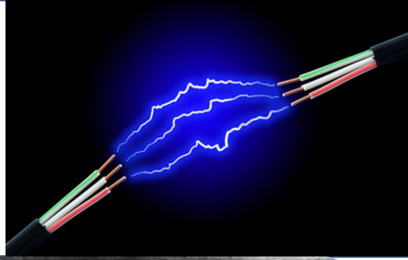
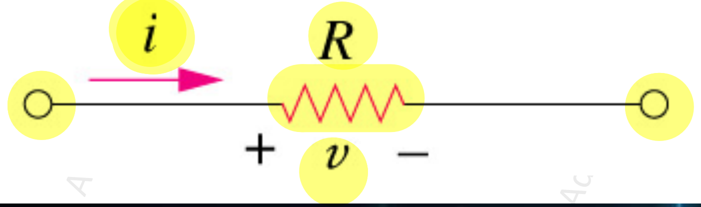
ELEC201: Electric Circuits

UNIT 2: Basic Laws

OHMS LAW



- **Georg Simon Ohm**, a German physicist is credited with finding the relation between current and voltage for a resistor.
- This relationship is called *Ohm's Law*
- Ohm's Law states that the voltage, (V) across a resistor is directly proportional to the current, (I) flowing through the resistance.
- The constant of proportionality is the resistance R.
- The resistance of an element is measured in units of Ohms Ω, (V/A)



$$v = iR \qquad \text{or } i = \frac{v}{R}$$

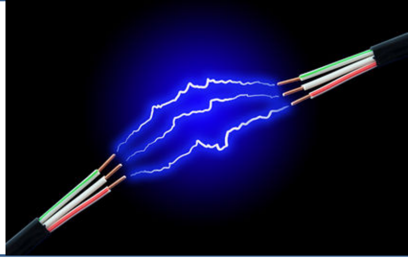
V = IR

Georg Simon Ohm

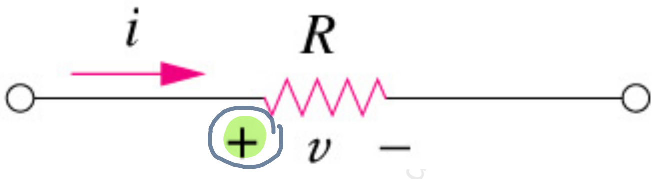
Ohm's Law

$$\boxed{V = IR}$$

Ohm's Law



- The higher the resistance, the less current will flow through for a given voltage.
- Ohm's law requires conforming to the passive sign convention.
  - When the current is entering the resistance from the positive sign, then $v=iR$.
  - When the current is leaving the resistance from the positive sign, then $v=-iR$.
  - The positive sign of a current is always when it flows in the direction from + (high potential) to – (lower potential) across a resistance.



$$v = iR$$

$$i = \frac{v}{R}$$

$$v = +iR$$

$$v = -iR$$

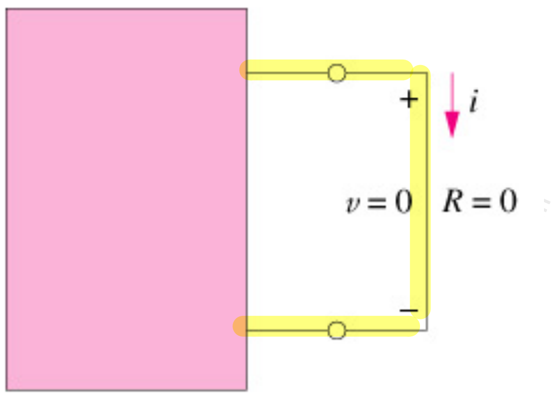
Short and Open Circuits

The value of *R* can range from zero to infinity.

An element with *R*=0 is a short circuit →

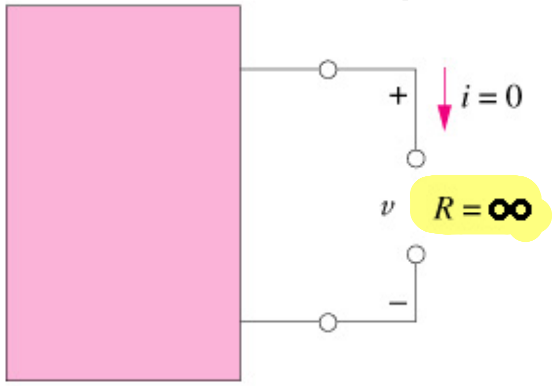
Ideally, any current may flow through the short.

