

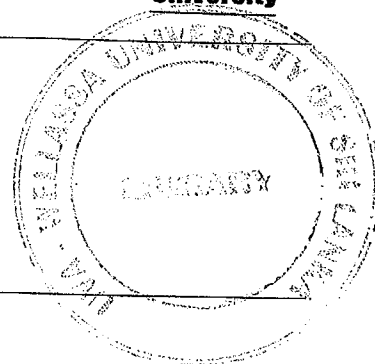
Instructions to candidates

Duration: Three (03) hours

Number of questions: Six (06)

Answer **all** questions

Mark allocation: 140



Charge of an electron = 1.6×10^{-19} C

Mass of an electron = 9.1×10^{-31} kg

Speed of light $c = 2.98 \times 10^8$ ms⁻¹

Plank constant $h = 6.63 \times 10^{-34}$ J.s

Avagadro's Number = 6.022×10^{23}

1.

- a. Briefly explain what you mean by "Band Theory of Solids"

(04 marks)

- b. Draw three energy band diagrams to represent a conductor, an insulator and a semiconductor. Clearly show the fermi energy level in each diagram.

(12 marks)

- c. Using the above diagrams **briefly** explain how you can use band theory to understand the difference between conductors, semi conductors and insulators.

(06 marks)

- d. **Briefly** explain why atomic theory fails and band theory succeeds when explaining the conductivity of magnesium and insulating property of carbon(diamond). Use energy band diagrams in your explanation.

(08 marks)

2.

- a. Write down equations for three distribution functions using the appropriate normalization constants.

(06 marks)

b. Using the equation for each distribution function, explain the differences between the Fermi-Dirac and Bose-Einstein statistics at very low temperatures and very small energies.

(06 marks)

c. Plot the graphs of distribution function $f(E)$ vs E for each distribution function you mentioned in part "a".

(06 marks)

d. Briefly explain what you mean by fermi energy.

(04 marks)

e. Compute the fermi energy for trivalent copper. The density of copper is 8.96 g/cm^3 and the molar mass of copper is 63.546 mol/g .

(08 marks)

3.

a. Write down an equation for the enthalpy in differential form.

(03 marks)

b. What are the natural variables of enthalpy ?

(03 marks)

c. Write down equations for T and V as partial derivatives of enthalpy.

(04 marks)

d. Assuming S and p are two independent variables and assuming that the order of partial derivatives can be exchanged, prove the Maxwell relation given below associated with enthalpy.

$$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p$$

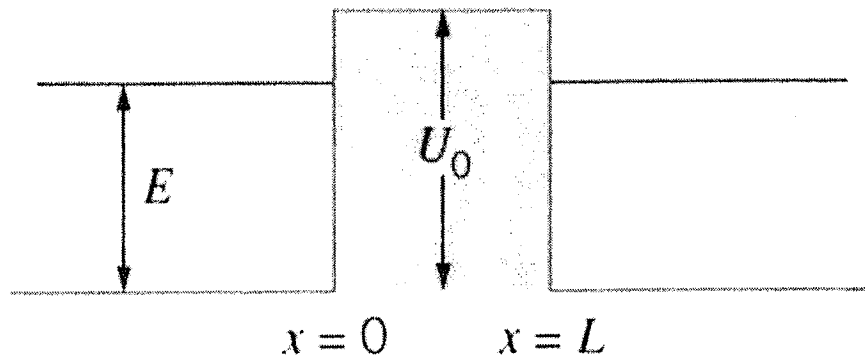
(05 marks)

4.

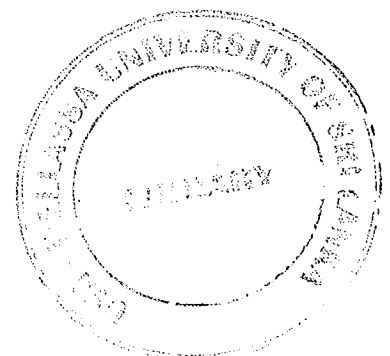
- a. Name three(03) experiments, results of which classical physics failed to explain. (06 marks)
- b. Using a schematic diagram **briefly** explain what you mean by photoelectric effect. (05 marks)
- c. A metal surface has a photoelectric cut-off wavelength of 320.6 nm.
- What is the work function for that metal? (03 marks)
 - It is illuminated with light of wavelength 246.8 nm. What is the stopping potential? (06 marks)

5.

- a. Based on the knowledge you gained on potential energy steps and potential energy barriers, **briefly** explain what you mean by "quantum tunneling". (06 marks)
- b. Give three examples for quantum tunneling effect. (06 marks)
- c. Consider the potential energy barrier shown in the figure below.



$$\begin{aligned} U(x) &= 0 & x < 0 \\ &= U_0 & 0 \leq x \leq L \\ &= 0 & x > L \end{aligned}$$



Particles with energy E less than U_0 are incident from the left. Draw the waveform of the incident wave ($x < 0$ region), decayed wave ($0 < x < L$ region) and the transmitted wave ($x > L$ region). Clearly show the relationships between wavelengths and amplitudes of three different wave forms in your drawing. (No need to derive the equation of any wave function and no need to write any equation of a wave function.)

(08 marks)

6.

a. Write down the four quantum numbers which are needed to describe the wavefunction of the electron in the hydrogen atom.

(04 marks)

b. Write down the range of values of the above mentioned quantum numbers.

(06 marks)

c. If the electron in the hydrogen atom is in the 1st excited state, label the different states of the wavefunction using the four quantum numbers you mentioned in part "a". How many different states are there?

(08 marks)

d. What is the degeneracy of the 1st excited state of the hydrogen atom?

(03 marks)

e. Write down the relationship between the degeneracy of a certain energy level and the principle quantum number associated with that energy level.

(04 marks)