# Semiconductor Electronics: Materials, Devices and Simple Circuits

<table>
<tr><th>Q.No</th><th>Question</th><th>Marks</th></tr>
<tr><td colspan="3">Multiple Choice Question</td></tr>
<tr><td>Q.188</td><td>Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.<br><br>Assertion (A): For the same doping concentrations, n-type Si material has a higher conductivity than p-type Si material.<br><br>Reason (R): In a semiconductor the electrons are less tightly bounded than holes.<br><br>A. Both assertion and reason are true and reason is the correct explanation for assertion.<br>B. Both assertion and reason are true but reason is not the correct explanation for assertion.<br>C. Assertion is true but the reason is false.<br>D. Assertion is false but the reason is true.</td><td>1</td></tr>
<tr><td>Q.189</td><td>Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.<br><br>Assertion(A): n-type semiconductors of silicon are electrically charged.<br><br>Reason(R): In n-type semiconductors, the doped atom has 1 more valence electron than silicon.<br><br>A. Both assertion and reason are true and reason is the correct explanation for assertion.<br>B. Both assertion and reason are true but reason is not the correct explanation for assertion.<br>C. Assertion is true but the reason is false.<br>D. Assertion is false but the reason is true.</td><td>1</td></tr>
<tr><td>Q.190</td><td>In an unbiased p-n junction at equilibrium, which of the following statements is true about diffusion current and drift current?<br><br>A. Diffusion current is equal to drift current<br>B. Drift current exists while diffusion current is zero<br>C. Diffusion current exists while drift current is zero<br>D. Neither drift current nor diffusion current exists</td><td>1</td></tr>
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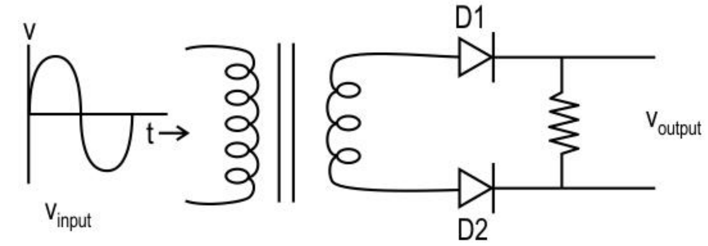
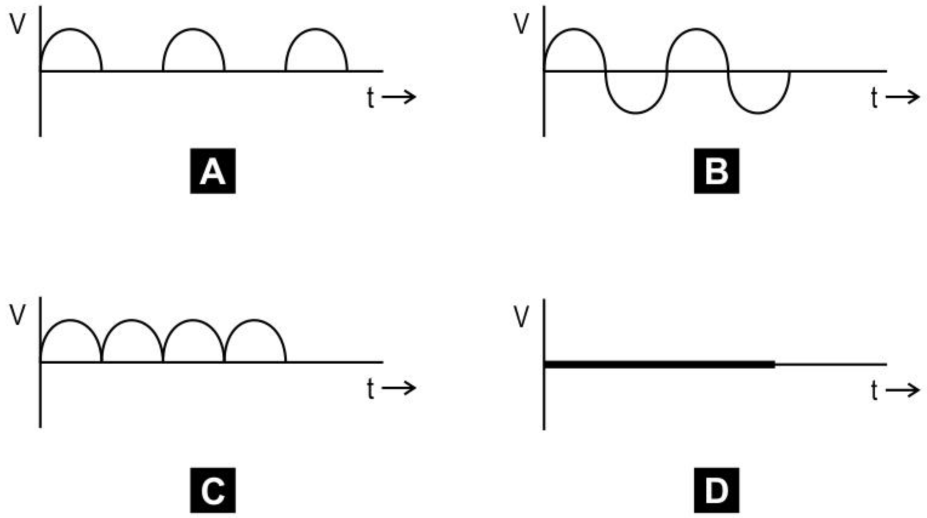
<tr><td>Q.191</td><td>

The diagram below shows a transformer whose output terminals are connected to two diodes $D_1$ and $D_2$.




Which of the following represents the waveform obtained at the output terminals of the transformer correctly?




A. A

B. B

C. C

D. D

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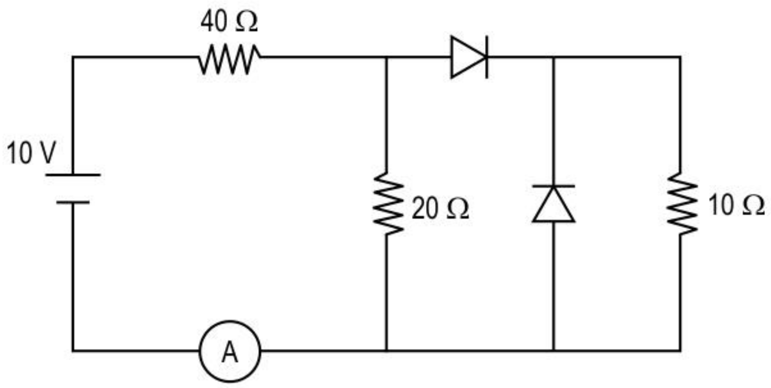
<tr><td>Q.192</td><td>

A 10V battery is attached to 3 resistors and two ideal diodes as shown below. What will be the reading of the ammeter?




