The Presbyterian University of East Africa

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DEPARTMENT OF EDUCATION

END OF SEMESTER EXAMINATIONS

APRIL 2020

**SPH 422: SEMICONDUCTOR PHYSICS AND DEVICES**

TIME: 2 HOURS

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

Useful constants;

K-Boltzmann's constant=$8.617 \times 10^{-5}$ eV/K

$n_i$- carrier density (at 300 K, for silicon, ni=$9.65 \times 10^{9}$ $cm^{-3}$

$N_C = 2.86 \times 10^{19}$ $cm^{-3}$ $N_v = 2.66 \times 10^{19}$ $cm^{-3}$ for silicon

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

## QUESTION ONE (20MKS)

a. (i). What is meant by energy gap? (1mk)

(ii).Distinguish between conductors, insulators and semi-conductors using the valence band theory (4mks)

b. (i). Use energy band diagrams to differentiate between direct bandgap and indirect bandgap semiconductors and give examples in each case. (2mks)

(ii). Explain the formation of n-type semiconductor (3mks)

c. i. Sketch a p-n junction in forward bias mode and showing the depletion layer (1mk)

ii. Explain what happens to the depletion layer in forward bias (2mks)

iii. Explain the effect on depletion layer in reverse bias mode (2mks)

d. (i). Sketch a diagram to show the N-P-N transistor biasing for common-base configuration. (2mks)

(ii).A transistor in a common base connection has a gain of 0.98. If the collector current is 20 mA, calculate the collector current. (3mks)

## QUESTION TWO (20MKS)

a. (i). A semiconductor is in general a single-crystal material. Distinguish between single –crystal, amorphous, and polycrystalline materials (3mks)

(ii). Calculate the packing fraction of BCC structure . (2mks)

b. Define binary, ternary and quaternary semiconductors and give examples in each case (5mks)

c. The diagram below shows a type of diode;


i. Identify the diode (1mk)

ii. Explain its operation (3mks)

iii. State one of its applications (1mk)

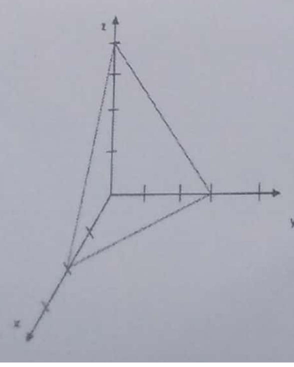
e. Describe the use of some special purpose diodes in fiber optic communication (5mks)

## QUESTION THREE (20MKS)

a. (i). calculate the miller indices for the crystal plane where a=1, b=∞ and c=1 (2mks)

(ii). Distinguish between diamond and zinc blende structures and give examples for each (3mks)

(iii). For a simple cubic lattice, find Miller indices for the planes below: (3mks)



ii. Explain what happens to the depletion layer in forward bias (2mks)

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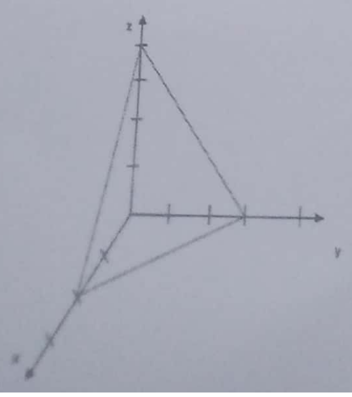

b. Silicon ingot is doped with $1x10^{17}$ phosphorus atoms/cm3 . Find:

(i) The carrier concentration $1\times10^{17}$ atoms/$cm^3$. (1mk)

**(ii)** The Fermi level at room temperature (300 K) $8.617\times10^{-3}\times300 \ln\left(\frac{2.86\times10^{19}}{1\times10^{17}}\right) = 0.1462$ eV. (3mks)

**c.** (i). What is meant by zener and avalanche breakdown? (2mks)

(ii). Sketch the V-I characteristics of a typical diode and show; (3mks)

a. Leakage current

b. Threshold voltage

c. Breakdown voltage

taught.

**d.** Explain the working of photodiode (3mks)

## QUESTION FOUR (20MKS)

a. A conduction wire has a resistivity of $1.54x10^{-8}$ ohm-meter and it has carrier concentration of 5.8x1028/m3 .

Calculate;

(i) Conductivity (3mks)

**(ii)** Electron mobility (2mks)

b. Explain the how a combination of four diodes can be used in full wave rectification (5mks)

c. Determine the germanium P-N junction diode current for the forward bias voltage of 0.25 V at room temperature of 26°C with reverse saturation current equal to 2 mA. Take η=2. ($V_T$ is given by T/11600 where T is absolute temperature)

d. A zener diode can be used as voltage regulator, meter protector and as awave shaper. Explain its application in the circuit below; (5mks)

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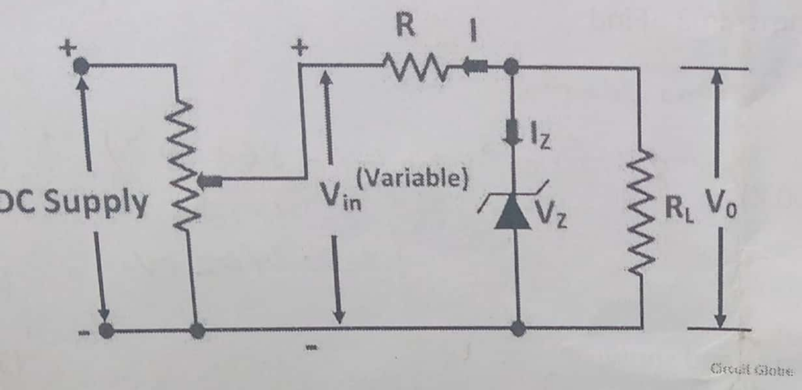



## QUESTION FIVE (20MKS)

a. Explain the following crystal growth techniques

i. Liquid-phase epitaxy (3mks)

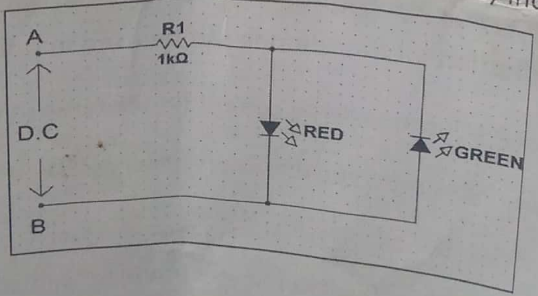
ii. Spray pyrolysis (3mks)

b. (i). Describe the four point probe technique (3mks)

(ii). A sample of Si is doped with $10^{17}$ phosphorus atoms/$cm^3$. Given that W=500 μm, A=0.0025 $cm^2$, I=1 mA and $B_z=1\times10^{-4}$ $Wb/cm^2$, find the Hall voltage. (3mks)

c. Explain how a tunnel diode works (4mks)

d. Explain the working of LEDs in the circuit diagram below as dc polarity indicator (4mks)

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