AUTHOR: Khizhnyak, N. A. SOV/57-28-7-32/35

TITLE: The Kernel of Maxwell Equations for Heterogenous Media
(Funktsiya Grina uravneniy Maksvella dlya neodnorodnykh sred)

PERIODICAL: Zhurnal tekhnicheskoy fiziki, 1958, Vol. 28, Nr 7, pp.
1592 - 1609 (USSR)

ABSTRACT:

According to the method of the Kernel the macroscopic Maxwell equations for limited bodies are deduced in integral form and several problems to be solved with these equations are investigated (homogenous figures, diffraction of electromagnetic waves at small bodies a. o.). The integral equations describing the electro-magnetic field at all space points are deduced (in the presence of finite or infinite dielectrics with random tensors of the dielectric and magnetic permeability). The physical importance of the integral summands for the points within and outside the electric field is investigated. Analogous equations for the two-dimensional case are deduced. It is shown that the anisotropic dielectric ellipsoid and the anisotropic elliptic cylinder are the only convex bodies the internal field of which is homogenous in the external

Card 1/2

The Kernel of Maxwell Equations for Heterogenous Media SOV/57-28-7-32/35

homogenous field. The electrostatic field which excites an homogenous field in an anisotropic dielectric prism is found. The problems of the scattering of electromagnetic waves on small anisotropic dielectric bodies and thin anisotropic dielectric rods is investigated. The scattering of electromagnetic waves at a small anisotropic ellipsoid and at a thin anisotropic elliptic cylinder is described as example. D. V. Volkov advised the author. A. I. Akhiyezer, I. M. Lifshits, Ya. B. Faynberg and A. G. Sitenko discussed the paper with the author. There are 13 references, 7 of which are Soviet.

ASSOCIATION: Fiziko-tekhnicheskiy institut AN USSR, Khar'kov (Physico-technical Institute, AS Ukrainian SSR, Khar'kov)

SUBMITTED: July 1, 1957

1. Electromagnetic waves--Mathematical analysis

Card 2/2

S/058/60/000/004/010/016
A003/A001

Translation from: Referativnyy zhurnal, Fizika, 1960, No. 4, p. 254, # 9374

AUTHORS: Khizhnyak, N.A., Shestopalov, V.P.

TITLE: The Peculiarities of Vavilov-Cherenkov's Effect in Anisotropic Waveguides

PERIODICAL: Uch. zap. Khar'kovsk. un-t, 1959, Vol. 102, Tr. Radiofiz fak., Vol. 3, pp. 69-74

TEXT: Energy losses are considered of a particle uniformly moving along the axis of a rectangular waveguide filled with a homogeneous and anisotropic dielectric with a diagonal tensor of dielectric constant. Expressions for the radiation field were obtained, and it was shown that in distinction from the case of a particle moving in an unbounded medium, the fields of common and uncommon waves are interconnected through boundary conditions and form an oscillation system similar to sympathetic pendula. It was shown that due to the coherence of the common and uncommon waves beats are originated. Changing the parameters of the waveguide, beats can be obtained pertaining to any region of the submillimeter

Card 1/2

S/058/60/000/004/010/016
A003/A001

The Peculiarities of Vavilov-Cherenkov's Effect in Anisotropic Waveguides

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waves (assuming that the principal oscillations are in the visual region). The authors show that, if it would be possible to detect the beats, the radiation discussed could be used for generating submillimeter oscillations.

N. A. Khizhnyak

Translator's note: This is the full translation of the original Russian abstract.

Card 2/2

S/058/60/000/004/011/016
A003/A001

Translation from: Referativnyy zhurnal. Fizika, 1960, No. 4, p. 254, # 9378

AUTHOR: Khizhnyak, N.A.

TITLE: Parametric Excitation of Oscillations in Electronic Beams

PERIODICAL: Uch. zap. Khar'kovsk. un-t, 1959, Vol. 102, Tr. Radiofiz. fak., No. 3, pp. 75-79

TEXT: The possibility is discussed of transmitting the kinetic energy of uniformly moving electrons to high-frequency electromagnetic oscillations by means of Cherenkov's parametric effect (RZhFiz, 1958, No. 3, # 6495). As an example, the instability is considered of an electronic beam uniformly moving along a cylindrical waveguide filled with dielectric disks of a homogeneous and isotropic dielectric. The real part of the propagation constant is calculated in a linear approximation, which determines the coefficient of wave amplification. It was shown that the distinguishing feature of the parametric amplification of oscillations is the following fact: The amplification coefficient depends on the number of the working harmonic and does not depend on the density of the beam. The range of the parameters of the system, at which an amplification is possible,

Card 1/2

S/058/60/000/004/011/016
A003/A001

Parametric Excitation of Oscillations in Electronic Beams

depends essentially on the density and does not depend on the velocity of the electrons. It is assumed that parametric generators and amplifiers will be applied in super-high-frequency engineering.

N.A. Khizhnyak

Translator's note: This is the full translation of the original Russian abstract.

Card 2/2

FAYNBERG, Ya.B.; KHIZHNYAK, N.A. [Khyzhniak, M.A.]; Silenok, G.A.
[Sylenok, Ho.O.]; BEREZIN, A.K.; NEKRASHEVICH, A.M.
[Nekrashevych, O.M.]

Spiral wave guide with an artificially anistropic dielectric.
Part 1. Ukr.fiz.zhur. 4 no.4:451 Jl-Ag '59. (MIRA 13:4)

1. Khar'kovskiy gosudarstvennyy universitet im.Gor'kogo.
(Wave guides) (Dielectrics)

BEREZIN, A.K.; NEKRASHEVICH, A.M. [Nekrashevych, O.M.]; SILENOK, G.A.
[Sylenok, H.O.]; FAYNBERG, Ya.B.; KHIZHNYAK, N.A. [Khyzhniak, M.A.]

Spiral wave guide with an artificially anisotropic dielectric.
Part 2. Ukr.fiz.zhur. 4 no.4:460-464 Jl-Ag '59. (MIRA 13:4)

1. Khar'kovskiy gosudarstvennyy universitet im. Gor'kogo.
(Wave guides) (Dielectrics)

SINEL'NIKOV, K.D.; KHIZHNYAK, N.A.; SAFRONOV, B.G.

[Motion of a flexible current-carrying coil in a non-uniform magnetic field] O dvizhenii gibkogo tokovogo vitka v neodnorodnom magnitnom pole. Khar'kov, Fiziko-tekhn. in-t AN USSR, 1960. 145-157 p. (MIRA 17:2)

9.1300,9.2520,9.2572,9.4230

77955
SOV/109-5-3-9/26

AUTHOR: Khizhnyak, N. A.

TITLE: Theory of Waveguides Filled With Dielectric Disks

PERIODICAL: Radiotekhnika i elektronika, 1960, Vol 5, Nr 3, pp 413-421 (USSR)

ABSTRACT: With the increasing importance of waveguides filled with dielectric disks as delay systems in traveling wave accelerators, powerful amplifiers and oscillators of SHF, there is a need for an exact theory of such waveguides, taking the thickness of disks and apertures in disks into consideration. This paper presents the results of work done by the author in this field during the period 1953-1957; reference is made also to his thesis (Library of the Physics-Technical Institute AS UkrSSR, 1957). (1) Waveguide Properties When Filled With Dielectric Disks of Finite Thickness Without Central Orifice. Such a waveguide is equivalent to one filled with an anisotropic dielectric. The equivalency

Card 1/15

is valid when inequality:

$$(a+b) \ll \lambda_g, \qquad (1)$$

is fulfilled, where $\lambda_g = \beta\lambda$ is wavelength in the waveguide; $\beta = v_{ph}/c$; $v_{ph}$ is phase velocity of wave; b, thickness of dielectric disks; a, distance between disks. If condition (1) is not fulfilled, the dispersion equation of a cylindrical waveguide with massive dielectric disks has the aspect of:

$$\cos k_3 L = \cos p_1 a \cos p_2 b - \frac{p_1^2 \varepsilon^2 + p_2^2}{2 p_1 p_2 \varepsilon} \sin p_1 a \sin p_2 b, \qquad (2)$$

where $k_3 = \omega / v_\phi = 2\pi / \lambda_g$; $L = a + b$; $p_1^2 = k^2 - (\sigma_0^1 / R)^2$; $p_2^2 = k^2 \varepsilon - (\sigma_0^1 / R)^2$; $k = 2\pi / \lambda$;

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

$\varepsilon$ is dielectric constant of the disks; R, waveguide radius; $\sigma_o^1$, first root of Bessel's function of zero order $J_o(\sigma_o^1) = 0$. Electric and magnetic field components of axially symmetric E-mode wave are:

$$E_z = D_0 J_0(k_1 r) \frac{W(z)}{\varepsilon(z)}, \qquad (3)$$

$$E_r = -D_0 \frac{1}{k_1} J_1(k_1 r) \frac{1}{\varepsilon(z)} \frac{dW(z)}{dz}, \qquad (4)$$

$$H_\varphi = -D_0 \frac{ik}{k_1} J_1(k_1 r) W(z), \qquad (5)$$

where $k_1 = \sigma_o^1/R$; $\varepsilon(z) = 1$ outside, and $\varepsilon(z) = \varepsilon$ inside the disks; $k_3 L = \psi$ and

$$W(z) = u_1(z) - \frac{u_1(L) - e^{-i\psi}}{u_2(L)} u_2(z). \qquad (6)$$

Card 3/15

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

Functions $u_1$ (z) and $u_2$ (z) are:

$$u_1(z) = \cos p_1 z \qquad \text{for } 0 \leqslant z \leqslant a,$$

$$u_1(z) = \cos p_1 a \cos p_2 (z-a) - \frac{\varepsilon_2 p_1}{\varepsilon_1 p_2} \sin p_1 a \sin p_2 (z-a) \qquad \text{for } a \leqslant z \leqslant L,$$

$$(7)$$

$$u_2(z) = \frac{\varepsilon_1}{p_1} \sin p_1 z \qquad \text{for } 0 \leqslant z \leqslant a,$$

$$u_2(z) = \frac{\varepsilon_1}{p_1} \sin p_1 a \cos p_2 (z-a) + \frac{\varepsilon_2}{p_2} \cos p_1 a \sin p_2 (z-a) \qquad \text{for } a \leqslant z \leqslant L.$$

The initial conditions to be satisfied are:

$$u_1(0) = 1, \quad \frac{1}{\varepsilon} \frac{du_1(0)}{dz} = 0, \quad u_2(0) = 0, \quad \frac{1}{\varepsilon} \frac{du_2(0)}{dz} = 1,$$

Card 4/15

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

$$S_1^{(n)} = \frac{1}{p_1^2 - \beta_n^2}\left\{e^{i\beta_n a}\left(i\beta_n W(a) - \frac{dW(a)}{dz}\right) - \left(i\beta_n W(0) - \frac{dW(0)}{dz}\right)\right\};$$

$$S_2^{(n)} = \frac{1}{p_2^2 - \beta_n^2}\left\{e^{i\psi}\left(i\beta_n W(L) - \frac{1}{\varepsilon}\frac{dW(L)}{dz}\right) - e^{-i\beta_n a}\left(i\beta_n W(a) - \frac{1}{\varepsilon}\frac{dW(a)}{dz}\right)\right\}.$$

The equation for high-frequency power is further derived as:

$$S = \frac{c}{8} D_0^2 \frac{kk_3 R^2}{k_1^2} J_1^2(\sigma_0^1) \frac{\sin k_3 L}{k_3 L} \frac{L}{u_z(L)}, \quad k_3 \equiv \beta_0.$$

The power flux is expressed by the electrical induction amplitude $D_0$ which is tied to the effective potential of the electric field along the wave guide axis $E_0$ by

Card 6/15

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

the relations:

$$E_0 = \frac{D_0}{L}\Phi, \quad \Phi = S_1^{(0)} + \frac{1}{\varepsilon} S_2^{(0)}.$$

