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III B.TECH - V SEMESTER (2025-26)

CSE-Artificial intelligence &Machine Learning

Electronic Devices and Circuits (231EC5O01)

Q.No		Question	Marks	CO No.	Taxonomy
		UNIT-1 (Review of Semiconductor Physics and Junction Diode Characteristics)			
1	A)	Explain about Hall effect. Derive an expression for Hall voltage. What are the applications of Hall effect?	8	CO1	Understand
	B)	In a P-type semiconductor, the Fermi level is 0.3 eV above the valance band at a room temperature of 300 K. Determine the new position of the Fermi level for temperatures of a) 350K and b) 400 K.	7	CO1	Apply
2	A)	Derive an expression for continuity equation and explain its importance.	8	CO1	Understand
	B)	Interpret the expression for Fermi level in case of intrinsic semiconductor.	7	CO1	Apply
3	A)	Draw the Energy band diagram of PN diode and also Explain	8	CO1	Understand
	B)	What is transition capacitance of a semiconductor diode? Explain how it arises	7	CO1	Understand
4	A)	Draw the V-I characteristics and explain about the effect of temperature on diode characteristics.	7	CO1	Understand
	B)	Explain the diffusion capacitance of a semiconductor diode and derive the expression for it.	8	CO1	Understand
5	A)	Explain PN diode characteristics in forward bias and reverse bias regions.	5	CO1	Understand
	B)	Explain about the current components in PN junction diode.	5	CO1	Understand
		UNIT-2 (Special Semiconductor Devices and Rectifiers and Filters)	**Marks**	**CO No.**	**Taxonomy**
1	A)	Explain construction and operation of a Half Wave rectifier and Find the PIV, RMS voltage ripple efficiency of Half Wave Rectifier.	8	CO2	Understand
	B)	A sinusoidal voltage whose Vm = 25V is applied to a half-wave rectifier. The diode may be considered to be ideal and RL = 1.5 KΩ is connected as load. Determine the following: (i) Peak value of current (ii) RMS value of current (iii) Ripple factor	7	CO2	Apply
2	A)	Explain construction and operation of full wave rectifier with Inductor filter?	7	CO2	Understand
	B)	Explain the construction and operation of SCR with characteristics.	8	CO2	Understand
3	A)	Interpret the construction and operation of a bridge rectifier and find PIV, RMS current, Rectifier efficiency & Ripple factor.	8	CO2	Understand
	B)	With neat diagram explain about varactor diode.	7	CO2	Understand
4	A)	Explain the construction and operation of UJT along with characteristics.	8	CO2	Understand
	B)	Compare HWR with FWR interms of their parameters.	7	CO2	Analyze
5	A)	Explain V-I characteristics of a Tunnel diode with the help of its Fermi level diagram.	7	CO1	Understand
	B)	In a bridge rectifier, the transformer is connected to 200V, 60Hz mains and the turns ratio of the step down transformer is 11:1. Assume the diode is ideal, find i) d.c. Voltage ii) d.c. Current iii) PIV	8	CO2	Apply

EDC MID-1 ANSWERS

UNIT-1

1 A) Explain about Hall effect. Derive an expression for Hall voltage. What are the applications of Hall effect?

Q1(a) Hall Effect

Definition

When a current flows through a semiconductor and a magnetic field is applied **perpendicular** to the current, a small voltage appears across the sides of the semiconductor.
This voltage is called the **Hall Voltage** and the effect is called the **Hall Effect**.

Explanation with Diagram

(You can draw this simple block diagram in the exam)

```sql
      + I (Current along x) -
      ----------------------->
   ______________________________
  |                              |
  |                              |   Magnetic Field (B) ⊗ into page
  |                              |
  |______________________________|
        + VH (Hall Voltage) -
```

- Current flows through the block.
- Magnetic field is applied perpendicular (into the paper).
- Charge carriers are pushed to one side → a voltage appears across the sides (Hall Voltage).
- The polarity of this voltage shows whether the material is **n-type (negative carriers)** or **p-type (positive carriers)**.

Derivation of Hall Voltage

1. Current density:

$$J = \frac{I}{A} = \frac{I}{w \cdot t}$$

2. Drift velocity of carriers:

$$v_d = \frac{J}{nq} = \frac{I}{nq \cdot w \cdot t}$$

3. Magnetic force balances electric force:

$$qE_H = qv_dB \quad \Rightarrow \quad E_H = v_dB$$

4. Hall Voltage:

$$V_H = E_H \cdot w = \frac{IB}{nqt}$$

Hall Coefficient

$$R_H = \frac{1}{nq}$$

- Negative for **electrons (n-type)**.
- Positive for **holes (p-type)**.

Applications of Hall Effect

1. To find whether a semiconductor is **n-type or p-type**.
2. To measure **carrier concentration** in semiconductors.
3. To calculate **mobility of carriers**.
4. Used in **Hall probes** to measure magnetic field strength.
5. Used in **current sensors, speed sensors, and position sensors**.

Final Results (to box in exam)

$$V_H = \frac{IB}{nqt}, \quad R_H = \frac{1}{nq}$$

2) B) Interpret the expression for Fermi level in case of intrinsic semiconductor.

Q2(b) Fermi Level in Intrinsic Semiconductor

Definition of Fermi Level

The **Fermi level (E_F)** is the energy level at which the probability of finding an electron is **50%** at absolute zero temperature.
It is the reference energy that tells us the distribution of electrons in the conduction band and holes in the valence band.

