Multiple choice questions. Twenty questions, 3 points each, 60 points total.

1. According the meson theory of nuclear forces, (a) the exchange of pions can produce either attractive or repulsive forces, (b) a nucleon does not change mass when it emits a pion, (c) the shifting of electrons and positrons between nucleons stabilizes the nucleus.

2. Which of the following statements can be used to explain unusual effective masses in crystals: (a) "waves is waves," (b) "holes isn't electrons," (c) "flat is fat."

3. The defining property of a crystal is the presence of (a) long-range atomic order, (b) short-range atomic order, (c) covalent bonds.

4. Which is ***not*** an example of an ionic crystal? (a) NaCl, (b) LiF, (c) SiC.

5. Covalent crystals (a) have high melting points, (b) have low melting points, (c) are soft.

6. Metallic bonding occurs when (a) the reduction in electron potential energy outweighs the increase in electron kinetic energy that accompanies it, (b) the electron kinetic energy is decreased by the mutual repulsion of the positive metal ions, (c) the electron potential energy is increased by the mutual attraction of the positive metal ions.

7. The mean free electron path that gives rise to Ohm's law is due to electron collisions with (a) other electrons, (b) positive ion cores, (c) defects and irregularities in the crystal structure.

8. Tritium, ${}^{3}_{1}H$, and helium-3, ${}^{3}_{2}He$, are examples of (a) isotopes of the same element, (b) nuclides, (c) nucleons.

9. An example of a van der Waals bond is (a) the H-O bond ***in*** a water molecule, (b) the C-H bond ***in*** methane, (c) the H-O bond ***between*** water molecules.

10. In the nuclide denoted by the symbol ${}^{A}_{Z}X$, A is (a) the number of neutrons, (b) the number of protons, (c) the number of nucleons.

11. In stable nuclei, (a) the number of neutrons tends to exceed the number of protons, (b) the number of protons tends to exceed the number of neutrons, (c) the number of neutrons plus protons tends to add up to an odd number.

12. The diffusion of atoms in a crystal is possible because of (a) screw dislocations, (b) point defects, (c) work hardening.

13. A good model for a nucleus would be (a) tightly-packed marbles in a plastic sphere, (b) a few marbles in a large plastic sphere, (c) grapes in a balloon.

14. The importance of the tunnel diode lies in (a) the rapidity with which a voltage change can alter the current, (b) the increase of the tunnel current at high external voltages, (c) the ease with which the diode breaks down for large reverse bias voltages.

15. The density of nuclei is (a) greater for nuclei with larger mass numbers, (b) about the same for all nuclei, (c) greater for nuclei with smaller mass numbers.

16. The nuclear binding energy per nucleon is of order (a) meV per nucleon, (b) eV per nucleon, (c) MeV per nucleon.

17. Pick the ***false*** statement. A solid will be an insulator if (a) it has an even number of valence electrons per structural unit, (b) it has an odd number of valence electrons per structural unit, (c) the band gap is large compared to k_BT.

18. The surface energy term reduces the total nuclear binding energy because (a) the number of neutrons in a nucleus is greater than the number of protons, (b) nucleons on the nuclear surface have fewer neighbors than interior nucleons, (c) a sphere has the least surface area for a given volume.

19. In an npn junction transistor, the base is made very thin so that (a) the reverse bias can drive holes from the collector back into the base, (b) holes can pass through it from emitter to collector without recombining with electrons there, (c) electrons can pass through it from emitter to collector without recombining with holes there.

20. In silicon, phosphorus (5 outer electrons) placed on a silicon (4 outer electrons) site contributes its "extra" electron to the conduction band, acting as a donor. The III-IV compounds, such as InSb, have the same crystal structure as silicon. When silicon is placed on an indium (3 outer electrons) site in indium antiminide, InSb, it acts as (a) a trap, (b) a donor, (c) an acceptor.

Multiple choice problems. Six problems, 5 points each, 30 points total.

1. Copper is a mixture of the $^{63}_{29}Cu$ and $^{65}_{29}Cu$ isotopes, and has a composite atomic mass of 63.55. Ignore the mass discrepancy due to binding energy. What percentage of $^{63}_{29}Cu$ is present in ordinary copper? (a) 72.5%, (b) 27.5%, (c) 7.25%, (d) 2.75%.

2. The binding energy per nucleon in $^{197}_{79}Au$ (mass = 196.966560 u) is (a) 7.711 MeV, (b) 7.916 MeV, (c) 7.711 MeV.

3. For zinc at 20 °C, the resistivity is $\rho=5.92\times10^{-8}$ Ω·m, the Fermi velocity is 1.82×10^{6} m/s, and the concentration of ***zinc atoms*** is 6.55×10^{28} m^{-3}. Zinc has a valence of 2. The mean free path between collisions of the free electrons in zinc is (a) 16.7 nm, (b) 33.4 nm, (c) 167 nm.

4. The range of wavelengths in visible light is about 400 to 800 nm. What is the ***minimum*** band gap for which a semiconductor begins to absorb visible light? (a) 1.55 eV, (b) 2.49 eV, (c) 3.10 eV, (d) 4.97 eV.

5. Gold melts at 1063 °C. What is the value of k_BT at the melting temperature of gold? (a) 5.51 eV, (b) 1.845 eV, (c) 0.115 eV, (d) 0.092 eV.

6. Copper has an atomic concentration of 8.5×10^{28} m^{-3} and a valence of 1. The conduction band in a copper sample of volume 1 cm^3 has how many ***available*** electron states? (Note that I am not asking for the number of filled electron states.) (a) 8.5×10^{22}, (b) 1.7×10^{23}, (c) 8.5×10^{28}, (d) 1.7×10^{29}.

Problems. Two problems, 15 points each, 30 points total.

1. Arsenic is present in a silicon sample. The effective mass of an electron in silicon is about 0.31 m_e, the dielectric constant of silicon is 12, and the energy gap in silicon is 1.1 eV. Assume that one of the five arsenic electrons revolves in a Bohr orbit around each As^+ ion in the silicon lattice.

   (a) Calculate the radius of the first Bohr orbit of the electron.

   (b) Calculate the ionization energy, in milli electron volts, of this electron. Do you expect most of the donors to be ionized at room temperature? Explain why or why not.

2. Calculate the energy of neutrons which have wavelengths comparable to the radius of a $^{197}_{79}Au$ nucleus? Is a relativistic calculation necessary? Explain why or why not.