SEICHE 2022

Introduction to Arduino
Lesson 4 and 5– IDE Essentials

Instructor: Paul Frommeyer

www.paulfrommeyer.com

Corporate Sponsor: DXC Technology

REMEMBER!

Immediately copy the latest lesson folder (Lesson6 today) from your USB flash drive to your hard drive where you previously copied the other flash drive files (probably Documents folder)

Lesson Plan Overview

Lesson 1 – Intro and Setup
[may require 2 classes]
- Introduction to class format
- Overview of lesson plan
- Presentation format (monitor, camera, screen, whiteboard)
- Inventory of Arduino kits
- Inventory of USB drives
- Installation of ESP32 serial port drivers (Windows only)
- Installation of Arduino software
- History of Computing

Lesson 2 and 3 – Laptop operation review
- Control panel/Settings location
- Home directories and folder hierarchy
- Arduino file locations
- Search functions
- Open questions and issues
- History of Computing redux

Lesson 4 and 5 – IDE essentials
- The boards manager
- Setting board type
- Installing Libraries
- Loading example sketches
- Finding and selecting the Arduino USB port
- Uploading a sketch to the microcontroller [Example Sketch#1]
- Basic Arduino sketch (program) structure
- Uploading your own sketch [Example Sketch #2]
- History of Telecommunications and Networking – Part 1

Lesson 6 – DC Electricity Basics and DMM Intro
- Quick review: DC vs AC electric currents
- DC current operation
- Voltage vs Amperage (current)
- Ohm's Law
- Series vs parallel circuits
- Introduction to basic DMM functions and usage
- Measuring voltage [DMM usage #1]
- History of Telecommunications and Networking – Part 2

Lesson 7 – Elementary Components
- Resistors [DMM usage #2]
- Diodes and LED's [DMM usage #3]
- Powering LEDs and dropping resistors
- Capacitors: Electrolytic (polarized) vs non-electrolytic (non-polarized)
- Simplified transistor operation
- Connecting an LED to a microcontroller [Class Sketch#1]
- Connecting a transistor to a microcontroller [Class Sketch #2]
- History of Telecommunications and Networking – Part 3

Lesson 8 – ESP32 External power sources [may require 2 classes]
- Microcontroller board power requirements
- Board power input options
- Components with different voltage requirements
- External power circuit design

Lesson 9 – Connecting LED's to the ESP32 controller board
- Microcontroller pinouts and diagrams
- Different types of pins
- Analog input
- Digital Input and digital output

Lesson 10 – Connecting smart LED strips
- Simplified serial communication protocols
- One-wire serial communication protocol
- Hardware vs software serial
- WS2812B and Neopixel connections
- External device power design

Lesson 11 – Connecting LCD and Matrix Displays
- The SPI serial protocol
- SPI connections
- SPI device external power design

Lesson 12 – Connecting Sensors [Time permitting]
- I2C serial protocol
- I2C connections
- I2C sensor board power design and external power

Lesson 13 – Connecting other sensors [Time permitting]
- Connecting buttons
- Connecting potentiometers
- Reading buttons
- Reading potentiometers

Lesson 6 – DC Electricity Basics

- Alternating vs Direct Current
- Direct Current Operation – Classical Current
- Voltage and Amperage – Water Analogy
- Ohm’s Law
- Ampacity, overloading, and current protection
- Overvoltage and risks
- Types of Electrical Loads
- Series vs Parallel Circuits
- Introduction to basic DMM functions and usage
- Measuring voltage
- History of Telecommunications and Networking P2

Ohm's Law - Overview

An understanding of Ohm's law is critical to working with microcontrollers and any circuits that use LED's