Intrinsic Semiconductor

- An **intrinsic semiconductor** is a pure semiconductor (like Si, Ge) without impurities.
- The number of **electrons in conduction band** = number of **holes in valence band**.
- Therefore, the Fermi level lies **exactly in the middle** of the band gap.

Mathematical Expression

For intrinsic semiconductors:

- Electron concentration in conduction band:

$$n = N_c e^{-\frac{E_c - E_F}{kT}}$$

- Hole concentration in valence band:

$$p = N_v e^{-\frac{E_F - E_v}{kT}}$$

Since in intrinsic semiconductors $n = p$, equating both:

$$N_c e^{-\frac{E_c - E_F}{kT}} = N_v e^{-\frac{E_F - E_v}{kT}}$$

Taking logarithm and rearranging:

$$E_F = \frac{E_c + E_v}{2} + \frac{kT}{2} \ln\left(\frac{N_v}{N_c}\right)$$

Interpretation

- If the **effective mass of electrons = effective mass of holes**, then $N_c = N_v$.
  Hence the second term becomes zero, and:

$$E_F = \frac{E_c + E_v}{2}$$

  → Fermi level lies **exactly at the middle of the energy gap**.
- If the **effective masses are not equal**, the Fermi level shifts slightly toward the band with the **heavier effective mass**.

Diagram (easy to draw in exam)

```pgsql
Energy
   ↑
   |          Ec (Conduction band edge)
   |
   |                ----
   |                 |    E_F (Fermi level, mid-gap)
   |                ----
   |
   |          Ev (Valence band edge)
   |
   +--------------------------------> Position
```

- E_c = Conduction band edge
- E_v = Valence band edge
- E_F lies at the middle (for intrinsic case).

Applications / Importance (write 2–3 points for marks)

1. Helps in **understanding carrier concentration** in semiconductors.
2. Explains the position of Fermi level for intrinsic materials.
3. Acts as a **reference energy** for doping cases (n-type, p-type).

Final Result (box in exam)

$$\boxed{E_F = \frac{E_c + E_v}{2} + \frac{kT}{2} \ln\left(\frac{N_v}{N_c}\right)}$$

- For intrinsic semiconductor with equal masses:

$$\boxed{E_F = \frac{E_c + E_v}{2}}$$

3) A) Draw the Energy band diagram of PN diode and also Explain.

Q3(a) Energy Band Diagram of PN Junction Diode

Introduction

- A **PN junction diode** is formed when a **p-type** semiconductor and an **n-type** semiconductor are joined together.
- At the junction, free electrons from the **n-side** diffuse into the **p-side**, and holes from the **p-side** diffuse into the **n-side**.
- This diffusion creates a **depletion region** with immobile ions, which produces a **built-in potential barrier**.
- The energy band diagram shows how the **conduction band (E_c)**, **valence band (E_v)**, and **Fermi level (E_F)** are aligned across the junction.

Energy Band Diagram (to draw in exam)

```pgsql
Energy ↑
        n-type side                     p-type side
        --------- Ec (conduction band) ---------
                   \                /
                    \              /
                     \            /
                      \__________/    <--- Built-in Potential (Vbi)
                      /          \
                     /            \
        --------- Ev (valence band) ---------

                    Ef (Fermi level: flat at equilibrium)
```

Explanation of diagram:

- On the **n-side**, the Fermi level is closer to the conduction band.
- On the **p-side**, the Fermi level is closer to the valence band.

- When they form a junction, the Fermi level becomes **constant throughout** at equilibrium.
- This bending of energy bands at the junction represents the **potential barrier** and **depletion region**.

Explanation

1. **Before joining (isolated p and n):**
    - n-type: Fermi level close to conduction band.
    - p-type: Fermi level close to valence band.
2. **After forming the junction (equilibrium):**
    - Electrons diffuse from n → p and holes diffuse from p → n.
    - This leaves behind charged ions, forming the **depletion region**.
    - The energy bands bend, creating a **barrier potential (V_bi)** that opposes further diffusion.
3. **Fermi Level:**
    - At equilibrium, the Fermi level E_F becomes **flat and continuous** across the junction.
    - This indicates there is **no net current** flow when unbiased.

Key Points to Write

- **Depletion region** is shown by the band bending.
- **Barrier potential (Vbi)** is the energy difference created at the junction.
- Fermi level is **constant at equilibrium**.

Applications / Importance (2–3 points)

1. Explains how current flows when diode is forward/reverse biased.

2. Helps to understand the role of **potential barrier**.
3. Useful for analyzing diode characteristics (covered later in Unit-1).

Final Answer (Box this in exam)

- At equilibrium:

$$E_F = \text{constant across the junction}$$

- Energy bands bend to form a **potential barrier** at the depletion region.
- Conduction band E_c, valence band E_v, and Fermi level E_F must be shown in the diagram.

4) A) Draw the V-I characteristics and explain about the effect of temperature on diode characteristics.

Q4(a) V–I Characteristics of a Diode and Effect of Temperature

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Introduction

A **PN junction diode** allows current to flow **easily in one direction (forward bias)** and **blocks current in the opposite direction (reverse bias)**.
The relation between **voltage (V)** across the diode and **current (I)** through the diode is called the **V–I characteristics**.

The diode current is given by:

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

- I_s: Reverse saturation current
- $V_T = \frac{kT}{q}$: Thermal voltage
- η: Emission constant (1 for Ge, 2 for Si)

V–I Characteristics (to draw in exam)

```perl
I ↑
   |       /
   |      /   Forward region
   |     /
   |----/------------------→ V
   |   /
   |  /
   | /
   |/     Reverse region (very small current)
   |
```

- **Forward Bias**: After a certain threshold (cut-in voltage), current increases exponentially.
  - For **Silicon (Si)**: cut-in ≈ **0.7 V**
  - For **Germanium (Ge)**: cut-in ≈ **0.3 V**
- **Reverse Bias**: Very small reverse current flows (reverse saturation current I_s).
  If reverse voltage is increased heavily, the diode breaks down.

