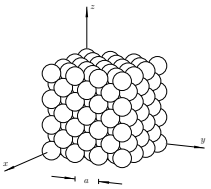
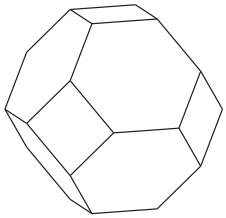
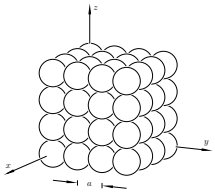
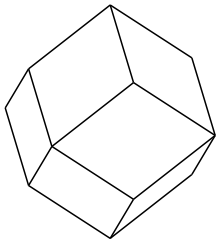
Physics 323, Section 1, Fall Semester 2019
Instructor: Lance Nelson
Final Exam
Dec 16 – Dec 18
This exam is **OPENED BOOK** and untimed. Feel free to start and stop as often as you'd like.

1. (5 pts) Which of the following is *not* a lattice vector of a bcc lattice?

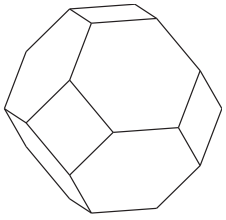
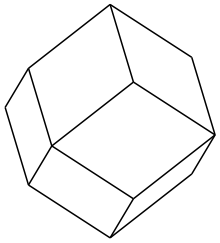
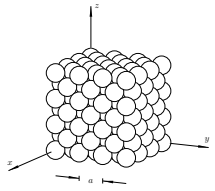
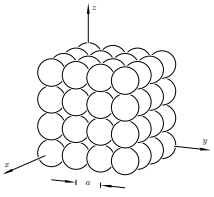
(a) $a(\hat{i}+\hat{j}+2\hat{k})$ (b) $a(\frac{1}{2}\hat{i}-\hat{j}+\frac{1}{2}\hat{k})$

(c) they are *all* lattice vectors of the bcc lattice. (d) $a(\frac{1}{2}\hat{i}-\frac{3}{2}\hat{j}-\frac{1}{2}\hat{k})$

2. (5 pts) Which of the following is a Brillioun zone for a copper (Cu) crystal?

(a)  (b)  (c)  (d) 

3. (5 pts) Which of the following is the Wigner-Seitz cell for a BCC lattice?

(a)  (b)  (c)  (d) 

4. (5 pts) The number of *atoms* per unit volume in silicon (Si) is

(a) $\frac{1}{4}a^{-3}$ (b) $\frac{1}{8}a^{-3}$ (c) a^{-3} (d) $4a^{-3}$

(e) $\frac{1}{2}a^{-3}$ (f) $2a^{-3}$ (g) $8a^{-3}$

5. (5 pts) The reciprocal lattice of cesium chloride (CsCl) is

(a) sc (b) bcc (c) fcc

6. (5 pts) The distance between reciprocal lattice points in the [100] direction in sodium (Na) is

(a) $2\pi/a$ (b) $4\pi/a$ (c) a (d) $2\pi\sqrt{3}/a$

(e) $2\pi\sqrt{2}/a$

7. (5 pts) A certain crystal has a bcc lattice. A phonon in that crystal has a wave vector $\mathbf{k} = (4\pi/a)(\hat{i} + \frac{1}{2}\hat{j} + \frac{1}{2}\hat{k})$. The wave vector of this phonon *in the first Brillouin zone* is equal to

(a) $(4\pi/a)\hat{i}$ (b) 0

(c) $(4\pi/a)(-\frac{1}{2}\hat{i}\,)$ (d) $(4\pi/a)(\frac{1}{2}\hat{j} + \frac{1}{2}\hat{k})$

(e) none of the above

8. (5 pts) A crystal with two atoms in the primitive unit cell

(a) will always (b) may

(c) will never

exhibit an optical branch in its phonon dispersion curves.

9. (5 pts) Consider a lattice wave with wave vector $\mathbf{k} = (2\pi/a)\hat{i}$ in a crystal of sodium (Na).

