Chapter 1

1 Crystal Structure

The left hand side of Fig. 1 shows a two-dimensional hexagonal lattice of atoms.

1. Draw the smallest possible unit cell of the lattice into the figure.
2. The right hand side of Fig. 1 shows four possible solutions for the corresponding reciprocal lattice. Which is the correct one? Answer: C

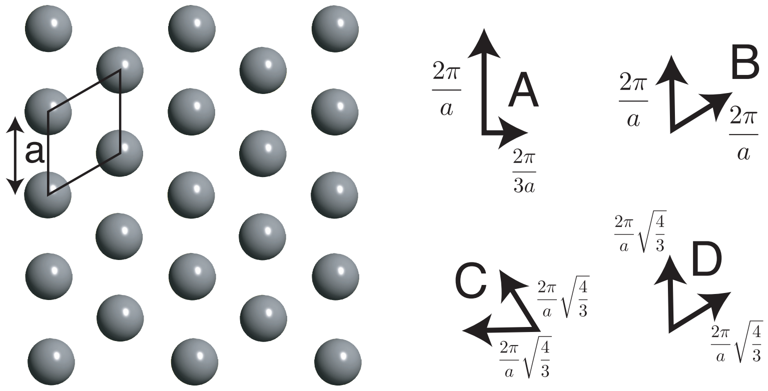

Figure 1: Two-dimensional hexagonal lattice and candidates for the corresponding reciprocal lattice.

2 Crystal Structure

Figure 2 shows two two-dimensional lattices of atoms.

1. Draw the vectors that describe the structures' Bravais lattices into the figure.
2. How many atoms do the smallest unit cells (or the basis of the two structures) contain?

A ( ) The left unit cell contains 2 atoms and the right unit cell contains 4.
B (x) The left unit cell contains 1 atom and the right unit cell contains 2.
C ( ) The left unit cell contains 1 atoms and the right unit cell contains 4.
D ( ) The left unit cell contains 2 atoms and the right unit cell contains 6.

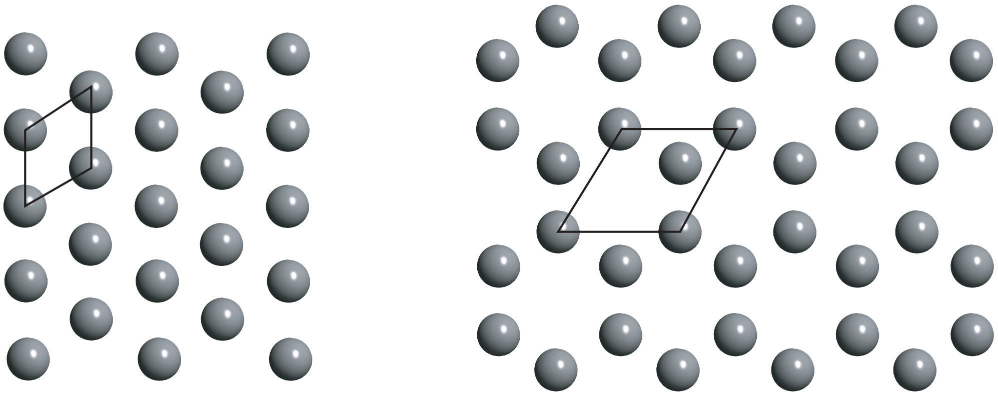

Figure 2: Two-dimensional crystals.

3 Crystal Structure

Figure 3(a) shows a two-dimensional crystal.

1. Which marked area in Figure 3(a) is the correct unit cell? Answer: C
2. Which set of reciprocal lattice vectors in Figure 3(b) corresponds to the correct unit cell in Figure 3(a)? Answer: C

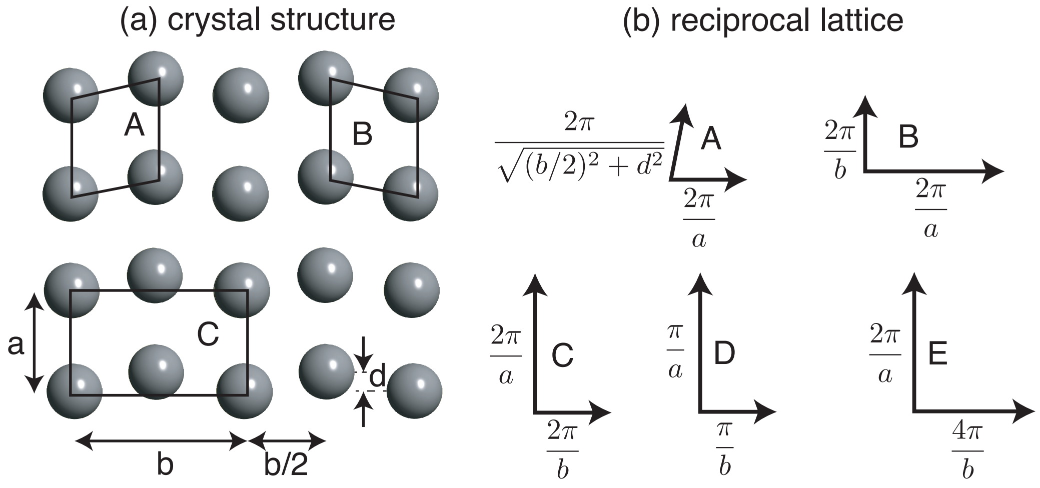

Figure 3: (a) A two-dimensional crystal. (b) Possible reciprocal lattice vectors with their length.

4 Crystal Structure

1. Figure 4 shows a two-dimensional lattice with different grey areas lined out.

   (a) Which of these grey areas IS NOT a unit cell of the lattice? Answer: D

   (b) Which unit cell is the Wigner-Seitz cell, i.e. the area of points closer to a given lattice point than to any other? Answer: B

   (c) How many lattice point does the cell C contain?

   - ( ) 1
   - (x) 2
   - ( ) 4
   - ( ) 6

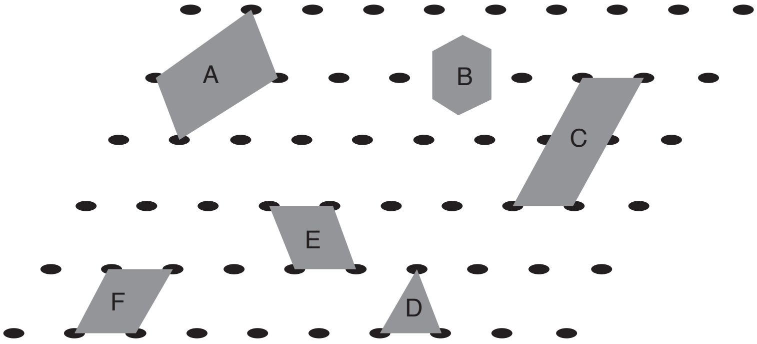

Figure 4: Two-dimensional Bravais lattice.