$$E = IR$$

E = Electromotive Force

I = Intensity

R = Resistance

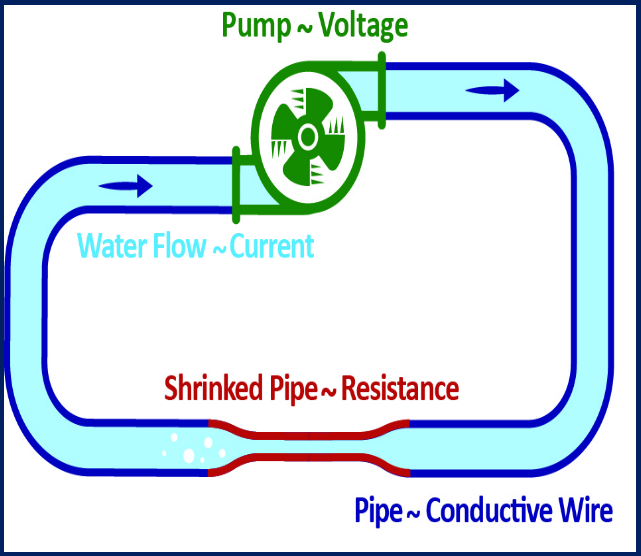
E = V = Volts

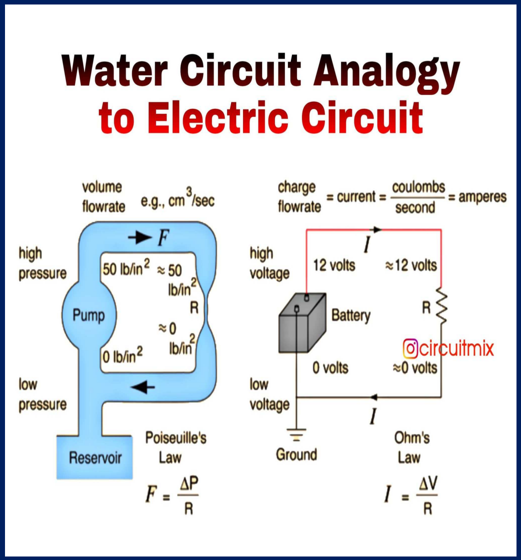
I = A = Amps

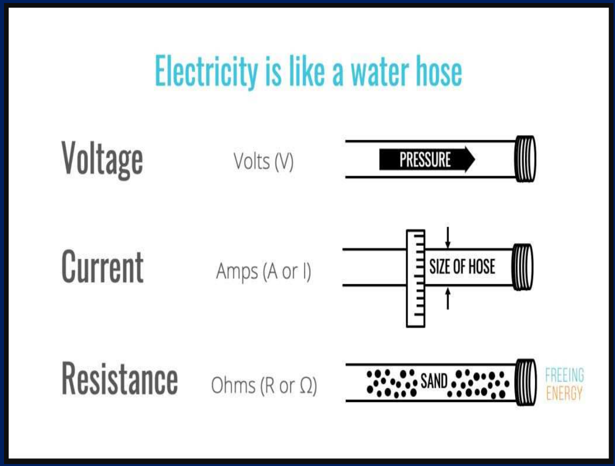
R = Ω = Ohms

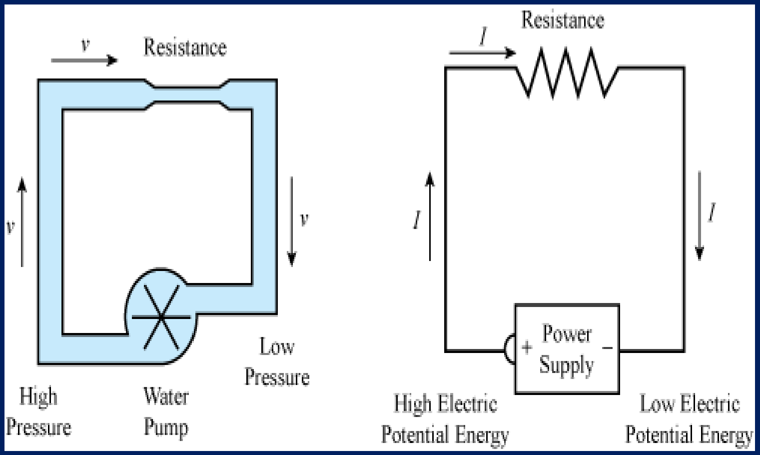
- **The generic term for a device which consumes electricity in a circuit is a <u>load</u>**
- **A no-load condition where electrons flow freely is called a short-circuit**
- **Short circuits are damaging to power sources, conductors, or both**