(a) All of the atoms are moving in phase with each other.

(b) There is not enough information given to determine the relative phases of the motion of the atoms.

(c) Half of the atoms are moving 180° out of phase with the other half

(d) None of the above.

10. (5 pts) If we raise the temperature of a metal, the average distance an electron travels between collisions will

(a) decrease. (b) stay the same.

(c) increase.

11. (5 pts) According to the classical model of metals, which of the following should have the largest Hall coefficient (in magnitude)?

(a) calcium (Ca) (b) nickel (Ni)

(c) strontium (Sr)

12. (5 pts) Consider the inelastic scattering of neutrons in a crystal. If the neutron absorbs a phonon, the *magnitude* of its momentum vector will generally

(a) decreases (b) remain the same

(c) increases

(d) since we do not know the direction of the absorbed phonon, we cannot say anything about the change of the magnitude of its momentum

13. (5 pts) Consider an electron state with energy greater than the Fermi energy. For temperatures above absolute zero, the probability that this state will be occupied by an electron is

(a) equal to 1 (b) equal to 0

(c) less than $\frac{1}{2}$ but greater than 0 (d) less than 1 but greater than $\frac{1}{2}$

(e) less than 1 but greater than 0

14. (5 pts) Consider a metal described by the free-electron model. Above the Fermi energy, the number of electron *states* (both occupied and unoccupied) per unit energy interval is

(a) greater than (b) less than (c) equal

that below the Fermi energy.

15. (5 pts) At $T = 0$, the resistance of a metal is due primarily to

(a) impurity atoms (b) phonons

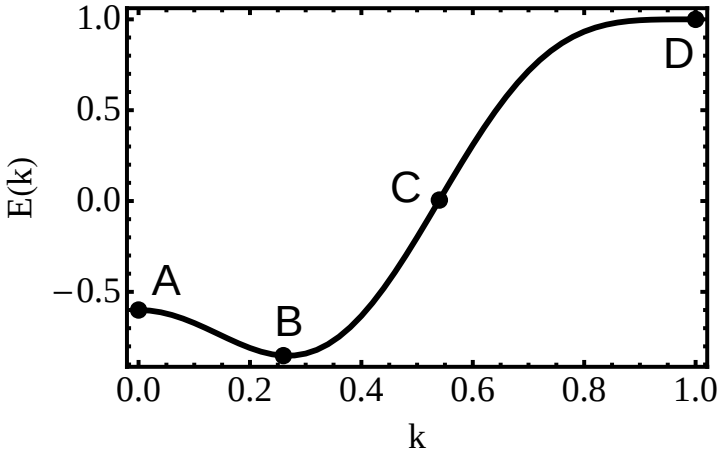
16. (5 pts) Iodine (I) is a non-metal. Its atomic number is 53. The number of *atoms* in a primitive unit cell

(a) must be an even number. (b) must be an odd number. (c) cannot be determined from the data given.

17. (5 pts) In the figure below is shown the energy of electron states along a line in the [100] direction ($+x$ direction) in k space. The points labeled A, B, C, D each refer to states occupied by electrons. The slope of the curve is zero at points A, B, D. Point C is a point of inflection. Electrons in which state have a positive effective mass? (Consider *infinite* effective mass to be *neither* positive nor negative.)

(a) B (b) D (c) None

(d) A (e) C



18. (5 pts) The charge density on the n-side of the the depletion layer of a p-n junction is

(a) positive. (b) negative. (c) zero.

19. (5 pts) When a p-n junction is reverse biased, the magnitude of the generation current is

(a) greater than. (b) less than. (c) the same as.

the magnitude of the recombination current.

20. (5 pts) If we forward bias a p-n junction, the depletion layer will

(a) become narrower. (b) remain the same width. (c) become wider.

21. (5 pts) In a bcc lattice, which of the following planes are spaced furthest apart?

