Georgia Institute of Technology

Linear Circuits

Nathan V. Parrish
PhD Candidate & Graduate Research Assistant
School of Electrical and Computer Engineering

An introduction to linear electric circuit elements and a study of circuits containing such devices.

Georgia Institute of Technology

Resistivity and Ohm's Law

Nathan V. Parrish
PhD Candidate & Graduate Research Assistant
School of Electrical and Computer Engineering

- *Learn how materials resist the flow of current*
- *Learn about Ohm's law – a law relating current and voltage through materials*
- *Find resistance of materials from their dimensions and electric properties*

Previous Class

- Discussed basic circuits
- Recap of module 1
- Introduction to module 2

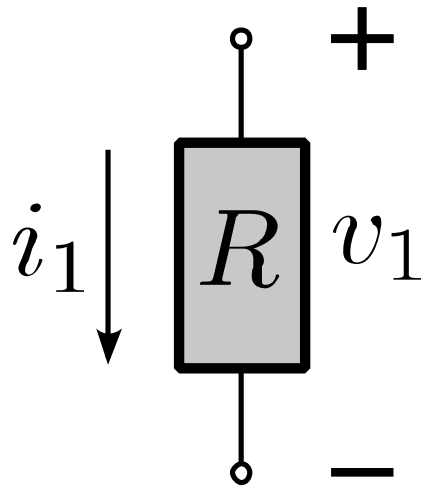
Module 2: Resistive Circuits

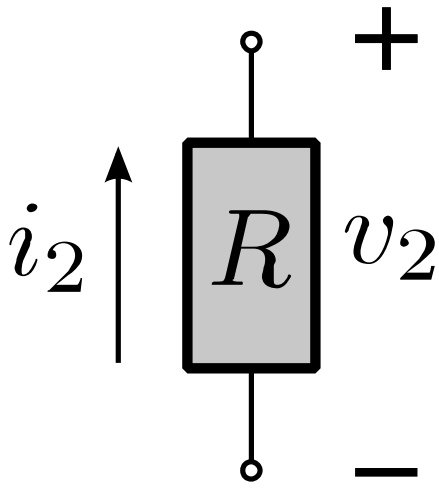
- Resistance and Ohm's Law
- Kirchhoff's Laws
- Resistors
- Superposition
- Obtaining Circuit Equations
- Maximum Power Transfer
- Wye-Delta and Wheatstone Bridge

Lesson Objectives

- Define resistance
- Calculate conductance from resistance
- Apply Ohm's Law to find currents, voltages, or resistances
- Calculate the resistance of a material using its dimensions and electrical properties

Ohm's Law



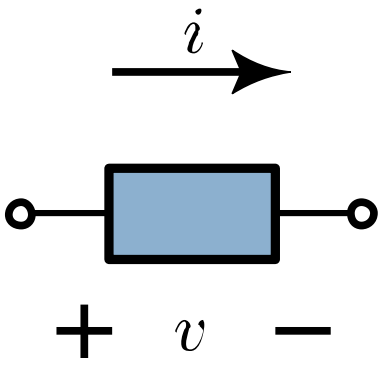


$$v_1 = i_1 R \qquad v_2 = -i_2 R$$

Resistance and Conductance

Resistance	
Units	ohm ($\Omega = \frac{V}{A}$)
Variable	R

Conductance	
Units	siemens (S=$\frac{\mathrm{A}}{\mathrm{V}}$)
	mho ($\mho = \frac{\mathrm{A}}{\mathrm{V}}$)
Variable	G



