# EE2104 (Aug-Nov 2024) (Mid Term Exam)
# Date: 18th Sept 2025, 8:30 – 10:00 am Total Marks: 30 points

**Name and Roll no.:**

**INSTRUCTIONS:**

- *Only allowed items: 1 A4 formulae sheet, Calculator, Stationary*
- *Workout the question in rough sheets, when you are satisfied with the solution write the fair answers in the limited space given below each question. Pencil markings will not be re-evaluated.*
- *Attach the formulae sheet.*
- *Report values in CGS units (for example 3D DOS = $cm^{-3}eV^{-1}$) – no marks for other units.*

Q1) A student solves the time-independent 1-D Schrödinger equation for a particle of mass $m$ in the presence of an attractive delta potential $V(x) = -V_0\delta(x)$(with $V_0 > 0$), and proposes the following bound-state solution (energy $E < 0$):

$$\Psi(x) = \begin{cases} A\, e^{-\kappa x}, & x > 0, \\ B\, e^{+\lambda x}, & x < 0, \end{cases} \quad \kappa, \lambda > 0$$

(a) Write down the general relations between $\kappa, \lambda$ and the energy $E$. **[2]**

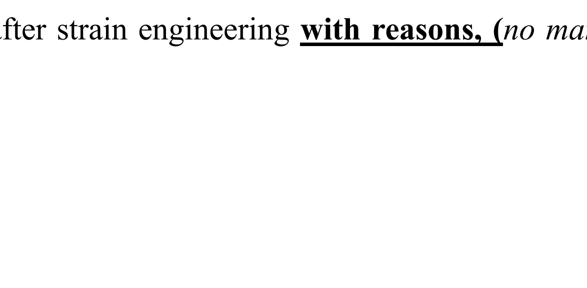
(b) Obtain the equation that determines $\kappa$, using (1) the requirement that $\Psi(x)$be continuous at $x = 0$, and (2) the derivative jump condition across a delta potential, [2]

$$\frac{d\Psi}{dx}\Big|_{0^+} - \frac{d\Psi}{dx}\Big|_{0^-} = -\frac{2mV_0}{\hbar^2}\,\Psi(0),$$

(c) Show that for the attractive delta potential there is exactly one bound state and find the bound-state energy $E$ (give the final expression in closed form). **[2]**

(d) Determine $A$ and $B$ **[2]**

Q2. The band structure for material (X) is presented below before (left) and after (right) strain engineering




(a) What are the x- and y axis in the graphs (with units) ? [1]

(b) Mark the regions **<u>on both the graphs</u>** that will contribute to quasi-equilibrium transport. [2]

(c) Indicate qualitatively (increase/decrease) how the following properties of the material have changed after strain engineering **<u>with reasons, (</u>***no marks without correct reasoning)* [2]:

1) Band Gap:

2) Electron Density of states:

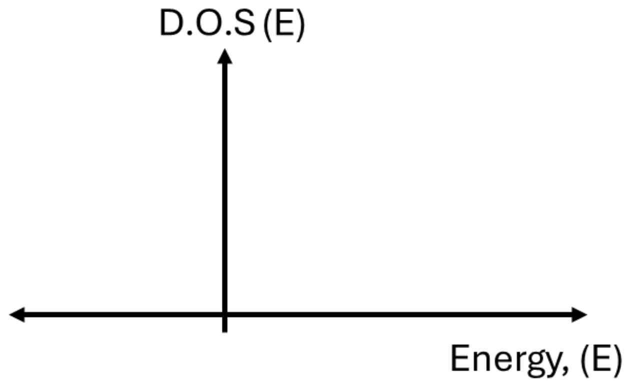
(d) Suggest which device applications become better suited **<u>before OR after</u>** strain engineering **<u>with reasons, (</u>***no marks without correct reasoning)* [2]

1) p-channel MOSFET:

2) Photodiode:

Q3) A **2-Dimensional semiconductor sheet** is synthesized in the lab. The measured mobility for electrons and holes in 1200 and 800 $cm^2V^{-1}s^{-1.}$ The lattice scattering time constant for both carriers is 0.1 ns. The time constants for impurity scattering in 0.546 ps and 0.182 ps for electrons and holes respectively. $E_g$ = 1 eV, $n_i$ = $10^7$ $cm^{-2}$Consider T=300 K.

(a) Derive, calculate and plot the density of states (in CGS units only) in conduction and valence band. Plot only in the axis given below. Assume that effective mass from band structure is same as effective mass to be used in DOS calculations. As per convention you can consider $E_v$ (max) to be at Origin [4]




(b) Derive and calculate the **Effective Density of States** for conduction and valence band. (CGS units only) [3]

(c) Calculate maximum possible conductivity considering and at what carrier concentration of electrons. [3]

Q4) A silicon sample is n-type with donor concentration $N_D = 10^{15}$ cm$^{-3}$. It is uniformly optically excited at room temperature with generation rate G = $10^{19}$ cm$^{-3}$ s$^{-1}$. Both electron and hole lifetimes are $\tau_n = \tau_p = 10$ μs. The hole diffusion coefficient is $D_p = 12$ cm$^2$ s$^{-1}$, $n_i = 1.510^{10}$ cm$^{-3}$. Electron mobility may be taken as $\mu_n$ = 1350 cm$^2$ V$^{-1}$ s$^{-1}$ for Si at this doping.

(a) Find the quasi-Fermi level separation under steady illumination. [3]

(b) Find the change in conductivity upon shining the light. [2]