Physics · Introduction to Modern Physics · Modern Electronics

Semiconductors

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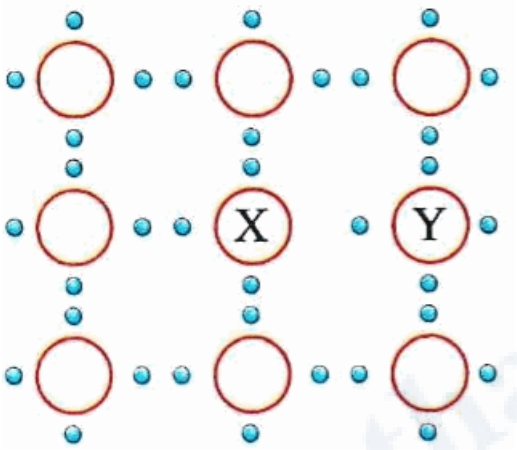
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Multiple choice questions — 64 questions

1 A pure silicon or germanium crystal becomes a perfect electric insulator at a temperature of .....

(A) 0°C (B) 273°C (C) −273°C (D) 273 K

2 The opposite figure shows part of a pure silicon crystal at room temperature with an incomplete covalent bond between atom (X) and atom (Y). This is because one of the two electrons of the bond .....



(A) was repelled by the other electron of the bond

(B) gained enough energy from the surroundings to become free

(C) moved to an inner energy level in atom (X)

(D) was gained by atom (Y)

3 A copper strip and a germanium crystal were cooled from 300 K to 200 K. The electric resistance .....

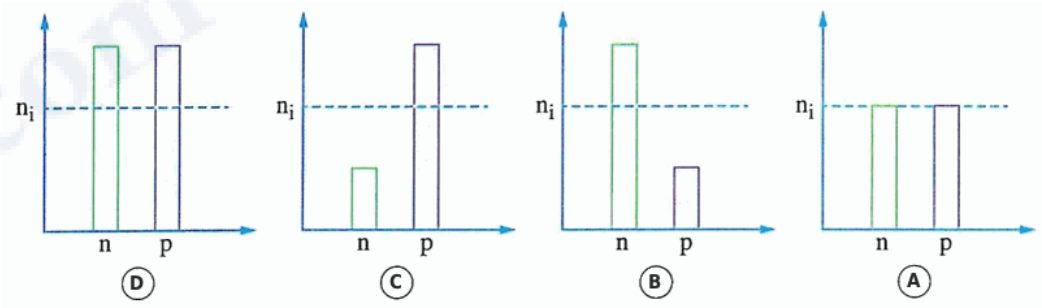
(A) increases for both

(B) decreases for both

(C) increases for the copper strip while it decreases for the germanium crystal

(D) decreases for the copper strip while it increases for the germanium crystal

4 In a pure semiconductor crystal at 25°C, the concentration of free electrons = the concentration of holes = n_i. Which of the following graphs represents the concentration of free electrons (n) and the concentration of holes (p) at 50°C?



5 Two pure silicon crystals A and B are at temperatures t_1 and t_2 respectively (where $t_2 > t_1$). The relation that expresses the concentration of free electrons (n) and the concentration of holes (p) in the two crystals is .....

(A) $n_A + n_B = p_A + p_B$
(B) $n_A + p_A = n_B + p_B$
(C) $n_A \times p_A = n_B \times p_B$
(D) $n_B - n_A > p_B - p_A$

6 Three pure silicon crystals x, y, z: crystal (x) is in thermal dynamic equilibrium, the temperature of crystal (y) is raised and the temperature of crystal (z) is lowered. Which of the crystals:

(1) contain positive charge carriers?

(A) Crystal (x) (B) Crystal (y) (C) Crystal (z) (D) All three crystals

7 Three pure silicon crystals x, y, z: crystal (x) is in thermal dynamic equilibrium, the temperature of crystal (y) is raised and the temperature of crystal (z) is lowered. Which of the crystals:

(2) have an increasing concentration of charge carriers?

(A) Crystal (x) (B) Crystal (y) (C) Crystal (z) (D) All three crystals

8 Three pure silicon crystals x, y, z: crystal (x) is in thermal dynamic equilibrium, the temperature of crystal (y) is raised and the temperature of crystal (z) is lowered. Which of the crystals:

(3) have an increasing resistivity?

(A) Crystal (x) (B) Crystal (y) (C) Crystal (z) (D) All three crystals

9 The element used to dope a silicon crystal to turn it into an n-type semiconductor is .....

(A) boron (trivalent)
(B) antimony (pentavalent)
(C) nickel (divalent)
(D) aluminium (trivalent)

10 When the proportion of trivalent impurities in a p-type semiconductor crystal is increased, the electric conductivity of the crystal .....

(A) increases
(B) decreases
(C) does not change
(D) cannot be determined

11 A p-type semiconductor crystal has a hole concentration X. When pentavalent impurities of concentration $1/2$ X are added to the crystal, its electric conductivity .....

(A) decreases
(B) stays unchanged
(C) increases
(D) cannot be determined

12 The majority charge carriers in a p-type crystal are .....

(A) free electrons (B) holes (C) positive ions (D) negative ions

13 A silicon crystal is doped with atoms of a pentavalent element. At equilibrium, the ratio between the concentration of holes and the concentration of free electrons, respectively, is .....

(A) less than one
(B) greater than one
(C) equal to one
(D) the information is not enough to decide

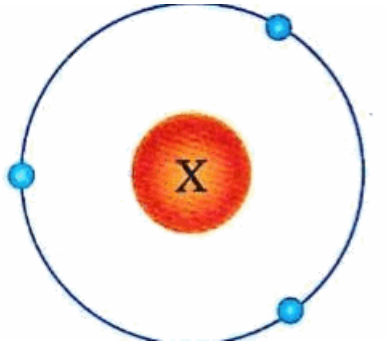
14 An n-type semiconductor crystal is .....

(A) negatively charged
(B) electrically neutral
(C) positively charged
(D) an electric insulator

15 In an impure (extrinsic) semiconductor crystal, if the concentrations of free electrons and holes are n and p respectively, then it is certain that .....

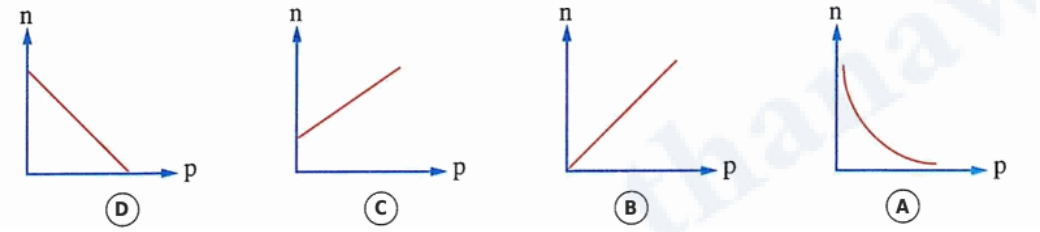
(A) $n > p$ (B) $n < p$ (C) $n = p$ (D) $n \neq p$

16 The opposite figure shows the outermost-level electrons of element $_{49}X$. If a pure semiconductor crystal is doped with atoms of this element, the resulting crystal is .....

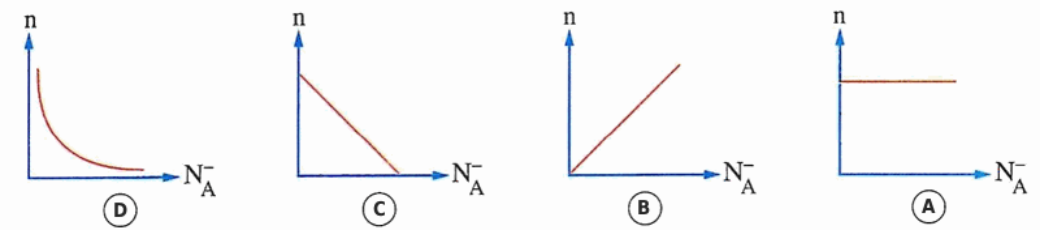


(A) n-type and neutral
(B) p-type and positively charged
(C) p-type and neutral
(D) n-type and negatively charged

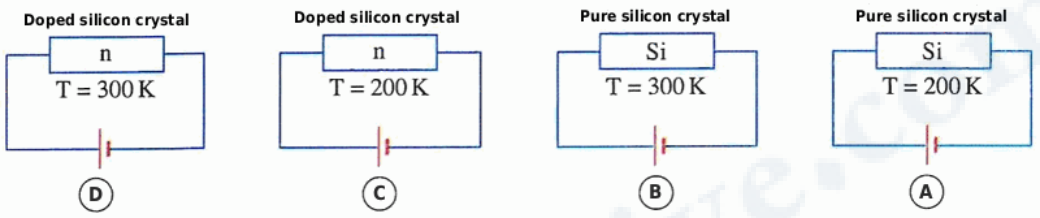
17 The graph that represents the relation between the concentration of free electrons (n) and the concentration of holes (p) in a pure silicon crystal as its temperature is raised is .....



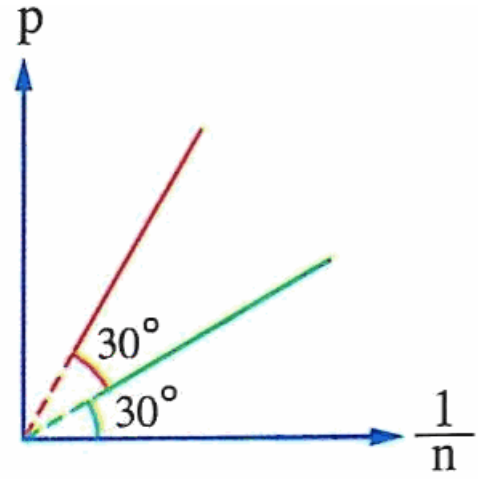
18 Which of the following graphs represents the relation between the concentration of free electrons (n) and the concentration of aluminium ions (N_A^-) in a p-type semiconductor crystal?



19 In which of the following circuits is the electric resistance to the current greatest?



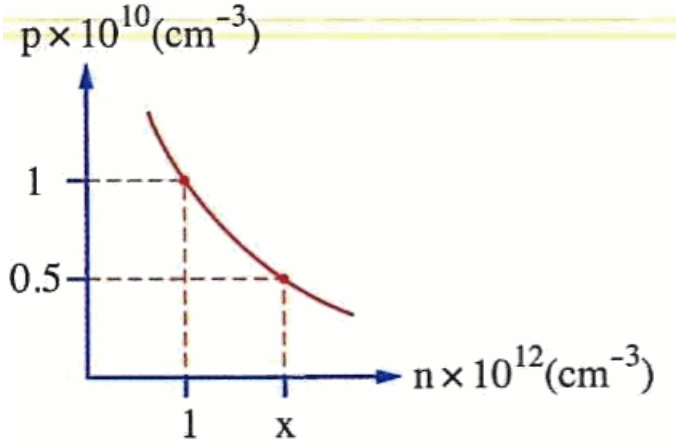
20 Two pure silicon crystals a and b at different temperatures $(t_b < t_a)$ were doped with phosphorus atoms. The opposite graph shows the relation between the hole concentration (p) in the doped crystal and the reciprocal of its free-electron concentration $(1/n)$. The ratio between the hole concentrations in the two pure crystals before doping (p_a/p_b) equals .....



(A) 3 (B) $\sqrt{(3)}$ (C) $1/3$ (D) $1/(\sqrt{(3)})$

21 A pure semiconductor crystal is doped with phosphorus atoms. The opposite graph shows the relation between the concentration of holes (p) and the concentration of free electrons (n) in the crystal:

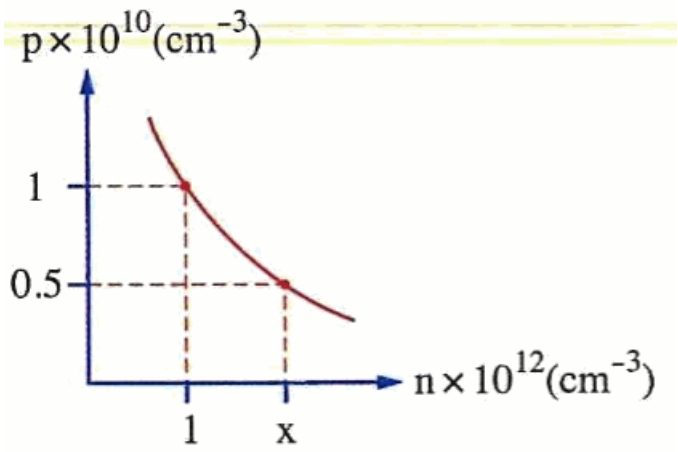
(1) The concentration of free electrons in the pure semiconductor crystal equals .....



(A) $10^{10}\ cm^{-3}$ (B) $10^{11}\ cm^{-3}$ (C) $10^{12}\ cm^{-3}$ (D) $10^{22}\ cm^{-3}$

22 A pure semiconductor crystal is doped with phosphorus atoms. The opposite graph shows the relation between the concentration of holes (p) and the concentration of free electrons (n) in the crystal:

(2) The value of (x) on the graph equals .....



(A) $1.5 \times 10^{12}\ cm^{-3}$ (B) $2 \times 10^{12}\ cm^{-3}$ (C) $2.5 \times 10^{12}\ cm^{-3}$ (D) $3 \times 10^{12}\ cm^{-3}$

23 Three identical pure silicon crystals a, b, c: crystal (b) was doped with aluminium atoms of concentration (X) cm^{-3} and crystal (c) was doped with phosphorus atoms of the same concentration (X) cm^{-3}. If they are at the same temperature, the correct order of the crystals by their free-electron concentration after doping is .....

(A) a = b = c (B) c > b > a (C) a < b = c (D) c > a > b

24 If the concentrations of free electrons and holes in a silicon crystal doped with arsenic impurities are $10^{13}\ cm^{-3}$ and $10^{9}\ cm^{-3}$ respectively, the concentration of each of the free electrons and holes in the pure silicon crystal equals .....

(A) $10^{9}\ cm^{-3}$ (B) $10^{10}\ cm^{-3}$ (C) $10^{11}\ cm^{-3}$ (D) $10^{13}\ cm^{-3}$

25 A semiconductor crystal contains free electrons of concentration $5 \times 10^{13}\ cm^{-3}$ and holes of concentration $8 \times 10^{12}\ cm^{-3}$, so the semiconductor crystal is .....

(A) n-type (B) p-type
(C) positively charged (D) pure

26 Two identical pure silicon crystals x and y have a free-electron (or hole) concentration of 10^{12} cm^{-3}. If crystal x is doped with antimony atoms of concentration 10^{14} cm^{-3} and crystal y with aluminium atoms of concentration 10^{14} cm^{-3}, the ratio between the hole concentrations in the two crystals (p_x/p_y) equals .....