Thus, the power flux is expressed through the amplitude of accelerating field $E_0$ by the equation:

$$S = \frac{c}{8} E_0^2 \frac{k k_3 b^2}{k_1^2} J_1^2(\nu_0) \frac{\sin k_3 L}{k_3 L} \frac{L}{u_2(L)} \left(\frac{L}{D}\right)^2. \quad (11)$$

Or, in the general case when condition (1) is not fulfilled, and a waveguide filled with dielectric disks is no longer equivalent to a waveguide filled with an anisotropic dielectric, the power flux is:

Card 7/15

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

$$S = \frac{c}{8}\frac{kk_3R^2}{k_1^2}E_0^2\frac{\epsilon_z^2}{\epsilon_r}J_1^2(\sigma_0^1)\frac{\sin k_3L}{k_3L}, \tag{12}$$

where $\epsilon_z = L/\Phi$ and $\epsilon_r = u_2(L)/L$ are some complex functions of frequency and waveguide parameters, which can be tentatively called effective permeability of a laminar medium. If the waveguide is used as delay system of a powerful backward wave tube, rather than for a linear accelerator, the power flux must be expressed by amplitude of the first harmonic. Then quantity $\epsilon_z$ in (12) changes. (2) Waveguide Properties When Internal Dielectric Disks Are Thick and Have a Central Orifice. Assuming a waveguide with diameter R filled with dielectric disks of thickness b and having an orifice radius $r_o$ and spaced at distances a, then in the first area $0 \leqslant r \leqslant r_o$ the axially symmetric electromagnetic field of E-mode is a superposition of an

Card 8/15

infinite number of harmonics:

$$E_z = \sum_{n=-\infty}^{\infty} a_n J_0(\chi_n r)\, e^{-i\beta_n z}, \qquad (13)$$

$$E_r = \sum_{n=-\infty}^{\infty} a_n \frac{i\beta_n}{\chi_n} J_1(\chi_n r)\, e^{-i\beta_n z}, \qquad (14)$$

$$H_\varphi = \sum_{n=-\infty}^{\infty} a_n \frac{ik}{\chi_n} J_1(\chi_n r)\, e^{-i\beta_n z}, \qquad (15)$$

where $\chi_n^2 = k^2 - \beta_n^2$, but $\beta_n$ are connected with the basic harmonic propagation constant by Flocke's relation:

$$\beta_n = \beta_0 + \frac{2\pi n}{L}. \qquad (16)$$

Card 9/15

The electromagnetic field in the second area $r_o \leqslant r \leqslant R$ is:

$$E_z = \sum_{m=-\infty}^{\infty} C_m Z_0 (\Gamma_m r) \frac{W_m(z)}{\varepsilon(z)}, \tag{17}$$

$$E_r = -\sum_{m=-\infty}^{\infty} C_m \frac{1}{\Gamma_m} Z_1 (\Gamma_m r) \frac{1}{\varepsilon(z)} \frac{dW_m(z)}{dz}, \tag{18}$$

$$H_\varphi = \sum_{m=-\infty}^{\infty} C_m \frac{ik}{\Gamma_m} Z_1 (\Gamma_m r) W_m(z), \tag{19}$$

where $\Gamma_m$ are roots of Eq. (2) for $k_3 = \beta_o$; function $W_m(z)$ is determined by (6) for $k_1 = \Gamma_m$;

$$Z_0(\Gamma_m r) = J_0(\Gamma_m r) N_0(\Gamma_m R) - J_0(\Gamma_m R) N_0(\Gamma_m r),$$
$$Z_1(\Gamma_m r) = J_1(\Gamma_m r) N_0(\Gamma_m R) - J_0(\Gamma_m R) N_1(\Gamma_m r).$$

Using the series (9) and (10) the field components $E_z^{II}$ and $H_{\varphi}^{II}$ are expressed as series and the amplitude equation derived as shown:

$$E_z = \sum_{n=-\infty}^{\infty} e^{-i\beta_n z} \sum_{m=-\infty}^{\infty} C_m A_{mn} Z_0(\Gamma_m r_0),$$

$$H_\varphi = ik \sum_{n=-\infty}^{\infty} e^{-i\beta_n z} \sum_{m=-\infty}^{\infty} C_m A'_{mn} \frac{1}{\Gamma_m} Z_1(\Gamma_m r_0). \qquad (20)$$

$$\sum_{m=-\infty}^{\infty} C_m A_{mn} Z_0(\Gamma_m r_0) \left[ \frac{J_1(\chi_n r_0)}{\chi_n r_0 J_0(\chi_n r_0)} - \frac{Z_1(\Gamma_m r_0)}{\Gamma_m r_0 Z_0(\Gamma_m r_0)} \frac{A'_{mn}}{A_{mn}} \right] = 0.$$

Here, n moves through all values from $-\infty$ to $+\infty$. The condition of resolving this equation is:

$$\left| \frac{J_1(\chi_n r_0)}{\chi_n r_0 J_0(\chi_n r_0)} - \frac{Z_1(\Gamma_m r_0)}{\Gamma_m r_0 Z_0(\Gamma_m r_0)} \frac{A'_{mn}}{A_{mn}} \right| = 0, \qquad (21)$$

Theory of Waveguides Filled With Dielectric Disks 77955
SOV/109-5-3-9/26

Equation (21) is the sought-for dispersion equation of the problem. For practical purposes only a few lines and columns of this equation, e.g., n = -1,0,+1 and m = -1,0, +1 are needed. In the present work the expansion of fields is done in terms of eigenfunctions of an inhomogeneous cylindrical waveguide; therefore, the convergence of the dispersion equation is the better, the smaller the orifice radius of the disks (for waveguides with metallic disks--the greater the orifice radius). If sufficiently small, i.e., when $2r_0 \lessgtr b$, the expressions for first area fields can be approximated as:

$$\begin{aligned} E_z &= D_0 \frac{w(z)}{\varepsilon(z)}, \\ E_r &= -i \frac{D_0}{2} r \frac{dw(z)}{dz}, \\ H_\varphi &= \frac{ikr}{2} D_0 w(z). \end{aligned} \qquad (22)$$

Card 12/15

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

At a given flux of h-f power from the oscillator, the power flux of each harmonic is determined by the structural periodicity of the waveguide. The amplitude of the accelerating field is determined by the power flux of the zero harmonic. It may happen that the latter will considerably exceed the oscillator flux (as power fluxes of harmonics are added algebraically) and negative harmonics are added rather than subtracted from the positive ones. This explains the high efficiency of disk-filled waveguides as compared to homogeneous with isotropic dielectric. (3) Parameters of Waveguide Filled With Dielectric Disks and Operating on a Traveling $\frac{\pi}{2}$ -Wave. Selecting an oscillator wave of 10 cm, assuming the dielectric permeability of disks to be $\varepsilon = 50$ and 80, and taking into consideration that $k_g L = \frac{\pi}{2}$, $a + b = \frac{\beta\lambda}{4}$, basic waveguide parameters are calculated and compiled in a table. From the results it appears that, using disks with dielectric constants of the order of 100, it is possible to achieve a delay system effective in phase velocity areas $\beta = 0.15-0.5$,

Card 13/15

i.e., where helical waveguides are no longer effective, and metal-disc-filled waveguides are not yet effective. For phase velocities 0.5-1.0 dielectric disk-filled waveguides are more effective than those with metal disks. By using dielectrics with $\varepsilon$ of the order of 1,000, effective wave delay up to phase velocities of the order of 0.07 is achieved. Further increase of permeability is useless, as it causes no further decrease in phase velocity. However, the flux of h-f power continues to decrease; therefore the use of dielectrics with $\varepsilon$ higher than 1,000 may be advantageous for power considerations. The above indicates that waveguides filled with dielectric disks could also be used for traveling wave linear proton accelerators, the problem of radial focussing being solved by their radial and phase stability. The help of A. I. Akhiezer and Ya. B. Faynberg is acknowledged. There is 1 table; and 7 references, 2 Soviet, 5 U.K. The U.K. references are: R. B. R. Shersby-Harvis, Nature, 1948, 162, 890; same et al., A.E.R.E. Report, Harwell, 1953; G. B. Walker,

Theory of Waveguides Filled With Dielectric Disks

77955
SOV/109-5-3-9/26

E. L. Lewis, Nature, 1958, 181, 38; W. Walkinshaw, Proc. Phys. Soc. 1948, 61, 246; R. B. R. Shersby-Harvis et al., Proc. I.E.E., 1957, 104B, 273.

ASSOCIATION: Physico-Technical Institute, AS UkrSSR (Fiziko-tekhnicheskiy institut, AN USSR).

SUBMITTED: May 4, 1959

Card 15/15

FAYNBERG, Ya.B.; KHIZHNYAK, N.A.

[Discharge density waves in modulated electron beams]
Volny plotnosti zariada v modulirovannykh puchkakh.
Khar'kov, Fiziko-tekhn. in-t AN USSR, 1960. 425-448 p.
(MIRA 17:1)
(Electromagnetic waves) (Electron beams)

69901

S/109/60/005/04/015/028
E140/E435

9.1300

**AUTHOR:** Khizhnyak, N.A.

**TITLE:** Loss of Energy of a Charged Disc Moving Uniformly in a Waveguide

**PERIODICAL:** Radiotekhnika i elektronika, 1960, Vol 5, Nr 4, pp 654-661 (USSR)

**ABSTRACT:** The losses of energy due to polarization of the medium and Cherenkov radiation of a charged disc in uniform motion in a delay system waveguide (uniformly loaded by a homogeneous and isotropic dielectric) are calculated. It is shown that the field established by the disc consists of a field "carried along" by the disc and a field which "separates off". The power flow and energy stored in these fields is calculated. In considering thick discs or systems of discs the "coherency" conditions are found. By a coherent system the author means one in which the energy lost by a system of N particles exceeds that of a single particle by the factor $N^2$. The author indicates how to avoid a formal infinite radiation power in the treatment of real systems where the number of particles is very large (may be assumed

Card 1/2

69901

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E140/E435

Loss of Energy of a Charged Disc Moving Uniformly in a Waveguide

to approach infinity). Acknowledgements are expressed to Ya.B.Faynberg who participated in discussing the work. There are 6 references, 3 of which are Soviet, 2 International and 1 English in Russian translation.

ASSOCIATION: Fiziko-tekhnicheskiy institut AN USSR (Physical-Technical Institute of AS UkrSSR)

SUBMITTED: May 4, 1959

Card 2/2

25375
S/089/61/011/001/004/010
B102/B214

24.6731 9.4230

AUTHORS: Khizhnyak, N. A., Tolok, V. T., Chechkin, V. V., Nazarov, N.I.