Effect of Temperature

1. **Reverse Saturation Current** (I_s) increases rapidly with temperature.
   - For every **10°C rise**, I_s roughly **doubles**.
2. **Forward Voltage (V_F)** decreases as temperature increases.
   - For Silicon, forward voltage drops by about **2 mV/°C**.
3. **Overall effect:**
   - At higher temperature → diode conducts **more current** at the same forward voltage.
   - Reverse leakage also increases, which can cause **thermal runaway** in power devices.

Explanation in Simple Steps

- At **room temperature**, Si diode needs **0.7 V** to conduct.
- If temperature rises, conduction starts at a slightly **lower voltage** (e.g., 0.68 V, 0.66 V, etc.).
- Reverse leakage current, normally very small, becomes **larger** at higher temperatures.

Applications of Temperature Effect

1. Important in designing **rectifiers and voltage regulators**.
2. Used in **temperature sensors** (diode junction as a thermometer).
3. Explains why **heat sinks** are required in power diodes/transistors.

Final Boxed Points

- Diode current equation:

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

- Cut-in voltages: **0.7 V (Si), 0.3 V (Ge)**
- I_s **doubles for every 10°C rise**
- Forward voltage decreases by ≈ **2 mV/°C**

4) B) Explain the diffusion capacitance of a semiconductor diode and derive the expression for it.

Q4(b) Diffusion Capacitance of a Semiconductor Diode

Introduction

- A **semiconductor diode** behaves like a capacitor under certain conditions.
- When the diode is **forward biased**, large numbers of electrons and holes are injected across the junction.
- This storage of charge in the depletion region and neutral regions gives rise to **Diffusion Capacitance (C_d)**.
- It is called diffusion capacitance because it is related to the **transport (diffusion) of carriers** across the junction.

Definition

Diffusion capacitance is the capacitance that appears in a diode under **forward bias**, due to the **storage of minority carriers** in the junction region.

Diagram (simple sketch for exam)

```mathematica
Forward biased PN junction:

   P-side (+) |—|<—| N-side (-)

Stored charge across junction → behaves like a capacitor
```

(Just draw a forward biased diode with "+" on P and "–" on N, then mark "Stored charge" across junction, label it as "Diffusion capacitance".)

Derivation of Diffusion Capacitance

1. **Stored Charge (Q):**
   In forward bias, charge stored in the junction is proportional to the diode current I and the carrier lifetime τ:

$$Q = I \cdot \tau$$

2. **Capacitance definition:**
   Capacitance is defined as rate of change of charge with voltage:

$$C_d = \frac{dQ}{dV}$$

3. Substituting Q:

$$C_d = \frac{d(I \cdot \tau)}{dV} = \tau \cdot \frac{dI}{dV}$$

4. Using diode current equation:

$$I = I_s \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

Differentiating:

$$\frac{dI}{dV} = \frac{I}{\eta V_T}$$

5. Final Expression:

$$C_d = \frac{\tau I}{\eta V_T}$$

Interpretation

- Diffusion capacitance is **directly proportional** to the diode current II.
- It is significant **only in forward bias** (because large current flows).
- In reverse bias, diffusion capacitance is negligible; instead, **transition capacitance** dominates.

Key Points to Write

- Exists under **forward bias**.
- Due to **minority carrier storage**.
- Formula:

$$\boxed{C_d = \frac{\tau I}{\eta V_T}}$$

Applications

1. Important in **high-frequency diode circuits** (since stored charge slows down switching).
2. Used in understanding **switching time** of diodes and transistors.
3. Affects the performance of **rectifiers** and **clipping circuits**.

5 A) Explain PN diode characteristics in forward bias and reverse bias regions.

Q5(a) PN Diode Characteristics in Forward and Reverse Bias

Introduction

- A **PN junction diode** conducts current in one direction (forward bias) and blocks current in the opposite direction (reverse bias).
- Its behavior can be studied using **V–I characteristics**.

The diode current equation is:

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

- I_s: Reverse saturation current
- $V_T = \frac{kT}{q}$: Thermal voltage
- η: Emission coefficient

---

1. Forward Bias Characteristics

- **Condition:** P-side connected to +ve of battery, N-side to –ve.
- The applied voltage reduces the **barrier potential**.
- When applied voltage > **cut-in voltage**:
  - Silicon (Si): ≈ **0.7 V**
  - Germanium (Ge): ≈ **0.3 V**
- After this, diode current rises **exponentially** with voltage.

Diagram (Forward Bias V–I curve):

```perl
I ↑
  |
  |        /
  |       /
  |      /
  |-----/-------------------→ V
       (Cut-in voltage)
```

---

2. Reverse Bias Characteristics

- **Condition:** P-side connected to –ve, N-side to +ve.
- Barrier potential increases → junction widens → very little current flows.
- Only a very small **reverse saturation current (I_s)** flows (due to minority carriers).
- If reverse voltage increases too much, **breakdown** occurs → large current suddenly flows (can damage the diode if not controlled).

