considering the relative efficiency $\varepsilon$ (compared to the efficiency $\varepsilon_0$ at the center of the counter circle), the constant $K$ can be eliminated and the following expression results:

$$\varepsilon = \frac{\varepsilon^*}{\varepsilon_0} = \frac{(x^2+1)(x^4+1)}{(x^4-1)^2+4x^4\sin^2(2\theta)} \quad (2)$$

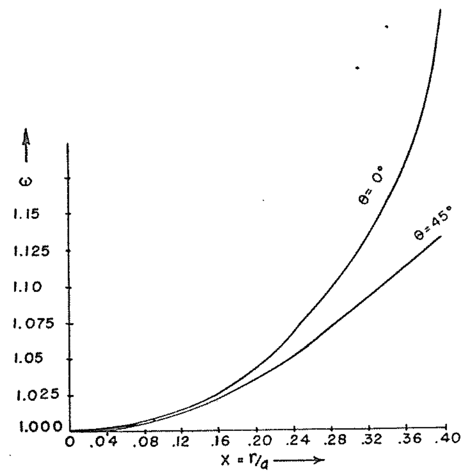


FIG. 3. ε versus $x$ (theoretical); ε and $x$ same as of Figs. 2 and 4.

Solution of equation (2) for $x$ as a function of $\theta$ at constant values of ε yields the curves shown in Fig. 2. For $\varepsilon = 1.05$, i.e., for an efficiency 5% greater than the efficiency at the center of the counter circle, the curve is approximately a circle of radius very nearly one-fifth the radius of the counter circle ($x = 0.2$). Curves for higher efficiency are also given and are seen to lie outside the curve for $\varepsilon = 1.05$. Thus, within this latter curve the efficiency is nowhere greater than 5% higher than the efficiency at the center.

In Fig. 3 are shown curves of ε as a function of $x$ at two values of $\theta$ (0° and 45°). The curve of $\theta = 0°$ (directly at one of the counters) is seen to rise much more rapidly than the curve for $\theta = 45°$ (halfway between two counters).

In Fig. 4 are shown curves of ε as a function of $\theta$ for several values of $x$. These curves quite describe the apparatus as defined or limited by the assumptions made above.

With regard to the variations of ε, it is of value to note that these are all positive and that the variation over a

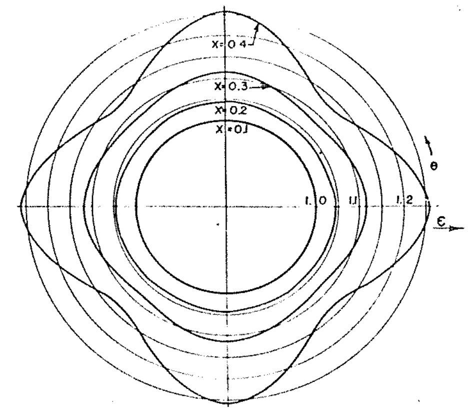


FIG. 4. ε versus $\theta$ (theoretical); ε = relative efficiency compared to efficiency at center.

distributed source is therefore generally less than that indicated by the smallest curve of Fig. 2 or Fig. 4 that fully contains the source.

Also, one should note that assumption 3 listed above is probably not fully justified when accurate measurements are being made. Consideration of the variation of ε with $\alpha$, for the type of counters and shielding used, indicates that considerably smaller variations of ε may be expected than those indicated by the above analysis.

For the accuracy desired (better than 5%) it is also essential to make corrections for the counting losses incurred by the "dead time" of the Geiger counters when the counting rates are greater than a few thousand per minute. Note, however, that these losses are smaller by a factor of 4 at any given counting rate because of the use of four Geiger counters.

An apparatus described by the analysis above was assembled, an da series of measurements were made to de-

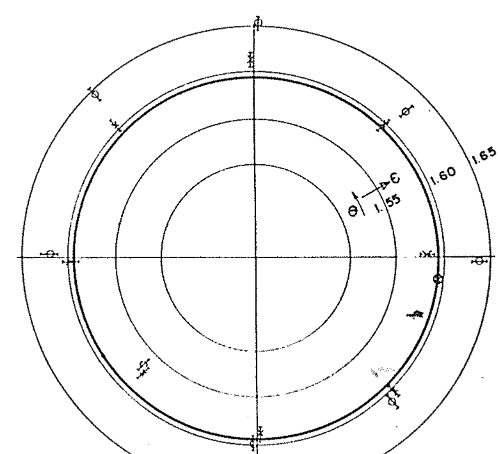


FIG. 5. ε versus $\theta$ (experimental).