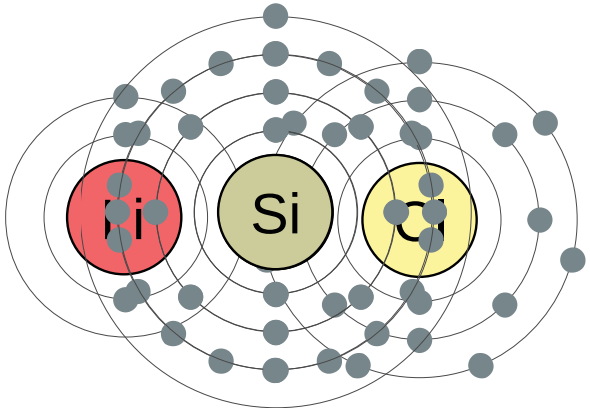
$$R = \frac{v}{i}$$

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

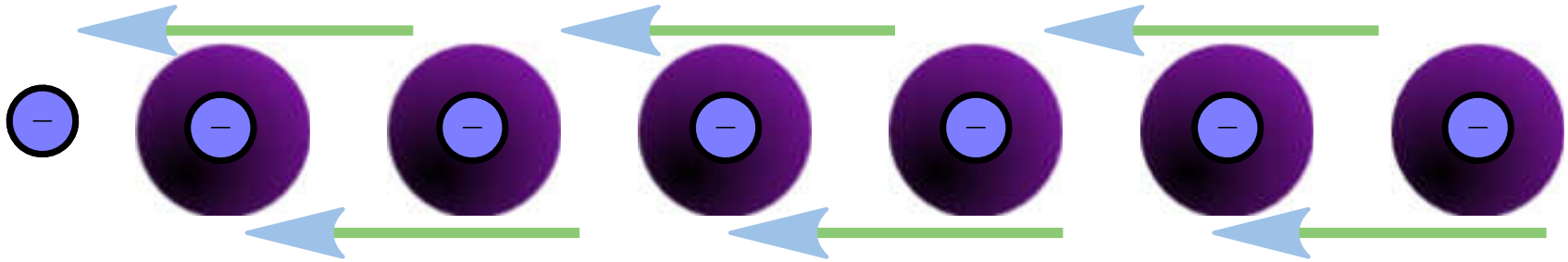
Reason for Resistance

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.38	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.798
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.96	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33		hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]		rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [277]	meitnerium 109 Mt [268]	darmstadtium 110 Ds [271]	roentgenium 111 Rg [272]							

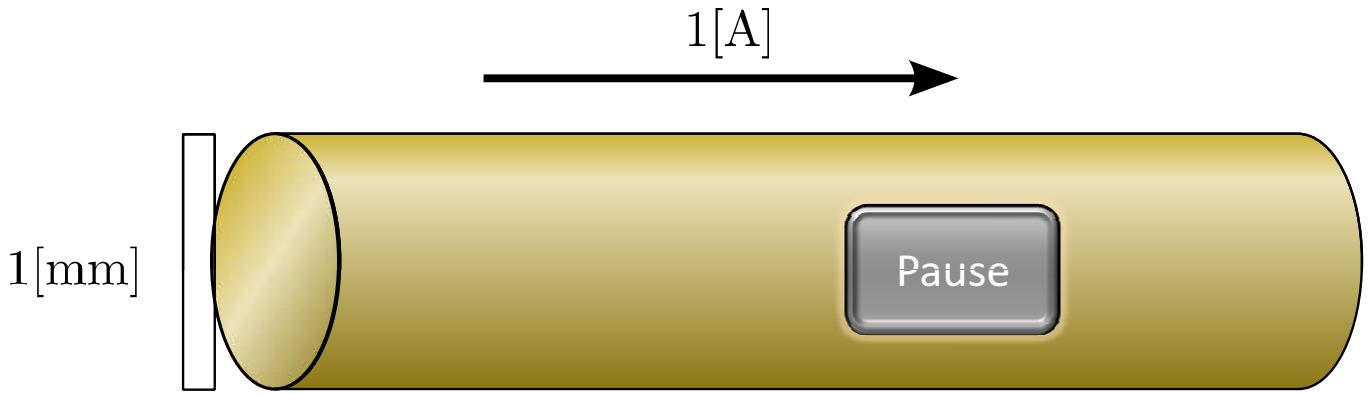
			lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.05	lutetium 71 Lu 174.97
			actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]	lawrencium 103 Lr [262]



The Electron Bucket Brigade



Example: Electron Drift Rate



Au free electron density: $5.9 \times 10^{22} \left[\frac{\mathrm{e}^-}{\mathrm{cm}^3}\right]$

