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EC160: Experiment 3

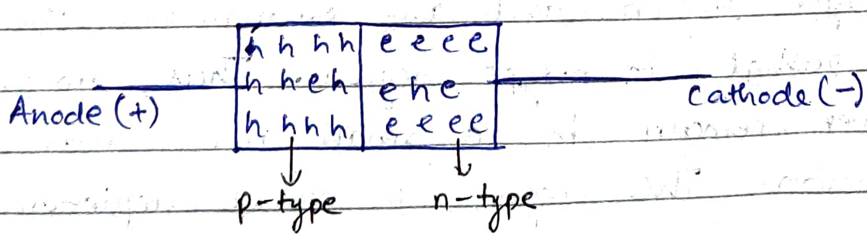
VI Characteristics of a Diode

Objectives:
- To study the structure and symbol on a p-n junction diode.
- To study the Diode equation.
- To study the functioning of a p-n junction diode in forward and reverse biasing.

Theory: A p-n junction diode is two-terminal semiconductor device, which allows the electric current in only one direction, while blocks the electric current in opposite direction.

Structure and Symbol of p-n junction diode

When a semiconducting material such as Silicon or Germanium is doped in such a way that one side has large number of acceptor impurities and the other side has a large number of donor impurities, a p-n junction diode is obtained.



h represents holes and e represent electrons.
The lead connected to p-type material is called as anode and that to the n-type is called as

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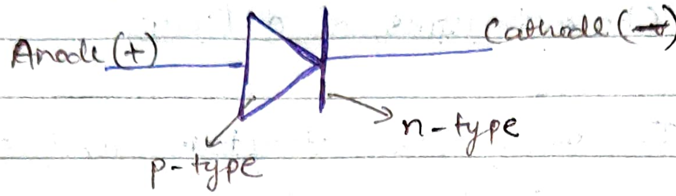
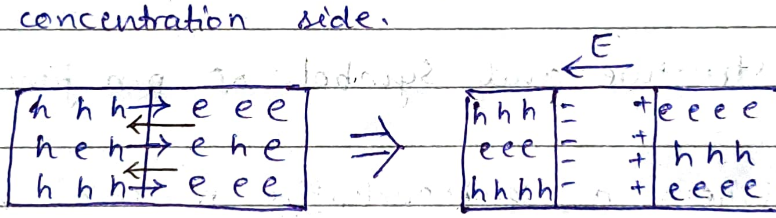
cathode. In electronic circuits p-n junction diode is represented as



The arrow represents p-type and the solid line represents n-side. The arrow points in the direction of flow of forward current.

p-n Junction diode with no biasing

In an unbiased p-n junction, the holes and electrons diffuse from high concentration side to low concentration side.



The diffusion of holes and electrons due to concentration difference creates an electric field near the junction. Any hole near the junction is pushed by electric field to p-type region and any electron near the junction is pushed to n-type region. Thus, no charge carrier remain in a small region near the junction. This region is called depletion layer.

The n-type region is at higher potential with respect to p-type. Hence, there is a potential barrier at the junction of p-n junction diode.

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Nevertheless, there are some energetic holes and electrons which surmount the barrier and some diffusion takes place. This diffusion results in an electric current from p-type to n-type region known as diffusioncurrent.

Due to thermal collisions, occassionally a covalent bond is broken and an electron-hole pair is created. Also, occassionally a conduction electron fills up a vacan bond and an electron-hole pair is destroyed. These processes continue in every part of material. However, if an electron-hole pair is created in depletion region, they are quickly pushed by the electric field towards p-type and n-type respectively. As electron-hole pairs are continuously created in depletion region, a current, known as drift current, flows from n-side to p-side.

The drift and diffusion current are in opposite directions. In steady state, the diffusion current equals the drift current in magnitude and there is no net transfer of charge.

p-n Junction diode in forward bias

When the positive terminal of battery is connected to p-~~type~~ side and negative terminal of battery to n-side of p-n junction diode, it is said to be forward biased.

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Due to forward bias connection, the potential of p-side is raised and hence the height of potential barrier decreases. This decreases the width of depletion region and hence more electrons and holes diffuse. This increases the diffusion current from p-type to n-type. The drift current remains unchanged because rate of formation of new electron-hole pairs is fairly independent of electric field. Hence, the diffusion current exceeds the drift current and a net current flows from p-side to n-side.

