PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

SEMICONDUCTOR AND SEMICONDUCTOR DEVICES

Examples

1. The mean free path of conduction electorns in copper is about 4×10^{-8}m. for a copper block, find the electric field which can give, on an average, 1eV energy to a conduction electron.

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2. Calculate the resistivity of an n-type semicondutor from the following data:density of conductionelectorns $= 8 \times 10^{13} cm^{-3}$,density of holes

$= 5 \times 10^{12} cm^{-3}$, mobility of conduction electron $= 2.3 \times 10^4 cm^2 V_{-1} s_{-1}$ and mobility of holes $= 100 cm^2 V_{-1} s_{-1}$.

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3. The i-V characteristic of a p-n junction diode is shown in figure.Find the approximate dynamic resistance of the p-n junction when (a) a forward bias of 1 volt is applied ,(b) a forward bias of 2 volt is applied is applied .

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4. Write the truth table for the logical function Z=(X and Y)or X.

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Worked Out Examples

1. A doped semiconductor has impurity levels 30meV bleow the conduction band,(a)Is the material m-type or p-type? (b)In a thermal collision,and amount kT of energy is given to the extra electron loosely bound to the impurity ion and this electron is just able to jump into the conduction band. Calculate the temperature T.

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2. The energy of a photon of sodium light $(\lambda = 589nm)$equal the band gap of a semiconducting material.(a)Find the minimum energy E requried to create a hole-electron pair.(b)Find the value of E/kTat a temperature of 300K.

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3. A p-type semoconductor has acceptor levels $57meV$above the valence band. Find the maximum wavelength of light which can create a hole.

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4. The band gap in germanium is $(\Delta E = 0.68 eV.)$.Assuming that the number of hole-electron pairs is proportional to `e^(-Delta E//2kT),find the percentage increase in the number of charge carries in pure germanium as the temperature is increased form 300K to 320K.

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5. The concentration of hole-electron pairs in pure silicon at T=300K is 7×10^{15}per cubic metre, Antimony is doped into silicon in a proportion of 1 atom in 10^7atons. Assuming that half of the impurity atons contribute electrons in the conduction band, calculate the foctor by which the number of silicon atoms per cubic metre is 5×10^{28}

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6. A potential barrier of 0.50V exists across a p-n junction.(a) If the depletion region is 5.0×10^{-7}m wide,what is the intensity of the electric field in this region?(b) An electron with speed$5.0 \times 10^5 ms^{-1}$approaches the p-n junction form the n-side.With what speed will it enter the p-side?

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7. The reverse-biased current of a particular p-n junction diode increases when it is expoesed to light of wavelength less than or equal to 600nm.Assume that the increases in carrier concentration takes place due to the creation of new hole-electron pairs by the light.Find the band gap.

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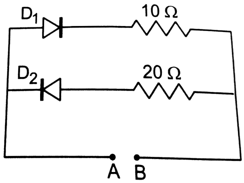
8. A 2V battery may be connected across the points A and B as shown in figure. Assume that the resistance of each diode is zero in forward bias and infinity in reverse bias.Find the current supplied by the battery if the positive terminal of the battery is connected to (a) the point A (b)the point B.



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9. A change of $8.0 mA$ in the emitter current brings a change of 7.9mA in the collector current. How much change in the base current is required to have the same change 7.9mA in the collector current?Find the values of $(\alpha)$and (β).

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10. A transistor is used in common-emitter mode in an amplifier circuit. When a signal 20mV is added to the base-emmiter voltage,the base current changes by $20(\mu)A$and the collector current changes by 2mA.The load resistance is $5k(\Omega)$.Calculate (a)the factor(β)(b)the input resistance R_{BE}, (c) the transconductance and (d) the voltage gain .

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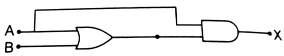
11. Construct the truth table for the function X of A and B represented by figure.



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Short Answer

1. How many 1s energy staates are presesnt in one mole of sodium vapour?Are they all filled in normal conditions? How many 3s energy states are present in one mole of sodium vapour?Are they all filled in normal conditions?

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2. There are energy bands in a solid. Do we have really continous evergy variation in a band or do we have very closely spaced but still discrete energy level ?

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3. The conduction band of a solid is partially filled at 0 K.will it be a conductor, a semiconductor or an insulator?