5 Unit cell of a lattice

Fig. 5 shows the unit cell of a crystal lattice. The unit cell contains three different atoms, so that the chemical formula for the material is $A_xB_yC_z$. The white atoms are on the faces of the cube. What are x, y, z?

- A (x) 1,1,3
- B ( ) 1,4,6
- C ( ) 1,4,8
- D ( ) 1,6,8

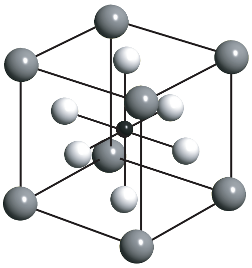

Figure 5: Unit cell of a lattice

6 The reciprocal Lattice

Figure 6(a) shows a two-dimensional crystal. Which set of reciprocal lattice vectors in Figure 6(b) corresponds to the correct unit cell in Figure 6(a)? Answer: A

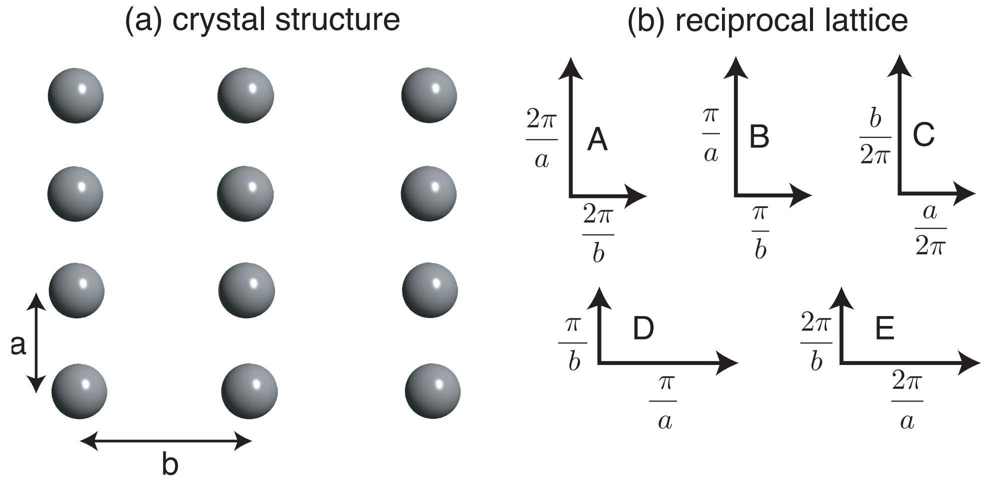

Figure 6: (a) A two-dimensional crystal. (b) Possible reciprocal lattice vectors with their length.

7 The Reciprocal Lattice

Figure 7 shows a two-dimensional crystal and the possible choices of the corresponding reciprocal lattice. Which is the correct one? Answer: D

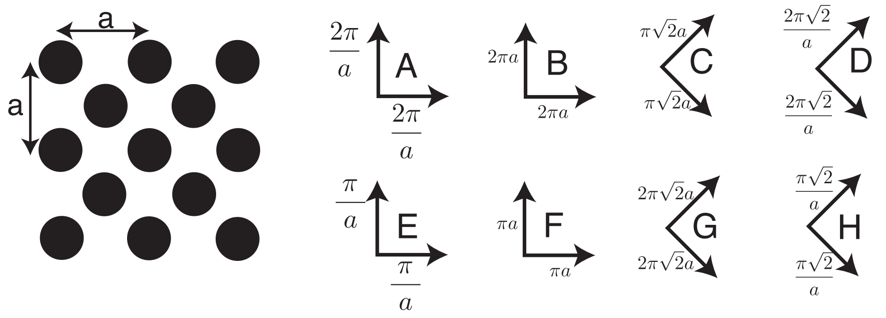

Figure 7: Left: A two-dimensional crystal. Right: The corresponding reciprocal lattice.

8 The Reciprocal Lattice

Suppose you have X-rays travelling through a three-dimensional crystal. X-rays can be described by plane waves (if the source is far enough away) and the amplitude of the electric field $\mathbf{E}$ can thus be written as

$$\mathbf{E} \propto e^{i\mathbf{k}\cdot\mathbf{r}}, \tag{1}$$

where $\mathbf{k}$ is the wave vector and $\mathbf{r}$ a position in the crystal.

1. Suppose now that you choose the wavelength of the X-rays such that $\mathbf{k} = \mathbf{G}$, where $\mathbf{G}$ is a reciprocal lattice vector of the crystal. It is clear that the direction of the X-ray beam has to be chosen such that it propagates along the direction $\mathbf{G}/|\mathbf{G}|$ with respect to the crystal, but what wavelength λ do you have to choose to achieve the right length of $\mathbf{k}$?

   A ( ) $\lambda = |\mathbf{G}|$
   B ( ) $\lambda = 2\pi|\mathbf{G}|$
   C ( ) $\lambda = 1/|\mathbf{G}|$
   D (x) $\lambda = 2\pi/|\mathbf{G}|$

2. Still assuming $\mathbf{k} = \mathbf{G}$, what statement holds for these plane waves?

   A (x) The plane waves always have the periodicity of the lattice, i.e. one gets the same value when moving the position by one lattice vector.
   B ( ) The plane waves do not necessarily have the periodicity of the lattice.
   C ( ) The plane waves always have the periodicity of the reciprocal lattice, i.e. one gets the same value when moving the position by one reciprocal lattice vector.
   D ( ) The plane waves do not necessarily have the periodicity of the reciprocal lattice.

9 X-ray diffraction

Figure 8 shows a cut through a reciprocal lattice and an arrow denoting the wave vector of the incoming X-rays. Draw the direction(s) in which you would expect to observe constructive interference as additional arrows into the figure.

