Unit 26 Diode circuits

When a diode is forward biased it is found in most practical cases that:

- For small currents, the voltage across the diode is the the knee voltage.
- For large currents, the voltage across the diode is given by:

$$V = V_k + I \times R_B$$

where V_k is the knee voltage as given in the summary for Unit 25.

It is found that, in the majority of applications, the current through a diode is at least 1 mA. Inspection of the diode characteristic curve in Figure 25.2 shows that the expected value for the voltage across the diode is then close to the knee voltage for currents in the range from 1 mA to about 100 mA. This is called the 'small signal region'. We therefore have the rule of thumb that, for small currents through the diode, the voltage across the diode is equal to the knee voltage.

For larger currents, such as those in rectifier circuits, we have to take into account the additional voltage drop across the diode bulk resistance of about 1 Ω. Generally speaking this correction will not amount to more than 0.4 V since diodes capable of carrying high currents (eg 10 A) are also designed to have low bulk resistances, much less than the 1 Ω of the 1N4005 type diodes.

The voltage across a forward biased diode is then given by:

$$V = V_k + I \times R_B \approx V_k \quad \text{for small currents}$$

It sometimes happens that components fail, so this rule is very useful for locating a faulty diode. If the circuit diagram indicates a forward biased diode when the power is on, then ≈0.7 V is the expected voltage across the diode. If the voltage is 0 V then the diode has failed to a short circuit or some external path is shorting the diode. If the voltage across the diode is greater than 1 V for a silicon diode then the diode is probably faulty and open circuit.

It is very easy to test a diode for diode action. Use a digital multimeter and set the range switch to the diode symbol on the resistance range. Disconnect at least one lead of the diode from the circuit. Measure the diode resistance in the forward and reverse directions. If the resistance is infinite in one direction and small in the other direction then the diode is still functioning. In most cases this is all that is required as it is unusual for a diode characteristic to deteriorate. The diode failure is usually total. It is also worth repeating your measurement for a new and unused diode to verify your procedure.

26.1 Examples

You may assume that any diode used in the examples and problems in this unit is a silicon diode having a knee voltage of 0.7 V, unless otherwise stated.

26.1 Calculate the current which flows in the circuit in Figure 26.1.

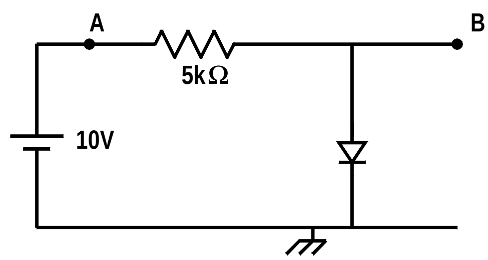

Figure 26.1: Example 26.1.

By inspection, the diode is forward biased. No large currents flow because of the 5 kΩ current limiting resistor, so we are working in the small signal region and therefore expect to have 0.7 V across the diode.

Therefore we have the equation:

$$10\,\mathrm{V} = I \times 5\,\mathrm{k}\Omega + 0.7\,\mathrm{V}$$

(You should always attempt to set up an equation of this form as a starting point in the solution of electronic circuit problems.)

This equation then reduces to:

$$I = \frac{10\,\mathrm{V} - 0.7\,\mathrm{V}}{5\,\mathrm{k}\Omega} = \frac{9.3\,\mathrm{V}}{5\,\mathrm{k}\Omega} = 1.86\,\mathrm{mA}$$

Measuring from ground (which we always presume is the line at the bottom of the circuit diagram), the voltage at point B is +0.7 V and the voltage at point A is +10 V. The voltage from B to A is 9.3 V.

If possible, you should set up this circuit in the lab and carry out these measurements yourself.

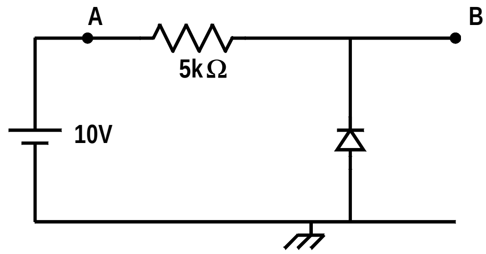

Figure 26.2: Example 26.2.

26.2 Calculate the current which flows in the circuit in Figure 26.2.

By inspection, the diode is reverse biased. This means that the current in the diode is about 10^{-10} A. The voltage drop across a $5\,\mathrm{k\Omega}$ resistor passing 10^{-10} A is $0.5\,\mu$V which can be taken to be zero.

The voltage at one end of the $5\,\mathrm{k\Omega}$ resistor is $+10$ V. Since there is no significant voltage drop across the resistor, the voltage at the other end is the same. Therefore the voltage at point B is $+10$ V.