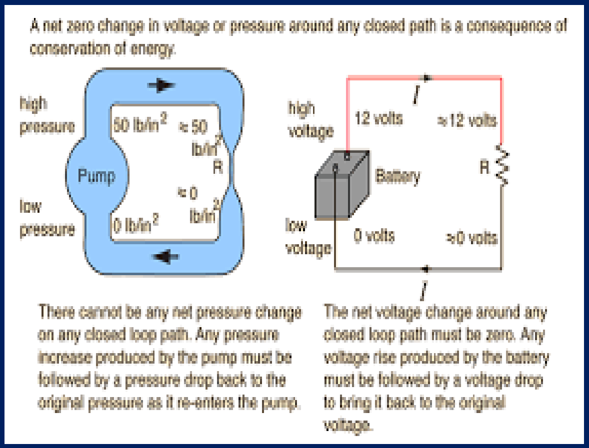
Ohm’s Law – Water Analogy









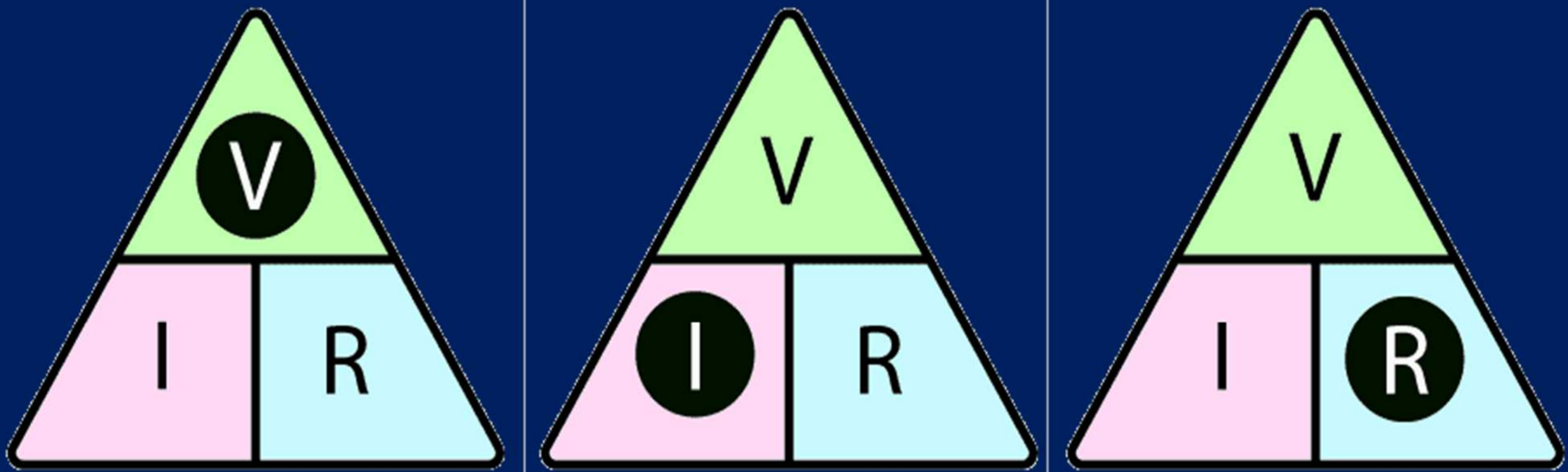


E = V = Volts

I = A = Amps

R = Ω = Ohms

Ohm's Law - Formulas

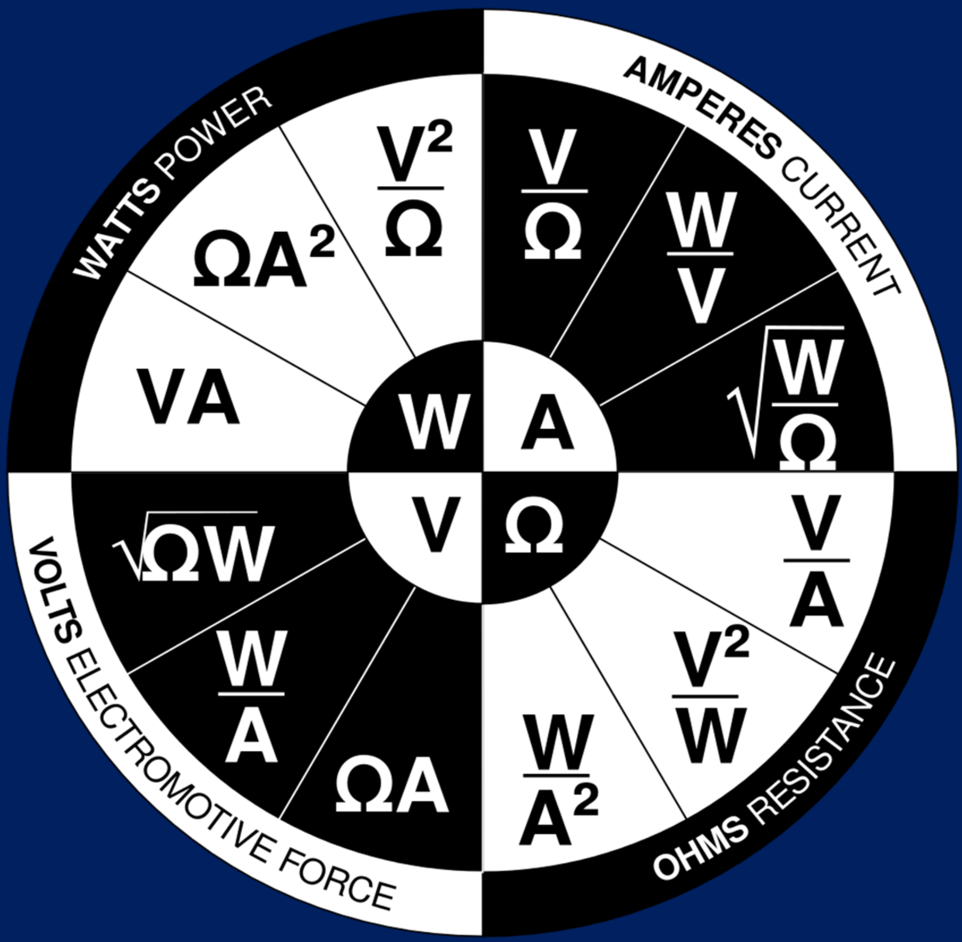


$$V = IR \qquad I = V/R \qquad R = V/I$$

Because Ohm's law is an equation, we restate (reformulate) the terms to solve for whatever factor (value) is unknown. Thus, you must know two of the quantities to derive the third. The pyramid (above) is an easy visual way to determine which equation you need. An even easier way is with an app. ☺

Ohm’s Law - Overview

You can also use the traditional four-factor wheel to solve for power, current, electromotive force, or resistance.



Power is determined by multiplying volts x amps. We pretend that this yields the power value in Watts, but watts may not match VA depending on the *power factor*– a complex concept that’s outside this class.

Ohm’s Law – Why Do We Care? - Ampacity

When electrons are blocked by resistance, it causes energy in the electrons to be lost. This energy is lost as heat (infrared electromagnetic radiation).

Resistance results whenever more electrons are forced through a conductor than the conductor can carry without loss (heating.)

The amount of current (amperage) that a given conductor can carry without excessive loss is called its **ampacity**.

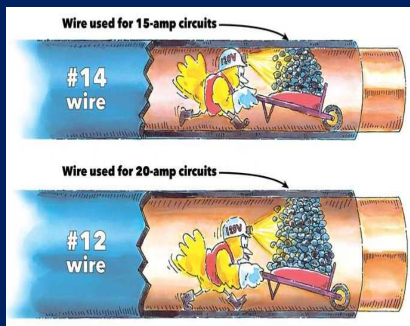
When the ampacity of a conductor is exceeded, that conductor becomes a resistor. The greater the excess, the greater the resistance.

As you would expect, the greater the resistance, the greater the energy loss– and thus the more heat is generated.

This can be a feature (think hair dryer) or a hazard (see below.)

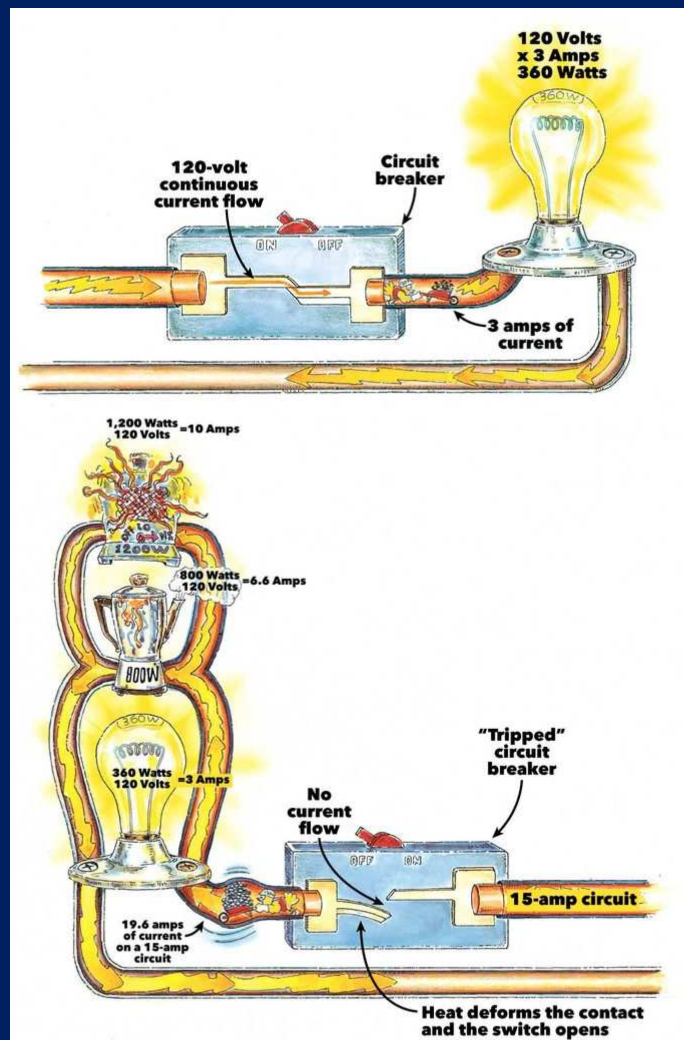
Exceeding the ampacity of a conductor is extremely dangerous. The conductor can heat to the point where a) the insulation catches fire, b) the conductor itself melts, or c) both. This is how electrical fires occur.

