ECE210 – PSD
Quiz 1
Marks: 10
Date: 03/02/2025
Time: 35 mins

DEPARTMENT OF ELECTRONICS & COMMUNICATIONS ENGINEERING

Answer all 5 questions
(keep your answer short and specific)

1. What will be the nature of electron wave function within a potential barrier (V) when,

(i) $V = +10\text{eV}$, and (iii) $V = -10\text{eV}$? **[1 + 1 = 2]**

Ae^{ik}

2. Show that the energy difference between two successive quantum energy levels in a quantum well is $\Delta E = (2n + 1)\,(\pi^2\hbar^2/2ma^2)$, where n is the energy level, a is the width of the quantum well and m is the mass of the particle. **[2]**

3. Find the zero-point energy for a particle in an infinite potential well for the following two cases: **[1 + 1 = 2]**

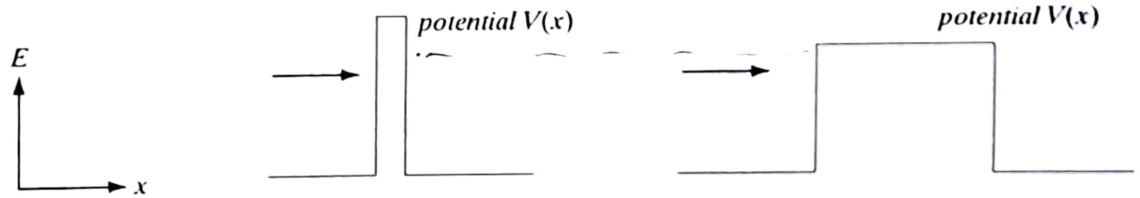
$E = \frac{n^2\pi^2\hbar^2}{2mL^2}$

(i) a 100gm ball confined on a 5m long line

(ii) an electron (mass ~10^{-30}Kg) confined to a 10^{-10}m atom.

(reduced Plank's constant ($\hbar$) = 1.05×10^{-34} joule)

4. Consider quantum mechanical particles incident from the left having well-defined energy as indicated by the vertical positions of the arrows in the two systems shown below. Which one will have a higher transmission probability and why? **[1 + 1 = 2]**



System 1
(narrow high potential barrier)

System 2
(wide low potential barrier)

5. If I say the photoelectric effect obeys the energy conservation via the relation [$h\nu = KE_{elec} + \Phi$] where $h\nu$ is the incident photon energy, and KE_{elec} is the photoelectron kinetic energy. Then what does Φ refer to? Is it a surface or bulk property of a material? Is it possible to have different Φ values for a particular material? **[1 + 0.5 + 0.5 = 2]**

ECE210 – PSD
Quiz 2
Marks: 10
Date: 17/02/2025
Time: 35 mins

DEPARTMENT OF ELECTRONICS & COMMUNICATIONS ENGINEERING

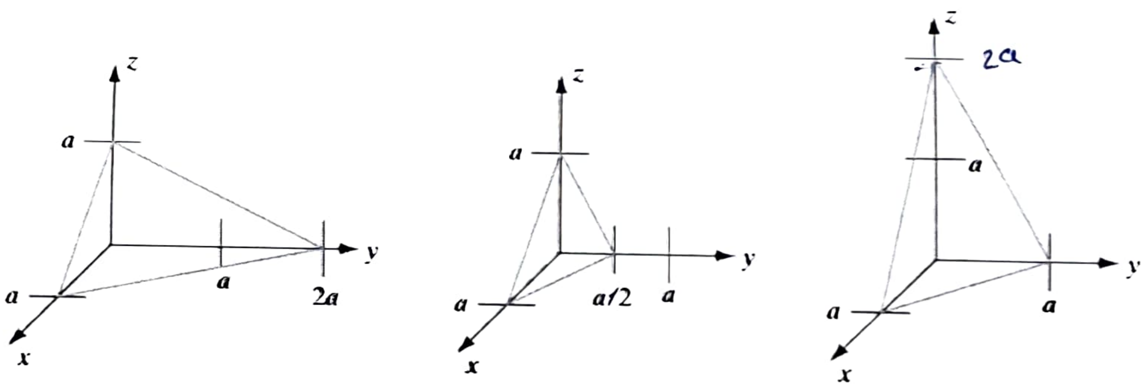
Answer all 5 questions
(keep your answer short and specific)

1. Why are x-rays used to study crystal structure instead of visible rays or gamma rays? When do we see Bragg's diffraction, for $\lambda \leq 2d$ or $\lambda \geq 2d$? Justify your answer. [λ is the incident wavelength and $\boldsymbol{d}$ is the interlayer spacing] **[1 + 1 = 2]**

2. Show that the reciprocal lattice of a simple cubic structure is another simple cubic, i.e., the simple cubic structure is self-reciprocal. **[2]**

