B.Eng (Hons.) Electronic Engineering

Cohort: BEE/23A/FT

Controlled Assignment in lieu of Class Test

MODULE: OPTOELECTRONIC DEVICES AND APPLICATIONS
MODULE CODE: BEE3208C
Duration: 48 Hours
Deadline: 17:00 Hrs Monday 09 February 2026

Instructions to Students:

- This Controlled Assignment has 15% module weight
- This assignment assesses Learning Outcome 1: Understand key concepts in quantum and statistical mechanics relevant to physical, electrical and optoelectronic properties of materials and their applications to devices that emit, modulate and detect photons.
- Total marks: **75**. Minimum Pass Marks = **37.5**
- Email me your assignment individually at bee23aft@rishiheerasing.net with filename <your_student_id>_ctrl_ass.doc or .pdf as attachment.

This controlled assignment contains 4 questions and 5 pages.

QUESTION 1: (18 MARKS)

a) Given that the band gap energy for Indium Phosphide *(InP)* is 1.344 eV at 300K, calculate the photon momentum that you can expect from such a material.

(3 marks)

b) A N-type semiconductor with $\mathbf{N_A}$ and $\mathbf{N_D}$ atoms concentrations of $1x10^{7}\ cm^{-3}$ and $3x10^{10}\ cm^{-3}$ respectively, calculate the electron concentration. ($\boldsymbol{n_i} = 1.4x10^{10}\ cm^{-3}$)

(3 marks)

c) According to the Fermi-Dirac function, at what temperature can we expect a 30% probability that electrons in copper will have an energy which is 5% above the Fermi level? (E_F (Copper) = 7 eV)

(5 marks)

d) An electron is moving in a piece of lightly doped silicon under an applied field at 27 ºC so that its drift velocity is one-tenth of its thermal velocity.

   i. Estimate the average number of collisions it will experience while drifting a region 1µm wide given $m_e^* = 0.26m_0$ and electron mobility = $0.14\ m^2V^{-1}s^{-1}$.
   ii. What is the applied voltage across this region?

(5+2 marks)

QUESTION 2: (16 Marks)

a) Explain how white light can be generated using a UV LED.

(3 marks)

b) Find the composition of the quaternary alloy $In_{1-x}Ga_xAs_{1-y}P_y$ in order for an LED to operate at 1.5 µm. The bandgap energy Eg of the quaternary alloy in eV is given by the empirical relationship $Eg = 1.35 - 0.72y + 0.12y^2$ where $x=0.5y$.

(6 marks)

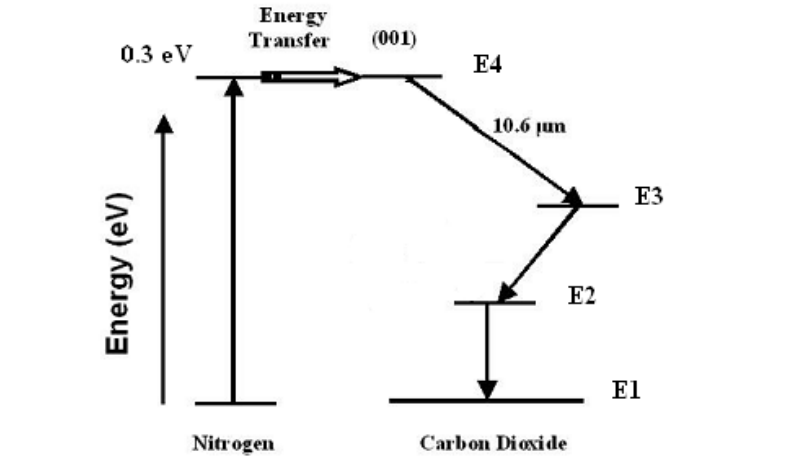
c) Given a particular Gallium Nitride *(GaN)* LED drawing a current 75 mA when the voltage is 3 V with an external conversion efficiency of 10% and operating at 400 nm wavelength.