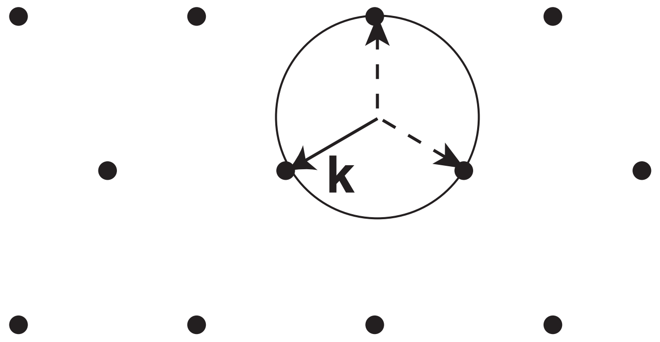

Figure 8: Cut through a three-dimensional reciprocal lattice with the wave vector of incoming X-rays denoted by an arrow.

Chapter 2

10 Cohesive energy and lattice energy

The table gives the cohesive energy and lattice energy for a couple of ionic crystals in eV per pair of atoms. Based on this information, which crystal would you expect to be most susceptible to being dissolved in water? Answer: KCl

Answer	Substance	cohesive energy	lattice energy
A	LiF	9.01	11.00
B	NaCl	6.70	8.24
C	KCl	6.75	7.48
D	KF	7.70	8.65

11 Cohesive energy

What is a typical value for the cohesive energy in a covalently bonded solid per atom?

A ( ) 0.5 meV

B ( ) 50 meV

C (x) 5 eV

D ( ) 500 eV

Chapter 3

12 Mechanical Properties

The yield strain ϵ_y of a metal is typically

A (x) $\epsilon_y \approx 0.01$

B ( ) $\epsilon_y \approx 1$

C ( ) $\epsilon_y \approx 10$

13 Mechanical Properties

Consider a graphite crystal as in Figure 9. Considering the bonding in graphite, in which direction do you expect to have a higher Young's modulus? (Note that this is not about shearing the crystal. It's about either expanding the sp^2 bonds in the planes or increasing the distance in between the planes.) :

A (x) in the direction parallel to the sp^2-bonded planes.

B ( ) in the direction perpendicular to the sp^2-bonded planes.

C ( ) roughly the same in both directions.

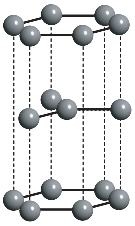

Figure 9: Structure of graphite.

14 Mechanical Properties

1. Consider the following materials: Rubber, Diamond, Lead. When ordering the materials with respect to their Young's modulus (from lowest to highest value), what is the correct order?

   A ( ) Rubber, Diamond, Lead

   B (x) Rubber, Lead, Diamond

   C ( ) Lead, Diamond, Rubber

   D ( ) Lead, Rubber, Diamond

   E ( ) Diamond, Lead, Rubber

   F ( ) Diamond, Rubber, Lead

Chapter 4

15 Thermal energy

What is the energy corresponding to $k_B T$ at room temperature?

A ( ) 2.5 meV.

B (x) 25 meV.

C ( ) 250 meV.

16 Vibrations

1. Fig. 10 shows the instantaneous displacements of atoms in a one-dimensional chain with one atom per unit cell and lattice constant a. What is the wave vector k corresponding to these vibrational modes?

   A (x) $k \approx 0$ for mode 1 and $k = \pi/a$ for mode 2.
   B ( ) $k \approx 0$ for mode 1 and $k = a/\pi$ for mode 2.
   C ( ) $k \approx 0$ for mode 1 and $k = a$ for mode 2.
   D ( ) $k \approx 0$ for mode 1 and $k = 2\pi/a$ for mode 2.
   E ( ) $k = -\pi/a$ for mode 1 and $k = \pi/a$ for mode 2.

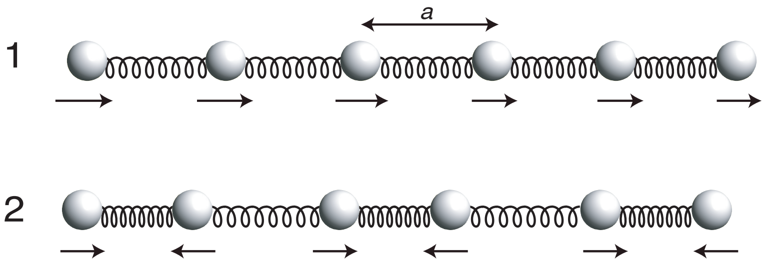

Figure 10: Instantaneous displacement (denoted by arrows) of atoms in a one-dimensional chain for two different vibrational modes.

2. What is the shortest possible wavelength λ for this chain?

   A (x) $\lambda = 2a$.
   B ( ) $\lambda = 2\pi/a$.
   C ( ) $\lambda = a/2$.

17 Vibrations

Fig. 11 shows the phonon dispersion of a material. This material has

A ( ) 1 atom per unit cell.

B ( ) 2 atoms per unit cell.

C (x) 3 or more atoms per unit cell.

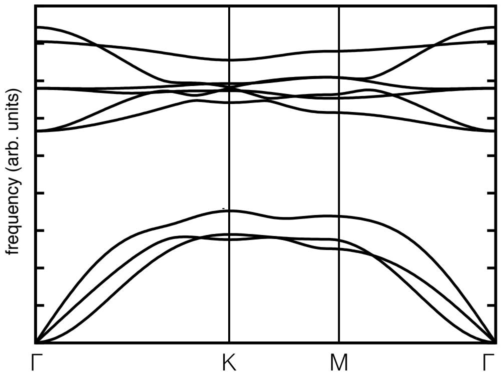

Figure 11: Phonon dispersion of a material.

18 Vibrations

The phonon dispersion of the semiconductor Bi_2Se_3 has

A ( ) only acoustic branches.

B (x) acoustic and optical branches.

C ( ) only optical branches.

19 Vibrations

Consider a one-dimensional chain of atoms with an equilibrium distance a between the atoms and nearest neighbour atoms connected by springs of force constant γ. Let the mass of the atoms be M.

1. Figure 12 shows different possibilities for the dispersion of the vibrational frequencies for this case. Which dispersion is correct? Answer: C

2. When using periodic boundary conditions for a finite chain of atoms, the number of allowed k-points in reciprocal space is restricted. If the total length of the chain is $L = Na$, where N is the total number of unit cells, what is the shortest and longest possible wave length for a vibrational mode when you apply periodic boundary conditions?

   A ( ) Shortest: a, longest L.
   B ( ) Shortest: $a/2$, longest $L/2$.
   C ( ) Shortest: a, longest $L/2$.
   D ( ) Shortest: $2a$, longest $L/2$.
   E (x) Shortest: $2a$, longest L.

