

NAME: _____

33-448 Solid State Physics Midterm #1 Wednesday, Feb. 10, 2016

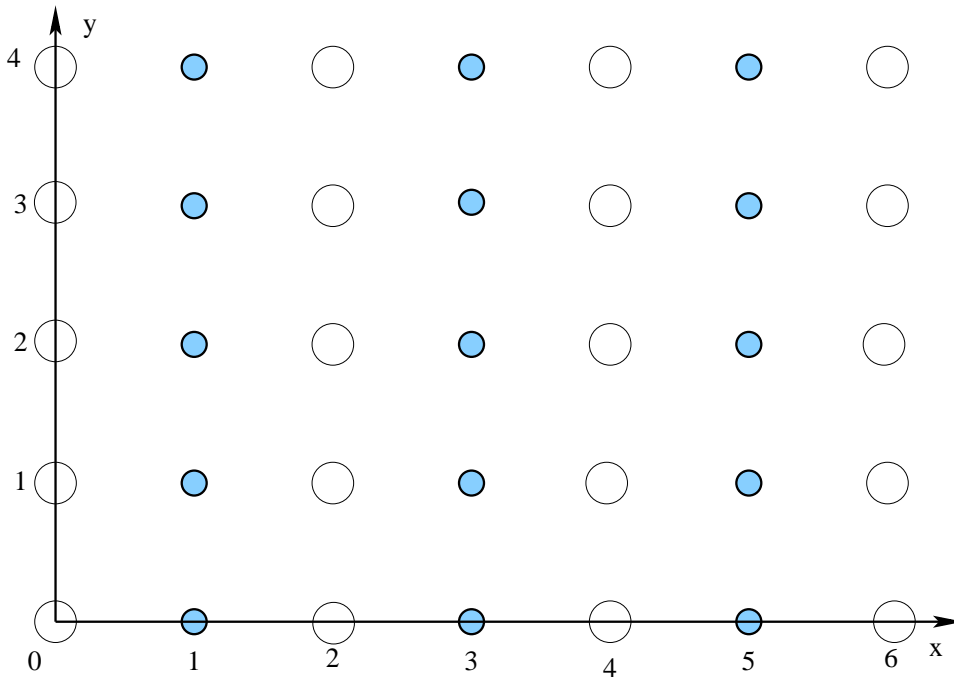
1. For the following problem you may find the following equations useful:

$$n(\vec{r}) = \sum_{\vec{G}} n_{\vec{G}} e^{i\vec{G}\cdot\vec{r}} \quad n_{\vec{G}} = \frac{1}{V_c} \int d^3\vec{r} n(\vec{r}) e^{-i\vec{G}\cdot\vec{r}}$$

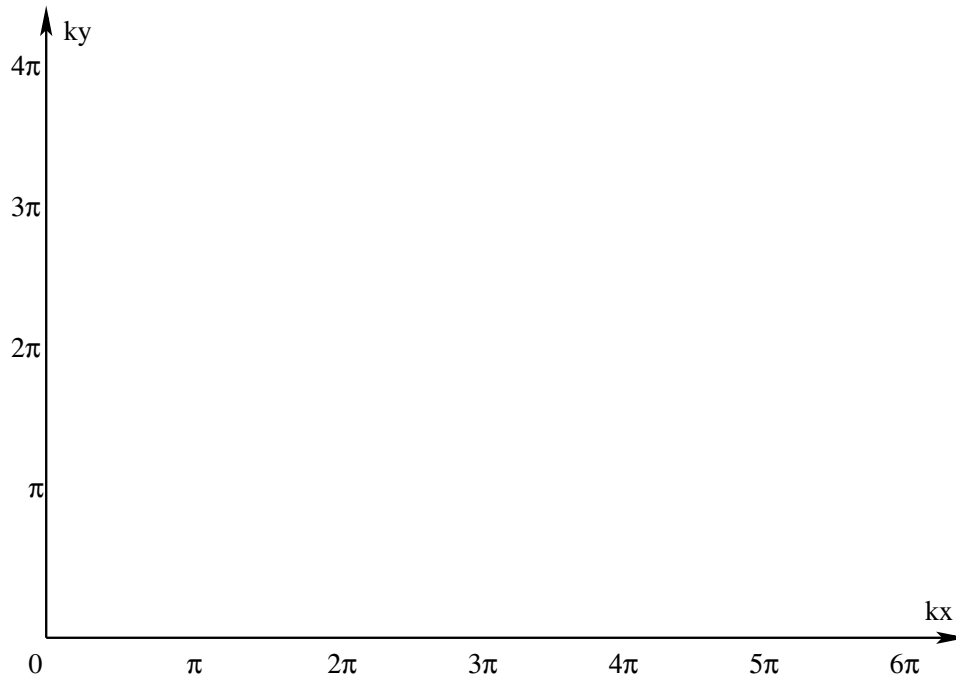
$$f = \int d^3\vec{r} n(\vec{r}) e^{-i\vec{G}\cdot\vec{r}} \quad S_{\vec{G}} = \sum_j f_j e^{-i\vec{G}\cdot\vec{r}}$$

