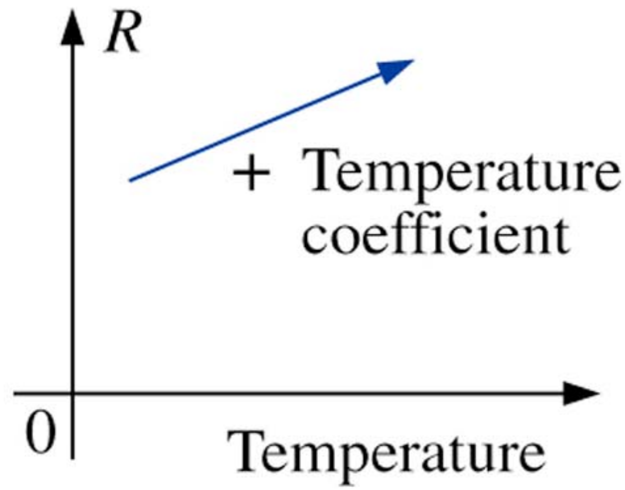
Today’s Lecture

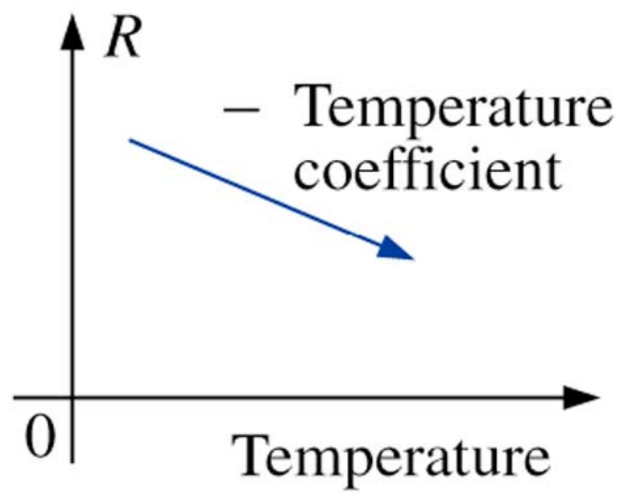
- Temperature Effects
- Superconductors
- Conductance
- Ohmmeters
- Thermistors / Photo Cell / Varistors

Temperature Effects - Recall

- For conductors, an increase in temperature results in an increase in resistance. Consequently, conductors have a positive temperature coefficient.



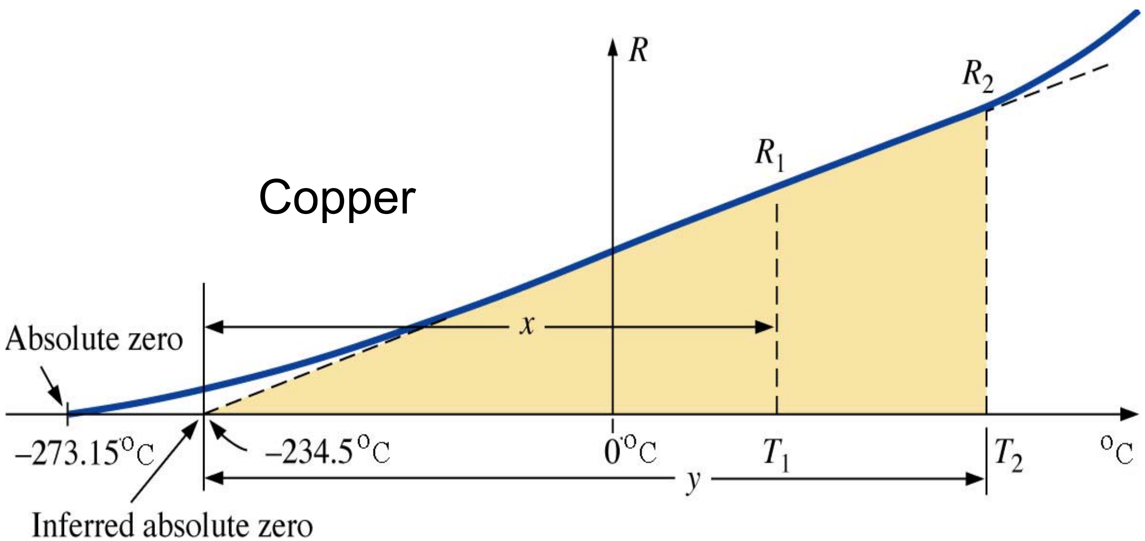
- For insulators & semiconductors, an increase in temperature results in a decrease in resistance. Consequently, insulators and semiconductors have a negative temperature coefficient.



