



MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SPECIAL NEEDS)

BACHELOR OF EDUCATION (SCIENCE)

SPH 340: SEMICONDUCTOR PHYSICS AND DEVICES

DATE: 18/4/2023

TIME: 8:30 – 10:30 AM

INSTRUCTIONS:

Answer question **ONE** which is compulsory and any other **TWO**

Useful Constants: Permittivity due free space, $\epsilon_0 = 8.854 \times 10^{-12} \text{CN}^{-1}\text{m}^{-1}$

Charge on electron, $e = 1.6 \times 10^{-19} \text{C}$

Planck's constant, $h = 6.626 \times 10^{-34} \text{Js}$

Mass of electron, $m_e = 9.1 \times 10^{-31} \text{kg}$

SECTION A

QUESTION ONE (COMPULSORY) (30 COMPULSORY)

- (a) Explain the major quantum improvements of the Bohr atomic model (3 marks)
- (b) Describe the Rutherford atomic model (5 marks)
- (c) For a PN junction, describe
 - (i) Diffusion current (2 marks)
 - (ii) Depletion layer (2 marks)
- (d) Charge recombination can be an advantage or a disadvantage. Explain giving an example for each a case. (4 marks)

- (e) A silicon crystal with 5×10^{28} atoms/m³ is doped at a concentration of 3 parts per million of a trivalent dopant. If the concentration of the intrinsic charge carriers in the crystal is $n_i = 1.5 \times 10^{16}$ m³, determine the number of: -
- (i) Holes (2 marks)
 - (ii) Conduction electrons (3 marks)
- (f) Explain five ways in which printed circuit boards (PCBs) have impacted modern electrical devices (5 marks)
- (g) (i) Define a transistor loadline (1 mark)
- (ii) Explain how a transistor loadline is obtained (3 marks)

SECTION B

QUESTION TWO (20 MARKS)

- (a) In terms of energy bands, distinguish between conductors and insulators. (4 marks)
- (b) Name and explain three factors that affect the energy band gap of a semiconductor. (6 marks)
- (c) (i) Show that the radius of the an electron in the nth orbit is given by $r_n = -\frac{\epsilon_0 n^2 h^4}{\pi e^2 m Z}$, where h is the Planck's constant, e , Z and m are the electronic charge, atomic number and mass respectively. (7 marks)
- (ii) Determine the radius of an electron in a hydrogen atom at the ground state (3 marks)

QUESTION THREE (20 MARKS)

- (a) Distinguish between intrinsic and extrinsic semiconductors (2 marks)
- (b) Why are P-type and N-type semiconductors considered electrically neutral (3 marks)
- (c) Describe the production of holes and their movement within a crystal lattice (5 marks)
- (d) Describe the working of a P-N junction (5 marks)
- (e) Using an illustration, describe the V-I characteristics of a P-N junction (5 marks)

QUESTION FOUR (20 MARKS)

- (a) Distinguish between thermionic emission and that from a photodiode. (2 marks)
- (b) Explain any two factors affecting photoelectric effect (4 marks)
- (c) After illuminating a material with beam of light of wavelength 320 nm, a potential of 1.6 V is required to stop the photoelectrons. Determine the: -
 - (i) Work function of the material (3 marks)
 - (ii) Maximum velocity of the photoelectrons (2 marks)
 - (iii) Maximum kinetic energy of the photoelectrons if the material was irradiated using 400 nm light. (3 marks)
- (d)
 - i) Describe a Fermi level. (3 marks)
 - ii) Using a simple illustration, explain how the Fermi level of a semiconductor is affected by doping using a pentavalent material. (3 marks)

QUESTION FIVE (20 MARKS)

- (a) Describe the working principle of a photodiode (5 marks)
- (b) Describe the structure of a Field Effect Transistor (FET) (5 marks)
- (c) Transistors have several applications in electrical circuits. Using simple circuit diagrams, explain how they can be used as a switch (5 marks)
- (d) A transistor has a collector current of 980 μA and a base current of $2 \times 10^{-5} \text{A}$. Determine the: -
 - (i) Emitter current (2 marks)
 - (ii) Current amplification factor (2 marks)
 - (iii) Current gain factor (1 mark)