TITLE: The possibility of acceleration of large pulsed currents in electron linear-accelerators

PERIODICAL: Atomnaya energiya, v. 11, no. 1, 1961, 34 - 40

TEXT: This paper presents an evaluation of the suitability of different electron linear accelerators for accelerating intensive pulsed currents since their region of application is only incompletely known as yet. The theoretical studies published here are based essentially on the work carried out over many years at the Fiziko-tekhnicheskiy institut AN USSR (Institute of Physics and Technology AS UkrSSR), Kharkov. First, the acceleration of pulsed currents in electron traveling-wave linear-accelerators is discussed. The effect of the pulsed beam on a traveling - wave accelerator ($\pi/2$ wave, $\lambda \simeq 10$ cm) and a waveguide type accelerator is studied. The most important effects are three: 1) A change of electrodynamic acceleration conditions. For $v_o \simeq c$ the electron beam affects the electrodynamic properties very little, for $v_o < c$ much more. With a load of a

Card 1/4

25375

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B102/B214

The possibility of ...

current of ~1a the amount of change in the phase velocity of the wave is $\Delta\beta = 2.6\%$ ($\beta = 0.5$), 1.3% ($\beta = 0.7$), 0.25% ($\beta = 0.9$); ($\beta = v/c$). 2) Effect of the energy ratios in the accelerating system. There is a displacement of the synchronous phase toward the wave peak, i.e. toward the limit of the region of phase stability. It is possible to improve the energy ratios by increasing the injection energy of the electrons of enlarging the section with an alternating phase velocity of the wave. In sections with constant phase velocity (=c), the loading of the accelerator by the electron beam leads to a decrease of the electron energy at the output of the accelerator. For example, 12 Mw are required to obtain a pulsed current with 1a and 5 Mev having a width of the energy spectrum of 10%. 3) Effect of the dynamic conditions in traveling - wave accelerators. There is an upper limit of the current; for example, at an accelerating field of $E_z \simeq 100$ kv/cm this limit lies at 10 a. In the following the acceleration of pulsed currents in linear accelerators with standing waves is discussed in an analogous manner. An acceleration system is considered which consists of one or more connected endovibrators in standing - wave operation ($\pi$ waves, $\lambda \simeq 2$m). In the decelerating phase, the beam is screened off from

Card 2/4

25375

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B102/B214

The possibility of ...

the field by drift tubes. For the acceleration of higher currents, this system has a number of advantages over the traveling-wave system, as there are: 1) Change of the electrodynamic conditions. When the condition $14.4\cdot10^{-6}(\lambda/R)^4J < 1/Q_o + JW/Q_oD_o$ is satisfied, the change of the electrodynamic properties caused by the electron beam does not limit the accelerated current. ($Q_o$ is the quality factor of the unloaded resonator, JW the h. f. power loss to the acceleration of the current of J amperes, $D_o$ the h.f. power losses to the walls of the system, and R the radius of the endovibrator.) 2) Change of the electrical conditions of acceleration. There is a lowering of the pulse duration, and there is an optimal energy given by $W_{opt} = 1.44\cdot10^{-5}Q_oD_o$. The maximum charge that can be accelerated to $W_{opt}$ is $Jt = 2\cdot10^{-4}\Delta E/E$ coulomb. This type of accelerator can accelerate much higher currents than the one mentioned before. Finally, the problem of particle dynamics in a standing wave accelerator is discussed. The longitudinal (phase) and transverse (radial) motions are separately discussed. The authors thank K. D. Sinel'nikov, and Ya. B. Faynberg for
Card 3/4

25375

The possibility of ... S/089/61/011/001/004/010
B102/B214

discussions. A. I. Akhiyezer and N. P. Selivanov are mentioned. There are 2 figures.

SUBMITTED: July 10, 1960

Card 4/4

25376
S/089/61/011/001/005/010
B102/B214

24.6731

**AUTHORS:** Tolok, V. T., Bolotin, L. I., Chechkin, V. V., Nazarov, N. I., Khizhnyak, N. A.

**TITLE:** A high-current electron accelerator

**PERIODICAL:** Atomnaya energiya, v. 11, no. 1, 1961, 41 - 45

**TEXT:** This paper presents a description of the 5-Mev electron linear-accelerator designed, built, and studied in 1955 at the Fiziko-tekhnicheskiy instutut AN USSR (Institute of Physics and Technology AS UkrSSR). The acceleration system consists of two coupled endovibrators excited to standing π waves with $f = 137.4 \cdot 10^{-6}$ cps. The accelerator is fed by 12 autogenerators each of which delivers to the endovibrators up to 100 kw with a pulse duration of 400 μsec. Each resonator is a 16-faced prism, 1100 mm long, the diameter of the inscribed circle of the prisms being 1500 mm. The prisms are made of 1 mm thick copper strips secured to a solid body. The drift tubes (100 mm diameter) form accelerating gaps, each 600 mm long. The h.f. generators work in two cycles with self excitation. The 12 modulators deliver at the anodes of the generator-tubes voltage

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Card 1/4

25376

A high-current electron ...

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B102/B214

pulses of up to 25 kv. The resonators are kept in a vacuum chamber maintained at a pressure of $(1-2)\cdot 10^{-6}$ mm Hg by two diffusion pumps. The electron gun (with tungsten cathode in the form of a flat spiral) is placed inside the drift tube. A special modulator supplies the gun cathode with negative voltage pulses of up to 70 kv and durations of $0.2\cdot 10^{-6}$ and $2\cdot 10^{-6}$ sec. In normal operation the injection current is 6 a; on pulsed over-heating of the spiral it amounts to 40 a. The construction of the injector provides for the possibility of using an L - cathode. The phase difference of the $\pi$ vibrations in the resonators is checked by an electron-beam phase meter, and the pulse height by a two-beam oscilloscope. The radial focusing of the beam at the output of the injector is accomplished by the radial component of the h.f. field. The elctron velocity at the output of the first acceleration gap is almost equal to the velocity of light and is not further affected by the radial component of the field. In the first gap there appears also a bunching effect which narrows the phase width of the beam from 2.2 to 1.6 radians, which value remains practically constant in the following gaps. At the exit of the accelerator the beam cross section is $\sim$10 mm with an aureole of about 60 mm. It is focused on

Card 2/4

the target by means of two magnetic lenses; its diameter then becomes 3 mm. To study the possibility of obtaining the maximum current, the particle energy spectra were recorded at the output of the accelerator for different currents. The following results were obtained: A current of 8.5 a with a pulse duration of 0.2 μsec is obtained for an electron energy of 4.5 Mev. A current of 15 a with a pulse duration of 0.2 μsec and an electron energy of 3.8 Mev is yielded from the maximum of the charge that can be accelerated ($3\cdot10^{-6}$ coulomb). At this pulse duration a current of up to 25 a may be obtained, but the maximum electron energy is only 3 Mev and the energy spectrum is broader. To reduce this fall of energy and the consequent broadening of the spectrum it is necessary to increase the energy fed to the resonators. A further decrease of the electron energy for obtaining increased current is not convenient because for radial focusing the electron must have relativistic velocity in the first gap. The value of the time average of the current for this accelerator is up to 50 μa for 15 pulses/sec, which must be increased to 100-150 pulses/sec for increasing the average current. The authors thank K. D. Sinel'nikov, P. M. Zeydlits, and Ya. B. Faynberg for discussions. V. I. Veksler and V. V. Vladimirskiy are mentioned.

25376

A high-current electron ... S/089/61/011/001/005/010
B102/B214

There are 5 figures and 4 references: 3 Soviet-bloc and 1 non-Soviet-bloc. The reference to the English-language publication reads as follows: M. Kelliher, J. Nugard, A. Gale. IRE Trans. Nucl. Sci., No. 3, 1 (1956).

SUBMITTED: July 26, 1960

Legend to Fig.1: 1) generator, 2) resonator, 3) electron gun, 4) connecting opening.

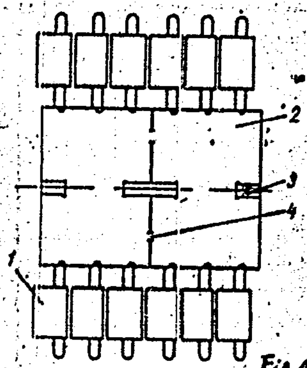

Fig.1

Card 4/4

S/781/62/000/000/006/036

**AUTHOR:** Khizhnyak, N. A.

**TITLE:** Contribution to the theory of nonlinear processes in a one-component plasma

**PERIODICAL:** Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza; doklady I konferentsii po fizike plazmy i probleme upravlyayemykh termoyadernykh reaktsiy. Fiz.-tech. inst. AN Ukr. SSR. Kiev, Izd-vo AN Ukr. SSR, 1962, 31-34,

**TEXT:** The author is particularly interested in the conditions under which traveling waves can be produced in a plasma, and shows that such a condition occurs when the total energy of the field plus particle system is constant at all points of space. This means that solutions in the form of traveling waves in a nonlinear plasma must be sought in devices where the kinetic energy of the electrons is converted into the oscillation energy of the field, i.e., in stationary modes of various amplifying devices. It is shown further that the prevalent notion that traveling wave solutions are obtained in the nonlinear theory with traveling waves whose velocity is determined by the amplitude of the oscillations is in error, since the rate of propagation of the traveling waves is determined primarily by the conditions under which the

Card 1/2

S/781/62/000/000/006/036

Contribution to the theory of nonlinear . . .

oscillations are excited and not by the amplitude of these oscillations. It is shown further that if the plasma density is replaced in the limit by its linearized value obtained from the continuity equation, the results go over into those of the linear theory not only formally, but also to an extent that the corresponding quantities obtained from the nonlinear solution go over into those obtained in the linear solution.

There are three Russian-language references.

Card 2/2

S/781/62/000/000/014/036

**AUTHOR:** Faynberg, Ya. B., Khizhnyak, N. A.

**TITLE:** Space charge waves in modulated beams

**PERIODICAL:** Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza; doklady i konferentsii po fizike plazmy i probleme upravlyayemykh termoyadernykh reaktsiy. Fiz.-tech. inst. AN Ukr. SSR. Kiev, Izd-vo AN Ukr. SSR, 1962, 71-72.

**TEXT:** The one-dimensional problem of modulation of two electron beams with compensated unperturbed space charge is investigated with the aid of the Boltzmann equation and in the approximation of the small-signal theory. The expression derived for the space charge behind modulating grids ($V_0$—amplitude of the modulating voltage at frequency $\omega$) is

Card 1/3

Space charge waves in modulated beams S/781/62/000/000/014/036

$$\varrho(x,t) = \frac{ie^2 V_0 e^{i\omega t}}{2\pi m}\int\limits_{\sigma-i\infty}^{\sigma+i\infty} \frac{\left(\int\limits_{-\infty}^{\infty} \frac{\partial f_0}{\partial\xi}\cdot\frac{d\xi}{i\omega+p\xi+\frac{1}{\tau}}\right) e^{px}\,dp}{1+\frac{4\pi e^2}{mp}\int\limits_{-\infty}^{\infty}\frac{\partial f_0}{\partial \xi}\cdot\frac{d\xi}{i\omega+p\xi+\frac{1}{\tau}}}, \quad (1)$$

and can be simplified if the roots of the denominator in the integrand are known.

The zeros of the denominator are investigated and the conditions under which the roots are complex are determined. It is shown that at specified beam parameters the greatest unstable frequency is determined by the relation

$$\omega_{\max} = \frac{(\xi_{10}\Omega_{20}+\xi_{20}\Omega_{10})-3\left(\Omega_{20}\frac{\sigma_1^2}{\xi_{10}}+\Omega_{10}\frac{\sigma_2^2}{\xi_{20}}\right)}{(\xi_{10}-\xi_{20})+3\left(\frac{\sigma_1^2}{\xi_{10}}+\frac{\sigma_2^2}{\xi_{20}}\right)}, \quad (2)$$

Card 2/3

S/781/62/000/000/014/036

Space charge waves in modulated beams

where $\xi_{10}$, $\xi_{20}$, $\Omega_{10}$, $\Omega_{20}$, $v_{T_1}$, and $v_{T_2}$ are the unperturbed velocities of translational motion, the plasma frequencies, and the thermal velocities of the first and second beams, respectively. Relation (2) is derived under the condition

$$S_1 = \frac{v_{T_1}^2\omega^2}{\xi_{10}^4\Omega_{10}^2} \ll 1, \quad S_2 = \frac{v_{T_2}^2\omega^2}{\xi_{20}^4\Omega_{20}^2} \ll 1. \tag{3}$$

With increasing parameters $S_1$ and $S_2$ in (3), the maximum unstable frequency decreases approximately as $1/v_t$. When $S_1 \gg 1$ and $S_2 \gg 1$, the thermal motion of the beam eliminates the instabilities.

There are no references.

Card 3/3

S/781/62/000/000/020/038

AUTHORS: Sinel'nikov K. D., Khizhnyak, N. A. Safronov B. G.