Diagram (Reverse Bias V–I curve):

```lua
I ↑
  |
  |---- (Very small reverse current: Is)
  |
  |
  |--------------------→ V (reverse)
                   |
                   | (Breakdown region)
```

Combined Forward & Reverse Bias V–I Characteristics

(Exam diagram should show both regions on one graph)

```pgsql
 I ↑
   |        /   Forward bias (exponential rise)
   |       /
   |------/
   |     |
   |     |  Reverse bias (tiny Is, then breakdown)
   |-----------------------------→ V
```

Effect of Temperature (write 2 points for full marks)

- Forward voltage decreases by about **2 mV/°C**.
- Reverse current doubles for every **10°C rise**.

Applications of Characteristics

1. Used in **rectifiers** (converts AC to DC).
2. Used in **clipping and clamping circuits**.
3. Reverse breakdown principle used in **Zener diodes for voltage regulation**.

Final Boxed Points

- Cut-in voltages: **0.7 V (Si), 0.3 V (Ge)**.
- Forward bias → exponential increase in current.
- Reverse bias → only small I_s until breakdown.

5) B) Explain about the current components in PN junction diode.

Q5(b) Current Components in a PN Junction Diode

Introduction

- A **PN junction diode** conducts current due to the movement of **charge carriers** (electrons and holes).
- The total diode current has **two main components**:
  1. **Electron current** from **n-side → p-side**
  2. **Hole current** from **p-side → n-side**

Thus, the diode current is the sum of **electron diffusion current** and **hole diffusion current**.

Current Components Explanation

1. **Electron Diffusion Current (I_n):**
   - Electrons from the **n-side conduction band** diffuse into the p-side.
   - These electrons become **minority carriers** in the p-region.
   - They recombine with holes, producing electron current.
2. **Hole Diffusion Current (I_p):**
   - Holes from the **p-side valence band** diffuse into the n-side.
   - These holes act as **minority carriers** in the n-region.
   - They recombine with electrons, producing hole current.
3. **Reverse Saturation Current (I_s):**
   - Even under reverse bias, a small **minority carrier current** flows.
   - This current is almost constant and depends strongly on **temperature**.

Diagram (to draw in exam)

```markdown
Energy Band Diagram of PN Junction

   Ec  ________                ________   Conduction Band
       |      \              /      |
       |       \            /       |
       |        \__________/        |
                Depletion Region

   Ev  --------                --------   Valence Band

   → Electron diffusion: n → p
   → Hole diffusion: p → n
```

- Show **electron current (I_n)** from n to p.
- Show **hole current (I_p)** from p to n.
- Label "Depletion Region" at the junction.

Mathematical Representation

The total diode current is:

$$I = I_n + I_p$$

Using diode current equation:

$$I = I_s \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

where

- $I_s = I_{n0} + I_{p0}$ = total reverse saturation current
- I_{n0}: electron component of saturation current
- I_{p0}: hole component of saturation current

Interpretation

- In **forward bias**: both I_n and I_p increase exponentially.
- In **reverse bias**: only a small I_s flows (due to minority carriers).

-

Applications / Importance

1. Helps to understand **diode V–I characteristics**.
2. Useful in analyzing **switching time** of diodes.
3. Explains why reverse saturation current depends on **minority carriers**.

Final Boxed Points

- Total diode current = **Electron current + Hole current**

$$\boxed{I = I_n + I_p = I_s \left(e^{\frac{V}{\eta V_T}} - 1\right)}$$

- **Forward bias** → diffusion currents dominate.
- **Reverse bias** → only small saturation current flows.

UNIT-2

1 A) Explain construction and operation of a Half Wave rectifier and Find the PIV, RMS voltage ripple efficiency of Half Wave Rectifier.

Got it — here's a **correct, clean, exam-ready 10-mark answer** for the Half-Wave Rectifier, written in **simple, easy English**, with a neat diagram, correct derivations, and all final boxed results you can copy in the exam.

1A) Half-Wave Rectifier — Construction, Operation, PIV, VrmsV_{\text{rms}}, Ripple & Efficiency (10 marks)

Construction (draw this in the exam) — (2 marks)