Ampacity – Sizing and Protection



- **Wire is sized by gauge, and each gauge of wire has a specific ampacity [for copper or aluminum, respectively]**
- **Ampacity is calculated based on summer temperature (90°F)**
- **Wire gauge is inversely proportional to size, e.g., an 18 gauge wire is smaller than a 6 gauge wire.**
- **You <u>can</u> use larger wire in place of smaller wire**
- **<u>Do not</u> use smaller wire in place of larger wire**

Overcurrent protection is based on conductors heating up when overloaded



Circuit Breaker – Heating of the conductor temporarily breaks the circuit; usually needs manual reset

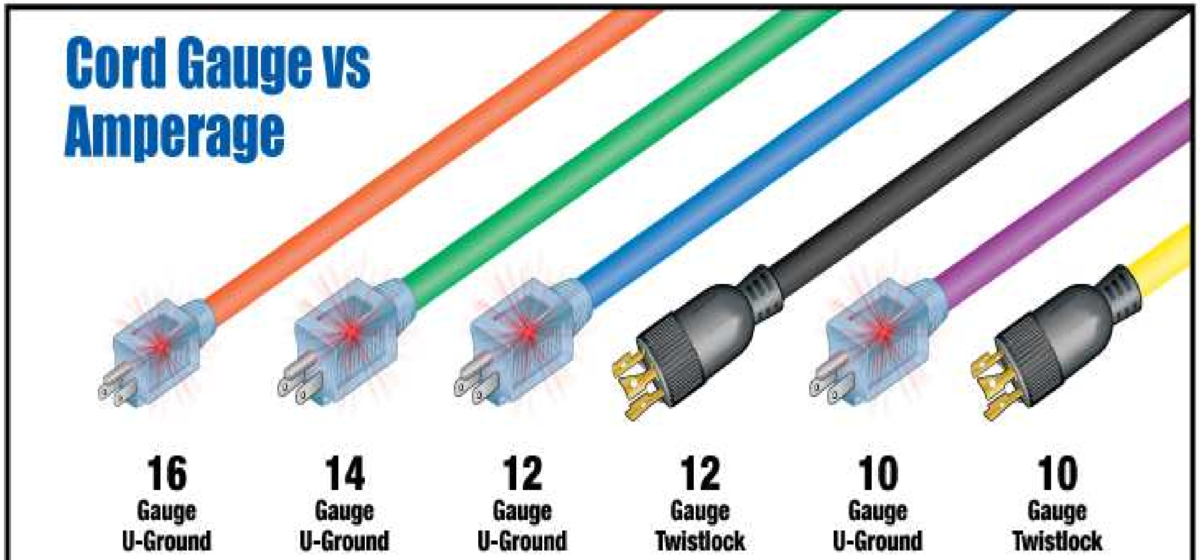
Fuse – Heating of the conductor melts it; it must be replaced

When there is no overload (which means, no heating), the circuit breaker stays closed, allowing electricity to flow

When there is an overload, the circuit breaker heats up, opening the circuit

Circuit breakers and fuses are sized to break the circuit BEFORE the conductor heats up to the point of damage – they have lower ampacity than the conductor they protect

Ampacity – A/C Power Cordage



Usage Guide

MEDIUM DUTY	HEAVY DUTY	EXTRA HEAVY DUTY	EXTRA HEAVY DUTY	ULTRA HEAVY DUTY	ULTRA HEAVY DUTY
Fans	Drills	Impact Hammers	Circular Saws	Generators	Generators
Small Appliances	Belt Sanders	Chain Saws	Chain Saws	Recipro Saws	Chop Saws
Stereos	Routers	Recipro Saws	Table Saws	Rotary Hammers	Rotary Hammers
Household Tools	Hedge Trimmers	Grinders	Worm Drives	Compressors	Tile Saws

Amperage Chart

	16 GAUGE	14 GAUGE	12 GAUGE U-GROUND	12 GAUGE TWISTLOCK	10 GAUGE U-GROUND	10 GAUGE TWISTLOCK
25ft.	13 Amps	15 Amps	15 Amps	20 Amps	15 Amps	20 Amps
50ft.	13 Amps	15 Amps	15 Amps	20 Amps	15 Amps	20 Amps
100ft.	10 Amps	13 Amps	15 Amps	15 Amps	15 Amps	20 Amps

Always use a service cord with ampacity sufficient for the load

The longer a conductor is, the more resistance it has.

This reduces ampacity.

And that causes *voltage drop* for long conductors or any conductor with reduced ampacity

Ampacity – Test Your Knowledge!

Match the load with a service cord and power source!

Leaf Blower
900W

Light Bulb
100W

Hair Dryer
1875W

4000lm LED
200W

Induction Stove
4,000W

Gaming Tower
1,000W

18ga 6ft

14ga 25ft

6ga 12ft

10ga 25ft

12ga 100ft

125V 30A

125V 15A

125V 2.5A

125V/250V 30A

Ohm’s Law – Why Do We Care? - Voltage

It is normally* not possible for a consumer of electricity to exceed it’s own ampacity (as long as it’s working normally.) A device never uses more *amperage* than it needs. You can safely plug a 1,000 watt light bulb into a 120 volt, 15 amp circuit (which provides 1800 watts of power.)

*Not true for constant current devices, which have theoretically infinite ampacity

Voltage is another matter. Devices are design to operate at specific voltages, or ranges of voltage. Voltage outside the permitted value(s) will always cause the device to malfunction. High voltage will almost always destroy the device. Low voltage may cause little to no damage (electronics, resistive loads) or total burn out (motors, most other inductive loads.)

Connecting a device to a higher voltage than it is rated for will destroy it.