26.3 Calculate the current which flows in the circuit shown in Figure 26.3.

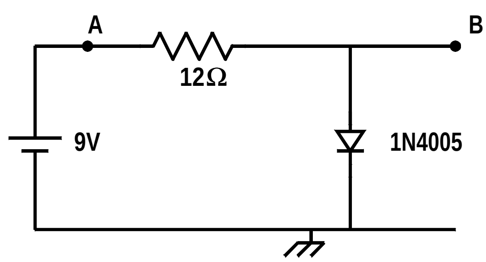

Figure 26.3: Example 26.3.

In this circuit, if the diode is replaced by a short, the current is:

$$\frac{9\,\mathrm{V}}{12\,\Omega} \approx 0.75\,\mathrm{A}$$

which is large, so we must use the large current approximation for the voltage across a diode:

$$V = V_k + I \times R_B$$

The required equation is then:

$$9\,\mathrm{V} = 0.7\,\mathrm{V} + I \times R_B + I \times 12\,\Omega$$

The diode type is a 1N4005 which we examined in Example 25.1. The bulk resistance was found to be $0.4\,\Omega$ so the equation becomes:

$$\begin{aligned} 9\,\mathrm{V} &= 0.7\,\mathrm{V} + I \times (0.4\,\Omega + 12\,\Omega) \\ \text{which gives} \quad 8.3\,\mathrm{V} &= I \times 12.4\,\Omega \\ \text{and a current} \quad I &= 0.67\,\mathrm{A} \end{aligned}$$

26.2 Problems

26.1 Calculate the current which flows in the circuit in Figure 26.4 and also calculate the voltages at points A and B measured with respect to ground.

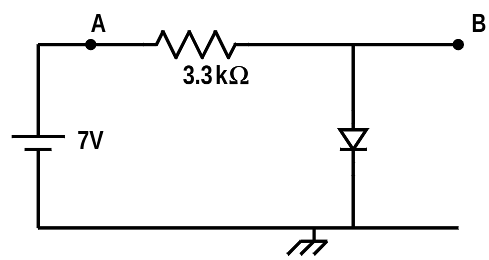

Figure 26.4: Problem 26.1.

26.2 Calculate the voltages at points A, B and C in the circuit in Figure 26.5.

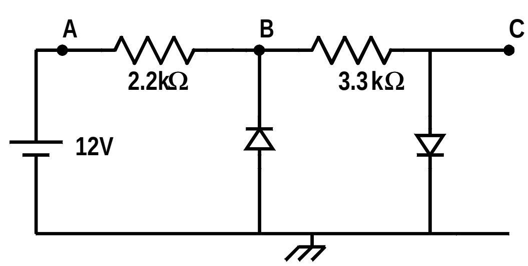

Figure 26.5: Problem 26.2.

26.3 Calculate the current which flows in the circuit in Figure 26.6 and also calculate the voltages at points A, B, C and D.

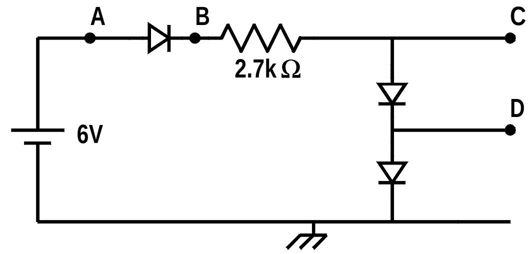

Figure 26.6: Problem 26.3.

26.4 Calculate the current which flows in the circuit in Figure 26.7 and calculate the voltages at points A and B.

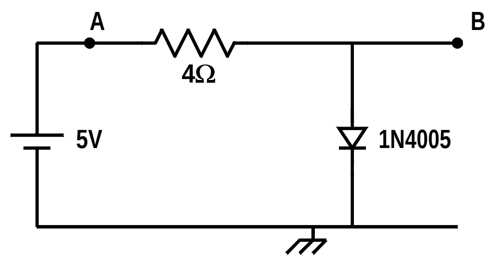

Figure 26.7: Problem 26.4.

26.5 Calculate the current which flows in each of the resistors and in the diode in the circuit in Figure 26.8. Calculate the voltages at points A and B.

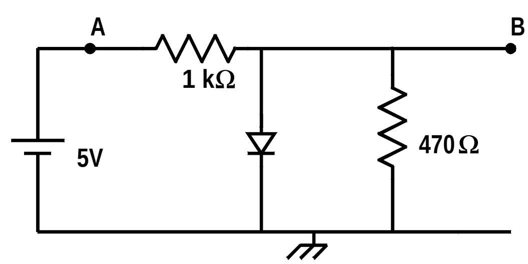

Figure 26.8: Problem 26.5.