Group work 2 March

1. The number of electrons in a Debye sphere for $n = 10^{17}\ \mathrm{m}^{-3}$, $KT_e = 10$ eV is approximately

(A) .---- ...-- .....

(B) ----- .-.-.- .---- ....-

(C) -.--. --... .-.-.- ....- -.--.- * -.--. .---- ----- -.--.- ^ ...—

(D) -.--. .---- .-.-.- --... -.--.- * -.--. .---- ----- -.--.- ^ .....

(E) -.--. ...-- .-.-.- ..... -.--.- * -.--. .---- ----- -.--.- ^ .---- -----

2. The electron plasma frequency in a plasma of density $n = 10^{20}\ \mathrm{m}^{-3}$ is

(A) 90 MHz
(B) 900 MHz
(C) 9 GHz
(D) 90 GHz
(E) None of the above to within 10 %

3. In 2013, the Voyager 1 spacecraft left the heliosphere, the region dominated by solar winds, and entered outer space. The plasma frequency jumped from 2.2 to 2.6 kHz. What was the change in plasma density?

4. Dusty plasma in Jupiter magnetosphere has the parameters:

$$Z_d \approx 10^3,\ m_d \approx 2 \times 10^{-12}\ \mathrm{g},\quad n_{d0} \approx 10^{-9}\mathrm{cm}^{-3}$$

$$T_e \approx 5 - 22\ \mathrm{eV},\ T_i \approx 60 - 120\ \mathrm{eV},\ n_{e0} \approx 1 - 23 \times 10^3\mathrm{cm}^{-3}$$

Calculate the following:

i. Debye length
ii. Dust frequency
iii. Intergrain distance

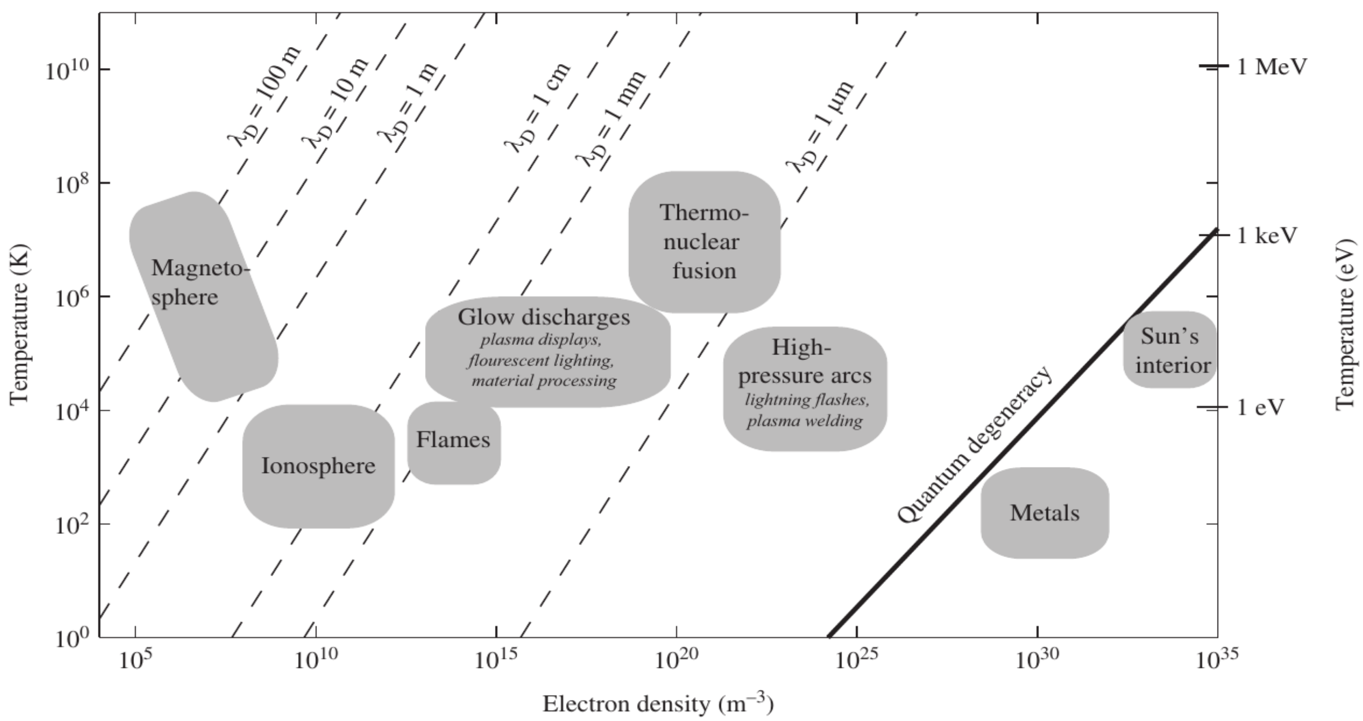
iv. **What is the kind of dusty plasma? Dust-in-plasma or dusty plasma**

5.

a) In the following figure, why do we consider the bold line as a border between classical and quantum plasma regimes?

b) Why do we consider the plasma in the Sun's interior and metals as quantum degeneracy state?

c) Using the following figure to calculate the plasma frequency in each application.



