Final Exam
Physics 240B

Do all questions. The exam is closed book, but two pages of notes are allowed.
A possibly useful formula: $\int_{-\infty}^{\infty} x^{2n} e^{-x^2} dx = \frac{(2n-1)(2n-3)(2n-5)...(3)(1)}{2^n}\sqrt{\pi}$

1. (15 points)

A semiconductor has valence band maximum at $\mathbf{k} = 0$, conduction band minimum at $\mathbf{k} = \frac{\pi}{5a}\hat{\mathbf{y}}$, and energy gap E_g. Find an expression for the largest wavelength of light that could excite an electron between the bands. Approximate the phonon dispersion relation with the result from the 1D monatomic chain.

2. (25 points)

a) Assume that the potential energy for atoms separated by $r_o + r$, where r_o is the equilibrium separation, is $U(r) = U_o + Cr^2 + Fr^4 + Hr^5$. Find an expression for the thermal expansion of the material, keeping the lowest and next-lowest order terms.

b) In what sense can one say that only odd terms affect thermal expansion? Comment in particular on the effect of the Fr^4 term in part a).

3. (20 points)

a) Consider a beam of neutrons with wave vector $\mathbf{k}_i \parallel \hat{\mathbf{x}}$, incident on a two-dimensional square lattice with primitive vectors $a\hat{\mathbf{x}}$ and $a\hat{\mathbf{y}}$. Find the minimum energy of the neutrons that allows phonon emission. (*Hint:* A picture, while not required, might help.)

b) Repeat part a) if $\mathbf{k}_i$ is instead in the $\frac{1}{\sqrt{2}}(\hat{\mathbf{x}} + \hat{\mathbf{y}})$ direction.

4. (20 points)

An electron pocket in a semiconductor has surface $A(k_x - k_{xo})^2 + Bk_y^2 + Ck_z^2 = 1$. What is the resonant frequency if a magnetic field of 1500 gauss is applied in the $(\frac{1}{2}, \frac{1}{2}, \frac{1}{\sqrt{2}})$ direction?

5. (20 points)

Evaluate the Debye-Waller factor in a two-dimensional Debye model at $T = 0$. You may start from the formula $2W = \frac{1}{N}\sum_{\mathbf{k}\nu}(2n_{\mathbf{k}\nu} + 1)\frac{\hbar^2(\epsilon_{\mathbf{k}\nu}\cdot\mathbf{q})^2}{2M\hbar\omega_{\mathbf{k}\nu}}$.