(a) (110) (b) (100). (c) (111).

as compared to the conventional low-temperature superconductors.

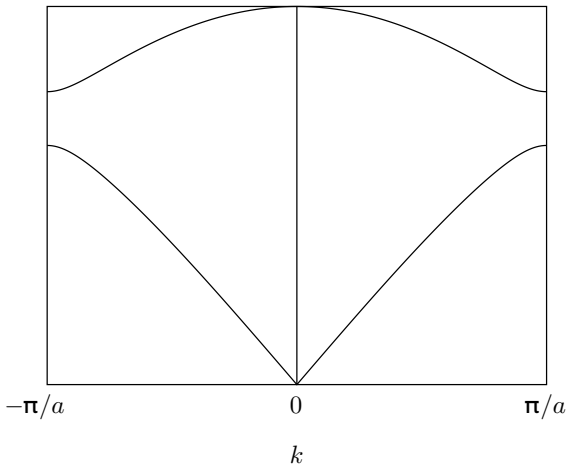
22. (5 pts) Consider the phonon dispersion curves of a one-dimensional crystal. (The y axis is $\omega(k)$.) Which of the following statements *must* be true?

(a) None of the above.

(b) The unit cell contains one atom.

(c) The relationship $\omega(k)$ is linear for k near the edge of the zone.

(d) The unit cell contains two atoms.



23. (5 pts) The average kinetic energy per conduction electron in a metal at room temperature is generally

(a) much greater than (b) much less than (c) about the same as k_BT.

24. (5 pts) The volume of the first Brillouin zone in Si is

(a) $2\pi^3 a^{-3}$ (b) $8\pi^3 a^{-3}$ (c) $32\pi^3 a^{-3}$

(d) $64\pi^3 a^{-3}$

25. (5 pts) If we raise the temperature of an extrinsic semiconductor, the *conductivity* will

(a) increase (b) decrease (c) remain the same

(Assume that the semiconductor is still extrinsic after the temperature is raised.)

26. (5 pts) If we raise the temperature of an intrinsic semiconductor, its conductivity will

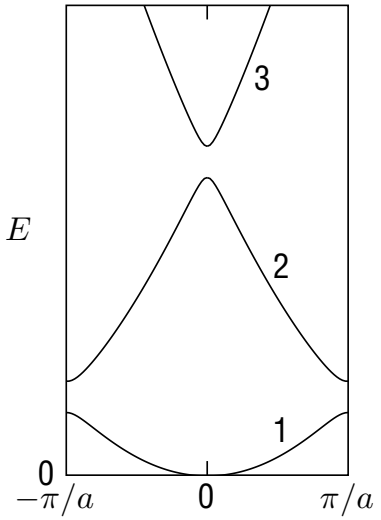
(a) remain the same (b) decrease

(c) increase

27. (5 pts) Consider a one-dimensional crystal with band structure shown below. (The x axis is the wave vector, k.) There are four electrons per unit cell. Which of the following statements *must* be true?

(a) The material is semiconducting (b) The material is a metal

(c) The unit cell contains 2 atoms, each with a valence of 2. (d) Band 2 is the conduction band.



28. (5 pts) When a p-n junction or a metal-insulator junction is initially created (before equilibrium is reached), which of the following is always true?

(a) Electrons will not flow (because of the field in the depletion region.) (b) Electrons will move across the junction into the side with the lowest Fermi energy.

(c) Holes will be created by the electric field in the depletion region. (d) Electrons will move to cancel out the field in the depletion region.

29. (10 pts) What is the difference between recombination current and generation current? Use a diagram to help your explanation.

30. (10 pts) The electrical conductivity of Aluminum and Copper are about the same (actually that of copper is slightly larger), even though Aluminum has twice as many valence electrons. Can you explain why?

31. (10 pts) Explain the meaning of the Hall coefficient. What would determine whether this coefficient is positive or negative?

32. (10 pts) Explain how an electron can have a negative effective mass.