Class 3
Ham Radio Technician Course

Leslie Rohde, N7LER • leslie@n7ler.com • Cell Phone: 512.207.0539

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Electronics

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Technician Level Electronics

- There are Sorta Two Kinds of Electricity
  - Direct Current (DC) and Alternating Current (AC)
- DC is Sorta Like Plumbing
- Ohm's Law
- DC Circuits and Schematics
- AC is Radio in Wires
- AC Circuits and Schematics

3

Electrical Plumbing

- A Battery is Like a Water Tower
- A Switch is Like an On-Off Valve
- A Resister is Like Pinching the Hose
  - Skinny Pipes Have More Resistance than Bigger Pipes
- A Potentiometer is Like a Gate Value (Variable Resistance)
- Increasing Resistance Decreases Flow (Current)
- Increasing Voltage Increases Flow (Current)

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The Plumbing Analogy

- Voltage ~ Pressure (psi)
- Resistance ~ “Back Pressure” (psi)
- Current ~ Flow Rate (gpm)

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Terminology

- Electromotive Force (EMF), abbreviated as “E”, is measured in Volts and is the Force that causes “electrons” to “flow”
- The resistance to that flow, and abbreviated by “R”, is measured in Ohms and written as the Greek letter Omega Ω
- The amount of “flow” is current measured in Amperes (Amps) and generally abbreviated as “I”

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Just For Fun

- One ampere is the current in which one coulomb of charge travels across a given point in 1 second
- One coulomb is equal to about 6.241 x 10^{18} electric charges

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Ohm's Law

$$E = I \times R$$

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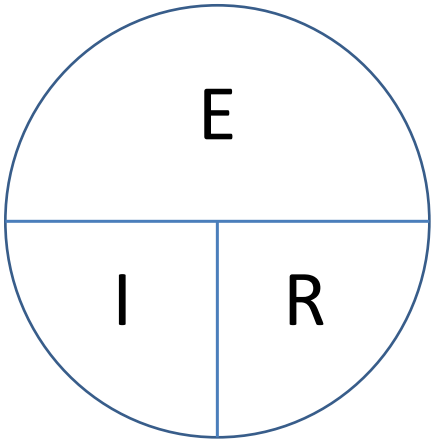
“The Magic Circle”



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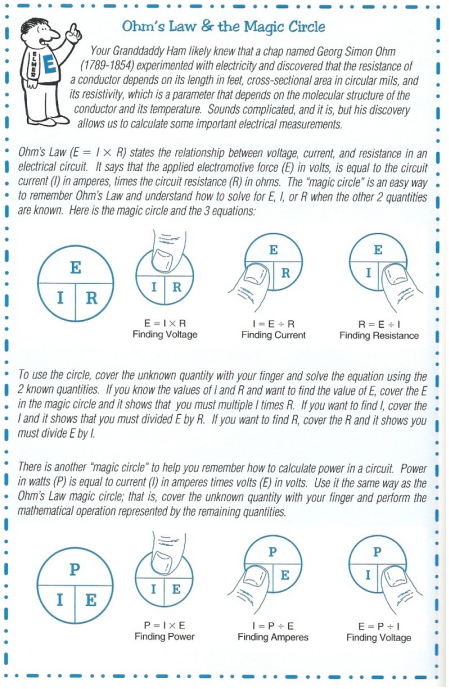
Using the “Magic Circle”



Ohm's Law & the Magic Circle

Your Granddaddy Ham likely knew that a chap named Georg Simon Ohm (1789-1854) experimented with electricity and discovered that the resistance of a conductor depends on its length in feet, cross-sectional area in circular mils, and its resistivity, which is a parameter that depends on the molecular structure of the conductor and its temperature. Sounds complicated, and it is, but his discovery allows us to calculate some important electrical measurements.

Ohm's Law (E = I × R) states the relationship between voltage, current, and resistance in an electrical circuit. It says that the applied electromotive force (E) in volts, is equal to the circuit current (I) in amperes, times the circuit resistance (R) in ohms. The "magic circle" is an easy way to remember Ohm's Law and understand how to solve for E, I, or R when the other 2 quantities are known. Here is the magic circle and the 3 equations:

E = I × R
Finding Voltage

I = E ÷ R
Finding Current

R = E ÷ I
Finding Resistance

To use the circle, cover the unknown quantity with your finger and solve the equation using the 2 known quantities. If you know the values of I and R and want to find the value of E, cover the E in the magic circle and it shows that you must multiple I times R. If you want to find I, cover the I and it shows that you must divided E by R. If you want to find R, cover the R and it shows you must divide E by I.

There is another "magic circle" to help you remember how to calculate power in a circuit. Power in watts (P) is equal to current (I) in amperes times volts (E) in volts. Use it the same way as the Ohm's Law magic circle; that is, cover the unknown quantity with your finger and perform the mathematical operation represented by the remaining quantities.

P = I × E
Finding Power

I = P ÷ E
Finding Amperes

E = P ÷ I
Finding Voltage

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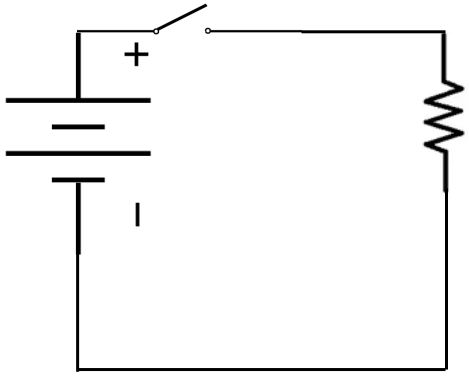
A Simple Schematic



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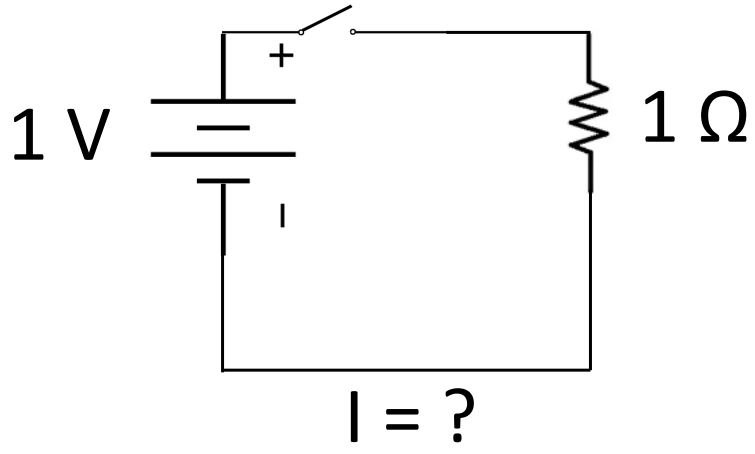
Applying Ohms Law



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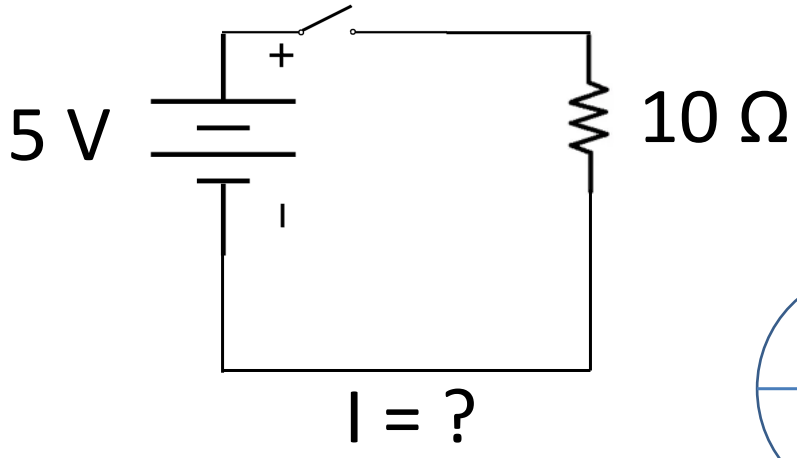
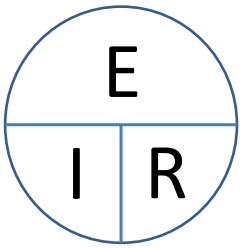
Applying Ohms Law





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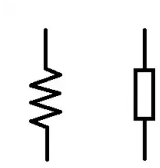
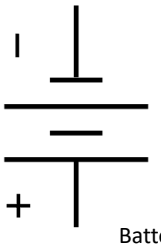
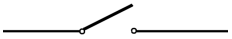
A Few Schematic Symbols



