Condensed Matter Physics: Weekly Problem 3

These problems are to be formatively self-assessed by you, the student. Students taking part in the peer-marking pilot scheme will also be required to mark one of their peer's weekly problems. A mark scheme, out of 10, will be provided with each solution to aid your assessment before your timetabled weekly workshop. Information underlined/boxed in red in the model solutions is required for marks to awarded.

Summary: In this problem, we will explore vibrations in solids using phonons as a model for describing the transmission of sound in crystalline solids. You will need to refer to Lecture 6.

Na 5K	Mg										
bcc	hcp	← Crystal structure →									
4.225	3.21	← a lattice parameter, in Å →									
	5.21	← c lattice parameter, in Å →									
K 5K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
bcc	fcc	hcp	hcp	bcc	bcc	cubic	bcc	hcp	fcc	fcc	hcp
5.225	5.58	3.31	2.95	3.03	2.88	complex	2.87	2.51	3.52	3.61	2.66
		5.27	4.68					4.07			4.95

a. The metal iron has a bcc structure with the unit cell length of $a = 0.287$ nm (Kittel Table 1.3, page 20). Calculate the speed of sound propagating along the [100] axis where the spring constant is $C = 5.00$ N m^{-1}. **[3 marks]**

b. At what wavelength would the speed fall to 50 % of the speed calculated above? **[1 mark]**

c. Explain physically why the speed drops. **[1 mark]**

d. What is the maximum frequency that can be generated along the [100] axis? **[2 marks]**

e. Describe the Debye approximation. Would the value for (d) above be lower or higher if the Debye approximation were used? Illustrate your answer with a sketch of the phonon dispersion curve in the first Brillouin zone. **[3 marks]**