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Electronic Devices — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Treat diodes as ideal unless a forward voltage drop is given. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Semiconductors · Semiconductor diode and its I–V characteristics · Diode as a rectifier · Light emitting diode · Photodiode · Solar cell · Zener diode as a voltage regulator · Logic gates

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. Pure silicon at room temperature has an intrinsic carrier concentration of $1.5 \times 10^{16}\ m^{-3}$. It is doped with 4.5×10^{22} arsenic atoms per m^3. The concentration of holes in the doped silicon is

(1) $1.5 \times 10^{16}\ m^{-3}$

(2) $4.5 \times 10^{22}\ m^{-3}$

(3) $5 \times 10^{9}\ m^{-3}$

(4) $3 \times 10^{6}\ m^{-3}$

2. Germanium doped with a small amount of indium (a group 13 element) becomes

(1) a p-type semiconductor, with holes as majority carriers

(2) an n-type semiconductor, with electrons as majority carriers

(3) a p-type semiconductor, with electrons as majority carriers

(4) an intrinsic semiconductor

3. Among diamond, silicon and germanium, the material with the smallest energy band gap at room temperature is

(1) diamond

(2) germanium

(3) silicon

(4) none: all three have the same band gap

4. A silicon diode (forward voltage drop 0.7 V) is connected in series with a 1 kΩ resistor across a 5 V battery, with the diode forward biased. The current is

(1) 5.0 mA

(2) 0.7 mA

(3) 5.7 mA

(4) 4.3 mA

5. Two branches are connected in parallel across a 6 V battery. Each branch is an ideal diode in series with a 2 Ω resistor; one diode is forward biased and the other is reverse biased. The current drawn from the battery is

(1) 6 A

(2) 3 A

(3) zero

(4) 1.5 A

6. A 50 Hz AC supply is rectified. The fundamental frequency of the ripple in the output is

(1) 50 Hz for both half-wave and full-wave rectification

(2) 100 Hz for half-wave and 50 Hz for full-wave rectification

(3) 100 Hz for both

(4) 50 Hz for half-wave and 100 Hz for full-wave rectification

7. The peak value of the output voltage of a full-wave rectifier (ideal diodes) is 20 V. The average (dc) value of the output voltage is about

(1) 12.7 V

(2) 6.4 V

(3) 14.1 V

(4) 20 V

8. A 6 V Zener diode is connected in reverse bias across a 300 Ω load. The pair is fed from a 10 V supply through a 100 Ω series resistor. The current through the Zener diode is

(1) 40 mA

(2) 60 mA

(3) 20 mA

(4) 10 mA

9. A voltage regulator has a 6 V Zener diode across a 300 Ω load, fed through a 100 Ω series resistor. The least supply voltage for which the load voltage is still held at 6 V is

(1) 6 V

(2) 10 V

(3) 7.5 V

(4) 8 V

10. A light emitting diode gives out light of wavelength 620 nm. The band gap of its semiconductor is about (hc = 1240 eV nm)

(1) 1.0 eV

(2) 2.0 eV

(3) 3.1 eV

(4) 0.62 eV

11. A photodiode is normally operated

(1) in reverse bias, because the fractional change in current caused by light is then much larger

(2) in forward bias, because the current is then larger

(3) in reverse bias, because then no current at all flows in the dark

(4) in forward bias, so that light can enter the junction

12. Which of the following statements about a solar cell is correct?

(1) It needs an external battery to work

(2) It is operated in reverse bias, like a photodiode

(3) It works without any external bias, and its I–V curve is drawn in the fourth quadrant

(4) It gives out light when it is forward biased

13. A silicon photodiode (band gap 1.1 eV) can detect light only if its wavelength is less than about (hc = 1240 eV nm)

(1) 564 nm

(2) 1240 nm

(3) 1127 nm

(4) 2255 nm

14. The output of a NOR gate is connected to the input of a NOT gate. The combination acts as

(1) an OR gate

(2) an AND gate

(3) a NAND gate

(4) a NOR gate

15. Each of two inputs A and B is passed through its own NOT gate, and the two outputs are fed to an AND gate. The combination is equivalent to

