

$$\textcircled{1} \quad V = 500 \text{ dm}^3 = 0.5 \text{ m}^3$$

$$P = 200 \text{ Pa}$$

$$t = 20^\circ\text{C} \rightarrow T = 293 \text{ K}$$

$$\underline{M = 1 \text{ g/mol} = 1 \cdot 10^{-3} \text{ kg/mol u ATOMSKOM STANJU (H)}}$$

$$\text{a)} \quad m = ?$$

↪ treba nam molekulska, $\times 2$

b)

? br čestica
boltzmanova konst



$$\text{a)} \quad pV = N k_b T = nRT = \frac{m}{M} RT \Rightarrow m = \frac{pV M}{RT}$$

$$R = 8.314 \text{ J/mol K}$$

↪ molarna
masa

Avogardov
broj $\text{N}_A = 6,02 \cdot 10^{23} \text{ mol}^{-1}$

$$M = 2 \cdot (1 \cdot 10^{-3} \text{ kg/mol})$$

$$\boxed{m = 8.21 \cdot 10^{-5} \text{ kg}}$$

$$\text{b)} \quad N = ? \quad n = \frac{m}{M} = \frac{N}{N_A} \Rightarrow N = N_A \frac{m}{M} = 2.47 \cdot 10^{22} \parallel$$

subject:

(2) $n = 10^{18} \text{ m}^{-3}$

$$k_B T_e = 0.517 \text{ eV} \rightarrow \text{termalna energija elektrona}$$

(pretvarat u J kad koriste se formula)

$$k_B T_e = 0.517 \cdot 1.6 \cdot 10^{-19} \text{ J} = 8.272 \cdot 10^{-20} \text{ J}$$

$$e = 1.6 \cdot 10^{-19} \text{ C}$$

$$m_e = 9.11 \cdot 10^{-31} \text{ kg}$$

$$\epsilon_0 = 8.85 \cdot 10^{-12} \text{ F/m}$$

a) $\omega_{pe} = ?$ plazmena frekv.

$$\omega_{pe} = \sqrt{\frac{n e^2}{m_e \epsilon_0}} = \sqrt{10^{18} \cdot (1.6 \cdot 10^{-19})^2}$$

$$\boxed{\omega_{pe} = 5.634 \cdot 10^{10} \text{ s}^{-1}}$$

b) $\lambda_D = ?$

$$\lambda_D = \sqrt{\frac{\epsilon_0 k_B T_e}{n e^2}} = \sqrt{\frac{8.85 \cdot 10^{-12} \cdot 8.272 \cdot 10^{-20}}{10^{18} \cdot (1.6 \cdot 10^{-19})^2}}$$

$$\boxed{\lambda_D = 5.347 \cdot 10^{-6} \text{ m}}$$

c) $N_D = ?$

$$N_D = \frac{4}{3} \pi \lambda_D^3 n$$

$$\boxed{N_D \approx 640}$$

subject:

Da

$$\textcircled{3} \quad k_B T_e = k_B T_i = 800 \text{ eV} = 800 \cdot 1.6 \cdot 10^{-19} \text{ J} = 1.28 \cdot 10^{-16} \text{ J}$$

$$n_0 = 10^{23} \text{ m}^{-3}$$

$$V_{ei} = ?$$

$$e = 1.6 \cdot 10^{-19} \text{ C}$$

$$m_e = 9.11 \cdot 10^{-31} \text{ kg}$$

$$\varepsilon_0 = 8.85 \dots$$

$$V_{ei} = \frac{n \cdot e^4 \ln(12\pi N_D)}{32 \sqrt{\pi m_e} \varepsilon_0^2 (2k_B T_e)^{\frac{3}{2}}} \overset{15.35}{\text{---}}$$

$$N_D = \frac{4\pi}{3} \lambda_D^3 n_0$$

$$\lambda_D = \sqrt{\frac{\varepsilon_0 k_B T_e}{n_0 e^2}} = 6.652 \cdot 10^{-7} \text{ m}$$

$$N_D = 1.23 \cdot 10^5$$

$$V_{ei} = 5.79 \cdot 10^7 \text{ s}^{-1}$$

b) $\alpha = ?$

$$\alpha = \frac{16 \pi m_e \varepsilon_0^2 (k_B T_e)^{\frac{3}{2}}}{\sqrt{m_e} e^2} = 2.126 \cdot 10^{-22} \text{ S//}$$