The diffusion increases as the applied potential difference is increased. When the applied potential is so high that the potential barrier is reduced to zero, the diffusion increases very rapidly.

The forward voltage at which the diode starts allowing large current to flow through it is called cut-in voltage. The cut-in voltage value for Silicon and Germanium diode is 0.6 V and 0.3 V respectively. Cut-in voltage is also known as knee voltage.

p-n Junction diode in reverse bias

If the p-side of diode is connected to negative terminal of battery and n-side to positive terminal of battery, it is said to be reverse biased.

In this case the potential barrier becomes higher as the battery further raises the potential of n-side. The width of depletion layer is increased. Diffusion becomes more difficult and hence diffusion current decreases. The drift current is not appreciably affected

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hence it exceeds the diffusion current. So, there is a net current from n-side to p-side. However, this current is small as drift current is small itself (typically in μA) and net current is even smaller. Thus during reverse bias, only a small current flows through the junction.

It is clear that p-n junction offers little resistance in forward biased condition and a large resistance in reverse biased condition. An ideal diode should not allow any current in reverse bias. A p-n junction diode is close to an ideal diode as it offers very small current in reverse biasing.

If the reverse-bias voltage across a p-n junction diode is increased, at a particular voltage the reverse current suddenly increases to a large value. This phenomenon is called breakdown of diode and the voltage at which it occurs is called breakdown voltage.

Diode Equation :- In the forward-biased and reverse-biased regions, the current (I_f), and the voltage (V_f), of a semiconductor diode are related by diode equation,

$$I_f = I_s\left(e^{V_f/nV_T} - 1\right)$$

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where I_s is reverse saturation current,
I_f is current through diode in forward bias,
V_f is the potential applied across diode in forward bias,
V_T is thermal voltage, given by,

$$V_T = \frac{kT}{q}$$

k is boltzmann constant, T is temperature in Kelvin, and q is electronic charge.

The empirical constant n, is a number that can vary according to voltage and current levels. It depends on electron drift, diffusion and carrier recombination in depletion region. Among the quantities affecting the value of n are diode manufacture and level of doping.

<u>Procedure to perform the experiment :</u>

(i) Forward Bias

Step-1 : Select the diode and resistor.
Step-2 : Make forward-bias connection of diode with battery.
Step-3 : Connect the voltmeter parallel to ~~resistor~~ diode ~~and~~ and ammeter in series with it.
Step-4 : Fix the value of resistance and vary of DC voltage.
Step 5 : Take the voltmeter and ammeter readings
Step-6 : Plot a VI graph.

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(ii) Reverse Bias:-

Step 1: Select the diode and resistor.
Step 2: Make reverse bias connection of diode with battery.
Step 3: Connect the voltmeter parallel to diode and ammeter in series with it.
Step 4:- Fix the value of resistance and vary the DC voltage.
Step 5:- Take the ammeter and voltmeter readings.
Step 6:- Plot a VI graph.

Simulation Results

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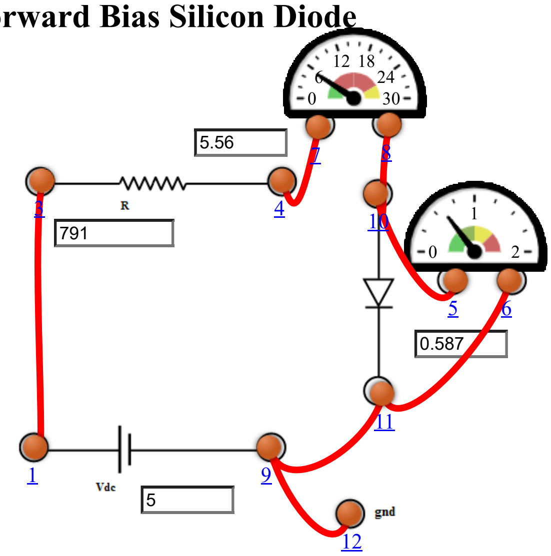
Forward Bias Silicon Diode

INSTRUCTION



CONTROLS

Select Diode: 1N4001

DC volt :

Resistance :

