# Charge, Voltage, Current, Power, & Frequency

# Charge: The Coulomb

One Coulomb of Electrons contains

6 240 000 000 000 000 000 Electrons

or 6.24 x $10^{18}$ or 6.24 exaelectrons!

Like Charges Repel, Unlike Charges Attract

$$F = k \times \frac{Q1Q2}{r^2}$$

where k= $9^9$

F in Newtons

# Separated Charges

Suppose two charges of 1 Coulomb each are 1 meter apart.

The force between them is:

$$F = 9^9 \frac{1C \times 1C}{1m^2} = 9^9 N = \frac{9^9 N}{9.8} = 918000000\,kg$$

That's almost a billion kilograms!

# Separated Charges

Turbo-Electric Charge

Rising Wind rubs against Falling Ice, separating charges.

Separated Charges build enough Potential Force to break the insulating properties of air, about 750V/mil.

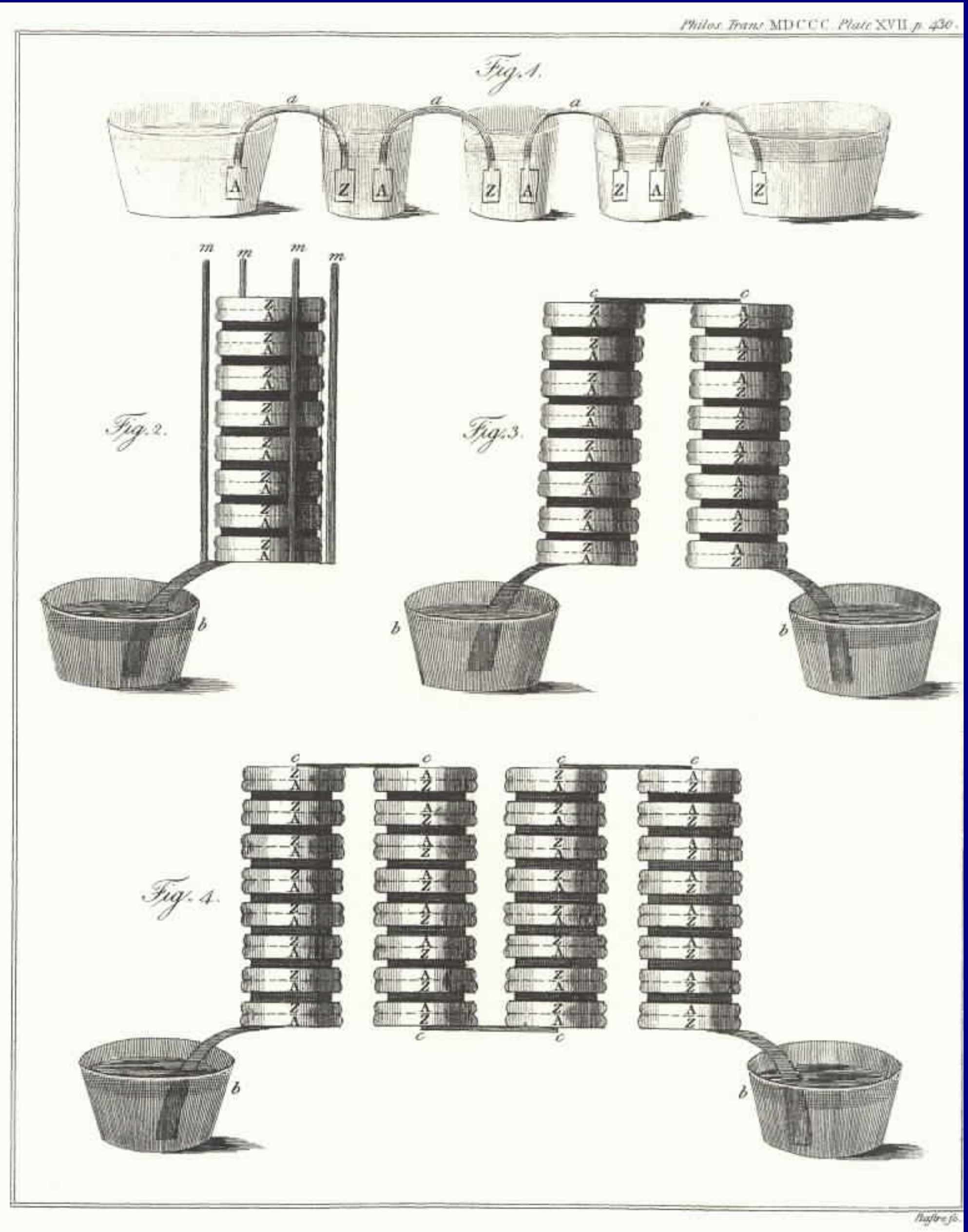

This is a Signal we Don't want to Catch!

# Chemical Cells

The first electrochemical cells were used around 250 BC in Persia to electroplate gold onto base metal for jewelry.

Alessandro Volta in Italy developed a multiple cell Silver-Zinc battery about 1800.