In practice this is just a connecting wire.

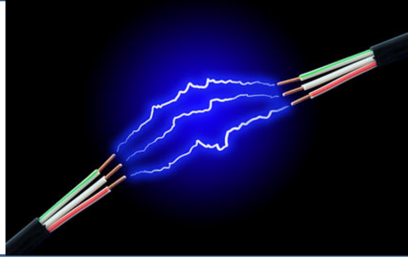


An element with *R*=∞ is a open circuit →

Here no matter the voltage, no current flows.

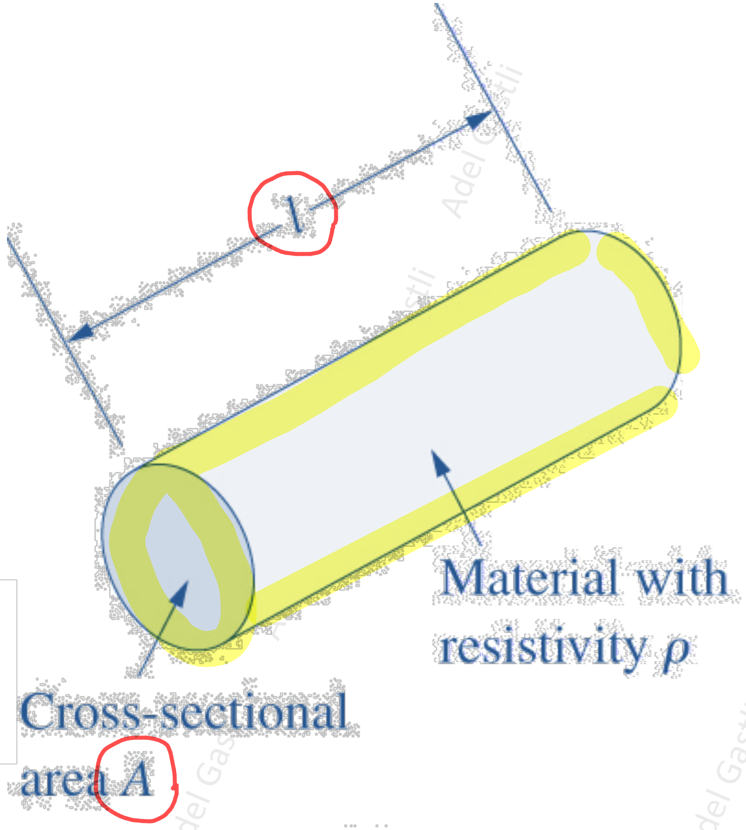


Resistivity/Resistance



- Materials tend to resist the flow of electricity through them.
- This property is called "**resistance**".
- The resistance of an object is a function of its length, *l*, and cross-sectional area, *A*, and the material's **resistivity**, ρ:

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

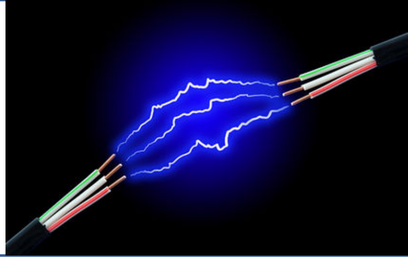


ρ = *resistivity of the material in (ohm – meter)*

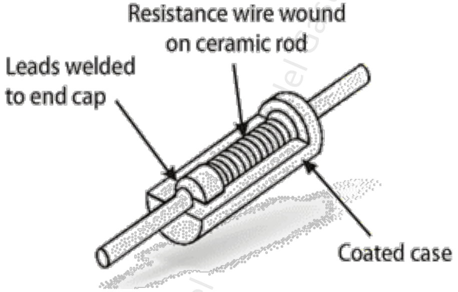
ℓ = *length of the material in (meter)*

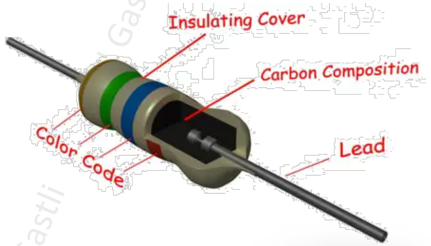
A = *Cross sectional area in* $(meter^2)$

