UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

SECOND SEMESTER EXAMINATIONS, APRIL/MAY 2019

COURSE NO: EL 174
COURSE NAME: Semiconductor Devices
CLASS: EL I **TIME**: 3 hours

Name: ____ Index Number: _______________

Instructions
Attempt all questions in Section A and Question 1 and any other question in Section B.

[Hint: $h = 6.625\times10^{-34}$ Js; $m = 9.11 \times 10^{-31}$ kg; $c = 3\times10^{8}$ m/s; $e = 1.6 \times 10^{-19}$ C; $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m]

SECTION A

This section comprises of 80 multiple choice questions. Attempt all questions in this section. All questions carry equal marks. Provide your answers in the Answer Booklet by writing the alphabet corresponding to the correct answer in each question.

Atomic Theory

1. According to Bohr's theory of atom, an electron can move in an orbit of __________.
   A. any radius B. certain radius
   C. some range of radii D. none of the above

2. The total energy of a revolving electron in an atom can __________.
   A. have any value above zero B. never be positive
   C. never be negative D. not be calculated

3. An atom is said to be ionised when any one of its orbiting electron __________.
   A. jumps from one orbit to another B. is raised to a higher orbit
   C. comes to the ground state D. is completely removed

4. Which subatomic particles have opposite charges?
   A. Electrons and neutrons B. Energy and neutrons
   C. Protons and electrons D. Protons and neutrons

5. Which subatomic particles have the same relative mass?
   A. Electrons and protons B. Energy and protons
   C. Neutrons and electrons D. Protons and neutrons

Semiconductor Physics

6. A semiconductor is formed by __________ bonds.
   A. covalent B. electrovalent
   C. co-ordinate D. none of the above

7. The most commonly used semiconductor is __________.
   A. germanium B. silicon
   C. carbon D. sulphur

8. A semiconductor has generally __________ valence electrons.
A. 2
B. 3
C. 6
D. 4

9. The strength of a semiconductor crystal comes from __________.
A. forces between nuclei
B. forces between protons
C. electron-pair bonds
D. none of the above

10. When a pentavalent impurity is added to a pure semiconductor, it becomes __________.
A. an insulator
B. an intrinsic semiconductor
C. *p*-type semiconductor
D. *n*-type semiconductor

11. Addition of pentavalent impurity to a semiconductor creates many __________.
A. free electrons
B. holes
C. valence electrons
D. bound electrons

12. In the depletion region of a pn junction, there is a shortage of __________.
A. acceptor ions
B. holes and electrons
C. donor ions
D. none of the above

13. A reverse biased pn junction has __________.
A. very narrow depletion layer
B. almost no current
C. very low resistance
D. large current flow

14. A pn junction acts as a __________.
A. controlled switch
B. bidirectional switch
C. unidirectional switch
D. none of the above

15. The leakage current across a pn junction is due to __________.
A. minority carriers
B. majority carriers
C. junction capacitance
D. none of the above

Quantum Theory

16. What did Max Planck propose to solve the black body radiator problem?
A. Radiation is made up of waves
B. Light changes its speed in different media
C. Light comes in packets of energy
D. Light has a continuous energy profile

17. The photoelectric effect was explained by Albert Einstein by assuming that __________.
A. light is a wave
B. light is a particle
C. an electron behaves as a wave
D. an electron behaves as a particle

18. When an electron falls from an orbit where $n = 2$ to $n = 1$, __________.
A. a photon is emitted
B. a photon is absorbed
C. no change in atomic energy
D. the atomic energy decreases to zero

19. Which of the following formulas can be used to determine the de Broglie wavelength?
A. $\lambda = hmv$
B. $\lambda = h/mv$
C. $\lambda = mv/h$
D. $\lambda = hm/c$

20. Consider an x-ray with a wavelength of $\lambda = 0.708\times10^{-8}$ cm. Calculate the photon energy corresponding to this wavelength.
A. 1.75×10^{4} eV
B. 2.81×10^{-8} eV
C. 2.81×10^{-15} eV
D. 7.08×10^{4} eV

21. Consider an electron traveling at a velocity of 10^{7} cm/s. Calculate its de Broglie wavelength.
A. 72.7 Å
B. 7.27 Å
C. 0.727 Å
D. 9.11 Å

