

ENGG2120 Fall 2011

Chapter 18 Assignment with Answers

1. Define Ohm's Law.

Ans:

Ohm's law is defined as

The potential difference (voltage) across a conductor is proportional to current passing through it.

$$V \propto I$$

$$V = IR$$

The constant of proportionality is called "resistance", R

Where,

V is applied voltage

I is measured current

R is resistance of the material

2. Consider a copper wire of length l and area of cross section A which has resistance R. What is the resistance of copper wire, if length is doubled and area of cross section is halved?

Ans:

Resistance of material is given by $R = \frac{\rho l}{A}$

Initial length = l

Initial area of cross section = A

Initial resistance is given by $R_i = \frac{\rho l}{A}$

Final length = $2l$

Final area of cross section = $A/2$

Final resistance of wire is

$$R_f = \frac{\rho 2l}{A/2} = 4 \frac{\rho l}{A} = 4R_i$$

The resistance of wire increases by 4 times

3. A silver metallic wire is in the form of a circular ring of radius 1 m and has area of cross section 1 mm^2 . Find the resistance of the wire? (Conductivity of wire is given by $6.8 \times 10^7 (\Omega \cdot \text{m})^{-1}$)

Ans:

Given radius of circular ring = 1 m

Total length of circular ring wire = $2\pi (1 \text{ m}) = 2\pi = 2 \times 3.14 = 6.28 \text{ m}$

Area of cross section = $1 \text{ mm}^2 = 10^{-6} \text{ m}^2$

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A}$$

$$R = \frac{l}{\sigma A} = \frac{6.28 \text{ m}}{(6.8 \times 10^7 (\Omega \cdot \text{m})^{-1})(10^{-6} \text{ m}^2)} = 0.0923 \Omega$$

4. An aluminum wire 8 mm in diameter is to offer a resistance of no more than 2.5Ω . Compute the maximum wire length. The conductivity of aluminum is given by $3.8 \times 10^7 (\Omega \cdot \text{m})^{-1}$.

Ans:

This problem asks us that we compute, for an aluminum wire 8 mm in diameter, the maximum length such that the resistance will not exceed 2.5Ω . Given conductivity of aluminum $\sigma = 3.8 \times 10^7 (\Omega \cdot \text{m})^{-1}$. If d is the diameter then

Combining Equations $l = \frac{RA}{\rho}$ and $\sigma = \frac{1}{\rho}$

Area of cross section $A = \pi \left(\frac{d}{2} \right)^2$

$$l = \frac{RA}{\rho} = R\sigma A = R\sigma \pi \left(\frac{d}{2} \right)^2$$

$$= (2.5 \Omega) [3.8 \times 10^7 (\Omega \cdot \text{m})^{-1}] \left[\pi \left(\frac{8 \times 10^{-3} \text{ m}}{2} \right)^2 \right] = 4772 \text{ m}$$

5. For non-metallic materials, what is the name of the region that lies between the valence and conduction bands?

Ans:

Energy band gap

6. Compute the electrical conductivity of a 5.1 mm diameter cylindrical silicon specimen 51 mm long in which a current of 0.5 A passes in an axial direction. A voltage of 25 V is measured across two probes that are separated by 38 mm.

Ans:

Electrical conductivity can be written as

$$\sigma = \frac{1}{\rho} = \frac{Il}{VA} = \frac{Il}{V\pi\left(\frac{d}{2}\right)^2}$$

Where,

σ - Conductivity

ρ - Resistivity,

V- Measured voltage (25V)

A- Area of the specimen ($A = \pi r^2$, where $r = d/2 = 5.1/2$ mm)

I- Current (0.5A)

l- Measuring length (38mm)

Incorporating the above values in the given equation leads to

$$\sigma = \frac{(0.5A)(38 \times 10^{-3} m)}{(25V)(\pi)\left(\frac{5.1 \times 10^{-3} m}{2}\right)^2} = 37.25 (\Omega \cdot m)^{-1}$$

The electrical conductivity of the given silicon specimen is $37.25 (\Omega \cdot m)^{-1}$

7. What is the distinction between electronic and ionic conduction?

Ans:

When a current arises from a flow of electrons, the conduction is termed electronic. When the current arises from ionic conduction, the net motion of charged ions the conduction is known as ionic conduction.

8. In terms of electron energy band structure, discuss reasons for the difference in electrical conductivity between metals, semiconductors, and insulators.

Ans:

For metallic materials, there are vacant electron energy states adjacent to the highest filled state; thus, very little energy is required to excite large numbers of electrons into conducting states. These electrons are those that participate in the conduction process, and, because there are so many of them, metals are good electrical conductors.

There are no empty electron states adjacent to and above filled states for semiconductors and insulators, but rather, an energy band gap across which electrons must be excited in order to participate in the conduction process. Thermal excitation of electrons will occur, and the number of electrons excited will be less than for metals, and will depend on the band gap energy. For semiconductors, the band gap is narrower than for insulators.

9. Write the difference between resistance and resistivity?

Ans:

Resistivity is measure of how well a particular material opposes an electric current, where as resistance measures how well a particular component in electric network resists in an electric current.

