D. J. SANGHVI COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC DEVICES SEM III
SYLLABUS

N.B. : **[Total Marks: 80]**

1) Question paper will comprise of 6 questions, each carrying 20 marks.
2) Question 1 will be compulsory for 20 marks which will cover topic from different modules in syllabus.
3) Standard constants values w.r.t to Si like $V_T, n_i, q, \epsilon_s, \epsilon_{ox}$ may or may not be given in exam.
4) Carry calculators in the exam room.
5) * marked topics are high priority.
6) **Advice:** a) Every question should include diagram of structure or EBD and characteristics to support your theory answer. b) Dont try to study everything in the subject, one can affort to leave some topic as per one's comfort. c) Lot of hardwork required for preparation of this subject that goes without saying.

✠ 01: ED Pre-requisites

Recommendations 01 : *Since the basic understanding of semiconductors is already established, one can **SKIP 01** completely.*

✠ 02: PN JUNCTION

1. PN structure and assumptions.
2. * Energy band diagram (EBD) of pn junction under equilibrium or zero-bias.
3. * Derivation of built-in potential (V_{bi}), Electric field (E) and Space-charge or depletion width (W).
4. * Analysis of pn junction in forward and reverse bias (No derivations expected, only conceptual understanding; refer pages 2-8 in notes dated 20/7/2016)
5. * EBD of pn junction in forward and reverse bias.
6. * Numericals on built-in potential (V_{bi}), Electric field (E) and Space-charge or depletion width (W) for a pn junction in zero-bias, forward bias and reverse bias.
7. Ideal diode equation derivation for a pn junction (*NOT in subject syllabus*), only minority carrier distribution for a pn junction concept needs to be studied.
8. * Numericals on Ideal-diode equation (reverse saturation current and diode current in forward and reverse bias)
9. * Zener and Avalanche breakdown mechanisms (explanation w.r.t to EBD's)
10. * PN junction capacitance: a) Diffusion capacitance and b) Depletion capacitance.
11. * Small- signal model of pn junction.
12. Numerical on Depletion capacitance.

13. * Ideal pn junction diode assumptions.
14. Reverse-bias generation current and forward-bias recombination current (No derivation expected)
15. Practical I-V characteristics of pn junction diode and its interpretation.
16. Effect of temperature on diode characteristics.

Recommendations 02 : *This is an easy, scoring but tricky device to study (coz it contains derivations, EBDs, lot of concepts and theory), be careful not to overwrite your answer in exam. Answer strictly in accordance with the question.*

University exam questions 02

1. Justify that the space charge width increases with reverse biased voltage in a p-n junction diode. **(DEC 2013, MAY 2016)** **[05]**

2. Derive the expression of built-in potential V_{bi} for a pn junction under zero-bias and hence calculate V_{bi} at T=300 K for $N_D = 10^{15}/cm^3$ and $N_D = 10^{15}/cm^3$. **(DEC 2013)** **[10]**

3. An abrupt PN junction has dopant concentration of $N_D = 2 \times 10^{16}/cm^3$ and $N_D = 2 \times 10^{15}/cm^3$ at T =300 K. Calculate: **(MAY 2014)** **[10]**
   a) Built-in potential V_{bi}
   b) W at $V_R = 0$ and $V_R = 8$ V
   c) E_{max} at $V_R = 0$ and $V_R = 8$ V

4. For the diode, define forward voltage drop, maximum forward current, dynamic resistance, reverse saturation current and reverse breakdown voltage. **(DEC 2014)** **[05]**

5. Draw the energy band diagram of PN junction in thermal equilibrium and explain it. **(DEC 2014)** **[05]**

6. What is space charge width? Derive an expression for it, when the diode is forward biased and reverse biased. **(DEC 2014)** **[10]**

7. Determine the ideal reverse saturation current density in Si pn diode at 300K. **[10]**
   Given: $N_A = N_D = 10^{16}/cm^3, n_i = 1.5 \times 10^{10}/cm^3, D_n = 25cm^2/s$, $D_p = 10cm^2/s$, $\tau_p = \tau_n = 5 \times 10^{-7}s$ **(MAY 2015)**

8. Draw the energy band diagram of PN junction for zero, forward and reverse bias, clearly showing junction diagram, depletion width, fermi energy level and barrier potential. **(MAY 2015)** **[10]**

9. Draw small signal model of pn junction diode and explain its main use. **(DEC 2015)** **[05]**

10. Derive equation of electric field for a pn junction under zero bias and hence derive equation of maximum electric field. **(DEC 2015)** **[10]**

✠ 03: ZENER DIODE

1. Zener diode I-V characteristics.
2. * Zener as voltage regulator (explain w.r.t line and load regulation)
3. * Zener breakdown mechanisms.
4. Backward diode characteristics and working.
5. * Varactor diode characteristics and working.