Diodes and Diode Applications

22. In the breakdown region, a zener diode behaves like a __________ source.
A. constant voltage
B. constant current
C. constant resistance
D. none of the above

23. A zener diode is destroyed if it__________.
A. is forward biased
B. is reverse biased
C. carrier more than rated current
D. none of the above

24. A series resistance is connected in the zener circuit to__________.
A. properly reverse bias the Zener
B. protect the Zener
C. properly forward bias the Zener
D. none of the above

25. A zener diode is __________ device.
A. a non-linear
B. a linear
C. an amplifying
D. none of the above

26. A zener diode has __________ breakdown voltage.
A. undefined
B. sharp
C. zero
D. none of the above

27. __________ rectifier has the lowest forward resistance.
A. solid state
B. vacuum tube
C. gas tube
D. none of the above

28. Mains ac power is converted into dc power for __________.
A. lighting purposes
B. heaters
C. using in electronic equipment
D. none of the above

29. The disadvantage of a half-wave rectifier is that the __________.
A. components are expensive
B. diodes must have a higher power rating
C. output is difficult to filter
D. none of the above

30. If the ac input to a half-wave rectifier is an rms value of $400/\sqrt{2}$ volts, then diode PIV rating is _____.
A. $400/\sqrt{2}$ V
B. 400 V
C. $400\sqrt{2}$ V
D. none of the above

31. The ripple factor of a half-wave rectifier is __________.
A. 2
B. 1.21
C. 2.5
D. 0.48

32. There is a need of transformer for __________.
A. half-wave rectifier
B. centre-tap full-wave rectifier
C. bridge full-wave rectifier
D. none of the above

33. The PIV rating of each diode in a bridge rectifier is ______ that of the equivalent centre-tap rectifier.
A. one-half
B. the same as
C. twice
D. four times

34. For the same secondary voltage, the output voltage from a centre-tap rectifier is __________ than that of bridge rectifier.
A. twice
B. thrice
C. four time
D. one-half

35. If the PIV rating of a diode is exceeded, __________.
A. the diode conducts poorly
B. the diode is destroyed
C. the diode behaves like a zener diode
D. none of the above

36. A half-wave rectifier has an input voltage of 240 V rms. If the step-down transformer has a turns ratio of 8:1, what is the peak load voltage? Ignore diode drop.
A. 27.5 V
B. 86.5 V
C. 30 V
D. 42.5 V

37. The maximum efficiency of a half-wave rectifier is __________.
A. 40.6%
B. 81.2%
C. 50%
D. 25%

38. The most widely used rectifier is __________.
A. half-wave rectifier
B. centre-tap full-wave rectifier
C. bridge full-wave rectifier
D. none of the above

Bipolar Junction Transistors

39. To operate properly, a transistor's base-emitter junction must be forward biased with reverse bias applied to which junction?
A. collector-emitter
B. base-collector
C. base-emitter
D. collector-base

40. The ends of a load line drawn on a family of curves determine __________.
A. saturation and cut-off
B. the operating point
C. the power curve
D. the amplification factor

41. If $V_{CC} = +18$ V, voltage-divider resistor R_1 is 4.7 kΩ, and R_2 is 1500 Ω, then the base bias voltage is __________.
A. 8.7 V
B. 4.35 V
C. 2.9 V
D. 0.7 V

42. The C-B configuration is used to provide which type of gain?
A. voltage
B. current
C. resistance
D. power

43. The Q-point on a load line may be used to determine __________.
A. V_C
B. V_{CC}
C. V_B
D. I_C

44. A transistor may be used as a switching device or as a __________.
A. fixed resistor
B. tuning device
C. rectifier
D. variable resistor

45. If an input signal ranges from 20–40 µA, with an output signal ranging from 0.5–1.5 mA, what is the ac beta?

A. 0.05	B. 20
C. 50	D. 500

46. Beta's current ratio is __________.

A. I_C/I_B	B. I_C/I_E
C. I_B/I_E	D. I_E/I_B

47. A collector characteristic curve is a graph showing __________.

A. I_E versus V_{CE} with V_{BB} held constant	B. I_C versus V_{CE} with V_{BB} held constant
C. I_C versus V_C with V_{BB} held constant	D. I_C versus V_{CC} with V_{BB} held constant

