In this section of *Resonance,* we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. "Classroom" is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.

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The Importance of Selecting Suitable Components and Apparatus in Physics Laboratories

Introduction

Presently, many science or engineering graduates do not get good jobs unless they have added some other degree or a diploma in fields like management or information technology to their credit. On the other hand, well established research institutions and industries are facing an acute shortage of graduates and post graduates to meet their requirements of human resource. They are eager to welcome science and engineering graduates who know their *basics* well but the number of such graduates is dwindling.

If we investigate the reasons for weak *basics*, we are sure to observe that this is partly due to weak laboratory training. One of the major aims of laboratory work is to provide the necessary reinforcement to the information and concepts conveyed to the students in theory classes. In the absence of *a planned experience* viz. an *experiment*, there is very little thinking (unless the individual is very bright) and consequently, information provided to the majority of students does not get transformed into even the essential basic level of knowledge.

Keywords
Diodes, zener, I–V characteristics.

There are a variety of reasons for the laboratory work to be poor in quality. One of them appears to be the fragmented knowledge about components, materials and apparatus used by the students in laboratories. Often many people complain about limited budgets and insufficient workforce in many academic institutions, particularly in science colleges. It may be true but that does not absolve us, the teachers, of the collective responsibility to strive for better science education. We firmly believe that there is ample scope to improve the quality of physics (and electronics) laboratory work even within the existing infrastructure and equipment and share a successfully tested exercise in support of our argument.

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The Experiment in Question

The study of the characteristics of a junction diode is a rudimentary experiment done in science and engineering faculties alike. Although the behavior of a diode under forward as well as reverse bias is fully discussed in the lectures, we observe that in many institutions, students are taught to plot the I-V characteristic of the diode under forward bias only. Thus the laboratory work is left incomplete.

The Teachers' Dilemma

We spoke to numerous junior and senior college teachers in this regard on a number of occasions. The commonly cited causes of skipping the characteristic under reverse bias condition, as reported by several teachers are:

1. High possibility of damaging a microammeter by the learner: It is well known that one requires an ammeter that is highly sensitive for recording the feeble current, usually of the order of microamperes.

2. The need to have a high voltage power supply: If one selects an ordinary diode like 1N4001 for studying the characteristic, it is necessary to use a high voltage DC power supply to permit a detectable magnitude of current to flow through the diode (and the ammeter). This is a serious difficulty accounting for the fact

that a high (about a hundred volts or more) DC voltage shock is more hazardous than an equivalent AC voltage shock.

3. Possible irrecoverable damage of the component: Even if we choose a rectifying diode to study characteristics, we run the risk of damaging the component if the applied reverse voltage exceeds a safe value (called its PIV rating). This is very important since the breakdown that occurs at such a voltage is irreversible. The device carries a very high electric current in such a breakdown. It causes *thermal runway* situation that causes permanent damage to the diode.

Although both these reasons are genuine, they consequently result in a serious deficiency in the knowledge of students if they are not exposed to the behavior of a diode that is back-biased. The *far-from-perfect basic knowledge* of the important electronic component is likely to trouble the students in future.

Thus, the teachers face a dilemma while working in the laboratory to consolidate their theory lesson about diodes – whether to permit students to handle microammeters in spite of the known risk of damage or to overlook the learning loss of students by avoiding the study of reverse-biased diode. Most of the teachers (notably including the good and sincere faculty) have favored the latter choice since they find that their institutions are not as sensitive towards academic losses as about material/ equipment losses.

A Simple Remedy to Overcome the Dilemma

Can we manage to plot the *complete* characteristic of a diode using neither a high voltage power supply nor a microammeter? The answer is an emphatic ‘yes’!

Is it possible to “eat the cake and have it too” in case of such a dilemma? Can we manage to plot the *complete* characteristic of a diode using neither a high voltage power supply nor a microammeter? The answer is an emphatic ‘yes’!

As we see, the family of diodes includes a variety of semiconductor devices for various applications like rectification, switching, regulation, photoemission and photo detection. Accordingly we have diodes like 1N4001 for rectification, zeners for regulation and LEDs or photodiodes with different operating regions of wavelengths. *Although all of these devices have some distinct identities, compositions/dimensions and applications to meet various requirements, they do have common features in their characteristics, which is why they are classified as diodes. Thus, selecting any diode from the family for our experiment is our prerogative.* We must look for a device that provides a current of a few mA in forward as well as reverse-bias conditions for conducting the experiment conveniently, without the need to use a microammeter and a high voltage power supply. We observed that 1 Z 5.1, a zener diode easily available at most places perfectly suits our needs and proves to be a satisfactory, cost effective choice. However, any zener diode up to 15 volts rating could work as well.

It is obvious that only reversal of the diode is necessary to study the characteristic under forward-bias conditions.

Figure 1 shows the experimental set-up that uses a single digital multimeter with ranges of 2 mV, 2 V and 20 V to provide us good precision in measuring voltage across the diode and current passing through it by applying Ohm's law to the series resistor by measuring voltage across it. It is obvious that only reversal of the diode is necessary to study the characteristic under forward-bias conditions. For the sake of economy, we have used a potentiometer and a moderately regulated fixed voltage dc power supply to apply a variable bias to the diode. However, one could also use a variable voltage regulator IC like LM 317 for convenience.

Table 1 shows the behavior of the device under reverse as well as forward bias. Note that the current passing through the diode has

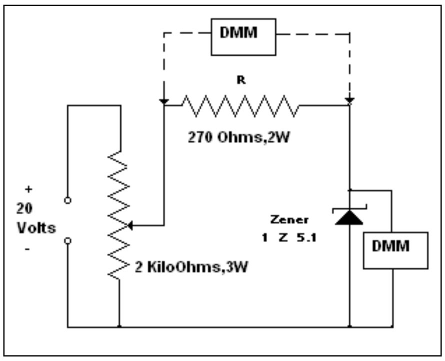


Figure 1. Experimental set-up using digital multimeter(s) to study the characteristic of a diode under reverse bias.

