(HW3)

Direct Electric Current and Resistors

Table 27.1

Resistivities and Temperature Coefficients of Resistivity for Various Materials

Material	Resistivity[a] $(\Omega \cdot m)$	Temperature Coefficient[b] $\alpha[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[c]	1.50×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon	640	-75×10^{-3}
Glass	10^{10} to 10^{14}	
Hard rubber	$\sim 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

[a] All values at 20°C.

1. In a particular cathode ray tube, the measured beam current is 30.0 μA. How many electrons strike the tube screen every 40.0 s?

$$I = \frac{\Delta Q}{\Delta t} \qquad \Delta Q = I\Delta t = (30.0 \times 10^{-6}\ \text{A})(40.0\ \text{s}) = 1.20 \times 10^{-3}\ \text{C}$$

$$N = \frac{Q}{e} = \frac{1.20 \times 10^{-3}\ \text{C}}{1.60 \times 10^{-19}\ \text{C/electron}} = \boxed{7.50 \times 10^{15}\ \text{electrons}}$$

15. 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 mm^2. What is the current in the wire?

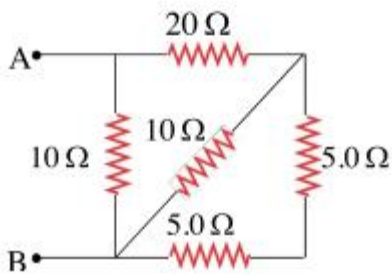
$$\Delta V = IR$$

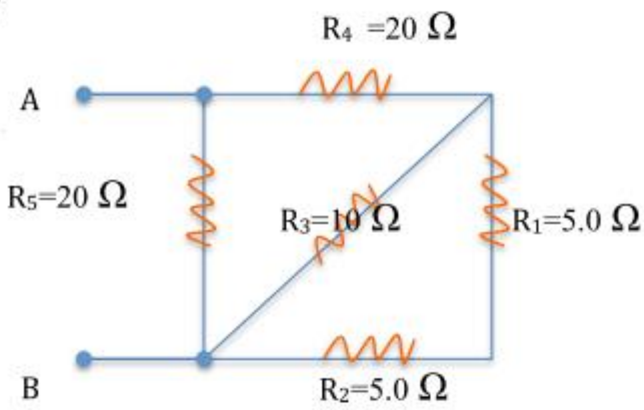
and $\quad R = \frac{\rho \ell}{A}$: $\qquad A = (0.600\ \text{mm})^2 \left(\frac{1.00\ \text{m}}{1\,000\ \text{mm}} \right)^2 = 6.00 \times 10^{-7}\ \text{m}^2$

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

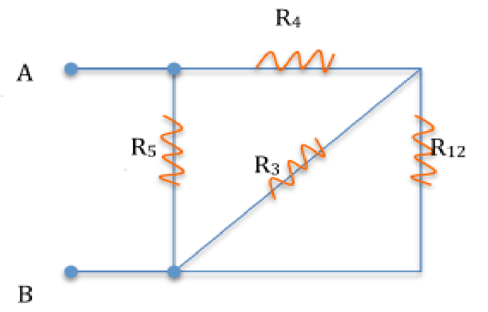
$$I = \boxed{6.43\ \text{A}}$$

Calculate the effective resistance between the points A and B in the figure below.



