LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

The Ionosphere, Solar Eclipse and Magnetic Storm

The total solar eclipse of June 19, 1936 was visible chiefly in Siberia. The National Bureau of Standards made extensive ionosphere measurements at Washington from June 17 to 20 for comparison with similar measurements made in the eclipse area. These measurements indicated that the ionosphere at Washington was in an abnormal condition from about the time of the beginning of the eclipse, which was at night in Washington, through the entire following day and night. Widely separated magnetic observatories reported a severe magnetic storm beginning at 1245 EST June 18 and ending at 0200 EST June 20. Since the abnormal conditions found in the ionosphere on June 19 resembled those found by us during many other magnetic disturbances it is believed that they were caused mainly by conditions associated with the magnetic storm rather than with the eclipse.

Fig. 1 summarizes the principal results. Ionosphere conditions were normal on June 17 and until 2200 EST on June 18. The $f_{F_2}{}^x$ then decreased sharply to an abnormally low value at 0100 EST June 19, simultaneous with a severe disturbance of Z. Values of $f_{F_2}{}^x$ then oscillated abnormally, with high absorption of F_2 reflections until about 0600 EST. The $f_{F_2}{}^x$ was lower than $f_{F_1}{}^x$ from then until about 1400 EST. The $f_{F_2}{}^x$ then rose slowly until about sunset, decreased again to low values late at night and became normal after sunrise June 20. The $f_{F_2}{}^x$ did not fall at the beginning of the magnetic storm on June 18 but did remain abnormally low during all of June 19. The rise of $f_{F_2}{}^x$ during the late afternoon of June 19 is chiefly a diurnal variation and is found on magnetically disturbed days as well as normal summer days.

The $f_{F_1}{}^0$ was also depressed on June 19 but no abnormal f_E values were observed. The sporadic E was much less in evidence on June 19 than on other days. The latter effect was also noted on field intensity records of W1XK (9570 kc/s, 600 km distant). These emissions were usually propagated by sporadic E for several hours during the early

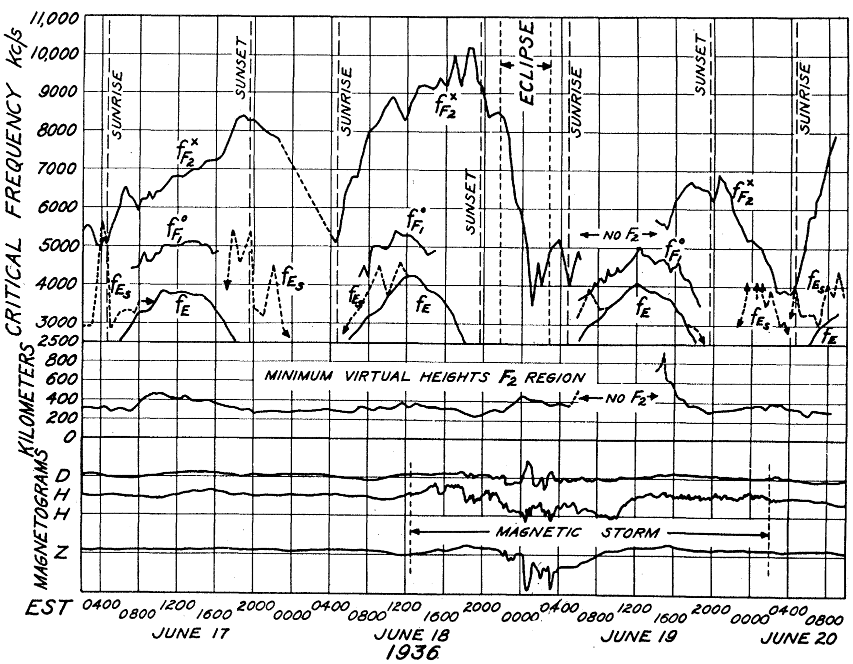

FIG. 1. The upper part of this figure shows the variation of critical frequencies with time. $f_{F_2}{}^x$ =critical frequency F_2 region extraordinary ray. $f_{F_1}{}^0$ =critical frequency F_1 region ordinary ray. f_E =critical frequency E region. f_{Es} =upper frequency limit of sporadic E. The middle part of the figure shows variation of minimum F_2 virtual heights with time. The lower part of figure shows the Cheltenham magnetograms. D, H and Z represent variations of declination, horizontal component and vertical component of the earth's magnetic field.

forenoon but failed on June 19. Weak transmission by scattered reflections also failed. Absorption of E transmission from W8XAL (6060 kc/s, 650 km distant) was greater than normal on June 19. The F_2 virtual heights were very high when $f_{F_2}{}^x$ began to increase above $f_{F_1}{}^x$ from 1400 to 1600 EST June 19.

This example of correlation of the condition of the ionosphere with a magnetic storm corroborates previous evidence obtained by us: (1) Disturbed radio conditions correlate much better with disturbances of the Z than with disturbances of the H component. (2) A severe magnetic disturbance beginning during the daytime may show little correlation with radio data while a severe magnetic disturbance before sunrise is accompanied by disturbed radio conditions during the whole of the following day. (3) The disturbed radio conditions include lowered critical frequencies, increased absorption, and increased virtual heights, indicating a diffusion of the ionosphere. (4) During a magnetic disturbance the higher part of the ionosphere is the most disturbed.

