Problem 1

For the H_2 molecule the equilibrium spacing of the two protons is 0.074 nm. The mass of a hydrogen atom is 1.67×10^{-27} kg. Calculate the wavelength of the photon emitted in the rotational transition $l = 2$ to $l = 1$.

Problem 2

If a sodium chloride (NaCl) molecule could undergo an $n \rightarrow n - 1$ vibrational transition with no change in rotational quantum number, a photon with wavelength 20.0 μm would be emitted. The mass of a sodium atom is 3.82×10^{-26} kg and the mass of a chlorine atom is 5.81×10^{-26} kg. Calculate the force constant k' for the interatomic force in NaCl.

Problem 3

The spacing of adjacent atoms in a crystal of sodium chloride is 0.282 nm. The mass of a sodium atom is 3.82×10^{-26} kg and the mass of a chlorine atom is 5.81×10^{-26} kg. Calculate the density of sodium chloride.

Problem 4

The gap between valence and conduction bands in silicon is 1.12 eV. A nickel nucleus in an excited state emits a gamma-ray photon with wavelength 931 fm. How many electrons can be excited from the top of the valence band to the bottom of the conduction band by the absorption of this gamma ray?

Problem 5

Calculate the density of states $g(E)$ for the free-electron model of a metal if $E = 7.0$ eV and $V = 1.0$ cm^3. Express your answer in units of states per electron volt.

Problem 6

The Fermi energy of sodium is 3.23 eV.
(a) Find the average energy E_{avg} of the electrons at absolute zero.
(b) What is the speed of an electron that has energy E_{avg}?
(c) At what Kelvin temperature T is kT equal to E_F?

Note that part (c) is called the **Fermi temperature** for the metal. It is approximately the temperature at which molecules in a classical ideal gas would have the same kinetic energy as the fastest-moving electron in the metal.

Problem 7

Germanium has a band gap of 0.670 eV. Doping with arsenic adds donor levels in the gap 0.010 eV below the bottom of the conduction band. At a temperature of 300 K, the probability is 4.40×10^{-4} that an electron state is occupied at the bottom of the conduction band. Where is the Fermi level relative to the conduction band in this case?

Problem 8

(a) A forward-bias voltage of 15.0 mV produces a positive current of 9.25 mA through a *pn* junction at 300 K. What does the positive current become if the forward-bias voltage is reduced to 10.0 mV?
(b) For reverse-bias voltages of −15.0 mV and −10.0 mV, what is the reverse-bias negative current?

Problem 9

A *pn* junction has a saturation current of 3.60 mA.
(a) At a temperature of 300 K, what voltage is needed to produce a positive current of 40.0 mA?
(b) For a voltage equal to the negative of the value calculated in part (a), what is the negative current?

Problem 10

The rotational spectrum of HCl contains the following wavelengths (among others): 60.4 μm, 69.0 μm, 80.4 μm, 96.4 μm, and 120.4 μm. Use this spectrum to find the moment of inertia of the HCl molecule about an axis through the center of mass and perpendicular to the line joining the two nuclei.

Problem 11

Compute the Fermi energy of potassium by making the simple approximation that each atom contributes one free electron. The density of potassium is 851 kg/m^3 and the mass of a single potassium atom is 6.49×10^{-26} kg.