Single diode rectifier with an AC source and a load R_L. A step-down transformer is optional.

```nginx
    AC source            Diode D           Load R_L
~~~~~~~~  —(primary)—   ┌—|>|—┐   —/\/\/\—
              ||        |     |
        (transformer)   |     |
                       ┴─────┴
```

Label: input $v_s = V_m \sin \omega t$, diode D, output v_o across R_L.

Operation (simple words) — (2 marks)

- **Positive half-cycle** ($v_s > 0$): Diode is **forward biased** → conducts → output follows the positive half sine across R_L.
- **Negative half-cycle** ($v_s < 0$): Diode is **reverse biased** → blocks → output is **zero**.
  So output is a series of positive half-sine pulses.

(Quick sketch of waveforms is useful.)

Derivations — (4 marks)

Let input $v_s = V_m \sin\theta$ where $\theta = \omega t$. Assume ideal diode and no losses.

1. Average (DC) output voltage

Only 0 to π contributes:

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} v_o\, d\theta = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta\, d\theta = \frac{V_m}{\pi}.$$

2. RMS output voltage

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} v_o^2\, d\theta} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\theta\, d\theta} = \frac{V_m}{2}.$$

3. Ripple factor r

AC component RMS is $V_{ac,rms} = \sqrt{V_{rms}^2 - V_{dc}^2}$. So

$$r = \frac{V_{ac,rms}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{V_m/2}{V_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} \approx 1.21.$$

4. Rectification efficiency η

$$\eta = \frac{P_{dc}}{P_{ac}} = \left(\frac{I_{dc}}{I_{rms}}\right)^2 = \left(\frac{V_m/(\pi R_L)}{V_m/(2R_L)}\right)^2 = \left(\frac{2}{\pi}\right)^2 = \frac{4}{\pi^2} \approx 0.4053\ (40.53\%).$$

Peak Inverse Voltage (PIV) — (1 mark)

For a single-diode half-wave rectifier the diode must withstand the peak of the input when it is reverse biased:

$$\boxed{\mathrm{PIV} = V_m}$$

(If a transformer secondary is used, V_m refers to the secondary peak.)

Peak Inverse Voltage (PIV) — (1 mark)

For a single-diode half-wave rectifier the diode must withstand the peak of the input when it is reverse biased:

$$\boxed{\text{PIV} = V_m}$$

(If a transformer secondary is used, V_m refers to the secondary peak.)

Final boxed results (copy these) — (1 mark)

$$\boxed{V_{dc} = \frac{V_m}{\pi}, \qquad V_{rms} = \frac{V_m}{2}}$$

$$\boxed{r = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} \approx 1.21, \qquad \eta = \frac{4}{\pi^2} \approx 40.5\%}$$

$$\boxed{\text{PIV} = V_m}$$

Short pros / cons (optional lines for full clarity)

- **Pros:** Very simple and cheap (one diode).
- **Cons:** Low efficiency, large ripple — usually requires a filter capacitor to get usable DC.

1)B) A sinusoidal voltage whose Vm = 25V is applied to a half-wave rectifier. The diode may be considered to be ideal and RL = 1.5 KΩ is connected as load. Determine the following: (i) Peak value of current (ii) RMS value of current (iii) Ripple factor

1(b) — Half-wave rectifier numerical

Given: Peak input voltage $V_m = 25\ \mathrm{V}$.
Load $R_L = 1.5\ \mathrm{k\Omega} = 1500\ \Omega$.
Ideal diode, half-wave rectifier.

Quick diagram / waveform (draw in exam)

Input: $v_s = V_m \sin \omega t$
Output: only positive half sinusoidal pulses (zero for negative half)

javascript Copy Edit

```javascript
v_s:  ~  /‾\  /‾\  /‾\  (full sine)
v_o:   /‾\   0   /‾\   0  (only positive halves)
```

(i) Peak value of current I_m

Peak current flows at peak voltage V_m:

$$I_m = \frac{V_m}{R_L} = \frac{25}{1500}\ \mathrm{A} = 0.016666\ldots\ \mathrm{A} = 16.667\ \mathrm{mA}.$$

Answer (i): $\boxed{I_m = 16.667\ \mathrm{mA}}$.

(ii) RMS value of current I_{rms}

For an ideal half-wave rectifier:

$$V_{rms} = \frac{V_m}{2} \quad \Rightarrow \quad I_{rms} = \frac{V_{rms}}{R_L} = \frac{V_m}{2R_L}.$$

So

$$I_{rms} = \frac{25}{2 \times 1500} = \frac{25}{3000} = 0.008333\ldots\ \mathrm{A} = 8.333\ \mathrm{mA}.$$

(You can also note $I_{rms} = \dfrac{I_m}{2}$.)

Answer (ii): $\boxed{I_{rms} = 8.333\ \mathrm{mA}}$.

(iii) Ripple factor r

For an ideal half-wave rectifier the ripple factor is a constant (derived from $V_{dc} = V_m/\pi$ and $V_{rms} = V_m/2$):

$$r = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} \approx 1.21.$$

Answer (iii): $\boxed{r \approx 1.21}$.

Final boxed summary (copy for answer sheet)

- $I_m = \frac{V_m}{R_L} = \frac{25}{1500} = \mathbf{16.667}\ \mathrm{mA}.$
- $I_{\mathrm{rms}} = \frac{V_m}{2R_L} = \frac{25}{3000} = \mathbf{8.333}\ \mathrm{mA}.$
- Ripple factor $r \approx \mathbf{1.21}$.

2 A) Explain construction and operation of full wave rectifier with Inductor filter?

Q2(a) Full-Wave Rectifier with Inductor Filter

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1. Construction (2 Marks)

- A **full-wave rectifier** uses either:
  - **Center-tapped transformer with 2 diodes**, OR
  - **Bridge rectifier with 4 diodes**.
- An **inductor (choke)** is connected **in series** with the load resistance R_L.
- The purpose of the inductor is to **oppose changes in current** and thus reduce the AC ripple.

Circuit (center-tap version, exam sketch):

```lua
      AC input
         ~
        ||      Secondary
       |  |---------|>|----+----/\/\/\----+
       |  |         D1     |     RL       |
       |  |                |              |
       |  |---------|<|----+              /
        ||      D2                    L(inductor)
         ~
```

- D1 conducts on +ve half cycle, D2 on –ve half cycle → load always gets positive half-sine.
- Inductor L in series with load RL → smoothes the current.

---

2. Operation (3 Marks)

1. **Without filter:**
   - Both halves of the AC input are rectified → pulsating DC at the output.
   - Frequency of ripple is **twice** the input supply frequency (2f).
2. **With inductor filter:**
   - The inductor opposes sudden changes in current (property of inductance).
   - During rising parts of waveform → inductor resists increase in current.
   - During falling parts → inductor releases stored energy, maintaining current.
   - As a result, output current becomes **smoother**, ripple is reduced.

---

3. Waveforms (sketch in exam) (2 Marks)

- **Before filter:** pulsating DC with gaps.
- **After inductor filter:** nearly flat DC current with small ripple.

