Hence,

$$\mu = \frac{v_d}{E} = \frac{e\tau}{m} \qquad (3.25)$$

where $\tau$ is the average collision time for electrons.

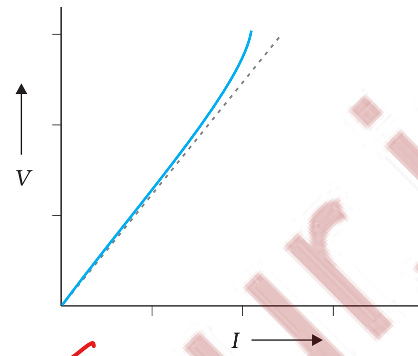


**FIGURE 3.5** The dashed line represents the linear Ohm's law. The solid line is the voltage $V$ versus current $I$ for a good conductor.

## 3.6 LIMITATIONS OF OHM'S LAW

Although Ohm's law has been found valid over a large class of materials, there do exist materials and devices used in electric circuits where the proportionality of $V$ and $I$ does not hold. The deviations broadly are one or more of the following types:

(a) $V$ ceases to be proportional to $I$ (Fig. 3.5).

(b) The relation between $V$ and $I$ depends on the sign of $V$. In other words, if $I$ is the current for a certain $V$, then reversing the direction of $V$ keeping its magnitude fixed, does not produce a current of the same magnitude as $I$ in the opposite direction (Fig. 3.6). This happens, for example, in a diode which we will study in Chapter 14.

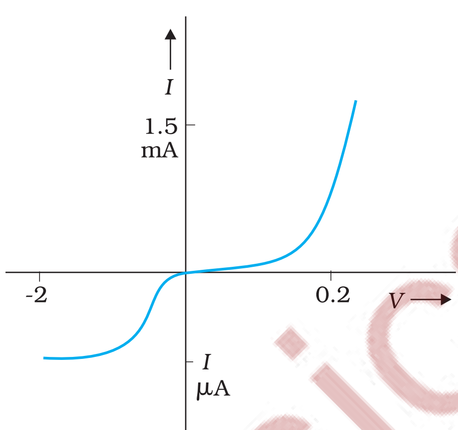


**FIGURE 3.6** Characteristic curve of a diode. Note the different scales for negative and positive values of the voltage and current.

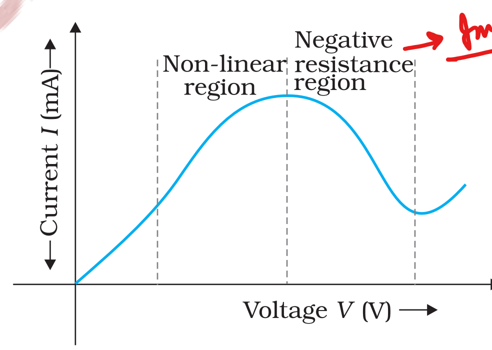


**FIGURE 3.7** Variation of current versus voltage for GaAs.

(c) The relation between $V$ and $I$ is not unique, i.e., there is more than one value of $V$ for the same current $I$ (Fig. 3.7). A material exhibiting such behaviour is GaAs.

Materials and devices not obeying Ohm's law in the form of Eq. (3.3) are actually widely used in electronic circuits. In this and a few subsequent chapters, however, we will study the electrical currents in materials that obey Ohm's law.

## 3.7 RESISTIVITY OF VARIOUS MATERIALS

The resistivities of various common materials are listed in Table 3.1. The materials are classified as conductors, semiconductors and insulators