A. 1/6 A

B. 1/5 A

C. 1/4 A

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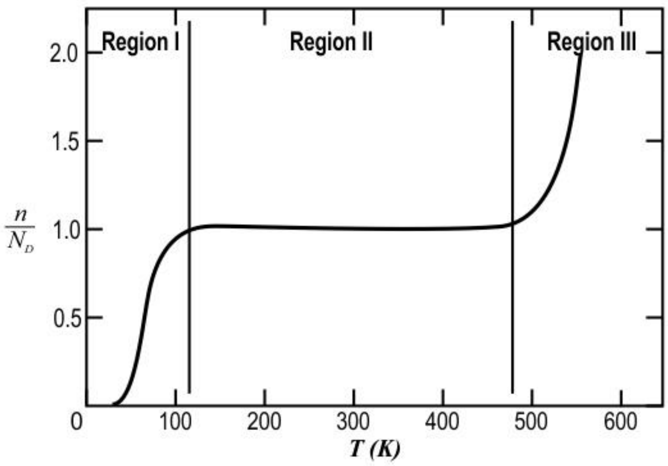
| | | |
|---|---|---|
| | D. 3/14 A | |
| | The graph below represents the variation of $n/N_D$ with temperature for an extrinsic n-type semiconductor. The temperature range indicated on the X-axis is divided into three regions, Regions I, II and III.<br><br><br>$n$: number of majority carriers<br>$N_D$: number of donor electrons<br>Study the graph and answer the following questions. | |
| Q.193 | Which region(s) has the maximum number of unionized donor atoms?<br>A. Only region I<br>B. Only region II<br>C. Only region III<br>D. Only regions I and III | 1 |
| Q.194 | Which of the following relation is definitely TRUE for the semiconductor in region II?<br>($n_e$ - concentration of free electrons; $n_h$ – concentration of holes)<br>A. $n_e > n_h$<br>B. $n_e < n_h$<br>C. $n_e = n_h$<br>D. $n_e > n_h$ and $n_h = 0$ | 1 |
| Q.195 | In which region(s) are thermally generated electrons comparable to donor electrons?<br>A. Only region I<br>B. Only region II<br>C. Only region III<br>D. Only regions 1 and II | 1 |
| Q.196 | An ideal diode and a resistor are connected to an ac source as shown. | 1 |

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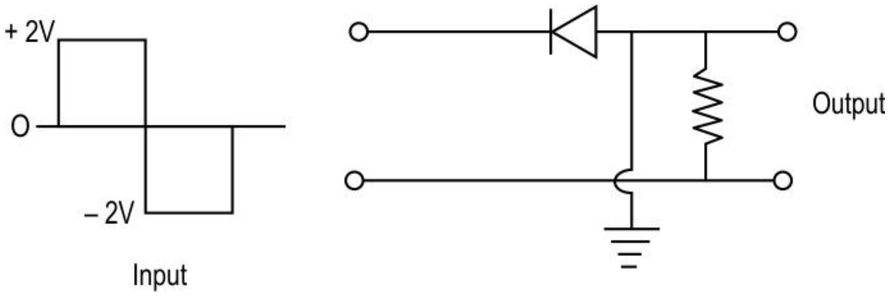


The input voltage is a square wave as shown above. What will be output across the resistor?

A. Only +2 V

B. Only -2 V

C. Either 0 V or +2 V

D. Either 0 V or -2 V
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<tr>
<td>Q.197</td>
<td>
An electron with an initial energy of 0.9eV diffuses from the n-side to the p-side of a diode whose potential barrier is 0.7eV. What is the energy of the electron when it just diffuses from the n-side to the p-side?

A. 1.5eV

B. 0.9eV

C. 0.7eV

D. 0.2eV
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<td>1</td>
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<tr>
<td colspan="3">Free Response Questions/Subjective Questions</td>
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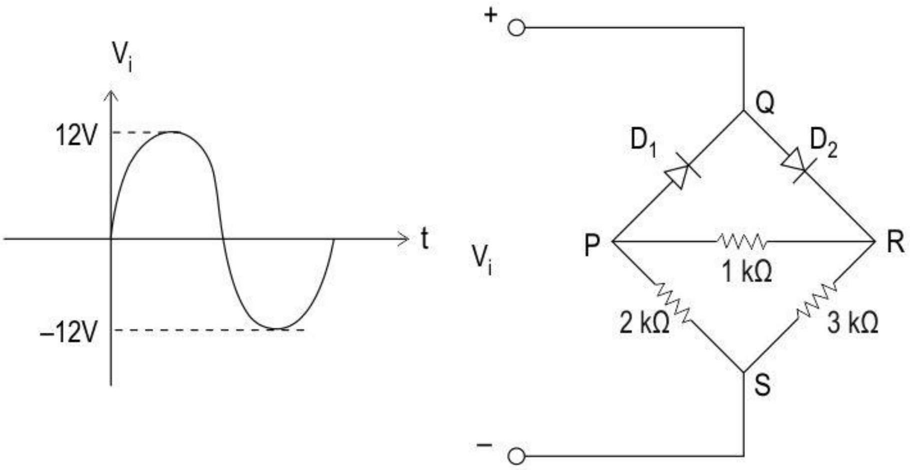
<tr>
<td>Q.198</td>
<td>
A sinusoidal input voltage $V_i$ is applied across a network of 2 ideal diodes and the 3 resistors as shown below.




Study the given network carefully. Considering the period when the positive half of the input voltage $V_i$ is fed into the network, answer the following questions:

(a) Identify which of the diodes would be conducting.
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<td>3</td>
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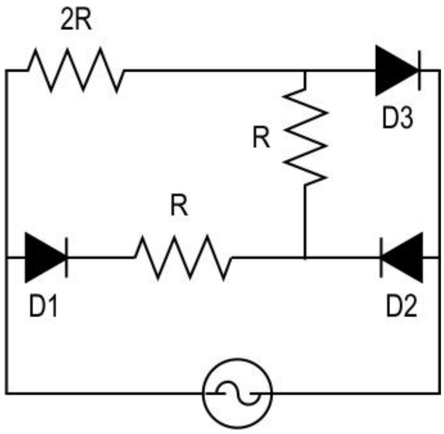
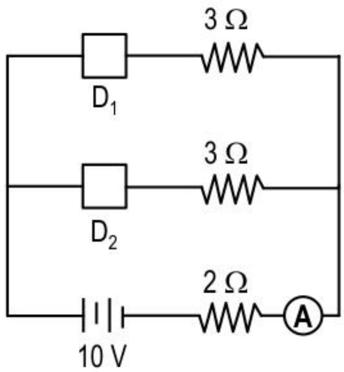
| | (b) Redraw an equivalent circuit diagram to show the flow of current and voltage drops across each of the circuit elements. Consider that ideal diodes offer zero resistance when forward-biased & infinite resistance when reverse-biased.<br><br>(c) Determine the output voltage $V_o$ across 1 kΩ, 2 kΩ and 3 kΩ respectively when the input voltage $V_{i,max}$ = 12V. | |
| Q.199 | A germanium sample at T = 300 K is doped with pentavalent impurity. If the concentration of the pentavalent impurity is 12 x $10^{17}$ $cm^{-3}$ , calculate the number of electrons and holes.<br><br>Assume, complete ionisation of the impurity atom. Given, intrinsic carrier concentration = 2.4 x $10^{13}$ $cm^{-3}$. | 2 |
| Q.200 | The image below shows a circuit with three diodes and three resistors connected to an AC source with an rms voltage V.<br><br><br>What is the average power delivered over one full cycle of AC in the above circuit? Show your calculations and arrive at the final answer in terms of V and R. (*Assume the diode is ideal.*) | 5 |
| Q.201 | $D_1$ and $D_2$ represent the position of two ideal diodes that are connected in an electric circuit.<br><br><br>If the ammeter reading is 2A, then with the help of diagram(s) show the possible orientation of $D_1$ and $D_2$. Explain. | 2 |
| Q.202 | The hole and electron concentration in the intrinsic semiconductor of germanium at room temperature is 2 x $10^{18}$ $m^{-3}$. After doping with an element | 2 |