Subject :

$$(4) n_0 = 10^{12} \text{ cm}^{-3} = 10^{18} \text{ m}^{-3} \quad \text{gustacia}$$

$$k_B T = 5 \text{ keV} = 8 \cdot 10^{-16} \text{ J}$$

$$v_{ei} = 2.8 \cdot 10^7 \text{ s}^{-1}$$

$$v_{ee} = 1.4 \cdot 10^7 \text{ s}^{-1}$$

$$m_e = 9.11 \cdot 10^{-31} \text{ kg}$$

$$\lambda_{SSD} = ?$$

$$\lambda_{SSD} = \frac{v_+}{\gamma} \quad \frac{mv_+^2}{2} = \frac{k_B T}{2} \rightarrow \begin{array}{l} \text{za 1 stupani} \\ \text{globale} \end{array}$$

$$\lambda_{SSD} = \frac{1}{v_{ee} + v_{ei}} \sqrt{\frac{k_B T}{m_e}}$$

$$v_+ = \sqrt{\frac{k_B T}{m_e}}$$

$$\boxed{\lambda_{SSD} = 0.706 \text{ m}}$$

$$(5) r_L = 7 \cdot 10^{-5} \text{ m}$$

$$B = 5 \text{ T}$$

$$a) v = ?$$

$$g \vec{v} \times \vec{B} \rightarrow \text{mag je olcomito}$$

$$g v B \sin \theta$$

$$b) \Omega = ?$$

contrary motion Lorentz force

$$\frac{mv^2}{r} = g v B$$

$$g = e = 1.6 \cdot 10^{-19} \text{ C}$$

$$r = r_L$$

$$m = m_e = 9.11 \cdot 10^{-31} \text{ kg}$$

$$v = \frac{e B r_L}{m_e}$$

$$\boxed{v = 6.15 \cdot 10^7 \text{ m/s}}$$

$$\Omega = \frac{g B}{m} = \frac{e B}{m_e} =$$

$$\boxed{\Omega = 8.78 \cdot 10^{11} \text{ s}^{-1}}$$

6 Ne - Te prostor

$$\text{jednačina prostora} \quad \frac{T_e^{3/2}}{n_e} = \frac{(\frac{\hbar}{2})^3}{(3m_e k)^{3/2}} / k^{\frac{3}{2}}$$

$$kT_e = 4 \text{ keV} = 6.4 \cdot 10^{-16} \text{ J}$$

$$n_e = 10^{14} \text{ cm}^{-3} = 10^{20} \text{ m}^{-3}$$

$$\frac{(kT_e)^{3/2}}{n_e} = \frac{(\frac{\hbar}{2})^3}{(3m_e)^{3/2}} \quad \begin{aligned} \hbar &= \frac{h}{2\pi} && \text{REDUCIRANA} \\ &&& \text{PLANCKOVA KONST.} \end{aligned}$$

$$h = 6.626 \cdot 10^{-34} \text{ Js} \rightarrow \text{PLANCKOVA KONST.}$$

$$m_e = 9.11 \cdot 10^{-31} \text{ kg}$$

$$\frac{(6.4 \cdot 10^{-16})^{3/2}}{10^{20}} = 1.62 \cdot 10^{-43}$$

$$\frac{(\frac{\hbar}{2})^3}{(3m_e)^{3/2}} = \frac{(\frac{h}{2\pi} \cdot \frac{1}{2})^3}{(3m_e)^{3/2}}$$

$$= 0.0323 \cdot 10^{(-102 - (-45))} = 0.0323 \cdot 10^{-57}$$

$$= 3.23 \cdot 10^{-59}$$

Kvantni efekti izraženiji kako temp. pada, a gustoća raste
(npr. metali)

Subject:

gustoća
bruja
ioniziranih
čestica

Date :...../...../.....

$$\textcircled{7} \quad \frac{n_i}{n_n} \approx 2.4 \cdot 10^{21} \frac{T^{\frac{3}{2}}}{n_i} e^{-\frac{U_i}{kT}}$$