48. With low-power transistor packages, the base terminal is usually the __________.

A. tab end	B. middle
C. right end	D. stud mount

49. When a silicon diode is forward biased, V_{BE} for a CE configuration is __________.

A. voltage-divider bias	B. 0.4 V
C. 0.7 V	D. emitter voltage

50. What is the current gain for a common-base configuration where $I_E = 4.2$ mA and $I_C = 4.0$ mA?

A. 16.8	B. 1.05
C. 0.2	D. 0.95

51. With a PNP circuit, the most positive voltage is probably __________.

A. ground	B. V_C
C. V_{BE}	D. V_{CC}

52. If a 2 mV signal produces a 2 V output, what is the voltage gain?

A. 0.001	B. 0.004
C. 100	D. 1000

53. Most of the electrons in the base of an NPN transistor flow __________.

A. out of the base lead	B. into the collector
C. into the emitter	D. into the base supply

54. In a transistor, collector current is controlled by __________.

A. collector voltage	B. base current
C. collector resistance	D. all of the above

55. Total emitter current is __________.

A. $I_E - I_C$	B. $I_C + I_E$
C. $I_B + I_C$	D. $I_B - I_C$

56. If a transistor operates at the middle of the dc load line, a decrease in the current gain will move the Q point __________.

A. off the load line	B. nowhere
C. up	D. down

57. Which is the higher gain provided by a CE configuration?

A. voltage	B. current
C. resistance	D. power

58. What is the collector current for a CE configuration with a beta of 100 and a base current of 30 μA?
A. 30 μA
B. 0.3 μA
C. 3 mA
D. 3 MA

Field Effect Transistors

59. A JFET has three terminals, namely __________.
A. cathode, anode, grid
B. emitter, base, collector
C. source, gate, drain
D. none of the above

60. A JFET is also called __________ transistor.
A. unipolar
B. bipolar
C. unijunction
D. none of the above

61. A JFET has high input impedance because __________.
A. it is made of semiconductor material
B. input is reverse biased
C. of impurity atoms
D. none of the above

62. In a JFET, I_{DSS} is known as __________.
A. drain to source current
B. drain to source current with gate shorted
C. drain to source current with gate open
D. none of the above

63. A MOSFET is sometimes called __________ JFET.
A. many gate
B. open gate
C. insulated gate
D. shorted gate

64. A MOSFET uses the electric field of a __________ to control the channel current.
A. capacitor
B. battery
C. generator
D. none of the above

65. The pinch-off voltage in a JFET is analogous to __________ voltage in a vacuum tube.
A. anode
B. cathode
C. grid cut off
D. none of the above

66. A MOSFET differs from a JFET mainly because __________.
A. of power rating
B. the MOSFET has two gates
C. the JFET has a pn junction
D. none of above

67. A certain D-MOSFET is biased at $V_{GS} = 0$ V. Its datasheet specifies $I_{DSS} = 20$ mA and $V_{GS(off)} = -5$ V. The value of the drain current is __________.
A. 20 mA
B. 0 mA
C. 40 mA
D. 10 mA

68. A certain p-channel E-MOSFET has a $V_{GS\,(th)} = -2$ V. If $V_{GS} = 0$ V, the drain current is __________.
A. 0 mA
B. $I_{D\,(on)}$
B. maximum
D. I_{DSS}

Silicon Controlled Rectifiers

69. Which of the following devices does not have a cathode terminal?

    A. SCR
    B. SCS
    C. Triac
    D. Shockley diode

70. Which of the following devices is unquestionably of the greatest interest today?

    A. SCR
    B. GTO
    C. LASCR
    D. SCS

71. Which of the following devices has a negative-resistance region in its characteristics curve?

    A. SCR
    B. SCS
    C. Unijunction transistor
    D. Phototransistor

72. Which one of the SCR terminals fires the SCR?

    A. Anode
    B. Cathode
    C. Gate
    D. All of the above

73. Which of the following devices has the smallest turn-off time?

    A. SCR
    B. GTO
    C. SCS
    D. LASCR

74. Which of the following devices has nearly the same turn-on time as turn-off time?

    A. SCR
    B. GTO
    C. SCS
    D. LASCR

75. Which of the transistors of an SCR are conducting when the SCR is fired and is in the conduction mode?

    A. npn
    B. pnp
    C. Both npn and pnp
    D. Neither npn nor pnp

76. Which of the following devices has (have) four layers of semiconductor materials?

    A. SCS
    B. GTO
    C. LASCR
    D. All of the above

77. Which of the following parameters are usually provided by the manufacturer on the specification sheet for SCRs?

    A. Turn-on time (t_{on})
    B. Turn-off time (t_{off})
    C. Junction and case temperatures (t_j and t_c)
    D. All of the above

