than those formed at low temperatures. This is found to be the case, although the basic cellular structure, however indistinct, is always detectable.

It is apparent that this type of construction of the oxide layer can explain the growth of porous films on aluminium. If formation is carried out in an electrolyte capable of dissolving the central column of the cells, growth of the oxide can continue, and a structure such as that found by Keller *et al.*[1] will result.

Anodic oxide films formed on tantalum, niobium and zirconium have not been found to exhibit similar structures, but films formed on zirconium are distinctly non-uniform in thickness.

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[1] Keller, F., Hunter, M. S., and Robinson, D. L., *J. Electrochem. Soc.*, **100**, 411 (1953).

[2] Altenpohl, D., Convention Record of I.R.E. 1954 National Convention, Part 3, p. 35.

Detection of Particles inside Potential Barriers

THERE appears to be some uncertainty regarding the interpretation of wave functions in classically inaccessible regions, where the total energy is less than the potential energy. The following question is asked often: Can one detect a particle inside a barrier without giving it enough energy to be, classically, in the region of localization?

It can be argued quite generally that one cannot. Localization is a transition to a state represented by a wave packet, construction of a packet requires oscillating functions, and oscillating functions imply real momenta and positive kinetic energies[1]. It is the purpose of this communication to present a thought experiment that illustrates this situation.

Consider a step function potential, with $V = 0$ for $x < 0$, and $V = V_0 > E$, the energy of the state, for $x \geqslant 0$. The wave function for $x \geqslant 0$ is then $\exp(-\alpha x)$, where

$$\alpha = \sqrt{2m(V_0 - E)}/\hbar$$

Let us consider localization of a particle by having it scatter a photon inside the barrier. We ask whether such localization is possible without a transfer of energy greater than $V_0 - E$ to the particle. One might think that one can go far into the barrier and use arbitrarily long wave-length, low-energy photons. Such a procedure will be shown to be unsuccessful.

Suppose that $I(x)$ is the intensity of photons travelling along the y direction at x, and that $I(x)$ has a maximum somewhere in the barrier. Let there be a collimating system and detector arranged to observe photons scattered through an angle θ. If a scattered photon is observed, the probability, $P(x)$, of it having been scattered at x is proportional to $I(x)$ times the probability of a particle being at x:

$$P(x) \sim I(x)\,\psi^*(x)\,\psi(x) \sim I(x)\exp(-2\alpha x)$$

If we are to claim detection inside the barrier, $P(x)$ must increase as x increases from zero. Therefore $I(x)$ must increase rapidly enough to overpower the decreasing exponential; $I(x)$ must increase faster than $\exp(+2\alpha x)$ toward its maximum. But then the effective width of the intensity distribution is less than $1/\alpha$. We now require that there be little diffraction of photons through an angle θ into the counter, so that we can conclude that most photons observed are indeed scattered. We have then an upper limit on the photon wave-length:

$$\lambda < \frac{1}{\alpha}\sin\theta$$

and a lower limit on the photon momentum:

$$p > h\alpha/\sin\theta$$

But then the momentum transferred to a particle that scatters one of the photons through an angle θ is no less than $h\alpha$, and the energy transferred is no less than

$$(h\alpha)^2/2m = (2\pi)^2\,(V_0 - E)$$

or more than enough to permit the particle to exist in the region $x \geqslant 0$.

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[1] Bohm, D., "Quantum Theory", 237 (Prentice-Hall, Inc., New York, 1951).

An Unexpected Effect in Sound Localization

WHILE sound localization by human subjects with unobstructed ears has been extensively explored, little is known of the effects of headgear on this function. Evidence from unpublished work on arctic headwear suggests that localization may be affected independently of threshold sensitivity; and following work on the Army 'combat cap' which failed to show any threshold changes due to the cap (Holding, D. H., and Dennis, J. P., unpublished Ministry of Supply Report, 1955), it was decided to investigate the effect of wearing the cap on the localization of pure 1,000 c./s. tones.

The cap is of light wind-resistant cloth, with ear-flaps loosely secured by a chinstrap. Sixteen subjects, eight research workers and eight soldiers, were each required to localize 128 stimuli of 0·5-sec. duration, at a sound-level of 25 db. (above 0·0002 dyne/cm.^{2}) at the subjects' head, with and without the combat cap. The 2,048 sound stimuli were presented in groups of sixteen stimuli in random order. The stimuli originated from four loudspeakers equidistant from the subject, in eight positions relative to the subject, whose seat was rotated 0°, 45°, 180° and 225°, in order to obviate experimental artefacts due to any acoustic irregularities of the speakers or of the fatigue laboratory in which the experiment was conducted. Localization was by forced-choice among the speakers, which were identified by numbers. A record was also kept of response times.

After transformation of the data by $\sin^{-1}\sqrt{x/n}$, analysis of variance of correct and incorrect responses showed a significant ($P < 0·01$) difference between cap and no cap, in favour of wearing the cap. The effect due to the cap interacted with the direction of sound source relative to the subject, the bulk of the improvement lying in the off-front area.

Fig. 1 is a graphical representation of the distribution of correct responses for both cap and no cap