(A) 10^{-2} (B) 10^{-4} (C) 10^{-6} (D) 10^{-8}

27 If the concentration of free electrons (or holes) in a pure silicon crystal is 10^{8} cm^{-3} and aluminium atoms of concentration 10^{10} cm^{-3} are added to it, then the concentrations of holes and free electrons, respectively, when the impurity atoms are fully ionized are .....

(A) holes: 10^{10} cm^{-3}, free electrons: 10^{8} cm^{-3}

(B) holes: 10^{8} cm^{-3}, free electrons: 10^{10} cm^{-3}

(C) holes: 10^{6} cm^{-3}, free electrons: 10^{10} cm^{-3}

(D) holes: 10^{10} cm^{-3}, free electrons: 10^{6} cm^{-3}

28 When a PN junction diode is connected to a battery in reverse bias .....

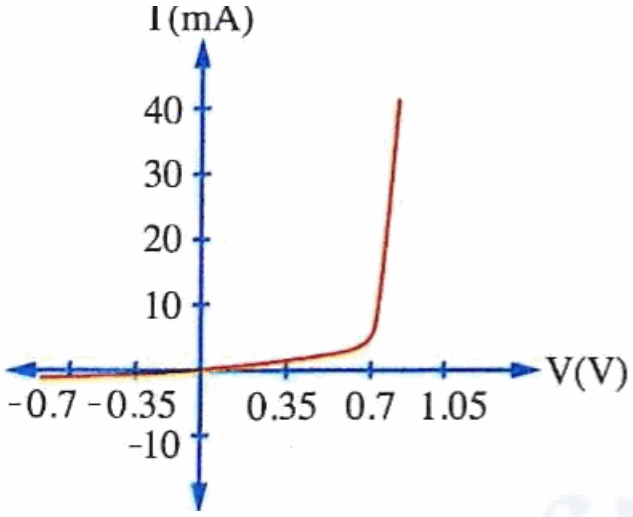
(A) the barrier potential increases and the resistance increases

(B) the barrier potential decreases and the resistance decreases

(C) the barrier potential increases and the resistance decreases

(D) neither the barrier potential nor the resistance changes

29 The opposite graph shows the relation between the current (I) through a PN junction diode and the potential difference (V) across it. The barrier potential of this junction is .....



(A) 1.2 V (B) 0.8 V (C) 0.7 V (D) zero

30 The depletion region in a PN junction diode has a high electric resistance because .....

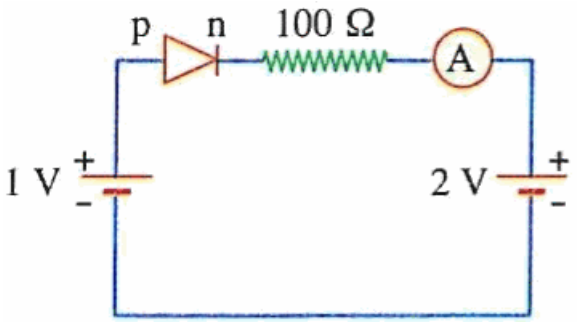
(A) it contains no charge carriers

(B) it contains a large number of charge carriers

(C) it contains free electrons only

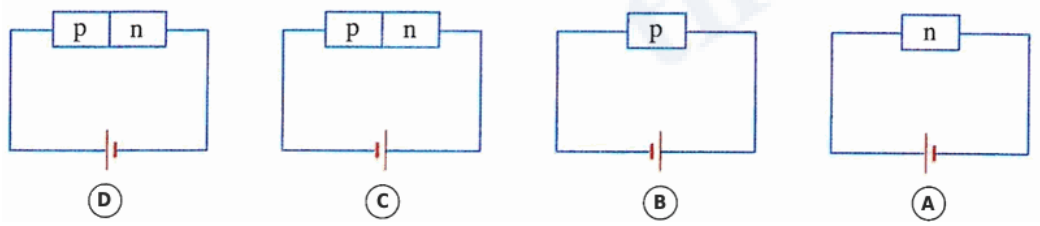
(D) it contains holes only

31 The reading of the ammeter in the circuit shown is .....

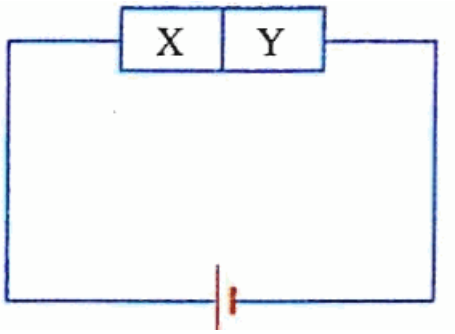


(A) zero (B) 1 mA (C) 10 mA (D) 30 mA

32 In which of the following circuits does no electric current flow?



33 The opposite figure shows a silicon PN junction diode. If region X contains arsenic atoms and region Y contains boron atoms, then .....



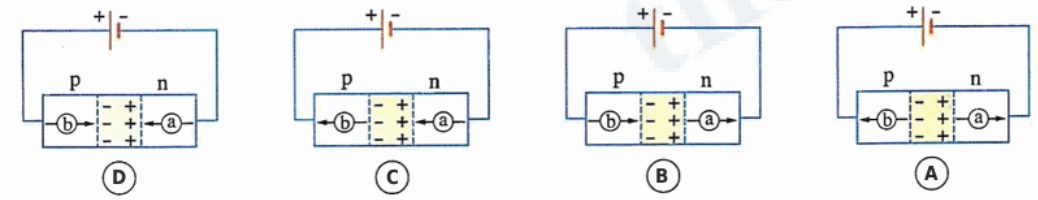
(A) type of region X: p, type of region Y: n, bias: forward

(B) type of region X: n, type of region Y: p, bias: forward

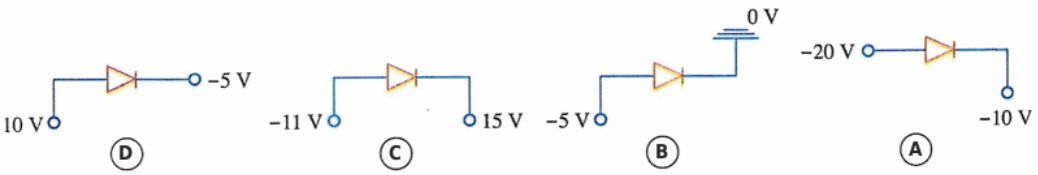
(C) type of region X: p, type of region Y: n, bias: reverse

(D) type of region X: n, type of region Y: p, bias: reverse

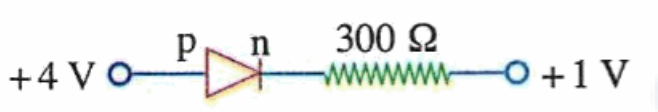
34 If a and b stand for the majority charge carriers in the two regions of the PN junction diode (n and p respectively), which of the following figures shows the directions of their motion in forward bias?



35 The figure that shows a diode connected in forward bias is .....

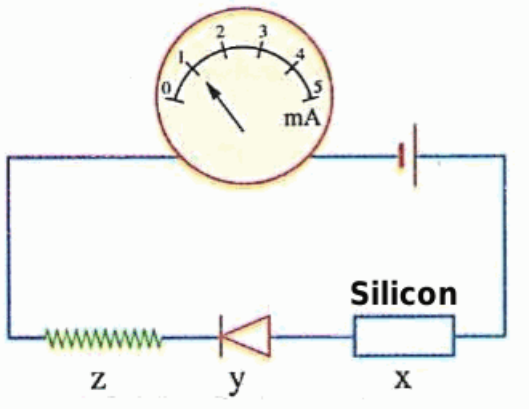


36 The opposite figure shows part of an electric circuit. Taking the resistance of the PN junction diode as negligible in forward bias and infinite in reverse bias, the current flowing is .....



(A) 0 (B) 10^{-2} A (C) 10^{2} A (D) 10^{-3} A

37 In the circuit shown, which of the following increases the reading of the milliammeter?



(A) Reversing the battery poles

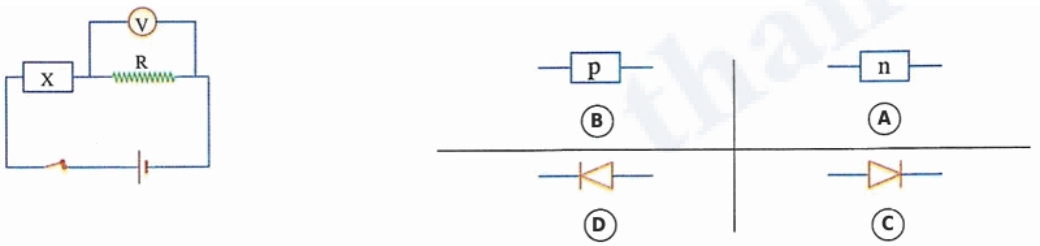
(B) Reversing the position of component y

(C) Raising the temperature of component x

(D) Raising the temperature of component z

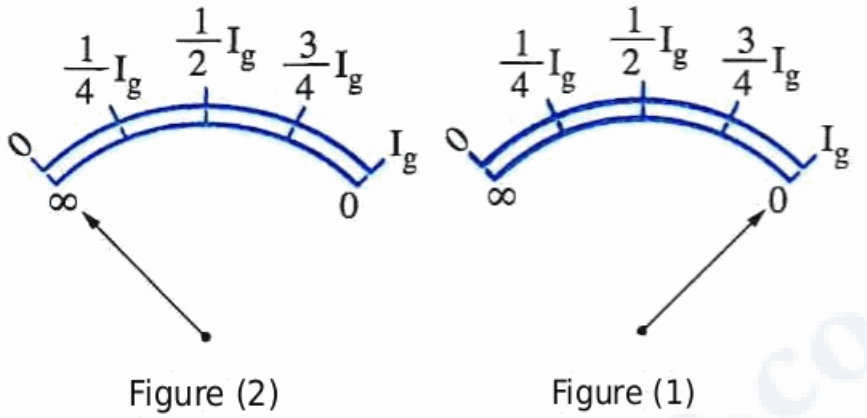
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38 In the opposite circuit, if the voltmeter reads almost zero, then element X is .....



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39 When a component was connected between the terminals of an ohmmeter, the pointer was as in figure (1), and when the component was reversed between the ohmmeter terminals, the pointer was as in figure (2). This component is .....



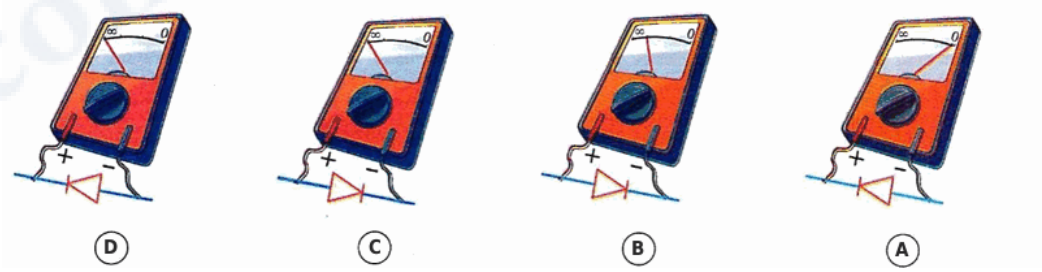
(A) a pure silicon crystal

(B) an n-type silicon crystal

(C) a p-type silicon crystal

(D) a PN junction diode

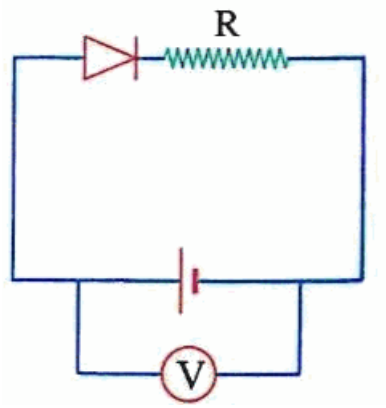
40 An ohmmeter's pointer reads zero on its scale when its terminals are connected together. Given that the resistance of a PN junction diode is negligible in forward bias and infinite in reverse bias, when a diode is connected between the ohmmeter terminals, which of the following figures shows the correct position of its pointer?



41 A PN junction diode can be represented by a resistance of 100 Ω in forward bias and an infinite resistance in reverse bias. The diode was connected to a 5 V potential difference with the p region connected to the positive potential, then reversed so that the p region is connected to the negative potential. The currents through the diode in the two cases, respectively, are .....

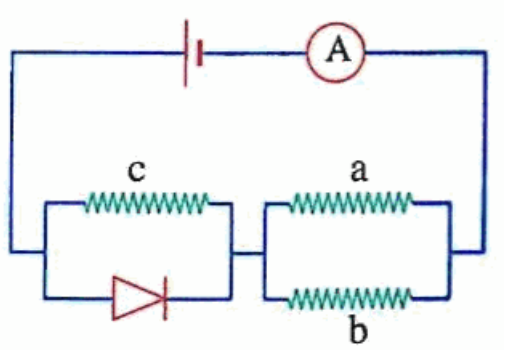
(A) 0, 0 (B) 0.05 A, 0 (C) 0, 0.05 A (D) 0.05 A, 0.05 A

42 In the circuit shown in the opposite figure, the voltmeter reads 1.5 V, the potential difference across the diode is 0.5 V and the electric power consumed in it is 100 mW. The value of resistance R is .....



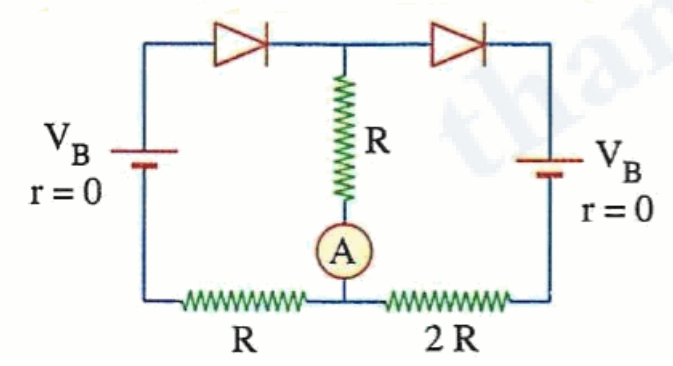
(A) 2.5 Ω (B) 5 Ω (C) 7.5 Ω (D) 10 Ω

43 The circuit in the figure consists of a cell of emf V_B with negligible internal resistance, three identical ohmic resistors (a, b, c) and a diode whose resistance in forward bias equals that of any of the resistors and is infinite in reverse bias. The ratio between the ammeter readings before and after reversing the diode, respectively, is .....