Inferred Absolute Temperature

- Used to determine the resistance at any temperature

$$\frac{|T_{ABS}| + T_1}{R_1} = \frac{|T_{ABS}| + T_2}{R_2}$$



Material	T_{ABS} (°C)
Silver	-234.0
Copper	-234.5
Gold	-274
Aluminum	-236
Tungsten	-204
Nickel	-147
Iron	-162
Nichrome	-2,250
Constantan	-125,000

Example - Inferred Absolute Temperature

The resistance of a length of aluminum wire is 4 Ω at 70°F, what is its resistance at 20°F ?

$$\text{Temp}_{\text{Celsius}} = \frac{5}{9}(\text{Temp}_{\text{Fahrenheit}} - 32°)$$

$$\therefore 70°\,\text{F} = 21.1°\,\text{C} \quad \text{AND} \quad 20°\,\text{F} = \text{-}6.7°\,\text{C}$$

$$\frac{|-236°| + 21.1°}{4\,\Omega} = \frac{|-236°| + \text{-}6.7°}{R_2}$$

$$\therefore R_2 = 3.567\,\Omega$$

Temperature Coefficient of Resistance

- Another means for calculating resistance at various temperatures

$$R_1 = R_{20^\circ}\left[1+\alpha_{20^\circ}\left(T_1 - 20^\circ C\right)\right]$$

where :

R_1 is the resistance @ T_1

α_{20} is the temp coefficient

R_{20} is the resistance @ 20°C

Material	***Temp Coefficient (α_{20})***
Silver	0.0038
Copper	0.00393
Gold	0.0034
Aluminum	0.00391
Tungsten	0.005
Nickel	0.006
Iron	0.0055
Constantan	0.000008
Nichrome	0.00044

Example - Temperature Coefficient

Determine the resistance of a 1000 ft coil of #12 copper wire sitting in the desert at a temperature of 115°F.

$$R_{20^\circ} = 1.588\,\Omega \quad \text{(from Table 3.2)}$$

$$\alpha_{20} = 0.00393 \quad \text{(from Table 3.6)}$$

$$\mathrm{T}_1 = 115^\circ F = 46.1^\circ C$$

$$\mathrm{R}_1 = \mathrm{R}_{20^\circ}\left[1 + \alpha_{20^\circ}\left(\mathrm{T}_1 - 20^\circ\mathrm{C}\right)\right]$$

$$\mathrm{R}_1 = 1.588\left[1 + 0.00393\left(46.1^\circ\mathrm{C} - 20^\circ\mathrm{C}\right)\right]$$

$$\mathrm{R}_1 = 1.751\,\Omega$$

Breakout Exercise #1

Find the temperature at which the resistance of a copper conductor will increase to 1Ω from a level of 0.8Ω at 20°C.