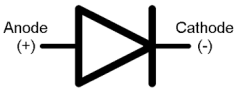
Resister



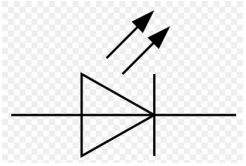
Battery



Switch



Diode



LED

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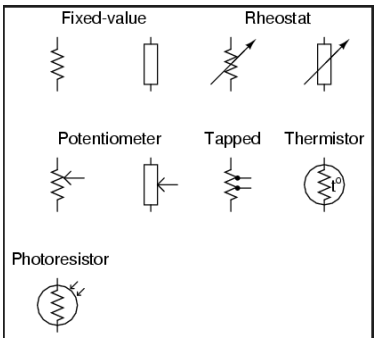
Resistors



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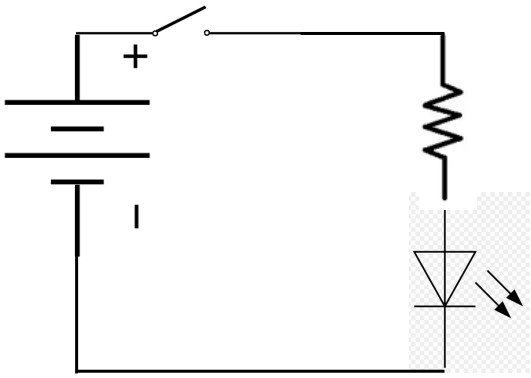
A Flashlight



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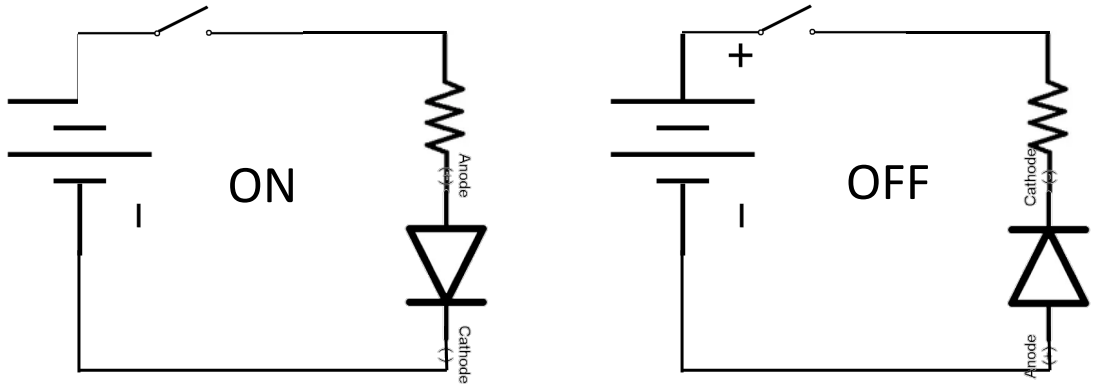
A Diode is a One-Way Valve



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Can you have a circuit without a ground?

18

Ground is Relative

- Chassis vs. Earth
- What is the very best ground?
- Is my ground your ground?
- Can you be a good ground?
- Wanna be?

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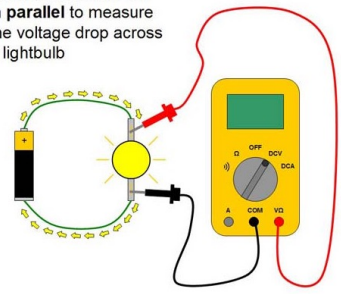
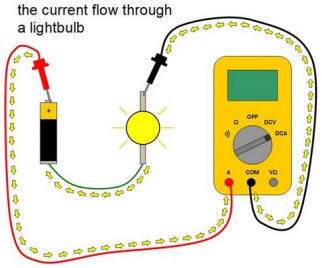
Measuring Voltage and Current

Voltage is measured across the Source.

Connect a multimeter in **parallel** to measure the voltage drop across a lightbulb



Connect a multimeter in **series** to measure the current flow through a lightbulb



Current is measured with the meter in line with the source. "+' line to the positive and "-" to the "sink" side of the circuit.

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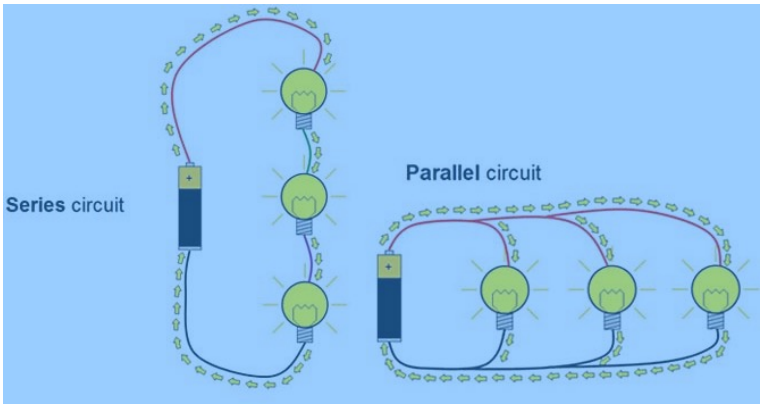
Parallel and Series Circuits



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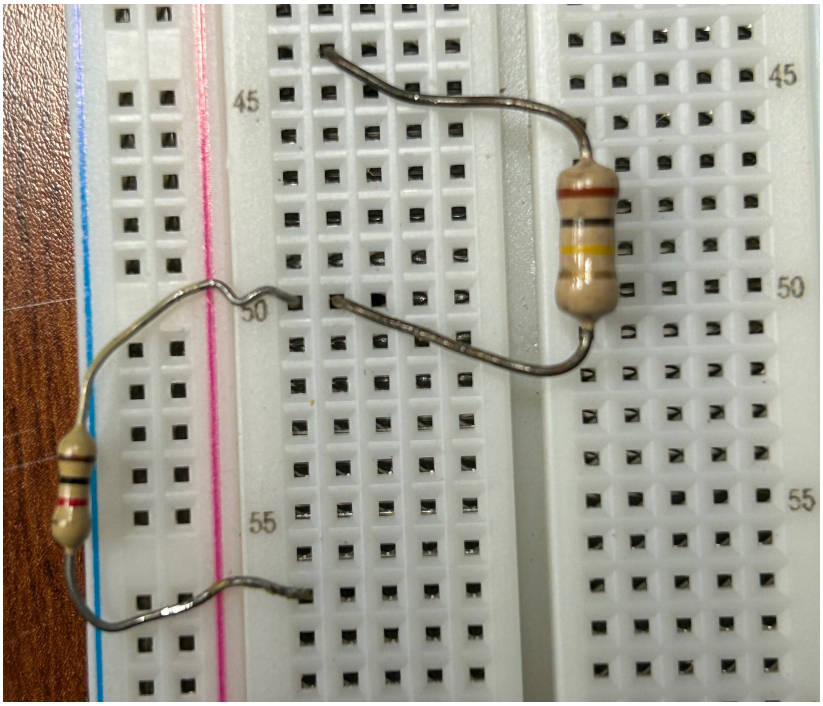
Series Resisters



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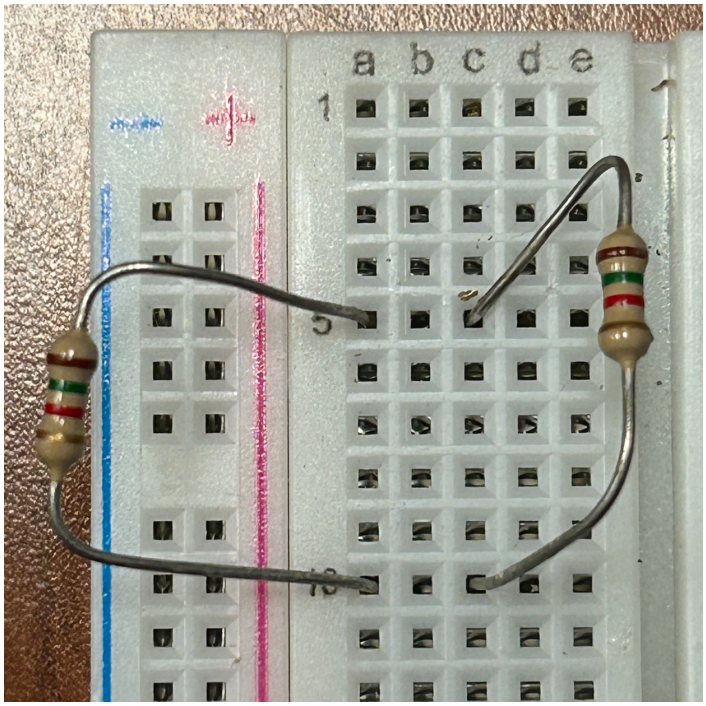
Parallel Resisters