TITLE: Motion of flexible current loop in inhomogeneous magnetic field

SOURCE: Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza; doklady I konferentsii po fizike plazmy i probleme upravlyayemykh termoyadernykh reaktsiy. Fiz.-Tekh. inst. AN Ukr. SSR. Kiev, Izd-vo AN Ukr. SSR, 1962, 93-101

TEXT: The motion of a flexible current loop, the radius of which can vary under the influence of electrodynamic forces, is of practical interest because it simulates the motion of plasmoids in external fields, and is furthermore of interest in itself. Previous work in this field by Osovets (refs. 2 and 3, Fizika plazmy i problem upravlyayemykh termoyadernykh reaktsiy [Plasma physics and the problem of controllable thermonuclear reactions], v. 2 and 3, Academy of Sciences USSR, 1958) have dealt with motions of a loop in external magnetic fields of definite geometry, but the present work is devoted to a study of unstable motion of current loops, both purely inductive and with account of ohmic

Card 1/2

losses. The equations of motion of the loop are formulated in Lagrangian form and solutions are obtained for a lossless loop, and for a loop in a linearly increasing matnetic field (in which the field actually slows down the loop and can even reflect it. Solution of the equations shows that the radius of the loop varies little with the dimensionless time, but the dimensionless axial distance covered by the loop increases in proportion to the time, which is an unexpected result.

The radial and axial stability of the loop are investigated also in the case of active resistance. The conditions for axial stability contain nothing new, but from the conditions obtained for the radial stability it follows that the loop can have a stable position in the presence of active resistance only when the average magnetic field and the magnetic field on the loop have different time dependences. The results are found to be in agreement with those obtained in refs. 2 and 3. There is one figure.

Card 2/2

44882

S/861/62/000/000/013/022
B125/B102

24,6730

**AUTHORS:** Selivanov, N. P., Faynberg, Ye. B., Stepanov, K. N., Khizhnyak, N. A.

**TITLE:** Choosing the best variant of a linear proton accelerator

**SOURCE:** Teoriya i raschet lineynykh uskoriteley, sbornik statey. Fiz.-tekhn. inst. AN USSR. Ed. by. T. V. Kukoleva. Moscow, Gosatomizdat, 1962, 186 - 202

**TEXT:** Two theories are studied: that of waveguides with dielectric discs fitted inside, used to accelerate protons to high energies, and that of radial focusing using alternate focusing and defocusing lenses. When the dielectric constant $\varepsilon = \varepsilon(x,y,z)$ and the conductivity $\sigma = \sigma(x,y,z)$ are time-independent, $\Delta\vec{A} + k^2\vec{A} - \mathrm{div}\vec{A}\cdot\mathrm{grad}(\ln k^2) = -(4\pi/c)\vec{j}$ holds, where $k^2 = i\omega(i\omega\varepsilon + 4\pi\sigma)/c^2$, $\omega$ denoting the frequency and $j$ the current density. In the case of an axisymmetric field and zero current the product $A(r,z) = R(r)Z(z)$ is formulated so as to obtain the components of electric and magnetic field strengths:

Card 1/4

Choosing the best variant of... S/861/62/000/000/013/022
B125/B102

$$\left.\begin{aligned} E_z &= E_0 J_0(mr)\, e^{i(\omega t - k_3 z)}; \\ E_r &= \frac{iE_0 k_3}{\frac{a+b}{a\varepsilon+b}\bar{k}_3^2 - \left(\frac{\omega}{c}\right)^2} \frac{m(a+b)}{(a+\varepsilon b)} J_1(mr)\, e^{i(\omega t - k_3 z)}; \\ H_\varphi &= \frac{iE\frac{\omega}{c} m}{\frac{a+b}{a\varepsilon+b}\bar{k}_3^2 - \left(\frac{\omega}{c}\right)^2} J_1(mr)\, e^{i(\omega t - k_3 z)}, \end{aligned}\right\} \quad (12).$$

The boundary conditions

$$A\big|_{z=z_s-0} = A\big|_{z=z_s+0}; \quad \frac{1}{k^2}\frac{\partial A}{\partial z}\bigg|_{z=z_s-0} = \frac{1}{k^2}\frac{\partial A}{\partial z}\bigg|_{z=z_s+0}. \qquad (2)$$

take account of the jump-like change in the properties of the medium at $z = z_s$. The formulas (12) agree with the known expressions for the components of an electromagnetic field in a waveguide containing an anisotropic dielectric, if the following condition is observed: The discs made of a homogeneous isotropic dielectric, that are fitted inside the waveguide, must be equivalent to an anisotropic dielectric having the effective $\varepsilon$ components

Card 2/4

$\varepsilon_r = (a+\varepsilon b)/(a+b)$, $\varepsilon_z = (a+b)\varepsilon/(a\varepsilon+b)$. The mean phase velocity in a waveguide containing discs is smaller than that in an empty waveguide; it is greater than that in one containing a dielectric. The attenuation of the fields due to the infinite conductivity is proportional to $e^{-\gamma z/2}$, where

$$\gamma = \frac{4\pi}{c^2}\omega\sigma\frac{b\sqrt{\varepsilon}}{\sqrt{(a\varepsilon+b)(a+b\varepsilon)}}\,\frac{1-\frac{a}{a+b}\frac{m^2c^2}{\omega^2}\frac{\varepsilon^2-1}{\varepsilon^2}}{\sqrt{\frac{(a+b)\varepsilon}{a\varepsilon+b}\frac{\omega^2}{c^2}-m^2}} \qquad (13)$$

and $m = 2.405/R$. The power losses per unit length from a waveguide containing dielectric discs amount to $D_1 = (1-e^{-\gamma})S \approx \gamma S$. When the structural period remains constant, the phase velocity of a wave in a waveguide fitted with dielectric discs is varied by changing the relative thickness $\eta = a/b$, of the discs. Linear accelerators with alternately arranged magnetic lenses possess regions of stable motion in the y and z directions corresponding to certain values of magnetic field gradient and lens length. The stability condition of the motion in such traveling-wave accelerators reads

$$H' = \frac{\pi E\cos\varphi_s}{\beta^2\lambda}\,\frac{\alpha_1+\alpha_2}{\alpha_2-\alpha_1},\quad l^2 = \frac{2\pi m\beta\lambda\sigma_z^2}{eE\cos\varphi_s}(\alpha_2-\alpha_1). \qquad (25),$$

Choosing the best variant of...

S/861/62/000/000/013/022
B125/B102

where l is the length of the lens. Proceeding from the equation of motion of a standing wave accelerator with drive tubes when there are six magnetic lenses per period, the condition obtained for the region of stable particle motion is given by

$$x = \frac{\beta\lambda}{4}\sqrt{\frac{4\pi eE\cos\varphi_s}{m\beta\lambda v_z^2}},$$

$$y = \frac{3\beta\lambda}{4}\sqrt{\frac{eH'}{mc^2\beta}}. \qquad (11).$$

There are 2 figures and 3 tables.

Card 4/4

44883

S/861/62/000/000/014/022
B125/B102

24.6730

**AUTHOR:** Khizhnyak, N. A.

**TITLE:** A waveguide containing dielectric discs working on a traveling π/2 wave

**SOURCE:** Teoriya i raschet lineynykh uskoriteley, sbornik statey. Fiz.-tekhn. inst. AN USSR. Ed. by T. V. Kukoleva. Moscow, Gosatomizdat, 1962, 203 - 210

**TEXT:** The dispersion effects and power flux in a waveguide are studied. The wavelength $\lambda_{wg}$ in the waveguide is taken to be of the same order as the period of the structure (a+b). If the dispersion equation

$$\cos k_3 L = \cos p_1 a \cos p_2 b - \frac{(p_1 \varepsilon^2 + p_2^2)}{2 p_1 p_2 \varepsilon} \sin p_1 a \sin p_2 b, \qquad (2)$$

holds for waveguides for accelerators with dielectric discs ($\varepsilon$) without apertures in them, then the r-f power flux is obtained as

$$S = \frac{c}{8} \frac{k k_3 R^2}{k_1^2} J_1^2(\sigma_0^1) \left( \frac{\sin k_3 L}{k_3 L} \right) \frac{L D_0^2}{u_2(L)}. \qquad (8).$$

Card 1/4

S/861/62/000/000/014/022
B125/B102

A waveguide containing...

R is the radius of the waveguide, $\sigma_0^1$ the first root of the zero-order Bessel function $J_0(\sigma_0^1) = 0$, a is the distance and b the thickness of the discs, $L = a+b$, $k = 2\pi/\lambda$, $k_3 = 2\pi/\lambda_{wg}$, $p_1^2 = k^2 - (\sigma_0^1/R)^2$, and $p_2^2 = \varepsilon k^2 - (\sigma_0^1/R)^2$. The equation defining the effective electric field strength $E_0$ on the axis of the waveguide is obtained from (8), together with

$$S = \frac{c}{8} E_0^2 \frac{k k_3 R^2}{k_1^2} J_1^2 \sigma_0^1 \left(\frac{\sin k_3 L}{k_3 L}\right) \frac{L}{u_2(L)} \frac{L^2}{\Phi^2}. \qquad (10).$$

For thin discs (2) holds, and $L/u_2(L) \approx (a+b)/(a+\varepsilon b) = 1/\varepsilon_r$. $L/\phi \approx (a+b)\varepsilon/(a\varepsilon+b)$ is the longitudinal component of the dielectric constant $\varepsilon_z = (a+b)\varepsilon/(a\varepsilon+b)$. When (1) is isolated,

$$S = \frac{c}{8} \varepsilon_0^2 \frac{k k_3 R^2}{k_1^2} J^2 \sigma_0^1 \left(\frac{\sin k_3 L}{k_3 L}\right) \frac{\varepsilon_z^2}{\varepsilon_r}; \qquad (11),$$

with the effective values $\varepsilon_r = u_2(L)/L$ and $\varepsilon_z = L/\phi$. In the special case

Card 2/4

of a traveling $\pi/2$ wave, (2) takes the form

$$\operatorname{ctg}\left[p_1 a\left(\frac{p_2}{p_1}\right)\left(\frac{\beta\lambda}{4a}-1\right)\right]= \qquad (13).$$
$$=\frac{1}{2}\left[\frac{p_{1\varepsilon}}{p_2}+\frac{p_2}{p_{1\varepsilon}}\right]\operatorname{tg} p_1 a.$$

The phase velocity $\beta = (4a/\lambda) + (1/\sqrt{\varepsilon - 1})$ for the limiting radius $R = R_{lim} = \lambda\sigma_0^1/2\pi$ of an empty waveguide is obtained from (13). This phase velocity decreases with the radius of the waveguide, at first rapidly and then more slowly. $\varepsilon_z = L/\phi$ depends only slightly on R and $\varepsilon$. The power flux increases with the radius of the waveguide, about proportionally to $R^4$; it decreases when $\varepsilon$ increases. For practical purposes, waveguides are chosen with R small and $\varepsilon$ large. When $R = R_{lim}$ and $\varepsilon$ is large, the power flux decreases with increasing dielectric constant. For this very reason, dielectrics of $\varepsilon > 1000$ are inappropriate. Reducing $\beta$ by raising $\lambda$ would be equally impractical as it would necessitate a very large increase in the power flux. However, it is possible to decelerate waves to $\beta = 0.07$ with

S/861/62/000/000/014/022
B125/B102

A waveguide containing...

dielectrics of $\epsilon \sim 1000$. If $\lambda$ = 10 cm, $\beta$ = 0.07 and $E_0$ = 20 kv/cm, then $S = 6 \cdot 10^6$ w and R = 3.83 cm. There are 5 figures.

Card 4/4

44888

S/861/62/000/000/019/022
B125/B108

24.6730

AUTHOR: Khizhnyak, N. A.