Recommendations 03 : *This is a straightforward device, one can't affort to lose marks here*

University exam questions 03

1. With the help of circuit diagram and characteristics, explain application of zener diode as a voltage regulator. **(MAY 2015, MAY 2016)** **[05]**

2. Explain the types of junction breakdown in case of zener diode. **(MAY 2016)** **[10]**

✠ 04: BIPOLAR JUNCTION TRANSISTOR

1. BJT structure and related configurations (CE, CC and CB).
2. * Working of npn and pnp transistor with input and output I-V characteristics in Common emitter configuration.
3. * EBD of npn and pnp BJT under zero-bias or equilibrium and forward-active mode.
4. * α and β relation for the transistor.
5. * Minority carrier distribution (MCD) in forward-active mode and related terms and diagram of MCD for npn transistor (***Attention**: Most students misintepretate this topic*)
6. Derivation of Minority carrier distribution (MCD) in forward-active mode for npn BJT. (*Rarely comes in exam*)
7. * MCD for npn transistor operating in cut-off, saturation and inverse-active mode.
8. Low frequency common base current gain, various current components in an npn BJT. (***Attention**: Most students misintepretate this topic*)
9. * Meaning of Emitter injection efficiency, base transport factor and recombination factor w.r.t BJT and related formulas.
10. Derivation of Emitter injection efficiency, base transport factor and recombination factor w.r.t npn BJT. (*Rarely comes in exam*)

11. * Eber's Moll model for an npn BJT and validity that is works for all operating modes (forward-active, saturation, inverse-active and cut-off modes) (***Attention**: For this topic, answer the question smartly*)

12. * Hybrid-Pi model for transistor.

13. * Non-ideal effects in BJT: a) Base width modulation b) High Level injection c) Non-uniform base doping d) Breakdown mechanisms in BJT and e) Emitter band-gap narrowing. (***Attention**: For this topic, study in brief*)

14. * Frequency limitation effects in BJT: Various time-delay factors in BJT, transistor cut-off frequency and beta cut-off frequency.

15. * Numerical on Emitter to collector transit time, transistor cut-off frequency and beta cut-off frequency.

16. Gummel-Pool Model for an npn transistor

Recommendations 04 : *This device is tough if one tries to study everything, concentrate on main topics. It has high weightage of marks being a single device*

University exam questions 04

1. Describe the time delay factors in the frequency limitation of the bipolar transistor. Hence, calculate the emitter-collector transit time, cut-off frequency and the beta cut-off frequency, with the following parameters. **(DEC 2013)** **[10]**

   $I_E = 50\mu A \;\; C_{je} = 0.4pf \;\; C_\mu = 0.05pf$

   $X_B = 0.5\mu m \;\; D_n = 25cm^2/s \;\; X_{dc} = 2.4\mu m$

   $r_C = 20\Omega \;\; C_S = 0.1pf$

2. What are various non-ideal effects in BJT and hence explain base width modulation in brief. **(MAY 2014)** **[05]**

3. Explain basic principle of operation of npn BJT with help of construction, minority carrier distribution and energy band diagram. **(MAY 2014)** **[10]**

4. Define the contributing factors towards the low frequency common base current gain of BJT. **(DEC 2014)** **[05]**

5. List the ideal-conditions of BJT and explain any two non-ideal effects. **(DEC 2014)** **[10]**

6. Draw Eber's Moll equivalent circuit of BJT and derive necessary expressions for current and voltages. **(DEC 2014)** **[10]**