# Volta's Battery

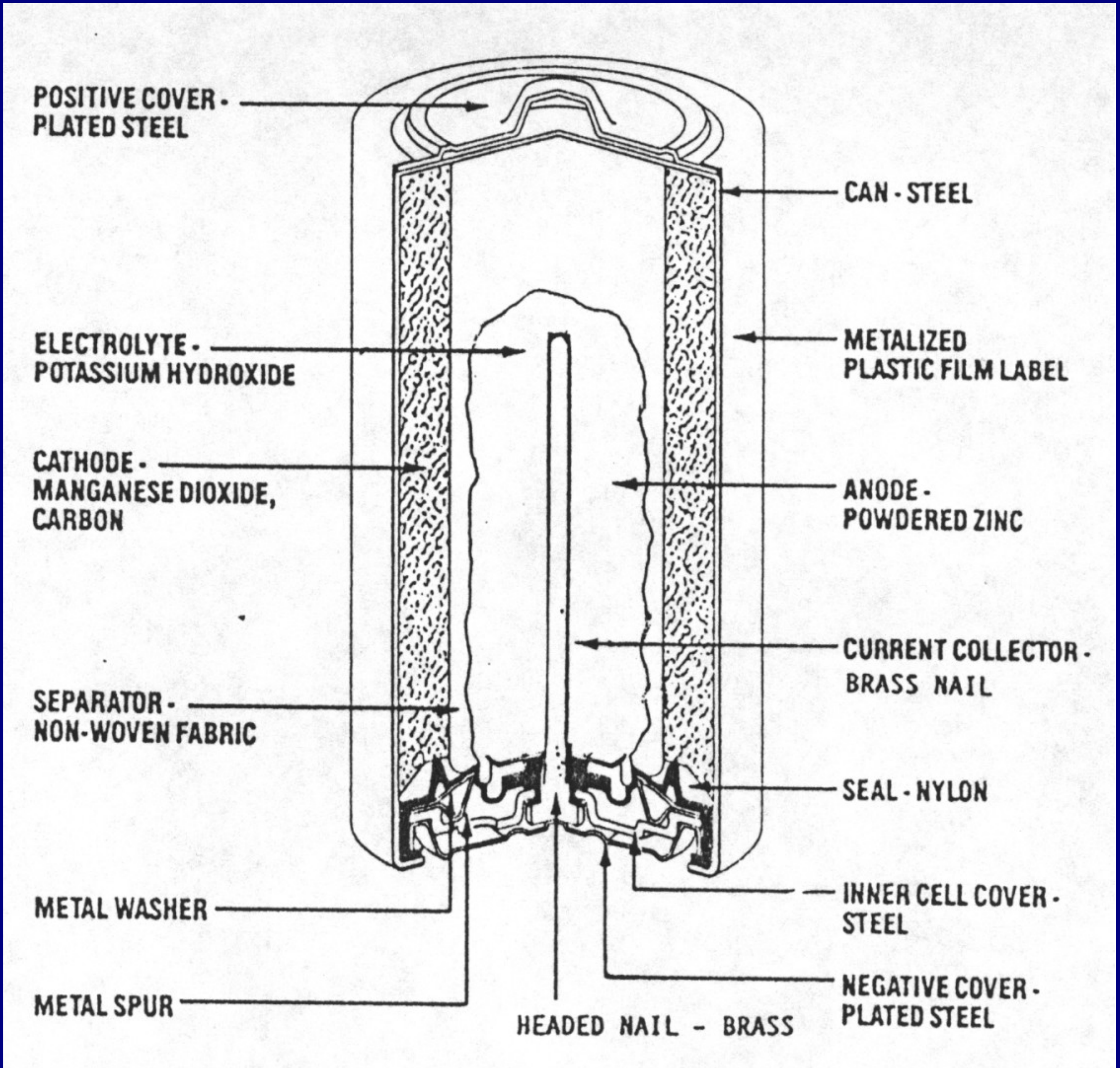



Volta built each cell by connecting a plate of silver to a plate of zinc with a moistened cloth between them.

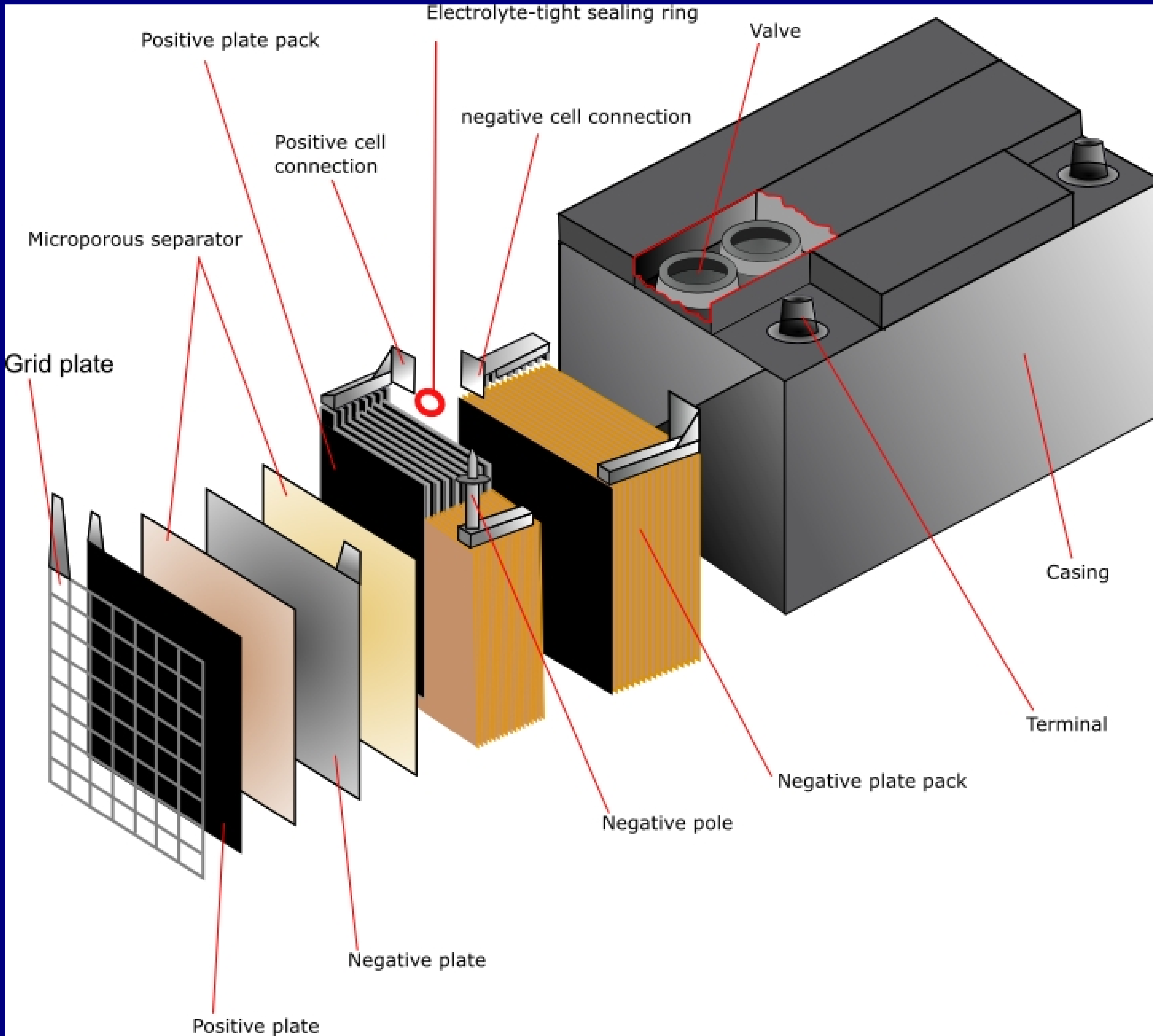
Stacking multiple cells in series increased the electrical potential and the strength of the shock!

# Modern Batteries

# Alkaline Cell



# Lead Acid Battery




Lithium Polymer Battery – Latest technology, high capacity, light, prone to catching fire if mis-treated.

# Solar Cell

Made with semiconductors

Silicon or Gallium-Arsenide.

Directly harnesses sunlight

to make electrical energy.

Light causes electrons to

move from one electrode

to another.

Prices have come down dramatically
as Quality improves.

# Large Arrays of solar Cells

Many cells in series produce clean power when the sun shines.

Some places are not as sunny as other places.

Not much good at night.

# Potential: The Volt

When One Joule of Energy moves One Coulomb of Charge there is One Volt of Potential.

$$Volt = \frac{Energy}{Charge}$$

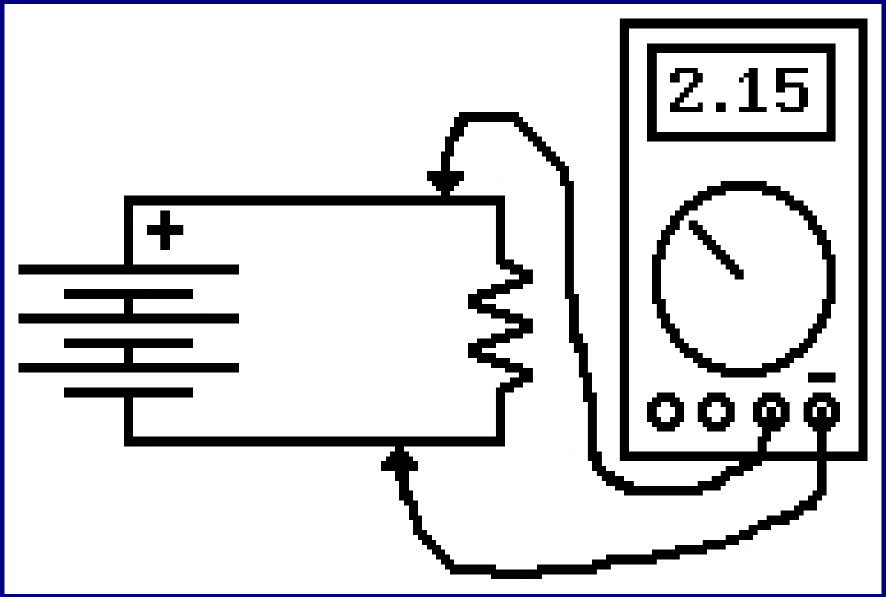
Potential Difference, or Voltage, is always with respect to some other point.