TITLE: The limiting current in a linear electron accelerator

SOURCE: Teoriya i raschet lineynykh uskoriteley, sbornik statey. Fiz.-tekhn. inst. AN USSR. Ed. by T. V. Kukoleva. Moscow, Gosatomizdat, 1962, 317 - 319

TEXT: The limiting current $J_{lim}$ is determined from the condition that the synchronous phase $\varphi_s$ at the rear end (z=1) of the accelerator is at the limit of phase stability, i.e. assumes the value $\pi/2$. Integrating the equation for $\varphi_s$, which follows from the law of conservation of energy and from the condition of stable acceleration, $E \sin\varphi = E_s \sin\varphi_s$ for $\sin\varphi_s|_{z=0} = \sin\varphi|_{z=0}$ leads to $(\sin\varphi_s/\sin\varphi)^2 - 1 = -J\int_0^z (E_0 e^{-Iz} \sin\varphi_s/S(z))dz$. $S(z) = kE_0^2 e^{-2Iz}$ is the power flux at the point z when the beam is absent, $I = \alpha_1/2k$. Thus, $J_{lim} = \cos^2\varphi_s 1/\int_0^1 (E(z))/S(z))dz$. The expression $J_{lim} = (S_0/V)\cos^2\varphi_s(1)$,

Card 1/2

where $V = \int_0^l E_0 \sin\varphi_s dz$, is valid if energy absorption on the walls of the waveguide is neglected. With S = 0.9 Mev, V = 1.6 Mev, and $\varphi_s(l) = 60^\circ$ the value of $J_{lim}$ is 150 ma. The present paper was composed in 1955.

FEDORENKO, Aleksandr Ivanovich; SELEGENEV, Vasiliy Yakovlevich;
KHIZHNYAK, N.A., kand. fiz.-matem. nauk, dots., otv. red.;
ALYAB'YEV, N.Z., red.

[Use of atomic energy in the national economy] Primenenie atomnoi energii v narodnom khoziaistve. Khar'kov, Izd-vo Khar'kovskogo univ., 1963. 166 p. (MIRA 17:8)

ACCESSION NR: AT4036075 S/2781/63/000/003/0332/0336

AUTHORS: Aleksin, V. F.; Khizhnyak, N. A.

TITLE: Diffusion of fully ionized plasma transverse to the magnetic field

SOURCE: Konferentsiya po fizike plazmy* i problemam upravlyayemogo termoyadernogo sinteza. 3d, Kharkov, 1962. Fizika plazmy* i problemy* upravlyayemogo termoyadernogo sinteza (Plasma physics and problems of controlled thermonuclear synthesis); doklady* konferentsii, no. 3. Kiev, Izd-vo AN UkrSSR, 1963, 332-336

TOPIC TAGS: plasma diffusion, ionized plasma, diffusion coefficient, plasma magnetic field interaction, magnetic pinch, plasmoid, magnetohydrodynamics, self similarity model

ABSTRACT: It is shown that in a fully ionized gas the coefficient of thermal conductivity is $(M/m)^{1/2}$ times larger than the diffusion co-

Card 1/3

ACCESSION NR: AT4036075

efficient (M -- ion mass; m -- electron mass), so that the gradient of temperature becomes equalized much more rapidly than the density gradient and the former need be taken into account only on the plasma boundary. The diffusion of a plasma pinch detached from the walls in a longitudinal magnetic field, or the diffusion of a plasmoid in a reference frame connected with the plasmoid, are considered neglecting longitudinal spreading. It is assumed that the plasma is stable against various types of disturbances. It is shown that the self-similar solution describes well the qualitative pattern of diffusion of the plasma pinch transversely to the magnetic field for arbitrary initial smooth particle-density distribution. Self-similar solutions can also be obtained for the temperature distribution. Magnetohydrodynamic instabilities can cause plasma to leave the pinch at a rate close to the thermal velocity of the ions. On the other hand, instability can produce turbulences in the plasma and also consequently increase the diffusion. "In conclusion we are grateful to K. D. Sinel'nikov and A. I. Akhiyezer for continuous interest in the

ACCESSION NR: AT4036075

work and for a discussion of the results." Orig. art. has: 17 formulas.

ASSOCIATION: None

SUBMITTED: 00 DATE ACQ: 21May64 ENCL: 00

SUB CODE: ME NR REF SOV: 003 OTHER: 002

Card 3/3

L 13328-63 EWT(1)/EWG(k)/BDS/EEC(b)-2/ES(w)-2
AFFTC/ASD/ESD-3/AFWL/SSD Pz-4/Pi-4/Pab-4 AT/IJP(C)
ACCESSION NR: AP3003951 S/0057/63/033/007/0820/0822

76
75

AUTHOR: Khizhnyak, N. A.; Kolesnikov, P. M.

TITLE: Theory of electrodynamic acceleration of plasma bunches in a coaxial [accelerator]

2

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 33, no. 7, 1963, 820-822

TOPIC TAGS: plasma physics, plasma acceleration, coaxial accelerator, plasma gun

ABSTRACT: An analytical derivation of acceleration equations is presented, based on the assumption of a perfectly conducting plasma bunch shunting the electrodes and a phase velocity much lower than the speed of light. The latter assumption imposes the requirement of considering the displacement-current terms. The result is a complex system of nonlinear integro-differential equations. Qualitative interpretation of the system indicates that the limiting velocity of the plasma is equal to the voltage wave velocity in the coaxial line. Conditions are determined for establishing the point beyond which the consideration of displacement currents is no longer necessary. Orig. art. has: 7 formulas and 1 figure.

Card 1/A

Khar'kov Aviation Inst.

L 16930-66 EWT(1)/T IJP(c)

ACC NR: AT6002496 SOURCE CODE: UR/3137/64/000/070/0001/0013

AUTHOR: Sinel'nikov, K. D.; Khizhnyak, N. A.; Repalov, N. S.; Zeydlits, P. M.; Yamnitskiy, V. A.; Azovskaya, Z. A.

63

341

ORG: none

21, 44, 55

TITLE: Injection of particles through an acute-angled magnetic trap into a mirror trap with increasing fields of the mirrors

SOURCE: AN UkrSSR. Fiziko-tekhnicheskiy institut. Doklady, no. 70, 1964. Inzhektsiya chastits v zerkal'nuyu lovushku s narastayushchim polem v probkakh cherez magnitnuyu lovushku ostrougol'noy geometrii, 1-13

TOPIC TAGS: magnetic mirror machine, ~~particle trapping~~, magnetic trap, computer calculation, charged particle

ABSTRACT: The authors investigate the passage of charged particles injected through an end slit parallel to the axis of the magnetic field through an acute-angled magnetic trap. 21, 44, 55 A general introduction of magnetic mirror effect is followed by a theoretical study of the effect of acute-angled field geometry on the eccentricity of particles passing through the zero field plane, and the filling of an increasing field mirror trap by particles passing

Card 1/2

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ACC NR: AT6002496

through the acute-angled trap. The paper gives 1) the conditions for the passage of particles with large and small displacement of the particle rotation center from the magnetic axis; and 2) the results of the numerical calculations of the trap filling carried out on the UMShN electronic computer. Curves presented depict the conversion of longitudinal into transverse velocity as a function of the injection-to-final-radius ratio, and as a function of the initial radial velocity, and particle trapping during a slow field increase. The results show that the method for particle trapping presented is technologically feasible. Acute-angled traps with higher field harmonics are not studied. Orig. art. has: 21 formulas and 8 figures.

SUB CODE: 20 / SUBM DATE: none / ORIG REF: 002

Card 2/2

L 8941-66 EWT(1)/ETC/EPF(n)-2/EWG(m) IJP(c) AT

ACC NR: AT5022287 SOURCE CODE: UR/3137/64/000/073/0001/0018

55, 44

AUTHOR: Khizhnyak, N. A.

44,55

55

GB+/

ORG: Academy of Sciences UkrSSR, Physicotechnical Institute (Akademiya nauk UkrSSR, Fiziko-tekhnicheskiy institut)

TITLE: Magnetic moment of a plasmoid impinging on a uniform longitudinal magnetic field

SOURCE: AN UkrSSR. Fiziko-tekhnicheskiy institut. Doklady, no. 073/P-027, 1964. Magnitnyy moment plazmennogo sgustka, naletayushchego na odnorodnoye prodol'noye magnitnoye pole, 1-18

21,44,55

TOPIC TAGS: plasmoid acceleration, charged particle, particle trajectory

ABSTRACT: The magnetic moment of a plasmoid is investigated theoretically. Computation of the magnetic moment of a charged particle entering longitudinally an axially symmetric magnetic field leads to an expression for the particle velocity which depends on the form of the field. Further extension of the results shows that particles with finite radius undergo velocity dispersion dependent on their radius. These results are applied to the problem of plasmoid motion using, additionally, a system of magnetohydrodynamic equations. The problem is restricted to consideration of plasma with infinite conductivity. The magnetic properties of low and high densi-

Card 1/2

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L 8941-66

ACC NR: AT5022287

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ty plasmoids are shown to differ considerably. Only low temperature plasmas are considered. The influence of thermal motion and the effect of collisions on the plasmoid behavior is discussed also and the resulting modifications are presented. The equations describing the behavior of the plasmoid form a closed set and are suitable for machine computation. Orig. art. has: 54 equations.

SUB CODE: 20/ SUBM DATE: 00/ ORIG REF: 011/ OTH REF: 006

PC

Card 2/2

L 8942-66 EWT(1)/ETC/EPF(n)-2/EWG(m)/EWA(h) IJP(c) AT/JN

ACC NR: AT5022313 SOURCE CODE: UR/3137/64/000/074/0001/0008

44,55 44,55

65

B+1

AUTHOR: Repalov, N. S.; Khizhnyak, N. A.

44,55

ORG: Academy of Sciences UkrSSR, Physicotechnical Institute (Akademiya nauk UkrSSR, Fiziko-tekhnicheskiy institut)

21,44,55 21,44,55

TITLE: Longitudinal oscillations in multivelocity plasmoids

SOURCE: AN UkrSSR. Fiziko-tekhnicheskiy institut. Doklady, no. 074/P-028, 1964. Prodol'nyye kolebaniya v mnogoskorostnom plazmennom puchke, 1-8

TOPIC TAGS: plasmoid, plasma beam, klystron 25

ABSTRACT: Thermal dispersion in klystrons is studied to determine the modulating properties of beam bunching. The appropriate equation of motion and Maxwell's equations are written for the ion and electrons for the collisionless case. By selecting particles within a small velocity interval, moving through modulating grids, Euler's equation can be written and a non-linear system results. Approximation methods are used to show that initial thermal dispersion introduces a multiplying factor which lowers the value of the current density of the beam. The multiplying factor is determined for the case of a step function distribution. The assumption of a Maxwell distribution is also discussed. The multiplying factor is shown to have a meaning of coherence in velocity space and it is determined that its structure is

Card 1/2

L 8942-66

ACC NR: AT5022313

2

similar to the coherence factor for the interacting spatially distributed beams. Orig. art. has: 16 equations.

SUB CODE: 20/ SUBM DATE: 00/ ORIG REF: 005/ OTH REF: 000

OC

Card 2/2

L 31285-65 EWT(d)/EWT(l)/EEC(b)-2/EWA(h) Pn-4/Pac-4/Peb/Pi-4/Pj-4

ACCESSION NR: AP5005348 S/0109/65/010/002/0334/0340

AUTHOR: Repalov, N. S.; Khizhnyak, N. A. 47 46

TITLE: Propagation of modulated beams in periodic media B

SOURCE: Radiotekhnika i elektronika, v. 10, no. 2, 1965, 334-340

TOPIC TAGS: electron beam, klystron 25

ABSTRACT: A single-variable problem of the interaction of a field-compensated [illegible] beam with a laminated dielectric whose boundaries are normal to the [illegible] is studied. A dispersion equation [illegible] the modulated [illegible] is solved in a hydrod[illegible] [illegible] certain conditions, a constant-density [illegible] beam may become [illegible] small fluctuations of the density [illegible] with increasing amplitudes. Formulas for the current density under resonance [illegible] are developed. the excita[illegible]

L 31285-65

ACCESSION NR: AP5005348 /

[illegible] amplitude of the modulating voltage becomes possible. The possibility of [illegible] above mechanism for compensating the space-charge effects in a [illegible] ber is considered. "The authors [illegible] A. Almentyn [illegible]

[illegible]

[illegible]TION: none

SUBMITTED: 02Jan64 ENCL: 00 SUB CODE: EC, NP

[illegible] REF SOV: 005 OTHER: 003

Card 2/2

L 18840-66 EWT(1) IJP(c) GS

ACC NR: AT5028589 SOURCE CODE: UR/0000/65/000/000/0388/0402

5B+1

AUTHOR: Sinel'nikov, K. D. (Academician AN UkrSSR); Khizhnyak, N. A.; Repalov, N. S.; Zeydlits, P. M.; Yamnitskiy, V. A.; Azovskaya, Z. A.

