NPRE 321 HW 5

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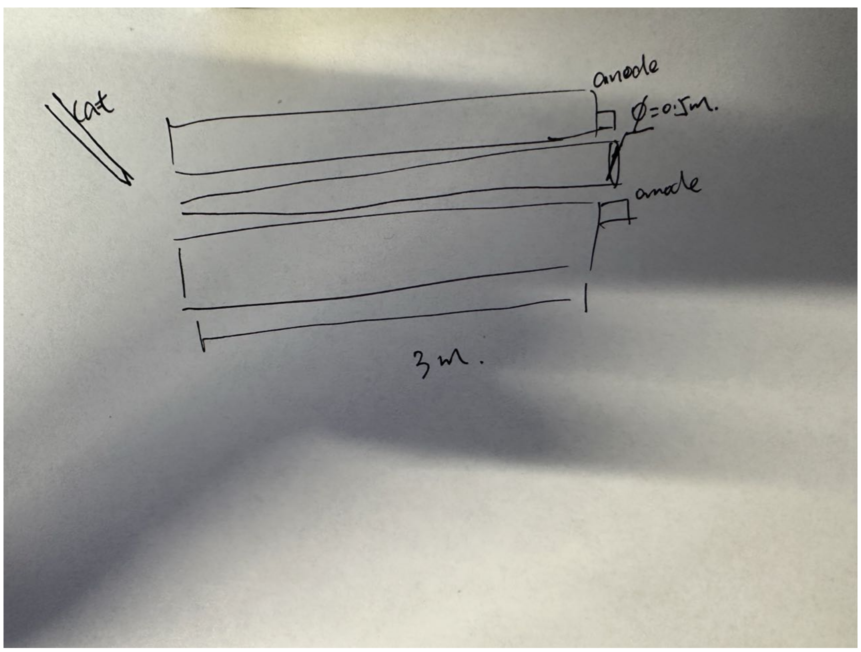
1.

a)



b)

$$\tau = \frac{R^2}{2D_b} = \frac{R^2}{2\left(\frac{kT_e}{16eB}\right)}$$
$$= \frac{0.25}{\frac{1.602\times10^{-19}\times5}{8\times1.602\times10^{-19}\times1}}$$
$$= 0.4\text{s}$$

c)

$$
\begin{aligned}
v^2 &= 2E/m \\
v &= \sqrt{2\frac{kT}{m}} \\
&= \sqrt{2 \times \frac{1.602 \times 10^{-19} \times 5}{1.007276 \times 1.661 \times 10^{-27}}} \\
&= 3.094 \times 10^4 \text{ m/s} \\
v_\perp &= \frac{1}{\sqrt{2}} v = 2.1878 \times 10^4 \text{m/s} \\
r &= \frac{vm}{qB} \\
&= \frac{2.1878 \times 10^4 \times 1.007276 \times 1.661 \times 10^{-27}}{1.602 \times 10^{-19} \times 1} \\
&= 3.66043 \times 10^{-23} \text{m}
\end{aligned}
$$

d)

$$
\begin{aligned}
\lambda_D &= \sqrt{\frac{\varepsilon_0 kT}{ne^2}} \\
&= \sqrt{\frac{8.854 \times 10^{-12} \times 1.602 \times 10^{-19} \times 5}{10^{20} \times (1.602 \times 10^{-19})^2}} \\
&= 1.6623 \times 10^{-6} \text{m} \\
\Lambda &= 12\pi n \lambda_D^3 \\
&= 12\pi 10^{19} \times (1.6623 \times 10^{-6})^3 \\
&= 1731.82 \\
\lambda_0 &= 3.4 \times 10^{13} \frac{T^2}{n \ln(\Lambda)} \\
&= 3.4 \times 10^{13} \times \frac{5^2}{10^{19} \ln(1731.82)} \\
&= 1.13 \times 10^{-5}
\end{aligned}
$$

e) The mean free path will dominant collisions.
$3/1.13 \times 10^{-5} = 2.63 \times 10^5$

2.

Semiconductor: Plasmas are extensively used in micro-fabrication processes, which involve patterning materials to create integrated circuits. Key processes include: Plasma Etching: Removing unwanted material to create patterns on silicon wafers. For instance, CF_4 gas is used to etch silicon (Si), where the plasma breaks molecular bonds, releasing free

fluorine (F) atoms. These atoms react with silicon to form volatile SiF_4 gas, which can be pumped away. To ensure thorough etching, O_2 is added to remove carbon residues, although careful control of gas mixtures is needed to avoid unwanted reactions. Plasma Deposition: Used to lay down thin films. This can be achieved through methods like:
Sputtering: A plasma ionizes gas (like argon), and the energetic ions bombard a target material, ejecting atoms that coat a substrate.
Chemical Vapor Deposition (CVD): Plasma assists in breaking down gases to deposit materials at lower temperatures, enhancing efficiency and creating chemically reactive species.

Surface Treatment: Plasma-Assisted Sputtering: Using reactive sputtering, materials like titanium (Ti) are combined with gases such as nitrogen (N_2) to create compounds like titanium nitride (TiN). This compound, often golden in color, coats tools for increased wear resistance.
Ion Implantation: Energetic ions from the plasma embed into the surface, altering its properties. High-energy plasma ions can also sputter away surface contaminants or create textured surfaces for specific applications.

source type:

1. Direct Current (DC) Plasmas: Simple to set up, with low density and temperature, ideal for straightforward applications. However, they tend to have high contamination and are used where uniformity is not critical.
2. Radiofrequency (RF) Plasmas: Commonly used in plasma processing, including: Capacitively Coupled Plasma (CCP): Simple to construct, suitable for processes without magnetic fields, but with lower plasma density.
   Inductively Coupled Plasma (ICP): Higher density and more uniform, making it suitable for etching and deposition where precision is needed. However, these setups are complex and require extensive cooling and pumping.
   Helicon Plasmas: Specialized ICPs with higher densities and uniform profiles, used in applications requiring fine control over plasma properties.
3. Magnetron Plasmas: Use microwave energy to create a high-density plasma near a cathode, ideal for sputtering. They allow for the deposition of metals, oxides, and insulating materials with uniform layers, although plasma density is relatively low.
4. Vacuum Arc Discharges: Produce fully ionized plasma for high-rate deposition with low substrate temperatures. However, they risk contamination and require magnetic filtering.