Unit 6 Power dissipation in resistors

- When a current flows through a circuit, energy is dissipated in the circuit at a rate given by:

$$\text{Power} \quad P = V \times I \quad \text{watts}$$

- For resistive circuits, application of Ohm's law, $V = I \times R$, gives:

$$\text{Power} \quad P = V \times I = I^2 \times R = \frac{V^2}{R} \quad \text{watts}$$

If we go back to the fundamental definition of electrical units, the unit of potential difference is the volt, the unit of charge is the coulomb and the unit of energy is the joule. Consequently, the relationship between the units is that one joule of energy is released or absorbed in moving one coulomb of charge through a potential difference of one volt.

The unit of electrical current is the amp which is equal to a flow of one coulomb of charge per second. The unit of work is the watt and is the rate at which energy is released or generated in joules per second.

The alternatives of release or absorption of energy must be considered because a device such as a battery, a generator or a solar cell drives current around a circuit, doing work on the circuit and releasing energy, whereas a resistor, light bulb or motor will have current driven through it and can be considered to absorb electrical energy from the circuit, the energy then appearing in the form of heat, light or mechanical work done by the motor.

When you select resistors for use in a circuit there are two parameters which you must consider. The first is the resistance, which is marked on the resistor with a colour code system. The second parameter is the maximum power rating for the resistor. This essentially relates to the physical size of the resistor, its ability to withstand heating without damage and its ability to dissipate heat to the surroundings. Most of the resistors used in transistor circuits operate with low voltages across them and with small currents and therefore do not heat up. In most cases the power rating of 0.125 W or one eighth watt is adequate and these resistors are readily available in small sizes. Once the power dissipation rating gets up to 25 W the resistors are usually

encased in aluminium housings with bolt holes to permit attaching the resistor to heat sinks to dissipate waste heat. Remember, a typical soldering iron used in electronics is rated at 25 W and this is used to melt the solder holding the circuit together!

6.1 Examples

6.1 A particular torch bulb operates from a 6 V battery and draws a current of 0.5 A. Calculate the total charge which flows around the circuit in 2 minutes operation. Calculate the power rating for the bulb.

$$\begin{aligned} \text{Total charge in 2 minutes} &= 0.5\,\text{A} \times 2 \times 60\,\text{s} \\ &= 60\,\text{coulombs} \\ \text{Power dissipation rate in bulb} &= V \times I \quad \text{watts} \\ &= 6\,\text{V} \times 0.5\,\text{A} \\ &= 3.0\,\text{W} \end{aligned}$$

6.2 Calculate the current flowing in a 12 V, 60 W car head lamp bulb. Which of the following wire conductor cross sections is used for the connection to the head lamp to prevent any significant heating of the wire: (0.1 mm^2), (0.5 mm^2), (1.5 mm^2), (5 mm^2), (12 mm^2)? Is single strand or multistrand conductor used in this application? Why? (See Problem 3.6.)

$$\text{Current} = \frac{60\,\text{W}}{12\,\text{V}} = 5\,\text{A}$$

6.2 Problems

6.1 A particular soldering iron is designed to operate from a 12 V supply and is rated at 25 W. Calculate the current which flows in the element of the soldering iron. Calculate the resistance of the element of the iron when it is at its operating temperature.

6.2 A car head lamp is rated at 80 W and operates on a 12 V supply. Calculate the resistance of the hot filament and the current which flows when the filament is at operating temperature. If the resistance of a tungsten filament increases by a factor of 5 in going from cold to operating temperature, calculate the surge current which flows immediately after switch-on. Explain why bulbs tend to fail at switch-on rather than while they are operating at their normal temperature.

6.3 The circuit in Figure 6.1 shows the resistor chain which is used to obtain the voltages which are applied to the dynodes in a photomultiplier tube. Calculate the voltages at each of the dynodes D_1 to D_7 and also calculate the minimum power rating for the resistors in the circuit. The resistor between the photocathode, PC, and D_1 is 150 kΩ and the remainder are all 100 kΩ.

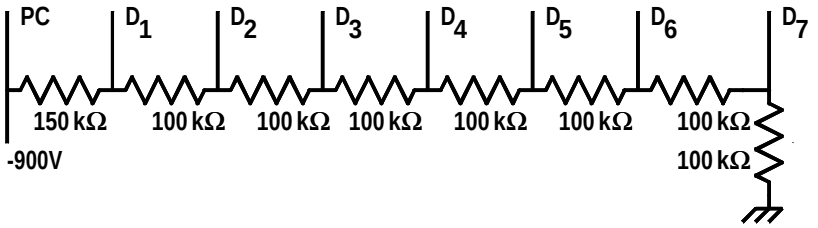

Figure 6.1: Problem 6.3.

6.4 A heat sink is used in electronics to dissipate heat from electronic components and prevent excessive temperature rises. Heat sinks are usually made from extruded aluminium having a large surface area and are rated in degree temperature rise above ambient per watt dissipation. A heat sink rated at 0.5 °C per watt is used to dissipate the heat from an 18 Ω resistor in which a current of 0.8 A is flowing.
Calculate the power dissipated in the resistor.
Calculate the temperature rise above ambient.

6.5 What is the cross section of the copper conductor in the mains lead for a typical piece of portable equipment such as a table lamp? What is the current carrying capacity of the cable? Many mains plugs are rated for a maximum current of 13 A and, when first purchased, contain 13 A fuses. Why should the fuse in the plug be changed if 5 A cable is connected to the plug? What is the function of the fuse?