Maxwell + Maxwell Math

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*Shown on this page: Maxwell Standard Regular and Italic, Display, Regular Sans Serif and this has to be integrated with respect to ϕ from $\phi = 0$ to $\phi = 2\pi$, which gives

$$2\pi\sigma a^2 \sin\theta \frac{f'(r)}{r} d\theta, \tag{6}$$

which has to be integrated from $\theta = 0$ to $\theta = \pi$.

Differentiating (3) we find

$$rdr = ab \sin\theta d\theta. \tag{7}$$

Substituting the value of $d\theta$ in (6) we obtain

$$2\pi\sigma \frac{a}{b} f'(r) dr, \tag{8}$$

the integral of which is

$$V = 2\pi\sigma \frac{a}{b}\{f(r_1) - f(r_2)\}, \tag{9}$$

where r_1 is the greatest value of r, which is always $a + b$, and r_2 is the least value of r, which is $b - a$ when the given point is outside the shell and $a - b$ when it is within the shell.

If we write α for the whole charge of the shell, and V for its potential at the given point, then for a point outside the shell

$$V = \frac{\alpha}{2ab}\{f(b+a) - f(b-a)\}. \tag{10}$$

For a point on the shell itself

$$V = \frac{\alpha}{2a^2} f(2a), \tag{11}$$

and for a point inside the shell

$$V = \frac{\alpha}{2ab}\{f(a+b) - f(a-b)\}. \tag{12}$$

We have next to determine the potentials of the two concentric spherical shells, the radii of the outer and inner shells being a, and b, and their charges α and β.

Calling the potential of the outer shell A, and that of the inner B, we have by what precedes

$$A = \frac{\alpha}{2a^2} f(2a) + \frac{\beta}{2ab}\{f(a+b) - f(a-b)\}, \tag{13}$$

$$B = \frac{\beta}{2b^2} f(2b) + \frac{\alpha}{2ab}\{f(a+b) - f(a-b)\}. \tag{14}$$

In the first part of the experiment the shells communicate by the short wire and are both raised to the same potential, say V.

By putting $A = B = V$, and solving the equations (13) and (14) for β, we find for the charge of the inner shell

$$\beta = 2Vb \frac{bf(2a) - a[f(a+b) - f(a-b)]}{f(2a)f(2b) - [f(a+b) - f(a-b)]^2}. \tag{15}$$

In the experiment of Cavendish, the hemispheres forming the outer shell were removed to a distance which we may suppose infinite, and discharged. The potential of the inner shell (or globe) would then become

$$B_1 = \frac{\beta}{2b^2} f(2b). \tag{16}$$

In the form of the experiment as repeated at the Cavendish Laboratory the outer shell was left in its place, but connected to earth, so that $A = 0$. In this case we find for the potential of the inner globe in terms of V

$$B_2 = V\left\{1 - \frac{a}{b} f(a+b) - \frac{f(a-b)}{f(2a)}\right\}. \tag{17}$$

74*d*.] Let us now assume, with Cavendish, that the law of the force is some inverse power of the distance, not differing much from the inverse square, and let us put

$$\phi(r) = r^{q-2}; \tag{18}$$

then

$$f(r) = \frac{1}{1-q^2} r^{q+1} \; *. \tag{19}$$

If we suppose q to be small, we may expand this by the exponential theorem in the form

$$f(r) = \frac{1}{1-q^2} r\left\{1 + q\log r + \frac{1}{1.2}(q\log r)^2 + \&c.\right\}; \tag{20}$$

And if we neglect terms involving q^2, equations (16) and (17) become

$$B_1 = \frac{1}{2}\frac{a}{a-b} Vq\left[\log\frac{4a^2}{a^2-b^2} - \frac{a}{b}\log\frac{a+b}{a-b}\right], \tag{21}$$

$$B_2 = \frac{1}{2} Vq\left[\log\frac{4a^2}{a^2-b^2} - \frac{a}{b}\log\frac{a+b}{a-b}\right], \tag{22}$$

from which we may determine q in terms of the results of the experiment.

74*e*.] Laplace gave the first demonstration that no function of the distance except the inverse square satisfies the condition that a uniform shell exerts no force on a particle within it †.

*{Strictly $f(r) - f(0) = \frac{1}{1-q^2} r^{q+1}$ if q^2 be less then unity.}

† *Mec. Cel.*, 1.2.

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