ORG: none

21,44,55

TITLE: Investigation of the charged particle motion in picket fence magnetic traps

SOURCE: Konferentsiya po fizike plazmy i problemam upravlyayemogo termoyadernogo sinteza. 4th, Kharkov, 1963. Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza (Physics of plasma and problems of controllable thermonuclear synthesis); doklady konferentsii, no. 4. Kiev, Naukova dumka, 1965, 388-402

TOPIC TAGS: magnetic trap, relativistic particle, plasma charged particle, particle trajectory, particle motion, magnetic field

ABSTRACT: The properties of charged particle motion in magnetic traps of the "picket fence" and "magnetic wall" (with negative field curvature) types are considered and their trajectories determined by numerical integrations. The traps are characterized by axial symmetry and small angles between field lines. The analytical form of the fields is described by the expansion of the scalar magnetic potential

Card 1/2

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ACC NR: AT5028589

in Bessel functions, retaining the first term only. Since both curl and divergence of the field within magnetic coils vanish, the magnetic intensity for "picket fence" traps (easily generalized to other geometries) is determined and analytical expressions are derived for two extreme cases of extended and compressed traps. A method for determining the fields in the throat area of the trap of a given radius is also given. Application of the Lagrangian and Hamiltonian of the charged particle motion and the utilization of the cyclic azimuthal coordinate of axisymmetric fields leads to derivation of a potential in which a particle moves and determines the extent of regions of particle confinement. It is found that there always exists a region through which particles can escape. The escape criteria and a classification of transmitted and reflected particles in which the gyroradius of the particles, and hence mass, play a strong role are presented. Additional classification relative to the initial particle parameters is also discussed. In particular, it is shown that the behavior of particles injected in a direction opposite to the system axis is similar to that of those injected parallel to the axis, excepting that the initial radial separation of the former from the axis is greater. Representative trajectories are graphed. The discussion is further generalized to the relativistic particles for which presently realizable magnetic confinement schemes require very strong fields. Orig. art. has: 17 figures, 34 formulas.

SUB CODE: 20/ SUBM DATE: 20May65/ ORIG REF: 002/ OTH REF: 002

Card 2/2 vmb

L 51999-65 EWT(1) UR/0057/65/035/005/0827/0832

ACCESSION NR: AP5012047

18
16

AUTHOR: Khizhnyak, N.A.

TITLE: Magnetic moment of a charged particle entering a uniform longitudinal magnetic field

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 35, no. 5, 1965, 827-832

TOPIC TAGS: charged particle motion charged particle beam, longitudinal magnetic field, magnetic moment, axial magnetic field

ABSTRACT: The author calculated the magnetic moment (ratio of the transverse [illegible] energy to the magnetic field strength) acquired by a charge particle entering the uniform region of an axially symmetric magnetic field. If the particle moves on the axis the magnetic moment remains zero; otherwise the magnetic moment depends on the distance of the particle in the field-free region from the symmetry axis, the velocity of the particle, the magnetic field strength in the uniform region, and the manner in which the longitudinal magnetic field strength rises from zero at large distances to its final uniform value. The calculations are performed by solving the equations of motion for simple assumed

Card 1/2

L 51999-65

ACCESSION NR: AP5012047

2

asymptotic forms of the magnetic field and joining the solutions so obtained to [illegible] for the region in which the field varies sufficiently smoothly. [illegible] results derived in this way are [illegible] which longitudinal [illegible] depends on the distance of the [illegible] of particles [illegible] of longitudinal velocities on entering [illegible] uniform [illegible] magnetic field. "In conclusion, the author expresses [illegible] to Academician K.D.Sinel'nikov of the AN USSR for his interest in the work, and to Yu.S.Azovskiy for numerous discussions." Orig. art. has: 34 formulas.

ASSOCIATION: None

SUBMITTED: 20Apr64 ENCL: 00 SUB CODE: EM

NR REF SOV: 001 OTHER: 007

839

Card 2/2

L 51997-65 EPF(n)-2/EPA(w)-2/EWT(1)/EWG(m) Pi-4/Po-4/Pz-6/Pab-10 IJP(c)
ACCESSION NR: AP5012048 AT UR/0057/65/035/005/0833/0846

63

B

AUTHOR: Khizhnyak, N.A.

TITLE: The magnetic moment of a plasma burst entering a uniform magnetic field

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 35, no. 5, 1965, 833-846

TOPIC TAGS: plasma, longitudinal magnetic field, axial magnetic field, magnetic moment, magnetohydrodynamics

ABSTRACT: The behavior of a plasma burst entering an axially symmetric magnetic field is discussed for the limiting cases of a rarefied and a dense plasma. The calculations are based on the "flexible current loop" model, the equations for which are obtained from the magnetohydrodynamic equations by integrating in Lagrange variables over the volume of the plasma. Collisions and thermal motions of the plasma particles are neglected. The magnetic moment and variation of the radius and length of the plasma are calculated for simple assumptions concerning the variation of the magnetic field in the region in which it increases from zero to its final uniform value. In the case of a rarefied plasma the relative change of the magnetic field due to the plasma current is negligible and each plasma particle moves in the unperturbed field. In the case of a dense plasma the

Card 1/2

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ACCESSION NR: AP5012048

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magnetic field is almost entirely expelled from the plasma by the induced currents. As a dense plasma enters a strong magnetic field the induced magnetic moment rises [illegible] m, and then decreases as a result of collapse of the plasma. The effects [illegible] motions and collisions are discussed in a final section, and equations [illegible] with the aid of which these effects [illegible] numerically. [illegible] I express my deep gratitude to Academician K.D. Sinel'nikov of the AN USSR for his constant interest in the work, and to Yu.S. Azovskiy for discussions." Orig. art. has: 79 formulas.

ASSOCIATION: None

SUBMITTED: 20Apr64 ENCL: 00 SUB CODE: ME

NR REF SOV: 010 OTHER: 000

Card 2/2

L 52016-65 EPF(n)-2/EPA(w)-2/EWT(1)/EWG(m) Po-4/Pi-4/Pz-6/Pab-10 IJP(c) AT/
WW

ACCESSION NR: AP5012049 UR/0057/65/035/005/0847/0857

59

AUTHOR: Khizhnyak, N.A.

TITLE: Motion of a finite plasma in the magnetic field of a toroidal solenoid

21

B

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 35, no. 5, 1965, 847-857

TOPIC TAGS: plasma, magnetic field, plasma polarization, plasma flow, plasma drift

ABSTRACT: The author discusses the motion of a plasma of finite extent in a [illegible] field with curved lines of force, such as is produced by a toroidal sole- [illegible] discussion was undertaken because it has been found (B. B. Safronov et al., [illegible] No. 6, 1962) that under suitable conditions the plasma will follow the [illegible] of force (and lose heavy impurity ions in the process), whereas G. [illegible] Fluids, 3, 961, 1960) has shown that the equations of motion in the [illegible] approximation predict that it will not. The author first solves the equations of motion for a single charged particle in an axially symmetric field having only an azimuthal component and discusses the motion of a rarefied plasma on the basis of this solution. It is found that the rarefield plasma tends to follow the lines [illegible] and that under suitable conditions of velocity, field strength, and field

Card 1/3

L 52016-65

ACCESSION NR: AP5012049

3

curvature, the plasma will lose heavy impurity ions to the walls of the container. To discuss the motion of a dense plasma the author uses the equations of the drift approximation with an additional term representing a current in the plasma parallel [illegible] plasma polarization. The interaction of this current with the magnetic field [illegible] cause the plasma to follow the curvature of the field. This current is [illegible] be due to short circuiting of the plasma polarization potential by that [illegible] the plasma that is still in a region of uniform field and is therefore not polarized. The supplementary term in the equations of motion is evaluated on the basis of this assumption and the additional assumption that the plasma is per- [illegible] conducting parallel to the magnetic lines of force (but not perpendicular to [illegible] the "exact" equations of motion for the present model are obtained. [illegible] are not solved, but the nature of their solutions is discussed at [illegible] and it is concluded that the equations are capable of accounting at [illegible] qualitatively for the observed behavior of the plasmas. "In conclusion, the author expresses his deep gratitude to Academician K.D.Sinel'nikov of the AN USSR [illegible] constant interest in the work and numerous fruitful discussions. The [illegible] expresses his deep gratitude to B.G.Safronov, V.S.Voytsenya, and other colleagues for fruitful discussions, and also to Z.A.Azovskaya for performing the calculations." Orig. art. has: 53 formulas and 3 figures.

L 52016-65

ACCESSION NR: AP5012049 O

ASSOCIATION: None

SUBMITTED: 20Apr64 ENCL: 00 SUB CODE: ME

NR REF SOV: 002 OTHER: 001

Card 3/3

L 7729-66 EWT(l)/EWP(m)/ETC/EPF(n)-2/EWG(m)/EWA(d)/EPA(w)-2/[illegible]/EWA(h)/ ~~EWA(c) IJP(c) WW/~~ AT

ACC NR: AP5025880 55 55 SOURCE CODE: UR/0057/65/035/010/1736/1742

AUTHOR: Kolesnikov, P.M.; Khizhnyak, N.A.

18/B

ORG: 44 55 Khar'kov Aviation Institute (Khar'kovskiy aviatsionnyy institut)

TITLE: On the nonlinear oscillations of the plasma behind a front on which charged particles are produced

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 35, no. 10, 1965, 1736-1742

21,44,55 1,44,55

TOPIC TAGS: plasma oscillation, plasma shock wave, mathematic physics, kinetic equation, nonlinear equation

ABSTRACT: The authors discuss the behavior of the completely ionized plasma behind an "ionization front" propagating in an unionized gas and ionizing it. The treatment is based on the inhomogeneous kinetic equations for the electron and ion distribution functions and Poisson's equation for the self-consistent electric potential describing the Coulomb interactions. The collision integrals are not included in the kinetic equations. These equations are solved by Cauchy's method of characteristics and the resulting general solution is specialized for the case of an infinitely thin ionization front and for delta-function and Maxwell distributions of the velocities of the nascent ions and electrons. It is shown that under certain conditions (which are derived) longitudinal traveling waves develop in the plasma with a frequency close to the

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Langmuir frequency. For the case of Maxwell distribution of the velocities of the nascent ions and electrons, a first integral of Poisson's equation is derived; this relates the amplitude of the oscillations to the electron and ion temperatures and to other parameters and plays a role analogous to that of a dispersion equation. The effect of an ionization front of finite thickness is discussed briefly. When the amplitude of the oscillations is small the finite thickness of the front reduces the amplitude but leaves the frequency unchanged. For high amplitude oscillations the thickness of the front also influences the frequency. Orig. art. has: 46 formulas.

SUB CODE: ME/ SUBM DATE: 13Jan64/ ORIG REF: 008/ OTH REF: 004

Card 2/2

L 23580-66 EPF(n)-2/EWT(1)/ETC(f)/EWG(m) IJP(c) AT/GS

ACC NR: AT6008838 SOURCE CODE: UR/0000/65/000/000/0005/0018

AUTHOR: Sinel'nikov, K. D.; Khizhnyak, N. A.; Repalov, N. S.; Zeydlits, P. M.; Yamnitskiy, V. A.; Azovskaya, Z. A.

53
B+1

ORG: none

TITLE: Injection of particles into a mirror trap with an increasing field through a magnetic cusp configuration

SOURCE: AN UkrSSR. Magnitnyye lovushki (Magnetic traps). Kiev, Naukova dumka, 1965, 5-18

TOPIC TAGS: ~~[illegible]~~ magnetic trap, plasma injection, particle trajectory, magnetic mirror.