(1) an OR gate

(2) an AND gate

(3) a NAND gate

(4) a NOR gate

16. Inputs A and B are fed to both a NAND gate and an OR gate, and the outputs of these two gates are fed to an AND gate. For the inputs (A, B) = (0, 0), (0, 1), (1, 0), (1, 1) in that order, the final outputs are

(1) 0, 0, 0, 1

(2) 0, 1, 1, 0

(3) 1, 0, 0, 1

(4) 1, 1, 1, 0

17. When the forward voltage across a diode is raised from 0.70 V to 0.72 V, the forward current rises from 10 mA to 20 mA. The dynamic resistance of the diode in this range is

(1) 2 Ω

(2) 36 Ω

(3) 70 Ω

(4) 0.5 Ω

18. Which of the following statements about a p–n junction is correct?

(1) In forward bias the depletion layer becomes wider

(2) In reverse bias the potential barrier becomes lower

(3) The reverse current is carried by majority carriers

(4) In forward bias the depletion layer becomes narrower and the potential barrier becomes lower

19. As the temperature of an intrinsic semiconductor rises, its electrical conductivity

(1) falls, as that of a metal does

(2) rises, because more electron–hole pairs are created

(3) stays the same

(4) becomes zero

20. A Zener diode used as a voltage regulator is connected

(1) in forward bias, in series with the load

(2) in reverse bias, in series with the load

(3) in reverse bias, in parallel with the load

(4) in forward bias, in parallel with the load

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

21. The peak output voltage of a full-wave rectifier with ideal diodes is 5π V. The average (dc) value of its output voltage (in V) is _____.

Answer: _____

22. A 12 V Zener diode regulates the voltage across a 1.2 kΩ load, fed from a 20 V supply through a series resistor R. For the Zener current to be 10 mA, R (in Ω) must be _____.

Answer: _____

23. Two silicon diodes, each with a forward drop of 0.7 V, are connected in series, both forward biased, with a 360 Ω resistor across a 5 V battery. The current (in mA) is _____.

Answer: _____

24. The semiconductor of an LED has a band gap of 1.9 eV. The wavelength (in nm) of the light it emits is _____ (to the nearest integer; hc = 1240 eV nm).

Answer: _____

25. A logic circuit has three inputs A, B and C. Its output is the AND of (A OR B) with (NOT C). The number of the eight input combinations for which the output is 1 is _____.

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(3)	(1)	(2)	(4)	(2)	(4)	(1)	(3)	(4)	(2)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(1)	(3)	(3)	(1)	(4)	(2)	(1)	(4)	(2)	(3)

Q21	Q22	Q23	Q24	Q25
10	400	10	653	3

WORKED SOLUTIONS

Q1. Answer (3). Arsenic (group 15) is a donor: $n \approx 4.5 \times 10^{22}\ m^{-3}$. In equilibrium $n_e\, n_h = n_i^2$, so $n_h = (1.5 \times 10^{16})^2/(4.5 \times 10^{22}) = 2.25 \times 10^{32}/4.5 \times 10^{22} = 5 \times 10^{9}\ m^{-3}$.

Q2. Answer (1). Indium has three valence electrons. Each indium atom leaves one of the four bonds with its germanium neighbours incomplete, which is a hole. Indium is therefore an acceptor and the material is p-type, with holes as majority carriers.

Q3. Answer (2). Typical band gaps: diamond about 5.4 eV (an insulator), silicon about 1.1 eV, germanium about 0.7 eV. Germanium has the smallest, which is why it has more thermally created carriers at room temperature.

Q4. Answer (4). The diode conducts and takes 0.7 V, leaving 5 − 0.7 = 4.3 V across the resistor: I = 4.3 V/1 kΩ = 4.3 mA.

Q5. Answer (2). An ideal diode has no resistance forward and does not conduct in reverse. The forward branch carries 6/2 = 3 A; the reverse branch carries nothing. Total 3 A.