$\checkmark \rightarrow \text{neutralne}$

stupanj
ionizacije $U_i = 14.5 \text{ eV} =$
 $T = 300 \text{ K}$

$$1 \text{ eV} = 1.6 \cdot 10^{-19} \text{ J}$$

$$k = 1.38 \cdot 10^{-23} \text{ J/K}$$

$$\hookrightarrow 1 \text{ eV} \sim 11600 \text{ K}$$

$$300 \text{ K} : 11600 \text{ K} = x : 1 \text{ eV}$$

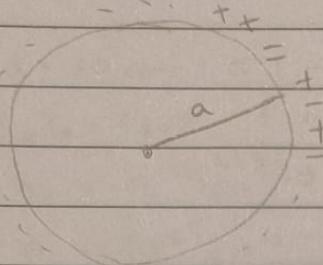
$$x = 0.0259 \text{ eV}$$

$$\frac{n_i}{n_n} \approx 2.4 \cdot 10^{21} \cdot \frac{300^{\frac{3}{2}}}{n_i} e^{\underbrace{-\frac{14.5 \text{ eV}}{0.0259 \text{ eV}}}_{e^{-560}}} \\ e^{-560} = (e^{-56})^{10}$$

$$\frac{n_i}{n_n} \approx 10^{-122}$$

\hookrightarrow nije plazma

(8)



JEDNOSTRUKA IONIZACIJA

IONI NEPOKRETNI
ELEKTRONI SE GIBAJU

$$n_i = n_0$$

$$k_B T_e \gg e\phi$$

$$n_e = n_0 e$$

$$n_e \approx n_0 \left(1 + \frac{e\phi}{k_B T_e}\right)$$

$$\frac{e\phi}{k_B T_e}$$

$$J = e(n_i - n_e) = e(n_0 - n_0 - n_0 \frac{e\phi}{k_B T_e}) = -e \frac{n_0 e^2 \phi}{k_B T_e}$$

POISSONOVA JDBA

$$\nabla^2 \phi = -\frac{J}{\epsilon_0} \quad \text{JER} \quad \vec{\nabla} \cdot \vec{E} = \frac{J}{\epsilon_0}$$

$$\vec{E} = -\vec{\nabla} \phi$$

$$\nabla^2 \phi = -\frac{J}{\epsilon_0} = -\frac{1}{\epsilon_0} \left(-\frac{n_0 e^2 \phi}{k_B T_e} \right)$$

$$\nabla^2 \phi = \frac{n_0 e^2}{\epsilon_0 k_B T_e} \phi, \quad \lambda_D = \sqrt{\frac{\epsilon_0 k_B T_e}{n_0 e^2}}$$

$$\nabla^2 \phi = \frac{1}{\lambda_D^2} \phi \quad \rightarrow \quad \nabla^2 \phi - \frac{1}{\lambda_D^2} \phi = 0 \quad \text{JDBA za } \phi$$

$$\phi = \frac{A}{r} e^{-r/\lambda_D} + \frac{B}{r} e^{r/\lambda_D}$$

Poč. uvjeti

$$r \rightarrow \infty, \phi \rightarrow 0 \Rightarrow B = 0$$

$$r \rightarrow a, \phi \rightarrow \phi_s \quad \text{ili} \quad \phi_s = \frac{A}{a} e^{-a/\lambda_D} \Rightarrow A = \frac{a \phi_s}{e^{-a/\lambda_D}}$$

$$A = a \phi_s e^{\frac{a}{\lambda_D}}$$

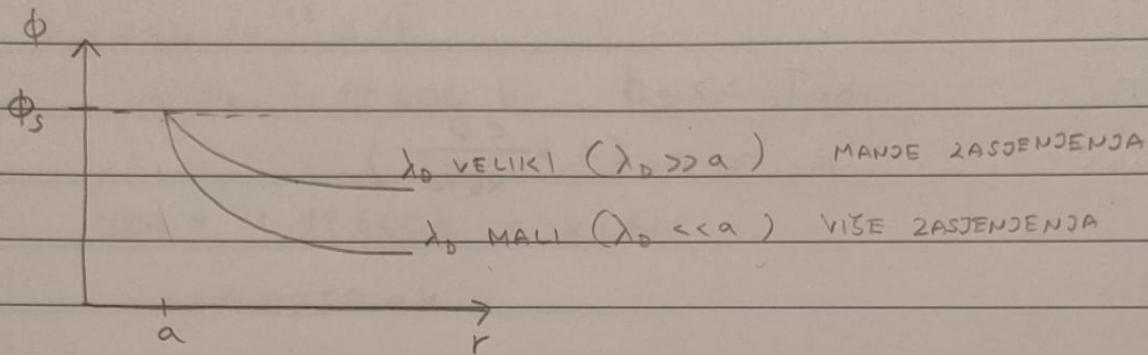
KON. RJ

$$\phi = \frac{A}{r} e^{-r/\lambda_D} = a \phi_s e^{a/\lambda_D} e^{-r/\lambda_D}$$