Add to Table

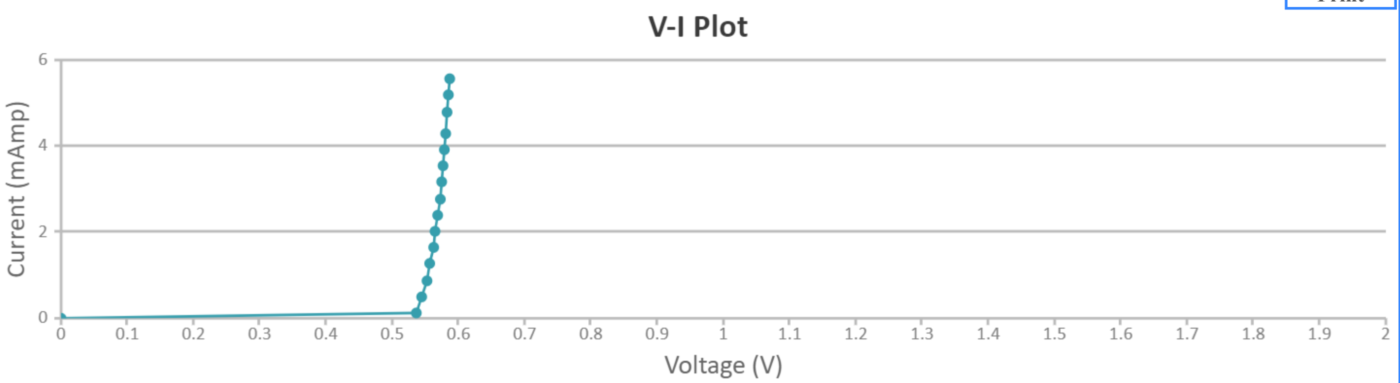
Print It

EXPERIMENTAL TABLE

Serial No.	Forward Voltage(Volt)	Forward Current(mAmp)
1	0	0
2	0.536	0.126
3	0.545	0.505
4	0.552	0.885
5	0.557	1.26
6	0.562	1.64
7	0.565	2.02
8	0.569	2.40
9	0.572	2.78
10	0.574	3.16
11	0.577	3.54
12	0.579	3.92
13	0.581	4.30
14	0.583	4.80
15	0.585	5.18

GRAPH PLOT

Print



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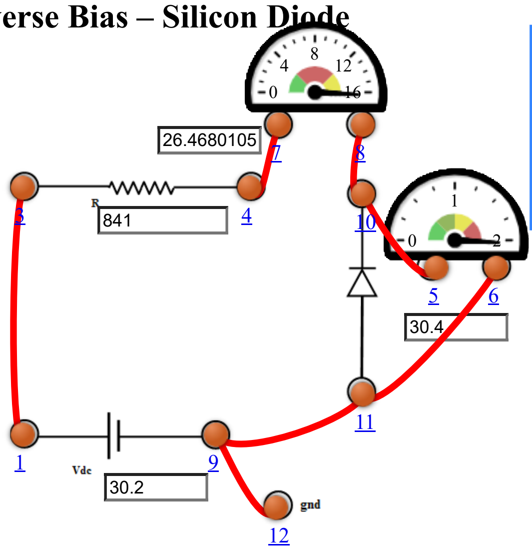
Reverse Bias – Silicon Diode

INSTRUCTION



CONTROLS

Select Diode: 1N4148

DC volt :

Resistance :

