406.

Problem 33.13 (RHK)

A solar cell generates a potential difference of $0.10\ \text{V}$ *when a* $500\text{-}\Omega$ *resistance is connected across it and a potential difference of* $0.16\ \text{V}$ *when a* $1000\text{-}\Omega$ *resistance is substituted. We have to find* (a) *the internal resistance and* (b) *the emf of the solar cell.* (c) *The area of the cell is* $5.0\ \text{cm}^2$ *and the intensity of light striking it is* $2.0\ \text{mW cm}^{-2}$. *We have to find the efficiency of the cell for converting light energy to internal energy in the* $1000\text{-}\Omega$ *external resistor.*

Solution:

(a)

Let the emf of the solar cell be $\text{E}\ \text{V}$ and its internal resistance be $r\ \Omega$. The solar cell generates a potential difference of 0.10 V when a $500\text{-}\Omega$ resistor is connected across it. From Ohm's law, we have

$$\frac{\text{E} \times 500\ \Omega}{500\ \Omega + r}\ \text{V} = 0.10\ \text{V}.$$

The other data is that it generates a potential difference of 0.16 V when a 1000-Ω resistance is connected across it. Using this data we write the second equation for determining the values of E and r. It is

$$\frac{\mathrm{E}\times 1000\ \Omega}{1000\ \Omega + r}\ \mathrm{V} = 0.16\ \mathrm{V}.$$

By dividing the two equations we get a linear equation, which can be solved for r. It is

$$\frac{500\ \Omega + r}{1000\ \Omega + r}\times\frac{1000}{500} = \frac{0.16}{0.10},$$

or

$$1000\ \Omega + 2r = 1600\ \Omega + 1.6r,$$

or

$$0.4r = 600\ \Omega,$$

$$\therefore\ \ r = 1500\ \Omega.$$

(b)

The emf of the solar cell is

$$\mathrm{E} = \frac{0.1\times\left(500+1500\right)}{500}\ \mathrm{V} = 0.4\ \mathrm{V}.$$

It is given that the area of the cell is $5.0\ \mathrm{cm}^2$ and the intensity of light striking it is $2.0\ \mathrm{mW\ cm}^{-2}$.

(c)

We will next find the efficiency of the cell for converting light energy to internal energy in the 1000-Ω external resistor. Current flowing through the 1000-Ω resistor connected to the solar cell is

$$i = \frac{0.4\ V}{(1000+1500)\ \Omega} = 0.16\times10^{-3}\ \text{A}.$$

Joule heat in the 1000-Ω resistor will be

$$P = i^2R = \left(0.16\times10^{-3}\right)^2 \times1000\ \text{W} = 2.56\times10^{-5}\ \text{W}.$$

Light energy absorbed by the cell per second is

$$U = \text{area of the cell} \times \text{intensity of light} = 5.0\times2.0\times10^{-3}\ \text{W}$$
$$= 10.0\times10^{-3}\ \text{W}.$$

Therefore, the percentage efficiency of the solar cell for converting light energy into internal energy is

$$e = \frac{2.56\times10^{-5}}{10\times10^{-3}}\times100 = 0.256\%.$$