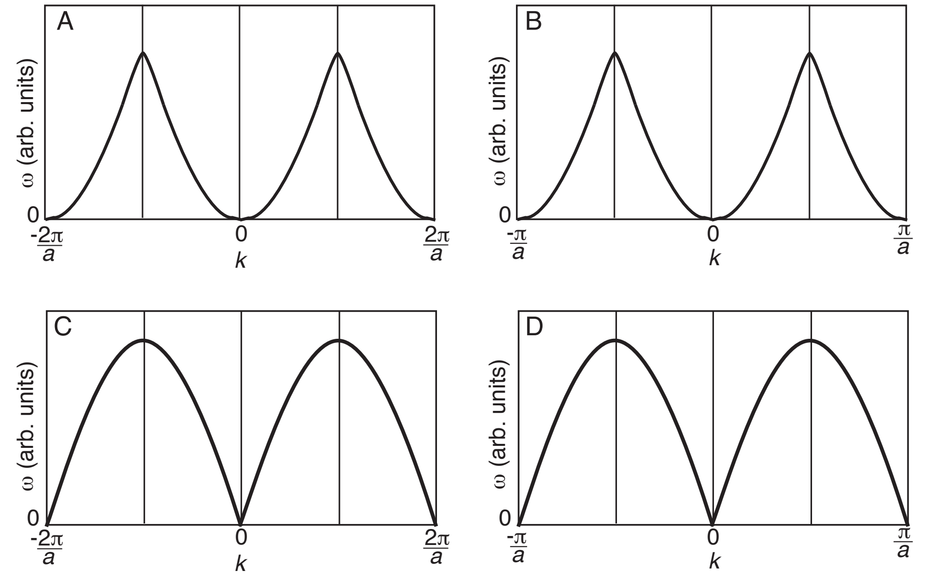

Figure 12: Dispersion of vibrational modes in a one-dimensional chain of atoms.

20 Heat capacity

Consider the heat capacity of a crystal. An approximate expression for the lattice contribution is

$$C = \frac{12\pi^4}{5} N k_B \left(\frac{T}{\Theta_D} \right)^3 \tag{2}$$

This expression is

A (x) representing the Debye model at low temperatures.

B ( ) representing the Einstein model at low temperatures.

C ( ) representing the Debye model at high temperatures.

D ( ) representing the Einstein model at high temperatures.

21 Heat capacity

What material has the highest molar heat capacity (the heat capacity for a solid made of N_A atoms) at 200 K?

A ( ) Diamond (Debye temperature ≈ 2200 K).

B ( ) Beryllium (Debye temperature ≈ 1440 K).

C (x) Lead (Debye temperature ≈ 100 K).

D ( ) The heat capacity is roughly the same in all three cases.

Chapter 6

22 Heat capacity of the electrons

In a typical metal, what fraction of the electrons contributes to the heat capacity at room temperature?

A ( ) all the electrons contribute.

B ( ) only half of the electrons contribute.

C (x) only a few percent of the electrons contribute.

23 Heat capacity

At very low temperatures, far below the Debye temperature, which type of solid typically has the highest heat capacity:

A (x) a metal.

B ( ) a semiconductor.

C ( ) an insulator.

24 Heat capacity

The free electrons in a metal give the highest relative contribution to the total heat capacity

A (x) at very low temperatures.

B ( ) at very high temperatures.

C ( ) near room temperature.

D ( ) never.

E ( ) for all temperatures.

25 Heat capacity

Consider the temperature-dependent heat capacity of a three-dimensional solids in Fig. 13. Note that what is plotted is C/T vs. T^2! What kind of solid does the curve correspond to?

A ( ) An insulator.

B ( ) A semiconductor.

C (x) A metal.

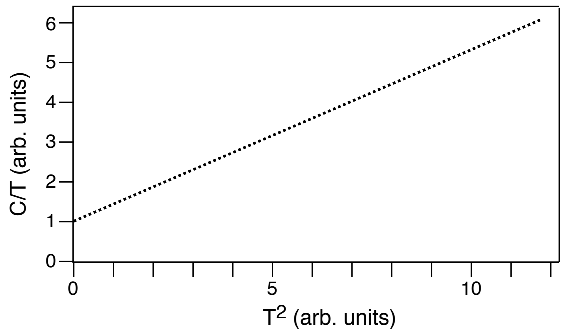

Figure 13: Temperature-dependent heat capacity of a solid.

26 Bloch wave functions

The electronic states in periodic solids can be described by Bloch wave functions. Does a Bloch wave function have the periodicity of the underlying Bravais lattice?

A (x) A Bloch wave can have the periodicity of lattice but it does not have to.

B ( ) A Bloch wave does always have the periodicity of lattice.

C ( ) A Bloch wave does never have the periodicity of the lattice.

27 Bloch theorem

Consider the wave function $\psi_{\mathbf{k}}(\mathbf{r})$ of an electron moving in a three-dimensional lattice with the Bravais lattice points given by the vectors $\mathbf{R} = m\mathbf{a_1} + n\mathbf{a_2} + o\mathbf{a_3}$. A Bloch wave function can have the form

A ( ) $\psi_{\mathbf{k}}(\mathbf{r}+\mathbf{R}) = e^{i\mathbf{k}\cdot\mathbf{R}}\psi_{\mathbf{k}}(\mathbf{r})$.

B ( ) $\psi_{\mathbf{k}}(\mathbf{r}-\mathbf{R}) = e^{-i\mathbf{k}\cdot\mathbf{R}}\psi_{\mathbf{k}}(\mathbf{r})$.

C ( ) $\psi_{\mathbf{k}}(\mathbf{r}) = e^{i\mathbf{k}\cdot\mathbf{r}}u_{\mathbf{k}}(\mathbf{r})$, with $u_{\mathbf{k}}(\mathbf{r}) = u_{\mathbf{k}}(\mathbf{r}+\mathbf{R})$.

D ( ) both A and C are correct but B is not.

E (x) A and B and C are all correct.

28 Effective mass

The electronic dispersion of a semiconductor near the conduction band minimum can be approximated by

$$E_c(\mathbf{k}) = E_g + \frac{\hbar^2|\mathbf{k}|^2}{m_e}, \tag{3}$$

where E_g is the band gap energy and m_e is the free electron mass. What is the effective mass of the electrons in this band? Answer: The effective mass is equal to the free electron mass m_e.