Voltage may be measured with reference to Ground, or Across a Component.

# Measuring Voltage

Voltage Measurement requires the meter leads to be connected between two points.

For example:
Across a Component or Between the Battery Terminals.




Set the Meter to a voltage range higher than the expected voltage

Match – to – and + to +

# Always!

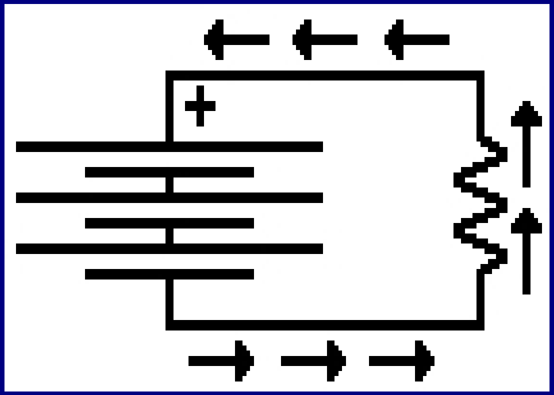
Set the Multimeter to the Desired Setting and Range BEFORE connecting to the circuit.

# NEVER!

Never Rotate the Setting Dial while connected to an active Circuit.

If you pass through the Current or Resistance Setting you will Blow a Fuse or Damage the meter!

# Current




When a complete conducting circuit exists between the Positive and Negative Terminals of a Voltage Source, a Current of Electrons will flow.

Ampere: The flow of One Coulomb of Charge past any Circuit Point in One Second.

$$I = \frac{Q}{t}$$

# "Classical" vs "The Real Thing"

Early Experiments could not determine what was flowing in a circuit, or in which direction.

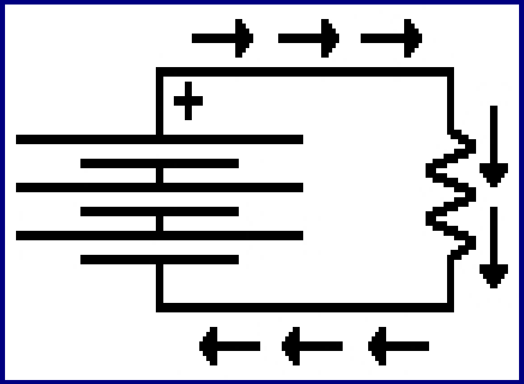
The Assumption was made that current was Positive to Negative, from abundance to scarcity.

J.J. Thompson discovered the electron in 1897, and announced the Electron Current in 1900.

By then Engineers had their electrical equations fixed, and have not yet awakened to reality.

There's no hope they ever will!

# Conventional Current Flow



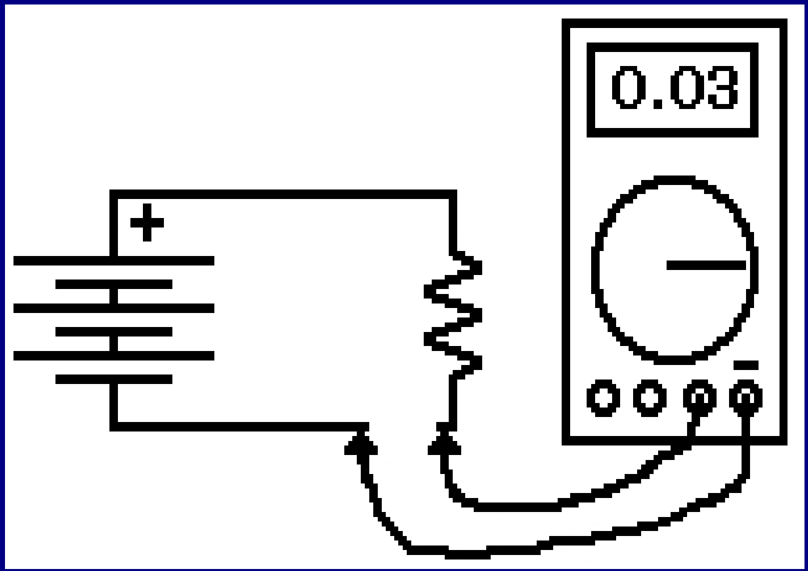

Potential and Conventional Current flows from Positive to Negative.

Electrons flow under the influence of Potential from Negative to Positive.

These two views are complementary, and useful in their own way.

# Measuring Current

As Current is the flow of Charge past a point, the Circuit must be opened to Insert the Meter.




This allows the current to flow through the Meter's measuring circuits.

Set the meter to the Highest Current Setting before connecting the Meter into the circuit. Then reduce the setting as required to measure the current.

# NEVER! NEVER EVER!

Never Connect a Meter that is in the Current Setting Across a Voltage Source.

The Meter Resistance to Current Flow is Very Low and the Huge Currents that result can destroy the meter fuse, maybe vaporize the meter leads, and burn or even kill you!

This may happen when Current measurements are being made, and then a voltage measurement is made without moving the meter dial to the voltage scale.

# Power

Power is measured in Watts, after James Watt.

One Joule for One Second is One Watt.

One Volt that delivers One Ampere is One Watt.

Power = Volts X Amperes

A ham rig draws 2.2A from a 13.6V power supply on receive. The Power Draw is 13.6V x 2.2A = 29.92W, or about 30 watts.

The same rig draws 18A on transmit, and the power supply voltage drops to 13.4V. The Power Draw is 13.4V x 18A = 241.2 watts.

The rig outputs 100W on transmit, so there is some waste heat produced during transmit. The waste heat is 241.2W – 100W = 141.2W, which warms the heat sink considerably after a few minutes of talk.

# Energy = Power Over Time

Notice that Power, the Watt, is Energy over Time. eg: Joule for a second or Volt X Ampere.

Power x Time gives us the Watt-Hour

$$Wh = P \times t$$

Your Electrical Utility bills for the power you used in units of Kilowatt-hours.

Kilowatt-hour = 1000 Watt-hour

A small amount of energy used over a long time could be equivalent to a large amount used for a short period of time.

# Horsepower

Power can also be expressed in Horsepower, where one hp is equal to 746 Watts.

I once worked an European station that was just pounding in, a very strong signal. I asked how much power he was running.

He responded “I'm running about 7 horsepower”.

How many watts is that?