1. The number of electrons in a Debye sphere for $n = 10^{17}$ m^{-3}, $KT_e = 10$ eV is approximately

(A) 135
(B) 0.14
(C) 7.4×10^3
(D) 1.7×10^5
(E) 3.5×10^{10}

Ans.

```
In[5]:=
KTe = 10.0;
n = 10^17;
λd = 7430 (KTe/n)^(1/2)
Nd = n (4/3) π λd^3
Out[7]= 0.0000743
Out[8]= 171813.
In[9]:= ScientificForm[Nd]
Out[9]//ScientificForm=
1.71813×10^5
```

2. The electron plasma frequency in a plasma of density $n = 10^{20}$ m^{-3} is

(A) 90 MHz
(B) 900 MHz
(C) 9 GHz
(D) 90 GHz
(E) None of the above to within 10 %

Ans.

```
In[1]:= n = 10^20;
fp = 9 √n
Out[2]= 90000000000
In[3]:= ScientificForm[N[fp, 11]]
ut[3]//ScientificForm=
9.0000000000×10^10
```

3. In 2013, the Voyager 1 spacecraft left the heliosphere, the region dominated by solar winds, and entered outer space. The plasma frequency jumped from 2.2 to 2.6 kHz. What was the change in plasma density?

```
In[1]:= (* fp=9√n *)
f1 = 2.2*10^3;
f2 = 2.6*10^3;
n1 = (f1/9)^2
n2 = (f2/9)^2

Out[3]= 59753.1

Out[4]= 83456.8
```

Plasma density increased.

---

4. Dusty plasma in Jupiter magnetosphere has the parameters:

$$Z_d \approx 10^3,\ m_d \approx 2\times10^{-12}\ \mathrm{g},\quad n_{d0} \approx 10^{-9}\mathrm{cm}^{-3}$$

$$T_e \approx 5 - 22\ \mathrm{eV},\ T_i \approx 60 - 120\ \mathrm{eV},\ n_{e0} \approx 1 - 23\times10^3\mathrm{cm}^{-3}$$

Calculate the following:

i. **Debye length**

```
In[13]:= (* λd = λdi λde / √(λdi^2+λde^2) , λd=λde *)
ne1 = 1*10^3;
Te1 = 5.0;
ne2 = 23*10^3;
Te2 = 22.0;
λd1 = 740 √(Te1/ne1)
λd2 = 740 √(Te2/ne2)

Out[17]= 52.3259

Out[18]= 22.8865
```

ii. **Dust frequency**

```
e = 4.8 * 10^-10;
Zd = 10^3;
nd0 = 10^-9;
md = 2 * 10^-12;
```

$$\omega pd = \sqrt{\frac{4\,\pi\, nd0\, Zd^2\, e^2}{md}}$$

Out[23]= 0.0000380479

iii. **Intergrain distance**

iv. **What is the kind of dusty plasma? Dust-in-plasma or dusty plasma.**

```
nd0 = 10^-9;
(*  is the intergrain distance *)
```

$$a = nd0^{-\frac{1}{3}}$$

```
1000
(*  λd<a , charged dust particles are considered as a
 collection of isolated dust grains,
" Dust in plasma" *)
```

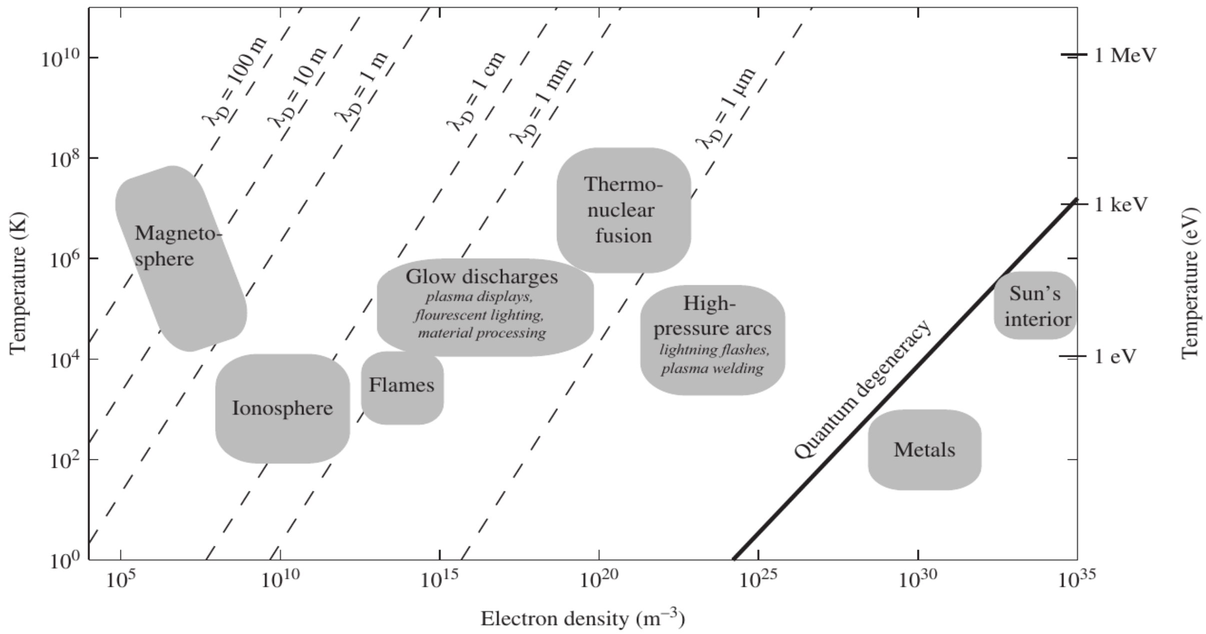
5.