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Power

- More Current (flow) can do more “work”
- More Voltage (pressure) can do more ”work”
- Power is the product of voltage and current
- The unit of power is the Watt
- One Watt = 1 Volt times 1 Amp

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High Pressure x Low Current

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Low Pressure x High Current

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High Pressure x High Current

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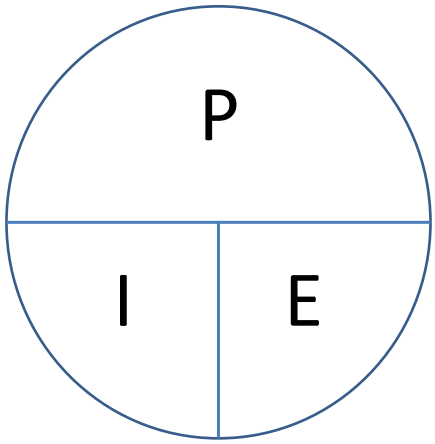
The Other "Magic Circle"



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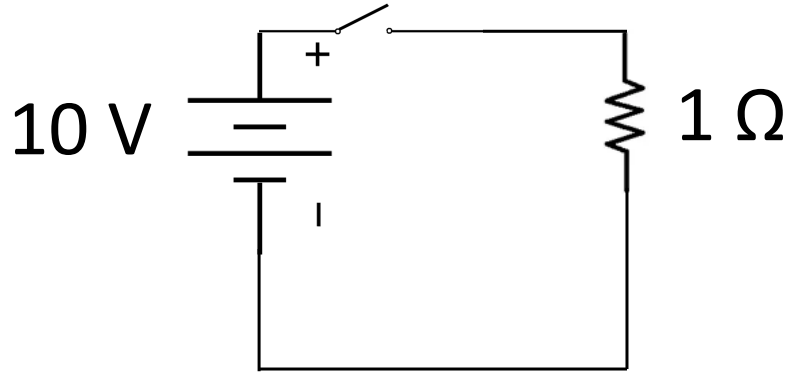
How Much Power is Dissipated?



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Semiconductors

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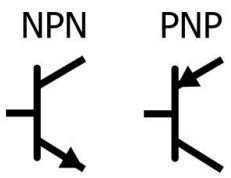
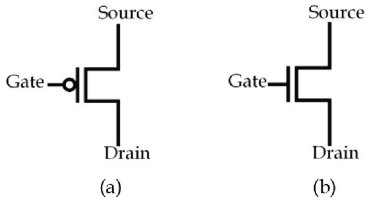
Transistors are Electrically Variable Resistors



Transistor



FET

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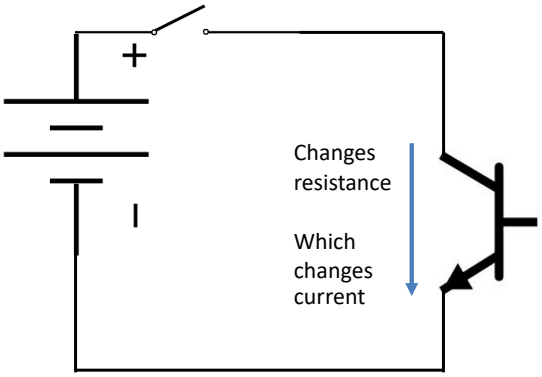
Simple Transistor Circuit



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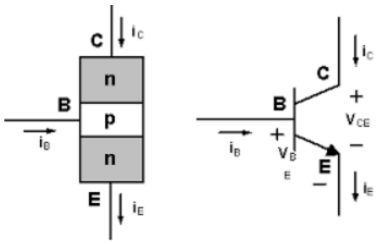
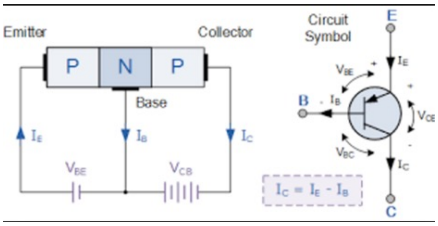
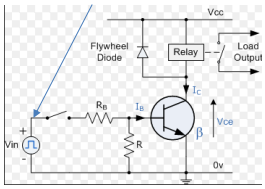
NPN and PNP Transistors





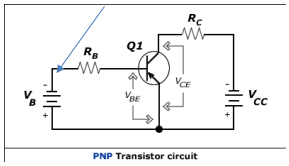
NPN = Never Points iN

Positive Voltage



Schematic Symbol is usually written with the base on the left, but the Collector and Emitter can be either up or down

Negative Voltage



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AC Electronics

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The “Plumbing” Metaphore No Longer Works Very Well

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Ohm’s Law Still Applies at Each Instant in Time

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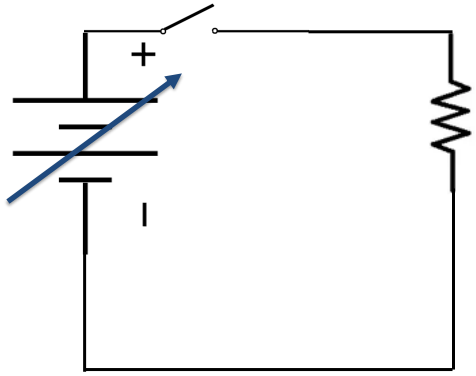
Suppose We Had a Variable Battery



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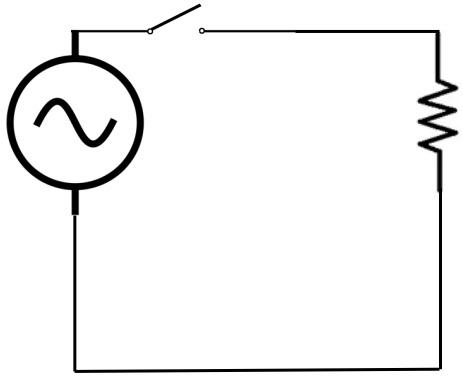
Suppose We Had a Variable Battery



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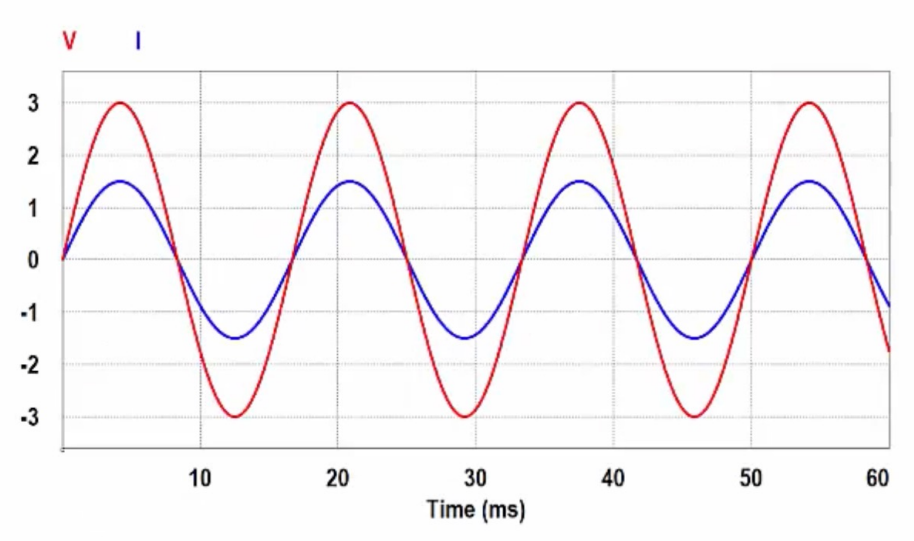
As Voltage Changes, So Does Current



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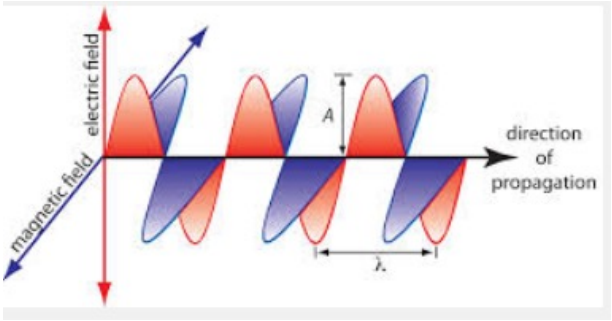
Electro-Magnetic Waves



Wave length = distance peak to peak
All radio has both electrical and magnetic fields

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Can You Have Just an Electric Wave?