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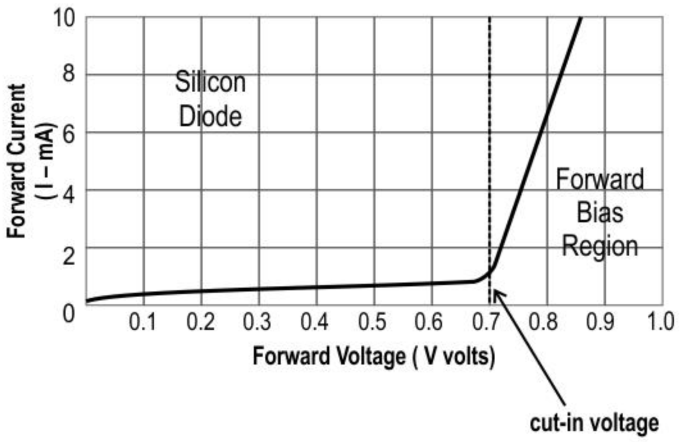
| | Q, the concentration of electrons in the doped semiconductor becomes 6 x $10^{22}m^{-3}$. The concentration of germanium atoms is 6 x $10^{30}m^{-3}$.<br>(a) Is Q trivalent or pentavalent element? Give reason.<br>(b) What is the ratio of atoms of element Q and germanium in the doped semiconductor? | |
| Q.203 | When a p-n junction is forward-biased and the voltage supplied exceeds the potential barrier the diffusion current increases exponentially as the number of holes diffusing into the n-region increases. Will the concentration of the holes become equal in p-region and n-region after some time and diffusion current become zero? Give a reason for your answer. | 2 |
| Q.204 | Shown below is the V-I characteristics curve for a forward-biased Si diode.<br><br><br>A Si diode along with a resistor R is connected in series to a battery of 2 V. If the value of R is 1000 Ω, will the diode now operate above its cut-in voltage? Justify your answer by showing the necessary mathematical calculations. | 2 |
| Q.205 | A diode is connected in series with a 3 V battery and a 30 Ω resistor. A drift current of 10 µA flows through the diode.<br>(a) What is the potential drop across the diode?<br>(b) Is the diode forward-biased or reverse-biased? Draw a circuit diagram to represent the above connections. | 3 |
| | Wireless charging of smartphones makes use of two coils, the primary coil present in wireless chargers and the secondary coil present in smartphones. The energy is transferred from one coil to the other during the charging of the phone. Together, these two coils work like an electrical transformer. The output of the secondary coil is fed into a full wave rectifier which is connected to the battery of the smartphone. A simplified circuit diagram of this arrangement is shown in the image below. | |

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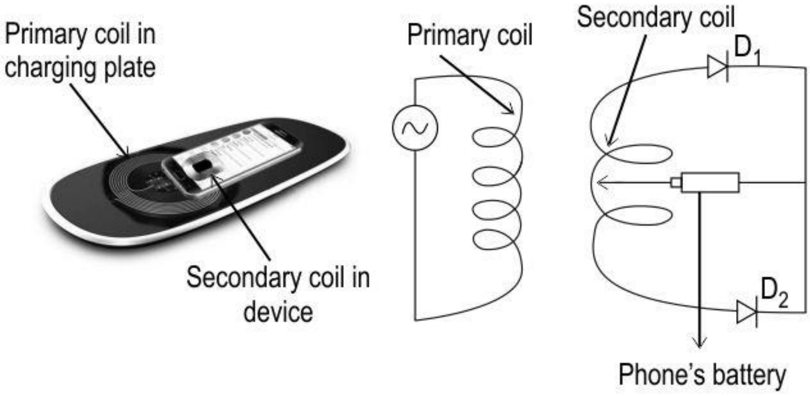
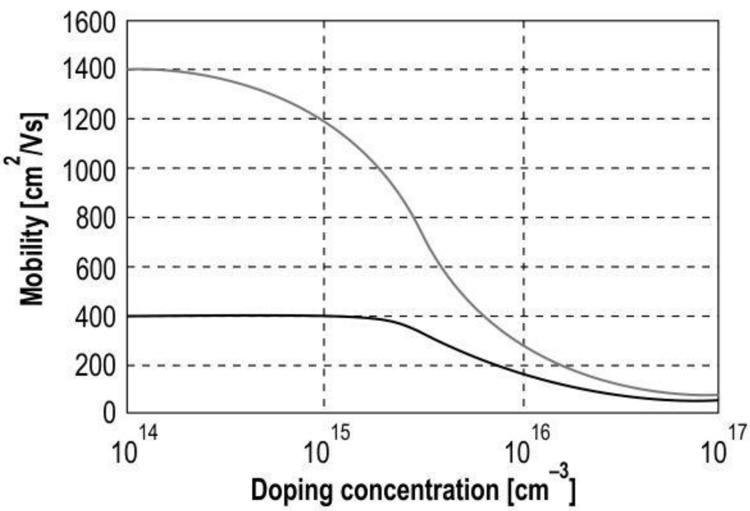
| |  | |
| Q.206 | If the power rating of the wireless charger is 220V-10W and the current induced in the secondary coil is 1.25 A, then calculate the peak voltage which acts as an input to the full wave rectifier circuit. Assume the efficiency of the wireless charger is 70%. | 2 |
| Q.207 | How will the charging of the phone be affected if the phone's battery is directly connected to the output of the secondary coil? Give reason. | 2 |
| Q.208 | If the frequency of the AC input fed to the primary coil is 50Hz, then what is the frequency fed to the phone's battery? Give a reason. | 1 |
| Q.209 | The graph below shows the variation in the mobility of electrons and holes for a Si semiconductor with doping concentration at 300 K.<br><br>The pentavalent doping concentration is $10^{15}$ $cm^{-3}$ and the concentration of intrinsic charge carriers at 300 K is about $10^{10}$ $cm^{-3}$.<br>(a) Find the concentration of majority and minority charge carriers.<br>(b) What is the conductivity of silicon at 300 K? *(Calculate conductivity assuming majority charge carriers only.)*<br>The magnitude charge on an electron/hole is 1.6 x $10^{-19}$ C. Assume complete dopant ionization. | 3 |
| Q.210 | In a representation of energy band diagram of a material X, the energy band that includes the energy levels of the valence electrons is the valence band, $E_v$ | 4 |