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4. In semiconductors, thermal collisions are responsible for taking a valence electorn to the conduction band.Why does the number of conduction electrons not go on increasing with time as thermal collisions continuously take place?

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5. When an electron goes fron the valence band to the conduction band in silicon,its energy is increased by 1.1eV.the average energy exchange in a thermal collision is of the order of kT which is only 0.026eV at room tempareture.How is a thermal collision able to take some of the electrons from the valence band to the conduction band ?

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6. What is the resistance of and intrinsic of an intrinsic semiconductor at 0K?

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7. We have valence electrons and conduction electrons in a semiconductor. Do we also have $va \leq nceho \leq s$and ,conduction holes`?

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8. When a p-type impurity is doped in a semiconductor,a large number of holes are created. This does not make the semiconductor chared.But when holes diffuse from the p-side to the n-side in a p-n junction,the n-side gets positvely charged.Explain.

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9. The drift current in a reverse-biased p-n junction increases in magnitude if the tempareture of the junction is increased. Explain this on the basis of creation of hole-electron pairs.

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10. An ideal diode should pass a current freely in one direction and should stoo it completely in the opposite direction. Which is closer to ideal-vacuum diode or a p-n junction diode?

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11. Consider an amplifier circuit using a transistor.The output power is several times greater than the input power.Where does the extra power come from?

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Objective 1

1. Electric conduction in a semiconductor takes place due to

A. electrons only

B. holes only

C. both electrons and holes

D. neither electrons nor holes

Answer: C

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2. An electric field us applied to a semiconductor.Let the number of charge carriers be n and the average drift speed be v.If the temperature is increased,

A. both n and v will increase

B. n will increase but v will decrease

C. v will increase but n will decrease

D. both n and v will decrease.

Answer: D

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3. Lets $n_p$and n_e be the number of holes and conduction electrons in an intrinsic semiconductor.

A. $n_p > n_e$

B. $n_p = n_e$

C. $n_p < n_e$

D. $n_p \neq n_e$

Answer: B

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4. Lets $n_p$and n_e be the number of holes and conduction electrons in an extrinsic semiconductor.

A. $n_p > n_e$

B. $n_p = n_e$

C. $n_p < n_e$

D. $n_p \neq n_e$

Answer: D

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5. A p-type semiconductor is

A. positive charged

B. negetively charged

C. uncharged

D. uncharged at 0K byt charged at higher temperatures.

Answer: C

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6. When an impurity is doped into an intrinsuc semiconductor,the conductivity of the semiconductor

A. increases

B. decreases

C. remains the same

D. becomes zero

Answer: A

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7. If the two ends of a p-n junction are joined by a wire ,

A. there will not be a steady current in the circuit

B. there will be a steady current from the n-side to the p-side

C. there will a steady current from the p-side to the n-side

D. there may or nay not be a current depending upon the resistance of the connecting wire.

Answer: A

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8. The drift current in a p-n junction is

A. from the n-side to the p-side

B. from the p-side to the n-side

C. from the n-side to the p-side if the junction is forward-biased and in the opposite direction if it is reverse-biased.

D. from the p-side to the n-side if the junction is forward-biased and in the opposite direction if it is reverse-biased.

Answer: A

9. The diffusion current in a p-n junction is

A. from the n-side to the p-side

B. from the p-side to the n-side

C. from the n-side to the p-side if the junction is forward-biased and in the opposite direction if it is reverse-biased.

D. from the p-side to the n-side if the junction is forward-biased and in the opposite direction if it is reverse-biased.

Answer: B

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10. Diffusion current in a p-n junction is greater than the drift current in magnitude

A. if the junction is forward-biased

B. if the junction is reverse-biased

C. if the junction is unbiased

D. in no case.

Answer: A

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11. Two identical p-n juctions may be connected in series with a battery in three ways.the potential difference across the two p-n junction are equal in

- circuit 1 and circuit 2
- circuit 2 and circuit 3
- circuit 3and circuit 1
- circuit 1 only.

Answer: B

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12. Two identical capacitors A and B are charged to the same potential V and are connected in two circuits at t=0 as shown in figure.The charges on the capacitor at a time $t = CR$ are, respectively,

- VC,VC
- VC//e,VC
- VC,VC//e
- VC//e,VC//e.