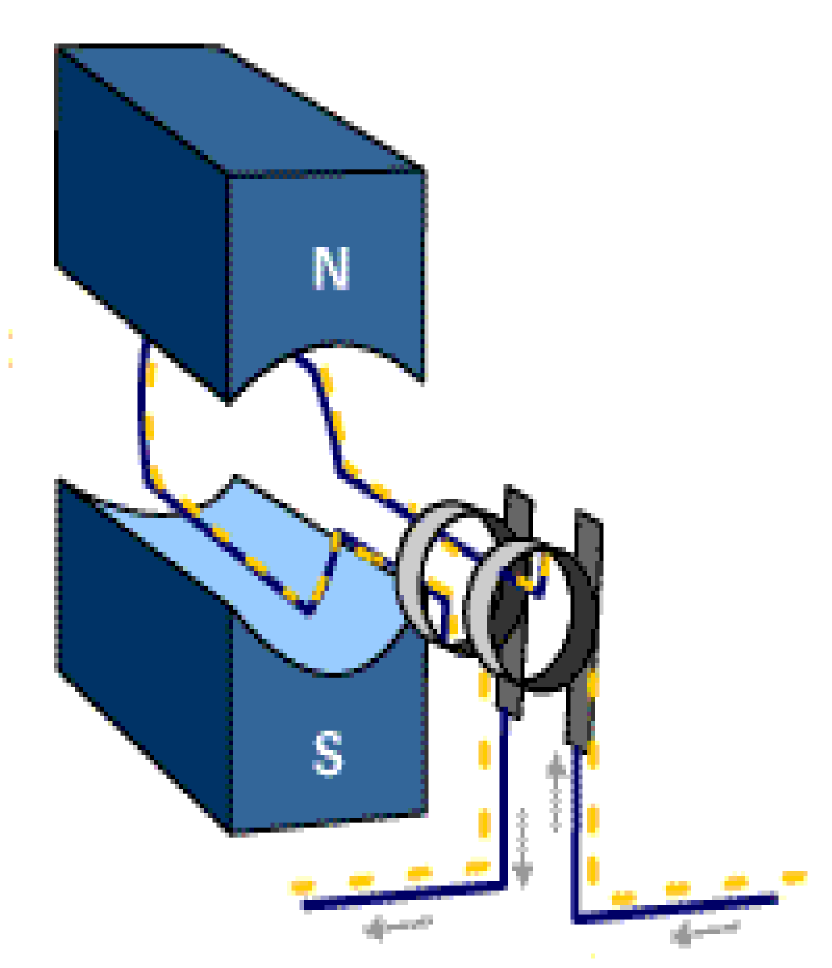
7hp x 746W = 5222W or
5.2kW
That's a tad over the legal limit!

# Alternating Current Fundamentals

The Voltages and Currents of Alternating Current (AC) sources change in polarity and magnitude over time.

Current first flows in one direction, and then reverses itself to flow in the opposite direction.

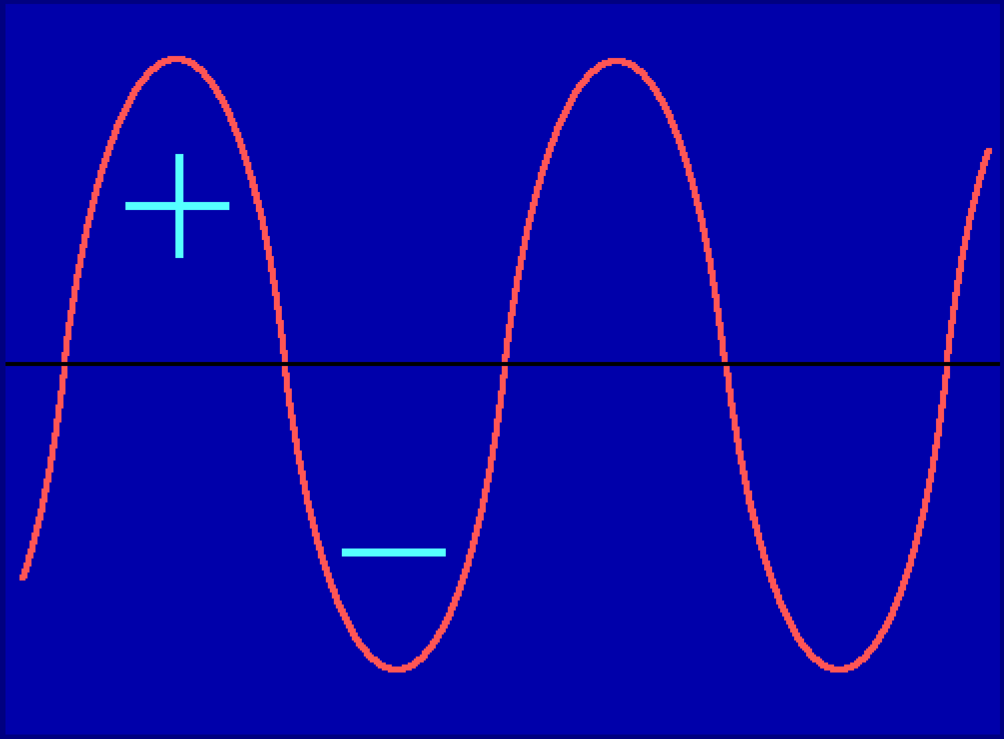
Rotating a coil in a magnetic field generates an alternating current.



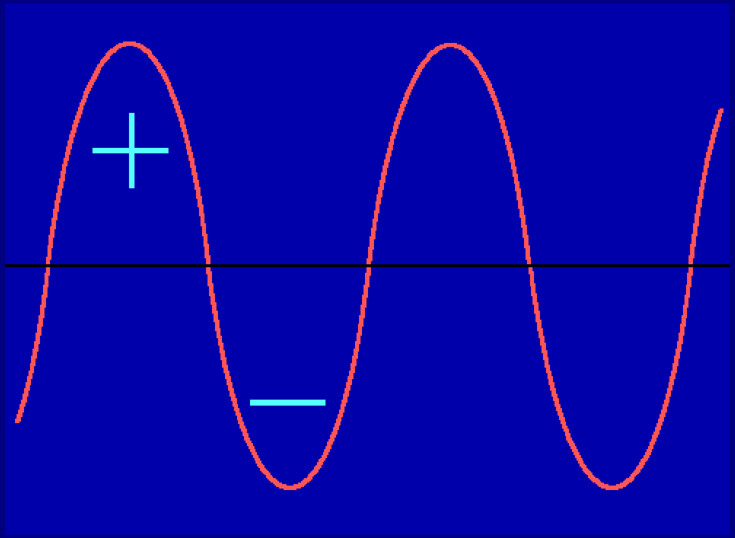
# WAVEFORM SHAPE

The shape of the constantly changing voltage or current is called the “waveform”

The simplest and most common waveform is the **Sine Wave.**




Other wave shapes are: Square, Triangle, Sawtooth, Trapezoidal, Parabolic, Pulse, Starting at zero value, the sine waveform increases to a maximum positive value, then decreases back to the zero value, changes polarity and increases to a negative maximum value, then decreases to zero value, changes polarity and begins once again to climb towards the maximum positive value.




This process can occur dozens, thousands, millions, billions, or even trillions of times a second.