3. **Draw the Wigner-Seitz cell of a 2D rectangular Bravais lattice with lattice parameters '*a*' and '*b*'. What will be the lattice parameters of your constructed Wigner-Seitz cell? [1 + 1 = 2]**

4. **Among Fig. (a), (b), and (c), which one is the (121) plane, and which one is the (212) plane? What will be the ratio of the inter-planer distance of (121) and (212) planes? [1 + 1 = 2]**



(a) (b) (c)

x y z
h ~~K~~ k = $\frac{1}{x}$ $\frac{1}{y}$ $\frac{1}{z}$

5. **Which kind of defects are introduced by doping in semiconductor crystals? Can we also call doping a point defect? Explain your answers. [1 + 1 = 2]**

ECE210 – PSD
Quiz 3
Marks: 10
Date: 07/04/2025
Time: 30 mins

DEPARTMENT OF ELECTRONICS & COMMUNICATIONS

Answer all 4 questions
(keep your answer short and specific)

[CO3]

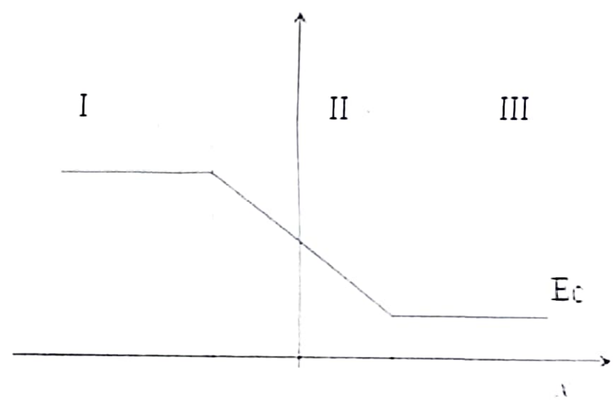
1. What is the meaning of excess carriers in semiconductors? Mention any mechanism for an excess carrier creation process in a semiconductor. **[1+1=2]**

[CO3]

2. Which one will have a higher recombination rate, in a direct or indirect band gap semiconductor, having a similar bandgap? Give an example of a device whose operating mechanism is primarily based on recombination process. **[1+1 = 2]**

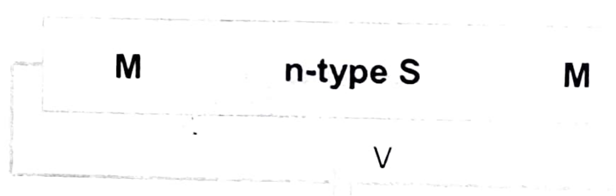
[CO2, CO4]

3. If you have conduction band (Ec) profile according to the attached plot, express Ec as a function of *x* for the three different regions and find out the corresponding electric fields and their directions. **[1.5+1.5 = 3]**



[CO2, CO4]

4. According to the attached M-S-M junction device (in which ($\Phi_M > \Phi_S$), where Φ is the work function), draw the energy band diagram under bias V = 0 and +V. **[1.5 + 1.5 = 3]**



ECE210 – PSD
Quiz 4
Marks: 10
Date: 17/04/2025
Time: 30 mins

DEPARTMENT OF ELECTRONICS & COMMUNICATIONS ENGINEERING

Answer all 5 questions
(keep your answer short and specific)

[CO2], [CO3]

1. In a 'pn' junction, where does the peak electric field occur? If you have a p++n++ junction, what changes do you expect in the peak electric field? **[2]**

2. Can we use a pn diode as a variable capacitor? If so, in which condition can we use it as a variable capacitor? **[2]**

3. What are the different types of heterostructures w.r.t the energy band alignment? Explain elaborately with band alignments. **[3]**

4. What are the consequences of Fermi-level pinning? **[2]**

5. Fill factor is one of the measures of a solar cell. What is the significance of it? **[1]**

ECE210 – PSD
MidSem Exam
Marks: 30
Date: 28/02/2025
Time: 1.00 Hrs.

DEPARTMENT OF ELECTRONICS & COMMUNICATIONS ENGINEERING

Answer all the questions
(keep your answer short and specific)

1. A particle of mass 'm' is confined to move in a quantum well in the (x, y) plane which consists of a pair of impenetrable walls at $x = \pm a$ but is unbound for the motion in the y-direction.

   (a) Let the total energy of the particle be E and the energy associated with the motion in the x and y directions be E_x and E_y, respectively. What are the allowed values of E_x, E_y and E?

   (b) Sketch E vs. k_y for various allowed values of E_x.

   (c) Suppose now an infinite potential barrier at $y = \pm a$ is imposed. Can the particle's energy be measured to be $3\pi^2\hbar^2/4ma^2$? Why? **[3 + 3 + 3 = 9]**

   [CO1]

2. (a) What is the difference between group velocity and phase velocity of a wave packet?