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Can You Have Just a Magnetic Wave?

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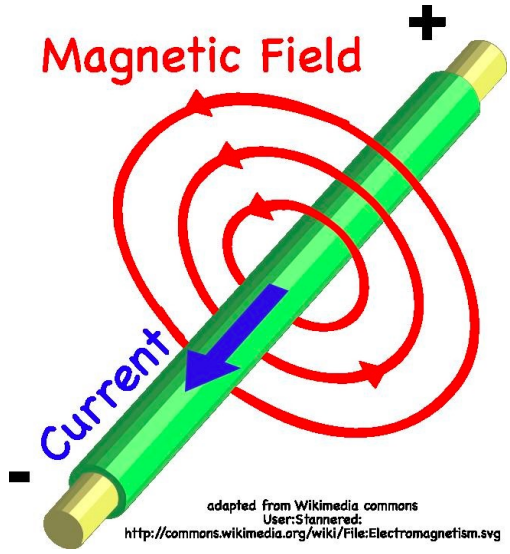
AC is Radio in Wires



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All Wires Leak AC

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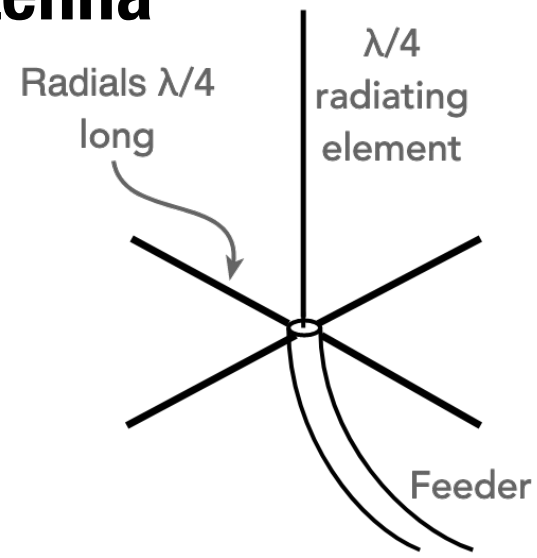
An Intentionally "Leaky" Wire We Call an Antenna



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Capacitors Store Energy as Electric Charge

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Change the Area of Overlap to Change the Capacity

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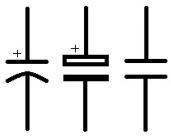
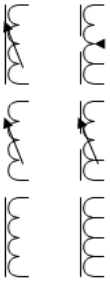
AC Components

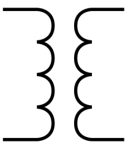


Capacitor

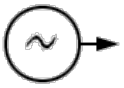
Crystal



Coils



Transformer



Oscillator

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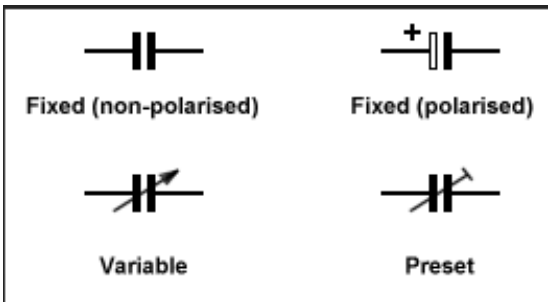

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Coils Store Energy as a Magnetic Field

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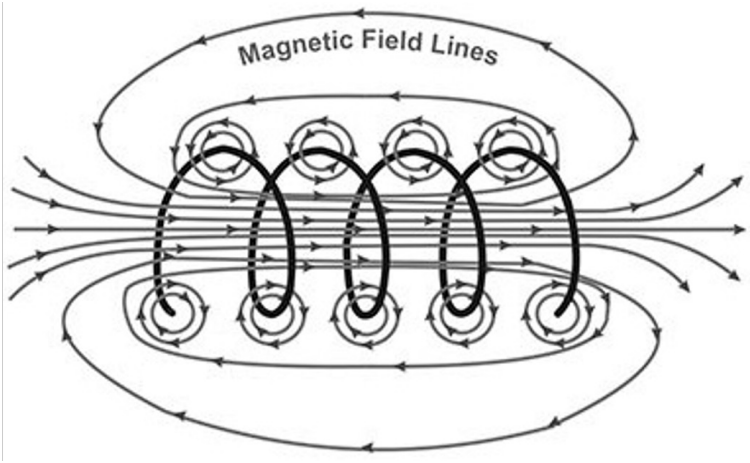
More Overlapping Fields Creates Greater "Resistance to Change" (Reactance)



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Coils (

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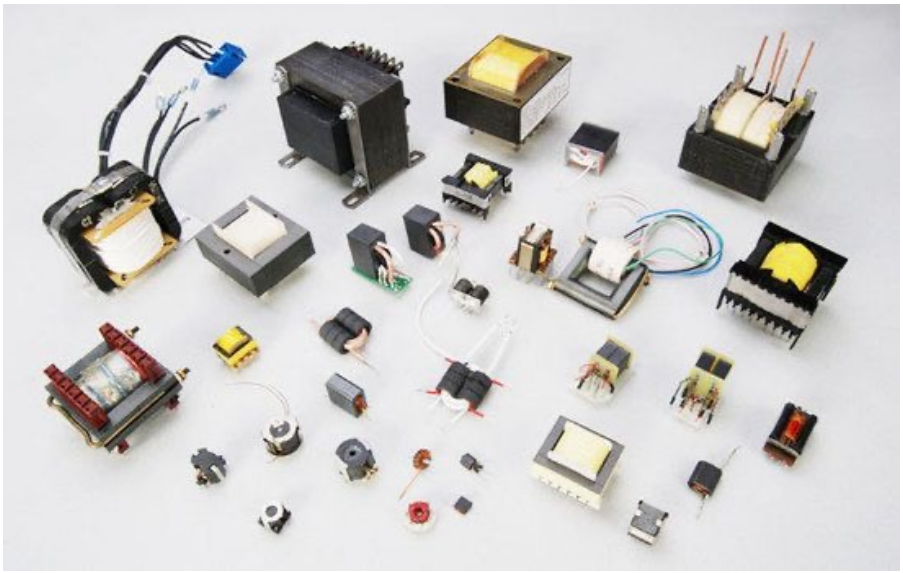
Transformers



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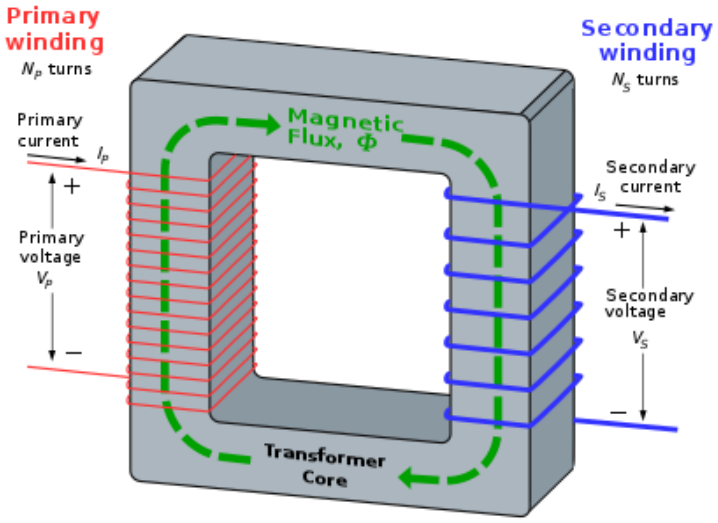
Transformers are Coils Talking to Each Other



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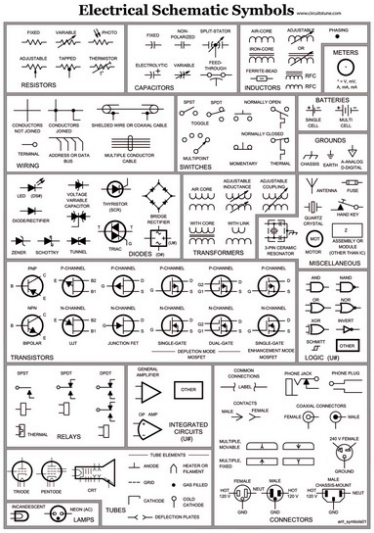
Electrical Schematics and symbols



Most used symbols in Radio

Resistors
Capacitors
Diode
Transistors
Coils
Switches
Relays
Plugs
Ground
Antennas
Connections

Most of these come in fixed value or variable.