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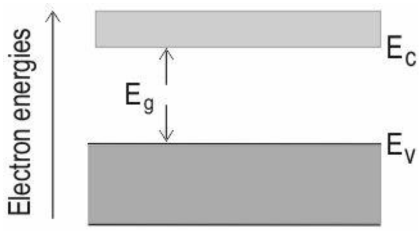
| | whereas the energy band above the valence band is the conduction band, $E_c$. The gap between the conduction and the valence band is represented by the energy gap, $E_g$. For the given sample material, the energy gap, $E_g$ is about 2.8 eV. If the given sample material has N atoms with 'p' number of valence electrons in each atom, then there would be a total of pN, the total number of electrons in its valance band.<br><br><br>(a) Identify the nature of the sample material X.<br>What happens to the electrons in the valence energy band at a temperature, say 40 $^{o}$C, that is, slightly above the room temperature?<br>If $N_e$ are the number of electrons in the conduction band at a given temperature of the material X and $v_d$ is their corresponding drift speed, comment what happens to these two parameters upon the increase in temperature of the material X? Explain.<br>(b) With the increase in the temperature of material X, both the number of charge carriers as well the extent of thermal vibrations in the lattice increase. Is the temperature coefficient of resistivity of material X - Negative, Zero OR positive? Give reason for your answer.<br>(c) Represent energy band diagram of a material with $E_g$ more than that of given material X<br>OR<br>Represent energy band diagram of a material with $E_g \leq 0$ | |
| Q.211 | In a forward biased, ideal pn diode, the applied forward potential is opposite to the potential barrier of the depletion region. A small forward voltage is sufficient to overcome the potential barrier. Once eliminated, the junction resistance is reduced to zero and an ideal pn junction has zero ohmic potential drop across itself. The voltage at which the current starts to increase rapidly is called threshold voltage or cut in voltage or knee voltage of the pn diode. If the diode voltage is more than knee voltage, it conducts easily otherwise it conducts poorly. For a silicon diode, $V_{(threshold)} = 0.7$ V<br>a. In the circuit given here, determine the voltage across an ideal silicon diode D and resistor R and the current through the diode and resistor, if E = 3 V and R = 2 k-ohm. | 4 |

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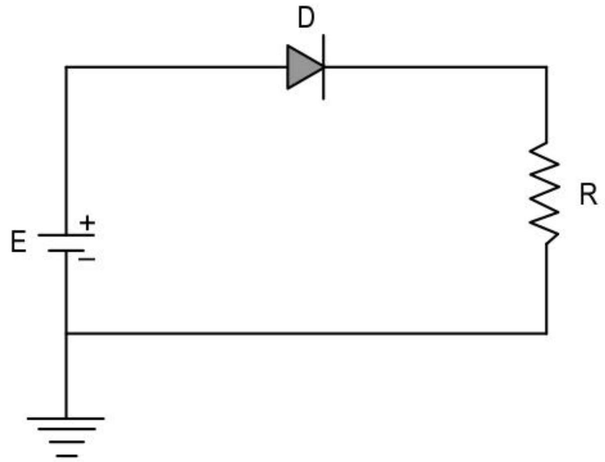
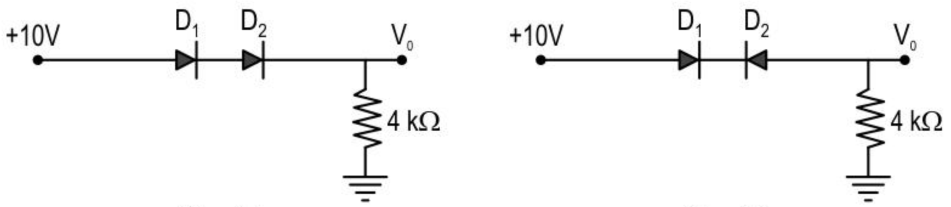
| | <br><br>b. How will the values in part (a) change in case E is made 0.3 V?<br>OR<br>How will the values in part (a) change in case the terminals of E are reversed? | |
| Q.212 | The threshold voltage for diodes $D_1$ and $D_2$ are 0.3 V and 0.7 V respectively.<br><br><br>Circuit I Circuit II<br>In circuit I, both the diodes $D_1$ and $D_2$ are forward biased. In circuit II, $D_1$ is forward biased whereas $D_2$ is reverse biased. Determine current through the diodes in series, $I_D$ and voltage $V_o$ in each of the two given circuits. | 2 |
| Q.213 | A p-n junction diode has a depletion layer of thickness 500 nm and an electric field 16 x $10^5$ V/m.<br>a. Find the barrier potential created.<br>b. Determine the minimum kinetic energy (in eV) that the conduction electrons must have so that they can diffuse from n-side onto p-side, in case of:<br>i. the junction is unbiased<br>ii. the junction is forward biased at 0.5 V<br>iii. the junction is reverse biased at 0.5 V | 2 |
| Q.214 | A non-ideal diode causes a voltage drop of 0.2 V when in forward bias. The diode burns out if the current through it exceeds 8 mA through it.<br>In which of the following instances will this diode run the risk of burning out? Show the working.<br>a. A battery of 4.2 V and resistor of 1 k-ohm connected in series to the diode.<br>b. A battery of 6.2 V and a resistor of 0.6 k-ohm connected in series to the diode. | 3 |

