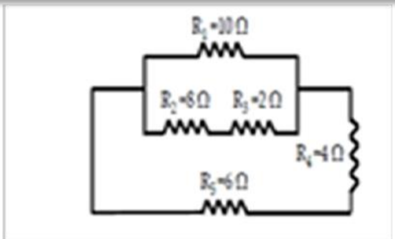
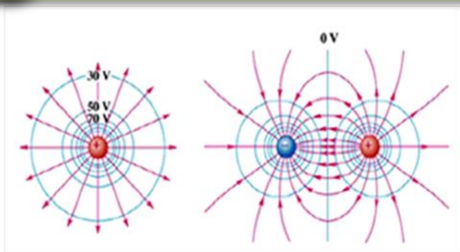
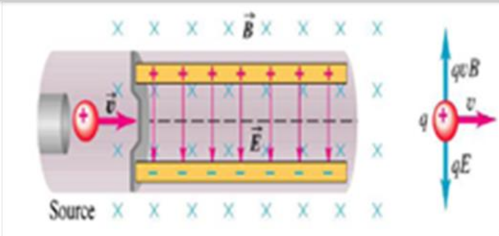
Physics-2







Ch-6

Current and Resistance

يوسـ زويل ـف

Best wishes and good Luck

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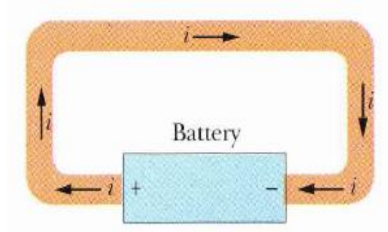
Current and Resistance
التيــار والمقاومــة



Current

$$I = \frac{Q}{t},$$ $$Q = n \cdot e$$ $$e = 1.6\times10^{-14} C$$

n = عدد الالكترونات

I = Current شدة التيار (A)

Q = Charge الشحنة (C)

t = time الزمن

Ex:1 In particular cathode ray tube, the measured beam current is $30 \mu A$.
How many electrons strike the tube screen every $40 S$

a) $7.49\times10^{15} e$ b) $5.92\times10^{15} e$ c) $3.75\times10^{15} e$ d) $1.87\times10^{15} e$

Solution

$I = 30 \times 10^{-6}$ A, $t = 40$ S

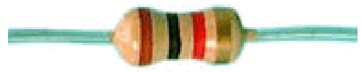
$Q = I \cdot t$

$= 30 \times 10^{-6} \times 40 = 12 \times 10^{-4}$ C

$Q = n \cdot e \quad \Rightarrow n = \dfrac{Q}{e}$

$$= \frac{12 \times 10^{-4}}{1.6 \times 10^{-19}} = 7.5 \times 10^{15} \text{ e}$$

Resistance



Resistance is the characteristic of the conductor that a effects on currents If we apply the same potential difference between the ends of geometrically similar rods of different conductors

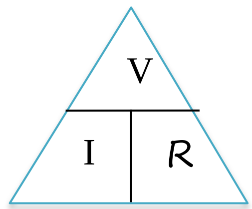
Ohm's Law

$$V = IR \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

V = Potential difference فرق الجهد

R = Resistance المقاومة Ω

I = Current A



Resistivity and Conductivity

$$R = \rho \frac{L}{A} \qquad \sigma = \frac{1}{\rho}$$

L = Length الطول

A = Area مساحة المقطع

ρ = Resistivity $(\Omega.m)$ المقاومة النوعية

σ = Conductivity التوصيلية

$$(\Omega.m)^{-1} = \Omega^{-1}.m^{-1}$$

Ex:2 A wire having a resistance of 3Ω is stretched so that its length is tripled while its volume remains unchanged. The resistance of the stretched wire is:

a) $27\,\Omega$ b) $9\,\Omega$ c) $\frac{1}{3}\,\Omega$ d) $3\,\Omega$

Solution

$R_1 = 3\,\Omega$, its length tripled $\Rightarrow L_2 = 3L_1$

Volume remains unchanged $V_1 = V2$

Volume = $A \cdot L$ $\Longrightarrow A_1 L_1 = A2\, L_2$ $\Longrightarrow A_1 L_1 = A_2\, 3L_1$

$A_1 = 3A_2$

$$\frac{R_1}{R_2} = \frac{\rho \frac{L_1}{A_1}}{\rho \frac{L_2}{A_2}} = \frac{L_1\; A_2}{L_2\; A_1} = \frac{L_1\, A_2}{3L_1\, 3A_2} \Rightarrow \quad \therefore \frac{3}{R_2} = \frac{1}{9} \Rightarrow R_2 = 27\,\Omega$$