# Three Terms Define a Sine Wave

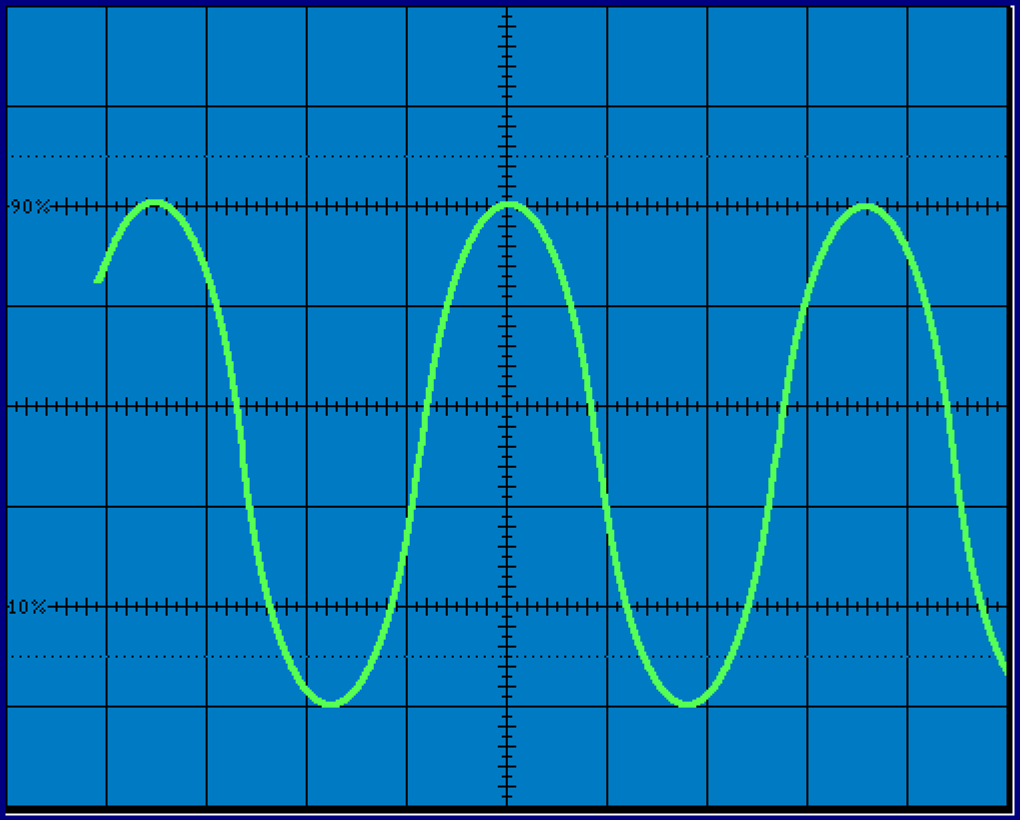
<u>Amplitude:</u> The strength of the wave, measured in volts or amperes.

<u>Frequency:</u> The number of times a complete wave will occur in one second.

<u>Phase:</u> That point in the sine wave cycle where the sine wave starts at “time zero”.

All three of these properties are exploited in telecommunications, for AM Radio, FM Radio, and PSK, used in digital cell phones and Amateur Digital Modes like PSK31.

# Sine Wave Measurement



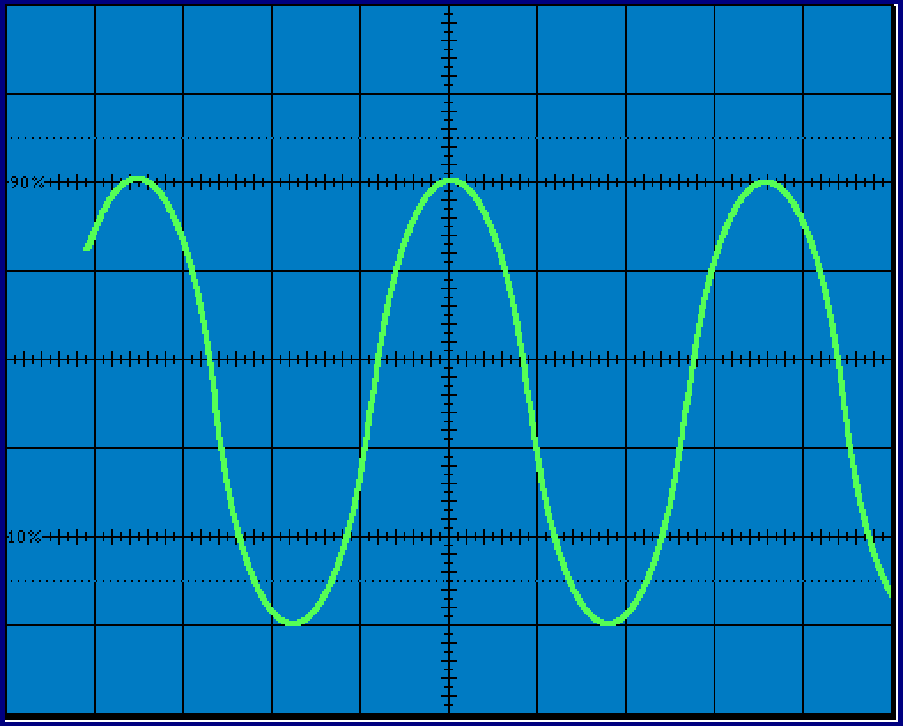

Here the wave is five grid divisions high.

With an Oscilloscope we measure voltage from the lower peak to the upper peak.

Set the waveform on a lower graticule line and a peak on the centre line.

Count the waveform height and multiply by the scope vertical sensitivity.

# Measurement in "Volts Peak to Peak"




Here the wave is five grid divisions high.

Vertical Sensitivity:

