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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2020 /2021 ACADEMIC YEAR

SECOND YEAR SECOND SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: PHY 222

COURSE TITLE: PROPERTIES OF MATTER

DATE: 22/07/2021 **TIME:** 1300 – 1600 HRS

INSTRUCTION TO CANDIDATES

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THIS PAPER CONSISTS OF 5 PRINTED PAGES **PLEASE TURN OVER**

REGULAR- MAIN EXAM

PHY 222: PROPERTIES OF MATTER

STREAM: BED SCIENCE **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

a) *Answer the TWO questions in **SECTION A** and any other **THREE** questions in **SECTION B**.*

b) *The following constants may be useful:*

Avogadro's number	6.02×10^{23} *molecules/mole*
Boltzmann's constant, k	1.38×10^{-23} *J/molecule. K*
Density of mercury	*13,600 kg/m3*
Universal gas constant, R	*8.314 J/Mol. K*
1 atm	1.01×10^{5} Pa
1atomic mass unit (u)	1.66×10^{-27} *kg*

$C_P = \frac{7}{2}R$

SECTION A (28 MARKS)

Question One (14 Marks)

a) Describe the differences between crystalline solids and amorphous solids. (2 Marks)

b) Define the following terms that are used in study of crystal structures

i) Lattice (1 Mark)

ii) Conventional unit cell (1 Mark)

iii) Packing fraction (1 Mark)

iv) Linear density (1 Mark)

v) Coordination number (1 Mark)

c) The potential energy of a system of two atoms is given by the expression:

$$U = -\frac{A}{r^2} + \frac{B}{r^{10}}$$

A stable molecule is formed with release of 8.0 eV of energy when interatomic distance is 2.8 Å. Calculate A and B. (4 Marks)

d) Using a well labelled diagrams, briefly differentiate between ionic, covalent, and metallic bonding. (3 Marks)

Question Two (14 Marks)

a) What is the meaning of mean free path? (1 Mark)

b) Sketch the Maxwell-Boltzmann distribution curves for a gas at different temperatures of 80 K and 300 K. (2 Marks)

c) A certain fluid has density of 1080 kg/m^3 and is observed to rise to a height of 2.1 cm in a 1.00 mm diameter tube. The contact angle between the wall and fluid is zero. Calculate the surface tension of the fluid. (3 Marks)

d) Describe Reynolds number by giving its expression and a brief explanation. (2 Marks)

e) Show that a sphere of radius r, density ρ falling through a medium of density σ and coefficient of viscosity η has terminal velocity given by: (4 Marks)

$$\frac{2}{9}\cdot\frac{r^2(\rho-\sigma)g}{\eta}$$

f) State the Van der Waal's gas equation and account for each term. (2 Marks)

SECTION B (42 MARKS)

Question Three (14 Marks)

a) There are only five two-dimensional Bravais lattices. An obvious example is the square net; what are the other four Bravais nets and their respective unit cell characteristics? (4 Marks)

b) If atoms are considered as contacting hard spheres, show that

i) the simple cubic lattice has packing fraction of 0.52. (4 Marks)

ii) Using well labelled BCC and FCC unit cells with side a, derive the expression of diameter in terms of a for the cubic cases. (6 Marks)

Question Four (14 Marks)

a)

i) Using well labelled diagram, show that for a cubic system the interplanar distance for the parallel planes (hkl) is given by $d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$. (3 Marks)

ii) Find the interplanar distance of (111) plane of Nickel crystal (FCC). The radius of Nickel atom is 1.245 Å. (2 Marks)

b) Sketch (110), (101) and 011 cubic lattice planes. (3 Marks)

c) Describe how to construct a Wigner-Seitz cell (3 Marks)

d) Two atoms that are infinitely far apart start to approach each other. Sketch on the axes the following variables

i) The attractive energy (1 Mark)

ii) The repulsive energy (1 Mark)

iii) The resultant energy (1 Mark)

Question Five (14 Marks)

a) The molar mass of oxygen molecules in a container at 300 K is 0.0320kg/mol. Calculate

(i) the most probable speed (2 Marks)

(ii) the average speed (2 Marks)

(iii) the rms speed for the molecules. (2 Marks)

b) In a certain particle accelerator, protons travel around a circular path of diameter 23.0m in an evacuated chamber, whose residual gas is at 295 K and 1.33×10^{-4} Pa pressure.

i) Calculate the number of gas molecules per cubic centimeter at this pressure.