$$n\lambda = 2d \sin \theta \quad \Delta\vec{k} = \vec{G}$$

(a) In the hypothetical 2D crystal structure shown below, the large and small atoms are of different types, respectively gallium (Z=31) and arsenic (Z=33). Draw the outline of one unit cell. Write expressions for the primitive translation vectors \mathbf{a}_1 and \mathbf{a}_2 and draw these on the figure. Draw and label lattice planes of Miller indices (1,0) (0,1) (1,1) (1,2) (2,1). Write the unit cell basis $\{\mathbf{R}_i, Z_i\}$.



(b) Write expressions for the primitive reciprocal lattice vectors \mathbf{b}_1 and \mathbf{b}_2 . On the axes shown below, plot points at the locations of diffraction peaks of Miller indices (1,0) (0,1) (1,1) (1,2) (2,1). Please be careful to place the points accurately, and label them. For each peak state the position in reciprocal space and the value of the structure factor S_G .

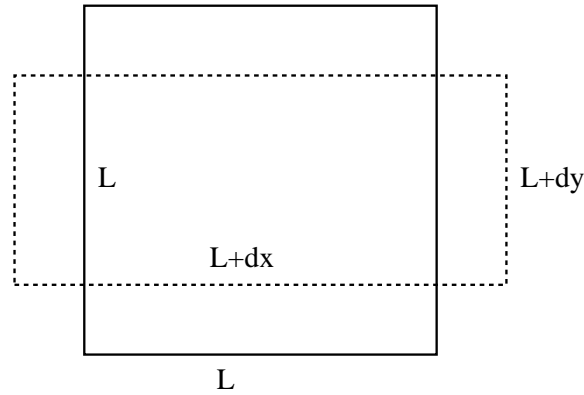


(c) Owing to electronegativity differences, arsenic can draw an electron from gallium. What extinctions (vanishing peaks) would occur in this case?

2. (adapted from Kittel #3.8) Recall the Voigt notation,

$$\begin{array}{ll}
 xx \rightarrow 1 & yz \rightarrow 4 \\
 yy \rightarrow 2 & zx \rightarrow 5 \\
 zz \rightarrow 3 & xy \rightarrow 6
 \end{array}$$

and the fact that for cubic symmetry the elastic tensor has only three independent constants, C_{11} , C_{12} , and C_{44} . Consider the following figure of an $LxLxL$ cube stretched by $dx > 0$ that spontaneously shrinks by $dy = dz < 0$. Stresses lie along the x direction but not y or z . The material is a cubic crystal whose symmetry axes are aligned with the cube.



(a) Derive an expression for the Poisson ratio $\nu \equiv -dy/dx$ in terms of the constants C_{ij} .

(b) Derive an expression for the Young's modulus $E \equiv \sigma_1/e_1$.

3. (Adapted from Kittel, “Elastic waves in cubic crystals”)

(a) Elastic waves propagating with \mathbf{K} in the cubic $[hkl]$ direction exhibit one longitudinally polarized mode and two transversely polarized modes only for special values of $[hkl]$. States these values and briefly justify your assertion without calculation.

(b) For what values of $[hkl]$ do the two transverse sound velocities equal each other? Briefly justify your answer without calculation.