7. What are non-ideal effects in BJT? Explain any one non-ideal effect in BJT. **[05]** **(MAY 2015)**

8. Draw and explain Eber's moll model of transistor. **(MAY 2015, MAY 2016)** **[05]**

9. What do you mean by different transistor models, explain Hybrid pi model. **(DEC 2015)** **[05]**

10. Explain the working of BJT considering all possible current density components in an NPN transistor operating in active mode. **(DEC 2015)** **[10]**

11. Explain minority carrier distribution in BJT considering transistor in active, cut-off and saturation mode. **(MAY 2016)** **[10]**

✠ 05: JUNCTION FIELD EFFECT TRANSISTOR

1. * JFET types: N-channel and P-channel JFETs and its structure. How JFET and BJT are different.
2. * Working of n-channel or p-channel JFET w.r.t output and transfer characteristics.
3. Analysis of output characteristics(also know as **DRAIN characteristics**) and transfer characteristics: Transconductance g_m, Shockley's equation relating I_D, I_{DSS} and V_P.
4. * JFET related terms: a) Internal pinch-off voltage b) Pinch-off voltage and c) Drain to source saturation voltage.
5. Device characteristics of n-channel JFET i.e derivation of I_D. (*Rarely comes in exam*)
6. * Numerical on Shockley's equation, transconductance g_m , internal pinch-off voltage V_{p0}, pinch-off voltage V_P and $(V_{DS})_{sat}$.
7. * Small signal equivalent circuit for JFET.
8. Frequency limitations factors and cut-off frequency for JFET.

Recommendations 05 : *This device is straightforward and simple. One needs to earn marks from this topic if question related to JFET is asked in exam*

University exam questions 05

1. Explain construction, working and characteristics of N-channel JFET, explain frequency limitation factors. **(DEC 2013, MAY 2015)** **[10]**

2. Explain difference between N-channel and P-channel JFET. Also explain characteristics (Drain and transfer) for N-channel JFET. **(MAY 2014)** **[10]**

3. Define internal pinch-off voltage, pinch-off voltage and drain to source saturation voltage of JFET. **(DEC 2014, MAY 2016)** **[05]**

4. Explain JFET with the help of construction and V-I characteristics, how it is different than BJT. **(DEC 2015)** **[05]**

5. For a n-channel JFET with $I_{DSS} = 8\text{mA}$, $V_P = -4\text{V}$ **(MAY 2016)** **[10]**

   i) If $I_D = 3\text{mA}$. Calculate the value of V_{GS}

   ii) Calculate $V_{DS(_{SAT})}$ for $I_D = 3\text{mA}$

   iii) Calculate transconductance (g_m)

✠ 06: MOSFET

1. * MOS capacitor as two terminal structure, EBD of MOSCAP in equilibrium and under applied external bias (i.e accumulation, depletion and inversion cases)
2. MOSFET construction and types.
3. * Concept of threshold voltage V_T and derivation of threshold voltage (***Attention:*** *Derivation of threshold voltage for a MOSFET is not given in Notes*)
4. * Numericals on threshold voltage V_T of both PMOS and NMOS
5. Concept of body effect and its effect on V_T
6. * MOSCAP C-V curve for low and high frequencies for p-type substrate and n-type substrate.
7. * Numerical on oxide capacitance, flat band capacitance and minimum gate capacitance.
8. * Derivation for I_D in linear region, i.e Gradual channel approximation for N-channel MOSFET.
9. * Derivation for I_D in saturation region, i.e Channel length modulation for N-channel MOSFET.
10. * Numericals on MOSFET region of operation, transconductance concept and MOSFET model
11. Short Channel Effect in MOSFETs (*Attention: In notes, around 47 pages(out of 70% of content is additional information) are given for SCE. Concise the contents to less than 10 pages and study accordingly.*)
12. Sub-threshold conduction current and its significance in MOSFETs (***Attention:*** *This topic is NOT in syllabus. This topic is part of Short channel effects only*)

Recommendations 06 : *This device is very important in terms of marks and application wise. Theory is very conceptual in MOSFETs, so while studying and writing in exam facts should be very clear*

University exam questions 06

1. Sketch low frequency capacitances versus gate voltage of a MOS capacitor with n-type substrate. Show individual capacitance components. **(DEC 2013)** **[05]**