Answer: B

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13. A hole diffuses from the p-side to the n-side in a p-n junction.This means that

A. a bond is broken on the n-side and the electron freed from the bond jumps to the conduction band

B. a conduction electron on the p-side jumps to a broken bond to complete it

C. a bond is broken on the p-side and the electron freed from the bond jumps to a broken bond on the p-side to complete it.

D. a bond is broken on the p-side and the electron freed from the bond jumps to a broken bond on the n-side to complete it.

Answer: C

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14. In a transistor,

A. the emitter has the least concentration of impurity

B. the collector has the least concentration of impurity

C. the base has the least concentration of impurity

D. all the three regions have equal concentrations of impurity.

Answer: C

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15. An incomplete sentence about transistors is given below :The emitter-.....junction is_and the collector -....junction is _.The appropriate words for the dotted empty positions are, respectively

A. collector'and 'base'

B. base'and 'emitter'

C. collector'and 'emitter'

D. base' and 'base'

Answer: D

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Objective 2

1. In a semiconductor,

A. there are no free electrons at 0K

B. there are no free electorns at any temperature

C. the number of free electrons increases with temperature

D. the number of free electrons is less that in a conductor.

Answer: A::B::D

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2. In a p-n junction with open ends,

A. there is no systematic motion of charge carriers

B. holes and conduction electorns systematically go from the p-side to the n-side and from the n-side to p-side respectively

C. there is no net charge transfer between the two sides

D. there is a constant electric field near the junction .

Answer: B::C::D

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3. The impurity atoms with which pure silicon may be increased by

A. phosphorus

B. boron

C. antimony

D. aluminium

Answer: B::D

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4. The electrical conductivity of pure germanium can be increased by

A. increrasing the temperature

B. doping acceptor impurities

C. doping donor impurities

D. irradiating ultraviolet light on it.

Answer: A::B::C::D

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5. A semiconducting device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit .If the polarity of the battery is reversed, the current drops to almost zero.The device may be

A. An intrinsic semiconductor

B. a p-type semiconductor

C. an n-type semiconductor

D. a p-n junction

Answer: D

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6. A semiconductor is doped with a donor impurity

A. The hole conecntration increases.

B. The hole concentration decreases.

C. The electron concentration increases.

D. the electron concentration decreases.

Answer: B::C::D

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7. Let i_E, I_C and i_B represent the emitter current,the collector current and the base current respectively in a transistor.then

A. $i_C$is slightly smaller than i_E

B. $i_C$is slightly greater than i_E

C. $i_B$is much smaller than i_E

D. $i_B$is much greater than i_E.

Answer: A::C

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8. In a normal operation of a transistor,

A. the base-emitter junction is forward-biased

B. the base-collector junction is forward-biased

C. the base-emitter junction is reverse-biased

D. the base-collector junction is reverse-biased.

Answer: A::D

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9. An AND gate can be prepared by repetitive use of

A. NOT gate

B. OR gate

C. NAND gate

D. NOR gate

Answer: C::D

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Objective Ii

1. In a p-n junction ,

A. new holes and conduction electorns are produced continuously throughout the material

B. new holes and conduction electrons are produced continuously throughout the material except in the depletion region

C. holes and conduction electrons recombine continously throughout the material

D. holes and conduction electrons recombine continuously throughout the material except in the depletion region.

Answer: A::D

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Exercises

1. Calculate the number of states per cubic metre of sodium in 3s band. The density of sodium is $1013kgm^{-3}$.How naby of them are empty?

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2. In a pure semiconductor the number of conduction electrons is 6×10^{19}per cubic metre.How many holes are there in a sample of size $1cm \times 1cm \times 1mm$?

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3. Indium antimonide has a band gap of 0.23eV between the valence and the conduction band.Find the temperature at which kT equal the band gap.

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4. The band gap for silicon is 1.1eV.(a)Find the ratio of the band gap to kT for silicon at room temperaature 300K.(b)At what tempareture does this ratio become one tenth of the value at 300K?(Silicon will not retain its structure at these high temperatures.)

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5. When a semiconducting meterial is doped with an impurity,new acceptor levels are created .In a particular thermal collision,a valence electrons recives an energy equal to 2kT and just reaches one of the acceptor levels. Assuming that the energy of the electron was at the top edge of hte valence band and that the temperature T is equal to 300K, find the energy of the acceptor levels above the valence band.

