Università di Ferrara — Dipartimento di Fisica
Prova Scritta Finale di Elettricità e Magnetismo
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I. In un generatore elettrostatico di Van de Graaff la cinghia isolante per il trasporto delle cariche è larga 30 cm, ha spessore trascurabile e si muove ad una velocità di 20 m/s. Sapendo che la carica superficiale depositata sulla cinghia è uniforme e genera, su ciascun lato di essa, un campo elettrico pari a 1.2×10^6 V/m, calcolare la corrente nel generatore in milliampere.

II. Si consideri un fascio di elettroni (massa $m_e = 9.1 \times 10^{-31}$ kg, carica $e = 1.6 \times 10^{-19}$ C) di impulso p che descrive un'orbita circolare di raggio R nel piano perpendicolare ad un campo magnetico $\mathbf{B}$ uniforme e costante. (a) Esprimere il legame tra le grandezze B, R e p (anche senza dimostrazione).

Nel betatrone, o acceleratore ad induzione, si accelerano gli elettroni facendo variare il campo magnetico. (b) Spiegare brevemente il funzionamento del betatrone; in particolare, fissando le idee su un campo variabile sinusoidalmente, dire perché è utilizzabile soltanto un quarto di ciclo.

Per mantenere gli elettroni su un'orbita di raggio costante durante l'accelerazione è necessario che il campo magnetico sia variabile nel tempo e anche non uniforme. (c) Dedurre che il flusso ϕ del campo attraverso il cerchio definito dall'orbita deve essere il doppio di quello che si avrebbe se il campo fosse uniforme. In altre parole, dimostrare che $\phi = 2 \cdot \pi R^2 \cdot B$, dove B è il modulo del campo sull'orbita. Suggerimento: calcolare la derivata rispetto al tempo dell'impulso $\dot{p}$, utilizzando la seconda legge della dinamica.

Può essere utile consultare il primo articolo di D. W. Kerst sull'acceleratore ad induzione [D. W. Kerst, Phys. Rev. **58**, 841, (1940)], riportato di seguito.

LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Acceleration of Electrons by Magnetic Induction

For some time it has been realized that it might be possible to make use of the electromotive force induced by a changing magnetic flux to accelerate charged particles traveling in an orbit around the changing flux. Although previous attempts to accelerate electrons by this means have been unsuccessful,[1,2] careful examination showed that it should be possible to get good magnetic focusing by the proper arrangement of a magnetic field to guide the electrons around the changing flux and that if the rate of change of flux within the orbit were sufficiently high it would be possible to capture electrons in usable orbits and that vacuum requirements should not be difficult to satisfy.

It seemed feasible to attempt the experiment with a 600-cycle per second magnetic field, since a sufficiently high rate of change of flux would be obtained and since it seemed that it would not be necessary to have a vacuum better than 10^{-6} millimeter of mercury in the acceleration chamber, in spite of the fact that at this frequency the length of the electron path would be of the order of 10^7 centimeters.

To hold the electrons in the acceleration chamber for such a long path it is necessary to fulfill the condition that $\phi=2\pi R_0^2H$, where ϕ is the flux enclosed by the orbit and H is the magnetic field at the orbit which causes the electrons to travel in a circle of radius R_0. When this condition is satisfied, the electron orbit neither shrinks nor expands, and the electrons can be accelerated by increasing ϕ and H together.

A laminated electromagnet with pole faces 8 inches in diameter, which satisfied all the necessary conditions, was constructed. The stable orbit was shrunk from R_0 toward the position of a tungsten target by causing saturation of the portion of the magnetic circuit which supplied the flux through the center of the orbit. X-rays produced by the impact of the electrons upon the target showed that the accelerator operated, and a lead collimator in front of a Geiger-Müller counter showed that the only portion of the acceleration chamber from which x-rays came was the target.

By taking the sweep voltage for an oscillograph from a coil surrounding the core of the magnet and putting the pulses from the Geiger-Müller counter circuit on the vertical deflection plates, the phase of the magnetic field at which the electrons struck the target could be determined. It was possible to hold the electrons in the acceleration chamber for one-fourth of a cycle during which the magnetic field changed from a low value to its maximum. Conservative estimates of the magnetic field at the target when the electrons strike it indicated that the energy of the electrons was about 2.2 Mev. This estimate was substantiated by a comparison of the absorption of the x-rays in lead with published data on the absorption of x-rays produced by 2-million-volt electrons.[3] After filtering the x-rays from the accelerator through about 1.8 cm of lead, their absorption coefficient is 0.57 cm^{-1}. A correction had to be made for scattering of x-rays from the magnet yoke. Since the absorption coefficient for x-rays produced by 2.0-Mev electrons is 0.62 cm^{-1}, the electrons in the new accelerator must have reached about 2.35-Mev energy before striking the target. The absorption measurements were taken with Lauritsen electroscopes, and calibration of the electroscopes showed that the intensity of the radiation was greater than the intensity of the gamma-rays from 10 millicuries of radium.

Of several suggestions which have been made for naming the apparatus, induction accelerator seems to be the shortest descriptive one.

It has been a great help to be able to discuss the theoretical aspects of the accelerator with Professor R. Serber and Professor H. M. Mott-Smith.

D. W. KERST

University of Illinois,
Urbana, Illinois,
October 15, 1940.

[1] Wideröe, Archiv f. Elektrotechnik **21**, 400 (1938).
[2] E. T. S. Walton, Proc. Camb. Phil. Soc. **25**, 469 (1929).
[3] D. L. Northrup and L. C. Van Atta, Am. J. Roentgenology and Radium Therapy **41**, 633 (1939).

Effect of an Eclipse on Cosmic Rays

A cable message received from Professor G. Wataghin of the University of Sao Paulo states that Messrs. Monteux, Occhialini and Santos have established the existence of an effect of an eclipse on cosmic rays. He adds that observation of the penetrating rays made by Santos and himself underground showed that their behavior was different from that of the total radiation.

We shall await with interest further details with regard to the nature and magnitude of this observed effect, which has heretofore been sought without success.

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Ryerson Physical Laboratory,
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October 4, 1940.