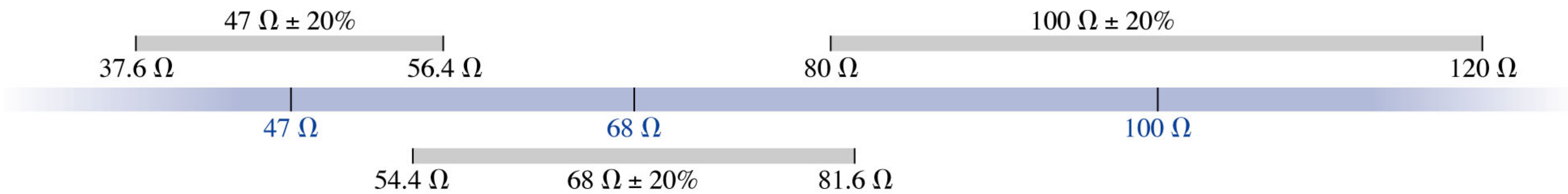
Standard Value Resistors

Ohms			Kilo-Ohms			Mega-Ohms	
1.0	10	100	1.0	10	100	1.0	10
1.1	11	110	1.1	11	110	1.1	11
1.2	12	120	1.2	12	120	1.2	12
1.3	13	130	1.3	13	130	1.3	13
1.5	15	150	1.5	15	150	1.5	15
1.6	16	160	1.6	16	160	1.6	16
1.8	18	180	1.8	18	180	1.8	18
2.0	20	200	2	20	200	2.0	20
2.2	22	220	2.2	22	220	2.2	22
2.4	24	240	2.4	24	240	2.4	
2.7	27	270	2.7	27	270	2.7	
3.0	30	300	3.0	30	300	3.0	
3.3	33	330	3.3	33	330	3.3	
3.6	36	360	3.6	36	360	3.6	
3.9	39	390	3.9	39	390	3.9	
4.3	43	430	4.3	43	430	4.3	
4.7	47	470	4.7	47	470	4.7	
5.1	51	510	5.1	51	510	5.1	
5.6	56	560	5.6	56	560	5.6	
6.2	62	620	6.2	62	620	6.2	
6.8	68	680	6.8	68	680	6.8	
7.5	75	750	7.5	75	750	7.5	
8.2	82	820	8.2	82	820	8.2	
9.1	91	910	9.1	91	910	9.1	

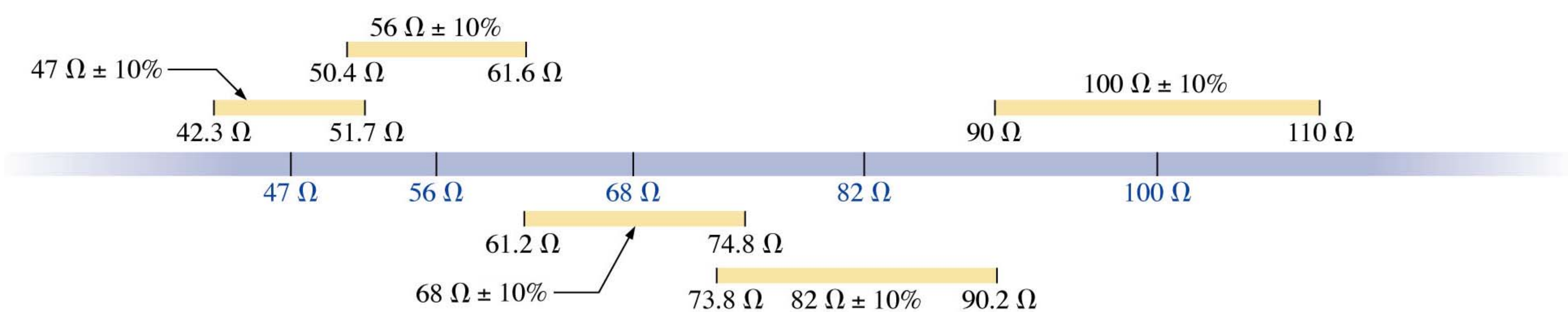
5%
5% & 10%
5%, 10%, & 20%

Standard Values Provide a Full Range of Values

Three Consecutive 20% Components : 47 Ω, 68 Ω & 100 Ω



Five Consecutive 10% Components : 47 Ω, 56 Ω, 68 Ω, 82 Ω & 100 Ω



Conductance

- Conductance is a measure of a material's ability to conduct electricity.
- Conductance is the reciprocal of resistance.
- The unit of conductance is the *Siemen* (S).