Combining capacitors and inductors (coils) makes a tuned circuit.

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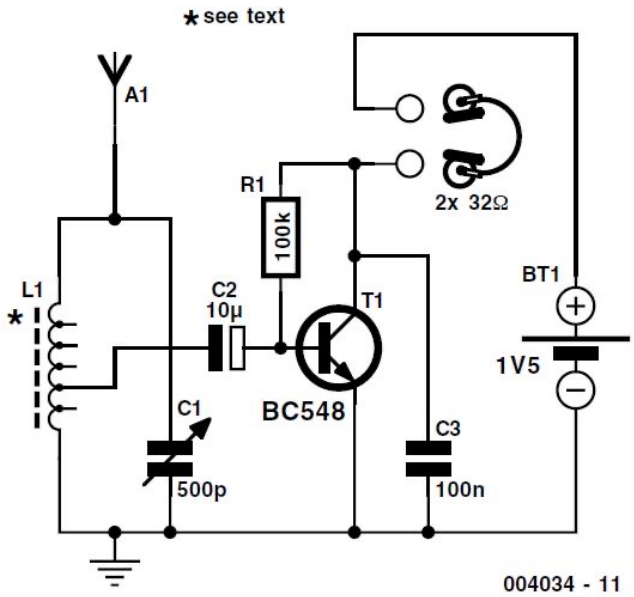
One Transistor Radio



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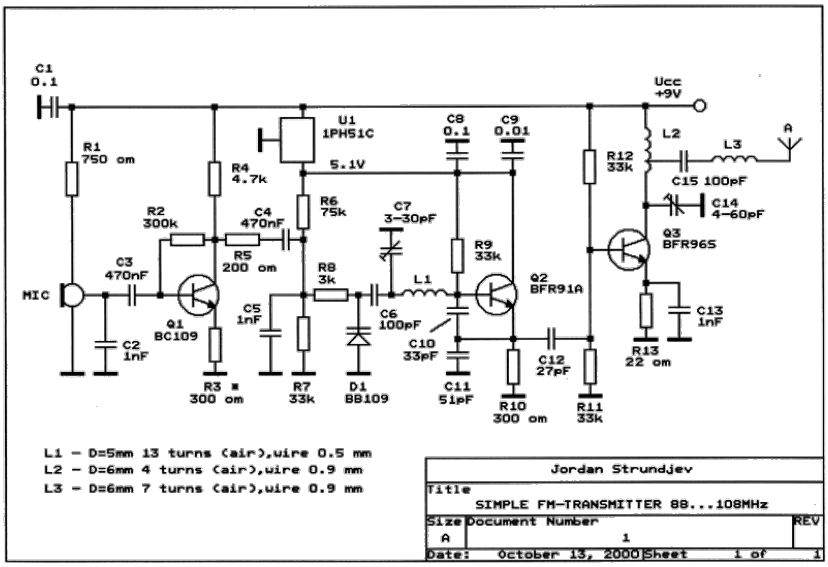
A Simple FM Transmitter



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Antennas
Our Most Special Electrical Component

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Resistance Resists DC

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Reactance/Impedance Resists AC

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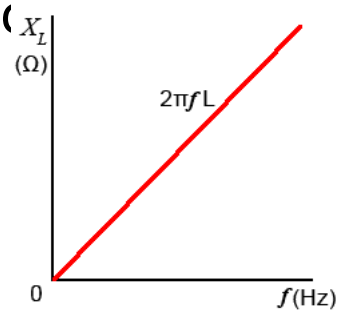
Inductors

- Zero resistance to DC
- Increasing reactance with frequency
- Also called inductance or induc
  reactance



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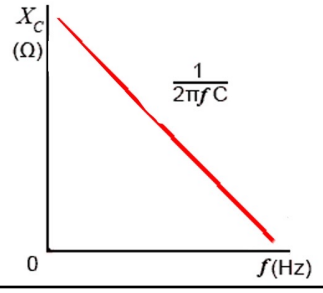
Capacitors

- Infinite resistance to DC
- Decreasing reactance with frequency
- Also called capacitance or capacitive
  reactance



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Tuned Circuits

- Combine inductance and capacitance
- Circuit will resonate at (theoretically) one frequency
- A crystal resonates because it is both inductive and capacitive
- At Resonance, Capacitance = Inductance

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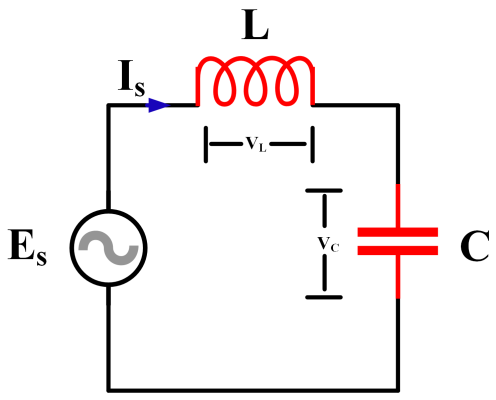
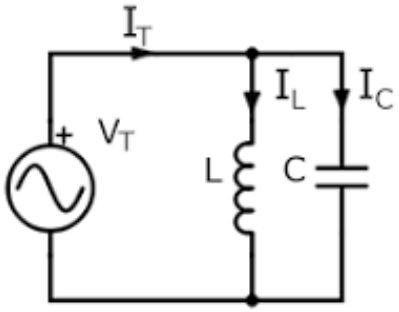
Tuned Circuits





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Everything has Impedance

65

Even "Empty Space" has Impedance (about 377 ohms)

66

Everything in the Universe Will Resonate at Some Frequency

HINT: RF Safety

67

Revisiting EM Waves

- EM waves permeate all space
- EM waves permeate all matter
- EM = RF = AC
- AC currents in wires radiate EM into space
- EM waves in space induce AC currents in wires

68

Antennas

- All wires are "leaky"
- Antennas are optimized for leakiness at a selected frequency
- Best transmit frequency = best reception frequency
- This is the "resonance" frequency
- Antennas are Tuned Circuits

69

Even EM Waves Have a Ground

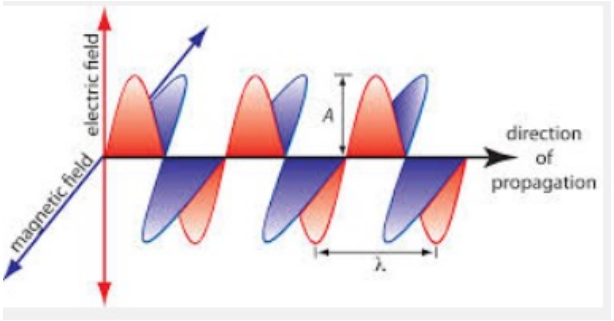
70

Guided Wave = AC in Wire

Unguided Wave = EM Radiation

71

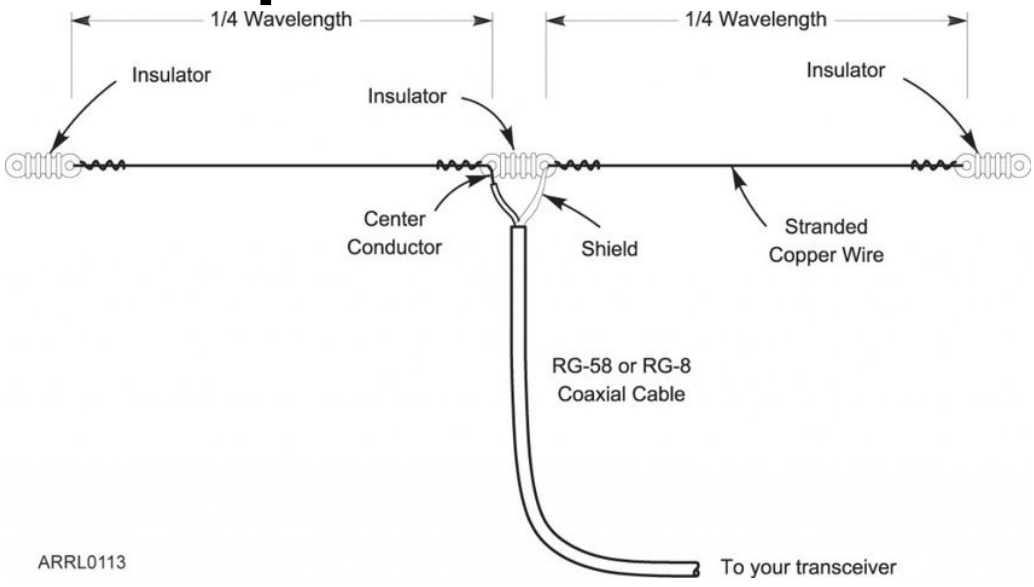
Electro-Magnetic Waves



Wave length = distance peak to peak
All radio has both electrical and magnetic fields