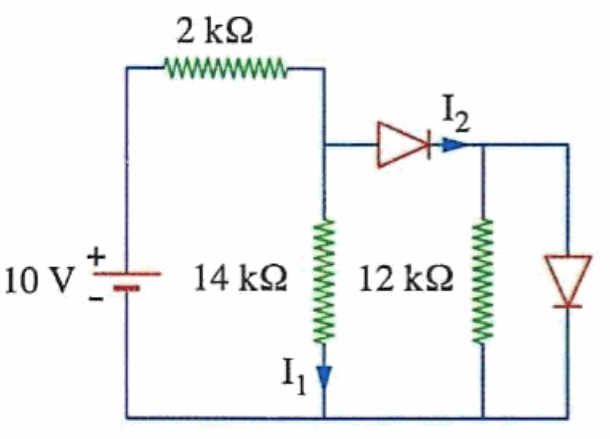
(A) *1/2* (B) *2/1* (C) *2/3* (D) *3/2*

44 In the circuit shown in the figure, if the resistance of the PN junction diode is negligible in forward bias and infinite in reverse bias, the ammeter reading is .....



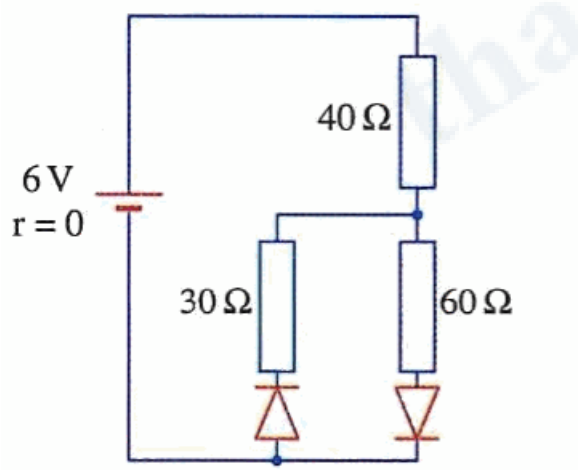
(A) $V_B/3R$ (B) $V_B/2R$ (C) $2V_B/3R$ (D) $3V_B/2R$

45 In the circuit shown in the figure, taking the resistance of the PN junction diode as negligible in forward bias and infinite in reverse bias, the values of I_1 and I_2 respectively are .....



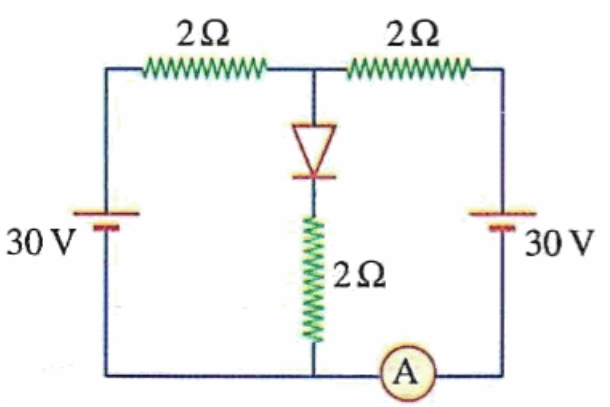
(A) 0, 0 (B) 5 mA, 5 mA (C) 0, 5 mA (D) 5 mA, 0

46 In the opposite figure, neglecting the internal resistance of the source and assuming the resistance of the two PN junction diodes is negligible in forward bias and infinite in reverse bias, the current through the 40 Ω resistor is .....



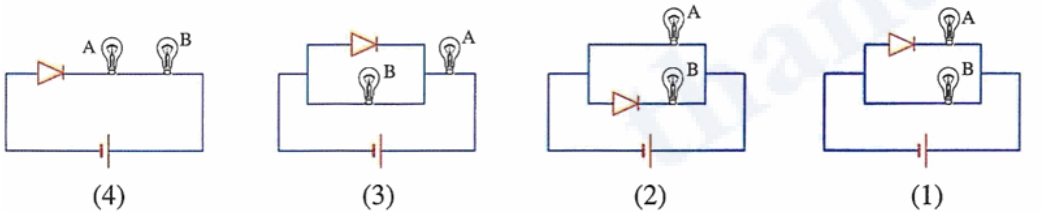
(A) 0 (B) 0.06 A (C) 0.1 A (D) 0.12 A

47 What happens to the reading of ammeter (A) when the PN junction diode in the circuit shown in the opposite figure is reversed?



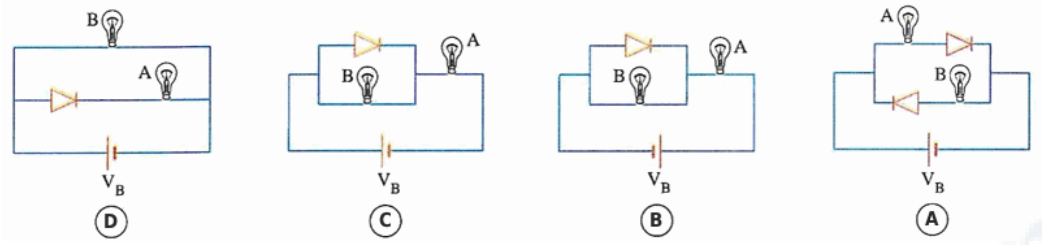
(A) It increases
(B) It decreases
(C) It becomes zero
(D) It does not change

48 Two identical lamps A and B were connected with a PN junction diode and a battery in several ways. In which of the following figures does lamp A light up?

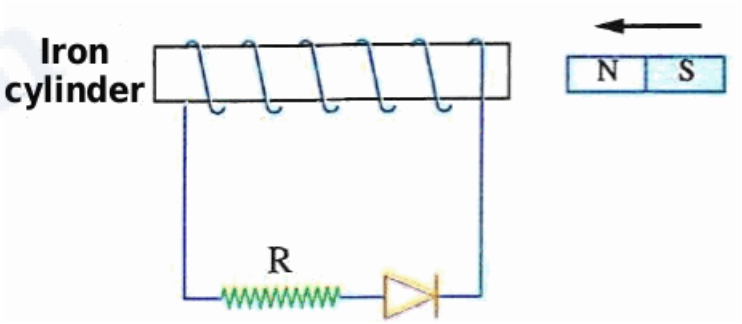


(A) (1), (3)
(B) (2), (3)
(C) (2), (4)
(D) (3), (4)

49 In the following circuits, the two lamps have the same resistance, which is five times the resistance of the PN junction diode in forward bias. In which of them is the brightness of lamp A less than that of lamp B?



50 A solenoid is connected to an ohmic resistor (R) and a PN junction diode. As a magnet approaches the coil as in the opposite figure .....



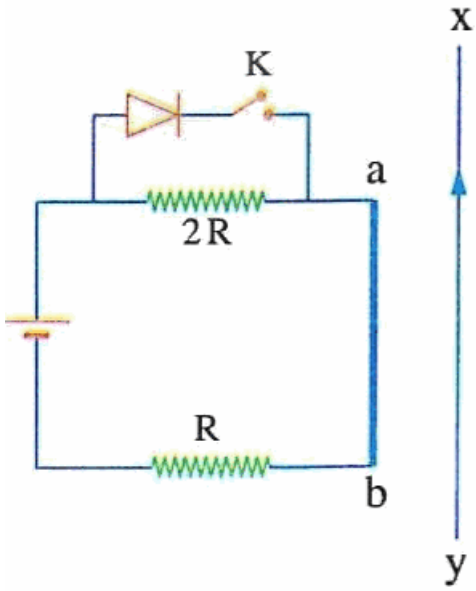
(A) coil: an emf is induced in it, resistor: a current flows through it

(B) coil: an emf is induced in it, resistor: no current flows through it

(C) coil: no emf is induced in it, resistor: a current flows through it

(D) coil: no emf is induced in it, resistor: no current flows through it

51 A long straight wire (xy) carrying a current is placed parallel to a straight wire (ab) of resistance (R) that is part of an electric circuit as in the opposite figure. If the resistance of the PN junction diode is negligible in forward bias and infinite in reverse bias, what happens to the magnitude of the mutual magnetic force between wires (ab) and (xy) when switch (K) is closed?



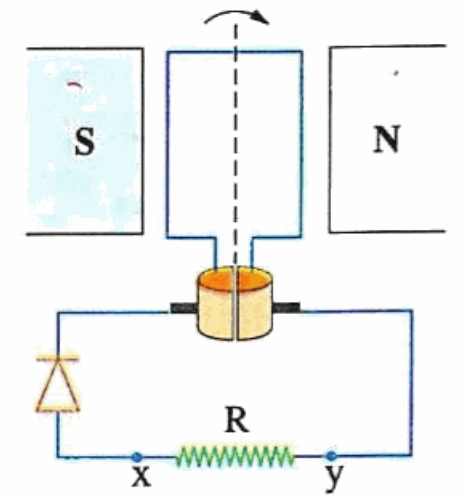
(A) It is halved

(B) It is doubled

(C) It becomes zero

(D) It does not change

52 The opposite figure shows a dynamo connected to an ohmic resistor (R) and a PN junction diode. The resistor (R) .....



(A) has a current that always flows from x to y

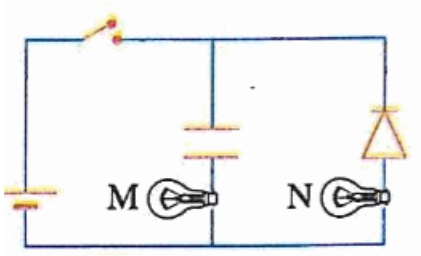
(B) has a current that always flows from y to x

(C) has an alternating current

(D) has no current

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53 Two similar lamps M and N are connected to a battery, a capacitor and a PN junction diode as shown in the opposite circuit. Which lamp flashes at the moment the switch is closed?



(A) M only

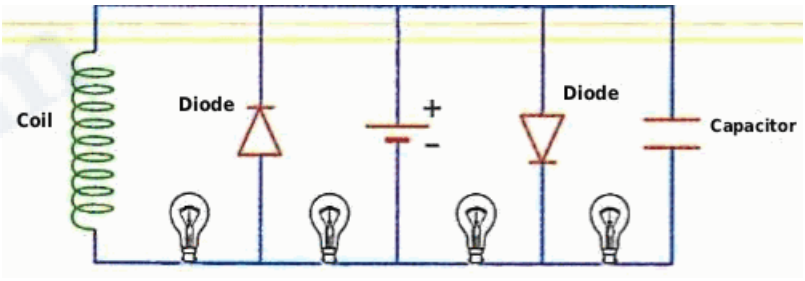
(B) N only

(C) M and N

(D) Neither lamp flashes

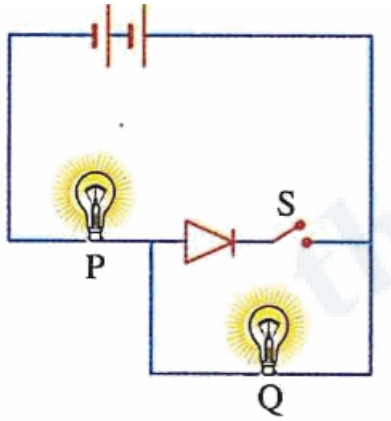
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54 The opposite circuit consists of several devices and four identical lamps. The number of lamps that light up in the circuit is .....



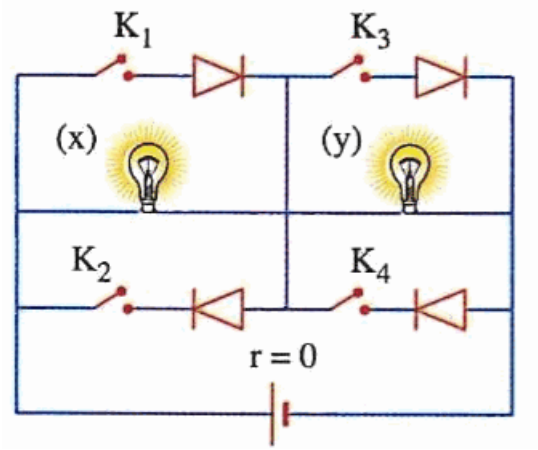
(A) 1 (B) 2 (C) 3 (D) 4

55 Two identical lamps P and Q are connected in an electric circuit with a PN junction diode as shown in the opposite figure. What happens to the brightness of the two lamps, respectively, when switch S is closed?



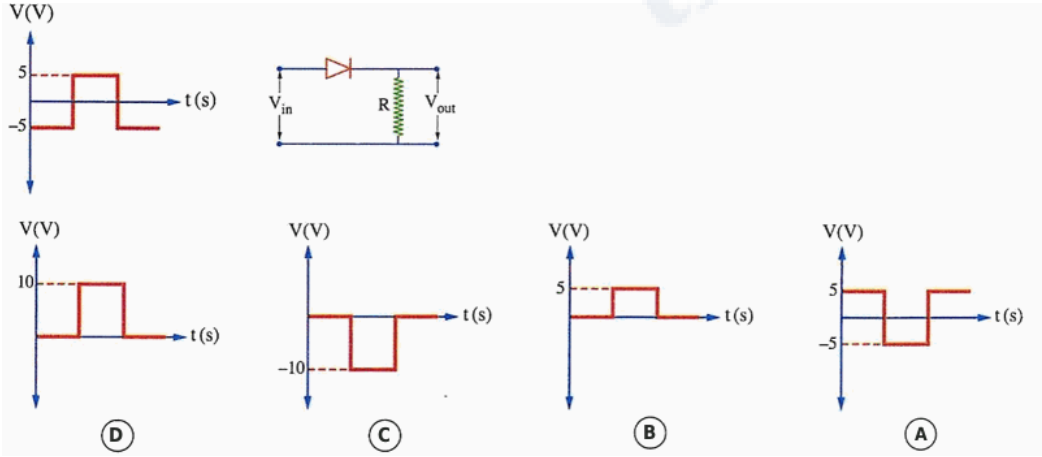
(A) goes off, goes off (B) stays on, goes off (C) goes off, stays on (D) stays on, stays on

56 Two identical lamps x and y are connected with several PN junction diodes through four switches as shown in the opposite circuit. Taking the resistance of each diode as R in forward bias and infinite in reverse bias, which two switches, when closed together, increase the brightness of lamp (x) and decrease the brightness of lamp (y)?