Add to Table

Plot

Check connection

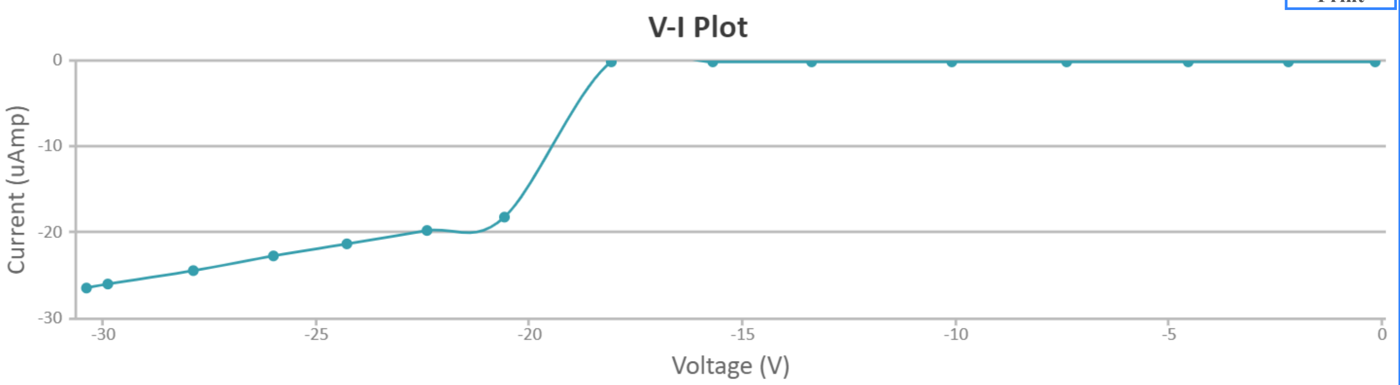
Print It

EXPERIMENTAL TABLE

Serial No.	Reverse Voltage(Volt)	Reverse Current(μAmp)
1	0.170	0.100
2	2.22	0.100
3	4.55	0.100
4	7.42	0.100
5	10.1	0.100
6	13.4	0.100
7	15.7	0.100
8	18.1	0.100
9	20.6	18.185801928133216
10	22.4	19.71954425942156
11	24.3	21.340929009640668
12	26.0	22.743207712532865
13	27.9	24.364592462751972
14	29.9	26.029798422436457
15	30.4	26.46801051709027

GRAPH PLOT

Print



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Forward Bias – Germanium Diode

INSTRUCTION

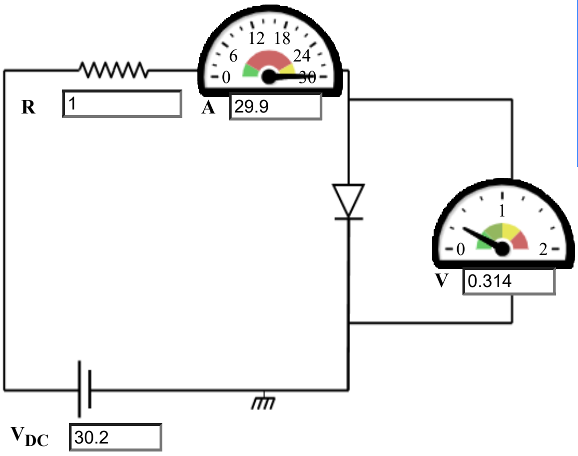
CONTROLS

DC volt : V

Resistance : K

Add to Table | Plot | Clear

Print It

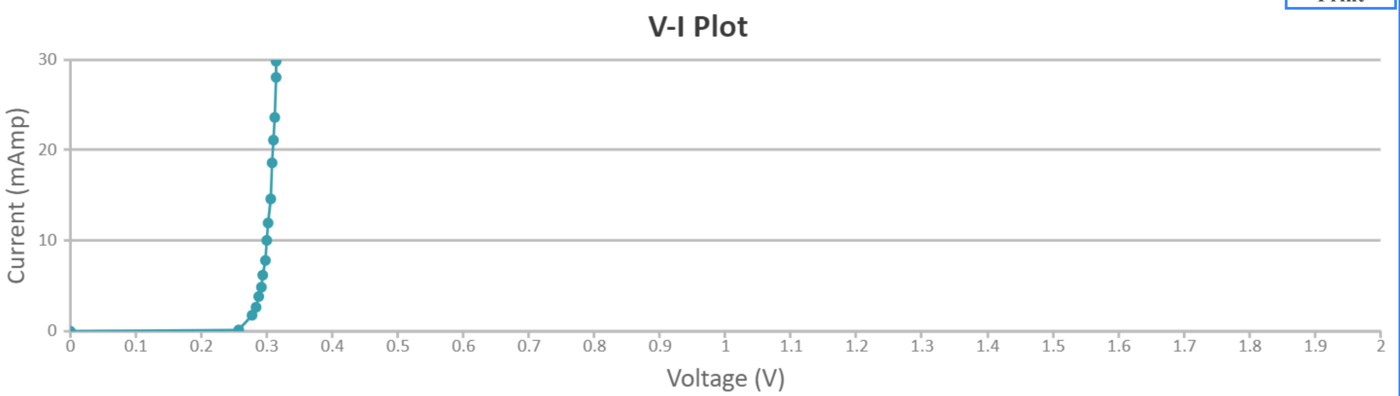


EXPERIMENTAL TABLE

Serial No.	Forward Voltage(Volt)	Forward Current(mAmp)
1	0	0
2	0.257	0.100
3	0.278	1.70
4	0.283	2.60
5	0.288	3.80
6	0.291	4.85
7	0.294	6.20
8	0.297	7.80
9	0.300	10.0
10	0.302	12.0
11	0.305	14.6
12	0.308	18.6
13	0.309	21.1
14	0.311	23.6
15	0.313	28.1