2V/div x 5 div =10Vpp

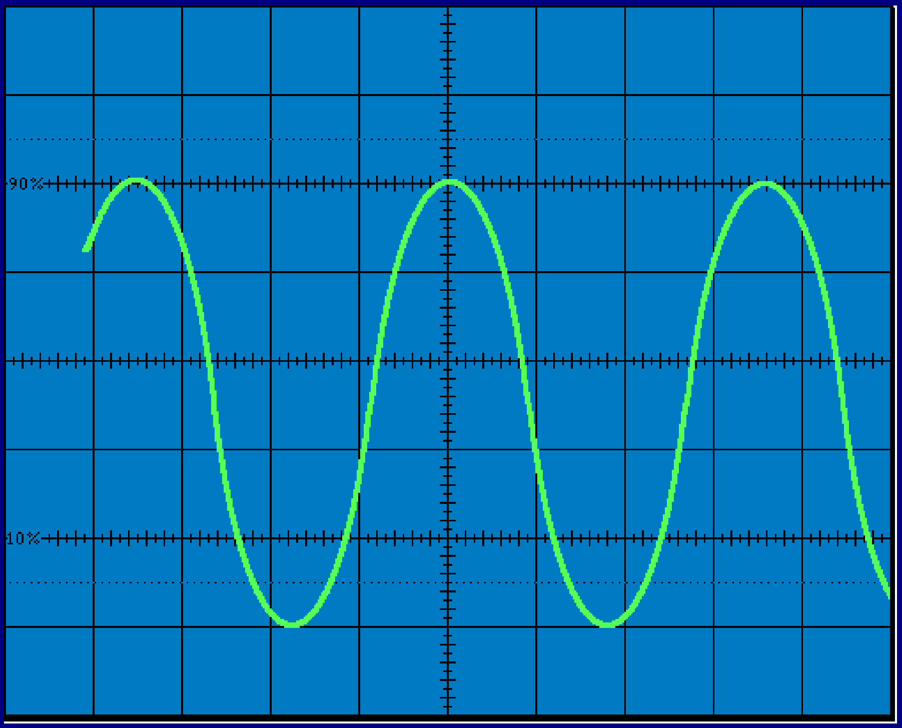
1V/div x 5 div = 5Vpp

.5V/div x 5 div = 2.5Vpp

.2V/div x 5 div = 1Vpp

.1V/div x 5 div = .5Vpp

# Constantly Changing Voltage !

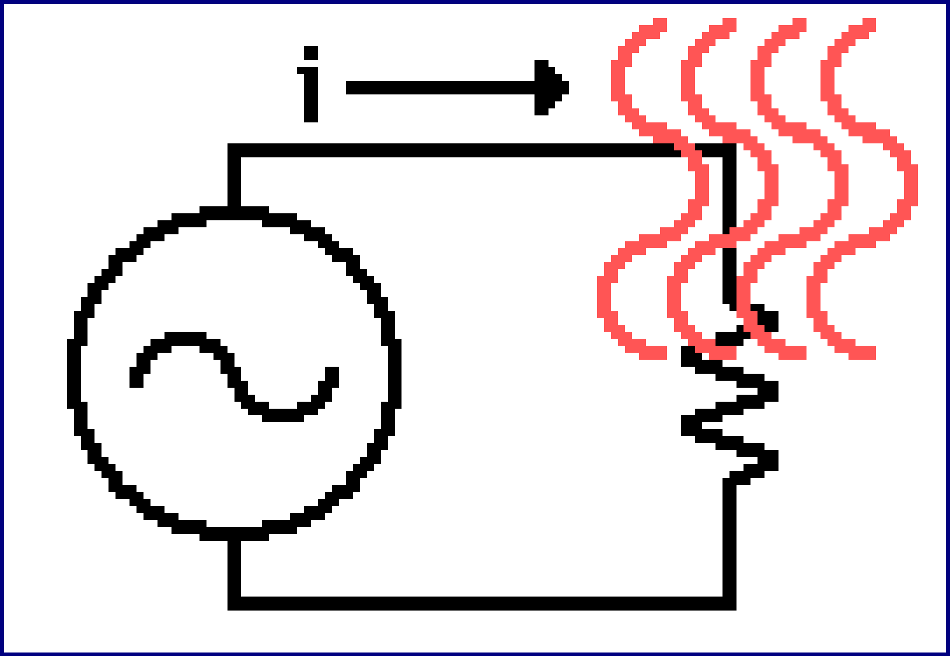



During the Sine Wave Cycle the instantaneous potential is constantly changing, from negative to positive and back again.

At times the voltage is low, even crossing through zero. At other times the voltage is at the peak potential.

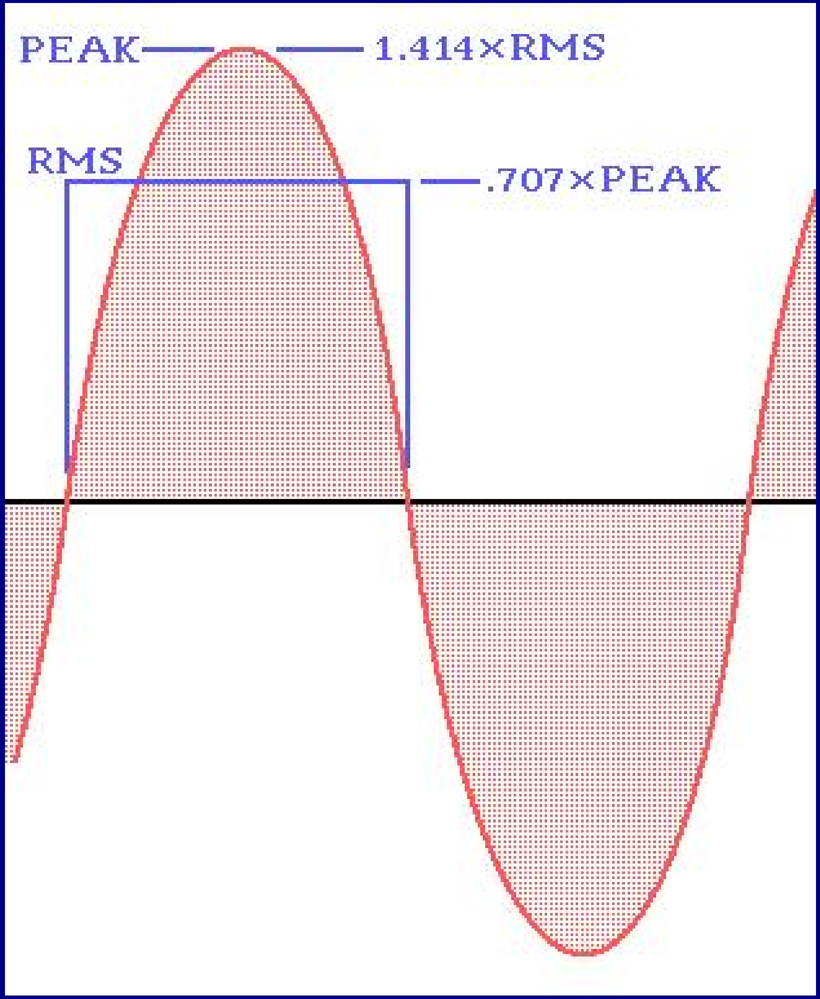
How do we meaningfully define AC Voltage?

# The Effective Value of an AC voltage or an AC current is:




**That DC voltage or current which would produce the same amount of power (heat) as the sine wave does.**

# Effective Values: "RMS"



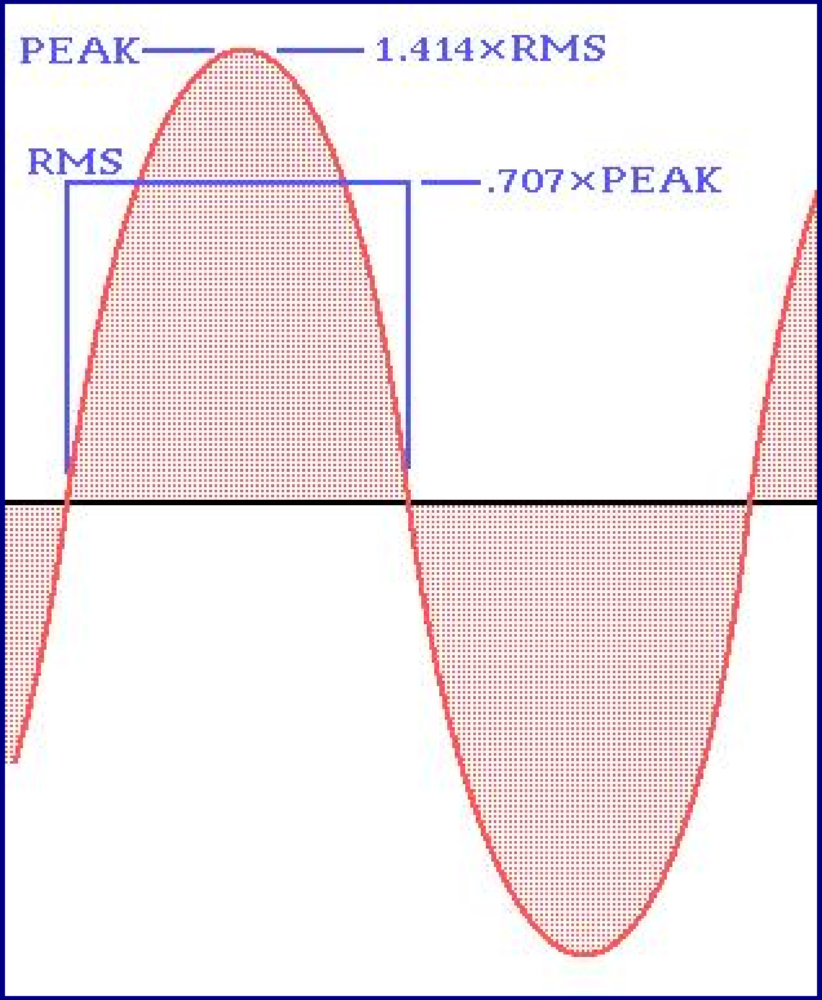

The Effective Voltage of a Sine Wave is 0.707 times the Peak Voltage.