a) In the following figure, why do we consider the bold line as a border between classical and quantum plasma regimes?

b) Why do we consider the plasma in the Sun's interior and metals as quantum degeneracy state?

a-b) classical treatment will not be valid because De Broglie wavelength of plasma particles is comparable to Debye length, so wave functions of particles will interfere.

c) Using the following figure to calculate the plasma frequency in each application.



In[9]:= (*Magnetosphere*)

$f1 = 9.0\sqrt{10^7}$

Out[9]= 28 460.5

In[10]:= (*Ionosphere*)

$f2 = 9.0\sqrt{10^{10}}$

Out[10]= 900 000.

In[11]:= (*Flames*)

$f3 = 9.0\sqrt{10^{14}}$

Out[11]= $9. \times 10^7$

In[13]:= (*Glow discharge*)

$f4 = 9.0\sqrt{10^{16}}$

Out[13]= $9. \times 10^8$

In[14]:= (*Thermonuclear fusion*)

$f5 = 9.0\sqrt{10^{21}}$

Out[14]= 2.84605×10^{11}

In[17]:= (*High pressure arcs*)

$f6 = 9.0\sqrt{10^{23}}$

Out[17]= 2.84605×10^{12}

In[18]:= (*Metals*)

$f7 = 9.0\sqrt{10^{30}}$

Out[18]= $9. \times 10^{15}$

In[20]:= (*Sun's interior*)

$f8 = 9.0\sqrt{10^{34}}$

Out[20]= $9. \times 10^{17}$

Constants & Formulas

Constants			
		mks	cgs
c	Velocity of light	3×10^{8} m/s	3×10^{10} cm/s
e	Electron charge	1.6×10^{-19} C	4.8×10^{-10} esu
m	Electron mass	0.91×10^{-30} kg	0.91×10^{-27} g
M	Proton mass	1.67×10^{-27} kg	1.67×10^{-24} g
M/m		1837	1837
$(M/m)^{1/2}$		43	43
K	Boltzmann's constant	1.38×10^{-23} J/K	1.38×10^{-16} erg/K
eV	Electron volt	1.6×10^{-19} J	1.6×10^{-12} erg
1 eV	Of temperature KT	11,600 K	11,600 K
ϵ_0	Permittivity of free space	8.854×10^{-12} F/m	
μ_0	Permeability of free space	$4\pi \times 10^{-7}$ H/m	

Formulas (H) for hydrogen				
		mks	cgs-Gaussian	Handy formula (n in cm^{-3})
ω_p	Plasma frequency	$\left(\frac{ne^2}{\epsilon_0 m}\right)^{1/2}$	$\left(\frac{4\pi ne^2}{m}\right)^{1/2}$	$f_p = 9000\sqrt{n}\,s^{-1}$
ω_c	Electron cyclotron frequency	$\frac{eB}{m}$	$\frac{eB}{mc}$	$f_c = 2.8$ GHz/kG
λ_D	Debye length	$\left(\frac{\epsilon_0 KT_e}{ne^2}\right)^{1/2}$	$\left(\frac{KT_e}{4\pi ne^2}\right)^{1/2}$	$740(T_{eV}/n)^{1/2}$ cm
r_L	Larmor radius	$\frac{mv_\perp}{eB}$	$\frac{mv_\perp c}{eB}$	$\frac{1.4\,T_{ev}^{1/2}}{B_{kG}}$ mm(H)

Dusty plasma Debye Radius:

$$\lambda_D = \frac{\lambda_{De}\lambda_{Di}}{\sqrt{\lambda_{De}^2 + \lambda_{Di}^2}}.$$

Dust plasma frequency:

$$\omega_{pd} = (4\pi n_{d0} Z_d^2 e^2 / m_d)^{1/2}.$$