$$G = \frac{1}{R} \quad (siemens, S)$$

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

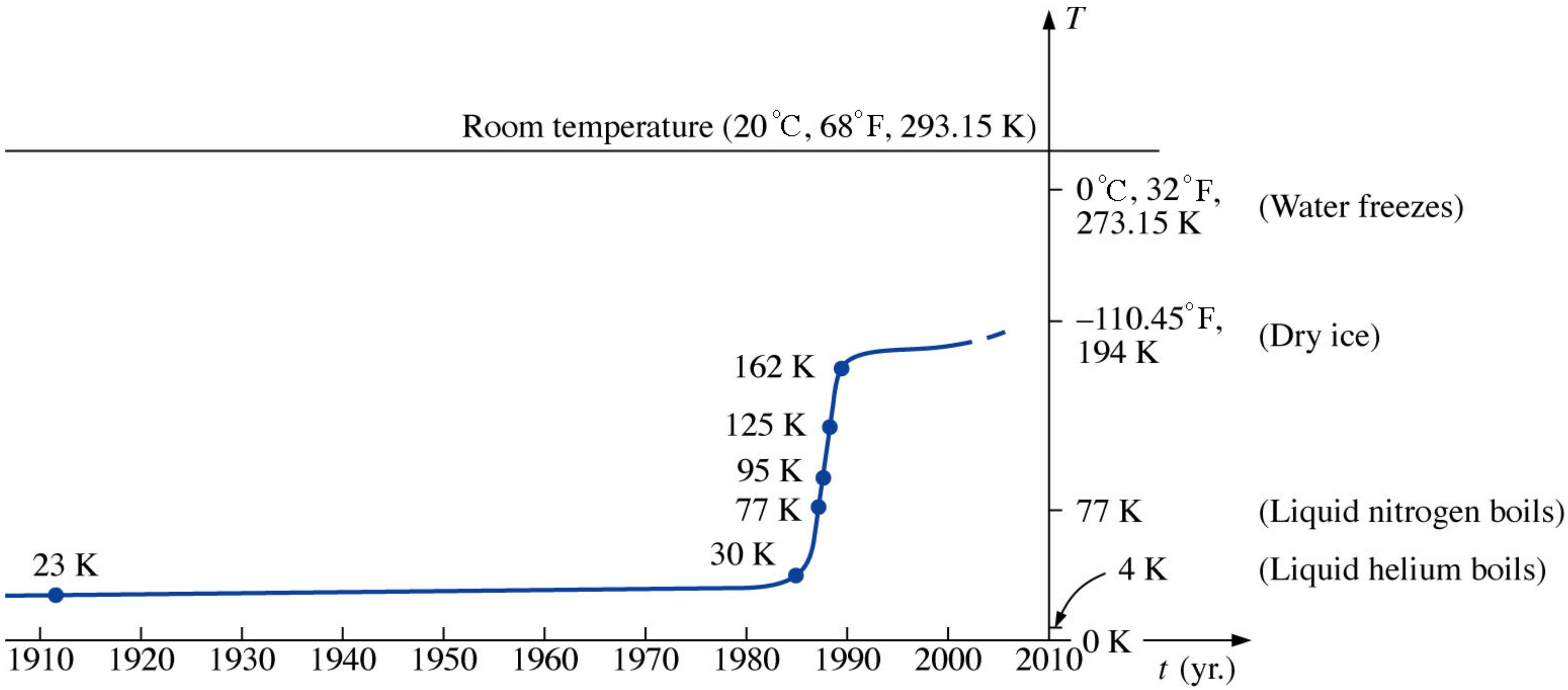
$\rho = CM\ \Omega/ft$ @ $T = 20°C$

$l = feet$

A = area in circular mils (CM)