```sql
Without filter:   /‾\_/‾\_/‾\_/‾\_/‾\_
With L filter:    ─────────~───────── (smoothed)
```

---

4. Expressions (2 Marks)

1. **DC Output Voltage:**

   For a full-wave rectifier (ideal):

$$V_{dc} = \frac{2V_m}{\pi}$$

2. **RMS Value:**

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

3. **Ripple Factor with Inductor Filter:**

   Ripple factor reduces as $\frac{1}{4\sqrt{3}fL/R_L}$.

$$r \approx \frac{R_L}{4\sqrt{3}fL}$$

   - Larger L → smaller ripple.
   - At higher frequency → smaller ripple.

---

5. Advantages of Inductor Filter (0.5 Mark)

- Gives good smoothing for **large DC currents**.
- Ripple factor decreases as inductance increases.

6. Disadvantages (0.5 Mark)

- Inductors are **bulky and costly**.
- Poor filtering at **light loads** (small current).

Final Boxed Points for Exam

- Rectifier converts both half-cycles into DC.
- With inductor filter:

$$V_{dc} = \frac{2V_m}{\pi}, \quad r \approx \frac{R_L}{4\sqrt{3} f L}$$

- Output DC is smoother, ripple reduced, efficiency improved.

2) B) Explain the construction and operation of SCR with characteristics.

Q2(b) Silicon Controlled Rectifier (SCR)

---

1. Construction (2 Marks)

- An **SCR** is a **4-layer, 3-junction, PNPN device**.
- Terminals:
    1. **Anode (A):** Connected to outer p-layer.
    2. **Cathode (K):** Connected to outer n-layer.
    3. **Gate (G):** Connected to inner p-layer, used to trigger conduction.

Exam sketch:

```mathematica
Anode (A) •—— P
          |    N
Gate (G) •─┤    P
          |    N ——• Cathode (K)
```

---

2. Operation (3 Marks)

- **Reverse bias (Anode negative wrt Cathode):**
  - J1 and J3 reverse biased → SCR blocks → small leakage current flows.
- **Forward bias without gate (Anode +, Cathode –):**
  - J1 & J3 forward biased, J2 reverse biased → SCR still in **forward blocking state** (no conduction).
- **Forward bias with gate pulse:**
  - When a small positive voltage is applied at the **Gate (G)**, J2 gets forward biased.
  - SCR turns **ON**, and large current flows from **Anode** → **Cathode**.
  - Once ON, gate loses control; current continues until anode current falls below **holding current** (I_H).

3. V–I Characteristics (with labeled regions) (3 Marks)

Diagram to draw (VI curve):

```perl
Current (I)
  ↑
  |        /
  |       /  (ON state, low resistance)
  |      /
  |     /
  |    /
  |   /
  |  /
  | / Blocking Region
  |__/_____________→ Voltage (V)
    Reverse   Forward
    Blocking  Blocking
```

---

4. Applications (1 Mark)

- Controlled rectifiers (AC to DC converters).
- Motor speed control.
- Lamp dimmers.

- Over-voltage protection circuits.

---

5. Final Boxed Points (copy in exam)

- SCR is a **4-layer PNPN, 3-terminal device (A, K, G)**.
- **OFF:** Reverse bias or forward bias without gate.
- **ON:** Gate pulse applied → conduction starts, continues till current $< I_H$.
- **V–I characteristics:** Shows reverse blocking, forward blocking, and conduction regions.

3) B) With neat diagram explain about varactor diode.

Q3(b) Varactor Diode

---

1. Definition (1 Mark)

- **A Varactor diode (also called Varicap diode) is a special PN junction diode that is always operated in reverse bias.**
- **Its junction capacitance changes with applied reverse voltage.**

---

2. Construction (2 Marks)

- **Similar to an ordinary PN junction diode, but optimized for capacitance variation.**
- **Lightly doped depletion region is designed to act as the dielectric of a capacitor.**
- **Terminals: Anode (P-region) and Cathode (N-region).**

Symbol (exam sketch):

```vbnet
----|>|----    (like diode symbol, but with 2 parallel plates on cathode side)
     | |
     | |  (represents capacitance)
```

---

3. Operation (2 Marks)

- Reverse bias applied:
  - Depletion region width increases with reverse voltage.
  - Wider depletion → **capacitance decreases**.
  - Smaller reverse voltage → narrower depletion → **capacitance increases**.
- So, capacitance is **inversely proportional** to reverse voltage.

Equation:

$$C_j = \frac{\varepsilon A}{W} \quad \text{where } W \propto \sqrt{V_R}$$

$$C_j \propto \frac{1}{\sqrt{V_R}}$$

---

4. VI Characteristics & C–V Characteristics (2 Marks)

- **V–I curve: Same as a diode in reverse bias (no conduction until breakdown).**
- **C–V curve: Shows junction capacitance decreases non-linearly with increase in reverse bias.**

(Exam sketch: curve falling as reverse voltage increases.)

---

5. Applications (2 Marks)

- **Used in tuning circuits of radio, TV, and mobile phones.**
- **Frequency modulation (FM) circuits.**
- **Automatic frequency control (AFC).**
- **Voltage Controlled Oscillators (VCOs).**

---

6. Final Boxed Points (copy in exam)

- **Operated only in reverse bias.**
- **Junction capacitance decreases with increasing reverse voltage.**
- **Symbol: diode + capacitor plates.**
- **Applications: tuning, VCO, frequency modulation.**

4) B) Compare HWR with FWR interms of their parameters.

Q4(b) Comparison of Half-Wave and Full-Wave Rectifiers

---

1. Basic Circuits (Exam Diagrams – 2 Marks)

Half-Wave Rectifier (HWR)

```nginx
AC in ~~~>|~~~ RL
```

- Only **one diode**.
- Uses **only one half-cycle** of input.

Full-Wave Rectifier (FWR) – Bridge

```markdown
       AC
   ~~~┌───┐
      |   |
   D1 |   |D2
      |   |
 RL ──┴───┴──
   D3      D4
```

- Uses **4 diodes** (or 2 with center-tap).
- **Both half-cycles** are rectified.