ABSTRACT: The behavior of a plasma in a magnetic mirror trap formed by particles injected through a cusp configuration is studied. The particles selected for investigation are those which at injection have curvature radius of less than 71% of the Larmor radius, i. e. those which proceed without reflection into the magnetic mirror region. The eccentricity of the particle trajectory (passing through the zero field plane) due to the cusp configuration is analyzed. Two competing processes become evident; one tends to establish an E-layer as in the Astron machines and another tends to fill the axial region of the mirror trap. The analysis is further extended to determine the accumulation in the magnetic mirror trap of particles passing through a

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ACC NR: AT6008838

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smooth cusp field having only a zeroth harmonic. The conversion of longitudinal energy into transverse particle energy is determined as a function of the initial radial distance of the trajectory from the magnetic axis. The number of particles trapped indicates that construction of an experimental machine is feasible provided the proper magnetic field configuration is used. It is estimated that a field with high harmonic components would trap particles with broader initial velocity and injection angle parameters. Orig. art. has: 7 figures, 10 formulas.

SUB CODE: 20/ SUBM DATE: 20Oct65/ ORIG REF: 032/ OTH REF: 000

Card 2/2 PB

L 29675-66 EWT(1)/ETC(f) IJP(c) AT/JXT(EX)
ACC NR: AT6012693 SOURCE CODE: UR/3137/65/000/114/0001/0009

68
67
B+1

AUTHOR: Khizhnyak, N. A.; Vodyanitskiy, A. A.

ORG: Physicotechnical Institute, Academy of Sciences UkrSSR (Fiziko-tekhnicheskiy institut Akademii nauk UkrSSR)

TITLE: Oscillations and heating of small plasma bunches incident on an axially-symmetrical magnetic field

SOURCE: AN UkrSSR. Fiziko-tekhnicheskiy institut. Doklady, no. 114, 1965. 0 kolebaniyakh i nagreve malykh plazmennykh sgustkov, naletayushchikh na aksial'no-simmetrichnoye magnitnoye pole, 1-9

TOPIC TAGS: plasmoid, plasma heating, plasma oscillation, magnetohydrodynamics

ABSTRACT: This is a continuation of earlier work by one of the authors (Khizhnyak, Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza [Plasma Physics and Problems of Controlled Thermonuclear Fusion], No. 4, AN UkrSSR, Kiev, in press) where it is shown that the equations of motion of a plasmoid can be represented in the hydrodynamic approximation in terms of the total current in the plasmoid and its self-induction. The present article deals with the azimuthal current induced in a plasma following the incidence of plasmoids on an axially-symmetrical magnetic field, and the interaction of these induced currents with the external mag-

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L 29675-66
ACC NR: AT6012693

netic field and its effect on the plasma heating. The system of magnetohydrodynamic equations is written out for an ellipsoidal plasmoid which is solved for two limiting values of a parameter defining the ratio of the Alfven frequency to the hybrid frequency. An analysis of the results shows that if the initial gas-kinetic pressure is smaller than the magnetic pressure, then the plasmoid will start contracting on entering the magnetic field, until the kinetic pressure of the plasma exceeds the magnetic pressure, and this contraction causes plasma heating. The next phase is expansion of the plasmoid accompanied by cooling. If the kinetic pressure initially is larger than the magnetic pressure, then the plasmoid will first expand and its temperature decrease. If the two pressures are equal, the plasmoid will move without change in radius, other than that due to collisions. Estimates are presented for the maximum and minimum of the temperature attained by the plasmoid. The authors thank Z. A. Azovskaya for help with the numerical calculations. Orig. art. has: 1 figure and 19 formulas.

SUB CODE: 20/ SUBM DATE: 00/ ORIG REF: 006

Card 2/2 ee

L 43917-66 EWT(1) IJP(c) AT/GD

(N)

ACC NR: AT6020400 SOURCE CODE: UR/0000/65/000/000/0037/0053

7/

B+/

AUTHOR: Khizhnyak, N. A.

ORG: none

2/

2/

TITLE: On the collapse of a plasmoid in an external growing magnetic field

SOURCE: AN UkrSSR. Issledovaniye plazmennykh sgustkov (Study of plasma clusters). Kiev, Naukova dumka, 1965, 37-53

TOPIC TAGS: plasmoid, plasma magnetic field, plasma interaction, controlled thermonuclear reaction, magnetohydrodynamics

ABSTRACT: The author discusses the conditions for effective collapse of a plasmoid, under conditions when the energy of the ions on the axes of the collapsing plasmoid can be maximal, since the collapse of plasmoids has been recently considered as a possible source of obtaining colliding fast ions on the axis, thereby generating neutrons of thermonuclear origin. Conditions are considered under which the energy of the ions on the axis can be maximal, and also under which the energy of the external alternating magnetic field can be transformed predominantly into the energy of the ionic component of the plasma. The analysis is based on the equations for the interaction between a small plasmoid and external fields, which are a further generalization of the equations of the model of the flexible current loop used to describe the interaction between a plasmoid and stationary fields. These in turn are a generalization of the equations of magnetohydrodynamics to include small limited plasma

Card 1/2

L 43917-66

ACC NR: AP6020400

formations. Equations for the self-inductance of the plasmoid, and the resistance of the plasmoid are derived and discussed, and conditions are given for ohmic and collisionless damping of the currents and the plasma, and for the frequency of the oscillations accompanying the collapse. Some of the results are compared with those obtained by others. Orig. art. has: 34 formulas.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 010/ OTH REF: 003

Card 2/2 JS

L 43916-66 EWT(l) IJP(c) AT/GD

ACC NR: AT6020401 (N)

SOURCE CODE: UR/0000/65/000/000/0053/0060

AUTHOR: Khizhnyak, N. A.; Vodyanitskiy, A. A.

ORG: none

76
B+1

TITLE: Heating of small plasmoids incident on an axially-symmetrical magnetic field

SOURCE: AN UkrSSR. Issledovaniye plazmennykh sgustkov (Study of plasma clusters). Kiev, Naukova dumka, 1965, 53-60

TOPIC TAGS: plasmoid, plasma heating, plasma interaction, plasma magnetic field, plasma oscillation, thermodynamic analysis

ABSTRACT: This is a continuation of earlier work (in: Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza, v. 4, Naukova dumka, Kiev, 1965) where it was shown that the equations of motion of a plasmoid can be represented in the hydrodynamic approximation in terms of the total current in the plasmoid and its self-induction. The present article deals with the heating of the plasmoid by the currents induced in it by the magnetic field. Since the magnetohydrodynamic equations for this case are quite complicated, the connection between the effective dimensions of the plasmoid and its thermodynamic quantities are determined under the assumption that the plasmoid has a sufficiently abrupt boundary with the vacuum and that the relaxation processes in the plasma are quite rapid and satisfy the equations of an ideal gas. The thermodynamic equations for the plasmoid are then written out on the basis of these approximations. The plasmoid is assumed spherical or spheroidal with

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ACC NR: AT6020401

small excentricity. Conditions under which the plasmoid entering the magnetic field will contract or expand, and the maximum and minimum values of the temperatures reached by the plasmoid, are then determined from the derived equations for several particular cases. Orig. art. has: 1 figure and 18 formulas.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 006

Card 2/2 JS

L 43915-66 EWT(l) IJP(c) AT/GD

ACC NR: AT6020402 (N) SOURCE CODE: UR/0000/65/000/000/0061/0068

AUTHOR: Cherkasova, K. P.; Khizhnyak, N. A.

58

β+1

ORG: none

TITLE: Coefficients of mutual inductance of coaxial spheroidal plasmoids

SOURCE: AN UkrSSR. Issledovaniye plazmennykh sgustkov (Study of plasma clusters). Kiev, Naukova dumka, 1965, 61-68

TOPIC TAGS: plasmoid, plasma magnetic field, plasma interaction, electric inductance

ABSTRACT: The method of flexible current loop for the analysis of interaction between plasmoids and specified magnetic fields, developed by the author earlier (in: Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza, v. 4, Naukova dumka, Kiev, 1965) is extended in this paper to describe the interaction between extended plasmoids with external magnetic fields. The extended plasmoid is represented in the form of a chain of coaxial cylindrical plasmoids which interact with one another. The individual links of the chain are chosen sufficiently small to be able to neglect the variation of the external magnetic field. The problem consists essentially of writing out the equation for the electric equilibrium for each of the individual plasmoids and determining the coefficients of mutual inductance and their behavior as functions of the plasmoid dimensions and the distances between their centers, since these coefficients are contained in the equation for the electric equilibrium. It is assumed in the determination of the inductance coefficients that only elec-

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L 43915-66

ACC NR: AT6020402

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tronic currents are excited in the plasmoid. The mutual inductance coefficient is first obtained for two spherical plasmoids, followed by calculation for oblate and prolate spheroids. The effect of certain approximations on the calculations are briefly discussed. Orig. art. has: 18 formulas.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 003/ OTH REF: 001

Card 2/2 pb

L 41068-66 EWT(1) IJP(c) GD/AT

ACC NR: AT6020411 (N) SOURCE CODE: UR/0000/65/000/000/0137/0148

58
B+1

AUTHOR: Khizhnyak, N. A.

ORG: none

TITLE: Plasma acceleration in crossed fields

SOURCE: AN UkrSSR. Issledovaniye plazmennykh sgustkov (Study of plasma clusters). Kiev, Naukovo dumka, 1965, 137-148

TOPIC TAGS: plasma acceleration, plasma injection, plasma gun, plasmoid, plasma density, plasma instability

2/

ABSTRACT: The present work considers the requirements for neutral plasma acceleration in crossed electric and magnetic fields. The analysis is performed for rail gun accelerators. It is shown that when the plasma density of the accelerated plasmoid is high, the plasmoid should be considered as an Ohmic load for typical circuit parameters employed in many experiments. If the density of plasma is low and the same circuit parameters are used, the load is capacitive. For the case of very low density or very low inductance circuit, the inductive characteristics of the plasma load emerge. The first two cases are considered in detail and examples are provided. It is found that the conditions for Ohmic loading of the gun by accelerating plasma are difficult to achieve. In the case of capacitive loading, 20% to 25% of the stored energy can be transferred

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ACC NR: AT6020411

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to the plasma, with the optimum plasmoid velocity being $(c/2)(E/H)$. Such loads are much more easy to achieve than Ohmic loads. It is also noted that account must be taken of the current variation in various portions of the plasmoid, which in turn may induce plasma instabilities which complicate the simplified behavior of plasma acceleration described above. Orig. art. has: 26 formulas, 1 figure.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 002

L 04833-67 EWT(1) IJP(c) AT/GD

ACC NR: AT6020450 (N) SOURCE CODE: UR/0000/65/000/000/0186/0195

AUTHOR: Repalov, N. S.; Khizhnyak, N. A. 63

B+1

ORG: none

TITLE: Longitudinal oscillations in multivelocity plasma beam

SOURCE: AN UkrSSR. Vzaimodeystviye puchkov zaryazhennykh chastits s plazmoy (Interaction of charged particle beams with plasma). Kiev, Naukova dumka, 1965, 186-195

TOPIC TAGS: plasma beam, motion equation, Euler equation, harmonic analysis, Debye length

ABSTRACT: One-dimensional oscillations in a compensated plasma beam with an arbitrary distribution function is studied. The equations of motion and fields and written for a collisionless plasma with a set of electrons traversing modulating grids. The ions are treated as a background charge compensating for the space charge. It is shown that the system can be described more simply by use of the Euler equation when the electron velocity spread is small. The equations are solved by an indirect method which is an extension of Bogolyubov's method, using Lagrange variables. This approach, described in considerable detail, leads to an expression for corrections to the initial current and density harmonics. The latter turn out to be coherence factors. This approach is applied to an example of Maxwellian distribution, where the coherence factors in the

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velocity space have the same sense and structure as coherence factors in the configuration space. Current and density harmonics are also derived as is the decay length of an n-th density harmonic. The method described is shown to be valid for those situations where the Debye radius is much smaller than the wavelength, since otherwise the nonlinear effect leads to nonoscillatory solutions. Orig. art. has: 16 formulas.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 004

Card 2/2 afs

L 04832-67 EWT(1) IJP(c) AT/GD
ACC NR: AT6020451 (N) SOURCE CODE: UR/0000/65/000/000/0195/0203

AUTHOR: Repalov, N. S.; Khizhnyak, N. A.

