EXAMPLE 1.1 Using SI Units and Prefixes for Powers of 10

If a signal can travel in a cable at 80% of the speed of light, what length of cable, in inches, represents 1 ns?

Solution

First, note that $1\text{ ns} = 10^{-9}\text{ s}$. Also, recall that the speed of light $c = 3 \times 10^8\text{ m/s}$. Then, 80% of the speed of light is $0.8c = (0.8)(3 \times 10^8) = 2.4 \times 10^8\text{ m/s}$. Using a product of ratios, we can convert 80% of the speed of light from meters per second to inches per nanosecond. The result is the distance in inches traveled in 1 nanosecond:

$$\frac{2.4 \times 10^8 \text{ meters}}{1 \text{ second}} \cdot \frac{1 \text{ second}}{10^9 \text{ nanoseconds}} \cdot \frac{100 \text{ centimeters}}{1 \text{ meter}} \cdot \frac{1 \text{ inch}}{2.54 \text{ centimeters}}$$

$$= 9.45 \text{ inches/nanosecond.}$$

Therefore, a signal traveling at 80% of the speed of light will cover 9.45 inches of cable in 1 nanosecond.

EXAMPLE 1.2 Relating Current and Charge

No charge exists at the upper terminal of the element in Fig. 1.5 for $t < 0$. At $t = 0$, a 5 A current begins to flow into the upper terminal.

a) Derive the expression for the charge accumulating at the upper terminal of the element for $t > 0$.

b) If the current is stopped after 10 seconds, how much charge has accumulated at the upper terminal?

Solution

a) From the definition of current given in Eq. 1.2, the expression for charge accumulation due to current flow is

$$q(t) = \int_0^t i(x)dx.$$

Therefore,

$$q(t) = \int_0^t 5dx = 5x\Big|_0^t = 5t - 5(0) = 5t\text{ C} \quad \text{for } t > 0.$$

b) The total charge that accumulates at the upper terminal in 10 seconds due to a 5 A current is $q(10) = 5(10) = 50\text{ C}$.

EXAMPLE 1.3 Using the Passive Sign Convention

a) Suppose you have selected the polarity references shown in Fig. 1.6(b). Your calculations for the current and voltage yield the following numerical results:

$$i = 4 \text{ A} \quad \text{and} \quad v = -10 \text{ V}.$$

Calculate the power associated with the circuit element and determine whether it is absorbing or supplying power.

b) Your classmate is solving the same problem but has chosen the reference polarities shown in Fig. 1.6(c). Her calculations for the current and voltage show that

$$i = -4 \text{ A} \quad \text{and} \quad v = 10 \text{ V}.$$

What power does she calculate?

Solution

a) The power associated with the circuit element in Fig. 1.6(b) is

$$p = -(-10)(4) = 40 \text{ W}.$$

Thus, the circuit element is absorbing 40 W.

b) Your classmate calculates that the power associated with the circuit element in Fig. 1.6(c) is

$$p = -(10)(-4) = 40 \text{ W}.$$

Using the reference system in Fig. 1.6(c) gives the same conclusion as using the reference system in Fig. 1.6(b)—namely, that the circuit element is absorbing 40 W. In fact, any of the reference systems in Fig. 1.6 yields this same result.

EXAMPLE 1.4 Relating Voltage, Current, Power, and Energy

Assume that the voltage at the terminals of the element in Fig. 1.5, whose current was defined in Assessment Problem 1.3, is

$$v = 0 \qquad t < 0;$$

$$v = 10e^{-5000t} \text{ kV}, \qquad t \geq 0.$$

a) Calculate the power supplied to the element at 1 ms.

b) Calculate the total energy (in joules) delivered to the circuit element.

Solution

a) Since the current is entering the + terminal of the voltage drop defined for the element in Fig. 1.5, we use a "+" sign in the power equation.

$$p = vi = (10{,}000e^{-5000t})(20e^{-5000t}) = 200{,}000e^{-10{,}000t} \text{ W}.$$

$$p(0.001) = 200{,}000e^{-10{,}000(0.001)} = 200{,}000e^{-10}$$

$$= 200{,}000(45.4 \times 10^{-6}) = 9.08 \text{ W}.$$

b) From the definition of power given in Eq. 1.3, the expression for energy is

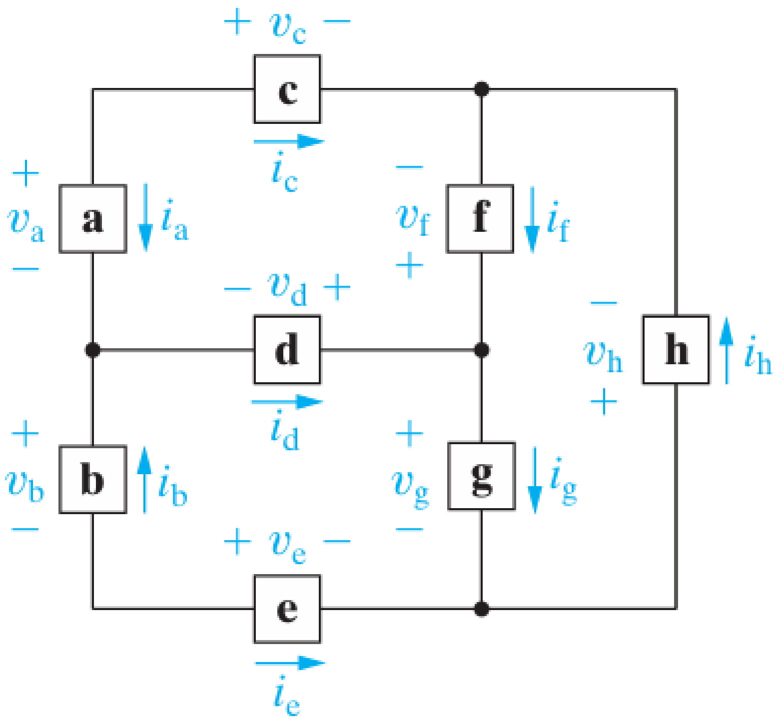
$$w(t) = \int_0^t p(x)dx.$$

To find the total energy delivered, integrate the expresssion for power from zero to infinity. Therefore,

$$w_{\text{total}} = \int_0^\infty 200{,}000e^{-10{,}000x}\,dx = \left.\frac{200{,}000e^{-10{,}000x}}{-10{,}000}\right|_0^\infty$$

$$= -20e^{-\infty} - (-20e^{-0}) = 0 + 20 = 20 \text{ J}.$$

Thus, the total energy supplied to the circuit element is 20 J.



Component	v**(V)**	i**(A)**
a	120	−10
b	120	9
c	10	10
d	10	1
e	−10	−9
f	−100	5
g	120	4
h	−220	−5