behaviour of a photodiode[2]; in the investigation of the collective conduction of charge observed in suitable materials and originating in the formation, through a quantum mechanism, of a coherent travelling charge wave[3]; in electrophysiology[4]; in the study of the properties of electrical conduction of few or even single biomolecules such as short strings of DNA adherent across the segments of conducting surfaces[5]. We limit ourselves to cite only these few examples, with the aim to stress the importance and spreading of the I–V characteristic tool in many different fields, and to support the call of a wide use of that technique in the education of scientists and engineers toward experimental practice.

The p-n semiconductor junction, one of the simplest elements with a non linear response, is yet the first choice starting point in the study of semiconductor devices which is a primary goal of modern labs for science and engineering undergraduate students[6]. In Ref. [7] the introduction states: *"The* p-n *junction diode is the most fundamental of all the semiconductor device (...). So basic is the theory of operation that many engineers have stated that to understand the* p-n *junction qualitatively and quantitatively helps one to understand the majority of all solid state devices."*

In the educational literature there are several examples of experimental papers studying the p-n junction both in diode devices or in transistors[8], focusing on the conformity of the measured I–V characteristics with the modelling equations[9] or on particular aspects, such as the possibility to measure the energy band-gap in diodes[10] or in light emitting diodes[11].

In this paper we present an apparatus, used in a class fractionated in small groups of two-three students, for investigating the I–V characteristics of a commercial diode at controlled temperatures, in order to test the compliance of the well-known Shockley equation with the behaviour of a real device. Temperature control, data collection and analysis are directed into a LabVIEW environment.

We present a detailed data analysis in order to invite student to appreciate the caution necessary to avoid some common pitfalls of the fitting procedures and to better appreciate the meaning and limits of a physical model. We also show how a deeper insight in the physical basis of the p-n junction could be obtained by examining the dependence of the basic diode model parameters from surroundings temperature. As an example, we report the exponential dependence of the saturation current on the inverse of the temperature and we show how the constants involved give information on the barrier height of the junction.

2. Terms of the model

The main objective of a laboratory session dedicated to the rectifying diode consists in the evaluation of according degree of the measured curve with the models. The ideal I–V characteristic of a p-n junction is not commonly treated in general physics textbooks, and it is usually approximated by the popular Shockley equation, omitting its considerably complex theoretical origin[7]:

$$I = I_S\left[\exp\left(\frac{V}{nV_T}\right) - 1\right] \tag{1}$$

The properly called Shockley equation has the *non ideality factor* $n = 1$, and is appropriate only for ideal junctions. For real junctions, n is greater than 1. The *thermal voltage* $V_T = kT/e$ has a value of 25.8 mV at room temperature. The *saturation current* I_S describes the level of conductivity of the diode, and ideally