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6. The band gap between the valence and the conduction bands in zinc oxide $(ZnO)$is 3.0eV.Suppose an electron in the conduction band combines with a hole in the valence band and the excess energy is released in the form of electromagnetic radiation.Find the maximum wavelength that can be emitted in this process.

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7. Suppose the energy liberated in the in the recombination of a hole-electron pair is converted into electromagnetic radiation.If the maximum wavelength emmited is 820nm,What is the band gap?

A. 0.5 e V

B. 2.5 e V

C. 1.5 e V

D. 15 e V

Answer: C

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8. find the maximum wavelength of electromagnetic radiation which can create a hole-electron pair in germanium.The band gad in germanium os 0.65eV.

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9. In a photodiode,the conductivity increases when the material is exposed to light.It is found that the conductivity changes only if the wavelength is less than 620nm.What is the band gap?

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10. Let $(\Delta)E$denote the energy gap between the valence band and the conduction band.The population of conduction electrons (and of the holes)is roughly proportional to $e^{-\Delta E/2kT}$. Find the ratio of the concentration of conduction electrons in diamond to that in silicon at room tempareture 300K.$(\Delta E)$for silicon is 1.1 ev and for diamond is 6.0eV.How many conduction electrons are likely to be in one cubic meter of diamond ?

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11. The conductivity of a pure semiconductor is roughly proportional to $\frac{T^3}{2}e^{-\Delta E/2kT} where$(Delta)E`is the band gap.The band gap for germanium is 0.74eV at 4K and 0.67eV at 300K.By what factor does the conductivity of pure germanium increase as the temperature is raised form 4K to 300K?

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12. Estimate the porportion of boron impurity which will increase the conductivity of a pure silicon sample by a factor of 100.Assume that each boron atom creates a hole and the concentration of holes in pure silicon at the same tempareture is7×10^{15}holes per cubic metre. Density of silicon is 5×10^{28}atoms per cubic metre.

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13. The product of the hole concentration and the conduction electron concentration turns out to be independent of the amount of any impurity doped. The concentration of conduction electrons in germanium is 6×10^{19}per cubic per cubic metre.When some phosphorus impurity is doped into a germanium sample, the concentration of conduction electrons increases to 2×10^{28}per cubic metre.Find the concentration of the holes in the doped germanium.

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14. The conductivity of an intrinsic semiconductor depends of tempareture as$(\sigma) = (\sigma_0)e^{-\Delta E / 2kT}$, where $(\sigma_0)$is a constant.find the temperature at which the conductivity of an imtrinsic germanium semoconductor will be double of its value at T=300 K .Assume that the gap for germanium is 0.650 eV and remains constant as the temperature os increased.

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15. A semiconducting material has a band gap if 1 eV.Acceptor impurities are doped into it which create acceptor level 1meV above the valence band.Assume that the transition form one energy level to the otheris almost forbidden if kT is less than $1/50$of the energy gap.Also,if kT is more than twice the gap, the upper levels have maximum polution.The temperature of the semiconductor is increaased form 0K.The concentration of the holes increase with temperature and after a certain temperature it becomes approximately constant.As the tamperature is further increased the hole concentration again starts increasing at certain temperature, Find the order of the temperature range in which the hoel concentration remains approximately constant.

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16. In a p-n junction, the depletion region is 400nm wide and and electric field of $5 \times 10^5 Vm_{-1}$exists in it (a)Find the geight of the potential barrier, (b)What should be the minimum kinetic energy of a conduction electron which can diffuse from the n-side to the p-side?

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17. The potential barrier exists across the junction is 0.2volt.What minimm kinetic energy a hole should have to diffuse from the p-side to the n-side if (a)the junction is unbiased,(b)the junction is forward-biased at 0.1volt and ©the junction is reverse-biased at 0.1volt?

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18. In a p-n junction,a potential barrier of 250 mev exsists across the junction.A hole with a kimetic energy of 300 meV approaches the junction. Find the kinetic energy of the hole when it crosses the junction if the hole approached the junction (a)from the p-side and (b)from the n-side.

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19. When a p-n junction is reverse-biased,the current becomes almost constant at 200 m/v,a current of $75(\mu)A$is obtained.Find the magnitude of diffusion current when the diode is (a)unbiased ,(b)reverse-biased at 200 mVand (c)forward-biased at 200mV.

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20. The drift current in a p-n junction is $2.0(\mu)A$. Estimate the number of electrons crossing a cross section per second in the depletion region.