(2 Marks)

ii) What is the mean free path of gas molecules if the molecular diameter is $2.00 \times 10^{-8} cm$. (2 Marks)

c) The temperature of 3.00 mol of an ideal diatomic gas ($C_V = \frac{5}{2}R$) is increased by 40 °C without the pressure of the gas changing. The molecules in the gas rotate but do not oscillate.

i) How much energy is transferred to the gas as heat (1 Mark)

ii) What is the change in the internal energy of the gas (1 Mark)

iii) How much work is done by the gas (1 Mark)

iv) By how much does the rotational kinetic energy of the gas increase (1 Mark)

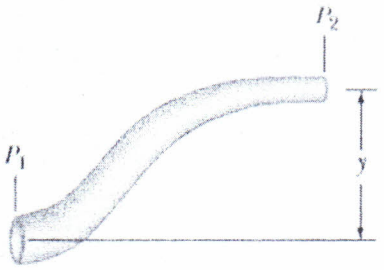
Question Six (14 Marks)

a) State Poiseuille's law of fluid flow. (2 Marks)

b) A pipe carrying water from a tank 20.0m tall must cross 3.00×10^2 km of wilderness to reach a remote town. Find the radius of the pipe so that the volume flow rate is at least $0.05m^3$ (Use viscosity of water $\eta=1.0\times10^{-3}$ N.s/m^3) (3 Marks)

c) The aorta in humans has diameter of about 2.0cm and at certain times the blood speed through it is about 55 cm/s. Is the blood flow turbulent? The density of whole blood is 1050 kg/m^3, and its coefficient of viscosity is 2.7×10^{-3} N.s/m^2. (3 Marks)

d) Water moves through a constricted pipe in steady, ideal flow. At the lower point shown in the figure below, the pressure $P_1=1.75\times10^4$ Pa and the pipe diameter is 6.00 cm. At another point y=0.25 m higher the pressure is $P_2=1.20\times10^4$ Pa and the pipe diameter is 3.00cm.



Find the speed of flow:

i) in the lower section (2 Marks)
ii) in the upper section (1 Mark)
iii) find the volume flow rate through the pipe. (1 Mark)

e) A water drop is placed on top of paraffin and another water drop on glass surface. Sketch the shape of water droplet on paraffin and glass surface showing the contact angle. (2 Marks)

Question Seven (14 Marks)

a) Distinguish between shear modulus and bulk modulus. (2 Marks)

b) A bone has a Young modulus of 18×10^9 Pa. Under compression, it can withstand a stress of about 160×10^6 Pa before breaking. Assume that a femur (thing bone) is 0.50 m long, calculate the amount of compression this bone can withstand before breaking.

(3 Marks)

c) Ships and sailing vessels often carry lead ballast in various forms, such as bricks, to keep the ship properly oriented and upright in the water. Suppose a ship takes on cargo and the crew jettisons a total of 0.5 m^3 of lead ballast into water 2.00 km deep. Take the density of sea water to be 1.025×10^3 Kg/m^3, and the bulk modulus of lead to be 4.2×10^{10} Pa. Calculate

i) the change in the pressure at that depth and (1 Mark)

ii) the change in volume of the lead upon reaching the bottom. (2 Marks)

d) Monochromatic x-rays (λ=0.166nm) from nickel target are incident on a potassium chloride (KCL) crystal surface. The spacing between the planes of atoms in KCL are 0.314 nm. At what angle (relative to the surface) should the beam be directed for a second-order maximum to be observed? (3 Marks)

e) What are the basic principles of the Laue's method, the rotating crystal method and the powder method of x-ray diffraction? (3 Marks)