



**UNIVERSITY EXAMINATION 2021/2022**  
**SECOND YEAR FIRST SEMESTER EXAMINATION FOR THE DEGREE OF**  
**BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONIC ENGINEERING,**  
**BACHELOR OF SCIENCE IN TELECOMMUNICATIONS & INFORMATION ENGINEERING,**  
**BACHELOR OF EDUCATION IN ELECTRICAL & ELECTRONIC ENGINEERING.**

***EEE 2101: PHYSICAL ELECTRONICS***

**DATE: NOVEMBER 2021**

**TIME: 2 HOURS**

**Instructions**

This examination paper contains **FIVE** questions. Attempt **compulsory QUESTION ONE** and **any other TWO** questions.

**Question 1**

- a) Sketch the (110) (100) and (111) planes for crystal lattices. **(3marks)**
- b) Discuss why quantum tunnelling can only be understood through the wave nature of matter as described by quantum mechanics and not the classical narrative of particles. Also, state one use of quantum tunnelling. **(4marks)**
- c) The addition of impurities increases the crystal's conductivity. Let's add  $n_d = 10^{24}/\text{m}^3$  phosphorous atoms to Si. Using the intrinsic carrier density,  $n_i = 5.2 \times 10^{15}$  for silicon, compute the density of holes,  $n_h$ , in this "doped" crystal. **(3marks)**
- d) How does the position of the Fermi Level change with?
  - i) increasing donor concentration **(2marks)**
  - ii) increasing acceptor concentration **(2marks)**
- e) Use the correct diagrams to illustrate the different types of point defects. **(4marks)**
- f) State the Fermi-Dirac equation and explain its purpose in semiconductor theory. **(3marks)**
- g) Find the mobility of electrons in copper if there are  $9 \times 10^{28}$  valence electrons/ $\text{m}^3$  and the conductivity of copper is  $6 \times 10^7$  mho/m. **(3marks)**
- h) Draw the Energy band diagram of p-n junction at equilibrium. **(6marks)**

**Question 2**

- a) Current flowing in a p-n junction is 0.2 mA at room temperature when a large reverse bias voltage is applied. Calculate the current when a forward bias of 0.1 V is applied. **(6marks)**
- b) When the density of states  $Z(E)$  is plotted against the energy it gives a

parabola shown in Fig. 2b.

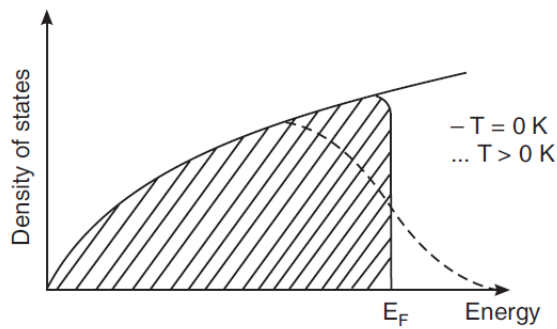


Fig. 2b

Discuss the graph at

- i)  $Z(E)$  versus  $E$  at  $T = 0$  (4marks)
- ii)  $Z(E)$  versus  $E$  at a much higher temperature (4marks)
- c) Compute the concentration of intrinsic charge carriers in a germanium crystal at 300 K. Given that  $E_g = 0.72$  eV and assume  $m_e^* = m_e$ . (6marks)

### Question 3

- a) With the aid of diagrams describe the Kronig and Penny simplified Model. (6marks)
- b) From the electron configuration of beryllium, it is expected that beryllium solid would be an insulator. However, it is known to be a conductor from this information draw the energy band configuration in beryllium solid. (4marks)
- c) In a solid, consider the energy level lying 0.01 eV below Fermi level. What is the probability of this level not being occupied by an electron? (6marks)
- d) Briefly outline how Avalanche breakdown occurs. (4marks)

### Question 4

- a) Clearly outline the derivation of Ohm's Law. (6mark)
- b) In a doped semiconductor, there are  $4.52 \times 10^{24}$  holes and  $1.25 \times 10^{14}$  electrons per cubic meter. What will be the carrier density in undoped specimen? Electron and hole mobilities are  $0.38 \text{ m}^2/\text{V} \cdot \text{s}$  and  $0.18 \text{ m}^2/\text{V} \cdot \text{s}$  respectively. Calculate the conductivity of intrinsic and the doped semiconductors. (6marks)
- c) Use appropriate diagrams to briefly outline how Zener breakdown Occurs. (4marks)
- d) With the aid of diagrams briefly describe how a P-N junction is formed. (4marks)

### Question 5

- a) Use appropriate diagrams to highlight the differences in the unit cell that is a building block to crystal lattices of solids. **(8marks)**
- b) Calculate the potential barrier for a germanium p-n junction at room temperature, if both the p- and n-regions are doped equally and to the extent of one atom per  $10^6$  germanium atoms. **(3 marks)**
- c) Find the drift velocity of free electrons in a copper wire of cross-sectional area  $10 \text{ mm}^2$  when the wire carries a current of 100 A. Assume that each copper atom contributes one electron to the free electron gas. Density of copper is  $8969 \text{ kg/m}^3$  and its atomic weight is 63.54. **(5 marks)**
- d) For the infinite potential well shown in Fig.5d show that the solution to the Schrodinger equation reduces to,  
 $\Psi_n(x) = A_n \sin \frac{n\pi}{a}x$ , for  $n = 1, 2, 3 \dots$  **(4marks)**

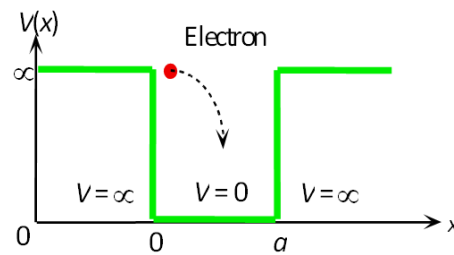


Fig. 5d