Ex:3 A conducting wire is 1m long and 1mm2 cross sectional area. If a current of 4A when a 2 V potential difference is applied between its ends. The conductivity of the material of the wire is:

a) $4\times10^{4}(\Omega m)^{-1}$ b) $3\times10^{-5}(\Omega m)^{-1}$ c) $2\times10^{-6}(\Omega m)^{-1}$ d) $2\times10^{6}(\Omega m)^{-1}$

Solution

$L = 1\text{ m}$, $A = 1\text{ mm}^2 = 1\times10^{-6}\text{ m}^2$

$I = 4\text{ A}$, $V = 2\text{ v}$, $\sigma = ??$

$$R = \frac{V}{I} = \frac{2}{4} = 0.5\,\Omega$$

$$R = \rho\frac{V}{I} \Rightarrow \rho = \frac{R\,A}{L} = \frac{0.5\times10^{-6}}{1} = 5\times10^{-7}\;\Omega\cdot\text{m}$$

$$\sigma = \frac{1}{\rho} = \frac{1}{5\times10^{-7}} = 2\times10^{6}\;(\Omega\cdot\text{m})^{-1}$$

Current density and Electric field strength

$I = n\,e\,V_d\,A$ $\quad J = \dfrac{I}{A}$ $\quad I = \dfrac{q}{t} = A\,J$ $\quad J = n\,e\,V_d$

$E = \dfrac{V}{L}$ $\quad E = \rho J = \dfrac{J}{\sigma}$ $\quad J = \dfrac{E}{\rho} = \sigma E$

J = Current density كثافة التيار A / m^2
A = Area of the surface
n = number of carrier charge (electrons)
عدد حاملات الشحنة (الالكترونات المتحركة) في وحدة الحجم (free electrons)
V_d = Drift speed. سرعة/ الالكترونات المتحركة
E = Electric field strength شدة المجال V/m

Ex:2 A conductor of uniform radius 1.2cm carries a current of 3A produced by an electric field of 120 V/m. what is the resistivity of the material:

a) 0.0181Ω.m. b) 0.027Ω.m. c) 0.034Ω.m. d) 0.054Ω.m.

Solution

$r = 0.012\ m$, $\therefore A = \pi r^2 = \pi (0.012)^2 = 0.0045\ m^2$

$I = 3\ A$, $E = 120\ V/m$

$$J = \frac{I}{A} = \frac{3}{0.0045} = 6631.46\ A/m^2$$

$$E = \rho J \Rightarrow \rho = \frac{E}{J} = \frac{120}{6631.46} = 0.0181\ \Omega \cdot m$$

Ex:3 If a current of 10A pass through a cylindrical wire of silver which the radius of its cross section is $10^{-3} m$. the drift speed of the free electrons if $1m^3$ of silver contains 5.6×10^{28} free electrons.is

a) 3.432×10^{-4} m/s b) 3.432×10^{-4} m/s c) 3.432×10^{-4} m/s d) 3.432×10^{-4} m/s

Solution

$I = 10\ A$, $r = 10^{-3}\ m$, $n = 5.8 \times 10^{28}$, $e = 1.6 \times 10^{-19}$

$A = \pi r^2$ (سلك اسطواني) $= \pi (10^{-3})^2 = 3.14 \times 10^{-6}\ m^2$

$$I = n e V_d A \Rightarrow V_d = \frac{I}{neA} \Longrightarrow V_d = 3.432 \times 10^{-4}\ m/s$$

Temperature and Resistance

$$R_T = R_0\left[1+\alpha(T-T_0)\right]$$
$$\rho_T = \rho_0\left[1+\alpha(T-T_0)\right]$$

$R_T = T$ المقاومة عند الدرجة

$R_0 = T_0$ المقاومة عند الدرجة

$\rho_T = T$ المقاومة النوعية عند الدرجة

$\rho_0 = T_0$ المقاومة النوعية عند الدرجة

α = Temperature coefficient of resistivity المعامل الحراري للمقاومة النوعية

Ex:4 If a copper wire has a resistance of 18Ω at 20^0C, what resistance will it have at 60^0C? (Neglect any change in length or cross sectional area due to change in temperature). $(\alpha_{copper} = 3.9\times10^{-3})$

a) 20.8Ω b) 21.7Ω c) 22.2Ω d) 23.6Ω

Solution

$T_0 = 20^0C$, $R_0 = 18\Omega$, $T = 60^0C$, $R_T = 3.9\times10^{-3}$

$$R_T = R_0\left[1+\alpha(T-T_0)\right]$$

$$= 18\,[1+3.9\times10^{-3}\,(60-20)] = 20.81\ \Omega$$

Electric Energy and Power

$$E = I\,V\,t = I^2\,R\,t = \frac{V^2}{R}\,t \qquad\qquad P = IV = I^2R = \frac{V^2}{R}$$