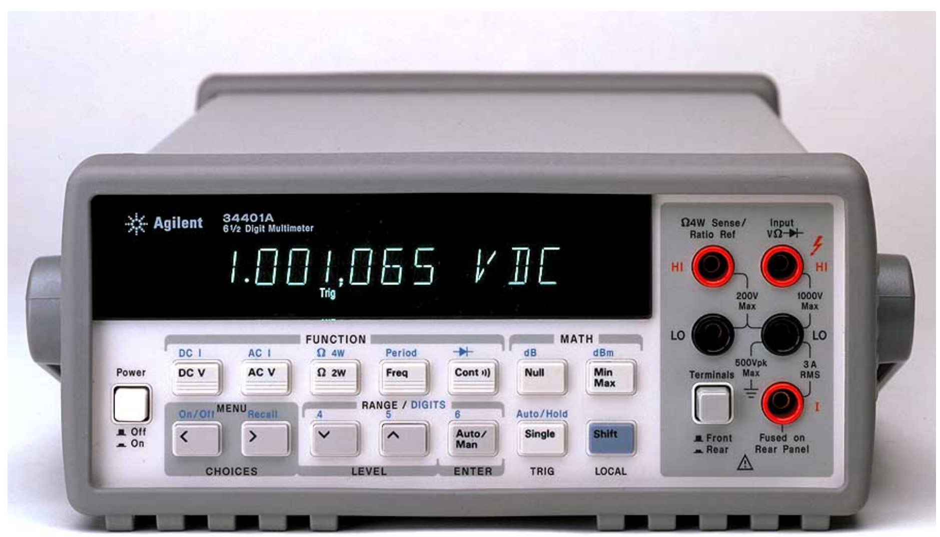
Superconductors

- Superconductors are conductors of electric charge that, for all practical purposes, have zero resistance
- Currently not practical for everyday use.



Ohmmeter

- Used to measure the resistance of individual or combined elements.
- Used to detect open-circuits (high-resistance) and short-circuits (low-resistance).
- Used to check continuity of connections.

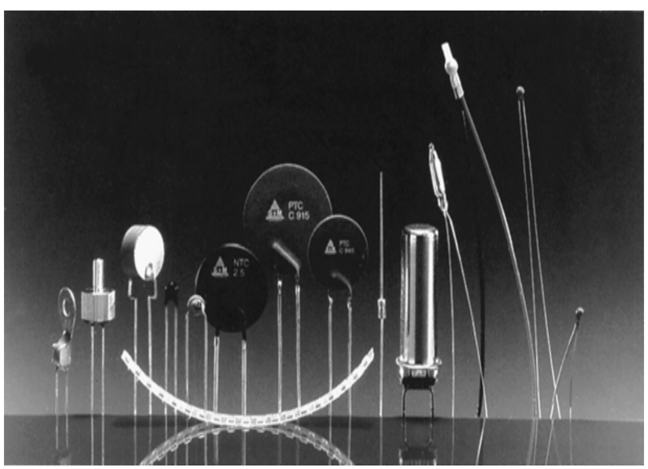


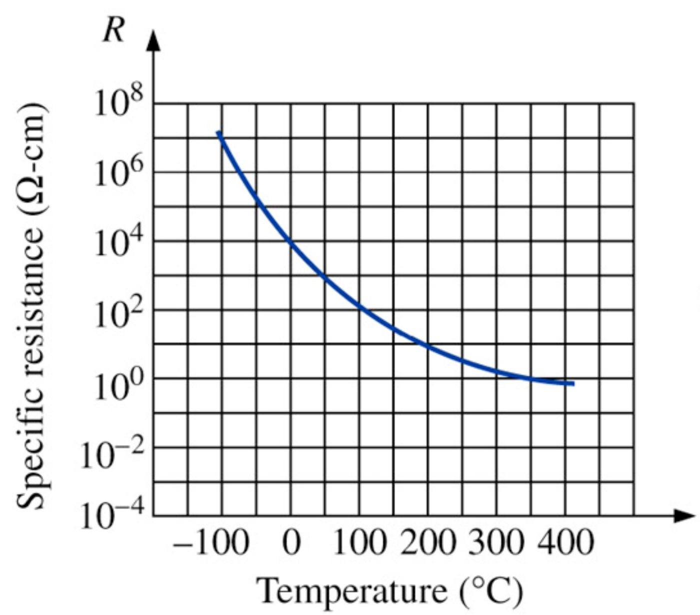
Ohmmeter Usage

- A ohmmeter applies a small voltage to the circuit and measures the current drawn. The resistance is determined by taking the ratio of voltage/current. This is Ohm's Law (more later).
- So…
  - Never connect a ohmmeter to a active circuit.
  - Never store a DMM in resistance mode.

Thermistors

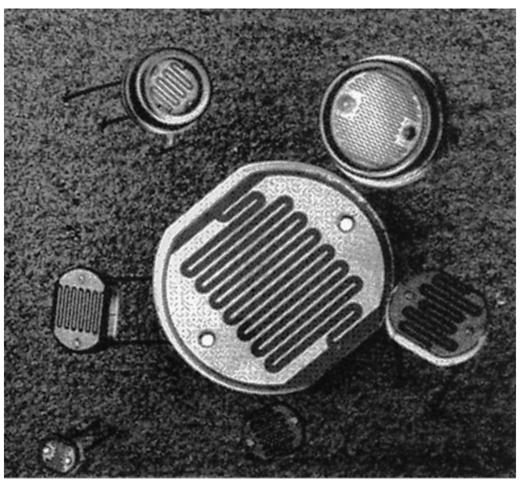
- Two-terminal semiconductor whose resistance is temperature sensitive
- Typically used in thermostats, automotive applications, and process-control.
- Available in a wide range of values.

