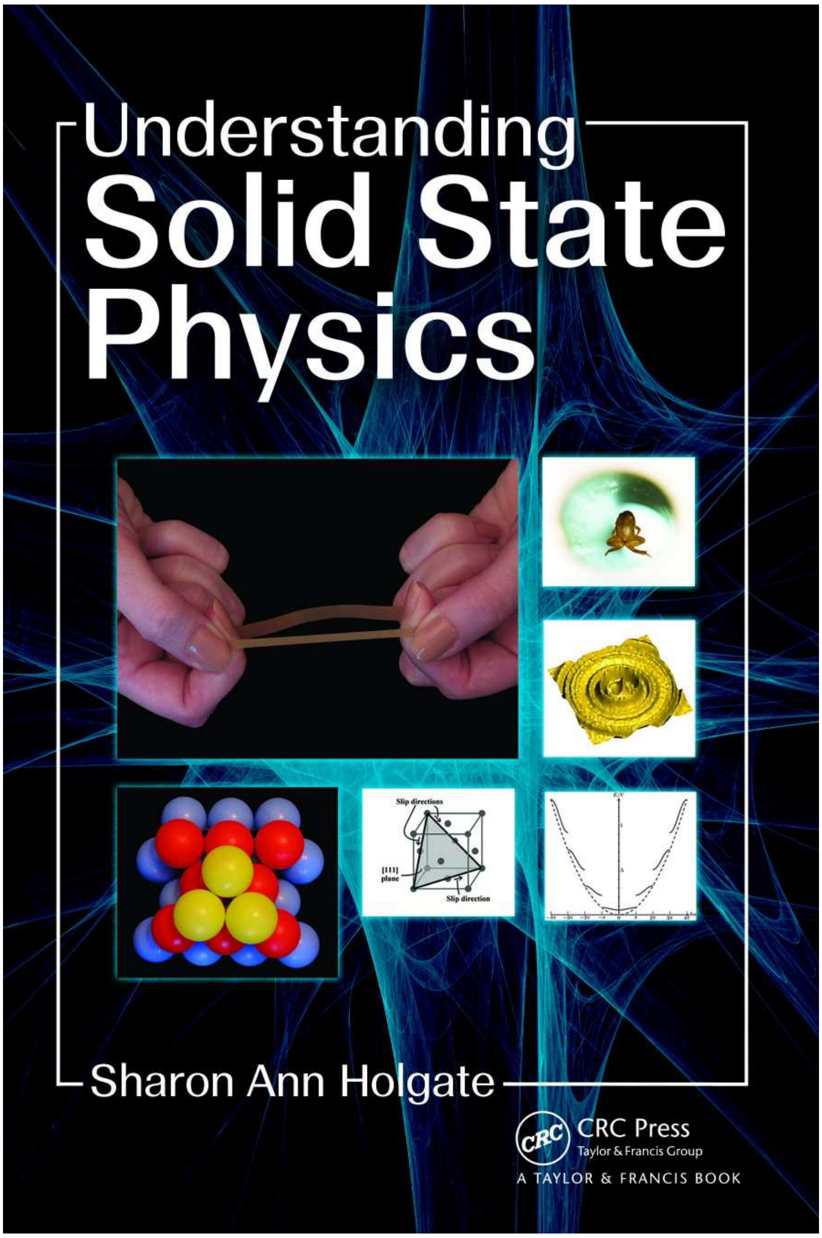
Understanding Solid State Physics

Additional Questions

Sharon Ann Holgate



Questions for Chapter 2

2.1(a) What structure does the compound caesium iodide crystallise in?

2.1(b) What does the term "coordination number" mean, and what is its value for the lattice representing your answer to part (a)?

2.1(c) What type of bonding does CsI have?

2.1(d) What is the electronic configuration of the two constituents of the compound when they are in solid form?

2.2 An atom has a partially filled outer shell, but can easily accept more electrons to fill it. How would you describe this atom?