29 Electronic Structure

Consider the electronic structure of a one-dimensional solid in the quantum mechanical nearly free electron model, as shown in Fig. 14. The point with the highest group velocity of the Bloch electrons is, answer: A

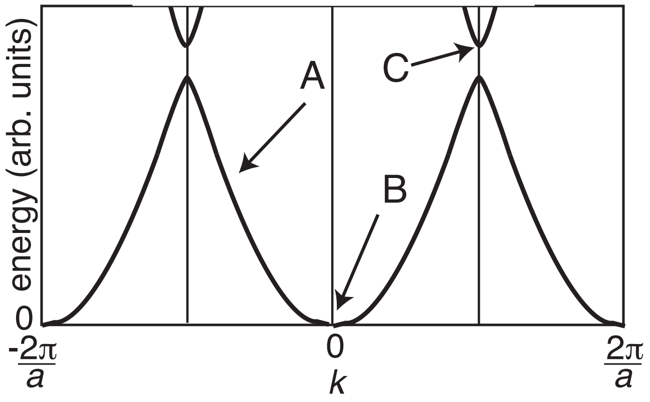

Figure 14: Band structure in the nearly free electron model.

30 Electronic Structure

The lattice-periodic potential $U(x)$ in a one-dimensional crystal with lattice constant a can be expressed by the Fourier series

$$U(x) = \sum_{n=-\infty}^{\infty} U_n e^{ixn2\pi/a}, \tag{4}$$

If the potential is to have real values (as opposed to complex values), the complex coefficients must fulfill

A ( ) $U_{-n} = U_n$

B (x) $U^*_{-n} = U_n$

C ( ) $U^*_{-n} = -U_n$

D ( ) $U_{-n} = -U_n$

31 Electronic Structure

Consider the electronic structure of a one-dimensional solid in the so-called quantum mechanical free electron model. In this case, a lattice-periodic potential is present but it is negligibly small.

1. Which of the electronic structures in Fig. 15 describes this situation? Answer: C
2. What is the effective mass of the electrons in the free electron model? Give your result here in units of kg. Answer: 9.1×10^{-31} kg

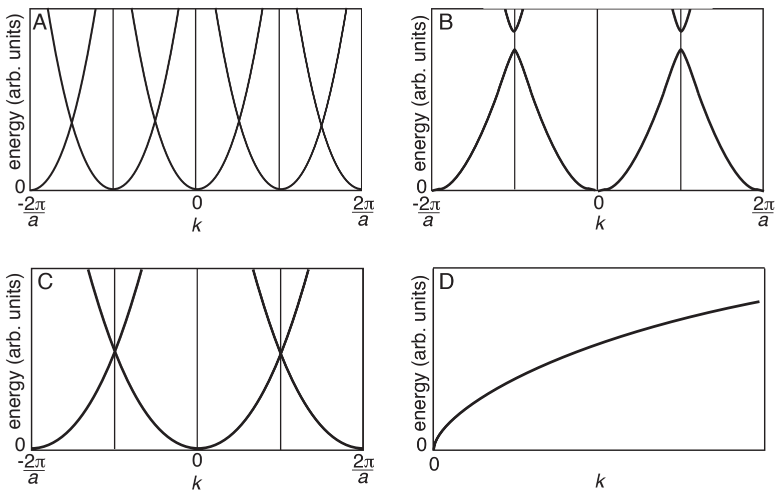

Figure 15: Free electron model.

32 Metals and Insulators

Is the statement "A three-dimensional crystal with an even number of electrons/unit cell is always an insulator" true?

A ( ) Yes

B (x) No

33 Metals, semiconductors and insulators

Figure 16 shows the electronic band structure of a single, two-dimensional sheet of TaS_2 (the structure is also shown in the inset). This material is

A (x) a metal.

B ( ) a semiconductor.

C ( ) an insulator.

34 Metals, semiconductors and insulators

Figure 17 shows the density of occupied states (shaded area) of a material, i.e. the density of states (dashed line) times the Fermi Dirac distribution at a very low temperature. This material is

A (x) A metal.

B ( ) A semiconductor.

C ( ) An insulator.

D ( ) There is not sufficient information to decide which of the above is correct.

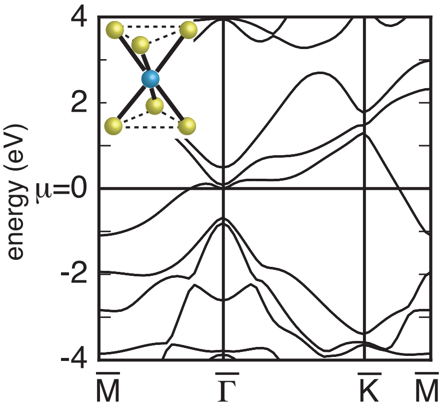

Figure 16: Band structure of a single layer of TaS_2. The structure is shown in the inset with the Ta atom in the centre and the S atoms above and below.

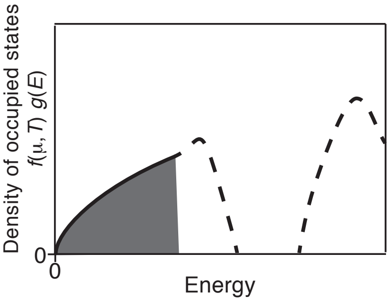

Figure 17: Density of occupied states of a material.

35 Metals, semiconductors and insulators

Figure 18 shows two possible structures of a single layer of MoS_2 and the corresponding band structures. The structures are called 1H and 1T and only differ by the relative orientation of the two sulphur triangles above and below the Mo ion. What can you learn about the electronic structure by inspecting the band structures?

A ( ) Both structures are metallic.

B ( ) Both structures are non-metallic.

C (x) The 1T structure is metallic and the 1H structure is not.

D ( ) The 1H structure is metallic and the 1T structure is not.

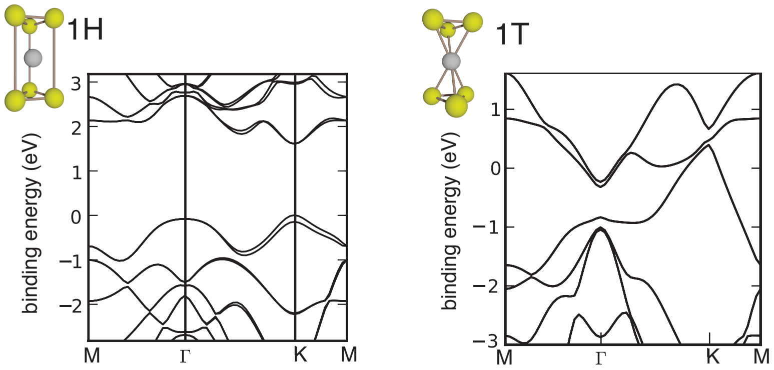

Figure 18: Structure and band structure of 1H and 1T modifications of MoS_2.