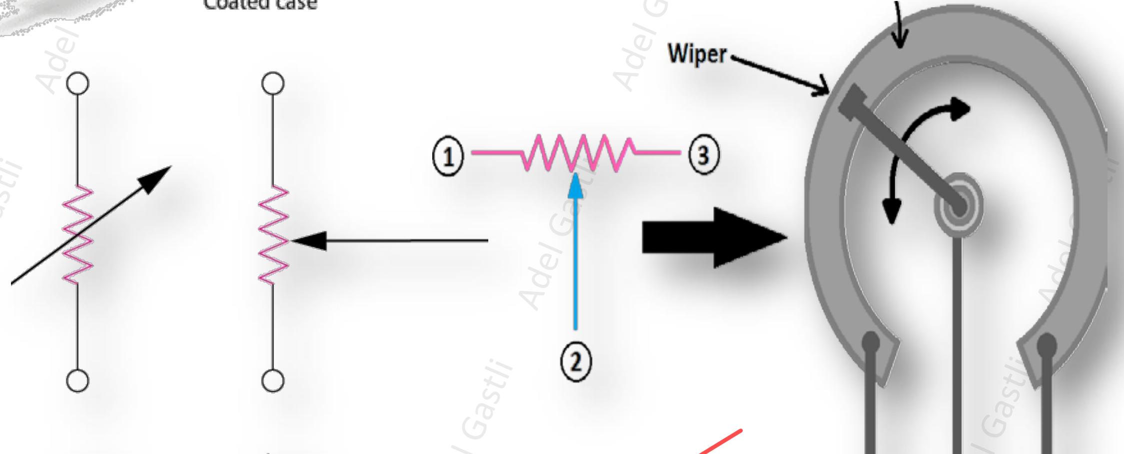
Resistivity/Resistance



- Good conductors like copper and aluminum have low resistivities, while insulators such as mica and paper have high resistivities.
- Resistances are usually made from metallic alloys and carbon compounds.
- A resistor is either fixed or variable.
  - Fixed Resistors have a constant value.
  - Common types of fixed resistance:
    - Wire wound
    - Composition
  - Variable resistors have adjustable resistance
  - Common types of variable resistance:
    - Potentiometer

