Letters to the Editor.

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The Motion of Radiating Masses and the Effect of Radiation Pressure.

THE equation of motion of a body which is losing mass by the emission of radiation is

$$m \frac{dv}{dt} = F, \quad (1)$$

where m is the momentary mass of the body and F the applied force. The simplest justification for this equation is found in the principle of relativity, which requires that v shall be constant when $F=0$.

In NATURE of February 27, p. 300, Sir Joseph Larmor suggests that considerations of inertia would seem to require the equation

$$\frac{d}{dt}(mv) = F, \quad (2)$$

and finds an apparent paradox in the incompatibility of this with my equation (1). The paradox disappears as soon as it is noticed that equation (2) ignores the momentum carried away by the shed mass. In time dt the momentum mv experiences a gain Fdt from the action of the force F , and a loss $-v \frac{dm}{dt} dt$ through the shedding of the mass $-\frac{dm}{dt} dt$. Thus

$$\frac{d}{dt}(mv) = F + v \frac{dm}{dt},$$

which is equivalent to my equation (1).

Either of these quite simple arguments appears to decide the question in favour of my equation (1), and this by a conclusive verdict, not the mere "adequate practical settlement" of Sir Joseph Larmor.

Sir Joseph further suggests that the aberration effect of radiation pressure may be of importance in the dynamics of binary systems. Calculation scarcely supports this view. In the average binary orbit the force exerted by radiation pressure is about 10^{-16} times that exerted by gravitation, and the tangential force is v/C times this, or say 10^{-10} times the force of gravitation. The cumulative effect of this force might become serious as the number of revolutions of the system approached 10^{19} , but binaries do not live long enough for this to happen, and the actual effect must be negligible.

Consequently I adhere to the solution I originally gave (*Monthly Notices*, November 1924 and October 1925) for the orbit of a radiating binary. The orbit is an ellipse, the shape of which undergoes no change but the dimensions of which steadily increase as the mass wastes away, the product of the mass and the diameter of the orbit remaining constant. For example, the sun's wastage of 250 million tons a minute to produce radiation must result in an expansion of the whole solar system; the diameter of the earth's orbit increases by two centimetres per annum, those of the other planets, comets, and meteorites expanding in exact proportion. If higher accuracy than this is called for, dynamical factors arising from tidal friction and elongation of mass seem likely to have more importance than pressure of radiation.

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NO. 2941, VOL. 117]

The Spectra of the Neutral Carbon Monoxide Molecule.

WE can now claim to have a fairly extensive knowledge of the radiation of the ionised carbon monoxide molecule CO^+ . The three associated spectra, namely, Deslandres' first negative bands, the comet-tail bands, and the associated system (*vide Proc. Roy. Soc., A*, vol. 108, p. 349) have been discussed by Prof. R. T. Birge and others, and in particular by Dr. Mulliken in an excellent comparative study with other typical one-valence electron emitters (*Phys. Rev.*, ii. 26, p. 561).

With regard to the spectra of neutral CO, I have recently been investigating some carbon spectra, arranging them in series, and assigning vibrational quantum numbers, and the results of this are presented in the present communication. About the time I had discovered the relationships referred to below, I had a communication from Prof. Birge in which he informed me of the substance of some of his work (published since in NATURE of February 13, p. 229). As my own findings are related to those of Prof. Birge, I am able through his kindness to correlate some of these results with mine; and these, together with a discussion of their significance, are given in this letter.

In a paper entitled "The Effect of Neon on Certain Spectra" to be published shortly in the *Phil. Mag.*, Mr. Cameron has given the wave-lengths of a new band-spectrum associated with carbon, the conditions for the production of which seemed to be peculiarly favourable in high-pressure neon. The spectrum lies between about $\lambda 2100$ and $\lambda 2600$, and falls into three or four groups having about five bands in each. Each band, however, is complex, being composed of five distinct sub-heads, and resembling the complex bands of the third positive carbon system or the fourth positive nitrogen system. I have made a quantum analysis of the above system and give it below (where only the second member of the quintuple heads is recorded for simplicity; *vide Table I.*).

TABLE I.

n'/n''	0	1	2	3	4	5	6	7	8
0	..	Present	44,244	42,160	40,102	..	..	..	..
1	..	..	Present	43,875	41,809	39,770	..	..	..
2	..	..	..	Present	Obsc.	41,457	39,444	..	..
3	..	..	..	..	..	..	41,099	39,113	..
4	..	..	..	..	..	..	..	40,739	38,783

Even under the most favourable conditions the system is not very strong, and Mr. Cameron suggests that his errors of wave-length may perhaps be so much as 0.5 Ångström units. I find that the system can be represented by

$$\nu = K + (1728.2 n' - 14.6 n'^2) - (2151.7 n'' - 12.7 n''^2),$$

where n' and n'' are initial and final quantum numbers, and K has the values 48534.3, 48496.5, 48478.2, 48461.0, and 48431.2.

Prof. Birge has informed me that the fourth positive carbon bands are completely represented by the formula

$$\nu = 64721 + (1499.28 n' - 17.24 n'^2) - (2147.74 n'' - 12.703 n''^2),$$

and that they are the 'resonance' band system of CO as shown by Leifson's absorption work in the extreme ultra-violet.

It is clear, therefore, that within the limits of experimental error Cameron's bands and the fourth positive carbon bands have the same final electronic state, which is the normal state of the carbon monoxide molecule.

Prof. Birge has informed me further that the Ångström bands are represented by

$$\nu = 22162 + (2158 n' - 76 n'^2) - (1499.28 n'' - 17.24 n''^2),$$