This is called the Root Mean Square value, or RMS.

$$0.707 = \frac{1}{\sqrt{2}}$$

To obtain Voltage Peak from Voltage Peak to Peak, just divide Vpp by 2.

# Converting RMS to Volts Peak




Often you will need to know the peak voltage when given the RMS. The Peak Voltage of a Sine Wave is 1.414 times the RMS value.

$$\frac{1}{0.707} = 1.414 = \sqrt{2}$$

6 volts RMS x 1.414
= 8.484 volts peak.

# All AC Values are RMS values

Voltage, Current, and Power measurements, unless stated as “Peak to Peak”, or “Peak” are always “RMS” values!

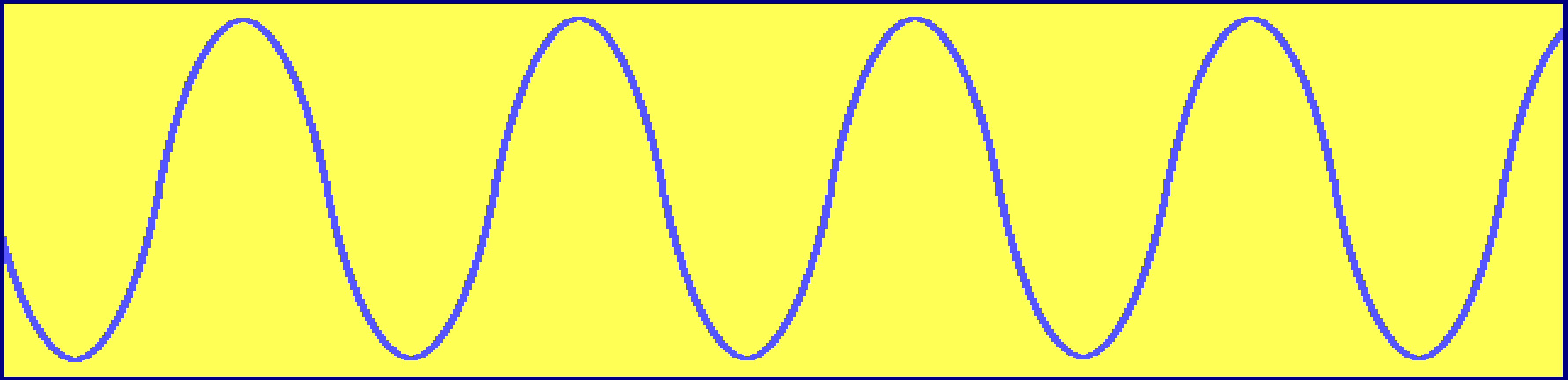
A 120 volt outlet provides 120 x 1.414 = 170 volts Peak. This is 340 volts Peak to Peak!

A transformer is marked 6.3V. Vp = ?

The same transformer is rated at 20A.

What peak current might flow?