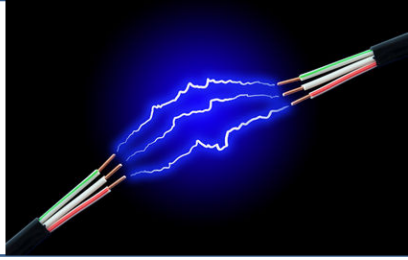


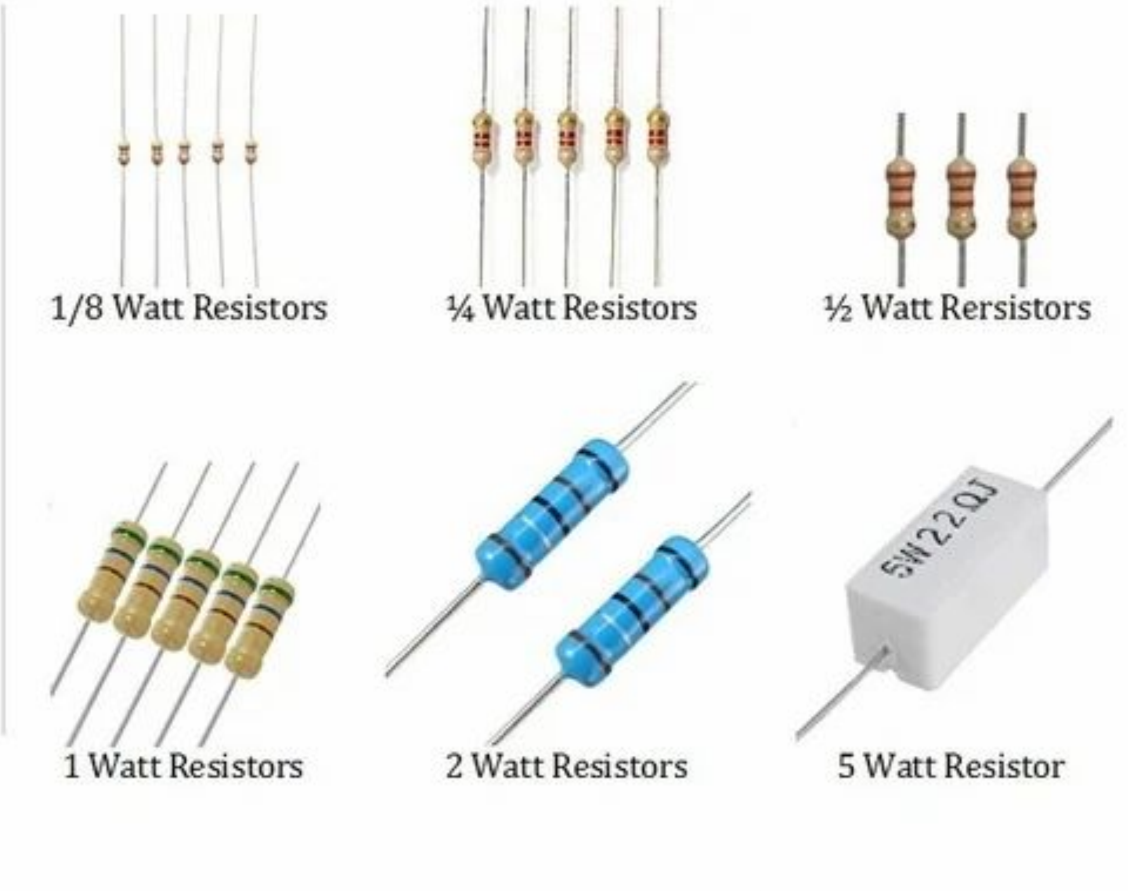




(a) (b)

Resistivity/Resistance





Fixed Resistances

Variable Resistances

Resistivity of Common Materials

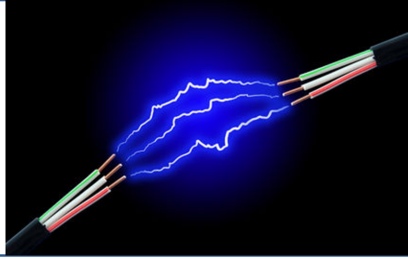


TABLE 2.1

Resistivities of common materials.

Material	Resistivity ($\Omega \cdot m$)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

$$\underbrace{V}_{Volt} = \overbrace{I}^{A}\,\underbrace{R}_{\Omega} \Rightarrow R = V/I$$

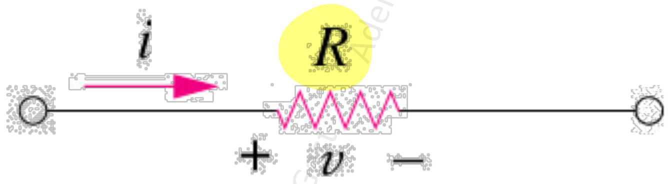
Reciprocal of resistance is called conductance:

$$G = 1/R = \frac{I}{V} \quad \left(\frac{1}{\Omega}\right)$$

Conductance is the ability of an element to conduct electric current, it is measured in mhos (℧) or siemens (S) =1/Ω

POWER DISSIPATION IN RESISTOR

- Running current through a resistor dissipates power.



$$P = vi = i^2R = v^2/R$$

- The power dissipated is a non-linear function of current or voltage.
- Power dissipated is always positive.
- A resistor can never generate power.

Example 2.1 An electric iron draws 2 A at 120 V. Find its resistance.

Solution:

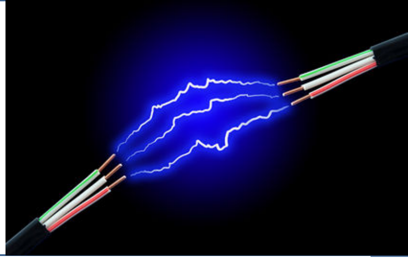
From Ohm's law,

$V = IR$

$R = V/I = \frac{120}{2} = 60\ \Omega$

Practice Problem 2.1 The essential component of a toaster is an electrical element (a resistor) that converts electrical energy to heat energy. How much current is drawn by a toaster with resistance 15 Ω at 110 V?