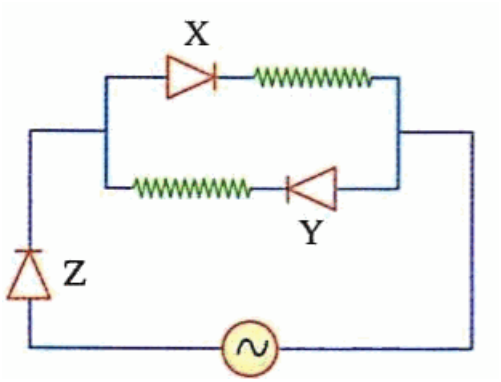


(A) switches (K_1), (K_3)
(B) switches (K_2), (K_4)
(C) switches (K_1), (K_4)
(D) switches (K_2), (K_3)

57 In the opposite figure, an electric signal passes through an ideal PN junction diode. Which of the following graphs represents the output signal (V_{out}) across resistor R?



58 Some PN junction diodes are designed to emit light only when forward biased; these are called light-emitting diodes. If three of these diodes are connected to a low-frequency AC source as shown in the opposite circuit, which of the following is correct?



(A) Diode X lights only when diode Z lights

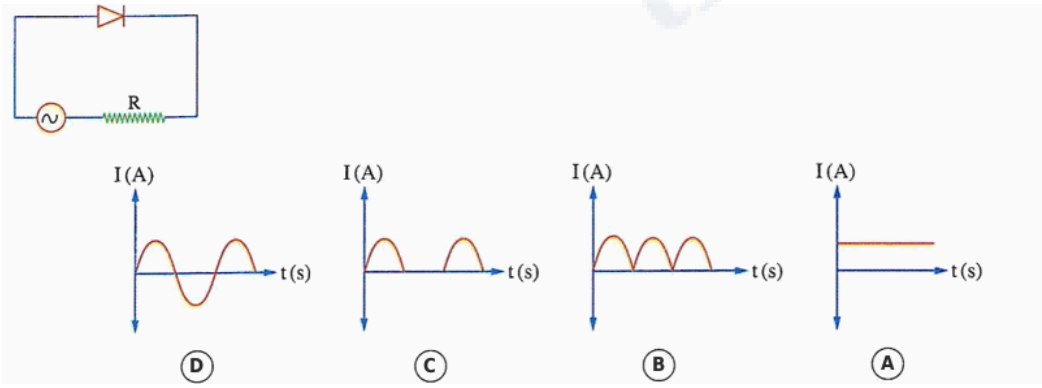
(B) Diode Z lights only when diode X is off

(C) Diode Y lights only when diode X is off

(D) All three diodes are always lit

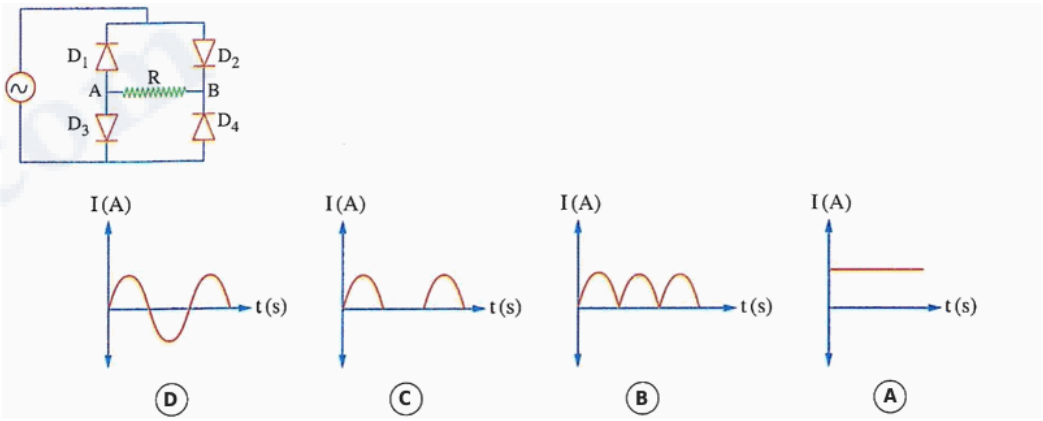
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59 From the opposite circuit, the graph that represents the relation between the current (I) through resistor R and time (t) is .....

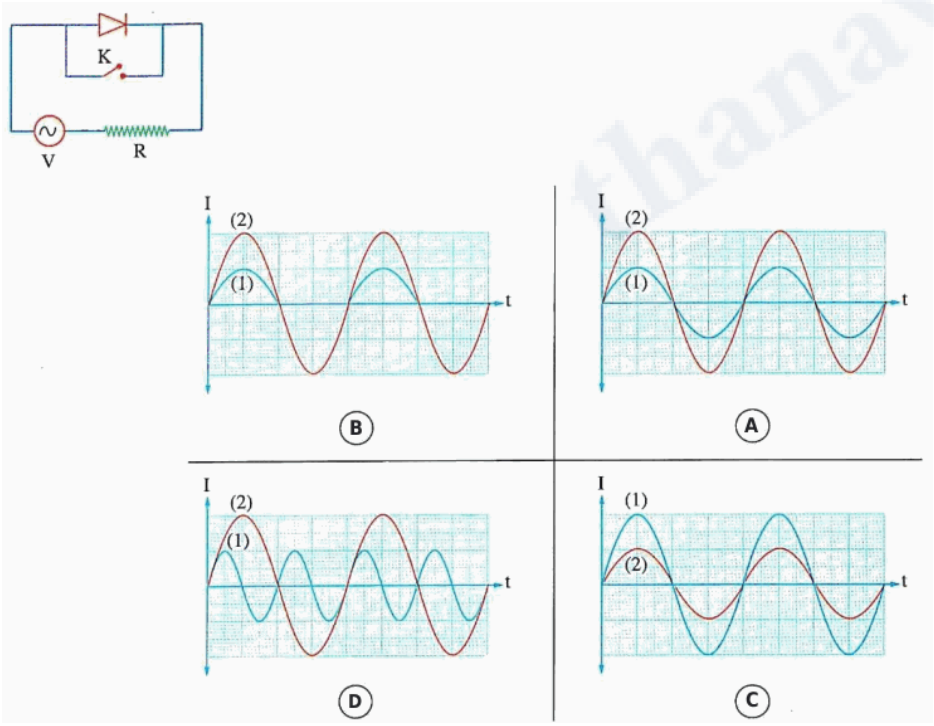


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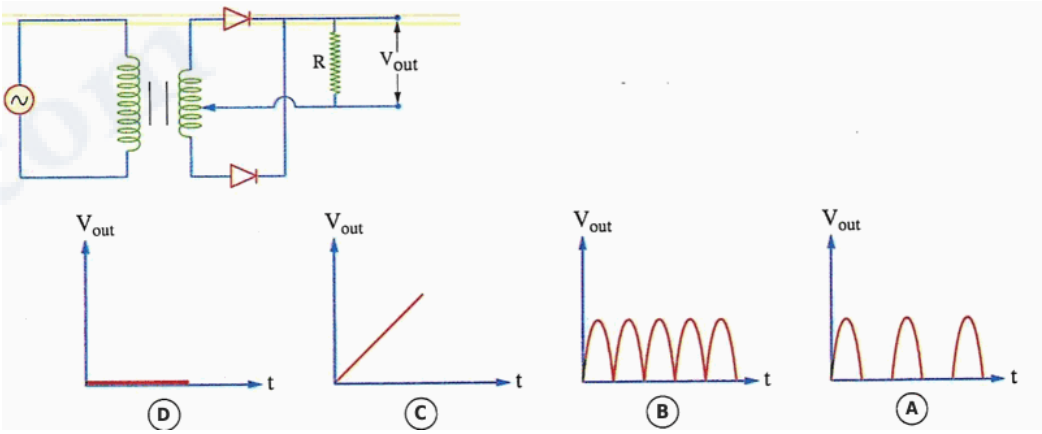
60 The opposite figure shows four PN junction diodes connected in an electric circuit. The graph that represents the relation between the current (I) through resistor R and time (t) is .....



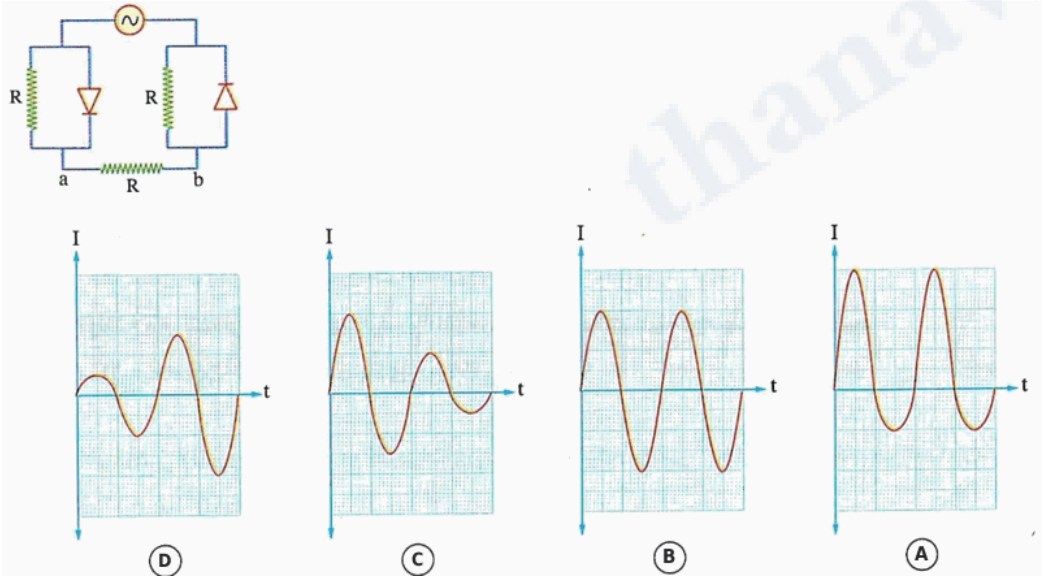
61 In the opposite figure, the resistance of the PN junction diode is R in forward bias and infinite in reverse bias. The graph that represents the relation between the current (I) through resistor R before closing switch K (curve 1) and after closing it (curve 2) and time (t) is .....



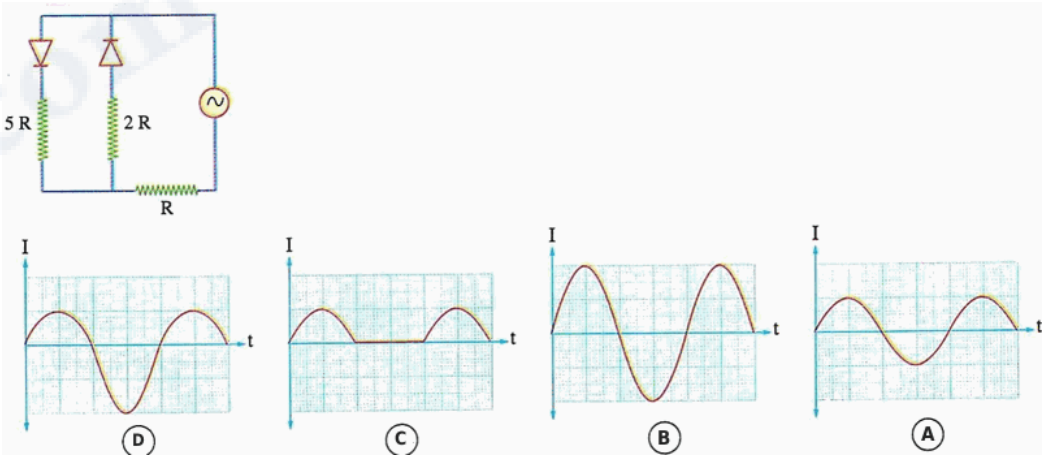
62 The graph that expresses the relation between the output voltage (V_{out}) and time (t) for the circuit shown in the opposite figure is .....



63 In the opposite circuit, if the resistance of the PN junction diodes is negligible in forward bias and infinite in reverse bias, the graph that expresses the current through the resistor between points a and b is .....



64 In the figure shown, if the PN junction diodes have negligible resistance in forward bias and infinite resistance in reverse bias, which of the following graphs represents the relation between the current through resistor R and time (t)?



Essay questions — 19 questions

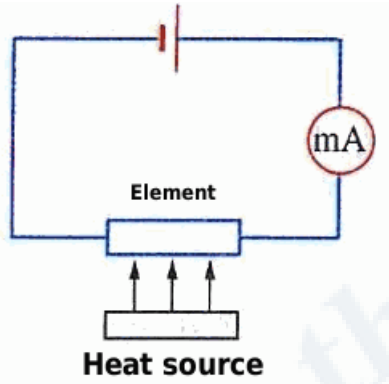
1 Why is a pure silicon crystal a poor conductor of electric current at low temperatures?

2 Give a reason: it is not preferred to heat a pure semiconductor a lot to increase its electric conductivity.

3 Using the figure in front of you, what happens to the reading of the milliammeter in the following two cases? Explain.

(1) If the element is a copper rod.

(2) If the element is a silicon crystal.



4 Explain why, when a pure silicon crystal is doped with phosphorus atoms, the electric conductivity of the crystal increases while its total electric charge does not change.

5 In a p-type semiconductor crystal:

(1) How many valence electrons should the impurity atom have?

(2) Explain whether doping the pure crystal with the impurity atoms makes it positively charged.

(3) What type of charge carriers is the majority in the semiconductor crystal?

6 If the concentration of free electrons (or holes) in a pure silicon crystal is $10^{10}\ cm^{-3}$ and phosphorus atoms of concentration $10^{12}\ cm^{-3}$ are added to it, calculate:

(1) the concentrations of free electrons and holes in this case.

(2) the concentration of aluminium atoms that must be added to the silicon crystal to bring it back as if it were pure.

7 Three silicon crystals x, y, z of the same size are at the same temperature. Crystal (x) is pure, crystal (y) is doped with phosphorus impurities of concentration $2 \times 10^{10}\ cm^{-3}$ and crystal z is doped with boron impurities of concentration $10^{10}\ cm^{-3}$. Explain why the electric conductivity of crystal z is greater than that of crystal x and less than that of crystal y.

8 A silicon crystal is doped with phosphorus atoms of concentration $2 \times 10^{10}\ cm^{-3}$. Explain what happens to its electric conductivity when the following are added:

(1) phosphorus atoms of concentration $10^{10}\ cm^{-3}$

(2) aluminium atoms of concentration $10^{10}\ cm^{-3}$

9 You have a PN junction diode and a battery:

(1) Explain how to connect them so that the electric field of the battery acts: (a) in the same direction as the electric field inside the junction. (b) opposite to the electric field inside the junction.