2.3 What type of bonding do silicon and diamonds have in common?

2.4 Name two types of non-directional bonding.

2.5 The cohesive energy of a solid is 9 eV/atom. What does this tell you about the solid?

2.6 What types of bonding are present in a graphite crystal?

2.7 What type of bonding do freshwater fish need to be thankful for, and why?

2.8 List all the different crystal systems - without looking them up!

2.9 Assuming iron (Fe) has a lattice parameter, a, of 0.287 nm, what is the atomic radius and atomic density of an iron crystal?

2.10 Calculate the packing fraction of the face-centered cubic structure.

2.11 Calculate the atomic density of a simple orthorhombic crystal with a = 1.046 nm, b = 1.288 nm and c = 2.448 nm.

2.12 What is a compound with multiple structures known as?

2.13 What does the term "polycrystalline" mean?

2.14 For a cubic crystal lattice, what do the following represent?

(a) <111>

(b) [010]

(c) (111)

(d) {100}

2.15 Identify the cubic structure that has atomic coordinates of 000, 100, 110, 010, 001, 101, 111, 011, $\frac{1}{2}\frac{1}{2}\frac{1}{2}$.

Questions for Chapter 3

3.1 **If you have a 1cm^3 sample of aluminium, how many vacancies would it contain at 250K if the energy needed to create the vacancy is 0.75eV and there are 10^{22} atomic sites in every cubic centimetre of the sample?**

3.2 **How would you describe an impurity that replaces an atom at a normal lattice site?**

3.3(a) **What is a colour centre?**

3.3(b) **What type of bonding do crystals containing colour centres have?**

3.3(c) **Are colour centres naturally occurring or artificially made?**

3.4 **What is a Schottky defect more commonly known as?**

3.5 **What does the symbol**  **represent?**

3.6 **Which of the following types of order is present in an amorphous solid? (a) short range order (b) long range order or (c) both short and long range order?**

3.7 **Which of the following types of order is present in a crystalline solid? (a) short range order (b) long range order or (c) both short and long range order?**

3.8 **What is a supercooled liquid?**

3.9 **What will the supercooled liquid in question Q3.8 form if it is cooled even further?**

3.10 **Are polymers amorphous or crystalline?**

3.11 **A polymer is soft and flexible to the touch, and when it is heated becomes even softer and more flexible. What type of polymer is it?**

3.12 **What is the main difference in structure between high-density and low-density polythene, and how does this affect the density?**

3.13 **Which of the following would you add to rubber and why? (a) Carbon, (b) Sulphur or (c) Mica?**

Questions for Chapter 4

4.1 What term is given to the force per unit cross-sectional area?

4.2 Name the unit strain is measured in.

4.3(a) What is the "limit of proportionality" often known as?

4.3(b) What type of diagram are you most likely to see the answer to Q4.3(a) indicated on?

4.3(c) Describe the relationship between stress and strain for a solid below its limit of proportionality.

4.3(d) Who discovered this relationship?

4.3(e) Express this relationship mathematically.

4.4 You are given two small samples of material. Sample A has a larger value of Young’s modulus than sample B. Without carrying out any tests on the materials and in the absence of any further information, what can you say about the properties of these materials?

4.5 What will the increase in length be in a 12cm long piece of aluminium (with a Young’s modulus of 69GPa) that is subjected to a tensile stress of 240MPa? (Assume the deformation is elastic.)

4.6(a) Which planes are the most likely slip planes in an fcc metal?

4.6(b) What is the slip direction for an fcc metal?

4.6(c) Are fcc metals ductile or brittle, and why?

4.7 What is the difference between elastic deformation and plastic deformation?

4.8 What is the standard way for evaluating the force (load) on a material?

4.9(a) What is the "compressibility" of a material a measure of?

4.9(b) What does Poisson’s ratio reveal?

4.9(c) Fluorite has a Mohs hardness value of 4, while feldspar has a Mohs value of 6. Which material is the hardest?