2. Draw band diagrams for accumulation, depletion and inversion regions for MOS capacitor. Also, calculate threshold voltage for a polysilicon gate n-channel MOS transistor with substrate at zero potential with the following parameters: **(DEC 2013)** **[10]**

   Substrate doping density $N_A = 10^{16} cm^{-3}$

Polysilicon gate doping density $N_D = 2 \times 10^{20} cm^{-3}$

Gate oxide thickness $t_{OX} = 500^o A$

Oxide-interface fixed charge density $N_{OX} = 4 \times 10^{10} cm^{-2}$

3. Explain in brief TWO terminal MOS structure. **(MAY 2014, MAY 2016)** **[05]**

4. Explain structure and operation of MOSFET considering different cases of threshold voltage V_T **(MAY 2014)** **[10]**

5. For an n-channel MOS transistor with $\mu_n = 600 cm^2/Vs$, $C_{OX} = 7 \times 10^{-8} F/cm^2$, $W = 20\mu m$, $L = 2\mu m$ and $V_{TO} = 1V$. Examine the relationship between the drain current and terminal voltage. **(MAY 2014, DEC 2014)** **[10]**

6. What are the types of MOSFET? Explain **(DEC 2014)** **[05]**

7. What is channel length modulation in MOSFET? Derive necessary expressions for current and voltages. **(DEC 2014)** **[10]**

8. Calculate threshold voltage for a polysilicon gate n-channel MOS transistor with substrate at zero potential with the following parameters: **(MAY 2015)** **[10]**

   Substrate doping density $N_A = 10^{16} cm^{-3}$

   Polysilicon gate doping density $N_D = 2 \times 10^{20} cm^{-3}$

   Gate oxide thickness $t_{OX} = 500^o A$

   Oxide-interface fixed charge density $N_{OX} = 4 \times 10^{10} cm^{-2}$

9. Derive the drain current equation I_D for MOSFET in ohmic and saturation regions. **(MAY 2015)** **[10]**

10. Explain channel length modulation with cross section of MOSFET. Write equations associated with this effect. **(MAY 2015)** **[05]**

11. Sketch and explain V-I and C-V characteristics of MOSFET. **(MAY 2015)** **[05]**

12. Derive equation of threshold voltage of a N channel MOSFET, also derive threshold equation in generalized form. **(DEC 2015)** **[10]**

13. Explain working of MOSFET considering possible cases of V_{GS} voltages. **(DEC 2015)** **[10]**

14. Explain channel length modulation in MOSFET. **(DEC 2015)** **[05]**

15. Compare Enhancement type and Depletion type MOSFET on the basis of their construction, working principle, characteristics and biasing. **(MAY 2016)** **[10]**

✠ 07: METAL SEMICONDUCTOR JUNCTIONS

1. * Rectifying contact (Schottky barrier diode): EBD of metal–n type semiconductor for ($\phi_m > \phi_s$) case in equilibrium, formation of Schottky barrier, EBD in forward and reverse bias.
2. Ideal junction properties (i.e evaluation of E_m, W, ρ) for metal–n type semiconductor for ($\phi_m > \phi_s$) case.
3. * Numerical on metal semiconductor junction i.e finding a) Ideal Schottky barrier height, b) built-in potential barrier, c) space charge width, and d) max E-field depletion capacitances at zero-bias or applied given bias.
4. EBD of metal–p type semiconductor for ($\phi_m < \phi_s$) case.
5. * Metal semiconductor ohmic contact: EBD of metal–n type semiconductor for ($\phi_m < \phi_s$) case at equilibrium, forward and reverse bias.
6. EBD of metal–p type semiconductor for ($\phi_m > \phi_s$) case.
7. * Difference between Schottky diode and pn diode
8. * Metal semiconductor ohmic contact: Tunneling barrier and specific contact resistance.
9. I-V characteristics of a Schottky barrier diode based on thermionic emission.
10. Non-ideal effects on barrier height : Fermi-level pinning, effect of surface states, Schottky effect. (*Difficult topic*)

Recommendations 07 : *This device contains lots of EBDs and its content is more but it has less weightage in terms of marks in exam*