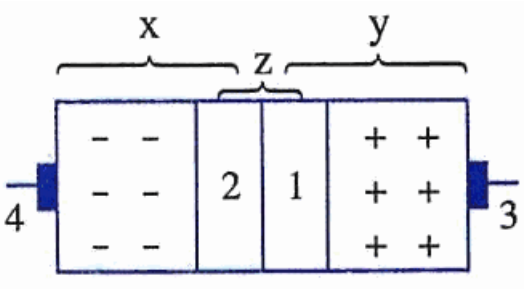
(2) Compare the results of the connection in each case on: (a) the barrier potential. (b) the width of the depletion region. (c) the flow of current through the junction.

10 The opposite figure shows a PN junction diode:

(1) What type of crystal is part (x), and what type is part (y)?

(2) What is the name of region (z) of the junction?

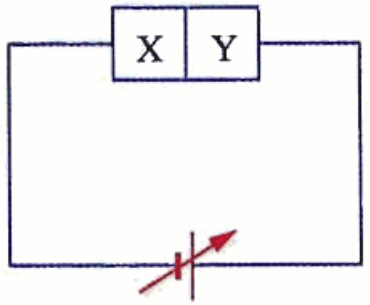
(3) Which battery pole is connected to end (4) in forward bias?



11 A PN junction diode: region X is doped with antimony while region Y is doped with boron. It is connected to a battery as shown in the figure:

(1) Is this forward or reverse bias?

(2) Sketch the relation between the current (I) through the junction and the potential difference (V) across its two regions.

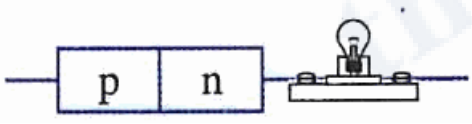


12 The opposite figure shows a PN junction diode connected in series with a small lamp:

(1) Complete the circuit by connecting a DC source so that the lamp lights up. Explain.

(2) What happens when the ends of the circuit are reversed with the DC source?

(3) State, with explanation, the type of current in the lamp if the DC source is replaced by an AC source.



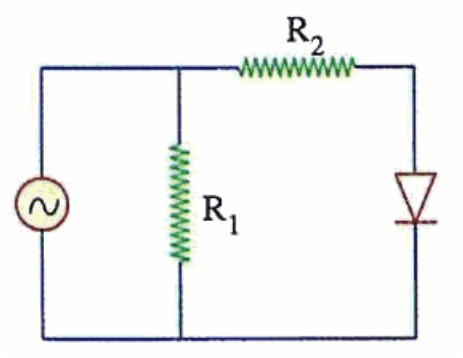
13 Compare between:

(1) the diffusion current and the drift current in a PN junction diode (in terms of: the direction of motion of free electrons - the cause of each).

(2) the PN junction diode and the ohmic resistor (in terms of: charge carriers - direction of current flow - effect of a temperature rise).

14 Explain how the polarity of a PN junction diode can be found.

15 In the circuit shown in the figure, why is the type of current in resistor R_1 different from that in resistor R_2?

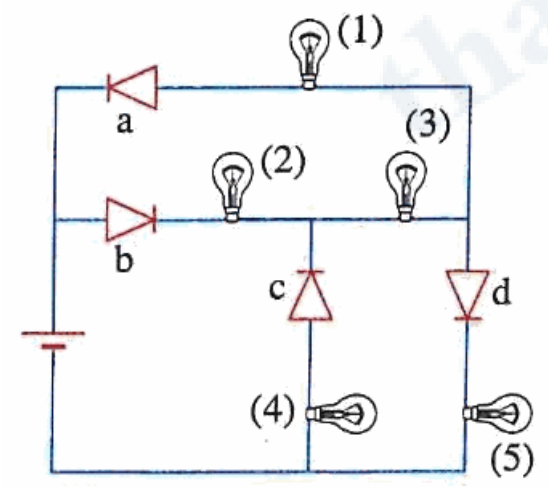


16 In the opposite circuit, a number of identical PN junction diodes and identical lamps are connected to an electric cell:

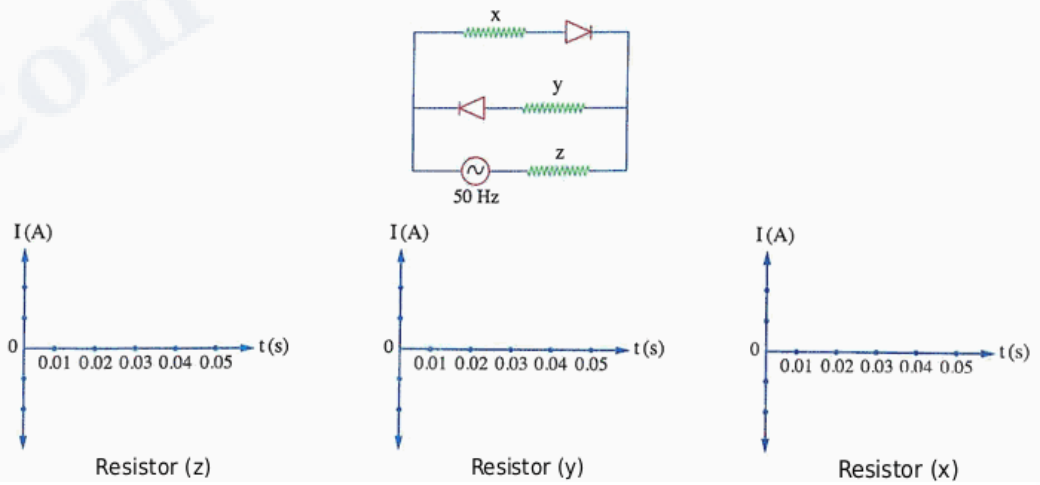
(1) Which lamps are lit? Why?

(2) Which of the four diodes, if reversed, makes no lamp light? Explain your answer.

(3) State, with explanation, the lamps that light with equal brightness when you reverse: (a) the electric cell. (b) the two diodes (a) and (c).



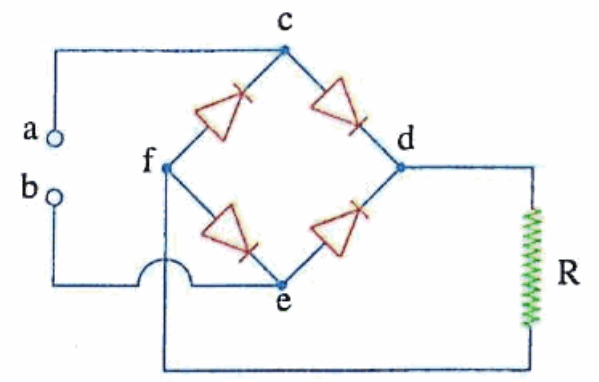
17 Three identical resistors x, y, z and two identical PN junction diodes are connected to an AC source of frequency 50 Hz as in the opposite figure. Use the following graphs to sketch the current in each of the three resistors during 0.05 s.



18 The opposite figure shows an electronic circuit containing four PN junction diodes, an ohmic resistor R and an electric source (ab):

(1) Give, by letters, the path of the current through the circuit when: (a) end a is positive and end b is negative. (b) end b is positive and end a is negative.

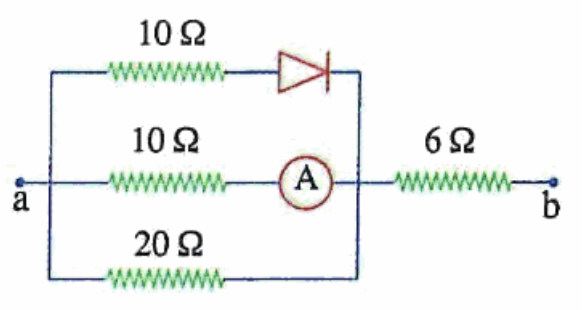
(2) In the light of your answer to part (1), can the current through resistor R be used to charge a car battery? Why?



19 The circuit in the opposite figure shows several resistors, an ammeter and a PN junction diode connected together. A battery of emf 5 volts with negligible internal resistance is connected between points a and b. Taking the resistance of the diode as negligible in forward bias and infinite in reverse bias, calculate the ammeter reading when:

(1) the potential of point a is higher than that of point b

(2) the potential of point b is higher than that of point a



Past exam questions — 30 questions

1 When a pure germanium (Ge) crystal is cooled to zero degrees Celsius (0°C), its electric conductivity ..... (Trial exam / June 2021)

(A) increases (B) decreases (C) becomes zero (D) does not change

2 If the concentration of free electrons in a pure germanium crystal in thermal dynamic equilibrium is $2 \times 10^8\ cm^{-3}$, the expected concentration of holes ..... (1st session 2021)

(A) is greater than $2 \times 10^8\ cm^{-3}$
(B) equals $2 \times 10^8\ cm^{-3}$
(C) is less than $2 \times 10^8\ cm^{-3}$
(D) equals zero

3 Assuming a pure silicon (Si) crystal and a copper wire are cooled to absolute zero (0 K), the electric conductivity ..... (2nd session 2021)

(A) becomes zero for silicon and increases for copper
(B) becomes zero for both silicon and copper
(C) increases for both silicon and copper
(D) increases for silicon and becomes zero for copper

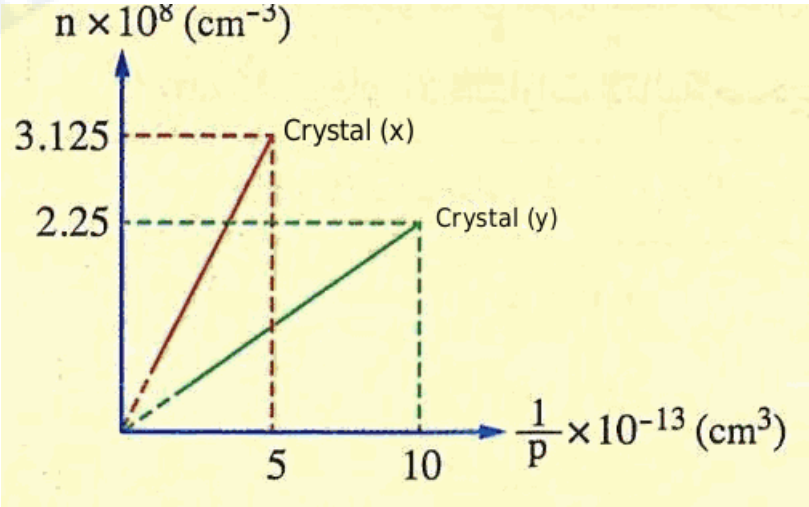
4 The table shows the charge carrier concentration of four samples of the same pure semiconductor material at different temperatures. Which of the following choices gives the correct order of the temperatures of these samples? (1st session 2022)

Sample W: $1.6 \times 10^{16}\ m^{-3}$, Sample X: $1.5 \times 10^{11}\ cm^{-3}$

Sample Y: $1.6 \times 10^{15}\ m^{-3}$, Sample Z: $1.5 \times 10^{10}\ cm^{-3}$

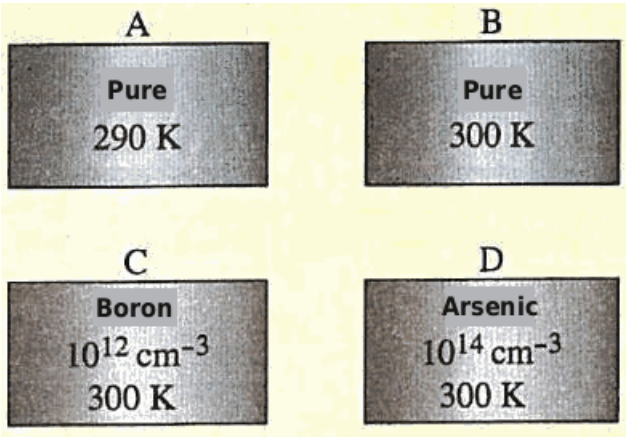
(A) $T_W > T_Y > T_X > T_Z$
(B) $T_X > T_W > T_Z > T_Y$
(C) $T_Z > T_X > T_Y > T_W$
(D) $T_Y > T_Z > T_W > T_X$

5 The graph shows the relation between the concentration of free electrons (n) and the reciprocal of the concentration of holes *(1/p)* for two impure crystals (x) and (y) of a semiconductor material. The ratio between the free-electron concentration in the pure crystal (x) $[n_{ix}]$ and the hole concentration in the pure crystal (y) $[n_{iy}]$ = ... (2nd session 2022)



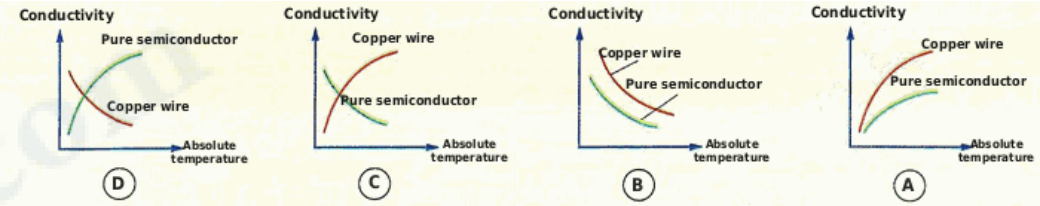
(A) *25/9* (B) *25/36* (C) *5/6* (D) *5/3*

6 The figure shows four silicon crystals of equal dimensions; each shows its temperature and the type and concentration of its impurity, if any. The order of the crystals by electric conductivity is ..... (Trial exam 2023)

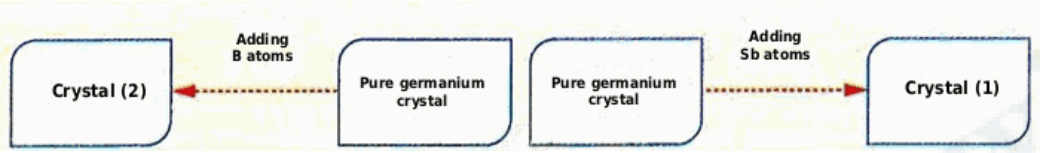


(A) $A > B > C > D$ (B) $D > C > B > A$ (C) $B = C = D > A$ (D) $C = D > B > A$

7 Which of the following graphs shows the relation between the electric conductivity of a pure semiconductor crystal and of a copper wire, and the absolute temperature? (1st session 2023)



8 Two identical pure germanium crystals each have a charge carrier concentration $(n = p = 10^{10}\ cm^{-3})$. Each was doped with atoms of an element of concentration $10^{12}\ cm^{-3}$ to get crystals (1) and (2) as in the figure. The types of the two crystals formed and the ratios of the two kinds of charge carriers in them are ..... (1st session 2024)



(A) crystal (1): n-type, crystal (2): p-type, $p_1/p_2 = 10^4$, $n_1/n_2 = 10^{-4}$

(B) crystal (1): n-type, crystal (2): p-type, $p_1/p_2 = 10^{-4}$, $n_1/n_2 = 10^4$

(C) crystal (1): p-type, crystal (2): n-type, $p_1/p_2 = 10^4$, $n_1/n_2 = 10^{-4}$