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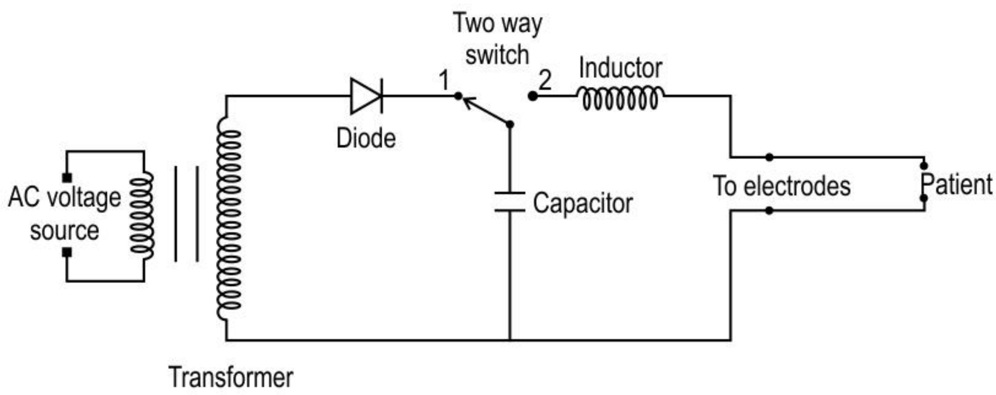
| Q.215 | Almost a constant electric current of 20 μA flows through a given pn junction diode in reverse bias. The current becomes 4 times in case the pn junction diode is forward biased.<br>Determine the diffusion current that flows through the given diode in case it is:<br>a. unbiased<br>b. reverse biased<br>c. forward biased | 2 |
| Q.216 | A certain biasing voltage is applied across the pn junction with an initial potential barrier of $V_o$. The holes approach the pn junction with a non-zero initial kinetic energy from either p or the n- side depending upon the nature of biasing applied.<br>a. If the holes approach the pn junction from p-side,<br>i. What type of biasing must have been applied across the pn junction?<br>ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer.<br>b. If the holes approach the pn junction from n-side,<br>i. What type of biasing must have been applied across the pn junction?<br>ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer. | 3 |
| | Defibrillators are devices that deliver a high dose of electric current to the human heart to restore a normal heartbeat. Defibrillation can be a life-saver for someone in cardiac arrest. To deliver a high dose of electric current, a capacitor is used to store a large quantity of charge. The capacitor then delivers this charge to the human heart in a very short time interval.<br>The image below shows a simplified defibrillator circuit.<br> | |
| Q.217 | (a) Identify the type of transformer used in the circuit and its purpose.<br>(b) What happens when the switch is in position 1 and position 2? | 2 |
| Q.218 | (a) Why is a diode used in the circuit?<br>(b) How will the device be affected if the diode is NOT included in the circuit? | 2 |

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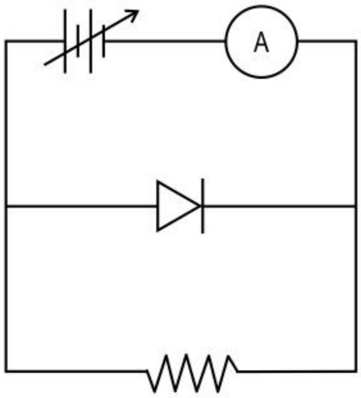
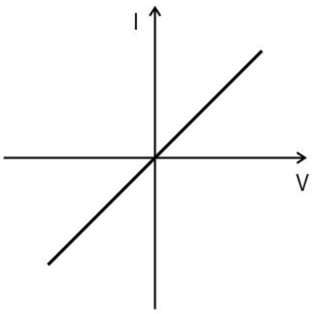
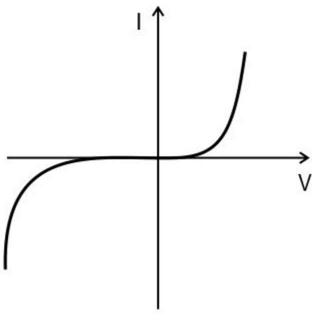
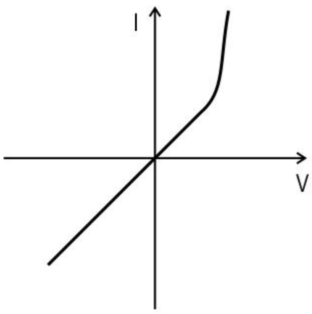
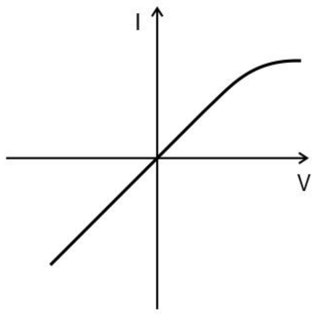
| Q.219 | (a) If the capacitor has a capacitance of 40 μF, charged to 2500 V, what is the energy stored in the capacitor?<br>(b) If 60% of this energy is passed through the patient in a pulse of about 3 ms, how much electrical power is delivered to the patient?<br>(c) Using the power calculated in part(b), calculate the current flowing from the capacitor plates to the patient's heart.<br>(d) What is the resistance of the path? *(The path of current from the capacitor plates through the patient's heart.)* | 4 |
| Q.220 | A diode and a resistor are connected in parallel to a variable DC power supply. An ammeter is connected to measure the current in the circuit.<br><br>Which of the following graphs correctly shows how the ammeter reading (I) varies with the voltage (V) supplied by the power supply?<br><br>A<br><br>B<br><br>C<br><br>D<br>A. A | 1 |

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| | B. B<br>C. C<br>D. D | |

## Answer key and Marking Scheme

| Q.No | Answers | Marks |
|---|---|---|
| Q.188 | A. Both assertion and reason are true and reason is the correct explanation for assertion. | 1 |
| Q.189 | D. Assertion is false but the reason is true. | 1 |
| Q.190 | A. Diffusion current is equal to drift current | 1 |
| Q.191 | D. D | 1 |
| Q.192 | D. 3/14 A | 1 |
| Q.193 | A. Only region I | 1 |
| Q.194 | A. $n_e > n_h$ | 1 |
| Q.195 | C. Only region III | 1 |
| Q.196 | D. Either 0 V or -2 V | 1 |
| Q.197 | B. 0.9eV | 1 |
| Q.198 | (a) Only $D_2$ will be conducting<br>[0.5 mark for correct statement]<br>(b) D1 will offer infinite resistance (open circuit). D2 will offer zero resistance (forward biased)<br>Equivalent circuit will be : | 3 |