36 Metals and semiconductors

Figure 19 shows the band structure of an unspecified material. This material is

A ( ) a metal.

B ( ) a direct band gap semiconductor.

C (x) an indirect band gap semiconductor.

37 Metals and semiconductors

1. Silicon is the most well-known semiconductor. It has the same structure as diamond with two atoms per unit cell and four electrons per atom. These 8 electrons per unit cell exactly fill four bands and this gives rise to the semiconducting character. In another structural modification, could Si be metallic?

   A (x) Yes.

   B ( ) No.

2. Figure 20 shows the band structure of some material. This material is

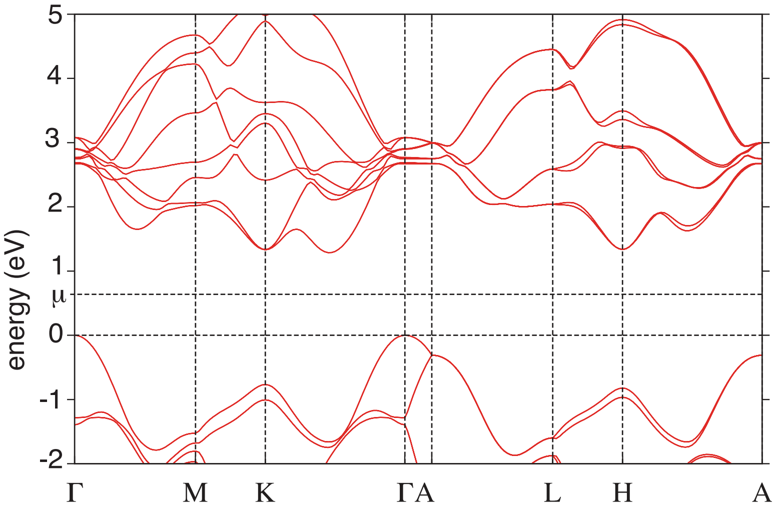

Figure 19: Band structure of a material.

A ( ) a metal.

B ( ) a direct band gap semiconductor.

C (x) an indirect band gap semiconductor.

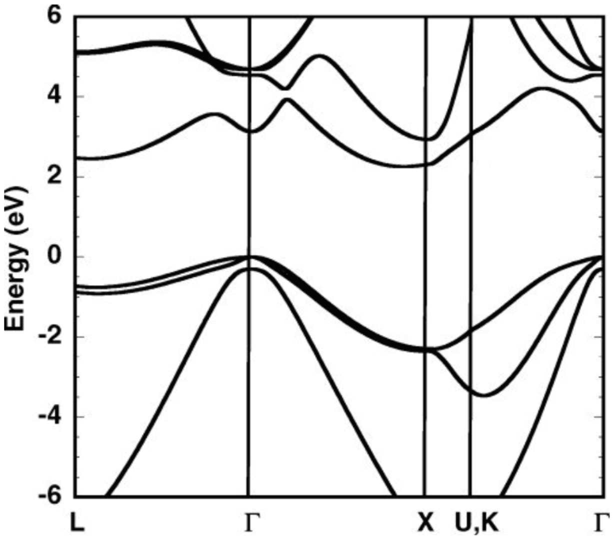

Figure 20: Band structure of a material.

38 Metals, semiconductors and insulators

Figure 21 shows the band structure and Brillouin zone of a material. The material is

A (x) a metal.

B ( ) a semiconductor.

C ( ) an insulator.

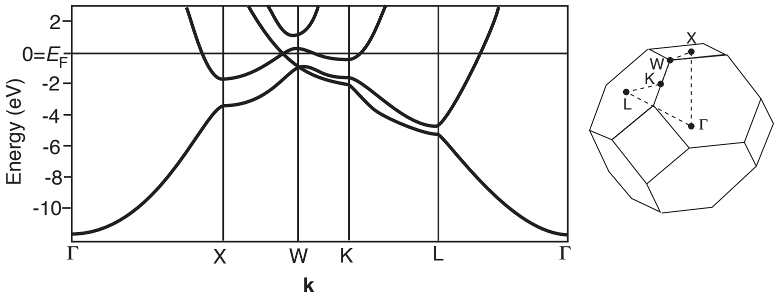

Figure 21: Band structure and Brillouin zone of a material.

Chapter 7

39 Intrinsic and doped semiconductors

In an intrinsic semiconductor, the chemical potential is found

A ( ) in the middle of the band gap.

B ( ) closer to the valence band maximum.

C ( ) closer to the conduction band minimum.

D (x) somewhere within the band gap but there is insufficient information in the question to determine where.

40 Metals and Semiconductors

1. How does the resistivity of a metal and a semiconductor typically change as the temperature is raised?

   A ( ) The resistivity increases in both cases.
   B ( ) The resistivity decreases in both cases.
   C ( ) The resistivity increases in the semiconductor and decreases in the metal.
   D (x) The resistivity decreases in the semiconductor and increases in the metal.

2. How does the mobility of electrons in a metal and in the conduction band of a semiconductor change as the temperature is raised?

   A ( ) The mobility increases in both cases.
   B (x) The mobility decreases in both cases.
   C ( ) The mobility increases in the semiconductor and decreases in the metal.
   D ( ) The mobility decreases in the semiconductor and increases in the metal.

41 Semiconductors

Consider a one-dimensional model for the electronic band structure in a semiconductor. The dispersion of the electronic states shall be given by

$$E(k) = E_0 - \gamma \cos ka, \tag{5}$$

where E_0 is an energy offset, γ is a positive parameter with the dimension of an energy, k is the one-dimensional wave vector and a the lattice constant. Calculate the effective mass close to $k = 0$. The effective mass is

A (x) $\hbar^2/(a^2\gamma)$

B ( ) $\hbar^2/(a^2\gamma^2)$

C ( ) $\hbar^2/(2a^2\gamma)$

D ( ) $\hbar^2/(4\pi a^2\gamma)$

E ( ) $\hbar^2/(2\pi a^2\gamma)$

F ( ) $\hbar^2/(2\pi a^2\gamma^2)$

42 Intrinsic and doped semiconductors

When a doped semiconductor has fewer free holes than the same materials in its intrinsic form, it is called

A (x) n-doped.