(D) crystal (1): p-type, crystal (2): n-type, $p_1/p_2 = 10^{-4}$, $n_1/n_2 = 10^4$

9 If the hole concentration in a pure semiconductor crystal is $10^{11}\ cm^{-3}$ and it is then doped with one kind of impurity so that the hole concentration becomes $10^9\ cm^{-3}$, which of the following choices is correct? (2nd session 2024)

(A) electron concentration $10^2\ cm^{-3}$, impurity: phosphorus

(B) electron concentration $10^2\ cm^{-3}$, impurity: aluminium

(C) electron concentration $10^{13}\ cm^{-3}$, impurity: boron

(D) electron concentration $10^{13}\ cm^{-3}$, impurity: antimony

10 The element that does not give a positive-type semiconductor when used to dope a silicon crystal is ..... (Sample exam 2025)

(A) boron (B^{+3})

(B) antimony (Sb^{+5})

(C) nickel (Ni^{+2})

(D) aluminium (Al^{+3})

11 When the temperature of a copper coil and of a silicon crystal is raised, the electric conductivity ..... (Sample exam 2025)

(A) increases for copper and decreases for silicon

(B) decreases for copper and increases for silicon

(C) increases for both

(D) decreases for both

---

12 The resistivity of a pure germanium crystal can be increased by ..... (Sample exam 2025)

(A) adding a pentavalent impurity

(B) lowering its temperature

(C) shining high-frequency radiation on it

(D) adding a trivalent impurity

---

13 Two identical crystals A and B of a pure semiconductor: the temperature of crystal A is T_1 and that of crystal B is T_2. If the temperature of the surroundings is T_0 where $(T_1 > T_0 > T_2)$, when each crystal reaches thermal equilibrium with the surroundings, the electric conductivity of crystal A ..... and the resistivity of crystal B ..... (Sample exam 2025)

(A) decreases , decreases

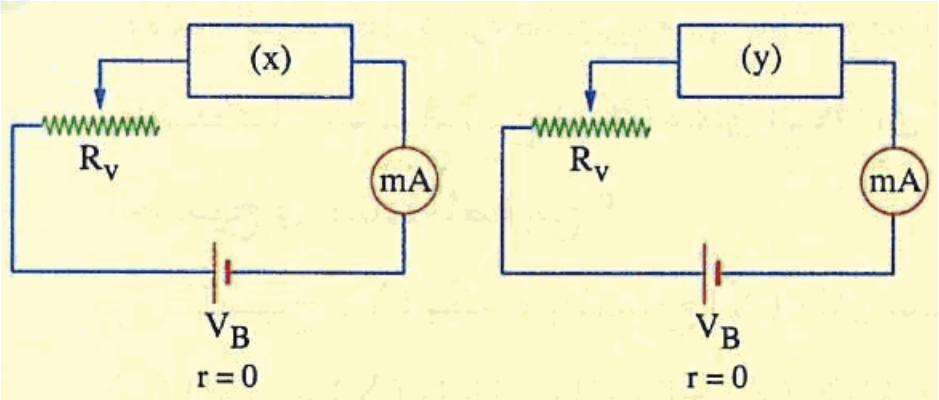
(B) increases , increases

(C) increases , decreases

(D) decreases , increases

---

14 Two different crystals (x) and (y) at a certain temperature were each connected separately in a closed electric circuit as shown in the figure. Crystal x is a pure semiconductor, while crystal (y) is a metal conductor. When the part of the rheostat resistance used is increased, the milliammeter (mA) reading in each circuit decreases. Which of the following actions can bring the milliammeter reading back to what it was? (Sample exam 2026)



(A) raising the temperature of crystal (x) and lowering the temperature of crystal (y)

(B) raising the temperature of crystal (y) and lowering the temperature of crystal (x)

(C) raising the temperature of both crystals (x) and (y)

(D) lowering the temperature of both crystals (x) and (y)

---

15 In a pure semiconductor crystal the concentration of free electrons (or holes) was 1.5×10^{12} cm^{-3}. When pentavalent impurity atoms of concentration 2×10^{13} cm^{-3} and trivalent impurity atoms of concentration 1×10^{13} cm^{-3} are added, then ..... (Sample exam 2026)

(A) the crystal is positive type (p), hole concentration 1×10^{13} cm^{-3}

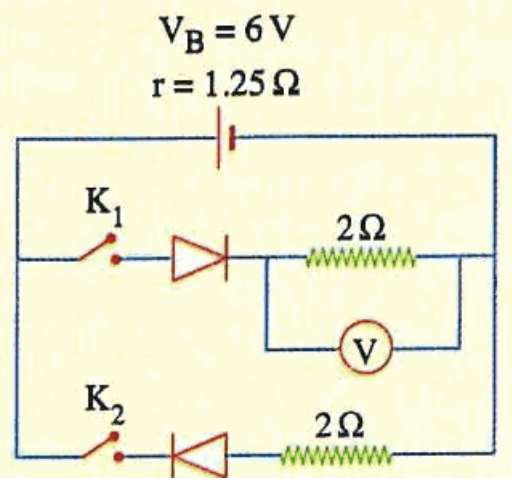
(B) the crystal is positive type (p), hole concentration 2.25×10^{11} cm^{-3}

(C) the crystal is negative type (n), hole concentration 1×10^{13} cm^{-3}

(D) the crystal is negative type (n), hole concentration 2.25×10^{11} cm^{-3}

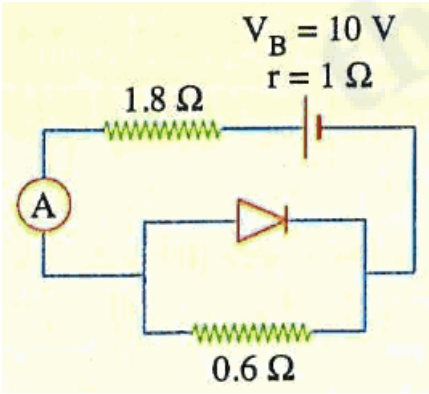
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16 In the circuit in front of you, the resistance of each diode is $0.75\ \Omega$ in forward bias and infinite in reverse bias. When switches K_1 and K_2 are closed, the voltmeter reading is ..... (1st session 2022)



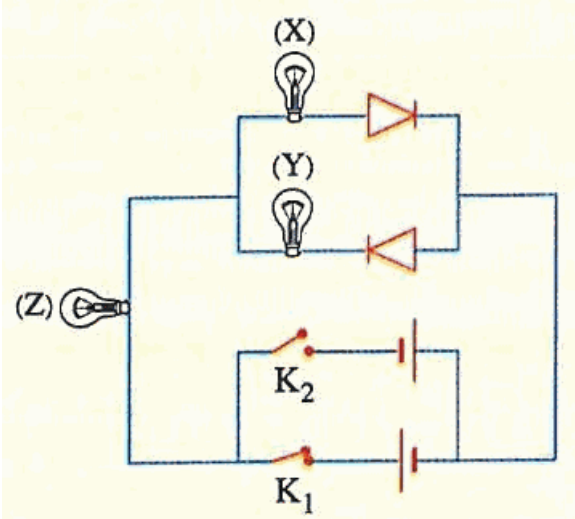
(A) 3 V (B) 0 V (C) 6 V (D) 4 V

17 In the circuit shown, assuming the resistance of the diode is $0.3\ \Omega$ in forward bias and infinite in reverse bias, the ammeter reading equals ..... (2nd session 2022)



(A) 2.94 A (B) 3.33 A (C) 2.71 A (D) 3.57 A

18 The figure shows an electric circuit with three lamps X, Y, Z connected as in the figure. When (K_1) is opened and (K_2) is closed, which choice gives the correct change in the lamps? (Trial exam 2023)



(A) Lamp (Y) lights up and lamp (X) stays on

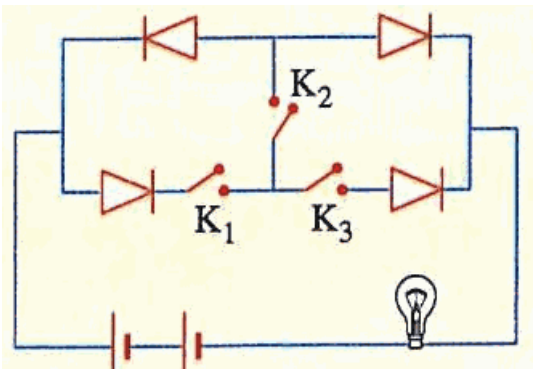
(B) Lamp (X) goes off and lamp (Z) goes off

(C) Lamp (Y) does not light and lamp (Z) goes off

(D) Lamp (X) goes off and lamp (Z) stays on

---

19 In the figure, if the resistance of the diode is $2\ \Omega$ in forward bias and infinite in reverse bias, which of the following cases makes the power consumed in the lamp as large as possible? (1st session 2023)



(A) K_1 closed, K_2 closed, K_3 closed

(B) K_1 closed, K_2 open, K_3 open

(C) K_1 closed, K_2 closed, K_3 open

(D) K_1 closed, K_2 open, K_3 closed

---

20 The electric field formed inside a PN junction diode at a given temperature becomes constant when ..... (2nd session 2023)

(A) all the holes move from the p region to the n region of the junction

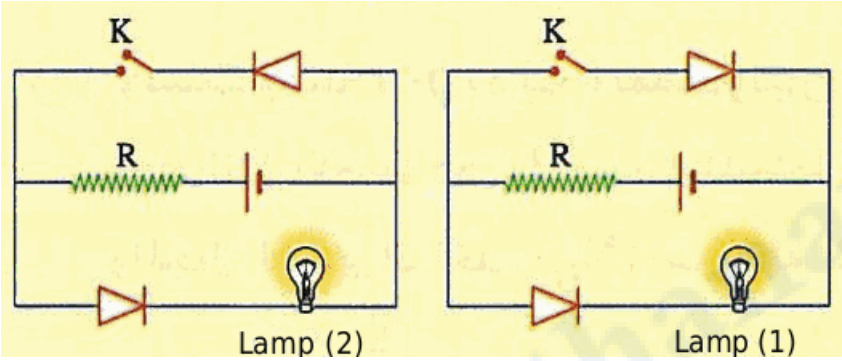
(B) all the free electrons move from the n region to the p region of the junction

(C) the diffusion current and the drift current inside the junction become equal

(D) each region of the junction becomes electrically neutral

---

21 The two opposite figures show two circuits, each containing two PN junction diodes. Given that the resistance of a diode is negligible in forward bias and infinite in reverse bias, when switch K is closed in both circuits ..... (1st session 2024)



(A) lamp (1): goes off, lamp (2): its brightness is not affected

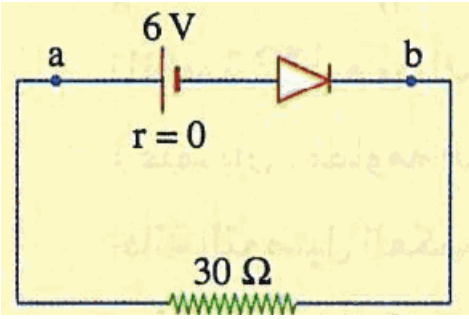
(B) lamp (1): becomes brighter, lamp (2): goes off

(C) lamp (1): becomes dimmer, lamp (2): becomes brighter

(D) lamp (1): its brightness is not affected, lamp (2): becomes dimmer

---

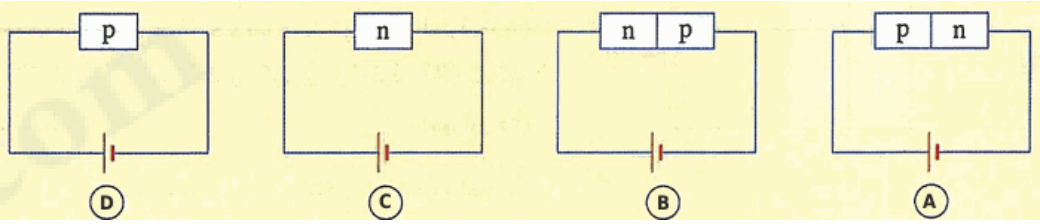
22 If a diode, a battery of negligible resistance and an ohmic resistor are connected as in the opposite figure, the potential difference between points a and b = ... (Note: the resistance of the diode is negligible in forward bias and infinite in reverse bias) (2nd session 2024)



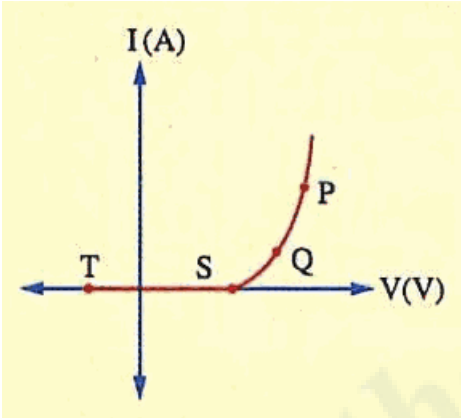
(A) 3 V (B) 0 V (C) 2 V (D) 6 V

---

23 In which of the following circuits is the electric resistance to the current greatest? (Sample exam 2025)

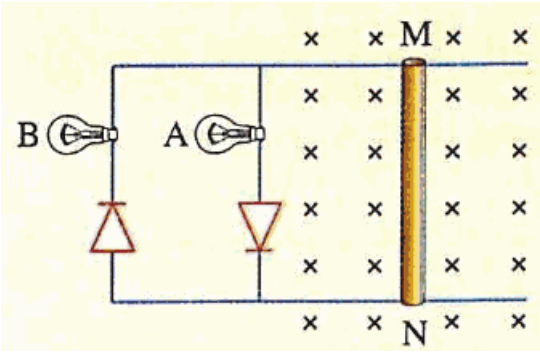


24 The graph shows the (I, V) characteristic curve of a diode. At which of the points shown on the graph is the resistance of the diode the highest? (Sample exam 2025)