$$b) \lambda_D \ll a \Rightarrow \phi = \frac{a\phi_s}{r} e^{a/\lambda_D} e^{-r/\lambda_D}$$

$$\lambda_D \gg a \Rightarrow \phi = \frac{a\phi_s}{r} e^{\cancel{a/\lambda_D}} e^{-r/\lambda_D} = \frac{a}{r} \phi_s e^{-r/\lambda_D}$$

$$\lambda_D = \sqrt{\frac{\epsilon_0 k_B T_e}{n_0 e^2}}$$



$$c) \iint_S \vec{E} \cdot d\vec{s} = \frac{A}{\epsilon_0} \iiint_V g dV$$

$$E \cdot 4\pi a^2 \epsilon_0 = \frac{Q_{SFERE}}{\epsilon_0}$$

$$E = -\frac{\partial \phi}{\partial r} = -\left(-\frac{a}{r^2} \phi_s e^{a/\lambda_D} e^{-r/\lambda_D} + \frac{a}{r} \phi_s e^{a/\lambda_D} e^{-r/\lambda_D} \cdot \left(-\frac{1}{\lambda_D}\right) \right)$$

$$= \frac{a}{r^2} \phi_s e^{a/\lambda_D} e^{-r/\lambda_D} \left(1 + \frac{a}{\lambda_D}\right) \quad \rightarrow \text{izgled el. polja}$$

$$\begin{aligned} Q_{SFERE} &= 4\pi a^2 \epsilon_0 E(a) \\ &= 4\pi a^2 \epsilon_0 \left(\frac{a}{r^2} \phi_s e^{a/\lambda_D} e^{-a/\lambda_D} \cdot \underbrace{\left(1 + \frac{a}{\lambda_D}\right)}_{e^0 = 1} \right) \\ &= 4\pi \epsilon_0 a \phi_s \left(1 + \frac{a}{\lambda_D}\right) \end{aligned}$$

KAPACITET

$$C = \frac{Q}{V} = \frac{4\pi \epsilon_0 a \phi_s \left(1 + \frac{a}{\lambda_D}\right)}{\phi_s - \phi_\infty} = 4\pi \epsilon_0 a \left(1 + \frac{a}{\lambda_D}\right)$$

↓
0

d) $a = 10 \text{ cm} = 0.1 \text{ m}$

$$k_n T_e = 1 \text{ keV} = 1 \cdot 10^3 \text{ eV} = 10^3 \cdot 1.6 \cdot 10^{-19} \text{ J}$$

1) $n_o = 10^{19} \text{ cm}^{-3}$

2) $n_o = 10^6 \text{ cm}^{-3}$

USPOREDITI S C U VAKUUMU

$$\lambda_0 = \sqrt{\frac{\epsilon_0 k_B T_e}{n_o e^2}}$$

① $\lambda_0 \gg a \Rightarrow C = 4\pi \epsilon_0 a \left(1 + \frac{a}{\lambda_0}\right)$

$$C = 4\pi \epsilon_0 a \quad \hookrightarrow \text{zanemarivo}$$

② $\lambda_0 \ll a \Rightarrow C = 4\pi \epsilon_0 a \left(1 + \frac{a}{\lambda_0}\right) = \frac{4\pi \epsilon_0 a^2}{\lambda_0}$

1) $\lambda_0 = 2.35 \cdot 10^{-3} \text{ cm} \Rightarrow C = 4.7 \cdot 10^{-8} \text{ F}$

2) $\lambda_0 = 23.4 \text{ cm} \Rightarrow C = 1.6 \cdot 10^{-11} \text{ F}$

$$C = \frac{Q}{V} \quad \Phi_s = \frac{Q}{4\pi \epsilon_0 a}$$

$$C = \frac{\Phi_s 4\pi \epsilon_0 a}{\Phi_s}$$

$$C = 4\pi \epsilon_0 a = 1.11 \cdot 10^{-11} \text{ F}$$

① KRATKA $\lambda_0 \rightarrow$ velika n_o ($\lambda_0^2 \sim \frac{1}{n_o}$) \Rightarrow DIELEKTRIK

②

\hookrightarrow u zadacima je najčešće zadan potencijal