---

2. Comparison Table (5 Marks)

Parameter	Half-Wave Rectifier (HWR)	Full-Wave Rectifier (FWR)
No. of Diodes	1	2 (center tap) or 4 (bridge)
Output Frequency	Same as input frequency (f)	Double the input frequency (2f)
DC Output Voltage	$V_{dc} = \frac{V_m}{\pi}$	$V_{dc} = \frac{2V_m}{\pi}$
RMS Output Voltage	$V_{rms} = \frac{V_m}{2}$	$V_{rms} = \frac{V_m}{\sqrt{2}}$
Ripple Factor (r)	1.21 (high ripple)	0.482 (low ripple)
Rectification Efficiency	40.6%	81.2%
PIV (Peak Inverse Voltage)	V_m	$2V_m$ (center-tap), V_m (bridge)
Transformer Use	Not compulsory	Usually required (step-down + CT in 2-diode type)
Output Quality	Poor, discontinuous DC	Better, smoother DC
Applications	Low-power, simple circuits	Power supplies, battery chargers

3. Explanation (2 Marks)

- HWR wastes half the AC input → low efficiency & high ripple.
- FWR uses both half-cycles → higher efficiency, lower ripple, better for practical DC supplies.
- Thus, **FWR is preferred** in almost all applications where DC power is required.

---

4. Final Boxed Results (1 Mark)

- V_{dc} → HWR: $\frac{V_m}{\pi}$, FWR: $\frac{2V_m}{\pi}$
- Efficiency → HWR: **40.6%**, FWR: **81.2%**
- Ripple factor → HWR: **1.21**, FWR: **0.482**

---

5) B) In a bridge rectifier, the transformer is connected to 200V, 60Hz mains and the turns ratio of the step down transformer is 11:1. Assume the diode is ideal, find i) d.c. Voltage ii) d.c. Current iii) PIV

5(B) Bridge Rectifier — V_{dc}, I_{dc}, and PIV

Given

- Mains = **200 V, 60 Hz** (RMS at primary)
- Step-down transformer **turns ratio** = **11:1** (primary : secondary)
- **Ideal diodes** (no drop)
- Load R_L: **not specified** → we'll give I_{dc} **numerically if** R_L **is given** and otherwise as a formula.

Circuit (exam sketch)

```java
      ~  Transformer secondary (Vs_rms)
     )|(
      ~          D1       D2
          ┌──|>|───+──|>|──┐
          |        |       |
         (+)       RL     (-)    → DC output
          |        |       |
          └──|<|───+──|<|──┘
                 D3         D4
```

- Each half-cycle: **two diodes** conduct in series; with **ideal** diodes, drop = 0.
- Output is **full-wave rectified** (ripples at $2f = 120$ Hz).

Step-1: Secondary RMS and Peak

Turns ratio = 11:1 (step-down), so

$$V_{s,\,rms} = \frac{200}{11} = 18.1818\ \text{V (RMS)}$$

$$V_m = \sqrt{2}\,V_{s,\,rms} = 1.4142 \times 18.1818 \approx \boxed{25.74\ \text{V (peak)}}$$

Step-2: DC (average) Output Voltage V_{dc}

For an **ideal bridge full-wave rectifier** (no diode drops):

$$V_{dc} = \frac{2V_m}{\pi} = \frac{2 \times 25.74}{\pi} \approx \boxed{16.38\ \text{V}}$$

Step-3: DC Load Current I_{dc}

$$I_{dc} = \frac{V_{dc}}{R_L}$$

- If R_L is provided, plug it in; otherwise leave as **formula**.
- Example (only if R_L were, say, $1\ \text{k}\Omega$): $I_{dc} = 16.38/1000 = 16.38\ \text{mA}$.

Step-4: Peak Inverse Voltage (PIV) per diode

For a **bridge** rectifier, each diode must withstand the **peak of the secondary**:

$$\boxed{\text{PIV} = V_m \approx 25.74\ \text{V}}$$

Final boxed answers

- $\boxed{V_{dc} \approx 16.38\ \text{V}}$
- $\boxed{I_{dc} = \frac{16.38}{R_L}\ \text{A}}$ (use your R_L to get the numeric value)
- $\boxed{\text{PIV} \approx 25.74\ \text{V}}$

Notes (write if space allows)

- Ripple frequency = $2f = 120\ \text{Hz}$.
- If diode drops were included (≈ 2×0.7 V per conduction path), V_{dc} would reduce slightly; **not needed here** (ideal diode).

* UNIT-2

- A sinusoidal voltage whose $V_m = 25V$ is applied to a half wave rectifier. The diode may be considered to be ideal and $R_L = 1.5k\Omega$ is connected to the load.

Determine the following
1) Peak value of current
2) Rms value of current
3) Ripple factor

Given data

$V_m = 25V$
$R_L = 1.5k\Omega$
$= 1500\Omega$.
Diode is ideal.