ORG: none

64
B+1.

2/

TITLE: Resonance propagation of an electron beam in a medium with a layered dielectric

SOURCE: AN UkrSSR. Vzaimodeystviye puchkov zaryazhennykh chastits s plazmoy (Interaction of charged particle beams with plasma). Kiev, Naukova dumka, 1965, 195-203

TOPIC TAGS: charged particle, electron beam, Lagrange equation, space charge

ABSTRACT: The demodulating mechanism of the space charge on the beam moving through a medium with a layered structure is investigated. The problem is treated in the hydrodynamic approximation. It is further assumed that the dielectric is transparent with respect to the beam particles and produces no dispersion. The dielectric boundaries are normal to the beam. The static fluctuations of beam electrons are compensated by an ion background moving with constant velocity. The motion is described in Lagrangian coordinates. The nonlinear nature of the equation permits only the consideration of the case of an infinitesimal modulation amplitude. Bogolyubov's method is employed to clarify the effect of nonlinearities in the case of the medium with one change in the dielectric constant (two-layer dielectric). It is found that resonance effects under some conditions lead to an unstable increase in the modulating amplitude. The restric-

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ACC NR: AT6020451

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tion of the problem to the region near the instability simplifies the equation under consideration. This solution reduces to that for beam bunching in klystrons where it is assumed that both dielectric layers have the same dielectric constant. Orig. art. has: 2 figures, 19 formulas.

SUB CODE: 20/ SUBM DATE: 11Nov65/ ORIG REF: 005/ OTH REF: 001

Card 2/2 afs

L 05787-67 EWT(1) IJP(c) AT

ACC NR: AT6033190 SOURCE CODE: UR/3137/65/000/270/0001/0020

AUTHOR: Khizhnyak, N. A.; Kalmykov, A. A.; Trubchaninov, S. A.; Naboka, V. A.

54
51
B+1

ORG: none

TITLE: On the adiabatic movement of plasma beams in a longitudinal magnetic field

2

SOURCE: AN UkrSSR. Fiziko-tekhnicheskiy institut. Doklady, no. 270/R057, 1965. K voprosu ob adiabatichnosti dvizheniya plazmennykh sgustkov v prodol'nom magnitnom pole, 1-20

TOPIC TAGS: plasma beam, longitudinal magnetic field, plasma density

ABSTRACT: The author discusses the entry mechanism of small plasma beams into an axially symmetrical magnetic field, depending on the particle density in the beam. The deductions from the theory are compared with an experimental study of magnetic moments of low- and high-density plasma beams. The experiments are found to agree with the theory on the substantial influence of plasma density on the magnetic moment of the plasma beam, and with the theory of the

Card 1/2

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3

dynamic interaction of beams with an axially symmetrical magnetic field. The model of a generalized current loop used in calculations can therefore be considered a satisfactory approximation of the description of plasma beams. In conclusion, the authors express their deep gratitude to K. D. Sinel'nikov, academician of the AN USSR, and to B. G. Safronov and V. S. Komel'kov for fruitful discussions which stimulated this work in many ways. Orig. art. has: 7 figures and 30 formulas.

SUB CODE: 20/ SUBM DATE: none/ ORIG REF: 013/ OTH REF: 006/

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L 11428-67 EWT(1)/EWT(m) IJP(c)

ACC NR: AP6021263 SOURCE CODE: UR/0057/66/036/009/1608/1621

AUTHOR: Khizhnyak, N.A.; Kalmykov, A.A.

47
43

ORG: none

21

TITLE: Dynamics of the current sheet and acceleration of plasma in an electrodynamic rail accelerator /9

SOURCE: Zhurnal tekhnicheskoy fiziki, v. 36, no. 9, 1966, 1608-1621

TOPIC TAGS: plasma gun, plasma acceleration, electromagnetic effect, mathematic physics

ABSTRACT: The authors discuss the production and acceleration of plasma in a rail accelerator having plane parallel electrodes. The problem is treated in one dimension, all quantities being assumed to depend only on the time and on one Cartesian coordinate, whose axis is parallel to the two electrodes and perpendicular to the electron current sheet, which is assumed to be initially present. The inertia of the electrons is neglected, and it is assumed that the electron Larmor radius is small compared with the electrode spacing. The electron motions are thus treated in the drift approximation when the plasma is rarefied, and with the effect of the Hall currents included when the plasma is dense. Ions are assumed to be formed in the current sheet and to lag behind, thus producing a longitudinal polarization field. It is shown that the form and magnitude of the polarization field play decisive roles in the shaping and

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6

acceleration of the plasma burst. To calculate the polarization field, the motion of the ions is described by the kinetic equation with a term representing the production of ions in the forward current sheet, and several simplifying assumptions are introduced, including the assumptions that the current sheet is thin and moves with constant velocity. It is shown that the polarization gives rise to longitudinal electrostatic waves in the plasma, and that as a result of these oscillations there are formed many closed current loops. An equation is derived relating the velocity of the center of mass of the plasma to that of the current sheet. The electrodynamic acceleration of the center of mass is described by equations similar to those of L.A. Artsimovich, C.Yu.Luk'yanov, I.P.Podgornyy, and S.A.Chuvatin (ZhETF, 33, 3, 1957) until the energy begins to be expended in the production of electrostatic oscillations. Whereas the energy of the plasma as a whole is determined by the total discharge current, the energy spectrum of the plasma particles depends significantly on the distribution of the current within the plasma. It is found that there is an optimum self-inductance for maximum acceleration efficiency, below which it is not desirable to reduce the parasitic inductance of the circuit. The authors thank K.D.Sinel'nikov, V.S.Komel'kov, A.I.Morozov, A.A.Rukhadze, B.G.Safronov, and M.I.Pergament for many fruitful discussions. Orig. art. has: 82 formulas and 1 figure.

SUB CODE: 20 SUBM DATE: --Sep66 ORIG. REF: 007 OTH REF: 011

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ACC NR: AP6031269 SOURCE CODE: UR/0057/66/036/009/1652/1664 63

**AUTHOR:** Khizhnyak, N.A.; Kalmykov, A.A.; Trubchaninov, S.A.; Naboka, V.A. 60

**ORG:** none

2/

**TITLE:** On the adiabaticity of the motion of plasma bursts in longitudinal magnetic fields

**SOURCE:** Zhurnal tekhnicheskoy fiziki, v. 36, no. 9, 1966, 1652-1664

**TOPIC TAGS:** hydrogen plasma, dense plasma, rarefied plasma, plasma dynamics, adiabatic process, plasma magnetic field, nonhomogeneous magnetic field, magnetic moment

**ABSTRACT:** This paper is concerned with the motion of plasma bursts along the axis of a longirudinally inhomogeneous axially symmetric magnetic field. The pliant current loop model, developed in a series of articles by N.A. Khizhnyak, V.G. Safronov, and K.D. Sinel'nikov (Sb. "Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza", t.I. Izd-vo AN UkrSSR, Kiyev, 1963; ibid. t. II, 1964; ZhTF, 35, 827, 1965; ZhTF, 35, 833, 1965), is generalized to take into account changes in the shape of the plasma. Equations of motion are derived under the simplifying assumptions that the deformation of the plasma is small, the plasma remains spheroidal (but may become either prolate or oblate), and the thermal expansion of the plasma during its interaction with the magnetic field is negligible. Particular attention is given to the magnetic moment of the plasma burst as a criterion of the adiabaticity of its motion. For a low density

Card 1/3

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plasma, the equations of the generalized pliant current loop model reduce to those of the independent particle model and the magnetic moment should remain constant as long as the usual adiabaticity condition is met. The magnetic moment of a dense plasma, on the other hand, should increase as the plasma moves into regions of higher magnetic field strength until it encounters a magnetic field of a critical strength, when the plasma should collapse and its magnetic moment should decrease rapidly. The theoretical predictions were tested experimentally. Hydrogen plasma bursts from a coaxial plasma gun, after traversing a 1 m long drift tube, entered the field of a series of six 17 cm long 8 cm inner diameter direct current solenoids, each capable of producing a 10 kOe field. The magnetic moments of the plasmas were measured with the aid of an external loop and internal magnetic probes that could be adjusted in the radial direction. The densities of the plasmas were determined with a shielded electrical probe, by cutoff of 3 and 0.8 cm microwaves, and with a 3 cm wavelength interferometer. The plasmas were found to behave in accordance with the theory. In particular, the magnetic moments of the plasmas with densities below $10^{12}$ $cm^{-3}$ remained constant until fields of the critical strength were encountered and then decreased monotonically and fairly rapidly, whereas the magnetic moments of the plasmas with densities above $10^{14}$ $cm^{-3}$ increased as the plasmas moved into regions of higher field strength, even though the independent particle adiabaticity condition was better satisfied by the high density plasmas than by the low density ones. It is concluded that the generalized current loop model provides a rather good approximate description of the behavior of plasma bursts. The work of several other investigators is discussed in the light of the present theory, and it is concluded that the plasma entrapment mechanism proposed

L 11421-67
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by J.L.Tuck (Phys. Rev. Lett., 3, 317, 1959) can be effective only under such conditions that the plasma traverses the magnetic field gradient region in a time shorter than the collapse time of the plasma, which is approximately the ratio of the plasma circumference to the Alfven velocity. The authors thank B.G.Safronov, V.S.Komel'kov, and Academician K.D.Sinel'nikov of the AN UkrSSR for fruitful discussions. Orig. art. has: 38 formulas and 7 figures.

SUB CODE: 20 SUBM DATE: 04Sept65 ORIG. REF: 011 OTH REF: 008

68-58-2-11/21

AUTHOR: Khizhnyak, N.D.

TITLE: The Determination of the Coefficient of Absorption of Naphthalene by Solar Oil (Opredeleniye koeffitsiyenta absorbtsii naftalina solyarovym maslom)

PERIODICAL: Koks i Khimiya, 1958, Nr 2, pp 47 - 49 (USSR)

ABSTRACT: The work was carried out in order to determine the influence of the velocity of gas and oil and the concentration of naphthalene in gas on the value of the absorption coefficient of naphthalene by the oil. The design of the apparatus in which the contact area between oil and gas can be exactly determined is described in some detail (Fig.1). The determination of naphthalene in gas was carried out by the polarographic method (Ref.3). The influence of the velocity of oil, i.e. density of spraying with oil on the coefficient of absorption (Fig.2) was found to be negligible. With increasing density of spraying from 0.4 to 2.4 $l/m^3$ the coefficient of absorption remained practically constant. The dependence of the coefficient of absorption of naphthalene on its concentration (Fig.3) was found to be of the form $K = f(c)^n$. The influence of gas velocity (from 0.1 to 0.8 m/sec), shown in Fig.4, can be expressed $K = f(v)$. On the basis of the experimental data, the following equation was derived:

Card1/2

68-58-2-11/21

The Determination of the Coefficient of Absorption of Naphthalene by Solar Oil

$$K = k\, v^{\alpha} \cdot c^{\beta} = 1.72 \cdot v^{1.78} \cdot c^{0.24}$$

Using this equation, the absorption coefficient for conditions corresponding to the works' condition was calculated. For gas velocity 0.8 m/sec, concentration of naphthalene in the incoming gas 0.4 $g/m^3$ the coefficient of absorption K = 0.950 . Using this coefficient, the required surface area of hurdles in an absorption column can be calculated. There are 1 table, 6 figures and 3 Soviet references.

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1. Naphthalene - Determination 2. Solar oil - Absorptive properties 3. Polarographic analysis - Applications