Table 1.

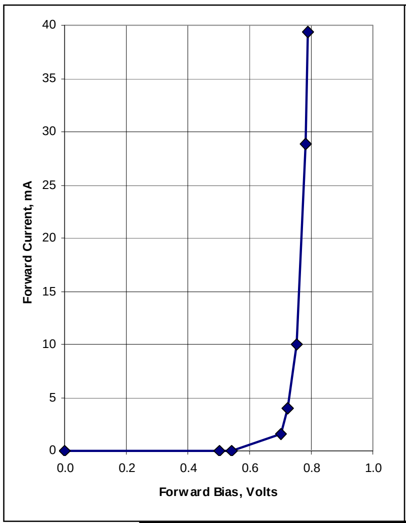
Forward voltage across the diode (volts)	Forward current through the diode (mA)	Reverse voltage across the diode (volts)	Reverse current through the diode (μA)
0.00	0.00	0.00	0.00
0.50	0.00	–0.10	0.00
0.54	0.01	–0.51	0.00
0.70	1.59	–1.08	0.00
0.73	3.99	–3.43	–0.36
0.75	10.03	–3.70	–0.72
0.78	28.84	–4.06	–2.17
0.79	39.35	–4.54	–7.97
		–4.72	–14.86
		–5.02	–44.57
		–5.16	–91.30
		–5.29	–333.33
		–5.33	–670.29
		–5.39	–30471.00

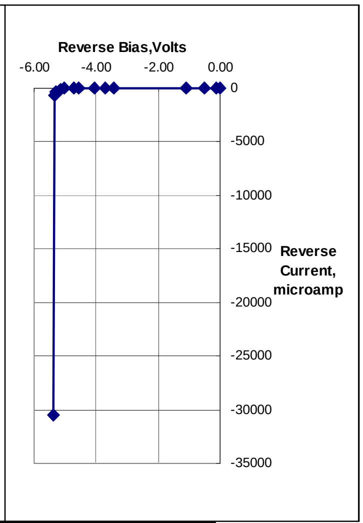
been calculated after dividing the voltage (measured by the DMM) by the series resistance (270 W) and suitably rounded off.

Discussion

Figures 2, 3 and 4 clearly bring out the advantages of using a zener diode in plotting the complete characteristics of a diode using a single digital multimeter. Students' attention should be specifically drawn towards the following salient features:

- Two separate graphs – one for forward bias (*Figure* 2) and the other for reverse bias (*Figure* 3) facilitate clearer visualization of the nature of variation of currents. This is particularly so since the forward current values are in mA whereas those under reverse bias are in microamperes.
- *Figure* 4 has been drawn to provide a clear idea about the order of resistance that a diode offers to a small signal (up to 4 volts in our case) when it is reverse-biased and acts as an open switch. The resistance would be [(–1.08) – (–3.43)]/[(0) – (– 0.36)] volt/microamp = 2.35/0.36 = 6.52 Megaohms.





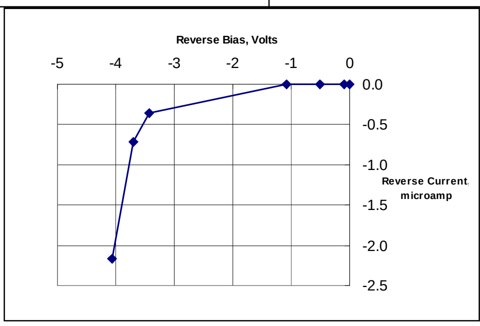


Figure 2 (left). Characteristic of a forward-biased diode using a digital multimeter.

Figure 3 (right). Characteristic of a reverse-biased diode using a digital multimeter.

Figure 4 (center). Partly magnified characteristic of the zener diode under reverse bias (non-conducting region only).

- On similar lines, one can calculate the order of resistance to a small signal in the forward-biased, saturated conduction state of the diode. In this condition an ideal diode that is expected to work like a closed (on-state) switch should offer zero resistance. Our observations show the value as small as [(0.79) – (0.78)]/[(39.35) – (28.84)] volt/milliamp = (0.01)/(10.51) = 0.95 Ω.

- The ratio of the off-state resistance to the on-state resistance (that should be infinite for an ideal switch) works out to be 6.52 MW / 0.95 W = 6.86 × 10^6.

- We did not have to use a high voltage supply to get satisfactory observations while reverse biasing the diode.

Due to precise measurements leading to highly reliable quantitative results, the set-up is quite efficient in terms of communicating physics ideas.

Conclusions

On the basis of the experiment conducted, we conclude that the choice of a suitable component is very important in ensuring the success of an experiment. The zener diode proves to be suitable to establish good correlation between theory and laboratory work related to a diode.

The thoughtful choice of an apparatus – a digital multimeter – is equally important since it enables us to precisely measure even weak currents in the diode. It also rules out the possibility of damage to a microammeter since its use is avoided.

The set-up becomes cost-effective since only one instrument is used to measure both current and voltage.

The set-up ensures operational convenience and safety since DMM does not need to be connected in series with the diode unlike an ammeter.

Due to precise measurements leading to highly reliable quantitative results, the set-up is quite efficient in terms of communicating physics ideas.

Suggested Reading

[1] http://onsemi.com
[2] http://inst.eecs.berkeley.edu/~ee100/su07/handouts/DiodeTransistorNotes.pdf