Introduction to Nuclear Fusion (409.308A)

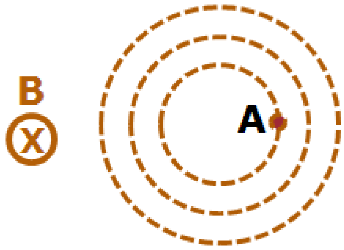
Final Examination

18 December, 2018

1. The magnetic field in a tokamak can be expressed as

$$B(r,\theta) = B_\theta(r,\theta)\hat{\theta} + B_\phi(r,\theta)\hat{\phi} = \frac{B_0}{1+\varepsilon\cos\theta}$$

(a) (10 points) Draw possible trajectories of a plasma ion placing initially at A on a poloidal plane shown below where the magnetic flux surfaces are indicated as dashed circles. The direction of the magnetic field is into the page.



(b) (20 points) The perpendicular particle diffusivity of fully ionised cylindrical plasmas can be derived as

$$D_\perp = \frac{\eta_\perp n \sum kT}{B^2}.$$

However it does not agree with experimental observations in tokamaks. Explain why.

2. The electromagnetic plasma wave can be described as below for plane waves with wave vector **k** and frequency ω for cold plasmas without external magnetic fields.

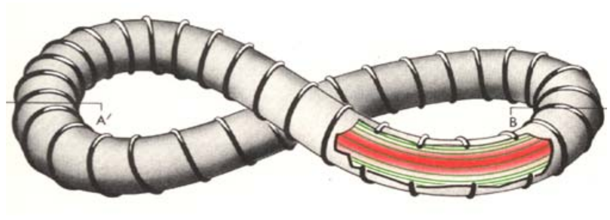
$$-\vec{k}(\vec{k}\cdot\vec{E}) + k^2\vec{E} + \mu_0\left(\sum_j \frac{n_j q_j^2}{m_j}\right)\vec{E} - \frac{\omega^2}{c^2}\vec{E} = 0$$

(a) (10 points) Which angle can **k** have against **E**?

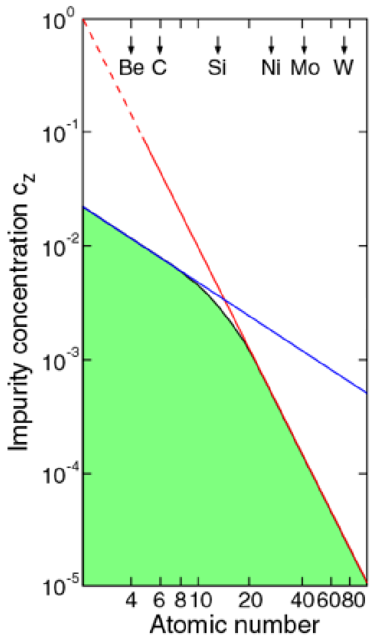
(b) (20 points) Derive dispersion relations.

3. (10 points) Calculate the Kruskal-Shafranov current upper limit set by the external kink mode for KSTAR where the major radius is 1.8 m, the minor radius 0.5 m, the toroidal magnetic field 3.5 T, and the plasma current 2 MA. Assume that $2\pi/\mu_0 = 5$.

4. (10 points) Explain how plasma particles can be confined in the system below.



5. (10 points) The choice of the plasma facing material is limited by the red and the blue curve in the figure below. Write down what these limitations are.



6. (10 points) Explain how the divertor removes the impurities in tokamak plasmas.

"Ask and it will be given to you;
seek and you will find;
knock and the door will be opened to you" (Matthew 7:7)

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