University exam questions 07

1. Explain schottky-barrier diode with the help of energy band diagram. **(MAY 2014)** **[10]**
2. Calculate the theoretical barrier height, built in potential barrier and maximum electric field in a metal semiconductor diode for zero applied bias. Consider a contact between tungsten and n type silicon doped to $N_d = 10^{16} cm^{-3}$ at T= 300K. The metal work function for tungsten is $\phi_m = 4.55$V and electron affinity for silicon $\chi = 4.01$V, $N_c = 10^{18} cm^{-3}$, $K = 1.38 \times 10^{-23}$ J/K, $\epsilon_s = 11.7 \times 8.85 \times 10^{-14}$, $e = 1.6 \times 10^{-19}$ C **(MAY 2015)** **[10]**
3. Explain Schottky effect. Derive the position of maximum barrier X_m **(MAY 2015)** **[10]**
4. Explain quantitative characteristics of Schottky diode. **(DEC 2015)** **[05]**

✠ 08: HETERO-JUNCTIONS

1. * Heterojunction materials.
2. * EBD of narrow and wide bandgap materials (i.e concept of straddling, staggered and broken gap).

3. * EBD of various heterojunctions before and after contact (i.e equilibrium case).
4. * Two dimensional electron gas concept.

Recommendations 08 : *This topics requires practice of EBD and one can earn full marks easily*

University exam questions 08

1. Explain the need of Hetero-junction. Explain the terms of straddling, staggered and broken gap in relation to heterojunction. Explain quantization of energy of an electron in potential well in heterojunction. Explain this concept w.r.t the ideal energy band diagram of an nN GaAs−AlGaAs heterojunction in thermal equilibrium. **(DEC 2013)** **[10]**

✠ 09: POWER DEVICES

1. PNPN diode: Basic structure, working and characteristics.
2. * SCR: Basic structure, working and characteristics, Two-transistor analogy of SCR, holding and latching current in SCR, mechanisms to turn-off an SCR.
3. DIAC: Basic structure, working and characteristics.
4. * TRIAC: Basic structure, working and characteristics.
5. * UJT: Basic structure, working and characteristics and UJT as relaxation oscillator with proper waveforms and circuit diagram.
6. PUT operation and characteristics and its difference from UJT.
7. * GTO: Basic structure, working and characteristics.
8. IGBT: Basic structure, working and characteristics.

Recommendations 09 : *This topic devices are heavy weightage in terms of marks*

University exam questions 09

1. Describe construction and V-I characteristics of IGBT. **(DEC 2013, MAY 2016)** **[05]**
2. Explain construction, working and characteristics of SCR. **(DEC 2013, MAY 2016)** **[10]**
3. Explain construction and characteristics of UJT. **(MAY 2014)** **[05]**
4. Explain construction, working and characteristics of TRAIC and DIAC. **(MAY 2014)** **[10]**
5. Explain construction, working and characteristics of UJT. **(DEC 2014)** **[05]**
6. Write short note on: **(DEC 2014)**
   a) SCR **[05]**
   b) IGBT **[05]**

7. With neat diagram, explain the operation of UJT relaxation oscillator. **(MAY 2015)** **[05]**

8. Explain basic structure and characteristics of: **(MAY 2015)** **[10]**
   i) SCR ii) DIAC

9. How PUT is different than UJT, explain. **(DEC 2015)** **[05]**

10. Explain construction, working and V-I characteristics of SCR. Also explain how SCR can be switched OFF. **(DEC 2015)** **[10]**

11. Explain construction, working and V-I characteristics of TRIAC. **(DEC 2015)** **[05]**

12. Write short note on DIAC-TRAIC **(MAY 2016)** **[05]**

✠ 10: OPTICAL DEVICES

1. Optical absorption concept: * Photon absorption coefficient, EHP generation rate.
2. * Solar cell: **PN junction solar cell**: construction, working, I-V curve in 4th quadrant. Also explain why solar cells are connected in series or parallel connections.
   Heterojunction Solar cell (explain its necessity i.e its ability capture wide range of light waves from solar spectrum, so we use multi-junction heterojunction solar cell).
   Amorphous Si solar cell.
3. **Photo detectors:** Photoconductor, * photodiode, * PIN photodiode, Avalanche photodiode
4. * Phototransistor: Structure and working
5. * Optocouplers: Operation, construction, specification and applications.

