Nevertheless, while the weight of experimental evidence strongly suggests that the main part of the magnetic variations is produced below the E-region, it is important to reconcile this conclusion with Cowling and Borger's valuable discussion of the relatively small theoretical conductivity likely to be found there. In this connexion the results of an earlier investigation by Cowling[6] may be important. He showed that the conductivity of an ionized medium can become almost independent of the magnetic field if polarization is set up by the Hall current. In the earth's atmosphere the Hall current is produced by the differential motion of ions and electrons across the earth's magnetic field under the influence of the atmospheric tide. Calculation shows that if polarization adequate to equalize the velocities of ions and electrons is set up, then the effective conductivity of levels below the E-region will be increased by factors of the order 10^2–10^3.

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April 27.

[1] Cowling and Borger, *Nature*, **161**, 515 (1948).
[2] Martyn, *Nature*, **160**, 535 (1947).
[3] Martyn, *Proc. Roy. Soc.* (in the press).
[4] Martyn, *Proc. Roy. Soc.* (in the press).
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WE have recently begun to investigate theoretically how atmospheric tidal motions should vary with height above the E-layer. The work is still in the exploratory stage, and too great reliance cannot be placed on the tentative results which have so far been obtained. These results, however, suggest that tidal motions should increase with height for some considerable way above the E-layer. Considerable phase-changes may also occur above the E-layer. Such results are difficult to incorporate into a general theory of the magnetic variations, and we do not claim to be able to do so: but Dr. Martyn's interpretation of the facts need not be the only possible one.

Dr. Martyn's final suggestion will, unfortunately, not wholly resolve the difficulties to which we directed attention. Polarization counters the magnetic reduction in conductivity fully only if the Hall currents are completely prevented from flowing, and in this case the polarization field must considerably exceed the original field which makes it arise. If, say, the Hall currents in the ionosphere were vertical, the polarization produced by accumulations of charge above and below the conducting layer would be only slowly dissipated, and would be able to build up to a size sufficient to produce the desired effect. But normally the polarization electric field has a horizontal part, which makes the polarization charges leak away as fast as they collect. Hence, while polarization may partially restore the reduction in conductivity due to the magnetic field, it cannot do so more than partially.

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Electromagnetic Level-Shift and Effect of Radiation Field

THE brilliant experiment of Lamb and Retherford[1] has conclusively demonstrated that in the hydrogen atom the $2S$-level is higher than the $2P_{1/2}$-level by about 10 megacycles, a result which reveals a breakdown of the Dirac equation of the electron when applied even to the simplest of the atoms. In a fundamental paper, Bethe[2] has given an explanation of the observed level-shift on the assumption that the transverse self-energy of the electron, in general, depends on the state in which the electron is.

The observed level-shift and Bethe's theory are likely to prove of considerable significance in astrophysics. It is to be observed that the shift in the Balmer lines arising on the above account is comparable to the Einstein solar red-shift. Again, because of the separation between the $2S$- and $2P_{1/2}$-levels the possibility, arising on account of the Stark perturbation, of the (forbidden) transition $2S \rightarrow 1S$, is severely restricted; that is, the $2S$-state would behave as a metastable state, a behaviour which would not have been possible if the levels $2S$ and $2P_{1/2}$ were coincident as demanded by the Dirac equation. The metastable $2S$-state would obviously have an influence on the hydrogen chromosphere. Further, in astrophysical applications, in determining level-shifts, account must be taken of the radiation field surrounding the atom.

It can readily be shown that the transverse self-energy of a free electron is affected by the radiation field, and in the case of temperature equilibrium the increase in the self-energy of the electron is given by

$$\frac{1}{137}\ \frac{\pi}{6}\ \frac{kT}{mc^2}\ kT,$$

where m is the electron rest-mass, k the Boltzmann constant and T the temperature. In the case of atomic levels, the effect of the radiation field becomes complicated (because of the infra-red catastrophe). The details of this investigation will be published elsewhere.

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The Proof of Wien's Law

A VITAL step in the proof of Wien's Law, $E(\lambda,T) = T^5\psi(\lambda T)$, for complete radiation, is the adiabatic change in volume of a cavity filled with radiation. In Wien's first proof (1893)[1] and in the more analytical version of it given by O. W. Richardson[2], the cavity is cylindrical in shape and is provided with a movable piston. In order that the distribution in direction may remain random during the expansion, Wien stipulated that the cavity walls should be "perfectly white" (that is, diffuse rather than specular reflectors).

Larmor (1900)[3] pointed out that the proof is simplified if the shape of the cavity is taken to be spherical; the wave-lengths of all components are then altered in the same proportion. It is not, however, obvious that the distribution in direction is maintained during the expansion if the internal spherical surface is perfectly reflecting. Westphal