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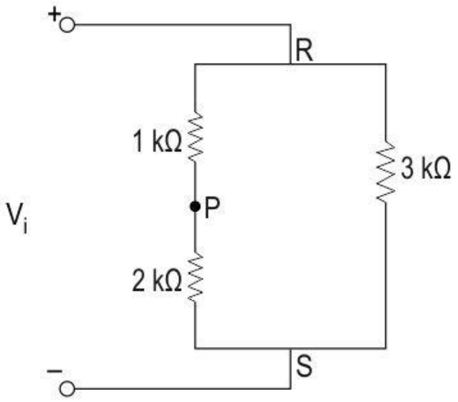
| | <br><br>[1 mark for the correct layout of the resistors in the equivalent network]<br>(c)<br>Voltage across R and S = 12 V<br>$V_1 + V_2 = 12$<br>(here $V_1$ is p.d across 1 k-ohm and $V_2$ is p.d across 2 k-ohm)<br>Also<br>$V_1/V_2 = R_1/R_2 = 1/2$<br>$2V_1 = V_2$<br>Substituting and solving,<br>$V_1 = 4$ V<br>$V_2 = 8$ V<br>These will be output voltages across 1kΩ and 2kΩ respectively.<br>The output voltage across 3 kW, will be same as that of $V_i$ that is, 12 V.<br>[0.5 mark for each correct voltage value across the resistors] | |
| Q.199 | Intrinsic carrier concentration $n_i$= 2.4 x $10^{13}$ $cm^{-3}$<br>Donor concentration $N_D$ = 12 x $10^{17}$ $cm^{-3}$<br>Number of electrons = 12 x $10^{17}$ $cm^{-3}$ (0.5 marks)<br>Number of holes = $n_i^2/N_D$ (0.5 marks)<br>Number of holes = $(2.4 \times 10^{13})^2/(12 \times 10^{17}) = 0.48 \times 10^9$ $cm^{-3}$ (1 mark) | 2 |
| Q.200 | During the positive half cycle, diodes D1 and D3 conduct while D2 does not. The circuit can be redrawn as follows: | 5 |

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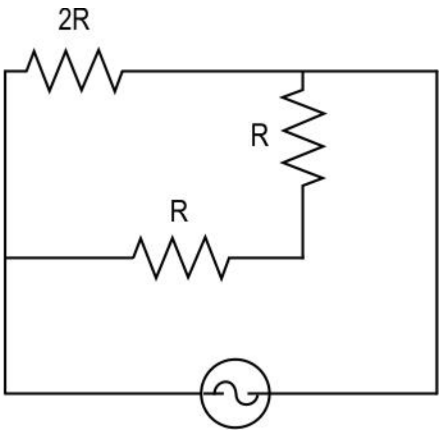
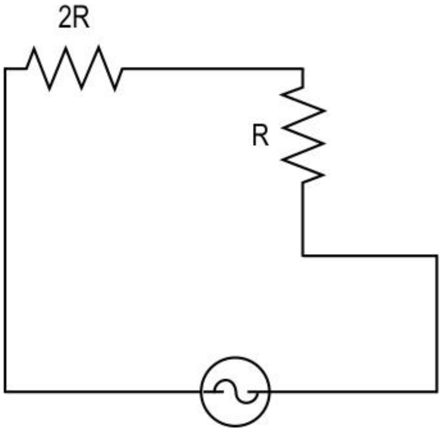
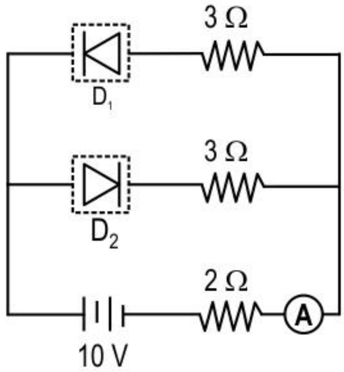
| | <br><br>Total resistance = R (1 mark)<br>Power delivered = $1/2(V^2/R)$ (0.5 marks)<br>During the negative half cycle, diodes D1 and D3 do not conduct while D2 conducts. The circuit can be redrawn as follows:<br><br><br>Total resistance = 3R (1 mark)<br>Power delivered = $1/2(V^2/3R)$ (0.5 marks)<br>Total power delivered = $1/2(V^2/R) + 1/2(V^2/3R) = 2V^2/3R$ (1 mark) | |
| Q.201 | I = 2 A<br>this implies that the total resistance of the circuit is 10/2 = 5 Ω. This is possible when one of the diodes is forward-biased and the other is reverse-biased. (1 mark)<br><br><br>**Possible orientation 1** | 2 |