Ohm's Law – Why Do We Care? - Arduino

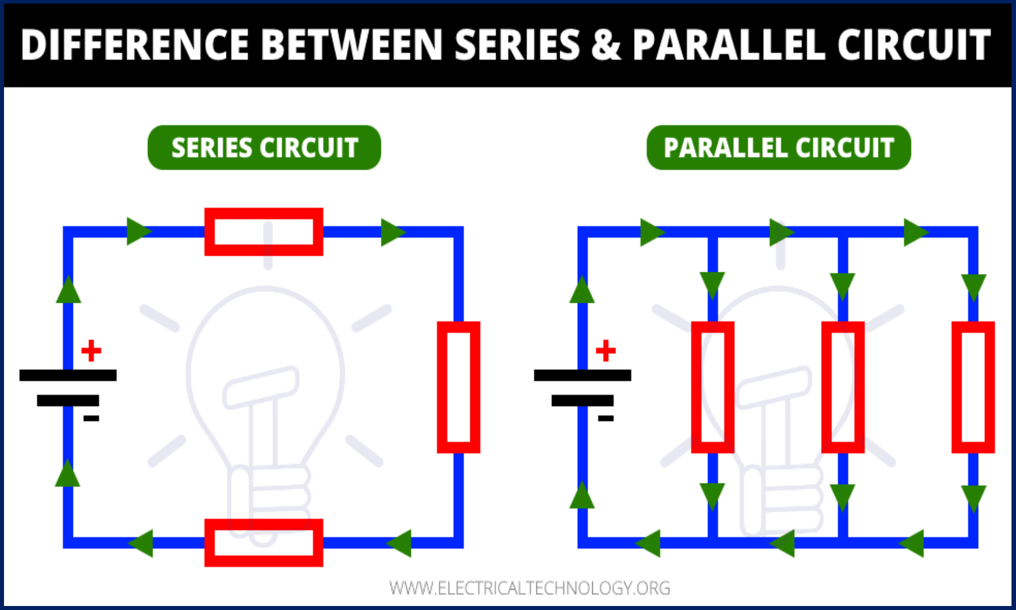
Nearly all Arduino IDE compatible boards have on-board voltage regulators which will accept a range of low voltage DC current and change it into the fixed DC voltage needed by the board's processor. That range is usually *very* narrow, and as covered previously board processor voltages are either 5 volts or 3.3 volts.

- **THERE IS NO OVERCURRENT PROTECTION FOR ELECTRONIC COMPONENTS**
- **THERE IS NO OVERVOLTAGE PROTECTION FOR ELECTRONIC COMPONENTS**
- **FAILURE TO CORRECLTY SIZE POWER DELIVERY AND USAGE CAN AND WILL DAMAGE MICROCONTROLLERS**

THE AMOUNT OF CURRENT (AND VOLTAGE!) A GIVEN PIN CAN SOURCE OR SINK *<u>VARIES BY BOARD</u>*

Types of Electrical Loads

- Resistive – Generate some sort of heat during operation; usually, generating heat is the purpose of the device (e.g. hair dryer)
- Inductive – Has a ferro-resonant electromagnetic component. Transformers and motors are the most common
- Constant current – The device must be supplied with a constant amount of current. The device will act as a short circuit without a current limiting device in series with the load. This usually destroys the device before it destroys the power source.

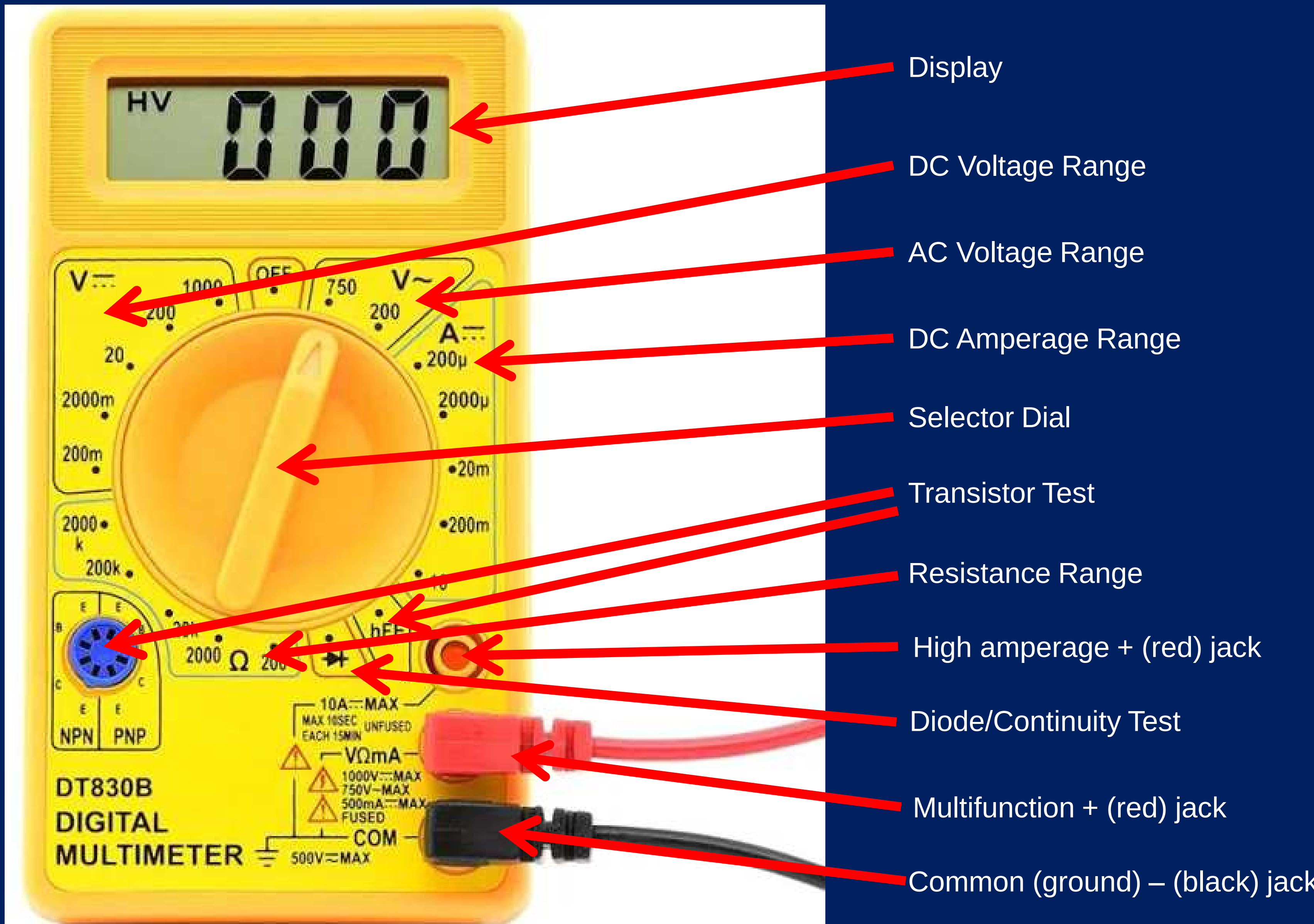


- Loads may be connected in series or in parallel.
- Series
  - Resistance is additive
  - Single points of interruption/failure
- Parallel
  - Amperage is additive
  - No single points of interruption/failure