Q6. Answer (4). A half-wave rectifier passes one pulse per cycle, so its output repeats every 1/50 s. A full-wave rectifier gives a pulse in each half cycle, so its output repeats every 1/100 s: a 100 Hz ripple, which is easier to smooth.

Q7. Answer (1). The output is $|20 \sin \omega t|$. Its average over a half cycle is $2V_m/\pi = 40/\pi \approx 12.7$ V. (6.4 V = V_m/π is the half-wave value; 14.1 V is the rms value.)

Q8. Answer (3). Without the Zener the load would get 10 × 300/400 = 7.5 V, more than 6 V, so the Zener conducts and holds the load at 6 V. Series current (10 − 6)/100 = 40 mA; load current 6/300 = 20 mA; Zener current 40 − 20 = 20 mA.

Q9. Answer (4). Regulation needs the Zener current to be at least zero. The load takes 6/300 = 20 mA, all of which must pass through the 100 Ω resistor: $V_m in = 6 + 0.02 \times 100 = 8$ V. Below that the Zener switches off and the load voltage falls.

Q10. Answer (2). In an LED the photon energy is about the band gap: $E = hc/\lambda = 1240/620 = 2.0$ eV (red-orange light).

Q11. Answer (1). Light creates extra electron–hole pairs, which change the minority-carrier (reverse) current a great deal compared with its small dark value. In forward bias the large majority-carrier current hides this change. A small dark current does still flow in reverse bias.

Q12. Answer (3). A solar cell is a p–n junction with no applied bias: light creates electron–hole pairs and the junction field drives them round the external circuit, so it is a source of emf. Its current flows opposite to the forward current while its voltage is positive, so the I–V curve lies in the fourth quadrant. Emitting light is what an LED does.

Q13. Answer (3). A photon must have at least the band-gap energy to create an electron–hole pair: $\lambda_max = hc/E_g = 1240/1.1 \approx 1127$ nm, in the near infrared.

Q14. Answer (1). NOR gives the complement of A + B; inverting it again gives A + B, the OR function.

Q15. Answer (4). The output is (NOT A)·(NOT B), which is 1 only when both inputs are 0. By De Morgan's theorem this equals NOT(A + B): a NOR gate.

Q16. Answer (2). NAND: 1, 1, 1, 0. OR: 0, 1, 1, 1. AND of these: 0, 1, 1, 0. The circuit gives 1 when exactly one input is 1.

Q17. Answer (1). $r_d = \Delta V/\Delta I = 0.02\ V/0.01\ A = 2\ \Omega$. (V/I = 70 Ω or 36 Ω would be the static resistance at one point.)

Q18. Answer (4). A forward bias opposes the built-in field, so the barrier falls and the depletion layer narrows, letting majority carriers cross. Reverse bias does the opposite (wider layer, higher barrier), and the small reverse current is carried by minority carriers.

Q19. Answer (2). More electrons gain enough thermal energy to cross the band gap, so the number of electron–hole pairs grows rapidly with temperature and the conductivity rises, unlike a metal.

Q20. Answer (3). In reverse breakdown the Zener voltage stays almost constant over a wide range of current. Connected in parallel with the load, it holds the load voltage at V_Z, with a series resistor taking up the difference from the supply.

Q21. Answer 10. $V_{dc} = 2V_m/\pi = 2 \times 5\pi/\pi = 10$ V.

Q22. Answer 400. Load current 12/1200 = 10 mA, so the series current is 10 + 10 = 20 mA. R = (20 − 12)/0.02 = 400 Ω.

Q23. Answer 10. I = (5 − 0.7 − 0.7)/360 = 3.6/360 A = 10 mA.

Q24. Answer 653. $\lambda = hc/E_g = 1240/1.9 \approx 652.6$ nm, i.e. 653 nm (red).

Q25. Answer 3. The output is 1 only when C = 0 and at least one of A, B is 1: (1, 0, 0), (0, 1, 0) and (1, 1, 0). That is 3 combinations.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: diode and Zener circuits by testing each diode state for consistency, rectifier outputs by averaging the waveform over a cycle, carrier numbers from the mass-action law, and logic circuits from complete truth tables.