Magnetic Shielding by a Hollow Iron Cylinder. Simplest Case

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XXI. *A New Integrating Apparatus.* By A. SHARP, B.Sc.*

(Abstract.)

THE paper describes an improved form of harmonic analyser, giving the amplitude and epoch of each constituent term, the mechanism of which is an inversion of that described in a communication made to the Society on April 13, 1894 (*ante*, p. 89). Numerous drawings accompany the paper, showing the various parts in detail. The mechanism is also shown to be applicable for integragraphs, and by suitable modification may be employed for mechanically integrating differential equations of various forms.

XXII. *Magnetic Shielding by a Hollow Iron Cylinder. Simplest Case.* By JOHN PERRY, F.R.S.*

I CONSIDER going and return electric conductors each at a distance a from the axis in a diametral plane of the hollow cylinder, the current in each being C .

As to the inducing magnetic potential, all over one half of the cylindric surface of radius a the potential is constant, πC , and all over the other half it is constant, being $-\pi C$. At a point P whose distance from the axis is r , the angle made by the axial plane through P and the plane through the conductors being θ , it is evident that V , the inducing potential, is

$$V = 4C \left(\frac{a}{r} \sin \theta + \frac{1}{3} \frac{a^3}{r^3} \sin 3\theta + \frac{1}{5} \frac{a^5}{r^5} \sin 5\theta + \&c. \right),$$

as this becomes $+\pi C$ or $-\pi C$ where $r=a$, and also satisfies $\nabla^2 V = 0$.

Let the coefficient of $\sin n\theta$ in V be denoted by $A_n r^{-n}$; let the corresponding coefficients be $A_1 r^n + A_2 r^{-n}$ for the total (induced plus inducing) potential inside the tube; $A_2 r^n + B_2 r^{-n}$ total in the iron and $B_3 r^{-n}$ in outside space. Let the inside

* Read June 22, 1894.

and outside radii of the iron cylinder be a_1 and a_2 . Then, on stating the equality of the potentials just inside and just outside the two surfaces, and also that the normal induction is the same on both sides, we have four equations, which enable the coefficients A_1 , A_2 , B_2 , and B_3 to be calculated. The two important ones are

$$B_3 = 4\mu A / \{(\mu + 1)^2 - e(\mu - 1)^2\},$$

where e stands for a_1^{2n}/a_2^{2n} ,

and
$$A_1 = -A\rho(1 - e)/a_1^{2n}(\rho^2 - e),$$

where $\rho = (\mu + 1)(\mu - 1)$.

If we take $a_2 = a_1 + t$, and t is small, since μ is large in iron, we have approximately

$$B_3 = A \left/ \left(1 + \frac{1}{2}\mu n \frac{t}{a_1} \right) \right.$$

The higher terms are unimportant. Taking the first: the unshielded potential was $4Car^{-1} \sin \theta$, and it is converted by shielding into $4Ca \sin \theta / r \{ 1 + \frac{1}{2}\mu t / a_1 \}$.

Thus, taking $\mu = 1200$, $a_1 = 150$ cm., $t = 5$ cm., the first and most important term is reduced to the 1/21st part of its unshielded value. The other terms are reduced to 1/61st, 1/101st, 1/141st, &c., parts of their unshielded values.

In this case the potential inside is very little less than when there was no iron, A_1 being $-A/a_1^{2n}$ for all values of t until t is small; of course A_1 is 0 when t is 0.

It is easy to extend the reasoning to several enveloping cylinders of iron, or to the case of any distribution of inducing potential which does not vary in a direction parallel to the axis.