

## 22.106 Neutron Interactions and Applications (Spring 2005)

**Term Quiz (closed book)**

**May 5, 2005**

### **Problem 1 (25%)**

Consider neutron elastic scattering at various incident energies in polycrystalline carbon at temperature T.

- Consider the scattering probability  $F(E' \rightarrow E)$  where  $E'$  and  $E$  are the incident and outgoing energies respectively. Explain why  $F$  should not depend on  $E'$  and  $T$  separately, but only on their ratio. Sketch  $F(E' \rightarrow E)$  as a function of  $E$  at three values of  $E'/k_B T$ ,  $\ll 1$ ,  $\sim 1$ , and  $\rightarrow \infty$ .
- Sketch the scattering cross section in the neutron energy range  $10^{-3}$  to  $0.1$  eV. Explain all the characteristic features of the cross section in this energy range, in particular indicate for each feature whether it is temperature dependent or not.

### **Problem 2 (20%)**

Discuss (explain) each of the following, then describe schematically how you would determine the quantity in question by MCNP:

- The escape probability of neutron slowing down across an arbitrary energy interval ( $E'$ ,  $E$ ) in a scattering and absorbing medium. Give an expression for this probability.
- The extrapolated boundary condition for the neutron flux in a spherical reactor with radius  $R$ . State the boundary condition.

### **Problem 3 (25%)**

- Define the Helmholtz free energy of a system. What makes this quantity difficult to calculate? Explain what is the thermodynamic definition of crystal melting. If you know the free energy, is this enough information to discuss the kinetics of melting?
- Explain how does a system evolve in Monte Carlo and molecular simulations. Explain how these simulations can be used to investigate the phenomenon of melting. What properties would be the same, and what would be different between MC and MD

### **Problem 4 (30%)**

- Describe schematically (but with mathematical expressions) how one can apply the Born approximation and Fermi pseudopotential to determine the scattering amplitude for neutron scattering by a system of  $N$  nuclei. (In your equations do not worry about factors that are irrelevant for a qualitative explanation.)
- Explain the difference between **coherent** and **incoherent** scattering in neutron scattering by taking an average of the scattering intensity  $I$  (over spin orientation and isotope abundance),

$$\bar{I} = \overline{\sum_{\ell} \sum_{\ell'} a_{\ell} a_{\ell'} \psi^*(\ell) \psi(\ell')}$$

where  $a_{\ell}$  is the scattering length of nucleus  $\ell$ , and  $\psi(\ell)$  is the scattered wave from this nucleus.