1. (20%) Explain briefly, but as clearly as possible, the following terms using words, and/or equations, and/or figures:
   (a) The Ewald construction
   (b) Van Hove singularity

2. (30%) For a simple cubic lattice, the distance between two neighboring \((hkl)\)-planes is \(d(hkl) = a/(h^2+k^2+l^2)^{1/2}\). There are 2 samples of crystalline powder, one is bcc lattice; the other is fcc lattice. The approximate positions of the first 3 diffraction rings (i.e. the Bragg angles \(\theta\)) are at 31.8\(^\circ\), 37.5\(^\circ\), and 59.5\(^\circ\) for sample A (\(\sin\theta = 0.527, 0.608, 0.862\)); and 33.2\(^\circ\), 50.8\(^\circ\), and 71.6\(^\circ\) for sample B (\(\sin\theta = 0.547, 0.775, 0.949\)).
   (a) Which sample is bcc, and which one is fcc? Explain why.
   (b) If the wavelength of the X-ray is 2 Å. Find out the lattice constant of the conventional unit cell for these two lattices.
   [Hint: The structure factor of the bcc lattice is not zero if \(h+k+l\) is an even integer; for fcc, it’s nonzero if \(h,k,l\) are all even or all odd.]

3. (20%) A two-dimensional sample has an area equals to 1 cm\(^2\). It has the lattice shown in the figure with lattice constant \(a = 2\) Å. The atoms are allowed to vibrate in all three dimensions, not just within the lattice plane.
   (a) How many acoustic and optical branches are there in the phonon spectrum?
      What is the number of normal modes in each of the branch?
   (b) In another crystal structure, a different type of atom is added to the center of the unit cell in the figure, how would the answer in (a) be changed?

4. (30%) (a) How would the low-temperature specific heat for a two-dimensional crystal vary with temperature \(T\)? Explain why.
   (b) Explain clearly why, at high temperature \(T\), the number of phonons are proportional to \(T\). Also explain clearly why the thermal conductivity \(K\) is proportional to \(1/T\) at high temperature.