B ( ) p-doped.

C ( ) pn-junction.

D ( ) np-junction.

43 Hall effect

The Hall effect can be used to determine:

A ( ) the carrier concentration in a semiconductor.

B ( ) the type of carriers present (electrons or holes).

C ( ) the effective mass of the carriers.

D (x) A and B

E ( ) B and C

44 Semiconductors

Consider an ideal intrinsic semiconductor in thermal equilibrium. No external forces or fields are applied to this semiconductor. Let n denote the concentration of electrons in the conduction band while p denotes the concentration of holes in the valence band. At room temperature, we have

A (x) $n = p$.

B ( )$n \approx p$ but $p \neq n$.

C ( )$n \ll p$.

45 Semiconductors

Figure 22 shows the electronic band dispersion near the fundamental gap of a semiconductor.

1. This material has

   A (x) a direct band gap.

   B ( ) an indirect band gap.

2. The following statement describes the band structure correctly:

   A ( ) The effective mass of the electrons is higher than that of the holes.

   B (x) The effective mass of the holes is higher than that of the electrons.

   C ( ) The effective masses of the electrons and the holes are equal.

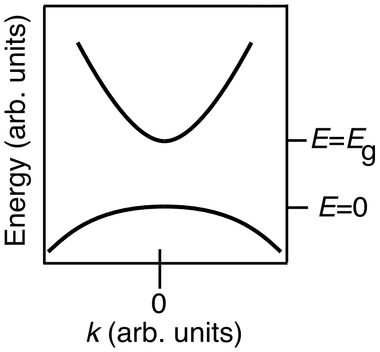

Figure 22: Band structure of a semiconductor.

46 Semiconductors

Figure 23 shows the qualitative formation of electronic bands in silicon: When the atoms are very far away from each other (large lattice constant a), the atoms have discrete s and p levels. As a is decreased, these levels turn into energy bands (grey shaded areas). Based on this figure, how would you expect the band gap to change as you increase the temperature of a silicon crystals? Hint: How would you expect the lattice constant to change as a function of temperature?

A ( ) The band gap stays the same.

B ( ) The band gap increases.

C (x) The band gap shrinks.

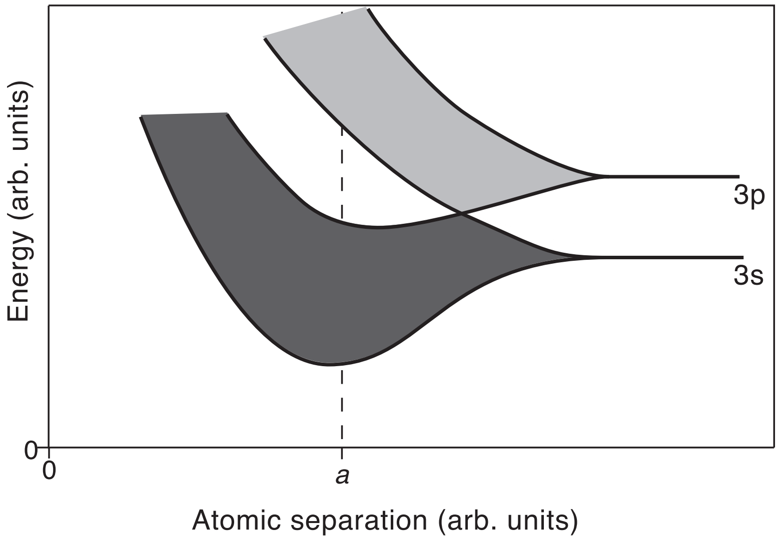

Figure 23: Band formation in silicon.

47 Semiconductors

The "ionization energy of a donor in a semiconductor" refers to the difference between:

A ( ) the energy of an electron bound to the donor and the top of the valence band.

B (x) the energy of an electron bound to the donor and the bottom of the conduction band.

C ( ) the energy of an electron bound to the donor and the bottom of the valence band.

D ( ) the energy of an electron bound to the donor and the top of the conduction band.

48 Intrinsic semiconductors

Consider an intrinsic semiconductor with the typical situation of the hole effective mass being higher than the electron effective mass. For temperatures of $0 < T \ll E_g/k_B$, the chemical potential is found

A ( ) in the middle of the band gap.

B ( ) closer to the valence band maximum.

C (x) closer to the conduction band minimum.

D ( ) somewhere within the band gap but there is insufficient information in the question to determine where.

49 Semiconductor Devices

Figure 24 shows a pnp metal oxide field effect transistor. What has to be the sign of the gate voltage needed to establish a conductive channel between source and drain?

A ( ) positive.

B (x) negative.

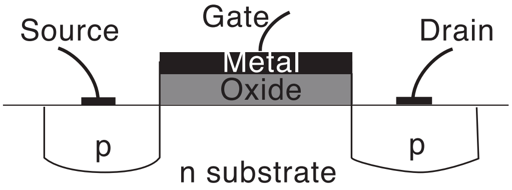

Figure 24: Sketch of a pnp field effect transistor with doping type (p/n) indicated.

50 Semiconductor Devices

Figure 25 shows the band energies near the junction of a p-type and n-type semiconductor. We assume that the semiconductor material on both sides is Si with a band gap of 1.1 eV. Just the doping is different.

1. The p-doped side is

   A ( ) on the left hand side.

   B (x) on the right hand side.

2. Let's assume that you connect a 4.5 V battery to this device.

   A ( ) If you connect the "+" side of the battery to the left hand side of the device and the "-" side of the battery to the right hand side, a higher current would flow than if you connect it the other way round.

B (x) If you connect the “-” side of the battery to the left hand side of the device and the “+” side of the battery to the right hand side, a higher current would flow than if you connect it the other way round.

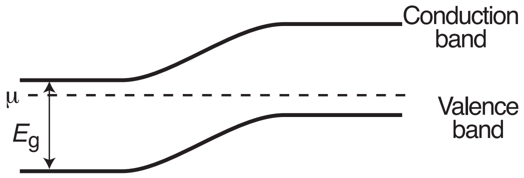

Figure 25: Valence band and conduction band near the junction between two semiconductors of different doping type.

51 Semiconductor Devices

Figure 26 shows the band structures of two semiconductors.