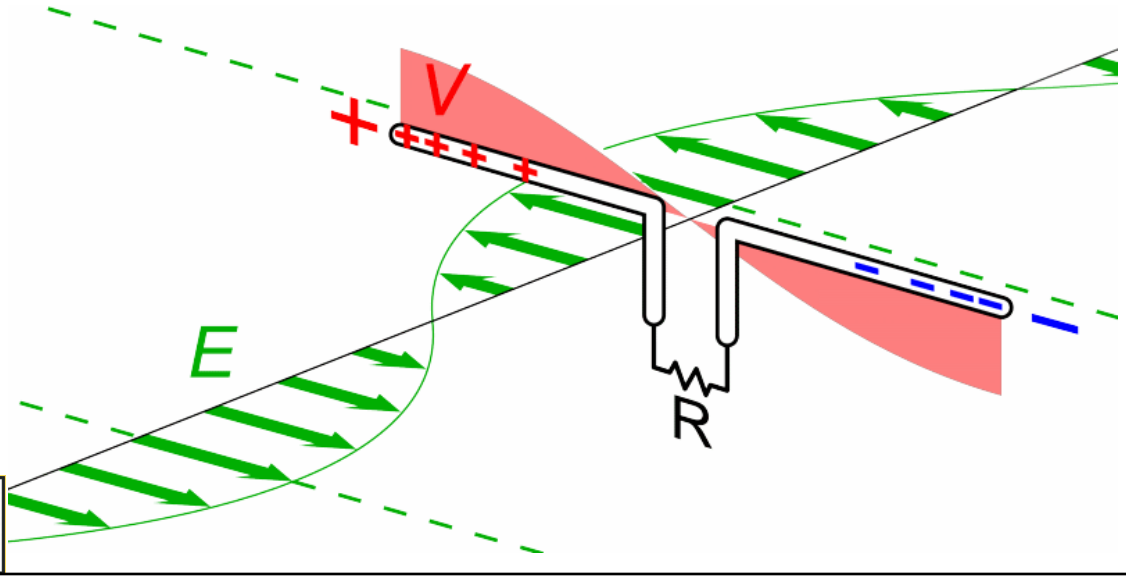
72

Half-Wave Dipole



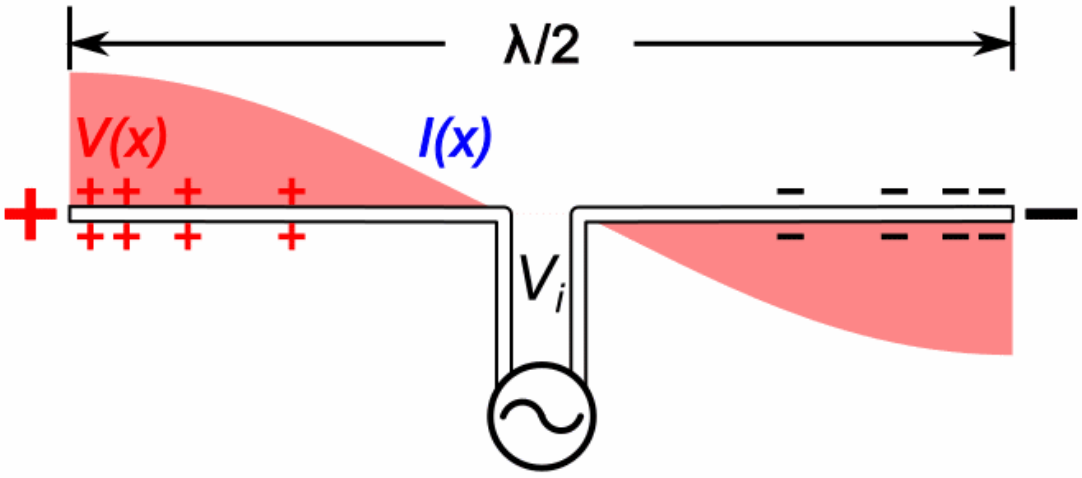
73

Half-Wave Dipole Receiving a Radio Wave



74

Voltage vs. Current in a Transmitting Antenna

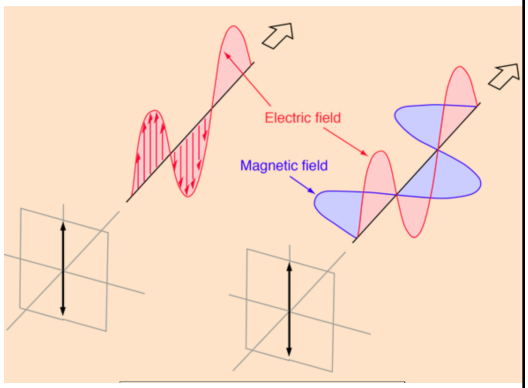


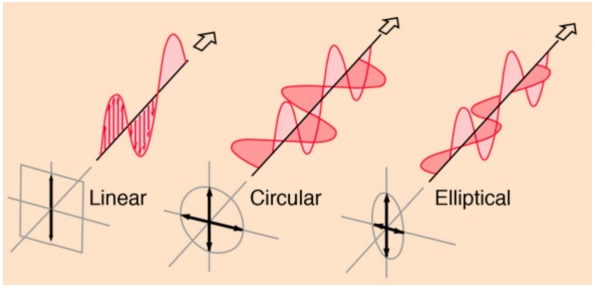
75

EM Wave Polarization

The orientation of the Electric field

- Horizontal
- Vertical
- Circular? Elliptical??





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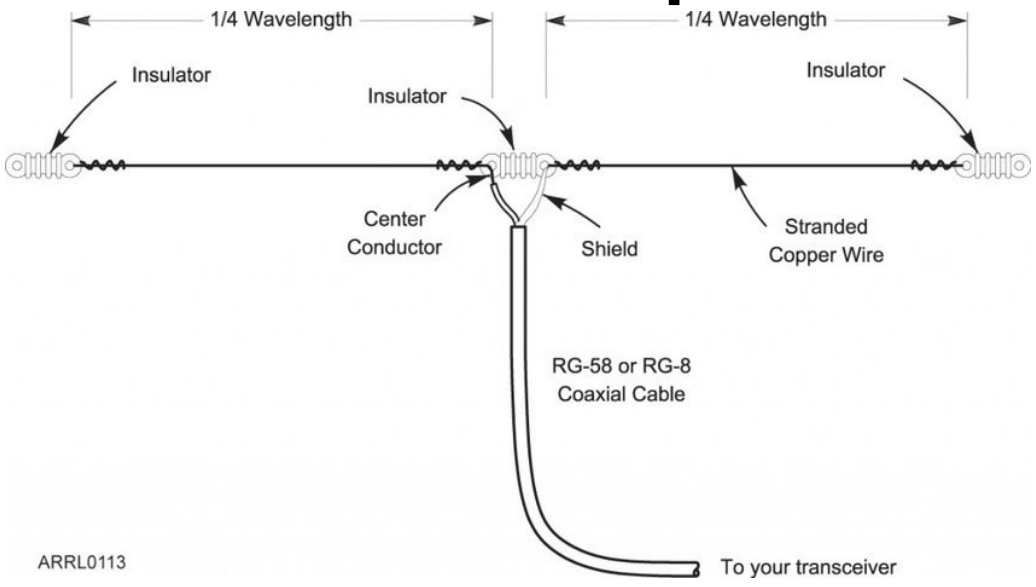
Half-Wave HORIZONTAL Dipole