Recommendations 10 : *This topic devices are easy and heavy weightage in terms of marks*

University exam questions 10

1. Sketch the I-V characteristics of a PN junction solar cell. **(DEC 2013)** **[05]**

2. Describe construction, working and characteristics of: **(DEC 2013)** **[10]**
   i) Photodiode and
   ii) Avalanche photodiode

3. Justify how phototransistor is more practical than photodiode. **(MAY 2014)** **[05]**

4. What is photovoltaic effect. Explain in detail Solar cell with working, characteristics and practical applications. **(MAY 2014)** **[10]**

5. Write short note on: **(DEC 2014)**
   a) Solar cell **[05]**
   b) Photodiode **[05]**

6. Compare photodiode with phototransistor. **(MAY 2015)** **[05]**

7. What are optocoulpers? Explain any one application of optocoupler. **(MAY 2015)** **[05]**

8. What is the basic operating principle of phototransistor. Draw V-I characteristics and explain its use in field of optoelectronics. **(DEC 2015)** **[05]**

9. What is the basic working principle of Solar cell. Explain construction, working and V-I characteristics. Also explain what is the need to connect solar cells in series or in parallel fashion. **(DEC 2015)** **[10]**

10. Write short note on Optocoupler. **(MAY 2016)** **[05]**

✠ 11: MESFET

1. * MESFET device structure, principle of operation, I-V characteristics.
2. High frequency performance.

Recommendations 11 : *This device is not at all hard. One can study and earn marks easily*

University exam questions 11

1. Discuss the device structure and principle of operation of MESFET. Derive the equation for current-voltage characteristics for MESFET. Describe the various regions of operation on V-I characteristics. **(DEC 2013)** **[10]**

2. Compare BJT, JFET and MESFET. **(DEC 2014)** **[10]**

3. Draw and explain construction and working of MESFET. **(MAY 2015)** **[05]**

4. What are the advantages of MESFET over MOSFET. Explain basic principle of operation of MESFET. **(DEC 2015)** **[05]**

5. Write short note on MESFET. **(MAY 2016)** **[05]**

✠ 12: MODFET (HEMT)

1. * MODFET fundamentals and structure
2. * Operation and V-I characteristics of MODFET along with its EBD.
3. Cutoff frequency of MODFET

Recommendations 12 : *This device have the foundation base in MESFET and heterojunctions*

University exam questions 12

1. Draw and explain construction and working of HEMT (MODFET). **(MAY 2015)** **[05]**

✠ 13: HETEROJUNCTION BJT

1. * Necessity of HBT. Explore the limitations of BJT
2. * Current gain in HBT
3. * Basic npn HBT structure with energy band diagram

Recommendations 13 : *This device have the foundation base in BJT and heterojunctions. One can easily earn marks.*

University exam questions 13

1. What is primary advantage of HBT over BJT? Draw and explain schematic cross section of an npn HBT structure with its energy band diagram when HBt is operated under active mode. **(DEC 2013)** **[10]**
2. What is HBT. Explain construction and energy band diagram of HBT. **(MAY 2014, DEC 2014)** **[10]**
3. What is HBT. Explain with the help of energy band diagram. **(DEC 2015)** **[05]**
4. Discuss HBT in details. **(MAY 2016)** **[10]**

✠ 14: Tunnel Diode

1. * Tunnel diode I-V characteristics and working along with the EBD in various cases.

Recommendations 14 : *This device is straightforward and one can score marks in it*

University exam questions 14

1. Explain construction and V-I characteristics of tunnel diode. **(DEC 2013)** **[10]**

2. Explain construction, working and V-I characteristics of tunnel diode.
   (DEC 2014, MAY 2016) **[10]**

✠ 15: TED(GUNN diode) and IMPATT diode

1. TED basic concept, negative differential resistance, V-I characteristics and working of GUNN diode
2. IMPATT diode: Static and dynamic characteristics

Recommendations 15 : *Have'nt covered this topic in class. So no comments on it.*

University exam questions 15

1. Explain concepts, construction, characteristics and working of GUNN diode. **[10]**
   (MAY 2014)
2. Explain structure, construction and working of IMPATT diode. **(DEC 2015)** **[10]**
3. Write short note on Gunn diode. **(MAY 2016)** **[05]**

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