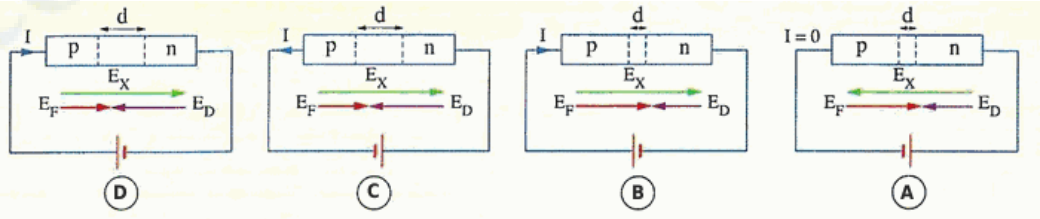
(A) S (B) P (C) Q (D) T

25 In the figure, for lamp (A) to light up, wire MN must move ..... (Sample exam 2025)

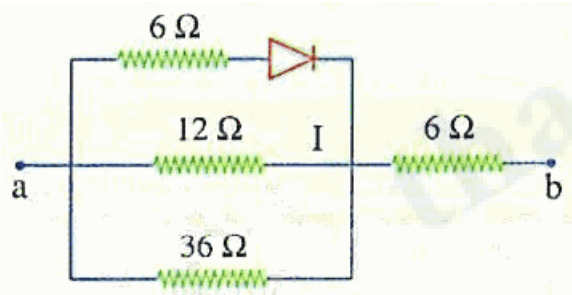


(A) to the right of the page
(B) to the left of the page
(C) perpendicular to the page, into it
(D) perpendicular to the page, out of it

26 A p-n junction (diode) was connected to an external DC source. Which of the figures in the following choices correctly shows the direction of the conventional current (I), the width of the depletion region (d), and the directions and strengths of the electric field due to the battery (E_X), the internal electric field (E_D) and the resultant electric field (E_F) acting on the p-n junction? (Sample exam 2025)

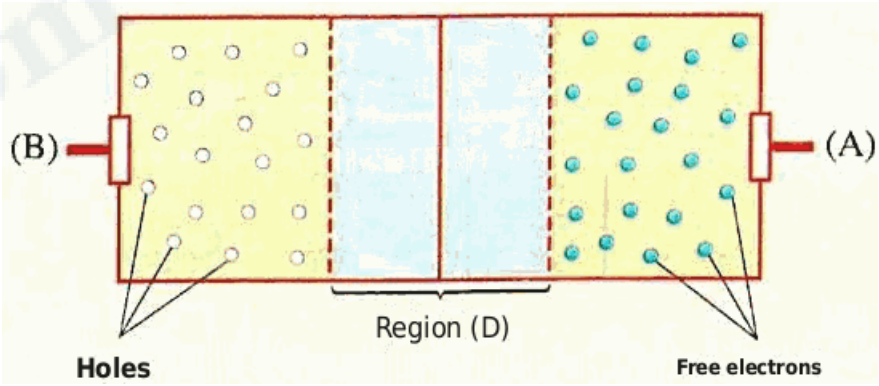


27 The figure shows part of an electric circuit. The electric potential at a is V_a and at b is V_b, with V_b greater than V_a. The current I through the 12 ohm resistor, in terms of V_a and V_b, is given by ..... (Note: the resistance of the diode is negligible in forward bias and infinite in reverse bias) (Sample exam 2025)



Ⓐ $(5(V_b - V_a))/48$ Ⓑ $(V_b - V_a)/32$ Ⓒ $(V_b - V_a)/20$ Ⓓ $(V_b - V_a)/15$

28 The diagram shows a PN junction diode not connected to a voltage source. What happens when end (A) is connected to the positive pole of a cell and end (B) to its negative pole? (1st session 2025)



(A) region D: becomes wider, free electrons and holes: move towards region D

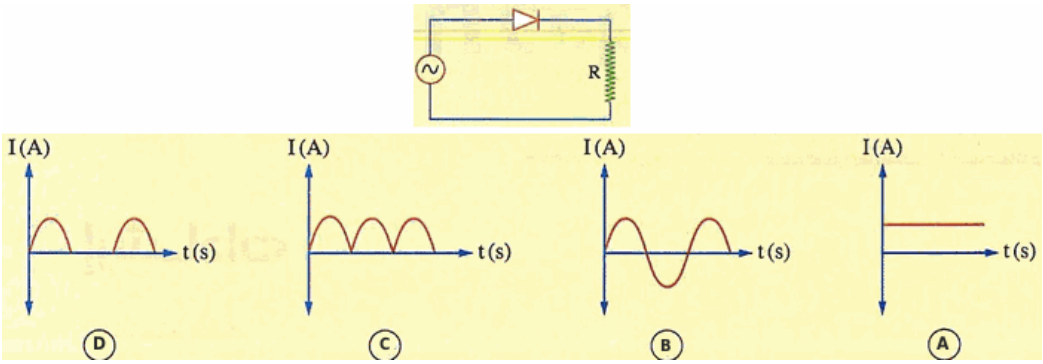
(B) region D: becomes narrower, free electrons and holes: gather at ends A and B

(C) region D: becomes narrower, free electrons and holes: move towards region D

(D) region D: becomes wider, free electrons and holes: gather at ends A and B

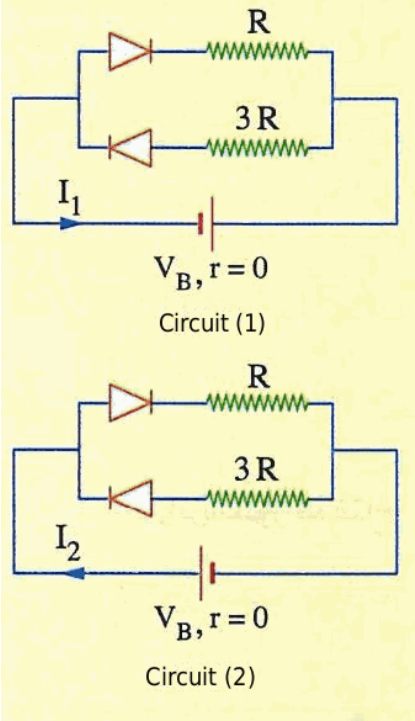
---

29 In the circuit shown in the figure, a PN junction diode is connected to an AC source and an ohmic resistor R. Which of the following graphs represents the relation between the current (I) through the ohmic resistor (R) and time (t)? (2nd session 2025)



---

30 The figure shows two electric circuits (1) and (2). Given that the resistance of the diode is (R) in forward bias and infinite in reverse bias, the ratio between the currents in the two circuits (I_2/I_1) = ... (Sample exam 2026)



(A) *1/2* (B) *1/1* (C) *2/1* (D) *4/1*

Answer key and solutions

Multiple choice questions

1 C	2 B	3 D	4 D	5 A	6 D	7 B	8 C	9 B	10 A
11 A	12 B	13 A	14 B	15 D	16 C	17 B	18 D	19 A	20 B
21 B	22 B	23 D	24 C	25 A	26 B	27 D	28 A	29 C	30 A
31 A	32 C	33 D	34 D	35 D	36 B	37 C	38 D	39 D	40 D
41 B	42 B	43 D	44 B	45 D	46 B	47 C	48 B	49 D	50 B
51 B	52 D	53 A	54 C	55 D	56 D	57 B	58 A	59 C	60 B
61 B	62 B	63 A	64 D						

1 **Answer (C)**

At absolute zero there are no free electrons, so the pure crystal becomes a perfect insulator.

$0\ K = -273\ ^\circ C$

2 **Answer (B)**

The electron gained enough energy from the surroundings to break the bond, so it became free and a hole was formed.

3 **Answer (D)**

The resistance of copper decreases on cooling.

The resistance of the semiconductor (germanium) increases on cooling because its free electrons decrease.

4 **Answer (D)**

In a pure crystal the electron concentration always equals the hole concentration,

and raising the temperature increases both together, so they become greater than n_i

5 **Answer (A)**

In each pure crystal

$n_A = p_A$

$n_B = p_B$

$n_A + n_B = p_A + p_B$

6 **Answer (D)**

All pure crystals contain holes (positive carriers) and free electrons.

7 **Answer (B)**

Raising the temperature increases the concentration of charge carriers in crystal (y).

8 **Answer (C)**

Lowering the temperature decreases the carriers, so the resistivity of crystal (z) increases.

9 **Answer (B)**

Antimony is pentavalent, so it gives an n-type crystal.

10 **Answer (A)**

More trivalent impurities increase the number of holes, so the conductivity increases.

11 **Answer (A)**

The pentavalent impurities give electrons that recombine with holes,
so the holes decrease from X to $X/2$ and the conductivity decreases.

12 **Answer (B)**

The majority carriers in a p-type crystal are holes.

13 **Answer (A)**

In an n-type crystal there are more electrons than holes,
so the ratio of the hole concentration to the electron concentration is less than one.

14 **Answer (B)**

An n-type crystal is electrically neutral because the number of protons equals the number of electrons.

15 **Answer (D)**

In an impure crystal the electron concentration differs from the hole concentration.

$n \neq p$

16 **Answer (C)**

The element has 3 electrons in its outermost level, so it is trivalent,

so the crystal is p-type: holes are the majority and the crystal is neutral.

17 **Answer (B)**

In a pure crystal $n = p$, so the relation is a straight line through the origin.

18 **Answer (D)**

In p-type:

$n\,p = n_i^2$

$p \approx N_A^-$

$n = (n_i^2)/(N_A^-)$

An inverse relation, so the graph is a hyperbola.

19 **Answer (A)**

The resistance is greatest in the pure crystal at the lowest temperature, 200 K.

20 **Answer (B)**

In the pure crystal before doping:

$p = n_i$

After doping:

$p = n_i^2 \cdot 1/n$

The slope equals n_i^2

$(n_{ia}^2)/(n_{ib}^2) = fractan\ 60° tan\ 30° = 3$

$p_a/p_b = (n_{ia})/(n_{ib}) = \sqrt{(3)}$

21 **Answer (B)**

$n_i^2 = n\,p = 10^{12} \times 10^{10} = 10^{22}$

$n_i = 10^{11}\ cm^{-3}$

22 **Answer (B)**

$n = (n_i^2)/p = (10^{22})/(0.5 \times 10^{10})$

$x = 2 \times 10^{12}\ cm^{-3}$

23 **Answer (D)**

The phosphorus-doped crystal (c) has more electrons than n_i

the pure crystal (a) has electrons equal to n_i

the aluminium-doped crystal (b) has fewer electrons than n_i

$c > a > b$

24 **Answer (C)**

$n_i^2 = n\,p = 10^{13} \times 10^9 = 10^{22}$

$n_i = 10^{11}\ cm^{-3}$

25 **Answer (A)**

Free electrons are more than holes, so the crystal is n-type.

26 **Answer (B)**

$p_x = (n_i^2)/N_D = (10^{24})/(10^{14}) = 10^{10}$

$p_y \approx N_A = 10^{14}$

$p_x/p_y = 10^{-4}$

27 **Answer (D)**

The holes equal the aluminium concentration

$p = 10^{10}\ cm^{-3}$

$n = (n_i^2)/p = ((10^8)^2)/(10^{10}) = 10^6\ cm^{-3}$

The required order: holes, then electrons.

28 **Answer (A)**

In reverse bias the barrier potential increases and the resistance increases.

29 **Answer (C)**

The barrier potential is the voltage at which the current clearly starts to flow.

$0.7\ V$

30 **Answer (A)**

The depletion region has no free charge carriers, so its resistance is high.

31 **Answer (A)**

The 2 V battery opposes the 1 V battery.

The resultant 1 V is in the reverse direction of the junction, so no current flows.

32 **Answer (C)**

In figure (C) the positive pole of the battery is connected to the n region,
so the bias is reverse and no current flows.

33 **Answer (D)**

Arsenic is pentavalent, so region X is n-type, and boron is trivalent, so region Y is p-type.
The positive pole is connected to the n region, so the bias is reverse.

34 **Answer (D)**

In forward bias, the majority carriers in each region move towards the junction.

35 **Answer (D)**

Forward bias: the potential of the p end is higher than that of the n end.
$10\ V > -5\ V$

36 **Answer (B)**

Forward bias with negligible resistance
$I = (4-1)/300 = 10^{-2}\ A$

37 **Answer (C)**

The resistance of a semiconductor (silicon) decreases when its temperature rises, so the current increases.

38 **Answer (D)**

A zero voltmeter reading means the junction is reverse biased, so no current flows.
It is the junction whose arrow points against the current.

39 **Answer (D)**

The reading changes when the terminals are reversed: a small resistance one way and a large one the other way.
This is a property of the PN junction diode.

40 **Answer (D)**

The connection in figure (D) is reverse,
so the resistance is infinite and the pointer is at the far left.

41 **Answer (B)**

Forward:

$I = 5/100 = 0.05\ A$

Reverse: the resistance is infinite, so the current is zero.

42 **Answer (B)**

$I = P/V_D = 0.1/0.5 = 0.2\ A$

$V_R = 1.5 - 0.5 = 1\ V$

$R = V_R/I = 1/0.2 = 5\ \Omega$

43 **Answer (D)**

The junction is forward biased and its resistance R is in parallel with c

$R_{c,D} = R/2\ R_{ab} = R/2$

$R_1 = R/2 + R/2 = R$

After reversing, the junction becomes open

$R_2 = R + R/2 = 3R/2$

$I_1/I_2 = R_2/R_1 = 3/2$

44 **Answer (B)**

The right junction is reverse biased, so no current flows from the right battery.

Only the left circuit:

$I = V_B/(R + R) = V_B/2R$

45 **Answer (D)**

The lower junction gives a path with no resistance, so it short-circuits the $12\ k\Omega$ and the $14\ k\Omega$ branch.

$I_1 = 0$

$I_2 = 10/(2\times 10^3) = 5\ mA$

46 **Answer (B)**

The junction in the $30\ \Omega$ branch is reverse biased, so no current flows in it.

$I = 6/(40 + 60) = 0.06\ A$

47 **Answer (C)**

When the junction is reversed, the middle branch is cut off.

The two batteries oppose each other in the remaining loop, so the resultant is zero and the current becomes zero.

48 **Answer (B)**

In (1) and (4) the junction is reverse biased, so lamp A is off.

Lamp A lights up in (2) and (3).

49 **Answer (D)**

In (D) the branches of the two lamps are in parallel.

The resistance of branch A is $5R + R = 6R$ and that of branch B is R

so the current in B is larger and it is brighter.

50 **Answer (B)**

The approaching magnet induces an emf in the coil,

but the resulting current is against the direction of the junction, so no current flows.

51 **Answer (B)**

Before closing:

$R_t = 2R + R + R = 4R$

After closing, the forward-biased junction short-circuits $2R$:

$R_t = R + R = 2R$

The current doubles, so the force doubles.

52 **Answer (D)**

The split ring makes the external current flow in one direction,

and here its direction is against the junction, so no current flows.

53 **Answer (A)**

Current flows through the capacitor at the moment of charging, so lamp M flashes.

The junction in the branch of N is reverse biased, so N does not light.

54 **Answer (C)**

The capacitor blocks direct current, so the lamp in its branch does not light.

The other three lamps light up.

55 **Answer (D)**

The junction is reverse biased, so closing the switch changes nothing.

Both lamps stay on.

56 **Answer (D)**

The two lamps are in series.