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Antenna Radiation Patterns

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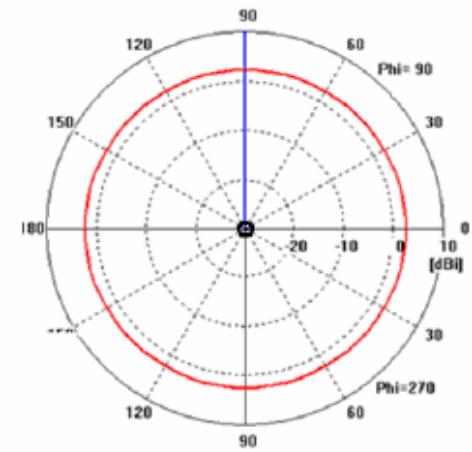
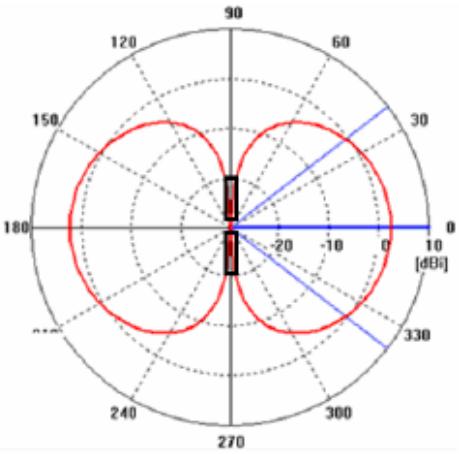
Horizontal Dipole Radiation Pattern





Side, End-On View

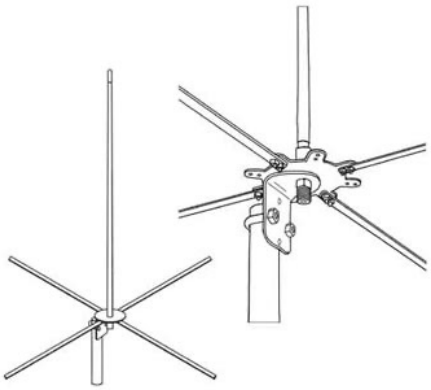
Top View

79

Vertical Monopole Antenna

- Where's the other half of the antenna?
- You need a ground plane
- Like the roof of a car
- Any car?

80



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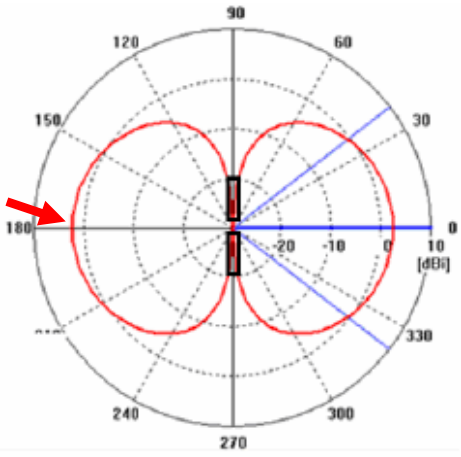
Antenna Gain

- All Gain is Relative (dbi)
- Directional Antennas are "Concentrators"
- Even the Dipole has a tiny amount of gain



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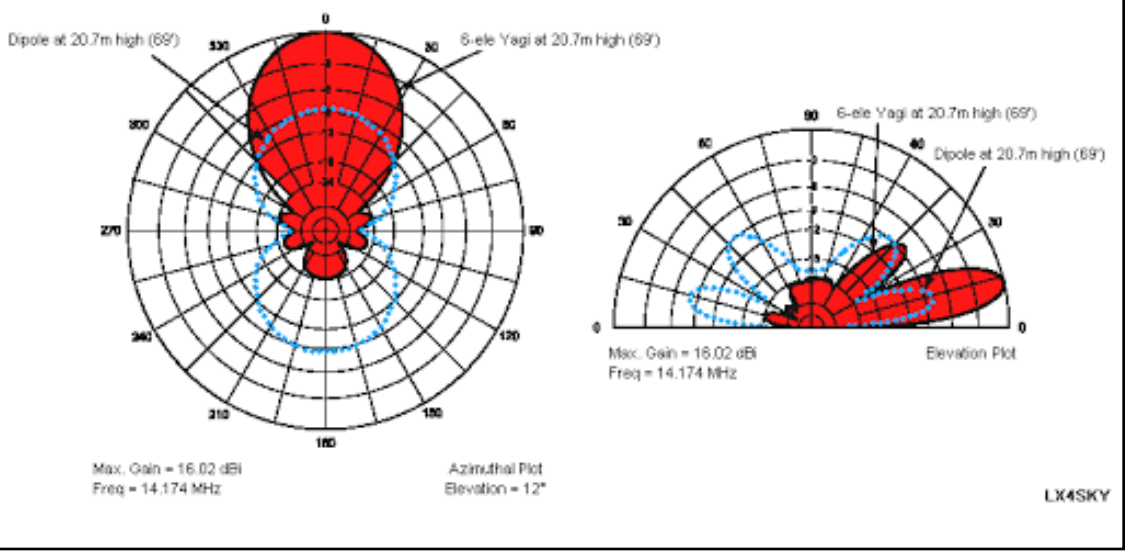
Yagi

83

Yag



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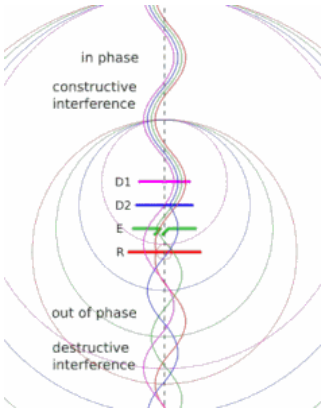
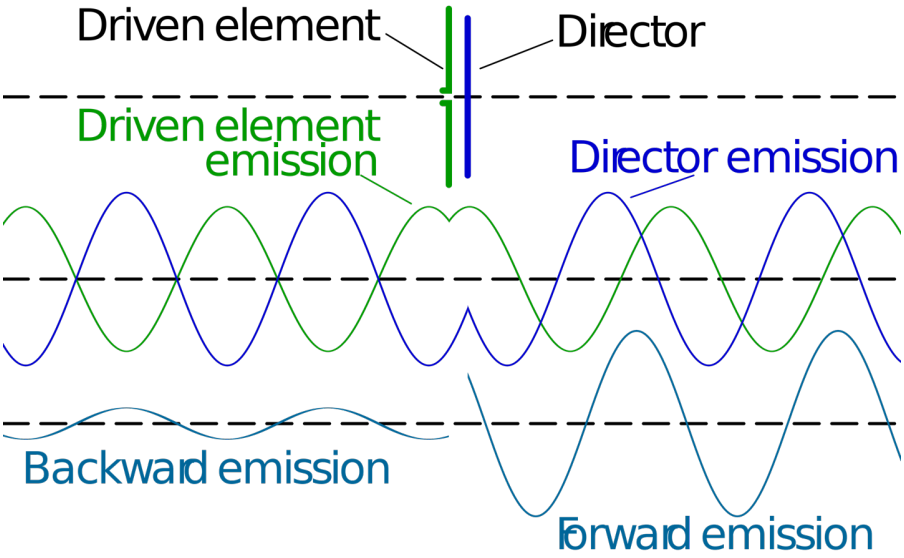
How the Yagi Works





85

Slim Jim

UHF 440-470 MHz Slim Jim Antenna

(4 customer reviews)

$37.00 – $41.00

Are you looking for a UHF omni antenna with a little more gain? Our UHF Slim Jim Antenna delivers up to 6dbi of gain on the 440 – 470 Mhz UHF bands, which is almost twice the gain of a J-Pole and 5 times the gain of a 1/4 wave ground-plane antenna. Plus the antenna also have the great low noise floor and wide bandwidth typical of our other antennas.