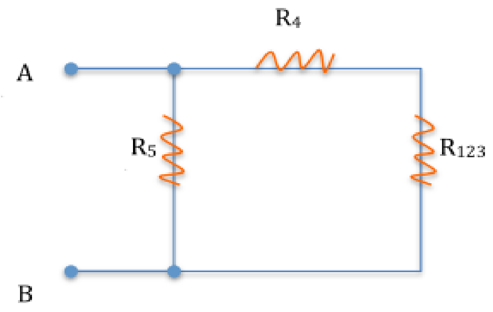


R_1=5Ω , R_2=5Ω, R_3=10Ω, R_4=20Ω. R_5=10Ω

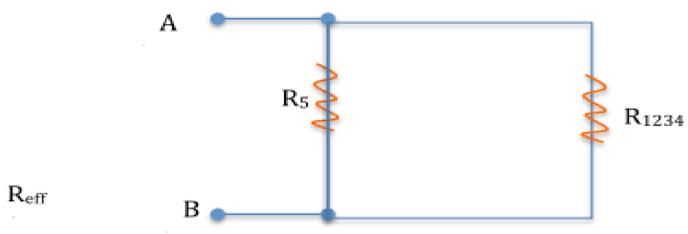


R_1 and R_2 are conncted in Series, Thus R_{12} is
$R_{12} = R_1 + R_2 = 10\Omega$
since R_{12} and R_3 are conncted in Parallel, Thus R_{123} is

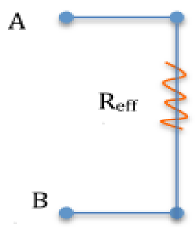
$$\frac{1}{R_{123}} = \frac{1}{\mathrm{R}_{12}} + \frac{1}{\mathrm{R}_3} \Rightarrow \frac{1}{R_{123}} = \frac{1}{10} + \frac{1}{10}$$
$$R_{123} = 5\Omega$$



R_{123} and R_4 are conncted in Series, Thus R_{1234} is
$R_{1234} = R_{123} + R_4 = 5+20=25\Omega$



since R_{1234} and R_5 are conncted in Parallel, Therefore the effective resisterse R_{eff} is given by



$$\frac{1}{R_{eff}} = \frac{1}{\mathrm{R}_{1234}} + \frac{1}{\mathrm{R}_5} \Rightarrow \frac{1}{R_{123}} = \frac{1}{25} + \frac{1}{10}$$
$$R_{12345} = 7.14\Omega$$

2. A copper wire has a resistance of 25 mΩ at 20 ° C. When the wire is carrying a current, heat produced by the current causes the temperature of the wire to increase by 27 ° C
(a). Calculate the change in the wire's resistance.
(b). If its original current was 10.0 mA and the potential difference across wire remains constant, what is its final current? (Given the temperature coefficient of resistivity for copper is 6.80x10 -3 ° C -1).

(a) $R_0 = 25m\Omega$

$T_0 = 20^0C \qquad \Delta T = 27^0C$

$\propto = 6.80\times10^{-3}C^{-1}$

By using the equation for R123 temperature variation of resistance thus

$R = R_0(1+\propto \Delta T) \Rightarrow R - R_0 = R_0 \propto \Delta T$

$\Rightarrow \Delta R = R_0 \propto \Delta T = 25\times10^{-3}\times6.80\times10^{-3}\times(27-20) = 1.19\times10^{-3}\Omega$

(b) $I_0 = 10mA$

$V \text{ is constant}$

By using equation for equation for temperature variation of resistance

$R = R_0(1+\propto \Delta T) \quad where \ R = \frac{V}{I}$

$\Rightarrow \frac{V}{I} = \frac{V}{I_0}(1+\propto \Delta T)$ but

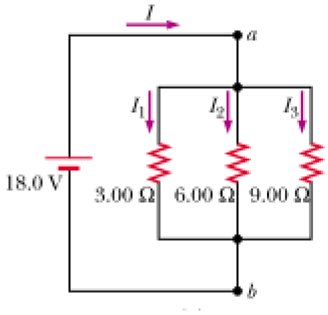
$V \text{ is constant}$

$\Rightarrow \frac{1}{I} = \frac{1}{I_0}(1+\propto \Delta T)$

$\Rightarrow \frac{1}{I} = \frac{1}{10\times10^{-3}}(1 + 6.80\times10^{-3}\times7)$

$\Rightarrow I = 9.54 \times10^{-3}A$

Three resistors are connected in parallel as shown in the figure below, A potential difference of 18.0V is maintained between points *a* and *b*.



(a). Find the current in each resistor.
(b). Calculate the power delivered to each resistor.