Lesson 6 – Basic DMM Usage

- Digital Multimeters (DMM’s) are used for measuring electrical flows
- Voltage, amperage, and resistance are the most common measurements
- Some DMMs have a continuity function which will sound a tone when a series circuit is complete with the DMM; this will also test diodes
- Some DMMs can also measure frequency, duty cycle (percent of frequency), capacitance, inductance, and transistor operation
- Some DMMs also have *autoranging*

DMM Features and Functions



DMM Measurement

- **<u>Polarity is important for all DC functions</u>**
- Voltage is measured *in parallel* with electric circuits
- Amperage must be measured *in series* with the electrical flow
- Resistance is normally measured in series on a dead circuit
- Resistance must never be measured on a live circuit; this will damage the multimeter
- Continuity determines whether there is end-to-end conductivity
- Because polarity matters, continuity also checks diodes

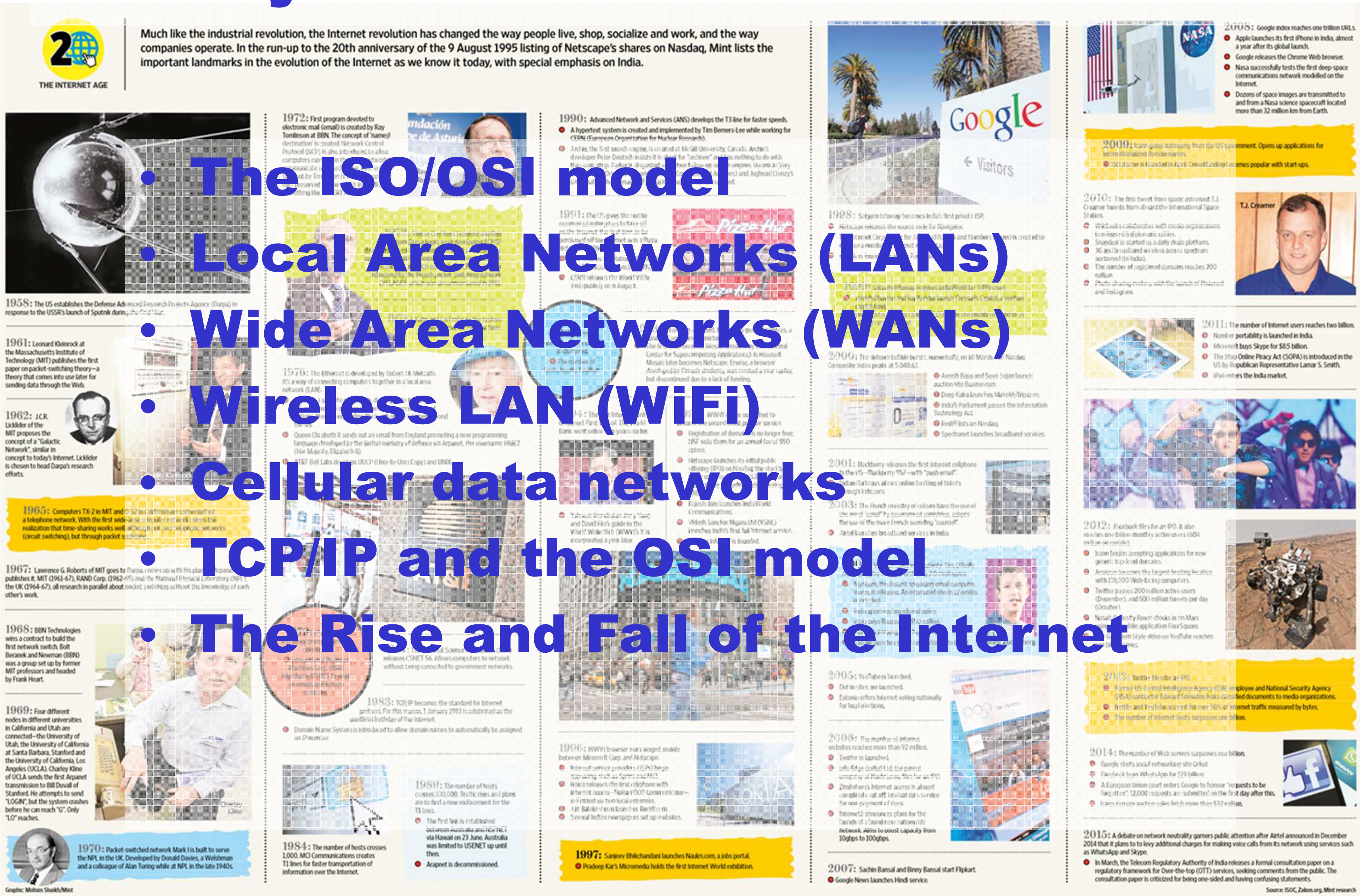
Let’s measure!

- Plug in your 5VDC 2A power supplies
- Assure the green barrel connector to screw terminal adapter is installed
- Attach a red male-to-male DuPont jumper to the + screw terminal
- Attach a black male-to-male DuPont jumper to the – screw terminal
- Keep the bare ends of the jumpers apart!!!!!
- Connect your alligator clip test leads to your multimeters (be sure black banana jack is plugged into the COM port on the meter!)

Let’s measure!

- Set your DMM selector dial for 200VDC (always use a larger range when first measuring something)
- Clip the red alligator clip to the red DuPont jumper
- Clip the black alligator clip to the black DuPont jumper
- Are you seeing anything on your meter?
- Change the meter setting to 20VDC
- What does your meter show now?