P = Power القدرة = rate of thermal energy معدل الطاقة الحرارية

E = Energy الطاقة

E = Power. Time

Ex:5 A light bulb rated at 30 W when it is operated at 120V. How many electrons pass in 10min?

a) 9×10^{15} b) 9.4×10^{20} c) 2.2×10^{21} d) 7.8×10^{21}

Solution

P = 30 W , V = 120 V , t= 10 × 60 = 600 S

$$P = I\,V \quad \Rightarrow I = \frac{P}{V} = \frac{30}{120} = 0.25 \text{ A}$$

$$Q = I\cdot t = 0.25 \times 600 = 150 \text{ C}$$

$$Q = n\cdot e \Rightarrow n = \frac{Q}{e} = \frac{150}{1.6\times10^{-19}} = 9.4\times10^{20}$$

Ex:6 Suppose you want to install a heating coil that will convert to heat at a rate of 300W for a current of 1.5A. The resistivity of the coil wire is $10^{-6}\ \Omega.m$ and its diameter is 0.3mm. length of the wire is:

a) 9.42m b) 7.86m c) 5.4m d) 3.4m

Solution

$A = \pi r^2 = \pi\ ((0.15 \times 10^{-3})^2$

$P = 300\ W$, $I = 1.5\ A$, $\rho = 10^{-6}\ \Omega.m$

$$P = I^2 R \Rightarrow R = \frac{P}{I^2} = \frac{300}{(1.5)^2} = 133.3\ \Omega$$

$$R = \rho \frac{L}{A} \Rightarrow L = \frac{R\,A}{\rho} = \frac{133.3 \times 70.7 \times 10^{-9}}{10^{-6}} = 9.42\ m$$

Ex:7 An electric heater operating at full power draws a current of 8A from a 110V circuit. Assuming the resistance remains constant then the current at which the heater dissipated 750 W is:

a) 2.9 A b) 0.74 A c) 4 A d) 7.4 A

Solution

$I = 8\ A$, $V = 110\ v$, $P = 750\ W$

$$R = \frac{V}{I} = \frac{110}{8} = 13.75\ \Omega$$

$$P = I^2 R \quad I^2 = \frac{P}{R} = \frac{750}{13.75} = 54.55$$

$$\therefore I = \sqrt{54.55} = 7.39\ A$$

Ex:8 5-V potential difference is maintained between the ends of a 2m long wire that has a diameter of 0.5mm. If the wire is made of a material has a resistivity of $7 \times 10^{-8}\,\Omega.m$. what is the current in the wire?

a) 3 A b) 9 A c) 7 A d) 5 A

Solution

$$V = 5\,v\,,\ L = 2\,m,\ \rho = 7 \times 10^{-8}\ \Omega \cdot m\,,\ r = 0.25 \times 10^{-3}\ m$$

$$A = \pi r^2 = \pi\,(0.25 \times 10^{-3})^2 = 196.25 \times 10^{-9}\ m^2$$

$$R = \rho \frac{L}{A} = 7 \times 10^{-8} \times \frac{2}{196.35 \times 10^{-9}} = 0.713\ \Omega$$

$$I = \frac{V}{R} = \frac{5}{0.713} = 7\ A$$

Ex:9 If R_1 and R_2 are the resistances of 100 W and 40 W electric bulbs respectively, designed to operate on the same voltage then:

a) $R_1 = 2R_2$ b) $2R_1 = 5R_2$ c) $5R_1 = 2R_2$ d) $2R_1 = R_2$

Solution

$P_1 = 100$ W , $P_2 = 40$ W , $V_1 = V_2$

$$P = \frac{V^2}{R} \Rightarrow \qquad \frac{P_1}{P_2} = \frac{\frac{V_1^2}{R_1}}{\frac{V_2^2}{R_2}} = \frac{V_1^2 R_2}{V_2^2 R_1}$$

$$\therefore \quad \frac{100}{40} = \frac{R_2}{R_1} \Rightarrow \qquad \therefore \quad \frac{R_2}{R_1} = \frac{5}{2} \Rightarrow 5R_1 = 2R_2$$