1) Peak value of current I_m.

$$I_m = \frac{V_m}{R_L}$$

$$= \frac{25}{1500} = 0.0167A.$$

$I_m = 0.0167 A$
$= 16.7 mA$

2) Rms value of current I_{rms} is

$$I_{rms} = \frac{I_m}{2}$$

$$= \frac{0.0167}{2}$$

$$= 0.0083 A$$

$$= 8.33 mA.$$

278.89

$\left(\frac{I_m}{2}\right)^2 \times \frac{\pi}{2}$

$$\text{Ripple factor} = \sqrt{\frac{I_{rms\,value}^2}{I_{dc}^2} - 1}$$

$$= \sqrt{\frac{(8.33)^2}{I_{dc}^2} - 1}$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{16.7\,mA}{\pi} = 5.31\,mA$$

$$\gamma = \sqrt{\frac{(8.33)^2}{(5.31)^2} - 1}$$

$$= \sqrt{\frac{69.39}{28.19} - 1}$$

$$= \sqrt{1.46}$$

$$\boxed{\gamma = 1.21.}$$

5(B) In a bridge rectifier., the transformer is Connected to 200V, 60Hz mains and the turns ratio of the step down transformer is 11:1 Assume the diode is ideal, find

i) dc voltage ii) dc current iii) PIV.

Given data

Mains voltage ~~V_{prim}~~ $V_{primary}$ = 200V.

Frequency $f = 60\,Hz$

Transformer turns ratio = 11:1

Diodes are ideal.

→ Secondary Voltage of transformer.

$$V_{secondary} = \frac{V_{primary\,rms}}{11}$$

$$= \frac{200}{11} = 18.18V.$$

→ Peak secondary Voltage = $V_{rms} = \frac{V_m}{\sqrt{2}}$

$$V_m = V_{rms} \times \sqrt{2}$$

$$= 18.18 \times \sqrt{2}$$

$$= 25.7V.$$

→ output voltage(dc) $V_{dc} = \frac{2V_m}{\pi} = \frac{2 \times 25.7}{\pi}$

$$= 16.37V.$$

→ Dc output current $I_{dc} = \frac{V_{dc}}{R_L} = \frac{16.37}{R_L}A.$

→ Peak inverse voltage PIV = V_m

$$= 25.7V$$

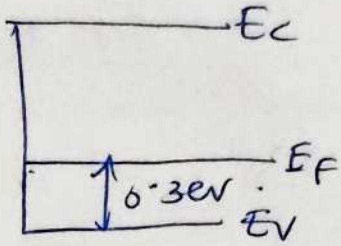
vivo Y300 5G
Kiranmayi Aug 19, 2025, 21:25

(1) In a p-type semiconductor the fermi level is 0.3 eV above the valence band at a room temp 300k. Determine the new position of the fermi level for temp of a) 350k b) 400k

Sol: In a p-type semi conductor

$E_F - E_V = 0.3\,eV$

$T = 300k.$



Fermi level in a p-type semi conductor

$$N_A = N_V e^{\frac{-(E_F - E_V)}{KT}}$$

$$N_A = 2\left(\frac{2\pi m_p k T}{h^2}\right)^{3/2} \cdot e^{\frac{-E_F - E_V}{KT}}$$

As doping concentration is constant $N_A = P$ (constant).

$$N_V(T_2)\, e^{-\left(\frac{E_{F_2} - E_{V_2}}{KT_2}\right)} = N_V(T_1) \cdot e^{\frac{-(E_{F_1} - E_{V_1})}{KT_1}}$$

$$\cancel{2}\left(\frac{\cancel{2\pi m_p k} T_2}{\cancel{h^2}}\right)^{3/2} e^{\frac{-(E_{F_2} - E_{V_2})}{KT_2}} = \cancel{2}\left(\frac{\cancel{2\pi m_p k} T_1}{\cancel{h^2}}\right)^{3/2} \cdot e^{\frac{-(E_{F_1} - E_{V_1})}{KT_1}}$$

$$\left(\frac{T_2}{T_1}\right)^{3/2} \cdot e^{\frac{-(E_{F_2} - E_{V_2})}{KT_2}} = e^{\frac{-(E_{F_1} - E_{V_1})}{KT_1}}$$

$$\ln\left[\left(\frac{T_2}{T_1}\right)^{3/2}\right] \ln\left[e^{\frac{-(E_{F_2} - E_{V_2})}{KT_2}}\right] = \ln\left[e^{\frac{-(E_{F_1} - E_{V_1})}{KT_1}}\right]$$

$$\frac{3}{2}\ln\left(\frac{T_2}{T_1}\right)+\left[\frac{-(E_{F_2}-E_{V_2})}{kT_2}\right]=\frac{-(E_{F_1}-E_{V_1})}{kT_1}$$

At 350 K

$$\frac{E_{F_2}-E_{V_2}}{k(350)}=\frac{3}{2}\ln\left(\frac{350}{300}\right)+\frac{0.3}{k(300)}$$

$$\frac{E_{F_2}-E_{V_2}}{8.617\times10^{-5}\times350}=0.231+\frac{0.3}{(8.617\times10^{-5})300}$$

$$\frac{E_{F_2}-E_{V_2}}{0.0301}=0.231+11.61$$

$$E_{F_2}-E_{V_2}=11.841\times0.0301$$

$$\boxed{E_{F_2}-E_{V_2}=0.357eV}$$

At 400k

$$\frac{E_{F_2}-E_{V_2}}{k(400)}=\frac{3}{2}\ln\left(\frac{350}{300}\right)+\frac{0.3}{k(300)}$$

$$\frac{E_{F_2}-E_{V_2}}{8.617\times10^{-5}\times400}=0.231+11.61.$$

$$E_{F_2}-E_{V_2}=11.841\times0.0344$$

$$E_{F_2}-E_{V_2}=0.415eV$$