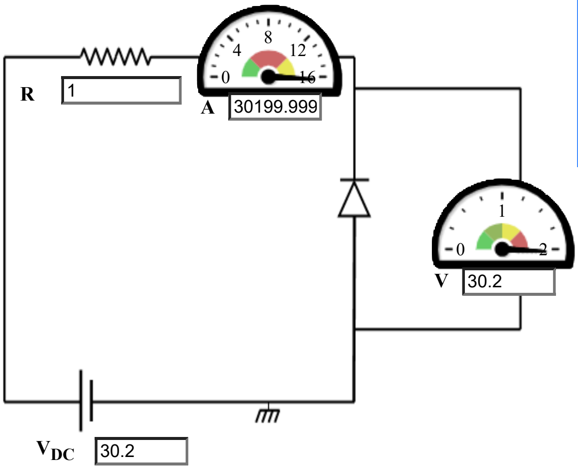
GRAPH PLOT

Print



Reverse Bias – Germanium Diode

INSTRUCTION



CONTROLS

DC volt : V

Resistance : K

Add to Table | Plot | Clear

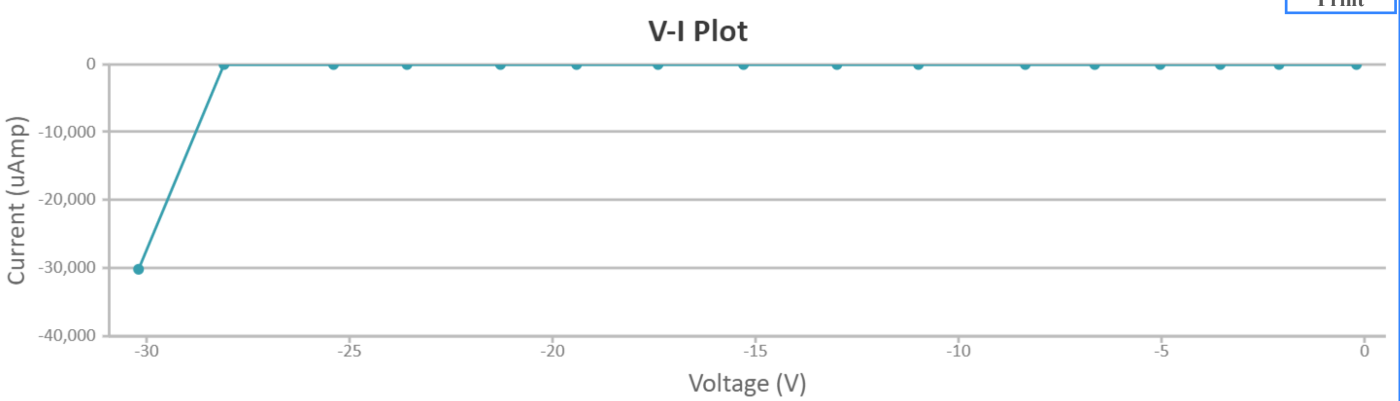
Print It

EXPERIMENTAL TABLE

No.	Voltage(Volt)	Current(µAmp)
1	0.200	0
2	2.10	0
3	3.55	0
4	5.05	0
5	6.65	0
6	8.35	0
7	11.0	0
8	13.0	0
9	15.3	0
10	17.4	0
11	19.4	0
12	21.3	0
13	23.6	0
14	25.4	0
15	28.1	0
16	30.2	30199.999999999996

GRAPH PLOT

Print



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Conclusions:- Performing the experiment in simulator, following conclusions can be drawn,

- In forward bias, a p-n junction diode offers little resistance while in reverse bias it offers a large resistance.
- The cut-in voltage for a silicon p-n junction diode is 0.6 V while that of a Germanium diode is 0.3 V.
- A diode offers current only in one direction.
- After a certain reverse voltage, the diode breaks down. The corresponding voltage is called breakdown voltage. Increasing the reverse voltage above breakdown voltage causes a large increase in current for very small change in reverse voltage.
- A p-n junction diode is a non-Ohmic device.