4.10(a) What are alloys of copper and zinc commonly known as?

4.10(b) Name two types of commonly used composite materials.

4.10(c) Annealing and quenching are both types of what?

4.10(d) What do you need to do to work harden (cold work) a crystalline material?

4.10(e) What type of defect does work hardening produce?

Questions for Chapter 5

5.1(a) State the Bragg law.

5.1(b) What do each of the terms represent?

5.2 The intensity of a diffracted beam is much greater from crystal A than from crystal B. If you ignored any potential differences in intensity due to crystal structure, what could you deduce about the individual atoms that make up crystals A and B?

5.3 You are carrying out an X-ray diffraction experiment on a crystal that has the face centred cubic structure. Would you expect to see diffraction from the (111) plane?

5.4(a) What types of radiation other than X-rays are commonly used to obtain diffraction patterns?

5.4(b) What do the initials LEED stand for?

5.4(c) Calculate the lowest neutron energy that will allow Bragg diffraction from the {110} planes of a silicon crystal with a lattice parameter, a, of 0.542 nm.

5.5 You obtain two X-ray diffraction patterns from a metal sample. The first pattern is recorded prior to the metal being work hardened, and the second is taken after the treatment. If you were to compare the before and after patterns, what is likely to be the main difference between them and why do we see this difference?

5.6(a) Is a sound wave longitudinal or transverse?

5.6(b) What is another description for the type of wave you did not choose as your answer in part 5.6(a)?

5.7 Which statement - (a), (b) or (c) - best describes a phonon?
(a) A large amplitude atomic vibration;
(b) A quantized packet of vibratory energy;
(c) The sound equivalent of an electron.

5.8(a) What does the symbol Θ_D stand for?

5.8(b) What is the significance of this quantity?

5.9 **Why is C_p (the specific heat at constant pressure) of a given solid slightly higher than the value of C_v (the specific heat at constant volume)?**

5.10 **Particle A has a longer mean free path than particle B. Which particle is most likely to make it from one side of a solid to the other?**

5.11 **A phonon can be scattered by which of the following? (a) Another phonon; (b) The surface of a solid; (c) An impurity atom; (d) A dislocation.**

5.12 **You have seen the results of an experiment to measure thermal conductivity in solids at 293K. The data is as follows (i) 429 $Wm^{-1}K^{-1}$; (ii) 1.4 $Wm^{-1}K^{-1}$, and (iii) 0.13$Wm^{-1}K^{-1}$. Match the following materials with their most likely result, (a) polystyrene, (b) silver and (c) fused silica.**

5.13 **What two contributions make up the total thermal conductivity of a solid?**

5.14 **If a 10cm long brass rod is clamped at one end and heated from 20°C to 40°C, how much would it expand lengthways?**

Questions for Chapter 6

6.1 What are insulators also known as?

6.2(a) Are ionic solids good or bad electrical conductors?

6.2(b) Why is this?

6.3 Are covalent solids good or bad electrical conductors?

6.4 Which physical property of solids has the widest range of values?

6.5 Are polymers insulators, conductors or semiconductors?

6.6(a) Does the resistivity of a metal increase or decrease with temperature?

6.6(b) Why is this?

6.6(c) What other non thermal factors contribute to the resistivity?

6.7(a) For metals and alloys, what is unusual about dividing the thermal conductivity of each solid by its electrical conductivity?

6.7(b) Your answer to part (a) is a law named after its discoverers. What is its name?

6.8(a) Which principle do electrons in a Fermi gas obey?

6.8(b) Briefly, what does the principle state?

6.8(c) In Pauli's quantum free electron model, what does the Fermi energy, E_F, represent?

6.8(d) According to this theory, does an electron have to be (i) above or (ii) below the Fermi energy to take part in conduction?

6.9(a) How will a particle with a negative effective mass behave in the presence of an applied electric field?

6.9(b) What is the "particle" in 6.9(a) commonly known as?