Closing K3 short-circuits lamp y, so the current in lamp x increases.

The junction in the K2 branch is reverse biased, so it has no effect.

57 **Answer (B)**

The junction passes the positive part only.

5 V appears across the resistor and the negative part is removed.

58 **Answer (A)**

X and Z are in series, so they light together in the half cycle in which Z conducts, and diode Y does not light.

59 **Answer (C)**

One diode gives half-wave rectification:

half of the cycle passes and the other half is zero.

60 **Answer (B)**

The bridge of four diodes gives full-wave rectification:

the current in the resistor is in one direction in both halves of the cycle.

61 **Answer (B)**

Before closing K:

$I = V/2R$ in the positive half only

After closing K the junction is short-circuited:

$I = V/R$ in both halves

62 **Answer (B)**

A centre-tapped transformer with two diodes gives full-wave rectification:

each diode conducts for one half of the cycle in turn.

63 **Answer (A)**

Positive half: both junctions are forward biased, so only R remains

$I = V/R$

Negative half: both junctions are reverse biased

$I = V/3R$

The positive half is three times larger.

64 **Answer (D)**

The positive half passes through the $5R$ branch:

$I = V/6R$

The negative half passes through the $2R$ branch:

$I = V/3R$

The negative half is twice the positive one.

Essay questions

1 **Model answer**

Because most of the covalent bonds between the atoms of the crystal are intact, so the concentration of free electrons and holes in the crystal is low.

2 **Model answer**

Because raising the temperature a lot breaks up the crystal lattice.

3 **Model answer**

(1) The milliammeter reading decreases, because the resistance of copper increases as its temperature rises.

(2) The milliammeter reading increases, because the resistance of silicon decreases as its temperature rises.

4 **Model answer**

Because each phosphorus atom shares four electrons of its outer level to form four covalent bonds with four neighbouring silicon atoms, and one electron is left over. The atom loses it and it becomes free, so the electric conductivity increases and the phosphorus atom becomes a positive ion.

After equilibrium: $n = p + N_D^+$

That is, the concentration of positive ions + the concentration of holes = the concentration of free electrons, so the total negative charge = the total positive charge.

5 **Model answer**

(1) Three electrons.

(2) It does not make it positively charged; it stays electrically neutral, because in a p-type crystal:

$p = n + N_A^-$

That is, the total negative charge = the total positive charge.

(3) Holes.

6 **Model answer**

(1) $n = N_D^+ = 10^{12}\ cm^{-3}$

$p = (n_i^2)/(N_D^+) = ((10^{10})^2)/(10^{12}) = 10^8\ cm^{-3}$

(2) The concentration of aluminium atoms needed = the concentration of the phosphorus atoms present $= 10^{12}\ cm^{-3}$

7 **Model answer**

The electric conductivity of crystal z is greater than that of crystal x, because impurities increase the electric conductivity of a semiconductor crystal.

The electric conductivity of crystal z is less than that of crystal y, because the impurity concentration in crystal z is less than in crystal y.

8 **Model answer**

(1) The electric conductivity of the crystal increases, because the concentration of free electrons increases.

(2) The electric conductivity of the crystal decreases, because adding aluminium impurities makes some holes and free electrons recombine, which lowers the concentration of free electrons in the crystal.

9 **Model answer**

(1) Connection: (a) the positive pole of the battery to the n region and the negative pole to the p region (reverse bias). (b) the positive pole of the battery to the p region and the negative pole to the n region (forward bias).

(2) In reverse bias: the barrier potential of the junction increases, the depletion region becomes wider, and no current flows in the circuit (a negligible small current due to the drift current).

In forward bias: the barrier potential of the junction decreases, the depletion region becomes narrower, and when the applied voltage exceeds the barrier potential the diode lets a current flow due to the motion of the majority charge carriers (the diffusion current).

10 **Model answer**

(1) x is an n-type region, y is a p-type region.

(2) The depletion region.

(3) The negative pole.

11 **Model answer**

(1) Forward bias.

(2) A curve starting from the origin: the current stays very small until the voltage exceeds the barrier potential, then the current increases quickly as the voltage increases.

12 **Model answer**

(1) Connect the positive pole of the source to the p-type region and the negative pole to the n-type region, so the junction is forward biased and lets the current flow through it, and the lamp lights up.

(2) When the connection to the DC source is reversed, the diode becomes reverse biased, so no current flows in the circuit and the lamp does not light.

(3) A half-wave rectified current, because the diode lets the current flow in one direction only (forward bias) and does not let it flow in the opposite direction (reverse bias).

13 **Model answer**

(1) Diffusion current: free electrons move in it from the n region to the p region, and it is caused by the difference in the concentration of charge carriers between the two regions.

Drift current: free electrons move in it from the p region to the n region, and it is caused by the internal electric field of the junction.

(2) PN junction diode: its charge carriers are free electrons and holes, it lets the current flow in one direction, and its resistance decreases as the temperature rises.

Ohmic resistor: its charge carriers are free electrons, it lets the current flow in both directions, and its resistance increases as the temperature rises.

14 **Model answer**

By connecting it to an ohmmeter, then reversing the connection and noting the reading, which shows the resistance of the junction: the reading is very large in one direction (reverse bias) and very small in the other direction (forward bias).

15 **Model answer**

Because the current in resistor R_1 is an alternating current, as the resistor lets the current flow in both directions, while resistor R_2 is in series with a PN junction diode that lets the current flow in one direction only, so its current is half-wave rectified.

16 **Model answer**

(1) In the position shown in the figure, diodes b and d are forward biased and diodes a and c are reverse biased, so the current flows in lamps (2), (3) and (5) and they light up.

(2) When diode d or b is reversed, no current flows in the circuit, so no lamp lights.

(3) (a) When the cell is reversed, diodes a and c become forward biased and diodes b and d reverse biased, so the current flows in lamps (1), (3) and (4) and each lights with the same brightness.

(b) Lamps (1), (2), (4) and (5) light with equal brightness, while lamp (3) does not light because the potentials at its two ends are equal.

17 **Model answer**

The period $T = 1/f = 1/50 = 0.02\ s$, so two and a half cycles pass in 0.05 s.

Resistor (x): a half-wave rectified current (half waves in the direction of its diode only, and zero in the other half cycles).

Resistor (y): a half-wave rectified current in the opposite direction (it flows in the half cycles in which the current of resistor x does not flow).

Resistor (z): a full alternating current (a sine wave), because it is in series with the source and carries the sum of the two currents.

18 **Model answer**

(1) (a) a → c → d → f → e → b

(b) b → e → d → f → c → a

(2) Yes, because the current through resistor R is full-wave rectified.

19 **Model answer**

(1) When the potential of a is higher than that of b, the diode is forward biased, so the resistors $10\ \Omega$, $10\ \Omega$ and $20\ \Omega$ are in parallel:

$1/R_1 = 1/10 + 1/10 + 1/20\ ,\ R_1 = 4\ \Omega$

$R' = 6 + 4 = 10\ \Omega\ ,\ I' = V_B/(R') = 5/10 = 0.5\ A$

$I = (I'\,R_1)/10 = (0.5 \times 4)/10 = 0.2\ A$

(2) When the potential of b is higher than that of a, the diode is reverse biased and no current flows in it, so the $10\ \Omega$ resistor in series with it is cancelled:

$R_1 = (10 \times 20)/(10 + 20) = 20/3\ \Omega\ ,\ R' = 20/3 + 6 = 38/3 = 12.67\ \Omega$

$I' = 5/12.67 = 0.395\ A\ ,\ I = (I'\,R_1)/10 = (0.395 \times 20/3)/10 = 0.263\ A$

Past exam questions

1	2	3	4	5	6	7	8	9	10
B	B	A	B	D	B	D	B	D	B
11	12	13	14	15	16	17	18	19	20
B	B	A	A	D	A	B	D	A	C
21	22	23	24	25	26	27	28	29	30
A	B	B	D	A	B	C	D	D	C

1 **Answer (B)**

Lowering the temperature decreases the broken bonds, so the concentration of free electrons and holes decreases and the conductivity decreases.

2 **Answer (B)**

In a pure crystal $n = p = n_i$

so the hole concentration equals $2 \times 10^8\ cm^{-3}$

3 **Answer (A)**

At 0 K there are no free electrons and no holes in silicon, so its conductivity becomes zero.

The resistance of copper decreases as the temperature is lowered, so its conductivity increases.

4 **Answer (B)**

Same units: $1.6 \times 10^{16}\ m^{-3} = 1.6 \times 10^{10}\ cm^{-3}$, $1.6 \times 10^{15}\ m^{-3} = 1.6 \times 10^{9}\ cm^{-3}$

The charge carrier concentration increases as the temperature rises:

$X: 1.5 \times 10^{11}$ then $W: 1.6 \times 10^{10}$ then $Z: 1.5 \times 10^{10}$ then $Y: 1.6 \times 10^{9}$

$T_X > T_W > T_Z > T_Y$

5 **Answer (D)**

$n \times p = n_i^2$

Crystal (x): $n_i^2 = 3.125 \times 10^8 \times (10^{13})/5 = 6.25 \times 10^{20}$, $n_{ix} = 2.5 \times 10^{10}$

Crystal (y): $n_i^2 = 2.25 \times 10^8 \times (10^{13})/10 = 2.25 \times 10^{20}$, $n_{iy} = 1.5 \times 10^{10}$

$(n_{ix})/(n_{iy}) = 2.5/1.5 = 5/3$

6 **Answer (B)**

The conductivity increases with the impurity concentration and with the temperature.

D (impurities 10^{14}) is greater than C (impurities 10^{12}), greater than B (pure, 300 K), greater than A (pure, 290 K).

7 **Answer (D)**

The conductivity of a pure semiconductor increases as the temperature rises, and the conductivity of copper decreases as the temperature rises.

8 **Answer (B)**

Crystal (1) is doped with antimony (pentavalent): n-type, $n_1 = 10^{12}$, $p_1 = ((10^{10})^2)/(10^{12}) = 10^8$

Crystal (2) is doped with boron (trivalent): p-type, $p_2 = 10^{12}$, $n_2 = 10^8$

$p_1/p_2 = 10^{-4}$, $n_1/n_2 = 10^4$

9 **Answer (D)**

The hole concentration decreased, so the impurity is pentavalent (donor), like antimony.

$n = (n_i^2)/p = ((10^{11})^2)/(10^9) = 10^{13}\ cm^{-3}$

10 **Answer (B)**

A trivalent impurity (boron, aluminium) gives the positive type p,
while antimony is pentavalent and gives the negative type n.

11 **Answer (B)**

As the temperature rises, the resistance of copper increases so its conductivity decreases, and the conductivity of silicon increases.

12 **Answer (B)**

Lowering the temperature of a pure semiconductor decreases the charge carrier concentration, so its resistivity increases.

13 **Answer (A)**

Crystal A cools from T_1 to T_0, so its conductivity decreases.
Crystal B warms from T_2 to T_0, so its conductivity increases and its resistivity decreases.

14 **Answer (A)**

To bring the current back, we decrease the resistance of each crystal:
the resistance of the semiconductor (x) decreases when its temperature rises, and the resistance of the metal conductor (y) decreases when its temperature is lowered.

15 **Answer (D)**

The net donor impurity concentration $= 2 \times 10^{13} - 1 \times 10^{13} = 1 \times 10^{13}\ cm^{-3}$, so the crystal is n-type

$p = (n_i^2)/n = ((1.5 \times 10^{12})^2)/(10^{13}) = 2.25 \times 10^{11}\ cm^{-3}$

16 **Answer (A)**

The diode in the upper branch is forward biased and the lower one is reverse biased, so no current flows in it.

$I = V_B/(R + r) = 6/(2 + 0.75 + 1.25) = 1.5\ A$

$V = IR = 1.5 \times 2 = 3\ V$

17 **Answer (B)**

The diode is forward biased and its resistance $0.3\ \Omega$ is in parallel with $0.6\ \Omega$:

$R_{//} = (0.3 \times 0.6)/(0.3 + 0.6) = 0.2\ \Omega$

$I = 10/(1.8 + 0.2 + 1) = 3.33\ A$

18 **Answer (D)**

When K_1 is opened and K_2 is closed, the polarity of the source is reversed,
so the diode of lamp (X) becomes reverse biased and it goes off, the diode of (Y) becomes forward biased and it lights up, and lamp (Z) in the main line stays on.

19 **Answer (A)**

Closing all three switches connects the forward-biased junctions in parallel, so the total resistance of the circuit decreases,
so the current in the lamp increases and the power consumed in it is the largest.

20 **Answer (C)**

The field inside the junction becomes constant at equilibrium, that is, when the diffusion current and the drift current become equal.

21 **Answer (A)**

In circuit (1), when K is closed, the current flows through a forward-biased diode of negligible resistance, which short-circuits lamp (1), so it goes off.
In circuit (2), the diode connected with K is reverse biased, so no current flows in it, and the brightness of lamp (2) is not affected.

22 **Answer (B)**

The diode is reverse biased, so no current flows in the circuit.
There is no voltage drop across the $30\ \Omega$ resistor, so $V_{ab} = 0$

23 **Answer (B)**

In circuit (B) the junction is reverse biased, so its resistance is greatest.

24 **Answer (D)**

At point T (the reverse-bias region) almost no current flows, so the resistance is the highest.

25 **Answer (A)**

The motion of wire MN induces an emf in it whose direction is given by Fleming's right-hand rule.
When the wire moves to the right of the page, the induced current is in the forward direction of the diode of lamp (A), so it lights up.

26 **Answer (B)**

In forward bias (positive pole to the p region), E_X is opposite to E_D, so the resultant E_F decreases, the depletion region becomes narrower and the current flows: figure (B).

27 **Answer (C)**

$V_b > V_a$, so the diode is reverse biased and no current flows in its branch.

$R_{//} = (12 \times 36)/(12 + 36) = 9\,\Omega$, $R_{eq} = 9 + 6 = 15\,\Omega$

$I_{total} = (V_b - V_a)/15$

$I_{12} = 36/48 \times (V_b - V_a)/15 = (V_b - V_a)/20$

28 **Answer (D)**

Connecting the n region (end A) to the positive pole and the p region (end B) to the negative pole is reverse bias,

so region D becomes wider and the free electrons and holes are pulled away from it, gathering at ends A and B.

29 **Answer (D)**

The diode lets the current flow in one direction only, so the current is half-wave rectified (figure D).

30 **Answer (C)**

In circuit (1) the current flows through the forward-biased diode branch with 3R: $R_1 = R + 3R = 4R$

In circuit (2) the direction is reversed, so the current flows through the other branch with R: $R_2 = R + R = 2R$

$I_2/I_1 = R_1/R_2 = 4R/2R = 2/1$