Resistance depends on dimensions of the material where as resistivity is independent of dimensions. Resistivity is inherent property of a particular material.

10. Match the followings

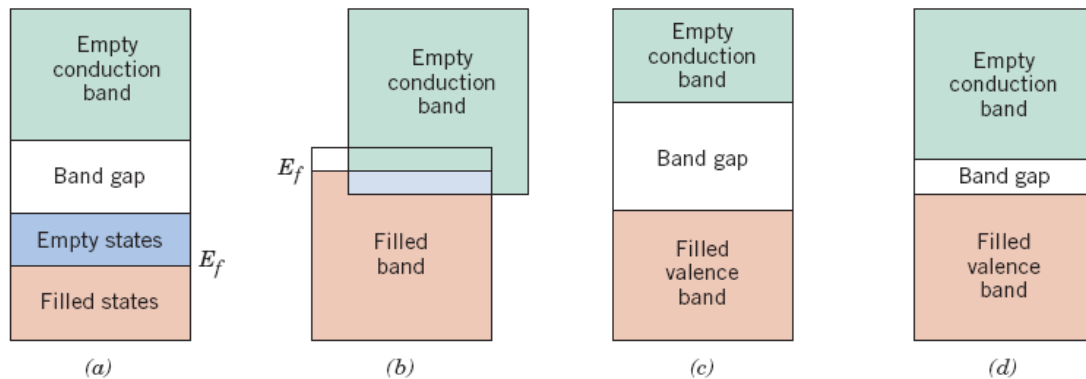
- | | |
|------------------------------|--------------------------|
| (a) Sodium Chloride Solution | - (1) Semiconductor |
| (b) Platinum | - (2) Ionic Conductor |
| (c) Nylon | - (3) Metallic Conductor |
| (d) Doped Silicon | - (4) Insulator |

Ans:

(a) – (2), (b) – (3), (c) – (4), (d) – (1)

11. Draw the possible electron band structure for metal, semiconductor and insulators.

Ans:



(a) - **The electron band structure of metals like copper**, in which there are available electron states above and adjacent to filled states, in the same band.

(b) - **The electron band structure of metals such as magnesium**, wherein there is an overlap of filled and empty outer bands.

(c) - **The electron band structure of insulators**, the filled valence band is separated from the empty conduction band by a relatively large band gap (> 2 eV).

(d) - **The electron band of semiconductors**, which is the similar as for insulators except that the band gap is relatively narrow (< 2 eV).

12. A copper wire 100 m long must experience a voltage drop of less than 6 V when a current of 5 A passes through it. Compute the minimum diameter of wire. ($\sigma = 12.0 \times 10^7 (\Omega\text{-m})^{-1}$)

Ans:

For this problem, given that a copper wire 100 m long must experience a voltage drop of less than 6 V when a current of 5 A passes through it, we have to compute the minimum diameter of the wire.

$$A = \frac{Il\rho}{V} = \frac{Il}{V\sigma}$$

For copper $\sigma = 12 \times 10^7 (\Omega\text{-m})^{-1}$. Furthermore, Cross sectional area $A = \pi\left(\frac{d}{2}\right)^2$ for a cylindrical wire, then

$$\pi\left(\frac{d}{2}\right)^2 = \frac{Il}{V\sigma}$$

or

$$d = \sqrt{\frac{4Il}{\pi V\sigma}}$$

When values for the several parameters given in the problem statement are incorporated into this expression, we get

$$\begin{aligned} d &= \sqrt{\frac{(4)(5A)(100m)}{(\pi)(6V)[12.0 \times 10^7 (\Omega\text{-m})^{-1}]} } \\ &= 1.329 \times 10^{-3} \text{ m} = 1.329 \text{ mm} \end{aligned}$$

13. With respect to the conductivity which of the following is correct

- (a) Silver > Copper > Iron
- (b) Copper > Silver > Iron
- (c) Iron > Copper > Silver
- (d) Copper > Iron > Silver

Ans:

(a) Silver > Copper > Iron

14. Compute the resistance of a copper wire 6 mm in diameter and 4 m long. Given conductivity of copper is $6.0 \times 10^7 (\Omega\text{-m})^{-1}$.

Ans:

In order to compute the resistance of this copper wire it is necessary to combine equations

$$R = \frac{\rho l}{A} \text{ and } \sigma = \frac{1}{\rho}$$

$$\text{Area of cross section } A = \pi \left(\frac{d}{2} \right)^2$$

Solving for the resistance in terms of the conductivity,

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A} = \frac{l}{\sigma \pi \left(\frac{d}{2} \right)^2}$$

Given conductivity of copper is $6.0 \times 10^7 (\Omega\text{-m})^{-1}$, and

$$\begin{aligned} R &= \frac{l}{\sigma \pi \left(\frac{d}{2} \right)^2} = \frac{4\text{m}}{[6.0 \times 10^7 (\Omega\text{-m})^{-1}] \left[\pi \left(\frac{6 \times 10^{-3} \text{m}}{2} \right)^2 \right]} \\ &= 2.35 \times 10^{-3} \Omega \end{aligned}$$