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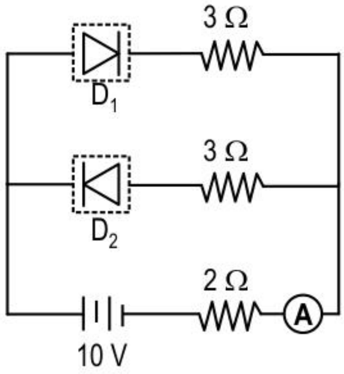
| | <br>**Possible orientation 2**<br>(*1 mark to be allocated only if both diagrams are drawn*) | |
| Q.202 | (a) Since the concentration of electrons increases on doping, it makes germanium an n-type semiconductor.<br>Hence, Q is a pentavalent element. ( 1 mark)<br>(b) Doped semiconductor is n-type. One electron is provided by 1 donor atom, Q.<br>Concentration of Q atoms = $6 \times 10^{22}$ $m^{-3}$<br>Ratio of Q atoms and germanium in doped semiconductor = $(6 \times 10^{22})/(6 \times 10^{30})$ = $1 : 10^8$ (1 mark) | 2 |
| Q.203 | The concentration of the holes never becomes equal in the p-region and n-region and hence diffusion current does not become zero. (1 mark)<br>This is because as the holes diffuse into the n-region they recombine with the electrons. Hence, the decrease in the concentration of holes from the p-region to the n-region is maintained by the recombination of holes and electrons. (1 mark) | 2 |
| Q.204 | We shall find the maximum value of R for which the diode operates at a voltage just above its cut-in voltage.<br>Since the diode and resistor are connected in series we get<br>$V = V_R + V_D$<br>$V_R = 2 - 0.7 = 1.3$ V (0.5 marks)<br>At cut-in voltage the current through the diode is 1mA<br>$\therefore R_{max} = V_R/I$<br>$R_{max} = 1.3/1 \times 10^{-3} = 1.3 \times 1000 = 1300\ \Omega$ (1 mark)<br>Hence, at 1000 Ω the diode will operate above its cut-in voltage. (0.5 marks) | 2 |
| Q.205 | (a) The potential drop across the 30 Ω resistor = $30 \times 10 \times 10^{-6}$ V = $300 \times 10^{-6}$ = 0.0003 V (0.5 marks)<br>Potential drop across the diode = 3 - 0.0003 = 2.9997 V (0.5 marks)<br>(b) The diode is reverse-biased in the circuit (1 mark) | 3 |

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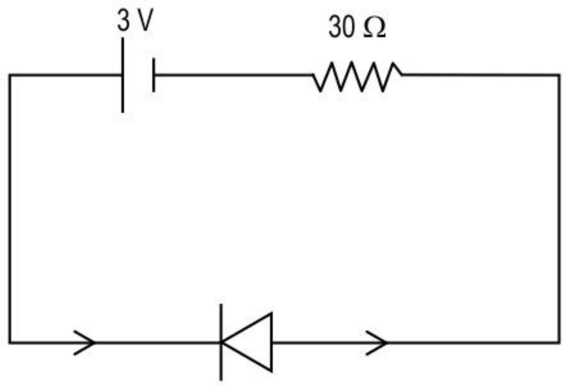
| | <br>(1 mark for circuit diagram.) | |
| Q.206 | Efficiency = $P_{output}$ / $P_{input}$ (0.5 marks)<br>$P_{output}$ = (70 × 10) /100 = 7 W<br>For secondary coil<br>P = VI (0.5 marks)<br>V = 7/1.25 = 5.6 V (0.5 marks)<br>$V_{rms}$ = 5.6 V<br>$V_{peak}$ = 5.6 × √2 = 7.9 V (0.5 marks) | 2 |
| Q.207 | The phone's battery will not get charged. ( 1 mark)<br>The output of the secondary coil is ac.<br>Thus the battery will charge during one half of the ac cycle and discharge during the next cycle. (1 mark) | 2 |
| Q.208 | The full wave rectifier rectifies both the half cycles of the AC input. (0.5 marks)<br>Hence, the frequency fed to the phone's battery is 100 Hz. (0.5 marks) | 1 |
| Q.209 | (a) Intrinsic concentration = $n_i = 10^{10}\ cm^{-3}$<br>Since the doped atom is pentavalent, majority charge carriers are electrons.<br>Concentration of electrons (majority charge carriers) $n_e$ = doping concentration = $10^{15}\ cm^{-3}$ (0.5 marks)<br>Concentration of holes (minority charge carriers) $n_h = n_i^2/n_e = 10^{20}/10^{15} = 10^5\ cm^{-3}$ (0.5 marks)<br>(b) $\sigma = \mu n_e e$ (0.5 mark)<br>Since the concentration of holes is much less than the concentration of electrons, conductivity can be calculated assuming only electron concentration.<br>$\mu = 1200\ cm^2/Vs$ for the given doping concentration of $10^{15}\ cm^{-3}$. (0.5 mark)<br>$\sigma = \mu n_e e$<br>$\sigma = 1200 \times 10^{15} \times 1.6 \times 10^{-19}$<br>$\sigma = 1920 \times 10^{-4}$ S/cm (1 mark) | 3 |

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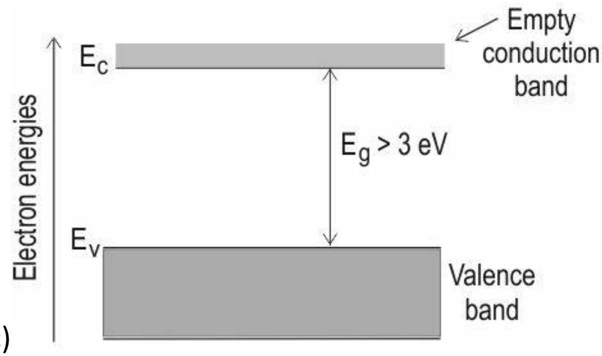
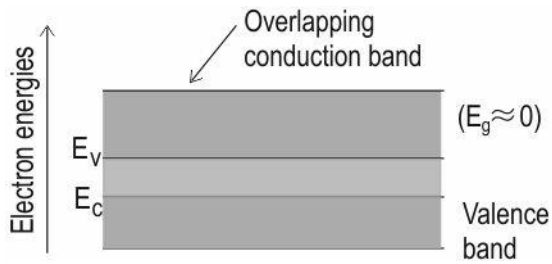
| Q.210 | (a) Semiconductor [0.5 mark]<br>The valence electrons will gain energy equal to or more than $E_g$ and jump from the valence band onto the conduction band.<br>[0.5 mark]<br>With the rise in temperature of the semiconductor, the conductivity increases due to increase in the number of electrons $N_e$ in the conduction band.<br>From the expression, $v_d = 1/N_e eA$ , as $N_e$ increases, the drift speed $v_d$ of the electrons decreases.<br>[0.5 mark for the correct mention and reason of change in $N_e$ and $v_d$]<br>(b) Temperature coefficient of resistivity of material X is Negative.<br>[0.5 mark for the correct answer]<br>The effect of an increase in the number of charge carriers (electrons and holes) exceeds the effect of increased lattice thermal vibrations, hence the resistivity decreases with the rise in temperature of material X.<br>[0.5 mark for the correct explanation]<br>(c)  <br>OR<br> <br>[1 mark for the correct representation of energy and valence band and correct labels of $E_c$, $E_v$ and $E_g$] | 4 |
| Q.211 | a. For E = 3 V and R= 2 k-ohm,<br>The pn diode is forward biased.<br>[0.5 mark for the correct identification of the bias of the pn]<br>$V_D = 0.7$ V<br>[0.5 mark for the correct value of $V_D$]<br>$V_R = 3 - 0.7 = 2.3$ V | 4 |