History of Telecommunications Part 2

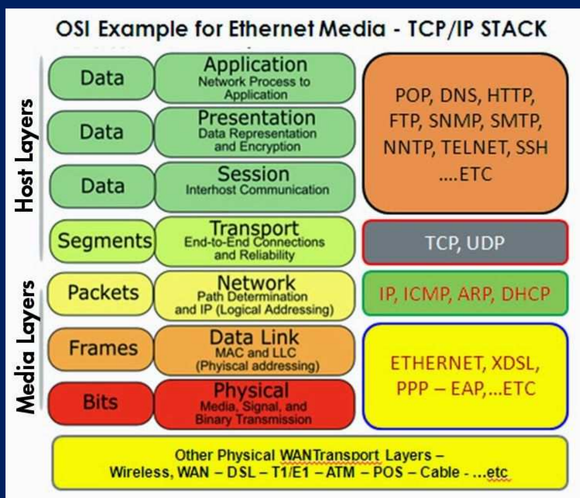


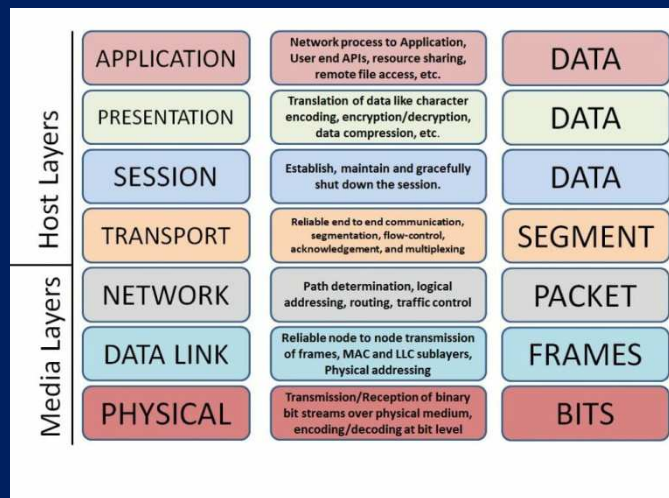
- The ISO/OSI model
- Local Area Networks (LANs)
- Wide Area Networks (WANs)
- Wireless LAN (WiFi)
- Cellular data networks
- TCP/IP and the OSI model
- The Rise and Fall of the Internet

The OSI/ISO Layered Network Model

- In a Quora post asking about the purpose of the OSI model, Vikram Kumar answered this way:
- “The purpose of the OSI reference model is to guide vendors and developers so the digital communication products and software programs they create will interoperate, and to facilitate clear comparisons among communications tools.”
- While some people may argue that the OSI model is obsolete (due to its conceptual nature) and less important than the four layers of the TCP/IP model, Kumar says that “it is difficult to read about networking technology today without seeing references to the OSI model and its layers, because the model’s structure helps to frame discussions of protocols and contrast various technologies.”
- If you can understand the OSI model and its layers, you can also then understand which protocols and devices can interoperate with each other when new technologies are developed and explained.

Source: Network World

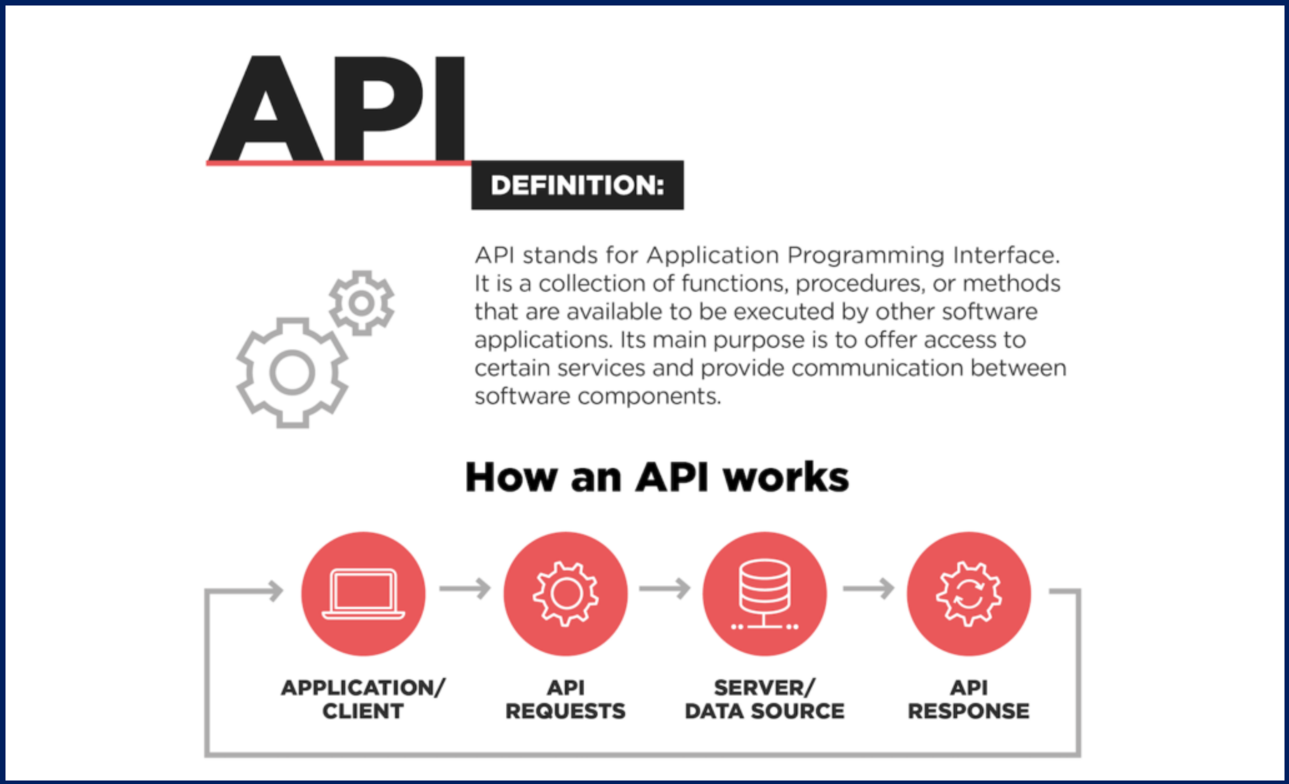


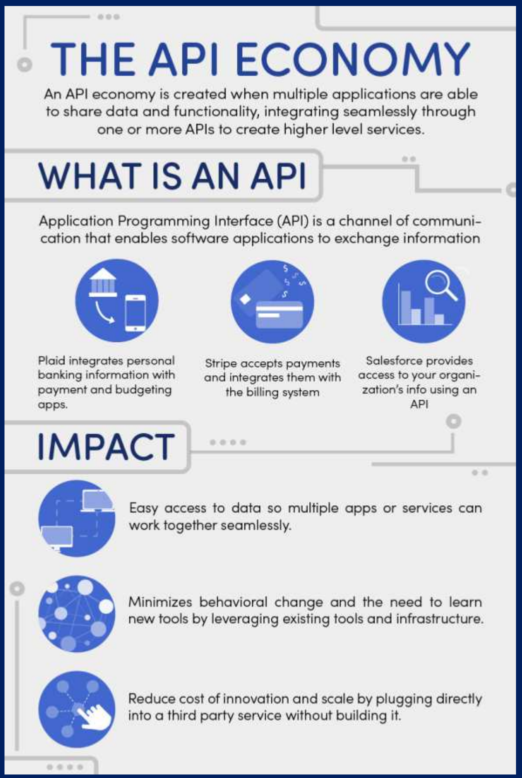


Layer			Protocol data unit (PDU)	Function[21]
Host layers	7	Application	Data	High-level APIs, including resource sharing, remote file access
	6	Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5	Session		Managing communication sessions, i.e., continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
	4	Transport	Segment, Datagram	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media layers	3	Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2	Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1	Physical	Bit, Symbol	Transmission and reception of raw bit streams over a physical medium