Quiz Performance

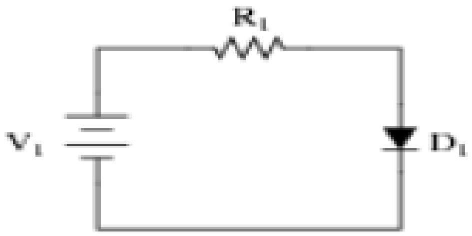
VI Characteristics of a Diode

THEORY (#) PROCEDURE (#) SIMULATION (#) QUIZ (#) ASSIGNMENT (#) REFERENCES (#)

Quiz

Test Your Knowledge!!

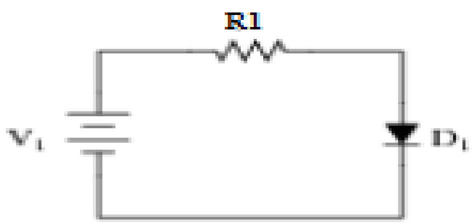
✓ 1. Predict how all component voltages and currents in this circuit will be affected as a result of the following fault.



Fault: Diode D1 fails OPEN

- (●) No current in circuit, no voltage across R1, full source voltage across D1.
- ( ) Increased current in circuit, full source voltage across R1, little voltage across D1.
- ( ) No current in circuit, no voltage across D1, full source voltage across R1.
- ( ) Large current in circuit, no voltage across R1, full source voltage across D1, D1 will most likely overheat and fail.

✓ 2. Predict how all component voltages and currents in this circuit will be affected as a result of the following fault.



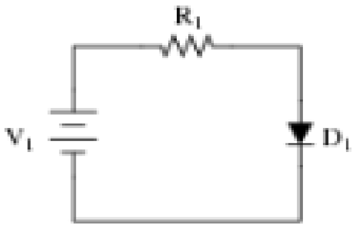
Fault: Resistor R1 fails OPEN

- ( ) No current in circuit, no voltage across R1, full source voltage across D1.
- ( ) Increased current in circuit, full source voltage across R1, little voltage across D1.

No current in circuit, no voltage across D1, full source voltage across R1.

Large current in circuit, no voltage across R1, full source voltage across D1, D1 will most likely overheat and fail.

✓ 3. Predict how all component voltages and currents in this circuit will be affected as a result of the following fault.



Fault: Diode D1 fails SHORTED

No current in circuit, no voltage across R1, full source voltage across D1.

Increased current in circuit, full source voltage across R1, little voltage across D1.

No current in circuit, no voltage across D1, full source voltage across R1.

Large current in circuit, no voltage across R1, full source voltage across D1, D1 will most likely overheat and fail.

✓ 4. Can a diode act as a Switch?

Yes

No

May Be

✓ 5. The V-I characteristics curve is almost a straight line above the knee point.

Yes

No

✓ 6. Reverse current in diode is a linear function of the Reverse voltage.

Yes

No

✓ 7. An ideal Si and an ideal Ge diode are connected in parallel with their anodes joined together and connected to a +5V supply and the cathodes joined together and connected to the other side of the supply voltage through a 1 K? resistor. If the current through the Si diode = I_S and the current through the Ge diode = I_G then select the correct answers from the options below.

I_S = 4.3 mA & I_G = 0 mA

I_S = I_G= 2.15 mA

I_S = 0 mA & I_G = 4.7 mA

I_S = I_G = 2.35 mA

✓ 8. A diode conducts when it is forward-biased, and the anode is connected to the ________ through a limiting resistor.

positive supply

negative supply

cathode

anode

/

✓ 9. A silicon diode measures a low value of resistance with the meter leads in both positions. The trouble, if any, is

- ( ) the diode is open.
- ( ) the diode is shorted to ground.
- (•) the diode is internally shorted.
- ( ) the diode is working correctly.

✓ 10. In a silicon diode reverse current is usually:

- (•) very small
- ( ) very large
- ( ) zero
- ( ) in the breakdown region

✓ 11. Which is the most widely used semiconductor?

- ( ) Copper
- ( ) Germanium
- (•) Silicon
- ( ) None of the above

✓ 12. What is the barrier potential of a Silicon diode and Germanium Diode at room temperature?

- ( ) Si=0.3,Ge=0.7
- ( ) Si=0.7,Ge=1
- ( ) Si=1,Ge=0.3
- (•) Si=0.7,Ge=0.3

Submit