6.9(c) How are these particles created in semiconductors, and what macroscopic property do they contribute to?

6.9(d) Why is the mass of an electron moving in a semiconductor said to be an "effective mass"?

6.10 State whether each of the following statements is true or false.

(a) At absolute zero the Fermi level in a semiconductor lies in the middle of the bandgap.

(b) At room temperature the Fermi level in an intrinsic semiconductor lies in the middle of the bandgap no matter what the values of the density of states are for the valence band and conduction band.

(c) The Fermi level in a p-type semiconductor moves nearer the middle of the bandgap the more acceptor atoms are present.

(d) The Fermi level in an n-type semiconductor moves nearer to the bottom of the conduction band as the number of donor atoms increases.

6.11(a) A piece of silicon at 300K is doped with $4x10^{17}$ antimony atoms cm^{-3}. What type of extrinsic semiconductor does this produce?

6.11(b) Indicate roughly where this dopant creates an additional energy level in a simple band diagram of the semiconductor.

6.11(c) If the intrinsic carrier concentration of silicon at 300K is $1.4x10^{10}$ cm^{-3}, what is the concentration of both electrons and holes in this sample?

6.12 When Si is incorporated into GaAs it can create one of two impurity levels either (a) 0.035eV above the valence band or (b) 0.0058eV below the conduction band. What do these two levels (a) and (b) indicate?

6.13 What is the mean free time and mean free path for a hole moving through a piece of p-type silicon at room temperature? Assume mobility for the hole equals 0.0458 $m^2V^{-1}s^{-1}$, and that its effective mass is 0.59 m_0.

6.14 What is the conductivity in a piece of silicon at 300K doped with (a) 6×10^{17} antimony atoms per cm^3; and (b) 5×10^{18} boron atoms per cm^3 if the hole mobility is 0.0458 $m^2V^{-1}s^{-1}$ and the electron mobility is 0.15 $m^2V^{-1}s^{-1}$.

6.15 Aside from thermal motion and drift velocity, what else can cause charge carriers to move in a semiconductor?

6.16(a) What does T_c signify?

6.16(b) What is the main difference between a type I and a type II superconductor?

6.16(c) Which type of superconductor (type I or type II) are the following solids more likely to be?

(i) an alloy

(ii) an element

6.17 If a sample of indium with a value of $H_c(0)$=0.0282 T is cooled below its superconducting transition temperature of 3.41 K, what is the approximate value of its critical field when it is at 2 K?

6.18 Which statement best describes the Meissner effect?

(i) the expulsion of current from a metal in a magnetic field when it is cooled below T_c;

(ii) the expulsion of magnetic flux from a metal in a magnetic field when it is cooled below T_c;

(iii) the expulsion of magnetic flux from a metal in an electric field when it is cooled below T_c;

(iv) the expulsion of magnetic flux from a metal in a magnetic field when it is held above T_c.

6.19(a) What is the name of the most widely used theory of conduction in superconductors?

6.19(b) In this theory, electrons with opposite spins become loosely bound together forming what?

Questions for Chapter 7

7.1 Which of the following statements best describes a diode?
(a) An electrical circuit that rectifies current;
(b) An electronic device with two electrodes;
(c) An electronic device with three electrodes.

7.2(a) What is the common term for a layer of p-type semiconductor sandwiched next to a layer of n-type semiconductor?

7.2(b) What function does your answer to part (a) most commonly perform?

7.3 What is the difference between a p-n homojunction and a p-n heterojunction?

7.4 Is the depletion region in a p-n junction largest when the junction is under (a) no bias, (b) reverse bias, or (c) forward bias?

7.5 When a p-n junction is under the condition given in your answer to question 7.4, do the drift currents or diffusion currents dominate?

7.6 What are the two main mechanisms for breakdown in p-n junctions?

7.7(a) How many regions of differently doped semiconductor make up a bipolar junction transistor?

7.7(b) How are these regions arranged, identifying from left to right?