Sidebar: Application Programming Interface

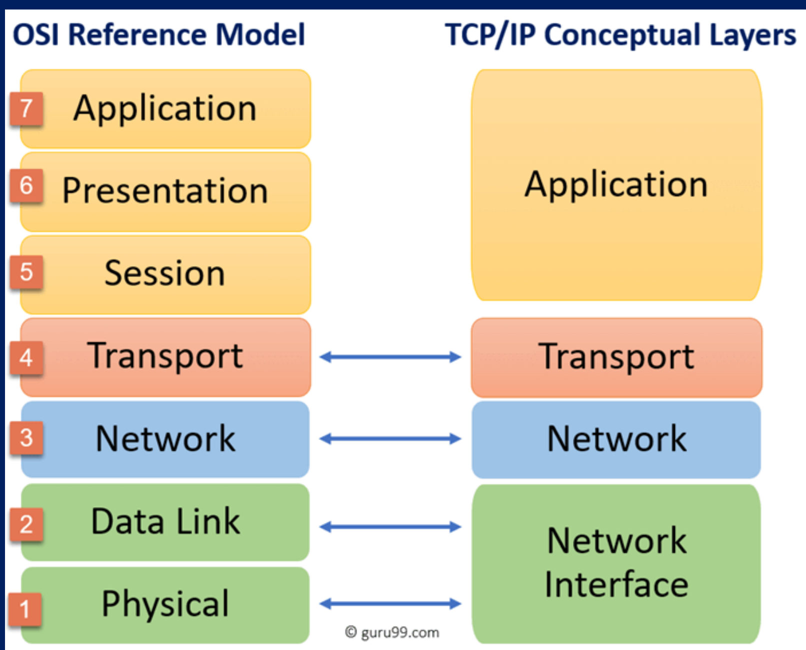
- Paul's definition: Set of formal data exchange protocols which define how one software program talks to another software program
- API's "abstract" the use of the software offering the API, allowing the internal operation of the software to remain hidden– that is, knowledge of the internals is not required to use the software
- The concept of the API, when extended to computer-to-computer communication, results in the ISO/OSI layer model

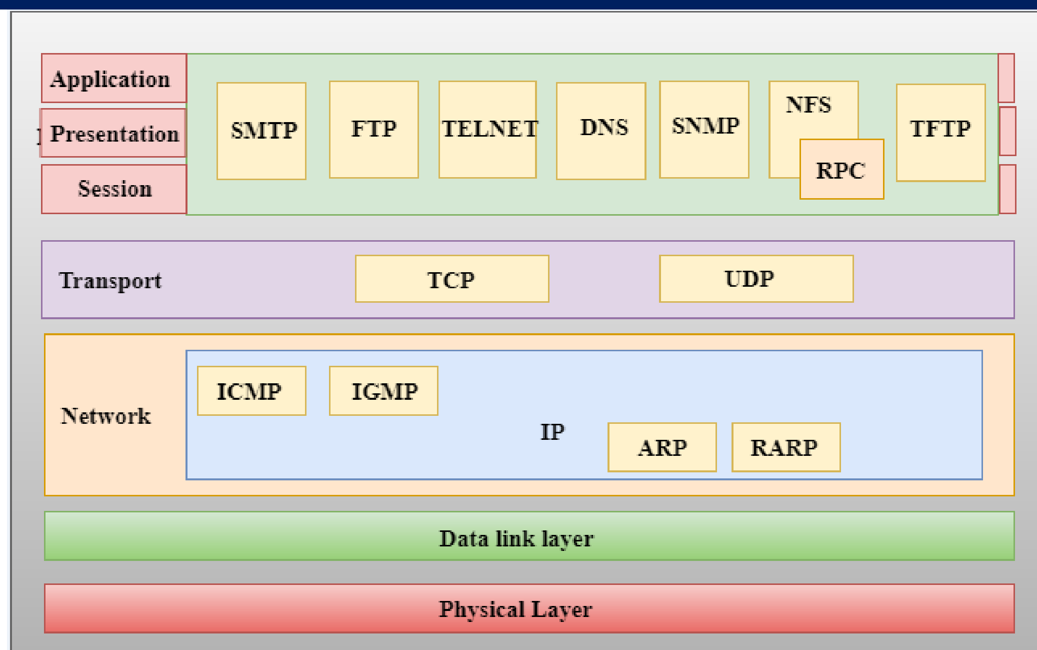




ISO/OSI vs The TCP/IP Model

- TCP/IP is the data interchange protocol used by the Internet for computer-to-computer (host-to-host) communications
- It only loosely follows the formal OSI/ISO reference model
- Many consider TCP/IP to be a separate model, but this is not entirely true
- We will not be studying TCP/IP in depth, but it is important to know that it exists and is the underlying protocol used in all web comms





Accurate **Inaccurate**

Formal End of Lesson 6

In next week's exciting episode

- Resistors [DMM usage #2]
- Diodes and LED's [DMM usage #3]
- Powering LEDs and dropping resistors
- Capacitors: Electrolytic (polarized) vs non-electrolytic (non-polarized)
- Simplified transistor operation
- Connecting an LED to a microcontroller [Class Sketch#1]
- Connecting a transistor to a microcontroller [Class Sketch #2]
- History of Telecommunications and Networking – Part 3
- History of Telecommunications – Part 2
  - Local Area Networks (LANs)
  - Wide Area Networks (WANs)
  - Wireless LAN (WiFi)
  - Cellular data networks
  - TCP/IP and the OSI model
  - The Rise and Fall of the Internet

Don't forget to return your USB drives!