   (b) Electrons move in a crystal as wave packets with a group velocity $v = \frac{d\omega}{dk}$ where ω is the angular frequency. Show that in a given electric field, these wave packets obey Newton's second law of motion, i.e., the force $\boldsymbol{F} = m^*\boldsymbol{a}$, where m^* is the effective mass (given by $m^* = \hbar^2/[\partial^2E/\partial\boldsymbol{k}^2]$) and $\boldsymbol{a}$ is the acceleration.

   (c) In which condition the effective mass formula $m^* = \hbar^2/[\partial^2E/\partial\boldsymbol{k}^2]$ is not valid? Explain your answer.

   (d) Can effective mass be negative? Justify your answer. **[2 + 5 + 2 + 2 = 11]**

   [CO1, CO2]

3. (a) What is a direct and indirect bandgap semiconductor? If you want to design an LED, which one will be your preferred material among these two? Explain your answer.

   (b) What is the difference between a non-degenerate and a degenerate semiconductor? What do you expect in temperature (T) dependent conductivity (σ) variation in a non-degenerate and a degenerate semiconductor (or plot σ vs. T)?

   (c) Calculate the probability of finding an electron at the nearest conduction band of the Fermi level at 300K when an intrinsic material has a bandgap value (i) E_g = 0 eV, (ii) E_g = 1 eV and (iii) E_g = 4 eV. Consider both the electron and hole effective masses are same. Similarly, find out the probability of occupation of a hole at the nearest valence band of the Fermi level for all the above cases. Explain your observations on expected carrier densities in the above situations.

   (Boltzmann's constant, k_B = 8.62 x 10^{-5} eV) **[2 + 2 + (3 × 2) = 10]**

   [CO1, CO3]

ECE210 – PSD
End-Sem Exam; Marks: 30
Date: 28/04/2025; Time: 2.00 Hrs.

ECE IIITD
DEPARTMENT OF ELECTRONICS & COMMUNICATIONS ENGINEERING

Answer all the questions
(Keep your answer short and specific.)

1. **(a)** We can represent a MOSFET using a capacitor model. Can you sketch a simple capacitor model of a MOSFET?

(b) What is a self-alignment process in a MOSFET, and why is it so important?

(c) Can we use a MOSFET as a variable resistor? If so, under what conditions we can use it as a variable resistor?

(d) Draw the energy band diagram of an n-p-n and p^+-i-n^+ device structure.

(e) Consider a MOSCAP structure on a p-type substrate (doping concentration = 10^{16} cm^{-3}). Assuming that no charges are present in the oxide, calculate the flat-band voltage of the structure if it employs an Al gate ($q\varphi_m$ = 4.1 eV). [Data: $q\chi$ (Si) = 4.05 eV and E_g (Si) = 1.12 eV]

(f) How does the effective mobility depend on the electric field? Which type of scattering mechanism dominates in a high electric field? **[2×6 = 12]** *[CO4]*

2. **(a)** At T = 0K, what is the density of holes in the valence band of a pure semiconductor?

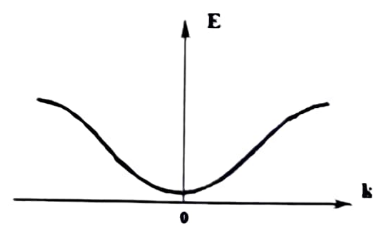
(b) An n-doped silicon is in equilibrium at T=700K. It has an electron concentration of $n = 7.148\times10^{16}$ cm^{-3} and an intrinsic carrier concentration of $n_i = 2.865\times10^{16}$ cm^{-3}. Then, what is the concentration of holes? What is the concentration of donors, N_D, if you assume that $N_A = 0$ and that all the donors are fully ionized? 6×10^{16}

(c) What is the expression of mobility according to the Drude model? If we have scattering times due to three different processes, then what is the total scattering time when all three mechanisms operate at the same time? **[1+2+2=5]** *[CO2, CO3]*

3. **(a)** In a straddling gap heterostructure, if you have ΔE_c = 0.2 eV and ΔE_v = 0.3 eV, then what will be the ΔE_g in this heterostructure? (*Notations are all standard notations.*)

(b) For a compound semiconductor like $Al_xGa_{(1-x)}As$, if the electron affinity and energy bandgap are defined as $\chi = (4.07 - 1.1x)$ eV and $E_g = (1.424 + 1.247x)$ eV for (x <0.45), then draw the energy band diagram for ***N-p*** and ***P-n*** heterojunction of $Al_{0.3}Ga_{0.7}As$: GaAs before and after making the contact. **[1+4 = 5]** *[CO2, CO3]*
3.586 1.97

4. **(a)** If a 1-D energy band diagram of an electron looks like the attached plot, then sketch the graphs of group velocity and effective mass with wave vector **k**.



(b) The conduction band minima in GaP occurs at the boundary of the first Brillouin zone along the [100] direction. The constant energy surfaces are ellipsoidal with $m_l^* = 1.12m_0$ and $m_t^* = 0.22m_0$. Determine the transport and density-of-states effective masses for electrons in GaP.

[2×2 + 2×2 = 8] *[CO2]*