# Waveform Frequency

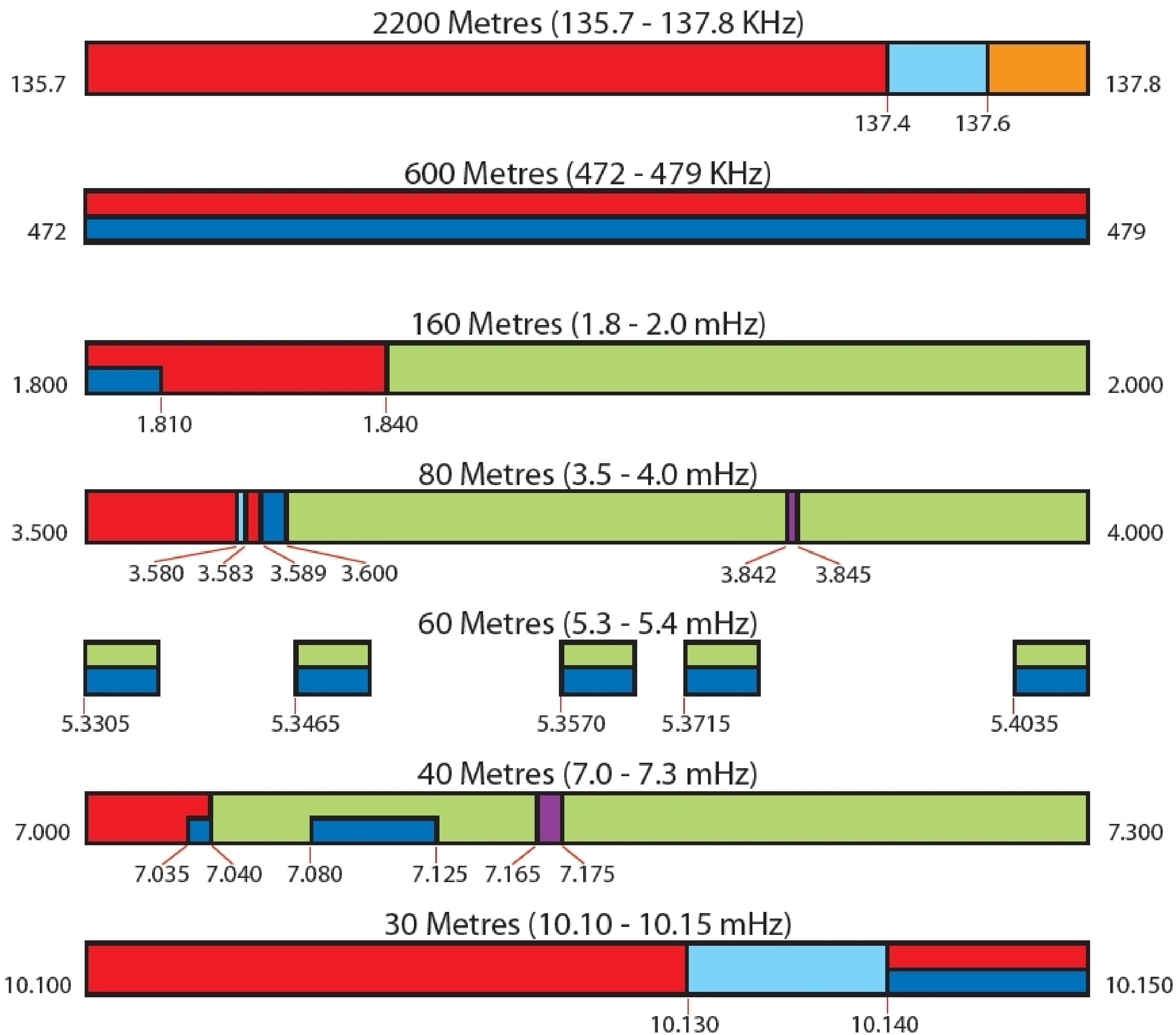


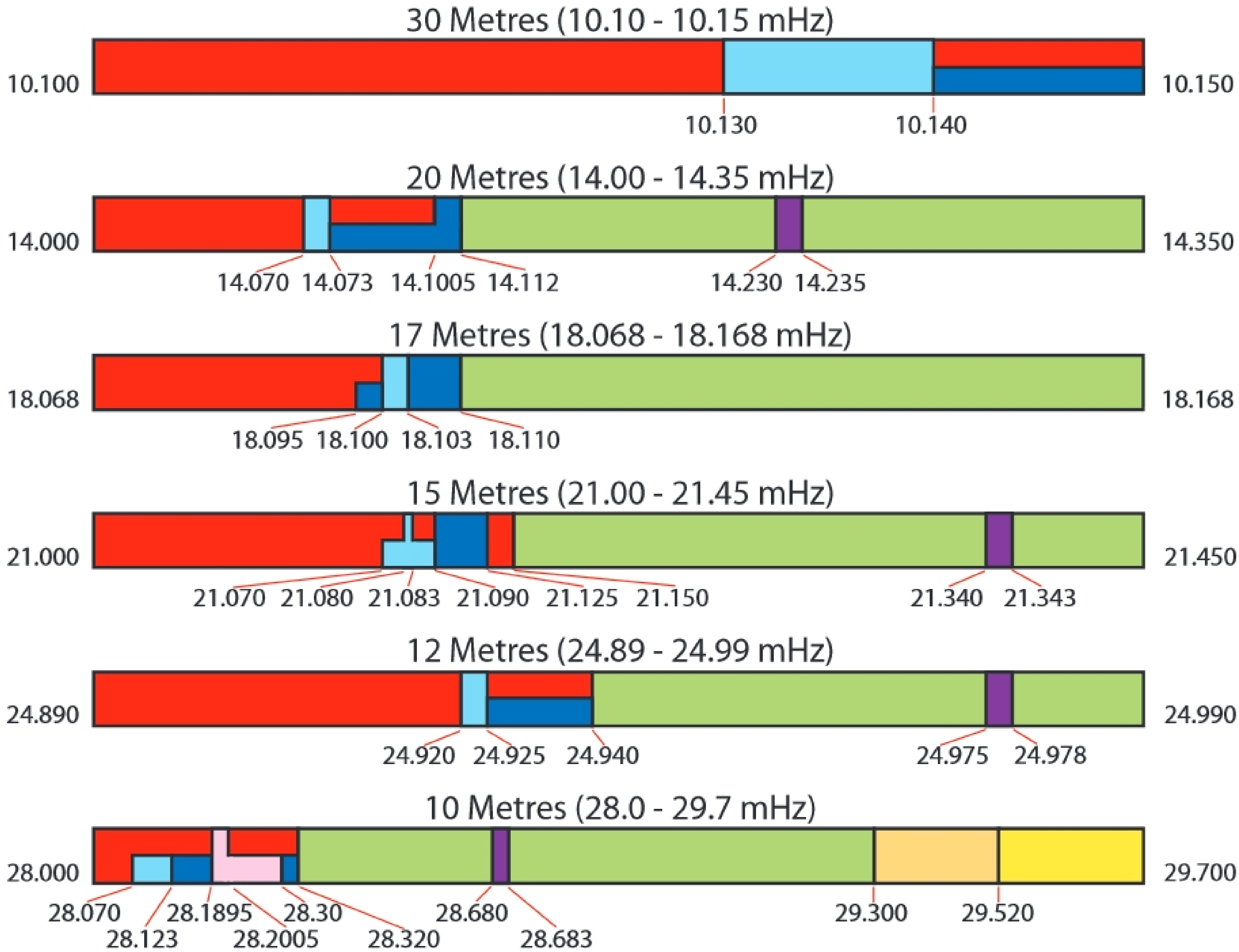
Frequency is the number of times something occurs in one second.

In North America, our electric power is distributed with a frequency of 60 complete cycles in each second.

Cycles Per Second is now called “Hertz” in respect of Heinrich Hertz, who lived from 1857 to 1894 and was the first to demonstrate experimentally the production and detection of James Clerk Maxwell's radio waves.

# The Lower HF Amateur Radio Bands





30 Metres (10.10 - 10.15 mHz)
10.100
10.150
10.130
10.140
20 Metres (14.00 - 14.35 mHz)
14.000
14.350
14.070
14.073
14.1005
14.112
14.230
14.235
17 Metres (18.068 - 18.168 mHz)
18.068
18.168
18.095
18.100
18.103
18.110
15 Metres (21.00 - 21.45 mHz)
21.000
21.450
21.070
21.080
21.083
21.090
21.125
21.150
21.340
21.343
12 Metres (24.89 - 24.99 mHz)
24.890
24.990
24.920
24.925
24.940
24.975
24.978
10 Metres (28.0 - 29.7 mHz)
28.000
29.700
28.070
28.123
28.1895
28.2005
28.30
28.320
28.680
28.683
29.300
29.520

| Band | Frequency | Max Band Width |
|---|---|---|
| 2200m | 135.7-137.8 kHz | 100 Hz |
| 600m | 472-479 kHz | 1 kHz |
| 160m | 1.800-2.000 MHz | 6 kHz |
| 80m | 3.500-4.000 MHz | 6 kHz |
| 60m | 5.332 MHz, 5.348 MHz, 5.3585 MHz, 5.373 MHz, 5.405 MHz, Max BW 2.8 kHz | |
| 40m | 7.000-7.300 MHz | 6 kHz |
| 30m | 10.100-10.150 MHz | 1 kHz |
| 20m | 14.000-14.350 MHz | 6 kHz |
| 17m | 18.068-18.168 MHz | 6 kHz |
| 15m | 21.000-21.450 MHz | 6 kHz |
| 12m | 24.890-24.990 MHz | 6 kHz |
| 10m | 28.000-29.700 MHz | 20 kHz |
| 6m | 50.000-54.000 MHz | 30 kHz |
| 2m | 144.000-148.000 MHz | 30 kHz |
| 1.25m | 219.000-225.000 MHz | 100 kHz |
| 70cm | 430.000-450.000 MHz | 12 MHz |
| 33cm | 902.000-928.000 MHz | 12 MHz |
| 23cm | 1.240-1.300 GHz | Not specified |
| 13cm | 2.300-2.450 GHz | Not specified |
| 10cm | 3.300-3.500 GHz | Not specified |
| 6cm | 5.650-5.925 GHz | Not specified |
| 3cm | 10.000-10.500 GHz | Not specified |
| 1.25cm | 24.000-24.250 GHz | Not specified |
| 6.4mm | 47.000-47.200 GHz | Not specified |
| 3.95mm | 76.000-81.500 GHz | Not specified |
| 2.45mm | 122.250-123.000 GHz | Not specified |
| 2.24mm | 134.000-141.000 GHz | Not specified |
| 1.24mm | 241.000-250.000 GHz | Not specified |