(a) V=18V R₁=3Ω , R₂=6Ω, R₃=9Ω,

$$I_1 = \frac{V}{R_1} = \frac{18}{3} = 6A$$
$$I_2 = \frac{V}{R_2} = \frac{18}{6} = 3A$$
$$I_3 = \frac{V}{R_3} = \frac{18}{9} = 2A$$

(b)

$$P_1 = I_1^2 R_1 = (6)^2(3) = 108\Omega$$
$$P_2 = I_2^2 R_2 = (3)^2(6) = 54\Omega$$
$$P_3 = I_3^2 R_3 = (2)^2(9) = 36\Omega$$

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35. The temperature of a sample of tungsten is raised while a sample of copper is maintained at 20.0°C. At what temperature will the resistivity of the tungsten be four times that of the copper?

$\rho = \rho_0(1 + \alpha \Delta T)$ or $\qquad \Delta T_W = \frac{1}{\alpha_W}\left(\frac{\rho_W}{\rho_{0W}} - 1\right)$

Require that $\rho_W = 4\rho_{0_{Cu}}$ so that $\qquad \Delta T_W = \left(\frac{1}{4.50 \times 10^{-3}/°C}\right)\left(\frac{4(1.70 \times 10^{-8})}{5.60 \times 10^{-8}} - 1\right) = 47.6°C$.

Therefore, $\qquad T_W = 47.6°C + T_0 = \boxed{67.6°C}$.

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39. What is the required resistance of an immersion heater that increases the temperature of 1.50 kg of water from 10.0°C to 50.0°C in 10.0 min while operating at 110 V?

The heat that must be added to the water is

$$Q = mc\Delta T = (1.50\ \text{kg})(4\,186\ \text{J/kg}^\circ\text{C})(40.0^\circ\text{C}) = 2.51 \times 10^5\ \text{J}.$$

Thus, the power supplied by the heater is

$$\mathcal{P} = \frac{W}{\Delta t} = \frac{Q}{\Delta t} = \frac{2.51 \times 10^5\ \text{J}}{600\ \text{s}} = 419\ \text{W}$$

and the resistance is $R = \frac{(\Delta V)^2}{\mathcal{P}} = \frac{(110\ \text{V})^2}{419\ \text{W}} = \boxed{28.9\ \Omega}$.

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41. Suppose that a voltage surge produces 140 V for a moment. By what percentage does the power output of a 120-V, 100-W lightbulb increase? Assume that its resistance does not change.

$$\frac{\mathcal{P}}{\mathcal{P}_0} = \frac{(\Delta V)^2/R}{(\Delta V_0)^2/R} = \left(\frac{\Delta V}{\Delta V_0}\right)^2 = \left(\frac{140}{120}\right)^2 = 1.361$$

$$\Delta\% = \left(\frac{\mathcal{P} - \mathcal{P}_0}{\mathcal{P}_0}\right)(100\%) = \left(\frac{\mathcal{P}}{\mathcal{P}_0} - 1\right)(100\%) = (1.361 - 1)100\% = \boxed{36.1\%}$$

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51. A certain toaster has a heating element made of Nichrome wire. When the toaster is first connected to a 120-V source (and the wire is at a temperature of 20.0°C), the initial current is 1.80 A. However, the current begins to decrease as the heating element warms up. When the toaster reaches its final operating temperature, the current drops to 1.53 A. (a) Find the power delivered to the toaster when it is at its operating temperature. (b) What is the final temperature of the heating element?

At operating temperature,

(a) $\mathcal{P} = I\Delta V = (1.53\text{ A})(120\text{ V}) = \boxed{184\text{ W}}$

(b) Use the change in resistance to find the final operating temperature of the toaster.

$$R = R_0(1 + \alpha\Delta T) \qquad \frac{120}{1.53} = \frac{120}{1.80}\left[1 + \left(0.400 \times 10^{-3}\right)\Delta T\right]$$

$$\Delta T = 441°\text{C} \qquad T = 20.0°\text{C} + 441°\text{C} = \boxed{461°\text{C}}$$