

## PHY 330: Second Problem Sheet (Hand-in 16 December 2011)

*The marks for the homework will be scaled to constitute 5% of the total mark for the module*

- a) i) Derive a formula for the wavevector of electron and hole created due to photon absorption of energy  $\hbar\omega$  in a direct gap semiconductor with band gap  $E_g$  and electron and hole effective masses  $m_e$  and  $m_h$ , respectively. **[1]**
- ii) Indium antimonide InSb is a direct gap material, which has energy gap  $E_g=0.18$  eV, electron ( $m_e$ ) and hole ( $m_h$ ) effective masses of  $0.014 m_0$  and  $0.18 m_0$  ( $m_0$  is the free electron mass), respectively. How much energy from a 0.5 eV photon is converted into free electron kinetic energy and how much is converted into free hole energy as a result of the photon absorption process? **[2]**
- b) Explain the concept of donors in semiconductors. Provide two examples each of donor and acceptor atoms for compound semiconductor such as GaAs. **[1]**
- c) The electron concentration at temperature 5 K in an n-type Germanium sample, where the number of donors exceeds that of acceptors, is  $1.94 \times 10^{10} \text{ m}^{-3}$ . Calculate donor ionisation energy if the electron effective mass is  $m_e = 0.56 m_0$  ( $m_0$  is the free electron mass). **[2]**
- d) Consider a thin film of copper with a thickness of 70 nm held in vertical magnetic field of 1 T. A current of 0.7 mA is passed along the length of this film. The Hall voltage measured in such configuration is 0.72  $\mu\text{V}$ . Derive the Hall coefficient and the electron concentration. **[2]**
- e) Explain what information about charge carriers can be obtained from cyclotron resonance measurements? Explain briefly why typical cyclotron resonance signal from Silicon contains four absorption peaks. **[1]**
- f) Explain the concept of plasmon. Describe briefly the experiment which reveals the existence of plasmons in metals. **[1]**
- g) Calculate the energy difference between the first and the second quantised electron levels in GaAs quantum well of thickness 140 Å. You may assume that the confined state energies approximate those of infinite square potential wells. The electron effective mass is  $0.066 m_0$  ( $m_0$  is the free electron mass). **[2]**