78. Which of the following areas is (are) applications of an SCS?

    A. Counters
    B. Pulse generators
    C. Voltage sensors
    D. All of the above

79. Which of the following is (are) the advantages of the SCS over a corresponding SCR?

    A. Reduced turn-off time
    B. Increased control and triggering sensitivity
    C. More predictable firing situation
    D. All of the above

80. Which of the following transistors is an SCR composed of?

    A. npn, pnp
    B. npn, npn
    C. pnp, pnp
    D. None of the above

SECTION B

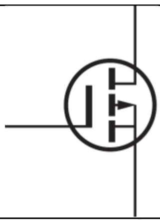
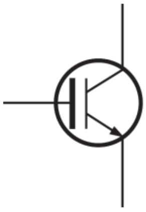
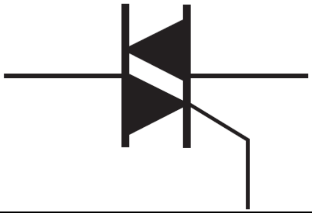
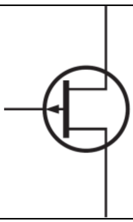
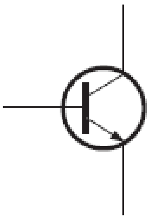
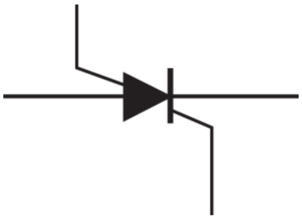
Attempt only two question in this section. Question 1 is compulsory. All questions carry equal marks.

QUESTION 1

a. Draw the electrical symbol for the following semiconductor devices: zener diode, Schottky diode, tunnel diode, PNP transistor, *n*-channel JFET, *p*-channel D-MOSFET, Dual-gate *n*-channel E-MOSFET, and LASCR. [8 *marks*]

b. Identify each of the electronic symbols in Table 1 below. [12 *marks*]

Table 1 Electronic symbols

SN	CIRCUIT SYMBOL	SN	CIRCUIT SYMBOL	SN	CIRCUIT SYMBOL
a.		b.		c.	
d.		e.		f.	
g.		h.		i.	
j.		k.		l.	