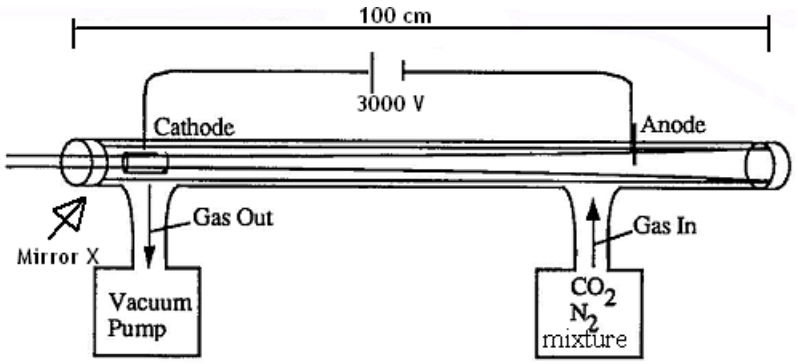
   i) What is the colour of the light emitted from the LED?
   ii) Calculate its external optical power output.
   iii) Calculate its internal quantum efficiency given that $T_r = 35ns$ and $T_{nr} = 50\ ns$.
   iv) Hence, calculate the internal optical power generated by the LED.

(1+2+1+3 marks)

QUESTION 3: (17 Marks)

Consider a **400 mW** nitrogen-carbon dioxide laser operating at **10.6 μm**. The operating temperature is **350 °C** and the current is **20 mA**. ***(mass of CO_2 molecule= 7.16×10^{-26} kg)***





a) Calculate the energy value at level E3 in eV and state which level is meta-stable?

b) Describe Mirror X above and calculate the efficiency of the laser?

c) Estimate the Doppler broadened linewidth ($\Delta \boldsymbol{\nu}$) in the output spectrum.

d) What are the mode number $\mathbf{m}$ values that satisfy the resonant cavity condition?

e) What are the mode separations in frequency ($\Delta \boldsymbol{\nu_m}$) and wavelength ($\Delta \boldsymbol{\lambda_m}$)?

(4+3+4+2+4 marks)

QUESTION 4: (12x2 Marks) *(MCQs can have more than one correct response)*

4.1. Single-element semiconductors usually have atoms with ___ valence electrons.

A) 3
B) 4
C) 5
D) None of the above

4.2. A diode conducts when it is forward-biased, the anode is connected to the ___ .

A) positive supply
B) negative supply
C) cathode
D) anode

4.3. As the forward current through diode increases, the internal resistance _____.

A) increases exponentially
B) decreases exponentially
C) remains the same
D) increases then decreases sharply

4.4. Which type of impurity atoms are added to increase the number of CB electrons in intrinsic silicon? .

A) bivalent
B) trivalent
C) pentavalent
D) None of the above

4.5. When matter is perturbed by a photon, it loses energy and the photon emitted has the same phase, frequency and direction of travel as the original photon. This quantum phenomenon is known as:

A) Optical Amplification
B) Spontaneous emission
C) Stimulated emission
D) None of the Above

4.6. Calculate the phonon energy that you can expect from a direct-band gap material with a lattice constant of **8.0889 Å** and velocity of sound of **330 m/s**.

A) 1.69 eV
B) 0.69 eV
C) 2.71×10^{-22} J
D) None of the above

4.7. The band-gap energy of Germanium at 300K is 0.67 eV. What is the minimum frequency of photons that will allow it to conduct?

A) 1.85×10^{16} Hz
B) 5.55×10^{16} Hz
C) 1.62×10^{14} Hz
D) 4.86×10^{16} Hz

4.8. What is a Silicon phonon energy given that the lattice constant of Si is 0.54 nm and that the speed of sound in Silicon is about 2.2 km/s at 293 K?

A) 1.22×10^{-24} eV
B) 16.9 meV
C) 4.95 eV
D) None of the above

4.9. The brightness of an LED depends on the _____; when source voltage is much _____ than diode voltage, then the brightness of the LED is fairly constant.

A) temperature: smaller
B) current; smaller
C) temperature: larger
D) None of the above

4.10. What happens if you connect an LED in reverse bias?

A) Higher Light intensity
B) Lower Light intensity
C) No change than if it was in forward bias.
D) None of the above

4.11. Which of the following affect(s) the overall efficiency of an LED?

A) Internal quantum efficiency
B) External conversion efficiency
C) Fibre coupling efficiency
D) None of the above

4.12. The colour of light emitted by an LED is influenced by the

A) Type of semiconductor material
B) The amount of doping
C) Temperature
D) Forward bias voltage

****** END OF CONTROLLED ASSIGNMENT ******