الجامعة المصرية للتعلم الإلكتروني الأهلية

THE EGYPTIAN E-LEARNING UNIVERSITY

Physics (2)

Section 08

Faculty of Information Technology
Egyptian E-Learning University

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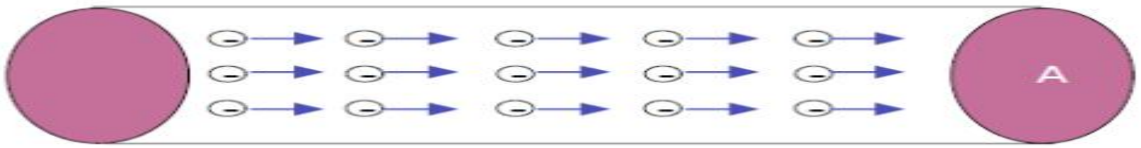
Electric current (I)



We can assume that all electrons travel with constant drift velocity

- The current is defined as the net charge (dq) that passes (perpendicular) through a given area per unit time.

$$I = \frac{dq}{dt}$$ Scalar quantity $$[I] = \frac{[q]}{[t]} = \frac{C}{Sec} = A$$

Materials that obeys Ohm's law are called Ohmic. Example : Metals

$R = \frac{\Delta V}{I}$: Ohm's Law $I = \frac{1}{R}\Delta V$

Conductivity (σ) $R = \frac{\ell}{\sigma A}$ $\sigma = \frac{1}{R}\frac{\ell}{A}$ **Units of σ $= \Omega^{-1}.m^{-1}$**

Resistivity (ρ) $\rho = \frac{1}{\sigma}$ $\rho = R\frac{A}{\ell}$ $R = \rho\frac{\ell}{A}$ **Units of ρ $= \Omega.m$**

The power ***P*** is defined as the rate at which the charge loses energy

$$P = \frac{\Delta U}{\Delta t}$$

$$P = I\,\Delta V = \frac{\Delta V^2}{R} = I^2 R$$

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Q1. **In the Bohr model of the hydrogen atom, an electron in the lowest energy state moves at a speed of 2.19×10^{6} m/s in a circular path of radius 5.29×10^{-11} m. What is the effective current associated with this orbiting electron?**

Solution

The period of the electron in its orbit is $T = 2\pi r / v$, and the current represented by the orbiting electron is

$$I = \frac{\Delta Q}{\Delta t} = \frac{|e|}{T} = \frac{v|e|}{2\pi r}$$

$$= \frac{\left(2.19 \times 10^{6}\ \text{m/s}\right)\left(1.60 \times 10^{-19}\ \text{C}\right)}{2\pi\left(5.29 \times 10^{-11}\ \text{m}\right)}$$

$$= 1.05 \times 10^{-3}\ \text{C/s} = \boxed{1.05\ \text{mA}}$$

Q2. **A 0.900 V potential difference is maintained across a 1.50 m length of tungsten wire that has a cross sectional area of 0.600 mm². What is the current in the wire? Note: $\rho_{tungsten} = 5.60 \times 10^{-8}\ \Omega.m$**

Solution

$\Delta V = IR$ and $R = \dfrac{\rho \ell}{A}$. The area is

$$A = \left(0.600\ \text{mm}^2\right)\left(\frac{1.00\ \text{m}}{1\,000\ \text{mm}}\right)^2 = 6.00 \times 10^{-7}\ \text{m}^2$$

From the potential difference, we can solve for the current, which gives

$$\Delta V = \frac{I\rho\ell}{A} \quad \rightarrow \quad I = \frac{\Delta V A}{\rho \ell} = \frac{(0.900\ \text{V})\left(6.00 \times 10^{-7}\ \text{m}^2\right)}{\left(5.60 \times 10^{-8}\ \Omega \cdot \text{m}\right)(1.50\ \text{m})}$$

$$I = \boxed{6.43\ \text{A}}$$

Q3. **A 100 W lightbulb connected to a 120 V source experiences a voltage surge that produces 140 V for a moment. By what percentage does its power output increase? Assume its resistance does not change.**

Solution

From $P = (\Delta V)^2 / R$, we find that

$$R = \frac{(\Delta V_i)^2}{P} = \frac{(120\ \text{V})^2}{100\ \text{W}} = 144\ \Omega$$

The final current is

$$I_f = \frac{\Delta V_f}{R} = \frac{140\ \text{V}}{144\ \Omega} = 0.972\ \text{A}$$

The power during the surge is

$$P = \frac{(\Delta V_f)^2}{R} = \frac{(140\ \text{V})^2}{144\ \Omega} = \boxed{136\ \text{W}}$$

So the percentage increase is

$$\frac{136\ \text{W} - 100\ \text{W}}{100\ \text{W}} = 0.361 = \boxed{36.1\%}$$

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Q4. **Batteries are rated in terms of ampere-hours (A . h). For example, a battery that can produce a current of 2.00 A for 3.00 h is rated at 6.00 A . h. (a) What is the total energy, in kilowatt-hours, stored in a 12.0 V battery rated at 55.0 A . h? (b) At $0.110 per kilowatt-hour, what is the value of the electricity at dollar that produced by this battery?**

Solution

(a) The total energy stored in the battery is

$$\Delta U_E = q(\Delta V) = It(\Delta V)$$

$$= (55.0\ \text{A}\cdot\text{h})(12.0\ \text{V})\left(\frac{1\ \text{C}}{1\ \text{A}\cdot\text{s}}\right)\left(\frac{1\ \text{J}}{1\ \text{V}\cdot\text{C}}\right)\left(\frac{1\ \text{W}\cdot\text{s}}{1\ \text{J}}\right)$$

$$= 660\ \text{W}\cdot\text{h} = \boxed{0.660\ \text{kWh}}$$

(b) The value of the electricity is

$$\text{Cost} = (0.660\ \text{kWh})\left(\frac{\$0.110}{1\ \text{kWh}}\right) = \boxed{\$0.072\ 6}$$

MSQ

(1)

How much energy is dissipated as heat during a two-minute time interval by a 1.5-kΩ resistor which has a constant 20-V potential difference across its leads?

a. 58 J
b. 46 J
c. 32 J
d. 72 J
e. 16 J

Answer (C)

(2)

How many electrons pass through a 20-Ω resistor in 10 min if there is a potential drop of 30 volts across it?

a. 5.6×10^{21}
b. 7.5×10^{21}
c. 9.4×10^{21}
d. 1.1×10^{21}
e. 3.8×10^{21}

Answer (a)

(3)

A cook plugs a 500 W crockpot and a 1000 W kettle into a 240 V power supply, all operating on direct current. When we compare the two, we find that

a. $I_{crockpot} < I_{kettle}$ and $R_{crockpot} < R_{kettle}$.
b. $I_{crockpot} < I_{kettle}$ and $R_{crockpot} > R_{kettle}$.
c. $I_{crockpot} = I_{kettle}$ and $R_{crockpot} = R_{kettle}$.
d. $I_{crockpot} > I_{kettle}$ and $R_{crockpot} < R_{kettle}$.
e. $I_{crockpot} > I_{kettle}$ and $R_{crockpot} > R_{kettle}$.

Answer (b)

(4)

If 5.0×10^{21} electrons pass through a 20-Ω resistor in 10 min, what is the potential difference across the resistor?

a. 21 V
b. 32 V
c. 27 V
d. 37 V
e. 54 V

Answer (c)