Linear Electron Density:

$$d_l = d_v A_s = 1.602 \times 10^{-19}[\mathrm{C}] \; 1.590 \left[\frac{\mathrm{e}^-}{\mathrm{C}}\right] \; 1 \; [\mathrm{cm}^2] = 4.634 \times 10^{20} \left[\frac{\mathrm{e}^-}{\mathrm{cm}}\right]$$

Electron Drift Velocity:

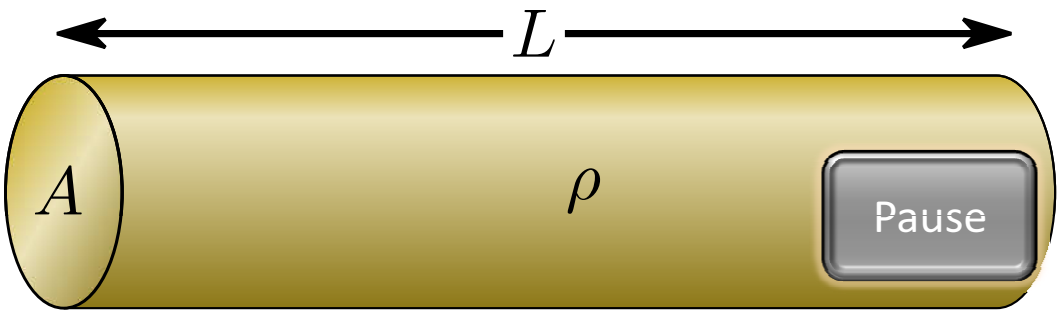
$$v_{\mathrm{e}^-} = \frac{1[\mathrm{C}]}{5.9 \times 10^{22}\left[\frac{\mathrm{e}^-}{\mathrm{cm}^3}\right] \pi 0.4^2 [\mathrm{cm}^2] \; 1.602 \times 10^{-19}[\mathrm{C}]} \frac{6.24 \times 10^{18}[\mathrm{e}^-]}{1[\mathrm{C}]} \frac{[\mathrm{cm}]}{4.634 \times 10^{20}[\mathrm{e}^-]} = -0.0135 \left[\frac{\mathrm{cm}}{\mathrm{s}}\right]$$

Rate of Electron Flow:

$$1[\mathrm{A}] = d_l \frac{[\mathrm{e}^-]}{[\mathrm{s}]}$$

$$|v_{\mathrm{e}^-}| = 0.485 \left[\frac{\mathrm{m}}{\mathrm{hr}}\right]$$

Resistivity

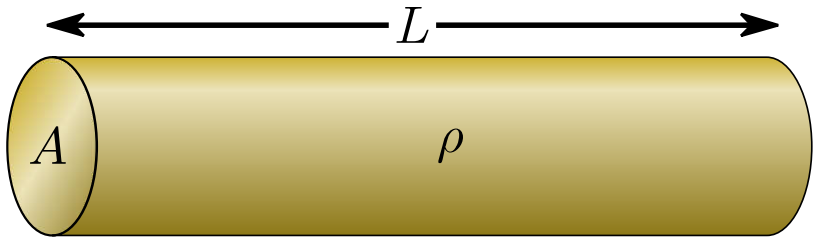


Resistivity	
Units	ohm meters (Ωm)
Variable	ρ

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

Finding Resistance

Approximate Resistivity ρ (Ωm)	
Conductors	
Aluminum	2.73×10^{-8}
Copper	1.72×10^{-8}
Gold	2.27×10^{-8}
Semiconductors	
Silicon	10^{-5} to 1
Insulators	
Glass	10^{12}
Quartz(fused)	10^{18}
Teflon	10^{22}



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

Summary

- Used background to see how voltage and current relate moving through materials
- Introduced Ohm's Law and its application
- Discussed the physical cause for resistance
- Described electron drift rate and calculated this value in a case study
- Calculated resistance using the dimensions and resistivity of a material

Next Class

- Look at laws which describe the relationships between devices in a system