A ( ) The material X has a direct band gap and the material Y has an indirect band gap.

B (x) The material Y has a direct band gap and the material X has an indirect band gap.

C ( ) Both materials have an indirect band gap.

D ( ) Both materials have a direct band gap.

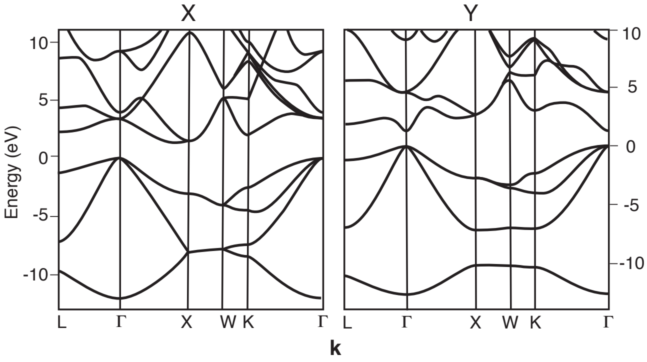

Figure 26: Band structures of two semiconductors

52 Semiconductor devices

Consider a pn-junction in thermal equilibrium and without an applied bias voltage. The chemical potential is

A ( ) at a higher energy on the p-side than on the n-side.

B ( ) at a higher energy on the n-side than on the p-side.

C (x) the same on both sides.

Chapter 8

53 Magnetism

The magnetic susceptibility for a paramagnetic material is

A ( ) negative

B ( ) zero

C (x) positive

54 Pauli paramagnetism

When an external magnetic field is applied to a metal, the alignment of the free electrons' spin magnetic moments with the field leads to a strong paramagnetic susceptibility ($\chi > 0.5$) for

A ( ) very low temperatures.

B ( ) very high temperatures.

C (x) never.

D ( ) for all temperatures.

55 Magnetism

What is the fraction of the conduction electrons in a metal that contribute to its paramagnetism (the so-called Pauli paramagnetism)?

A ( ) all the electrons contribute.

B ( ) only roughly 50% contribute.

C (x) less than 10% contribute.

56 Magnetism

In our quantum mechanical treatment of magnetism for free electrons, we found a contribution to the first order energy perturbation of

$$\frac{e^2}{8m_e} B_0^2 \langle \psi | (x^2 + y^2) | \psi \rangle. \tag{6}$$

This contribution gives rise to

A ( ) paramagnetism.

B (x) diamagnetism.

C ( ) ferromagnetism.

D ( ) anti-ferromagnetism.

57 Magnetism

Consider the temperature dependent magnitization of a ferromagnetic material (without externally applied magnetic field). This is

A ( ) Constant below the Curie temperature and zero above.

B (x) Decreasing from $T = 0$ to the Curie temperature and zero above.

C ( ) Increasing from $T = 0$ to the Curie temperature and zero above.

D ( ) Constant and large up to the Curie temperature and much smaller above the Curie temperature.

Chapter 9

58 Dielectrics

1. We have modelled the frequency-dependence of the dielectric function $\epsilon(\omega)$ in an ionic crystal by a single harmonic oscillator that can couple to electromagnetic radiation. Figure 27 shows the result. Can you identify the real and imaginary parts of $\epsilon(\omega)$?

   A (x) The left side shows the real part and the right side the imaginary part.

   B ( ) The right side shows the real part and the left side the imaginary part.

2. At what frequency does the system absorb most energy of the incoming radiation?

   A ( ) at very low frequencies

   B (x) at ω_0, the resonance frequency of the oscillator

   C ( ) at very high frequencies

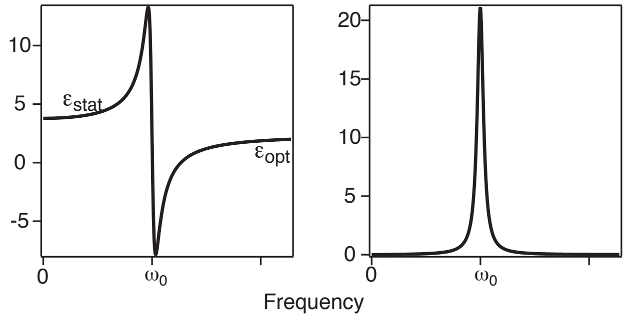

Figure 27: Real and imaginary part of the dielectric function for a single harmonic oscillator.

Chapter 10

59 Superconductivity

Superconducting materials loose the property of being superconducting above the critical temperature T_C. There are other factors that can cause the superconductivity to break down. Name one example. Answer: current density, magnetic field

60 Superconductivity

Suppose that you could change the vibrational energies in a superconducting material without changing anything else. What would you expect to happen to the superconducting transition temperature when you increase all the vibrational energies? It would

A (x) increase.

B ( ) decrease.

C ( ) remain the same.

61 Superconductivity

Compare the absolute magnitude of a superconductor's magnetic susceptibility $|\chi_m^S|$ to that of the diamagnetic material graphite $|\chi_m^{gr}|$.

A (x) $|\chi_m^S| \gg |\chi_m^{gr}|$ (i.e. orders of magnitude different)

B ( ) $|\chi_m^S| \ll |\chi_m^{gr}|$ (i.e. orders of magnitude different)

C ( ) $|\chi_m^S| \approx |\chi_m^{gr}|$ (i.e. similar order of magnitude)

62 Superconductivity

Suppose that you could change the mass of the atoms in a superconductor without changing anything else. How would an increased mass affect the superconducting transition temperature T_C?

A ( ) T_C would not be affected.

B ( ) T_C would increase.

C (x) T_C would decrease.

63 Superconductivity

Suppose that you could change the force constants between the atoms in a superconductor without changing anything else. How would a higher force constant affect the superconducting transition temperature T_C?

A ( ) T_C would not be affected.

B (x) T_C would increase.

C ( ) T_C would decrease.

64 Superconductivity

What role plays the density of states at the Fermi energy of a metal with respect to the superconducting transition temperature T_C? Increasing the density of states at the Fermi energy causes T_C to

A (x) increase.

B ( ) decrease.

C ( ) remain more or less the same.

65 Superconductivity

The magnetic susceptibility of a superconductor in the superconducting state is

A ( ) positive.

B ( ) zero.

C (x) negative.

66 Superconductivity

In the superconducting state, a superconductor is

A ( ) paramagnetic.

B (x) diamagnetic.

C ( ) ferromagnetic.

D ( ) anti-ferromagnetic.