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June 30, 1936.

On the Magnetic Scattering of Neutrons

The direct experimental evidence of the neutron, obtained so far, indicates its mass and the range of forces within which it interacts with other heavy particles. The angular moments of nuclei make it practically sure that it has an angular momentum $\frac{1}{2}h/2\pi$. Furthermore there are good theoretical reasons to believe that it should have a magnetic moment of the same order of magnitude as the measured moment of the proton but having the opposite direction with respect to the angular momentum; these conclusions are partly based on Fermi's theory of the β-decay, partly on the known magnetic moment of the deuteron. Since the Stern-Gerlach method may meet considerable difficulties when applied to neutron beams, we want to propose a different way of obtaining information about the magnetic moment of the neutron which seems considerably simpler and promising in several other respects.

Consider an atom (or molecule) which in its ground state has a total magnetic moment $\boldsymbol{\mu}$ caused by the spin or the orbital motion of the atomic electrons. The magnetic field around and within the atom can in any case be described by an average dipole density distribution $\boldsymbol{\mu}g(\mathbf{r})$ with $\int g(\mathbf{r})d\tau=1$. It will scatter neutrons on account of two reasons:

(1) Because of the interaction of the neutron with the atomic nucleus (or nuclei);
(2) Because of the inhomogeneous magnetic field in its surrounding acting on the magnetic moment of the neutron.

Although the forces on the neutron due to the second cause have to be assumed to be extremely much weaker than those due to the first cause, they act on distances so much larger that the scattering effect of both on slow neutrons becomes of the same order of magnitude. Treating the interaction due to both causes as small disturbances of the plane waves, which represent the incoming and scattered neutron one readily obtains a formula for the magnetic influence on the scattering process.

Let Θ be the angle between the orientation of $\boldsymbol{\mu}$ and the direction of incidence of a neutron with velocity v, $\gamma_n=\mu_n/[(e/Mc)\cdot(h/4\pi)]$ the magnetic moment of the neutron μ_n, measured in units of the Bohr magneton, divided by the ratio of masses M/m of the neutron and electron and $\mathbf{q}=\mathbf{k}_0-\mathbf{k}_1$ the difference between the vectors of propagation of incident and scattered wave, both having equal magnitude $k_0=k_1=2\pi Mv/h$. The cross-section ϕ_ω per unit solid angle for scattering under an angle ϑ against the direction of incidence and an azimuth φ against the common plane of $\boldsymbol{\mu}$ and $\mathbf{k}_0$ is then given by

$$\phi_\omega=\sigma_\omega\left|1\pm\frac{\gamma_n\gamma_e}{2(\sigma_\omega)^{\frac{1}{2}}}\frac{e^2}{mc^2}\left(\sin\theta\cos\frac{\vartheta}{2}\cos\varphi-\cos\theta\sin\frac{\vartheta}{2}\right)^2F(\mathbf{q})\right|^2, \quad (1)$$

where γ_e is the absolute magnitude of the atomic moment μ, measured in units of the Bohr magneton, and

$$F(\mathbf{q})=\int\exp\,(i(\mathbf{q}\cdot\mathbf{r})g(\mathbf{r})d\tau \quad (2)$$

is an atomic form factor, determined by the distribution of magnetism in the atom, which approaches unity for $1/q$ being large compared with atomic dimensions. The plus or minus sign in formula (1) is valid for neutrons with a magnetic moment oriented parallel or antiparallel to $\boldsymbol{\mu}$, respectively.

Formula (1) for the scattering cross section per atom remains practically valid also for the case of a ferromagnetic polycrystalline substance, the only difference being that for the determination of $\mathbf{q}$ only such neutron velocities v are to be used for which the condition of interference at microcrystals with properly chosen orientation can be satisfied. Furthermore one has to consider that γ_e becomes temperature dependent:

$$\gamma_e(T)=\gamma_e(0)\frac{I(T)}{I(0)} \quad (3)$$

[$I(T)$ = Intensity of magnetization at saturation and at absolute temperature T] because of the decreasing average magnetization per atom as the temperature T approaches the Curie point; at saturation the angle θ in (1) is the angle between the magnetizing external field and the direction of incidence of the neutrons. While for fast neutrons the second term in (1) is negligible, it is quite considerable for neutrons with thermal energy, for which the wave-length is comparable with atomic dimensions, since $F(\mathbf{q})$ has then the order of magnitude one. The importance of the magnetic effect is measured by the number $k=(\gamma_n\gamma_e/2(\sigma_\omega)^{\frac{1}{2}}\cdot(e^2/mc^2)$ which, for example for magnetized iron with $\gamma_e\cong 2$, $(\sigma_\omega)^{\frac{1}{2}}$ = radius of the iron nucleus $=5.10^{-13}$ cm and assuming $\gamma_n=1$ becomes $k\cong 0.7$.