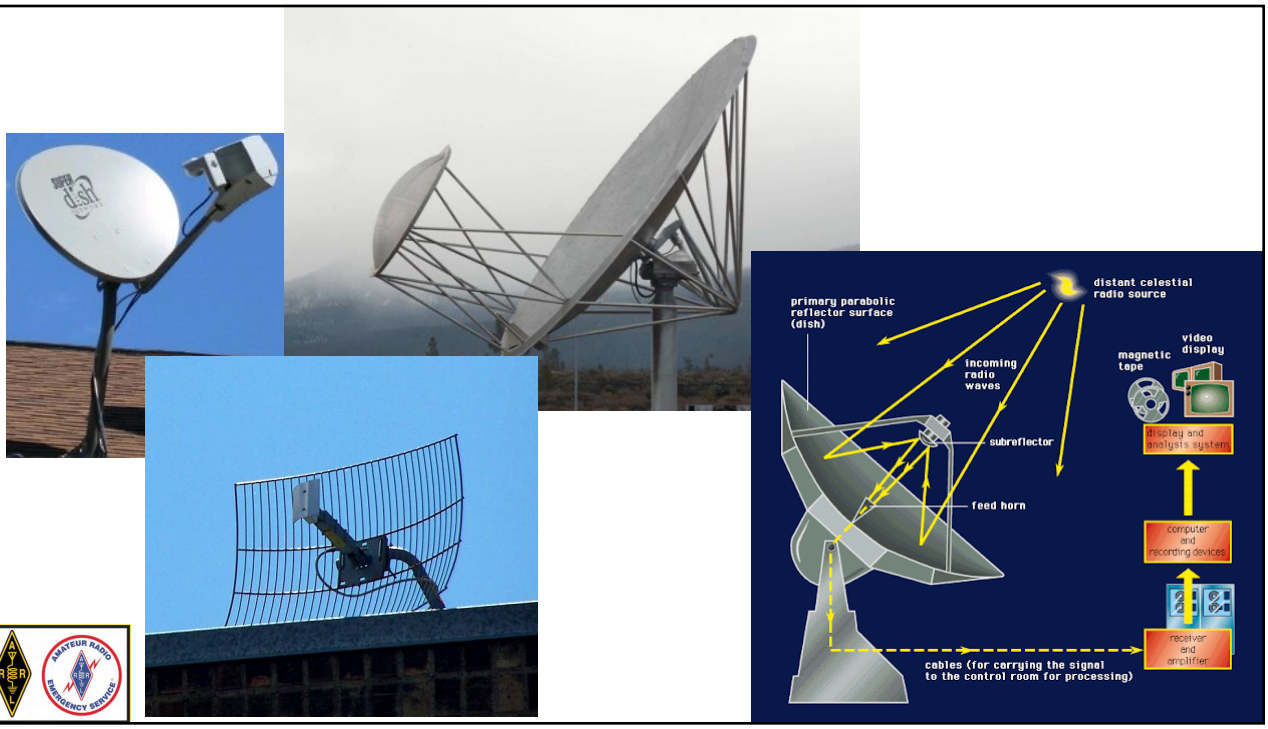
UHF Slim Jim Antenna 440-470MHz: 440-450MHz Amateur Radio

connector: SO-239 Clear

$37.00

1 Add to cart

86



87

Just a Few Types of Antennas

- Half-wave Dipole
- Quarter-wave vertical
- 5/8-wave vertical
- Yagi
- Dish
- Hourglass loop

88

Logarithmic Units

89

WHY?

90

Use a Calculator

- dB = 10 * $\log_{10}$(power ratio)
- Power ratio = 2:1
- Log_{10} (2) = 0.3 3db
- Log_{10} (10) = 1 10db

91

Or Just Know These Common Values

- 3db = 2x
- 6db = 4x
- 9db = 8x
- 10db = 10x

92

dB of What?

- dBi – compared to a (theoretical) "isotropic antena"
- dBm – compared to 1 mW
- dBv – compared to 1 mV

93

Test Yourself

- Prior to 2003, spurious emissions had to be 40 dBm or lower
- Post 2003, this was changed to 43 dBm

- How much difference is that in linear units?

94

95

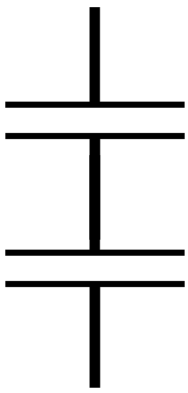
Moving Up to General

96

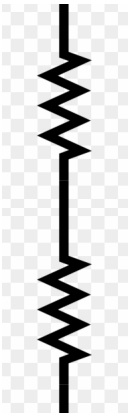
Parallel vs. Series Components

97

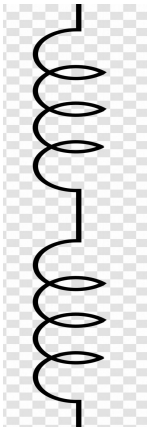
In Series



Special



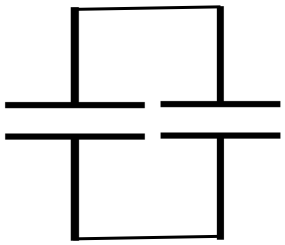
Just Bigger



Just Bigger

98

In Parallel



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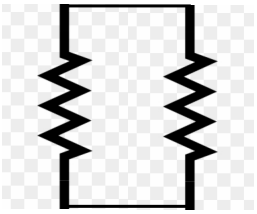

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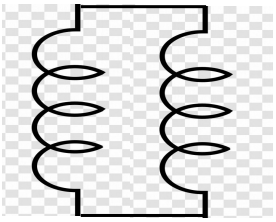


Special

99

The "Special" Ones

$$X_{total} = \frac{1}{\frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + \ldots}$$

100

Computing Parallel Resistance

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

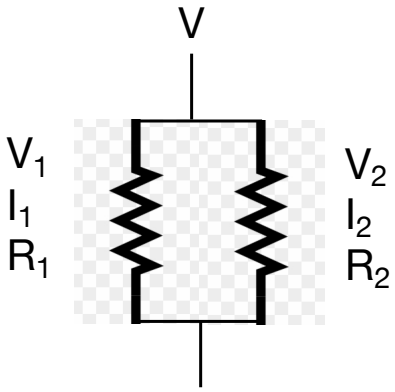
101

Computing Parallel Coils

$$L_{total} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2}}$$

102

Kirchhoff's Laws



Force applies equally: $V = V_1 = V_2$

Charge/Current is conserved: $I = I_1 + I_2$

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RMS Voltage

- Stands for "Root Mean Squared"
- the "amount of AC power that produces the same heating effect as an equivalent DC power"
- $V_{RMS} = 0.7071 * V_{peak}$
- $0.7071 \sim 1/\sqrt{2} = (\sqrt{2})/2$

104

Gravitational Potential Energy

$$\text{PE grav.} = m \times h \times g$$

Where:

- PE grav. - **Gravitational potential energy** of an object;
- m - **Mass** of the object in question;
- h - **Height** of the object; and
- g - **Gravitational field strength** acting upon the object (1 g or 9.81 m/s^2 on Earth).

105

Electric Field ~ Gravity Field

- When a battery is connected into a circuit, the excess of positive and negative charges at the battery terminals cause an electric field to exist in the circuit.
- Electrons in the circuit have electric potential energy because of their position in the electric field; there is a difference in electric potential energy (a 'potential difference' or a 'voltage') between any two points in the circuit.
- Charge gains electric potential energy as it passes through the battery; this is transformed into other energy forms as charge moves around the circuit.
- 'Voltage' is about differences in electric potential energy for each change. This is very helpfully reinforced by using 'joule per coulomb' instead of 'volt' when measuring voltage.
- The greater the voltage, the greater the electric field in a circuit and the greater the electric potential energy per charge transformed as charges move in the circuit.

106

Electrical Potential Energy

Electric Potential Difference

The **electric potential difference** between points **A** and **B**, $V_B - V_A$ is defined to be the change in potential energy of a charge **q** moved from **A** to **B**, divided by the charge. Units of potential difference are joules per coulomb, given the name volt (V) after Alessandro Volta.

$$1\,V = 1\,J/C \tag{7.3.2}$$

107

Definitions

Volt:

1 Joule of energy per Coulomb of charge

Ampere:

1 coulomb of charge moving past a point in one second

108

Power = Energy/Time

- 1 Watt = (1Joule/Coulomb) *(1 Couloumb / 1 s)
- V = 1Joule/Coulomb
- A = 1 Couloumb / 1 s

- 1 Watt = Volt * Amp

109