

CHUKA



UNIVERSITY

UNIVERSITY EXAMINATIONS

EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE
AND BACHELOR OF EDUCATION SCIENCE

PHYS 281: INTRODUCTION TO MATERIAL SCIENCE

STREAMS: BED (SCI) & BSC

TIME: 2 HOURS

DAY/DATE: TUESDAY 29/08/2023

2.30 P.M. – 4.30 P.M

INSTRUCTIONS:

- Answer Question One and any other Two Questions
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely
- You may use the generic integrals;

$$\int_0^{\infty} x^{2n+1} e^{-ax^n} dx = \frac{n!}{2a^{n+1}} (a > 0) \text{ and}$$

$$\int_0^{\infty} x^{2n} e^{-ax^2} dx = \frac{1.3.5 \dots (2n-1)}{2^{n+1} a^n} \sqrt{\frac{\pi}{a}}$$

QUESTION ONE

- State and briefly describe the five different bonds that are encountered in matter (5 marks)
- Differentiate a solid from a fluid. (2 marks)
- What are `Miller Indices` (2 marks)
- Calculate the radius of an iridium atom given that Ir has an FCC crystal structure, a density of 22.4 g/cm³, and an atomic weight of 192.2 g/mol. (5 marks)
- Calculate the interplanar distances of (234) family of planes in simple cubic structure of copper with lattice spacing of 455.176 Å (2 marks)
- Sketch a general pV against T (kelvin temperature) graph for an ideal gas. (3 marks)

- g. Calculate the most probable, the mean, and the root mean square velocities of a molecule of a gas whose density under standard atmospheric pressure (1.013×10^5) is equal to $\rho = 1.00$ g/l. (6 marks)
- h. Water leaves the jet of a horizontal hose (of uniform cross-section at a speed of 20 m/s . If the velocity of the water within the hose is 0.6 m/s, calculate using Bernoulli's theorem the pressure P within the hose. Take the density of water to be 1000 Kg/m^3 and the atmospheric pressure to be $100,000 \text{ N/m}^2$. (5 marks)

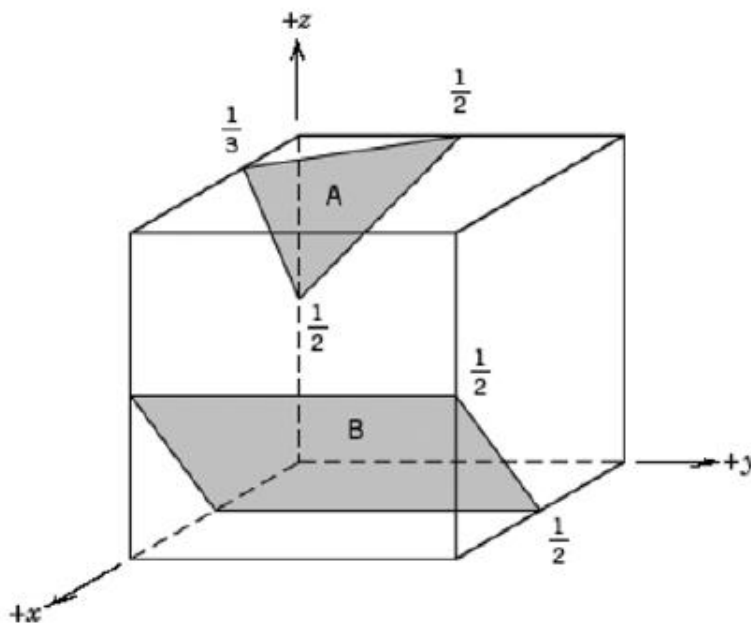
QUESTION TWO

- a. The net potential energy between two adjacent ions, E_N , may be represented as,

$$E_N = -\frac{A}{r} + \frac{B}{r^n}$$

Calculate the bonding energy E_0 in terms of the parameters A , B , and n (8 marks)

- b. Determine the Miller indices for the planes shown in the following unit cell (6 marks)



- c. For BCC iron, compute :

- i. The interplanar spacing, and (2 ½ marks)
- ii. The diffraction angle for the (220) set of planes. The lattice parameter for Fe is 0.2866 nm (2.866 \AA). Also, assume that monochromatic radiation having a wavelength of 0.1790 nm (1.790 \AA) is used, and the order of reflection is 1. (3 ½ marks)

QUESTION THREE

- a. Show for the body-centered cubic crystal structure that the unit cell edge length a and the atomic radius R are related through $a = 4R/\sqrt{3}$ (7 marks)
- b. Show that the atomic packing factor for BCC is 0.68. (6 marks)
- c. Iron has a BCC crystal structure, an atomic radius of 0.124 nm, and an atomic weight of 55.85 g/mol. Compute and compare its density with the experimental value of 7874 kg/m³ (Use atomic weight of Iron, $A_{\text{Fe}} = 55.85$ g/mol and $N_A =$ Avogadro's number (6.023 x 10²³ atoms/mol) (7 marks)

QUESTION FOUR

- a. The Maxwell distribution of molecular speeds in an ideal gas is given by:

$$P(v)dv = 4\pi \left(\frac{M}{2\pi RT} \right)^{\frac{3}{2}} V^2 e^{-MV^2/2RT} dv$$

Where v is the speed of a molecule (from 0 to infinity), and $P(v)dv$ is the fraction of molecules with speeds between v and $v + dv$. Starting with the above equation,

- i. The average speed V_{avg} (7 marks)
 - ii. The $V_{\text{r.m.s}}$ (5 marks)
 - iii. Find an expression for V_p , the most probably speed of a molecule in a gas. HINT: the most probably speed corresponds to the peak in a plot of number of molecules vs speed. (4 marks)
- b. Atomic weight of Chlorine is 35.5. Find the root means square velocity of chlorine molecules at 0 °C $R = 8.31 \text{ J mole}^{-1} \text{ K}^{-1}$ (4 marks)

QUESTION FIVE

- a. What is meant by the term 'liquid crystal'? (2 mark)
 - b. State and explain three phases of liquid crystals (3 marks)
 - c. Define or explain surface tension with due regard to liquids (1 marks)
 - d. Derive Bernoulli's theorem for fluid flow (9 marks)
 - e. Calculate the work done in spraying a drop of mercury 1 mm in radius into one million identical droplets all of them the same size. Take the surface tension of mercury to be 550 dynes per cm where 1 dyne = 1.0 x 10⁻⁵ N and 1 erg = 1.0 x 10⁻⁷ J (5 marks)
-