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| | [0.5 mark for the correct value of VR]<br>$I_D = I_R = V_R/R = 2.3/2 \times 10^{-3} = 1.15$ mA<br>[0.5 mark for the correct values of $I_D$ and $I_R$ ]<br>b. For E = 0.3 V and R= 2 k-ohm,<br>The pn diode doesn't reach its threshold voltage value.<br>[0.5 mark for the correct identification of the bias of the pn]<br>So $V_D = 0.3$ V, so the pn diode is in open condition. It will not conduct.<br>[0.5 mark for the correct value of $V_D$]<br>$I_D = 0 = I_R$<br>[0.5 mark for the correct values of $I_D$ and $I_R$ ]<br>$V_R = 0$<br>[0.5 mark for the correct value of $V_R$]<br>OR<br>If the terminals of the applied E are reversed, at E = 3 V,<br>the pn diode is in reverse bias.<br>[0.5 mark for the correct identification of the bias of the pn]<br>So $I_D = 0 = I_R$<br>[0.5 mark for the correct values of $I_D$ and $I_R$ ]<br>$V_R = 0$<br>[0.5 mark for the correct value of $V_R$]<br>$V_D = 3V$<br>(voltage across the pn diode can be non-zero in open circuit condition)<br>[0.5 mark for the correct value of $V_D$] | |
| Q.212 | In circuit I :<br>$V_{D1} = 0.3$ V<br>$V_{D2} = 0.7$ V<br>So $V_o = 10 - V_{D1} - V_{D2} = 10 - 0.3 – 0.7 = 9$ V<br>$I_D = V_o/R = 9/(4 \times 10^{-3}) = 2.25$ mA<br>[0.5 mark for correct value of $V_o$ and $I_D$]<br>In circuit II:<br>$D_1$ is forward biased whereas $D_2$ is reverse biased, this means that the overall circuit is open circuit.<br>So $I_D = 0$<br>$V_o = 0$<br>[0.5 mark for correct value of $V_o$ and $I_D$] | 2 |

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| Q.213 | a. Electric field = V/d<br>V = E. d = 16 x $10^5$ x 500 x $10^{-9}$ volt = 0.8 volt<br>[0.5 mark for the correct value]<br>b.<br>i. if the junction is unbiased :<br>KE required = eV = 0.8 eV<br>ii. if the junction is forward biased at 0.5 V<br>KE required = (0.8 – 0.5) eV = 0.3 eV<br>iii. if the junction is reverse biased at 0.5 V<br>KE required = (0.8 + 0.5) eV = 1.3 eV<br>[0.5 mark for the correct value of each of the KE values] | 2 |
| Q.214 | a. The given non-ideal diode causes a voltage drop of 0.2 V.<br>So when a battery of 4.2 V and resistor of 1 k-ohm connected in series to the diode, the voltage drop across the resistor will be: 4.2 – 0.2 = 4 V<br>Current through resistor & diode = I = 4/1000 = 0.004 = 4 mA.<br>The diode does not burn out in this case.<br>[1 mark for the correct calculation of current flowing through the diode]<br>[0.5 mark for the correct conclusion]<br>b. When a battery of 6.2 V and resistor of 0.6 k-ohm connected in series to the diode, the voltage drop across the resistor will be: 6.2 – 0.2 = 6 V<br>Current through resistor & diode = I = 6/600 = 0.01 A = 10 mA.<br>The diode will burn out in this case as the current exceeds the max. safe limit of 8 mA.<br>[1 mark for the correct calculation of current flowing through the diode]<br>[0.5 mark for the correct conclusion] | 3 |
| Q.215 | a. Given is the drift current = 20 µA and forward biasing current of 4 x 20 = 80 µA<br>In case of unbiased condition,<br>Diffusion current = drift current = 20µA<br>[0.5 mark for the correct value]<br>b. In case of reverse biased,<br>Diffusion current = 0<br>[0.5 mark for the correct value]<br>c. In case of forward biased,<br>Diffusion current – drift current = Biasing current<br>Diffusion current – 20 = 80 | 2 |

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| | Diffusion current = 100 µA<br>[1 mark for the correct value] | |
| Q.216 | a. i. Forward biasing<br>ii. Decreases.<br>Holes are pushed through the pn junction in the direction opposite to the electric field across the barrier potential of the depletion region.<br>[0.5 mark for each point]<br>b. i. Reverse biasing<br>ii. Increases.<br>Holes are swept through the pn junction in the direction same as the electric field across the barrier potential of the depletion region.<br>[0.5 mark for each point] | 3 |
| Q.217 | (a) Step-up transformer. It is used to increase the output voltage across the secondary coil. ( 1 mark)<br>(b) When the switch is in position 1, the capacitor gets charged and when the switch is in position 2, the capacitor gets discharged. (1 mark) | 2 |
| Q.218 | (a) The diode is used for rectification.<br>OR<br>The diode is used to convert AC to DC.<br>(1 mark)<br>(b) For the device to work properly, the capacitor needs to be fully charged. If the diode is NOT included in the circuit, the capacitor will get continuously charged and discharged and will not be fully charged when needed. (1 mark) | 2 |
| Q.219 | (a) C = 40 µF; V = 2500 V<br>E = CV2/2<br>E = 40 x 10-6 x 2500 x 2500 / 2<br>E = 125 J (1 mark)<br>(b) 60% of E = 125 x 60/100 = 75 J (0.5 marks)<br>Power = E/t<br>Power = 75/(3 x 10-3) = 25000 W ( 0.5 marks)<br>(c) Power = 25000 W<br>V = 2500 V<br>I = P/V = 25000/2500 = 10 A (1 mark)<br>(Please note this is a really high current which can be fatal in general. But in the case of a defibrillator, the current passes for an extremely small interval of time and can help save a person.) | 4 |

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| | (d) R = V/I = 2500/10 = 250 ohm (1 mark) | |
| Q.220 | C. C | 1 |