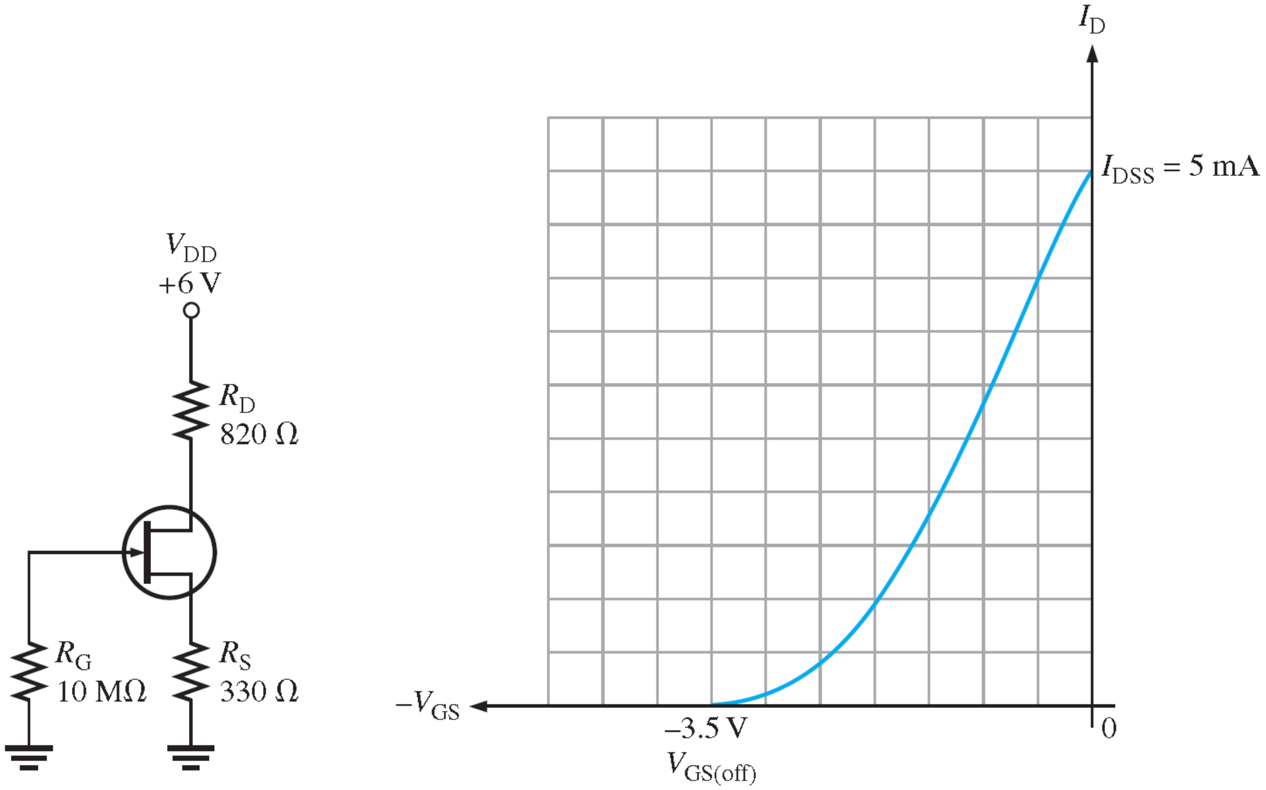
Question 2

a. Find the value of RS required to self-bias a *p*-channel JFET with I_{DSS} = 18 mA and $V_{GS(off)}$ = 8 V. Assume V_{GS} to be 4 V. [5 *marks*]

b. Graphically determine the Q-point for the circuit in Figure 1(a) using the transfer characteristic curve in Figure 1(b). [5 *marks*]

c. The datasheet for an E-MOSFET gives $I_{D(on)}$ = 100 mA at V_{GS} = 8 V and $V_{GS(th)}$ = 4 V. Find I_D when V_{GS} = 6 V. [5 *marks*]

d. For a certain D-MOSFET, I_{DSS} = 18 mA and $V_{GS(off)}$ = 10 V.
   i. Is this an *n*-channel or a *p*-channel? [1 *mark*]
   ii. Determine I_D at V_{GS} = 4 V. [2 *marks*]
   iii. Determine I_D at V_{GS} = -4 V. [2 *marks*]



(a) (b)

Figure 1 Electric circuit and its corresponding graph for Question 2b

Question 3

a. Determine the resistance of a certain 4-layer diode in the forward-blocking region if $V_{AK} = 15$ V and $I_A = 1$ µA. If the forward-breakover voltage is 50 V, how much must V_{AK} be increased to switch the diode into the forward-conduction region? [5 *marks*]

b. Explain the operation of an SCR in terms of its transistor equivalent. [5 *marks*]

c. Explain the turn-on and turn-off operation of an SCS in terms of its transistor equivalent. [5 *marks*]

d. To what value must the variable resistor be adjusted in Figure 2 to turn the SCR off? Assume $I_H = 10$ mA and $V_{AK} = 0.7$ V. [5 *marks*]

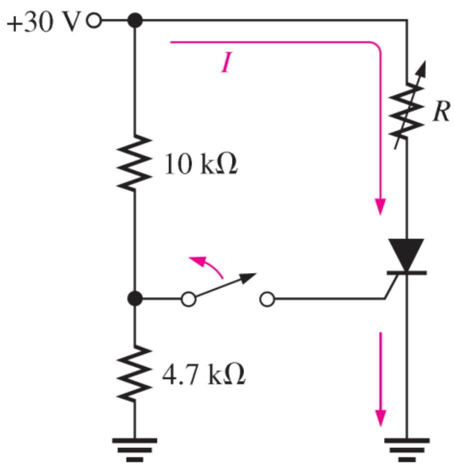


Figure 2 Electric circuit for Question 3d

Dr S. Nunoo/J. C. Attachie