7.8 In general, what two main functions do transistors perform when they are part of an electronic circuit?

7.9 What is the difference between a 'unipolar' and a 'bipolar' device?

7.10 What is the significance of the gate threshold voltage, V_{GT}, in a MOSFET?

7.11(a) Name the three basic processes that can occur between a photon and an electron in a solid.

7.11(b) Which of these processes forms the basis for laser operation?

7.12 What name is given to a semiconductor in which the valence band maximum occurs at a different value of wavevector, *k*, to the conduction band minimum?

7.13(a) What type of diode forms the basis for an LED?

7.13(b) In order for the LED to emit light, does the diode in your answer to part (a) have to be forward biased or reverse biased?

Forward.

7.13(c) What determines the colour of the light emitted by an LED?

7.14(a) Is silicon a good material to make a diode laser from?

7.14(b) Why is this?

7.14(c) How is the laser cavity formed in a diode laser?

7.15 Describe in simple terms how a solar cell works.

7.16(a) Name the three most widely used techniques for growing "perfect" semiconductor crystals?

7.16(b) What is the purpose of a seed crystal, and which of these processes uses one?

7.16(c) Which technique can be used to increase the purity of existing crystals?

7.17(a) What type of structure does epitaxy produce?

7.17(b) What defects can occur when growing heterostructures?

7.18 What is the magnitude of the dipole moment of a pair of point charges 6nm apart from one another if one charge has the value +4pC and the other -4pC?

7.19 Name the three different types of polarisation in materials.

7.20 What type of dielectric material has an electric dipole moment when it is below a certain critical temperature even when it is not in an electric field?

7.21 What happens when a piezoelectric material is subjected to stress?

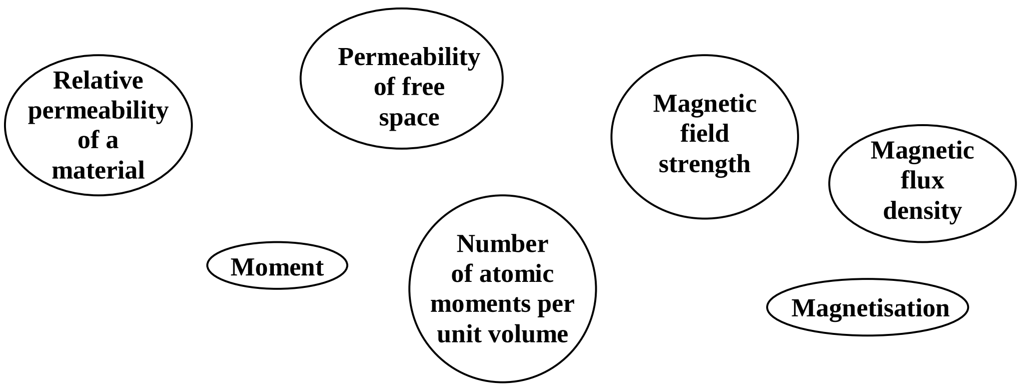
Questions for Chapter 8

8.1 Which statement describes the Bohr magneton?

(a) The total magnetic moment of a free electron
(b) The spin magnetic moment of a free electron
(c) The spin magnetic moment for an electron in an atom
(d) The total magnetic moment for an electron in an atom

8.2 Draw a line to connect each symbol with the magnetic quantity or property it represents

μ_0 m $\mathbf{B}$ μ_r $\mathbf{H}$ $\mathbf{M}$ n



8.3(a) What unit is the magnetic susceptibility, χ , measured in?

8.3(b) How does χ relate to the magnetisation?

8.4 What does the term "field vector" mean?

8.5 Which type of magnetism is being described by the following statement?

The weakest form of magnetism, that only exists in the presence of an applied magnetic field.

8.6(a) Does a paramagnetic solid tend to obey Curie's law or the Curie-Weiss law?

