$G_1 = G_2 = 0.2S$, $G_3 = 0.1S$. The matrix equation is $\begin{bmatrix} 0.2+0.2 & -0.2 \\ -0.2 & 0.2+0.1 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 1 \\ -0.5 \end{bmatrix}$ or $\begin{bmatrix} 0.4 & -0.2 \\ -0.2 & 0.3 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 1 \\ -0.25 \end{bmatrix}$. The easiest way in practice is to use a computer to solve this matrix equation. Using R we will code it as

```
G=matrix(c(0.4,-0.2,-0.2,0.3),ncol=2,byrow=TRUE)
Is=c(1,-0.25)
Vn <- solve(G,Is)
```

Note the matrix, current, and voltage vectors are

```
> print(list(G=G,Is=Is,Vn=Vn))
$G
     [,1] [,2]
[1,]  0.4 -0.2
[2,] -0.2  0.3
$Is
[1]  1.00 -0.25
$Vn
[1] 3.125 1.250

>
```

The solution is $\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 3.125 \\ 1.250 \end{bmatrix}$V.

Observe that the current sources can be thought of current *injection* at node 1 and current *export* (or negative injection) at node 2. These values have forced the voltages V_1 and V_2 to acquire the values shown. We can think of power injection at node 1 $P_1 = V_1 I_{s1}$ and power injection (negative or export) at node 2 $P_2 = V_2 I_{s2}$. This terminology becomes useful later when we talk about power flow in the grid.

Example 3.9

Calculate power injected at node 1 as $P_1 = V_1 I_{s1} = 3.125 \times 1 = 3.125$ W and power injected (negative or exported) at node 2 as $P_2 = V_2 I_{s2} = 1.25 \times (-0.25) = -0.3125$ W. The difference of 2.8125 W must be the power dissipated in the circuit. If we calculate the sum of power dissipated in all three resistors, we get $P_{diss} = V_1^2 G_1 + V_2^2 G_3 + (V_2 - V_1)^2 G_2 = 2.8125$ W.

3.3.4 Mesh Analysis

Mesh analysis is the dual of nodal analysis when applied to independent loops (i.e., meshes). Think of the circuit in Figure 3.12 and setting up a system of equations for the unknown currents using KVL

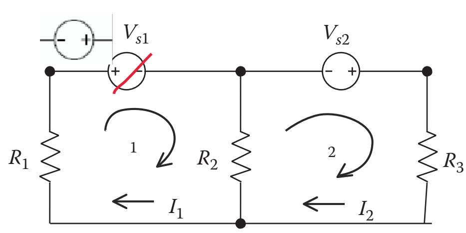

FIGURE 3.12 A simple circuit to explain mesh analysis.

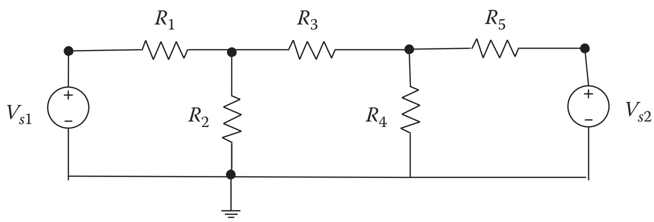

FIGURE 3.24 Circuit to solve by mesh analysis.

What is the power lost in the wires and power delivered to the bulbs? Discuss the results. How could you reduce wire power loss?

3.8. Based on Problem 2.11 from Masters [5], in a home, lights draw 20 A and are on 10 hr every day, and are located about 30 m from the wiring panel. You know that 12-gauge wire can carry this current but you are considering whether to buy 10-gauge wire to save money as potential lower wire loss. Assume "Romex" wire (2 wire + ground) costs \$1.50 per m for 12 gauge and \$2.00 per ~~ft~~ m for 10 gauge, and utility rates are \$0.10 per kWh. How many years (simple payback period) would it take to pay the extra cost of heavier duty wire?

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