

Midterm Exam – OPT 507  
October 22, 2002

1. (30 points) The band structure for a one-dimensional linear chain in tight binding approximation can be written as

$$E(k) = E_\alpha - 2A\alpha e^{-\alpha a} \cos k a$$

where  $a$  is the lattice spacing;  $A$ ,  $\alpha$  and  $E_\alpha$  are constants.

- (a) (10 points) Plot the energy band in the first Brillouin zone.
- (b) (10 points) Calculate the effective mass of the band at the  $\Gamma$  point (i.e., near  $k \cong 0$ ).
- (c) (10 points) How wide is the band? Does the band get narrower or wider as the lattice spacing increases? Why?
2. (30 points) Draw and discuss the dispersion curves for:

- (a) acoustic phonons
- (b) optical phonons
- (c) surface plasmons
- (d) photons
- (e) free electrons
- (f) polaritons
3. (20 points) Consider free electrons of mass  $m_0$  in a metal. The electrons are subject to an electromagnetic force  $-eE e^{-i\omega t}$  and a viscous drag  $Cv$ , where  $C$  is a constant and  $v$  is the electron velocity. Show that Ohm's law  $J = \sigma E$ , where  $\sigma$  is the conductivity, is valid for this free-electron model when  $\omega = 0$  and calculate  $\sigma$ .
4. (20 points) Plot the absorption coefficient of an indirect gap semiconductor from below the indirect bandgap  $E_g^{\text{ind}}$  to above the direct bandgap energy  $E_g^{\text{dir}}$  in the following figure. Explain your answer and describe the mathematical form of the functions you have plotted. What is the lowest photon energy at which the absorption starts?