8.6(b) State the formula for your answer to part (a)

8.7(a) **Which way do the magnetic moments of the individual atoms of a ferromagnetic material point within a single domain?**

8.7(b) **Does the existence of domains reduce or increase the overall magnetic energy of a ferromagnet?**

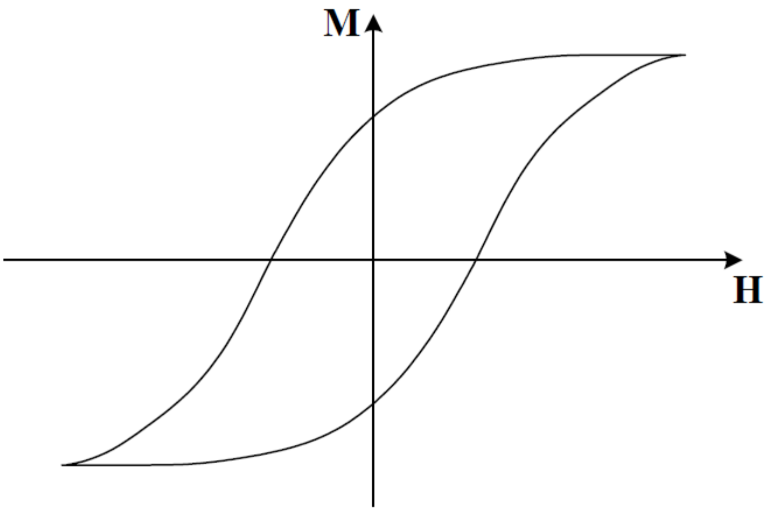
8.7(c) **What is the region between adjacent domains known as?**

8.7(d) **Describe the main changes in domain structure in a ferromagnetic material as an applied magnetic field is increased.**

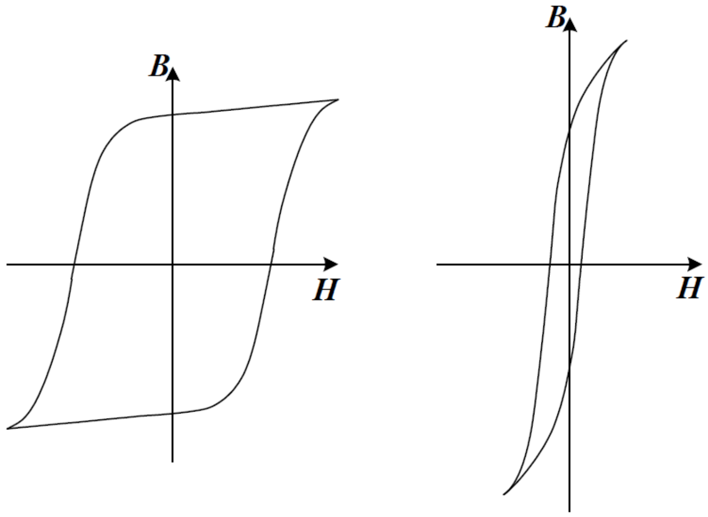
8.8(a) **What does the term "saturation magnetisation" mean?**

8.8(b) **What symbol is used to denote the saturation magnetisation?**

8.8(c) **Indicate the saturation magnetisation, and the remanence, M_r, on the following hysteresis loop.**



8.9 **Which batch of magnets, Batch A or Batch B, suffer the greatest energy losses as they go round their respective hysteresis cycles?**



Batch A Batch B

8.10 **Calculate (a) the magnetic field strength, and (b) the magnetic flux density for a solenoid 20cm long, with 60 turns and carrying a current of 0.16A in a vacuum.**

Suggested Essay Topics

1. The recycling industry in 2020. What should it look like and why?
2. Magnetism through history.
3. Describe your vision for the future of solar power.
4. Medical applications of solid state physics.
5. Congratulations! You've been given $1million USD to develop an innovative product or device based on one of the theories discussed in this book. What do you develop and why?

Suggested length 2000–2500 words. Each topic to include at least five references to external sources of information.