Answer: $I = V/R = \frac{110}{15} = 7.333\ A$



Example 2.2

In the circuit shown in Fig. 2.8, calculate the current i, the conductance G, and the power p.

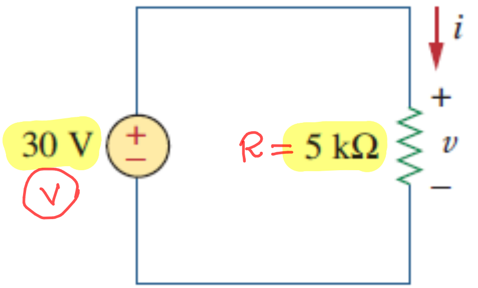


Figure 2.8
For Example 2.2.

Solution:

The voltage across the resistor is the same as the source voltage (30 V) because the resistor and the voltage source are connected to the same pair of terminals. Hence, the current is

$$V = iR$$

$$i = V/R = \boxed{\frac{30}{5 * 10^{3}} = 6 * 10^{-3} \text{ (A)} = 6 \text{ mA}}$$

The conductance is

$$G = 1/R = \frac{1}{5 * 10^{3}} = \boxed{0.2 * 10^{-3} \ \Omega^{-1}}$$

We can calculate the power in various ways using either Eqs. (1.7), (2.10), or (2.11).

or $p = Vi = 30 * 6 * 10^{-3} = 180 * 10^{-3}$ Watt $= 180$ MW

or $p = i^2 R$

$p = V^2/R$

Practice Problem 2.2

For the circuit shown in Fig. 2.9, calculate the voltage v, the conductance G, and the power p.

Answer: $V = IR = 3 * 10^{-3} * 10 * 10^{3} = 30$ V

$G = 1/R = \frac{1}{10 * 10^{3}} = 0.1 * 10^{-3}\ \Omega^{-1}$

$P = VI = 30 * 3 = 90$ MW

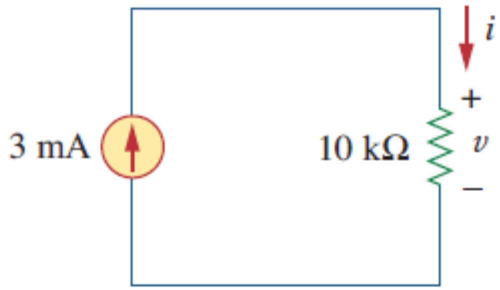
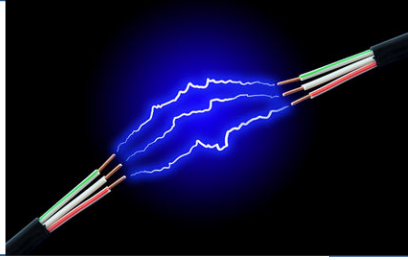


Figure 2.9
For Practice Prob. 2.2



Example 2.3

A voltage source of $20 \sin \pi t$ V is connected across a 5-kΩ resistor. Find the current through the resistor and the power dissipated.

Solution:

$V = iR$

$$i = \frac{V}{R} = \frac{20 \sin \pi t}{5 * 10^3} = 4 * \cancel{10^{-3}} \sin \pi t \rightarrow \cancel{A} = 4 \sin \pi t \ \text{mA}$$

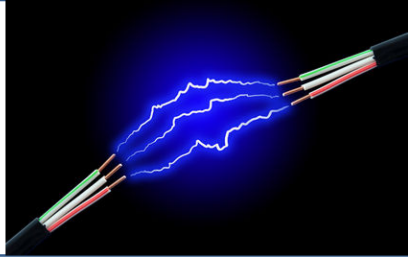
Hence,

$$p = vi = 20 \sin \pi t * 4 \sin \pi t = 80 \sin^2 \pi t \ \text{mW}$$

Practice Problem 2.3

A resistor absorbs an instantaneous power of $30 \cos^2 t$ mW when connected to a voltage source $v = 15 \cos t$ V. Find i and R.