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21. The current-voltage characteristic of an ideal p-n junction diode is given by

$i = i_0(e^e V / kT - 1)$

where the drift current $i_0$equals $10(\mu)A$.Take the temperature T to be 300K.(a)Find the voltage $v_0$for which $e^{eV/kT} = 100$.One can neglect the term 1 for vlatages greater than this value (b)Find an expression of the dynamic resistance of the diode as a function of V for $V > V_0$.(c)Find the voltage for which the dynamic resistance is $2.0(\Omega)$

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22. Consider a p-n junction diode having the characterstic $i = i_0(e^e V / kT - 1)$where $i_0 = 20(\mu)A$.The diode is oprated at T=300K. (a)Find the current through the diode when a voltage of 300 mV is applied across it in forward bias, (b)At what voltage does the current double?

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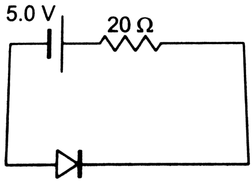
23. Calculate the current through the circuit and the petential difference across the diode shown in figure .The drift current for the diode is $20\mu A$.



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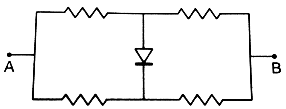
24. Each of the resistance shown in figure has a value of 20Ω.Find the equivalent resistance between A and B.Does it depend on whether the point A or B is at higher potential ?

In problem 25 to 30,assume that the resistance of each diode is zero in forward bias and is infinity in reverse bias.



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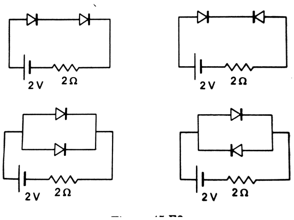
25. Find the current through the resistance in the circuits shown in figure



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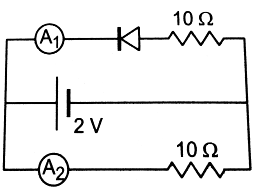
26. What are the readings of the ammeter A_1 and A_2 shown in figure.Neglect the resistances of the meters.



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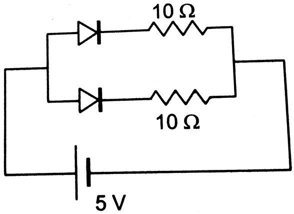
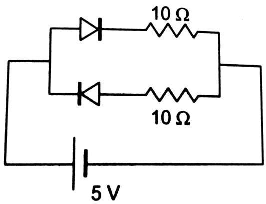
27. Find the current through the battery in each of the circuit shown in figure





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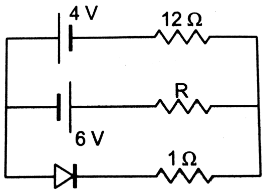
28. Find the current through the resistance R in figure.If (a)$R = 12\Omega$(b) $R = 48\Omega$.



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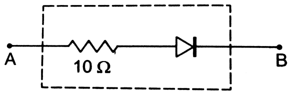
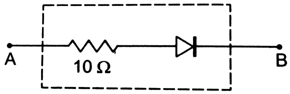
29. Draw the current-voltage characteristics for the device shown in figure between the terminal A and B.





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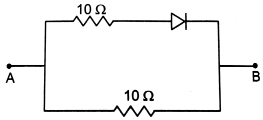
30. Find the equivalent resistance of the network shown in figure



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31. When the base current in a transistor is changed from $30\mu A$to 80 mu

A

$, the col \le c \to r current is chan \ge df$ or $m1.0mA \to 3.5mA. F \in d the cu$

beta`.

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32. A load resistor of $2k\Omega$is connected in the collector branch of an amplifier circuit using a transistor in common-emitter mode.The current gain$\beta - 50$.The input resistance of the transistor is $0.50k\Omega$. If the input current is changed by $50\mu A$,(a)by what amount soes the output voltage change by ,(b)by what amount does the input voltage change and (c) what is the power gain ?

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33. Let $X = A\overline{BC} + B\overline{CA} + C\overline{AB}$.Evalute X for

(a)$A = 1, B = 0, C = 1$

(b)$A = B = C = 1$

$A = B = C = 0$

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34. Design a logical circuit using AND, OR and NOT gatesto evaluate $A\overline{BC} + B\overline{CA}$.

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35. Show that $AB + \overline{AB}$is always 1.

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