Condensed Matter Physics 2023
Quiz 5 (Week 12)

1. For the infinite one-dimensional chain (atoms of mass M connected by springs), sketch and describe the dispersion relation. Explain how it would vary for increasing M, and what is the value of the sound velocity and how to find it.

2. The energy gap of ZnSe is 2.3 eV.
   (a) Is ZnSe transparent to visible light? Explain your answer.
   (b) How could you increase the electrical conductivity of this material? Give reasons.

3. If no electron-hole pairs were created in silicon (Si) until the temperature reached the value corresponding to the energy band gap, 1.12 eV, at which temperature would Si become conductive? [Hint: the thermal energy is given by $E_{\text{th}} = \frac{3}{2}k_B T$.] Could this physically happen given the temperature found?

4. An intrinsic semiconductor has a simple cubic crystal structure with lattice parameter $a = 5.3$ Å. The valence (v) and conduction (c) bands are well approximated by:

$$\epsilon_v(\mathbf{k}) = A + B\left[\cos(k_x a) + \cos(k_y a) + \cos(k_z a)\right]$$

$$\epsilon_c(\mathbf{k}) = C - D\left[\cos(k_x a) + \cos(k_y a) + \cos(k_z a)\right]$$

   with $A = -4.1$ eV, $B = 0.4$ eV and $D = 0.3$ eV,.
   (a) Find C, knowing that the band gap is $E_g = 0.6$ eV. [Hint: at which $\mathbf{k}$ is ϵ_v maximum, and at which $\mathbf{k}$ is ϵ_c minumum?]
   (b) Determine the values of the effective mass of electrons and holes at the bottom of the conduction band and top of the valence band, respectively.
   (c) Determine the density of electrons in the conduction band and holes in the valence band at $T = 300$ K.