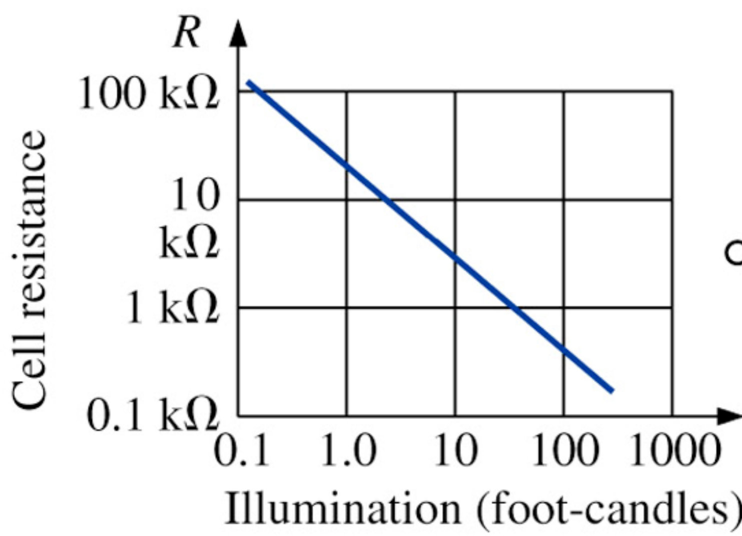


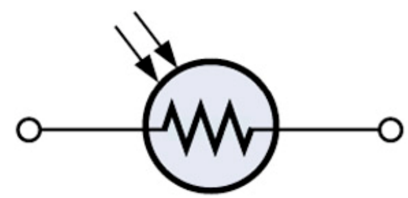


Photoconductive Cell

- Two-terminal semiconductor whose resistance is determined by the intensity of the incident light.
- Typically used in street lights, automotive applications, and cameras.

