(1914)[4] makes the walls of his spherical cavity "white", possibly because of Wien's prescription of white walls for the cylindrical cavity.

Though Larmor's proof has been given in extended form in current texts, it appears not to have been demonstrated that, in the case of a spherical reflecting cavity, the change of angle with the normal which ensues on reflexion at the moving surface is compensated by the change of radius between reflexions. If i, θ are angles of incidence and reflexion respectively as the surface moves slowly outwards with speed dr/dt, $\theta - i = (2 \sin \theta /c)dr/dt$. The angle of incidence i' at the succeeding reflexion satisfies the equation $\sin \theta / \sin i' = 1 + dr/r$, where $dr = (2 r \cos \theta /c)dr/dt$.

Thus $\sin i' - \sin \theta = - (2 \sin \theta \cos \theta /c)dr/dt$, and $i' - \theta = - (2 \sin \theta /c)dr/dt$, giving $i' = i$.

The angle of incidence remains the same at successive reflexions, and we may consider as a distinct group the radiation which is incident at angles between, say, θ and $\theta + d\theta$. If, at some temperature, $u_\theta d\theta$ is the energy density of the group in the immediate neighbourhood of the wall, and u represents the total energy density, it can be shown that $u_\theta = u \sin \theta$, while the pressure due to the group on the wall is $u_\theta \cos^2 \theta \, d\theta$ and the energy of the group in the whole sphere is $U_\theta d\theta = 4\pi r^3 u_\theta \cos^2 \theta \, d\theta$. The energy equation for the group in expansion is then:

$$dU_\theta + 4\pi r^2 u_\theta \cos^2 \theta \, . \, dr = 0,$$

whence

$$r du_\theta + 4 u_\theta \, dr = 0.$$

Comparing this with the equation for the whole radiation

$$r du + 4u \, dr = 0,$$

it is seen that the energy of each group is altered in the same proportion during the expansion, and the distribution in direction is maintained.

Wien (1894)[5] showed that this was true for a group at nearly normal incidence ($\theta = 0$); but the general case appears not to have been discussed. Larmor inserted a material particle in his cavity in order to maintain normal distribution in wave-length; but it is not clear from his argument, which is couched in very general terms, that the calculation of the change of wave-length from the Doppler effect is valid when the particle is present. Planck[6] has shown that for a cavity of any shape, the distribution in wave-length remains normal whether the small material particle is present or not; his demonstration of this, like the proof given by Wien for a cylindrical cavity, is valid only if random distribution in direction is maintained. The spherical reflecting cavity, without a material particle, thus provides a satisfactory proof when supplemented by the demonstration above of the maintenance of random direction and by Planck's proof of the maintenance of the distribution in wave-length.

E. O. Hercus

Department of Physics,
University of Melbourne.

---

[1] *Sitz. kön. preuss. Akad. Wiss.*, 55 (1893).

[2] "The Electron Theory of Matter", 339–342 (Camb. Univ. Press, 1916).

[3] B.A. Report, Bradford, 657 (1900); "Collected Papers", **2**, 217.

[4] *Verh. deut. phys. Ges.*, **16**, 93 (1914).

[5] ***Wied. Ann.***, **52**, 132 (1894).

[6] "Wärmestrahlung", 68 (1906). The argument of pp. 69–70 fails for a perfectly reflecting cylindrical cavity.

Photo-electric Star-following Telescopes

Experiments have recently been conducted by the Telecommunications Research Establishment at the Royal Observatory, Greenwich, to investigate the automatic guiding of an astronomical telescope on a star. The work was done on the 13-in. astrographic refractor and the degree of success achieved was as follows.

In June 1947, using a very sluggish servo system, that is, one with a natural frequency of the order of 1/10 cycle per min., the steady state error in follow was less than 1″ (corresponding to an image movement of 0·001 in.).

The irregular refraction of the atmosphere causes the apparent direction of a star to vary at frequencies up to at least one cycle per second. Accordingly, a system with a more rapid response was built. In January 1948, using a servo system with a natural frequency of the order of ¼ cycle per sec., there was a random steady state error of some few seconds of angle, owing to the larger band-width.

The servo system derives its 'knowledge' of misalignment from an error detection device comprising a graticule in the focal plane of the telescope, and in the form of a disk divided into equal sectors alternately opaque and transparent. The image of the star being followed is made to describe a circle over the face of the disk. Behind the disk is a photo-cell which collects the transmitted light in the form of pulses. When the telescope is aligned on the star, the circle of movement of star image is concentric with the disk and the pulses of transmitted light are of equal duration and separation; but when the circle of image movement is eccentric due to relative movement between star and telescope, the pulses then transmitted are effectively modulated in frequency. The amplitude and phase of this modulation give a linear measure to a first order of the telescope misalignment in magnitude and direction. The misalignment signal controls the acceleration of a servo motor which drives the telescope.

Since the astrographic telescope at Greenwich has a fixed plate-holder, guiding is possible only in right ascension; hence only one rectangular component of the misalignment information is required and used.

Consideration is now being given to the use of this or a similar system to guide automatically the 100-in. Isaac Newton telescope planned for erection at Herstmonceux.

A. Uttley
S. Jones
L. Manns

Telecommunications Research Establishment,
Great Malvern.

April 8.

Presence of Cobalt in the Anti-Pernicious Anæmia Factor

Independent investigation here and in the United States led to the recent isolation of the anti-pernicious anæmia factor as red needle-shaped crystals[1–3]. Examination of its ash has now unexpectedly revealed the presence of cobalt.

In four separate batches of crystals we have detected cobalt by the characteristic cobalt blue borax bead and by the specific red colour reaction with nitroso *R* salt. Colorimetric estimations