Answer:



Practice Problem

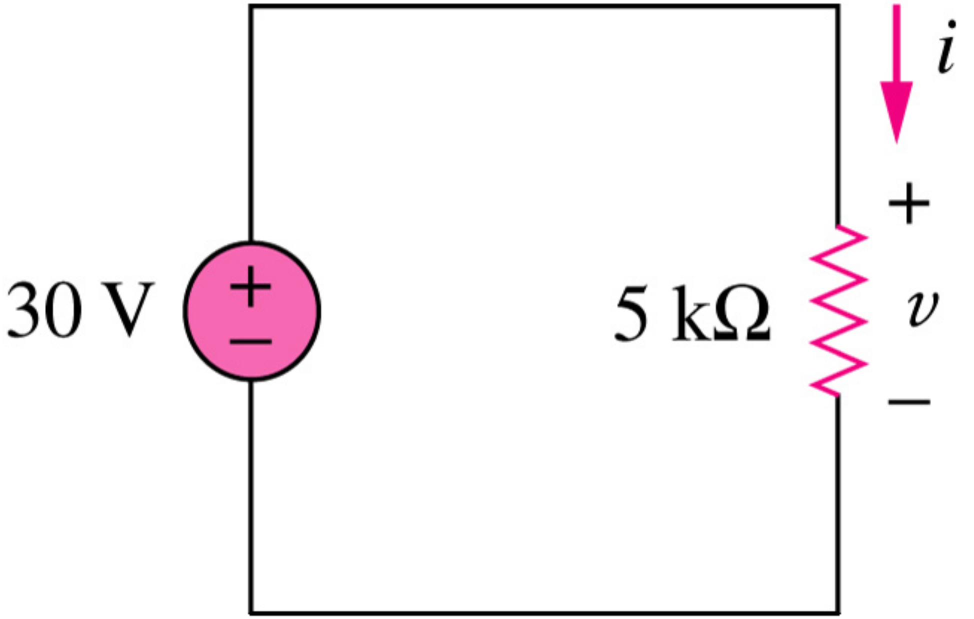
- In the circuit shown below, calculate the current *i*, the conductance *G,* and the power *p*.

$I = V/R =$

$G =$

$P =$

$=$

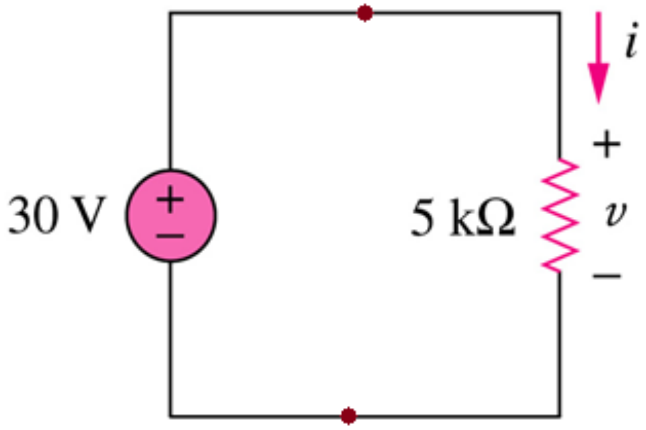


SOLUTION:

Voltage across resistor = Voltage across source

→ Voltage across resistor = *30 V*

connected to the same two points.



$$I = \frac{V}{R} = \frac{30}{5\times10^{3}} = 6\times10^{-3}\ \text{A} = 6\ \text{mA}$$ (Ohm's Law)

$$G = \frac{1}{R} = \frac{1}{5\times10^{3}} = 0.2\times10^{-3}\ \text{S} = 0.2\ \text{mS}$$ (Conductance)

$$p = VI = I^2R = \frac{V^2}{R} = V^2G = 30^2\times0.2\times10^{-3} = 180\ \text{mW}$$

Practice Problem

- A resistor absorbs an instantaneous power of $p=20\cos^2 t$ mW when connected to a voltage source $v = 10\cos t$ V. Find I and R.

$$p = vi \Rightarrow i = \frac{p}{v}$$

$$i = \frac{20\cos^2 t \ \text{mW}}{10\cos t \ \text{V}} = 2\cos t \ \text{mA}$$

$$R = \frac{v}{i} = \frac{10\cos t \ V}{2\cos t \ mA} = 5\,k\Omega$$

END OF LECTURE #1