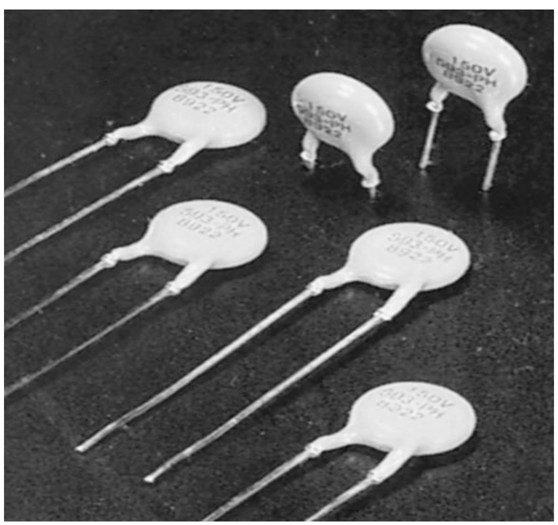


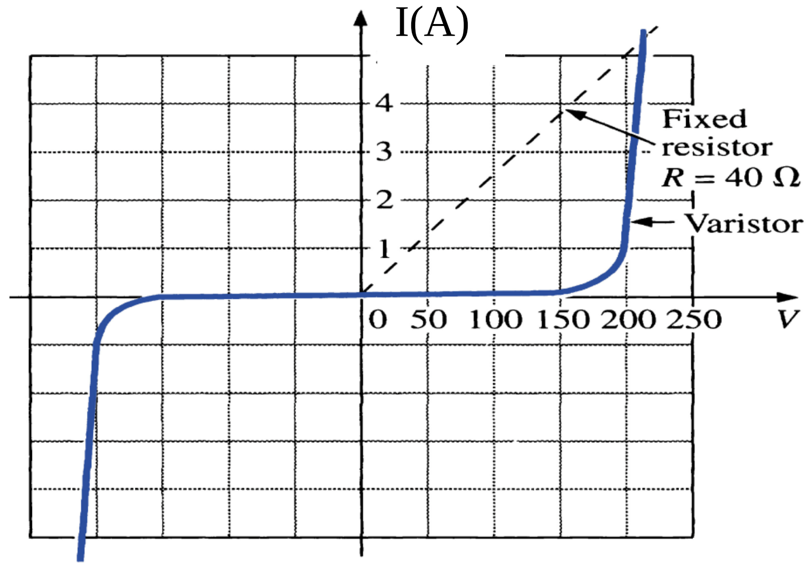




Varistors

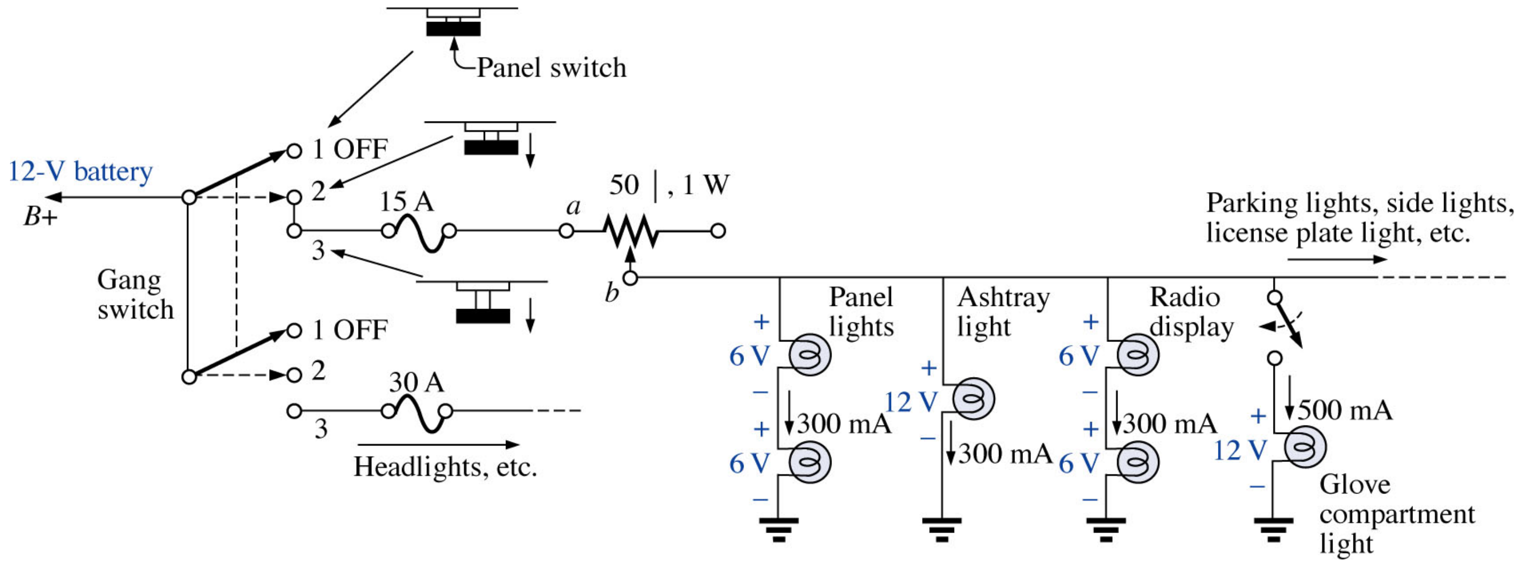
- Are voltage-dependent nonlinear resistors used to suppress high-voltage transients.
- They limit the voltage that can appear across on a sensitive device or system.
- Frequently used in surge protectors and PC power supplies.



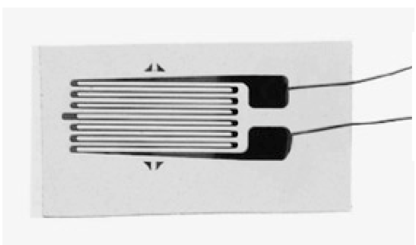


Applications

Automobile Dimmer Control



Strain Gauge



12-Ω terminal resistance

Overall length: 5.5mm ≅ 0.22"