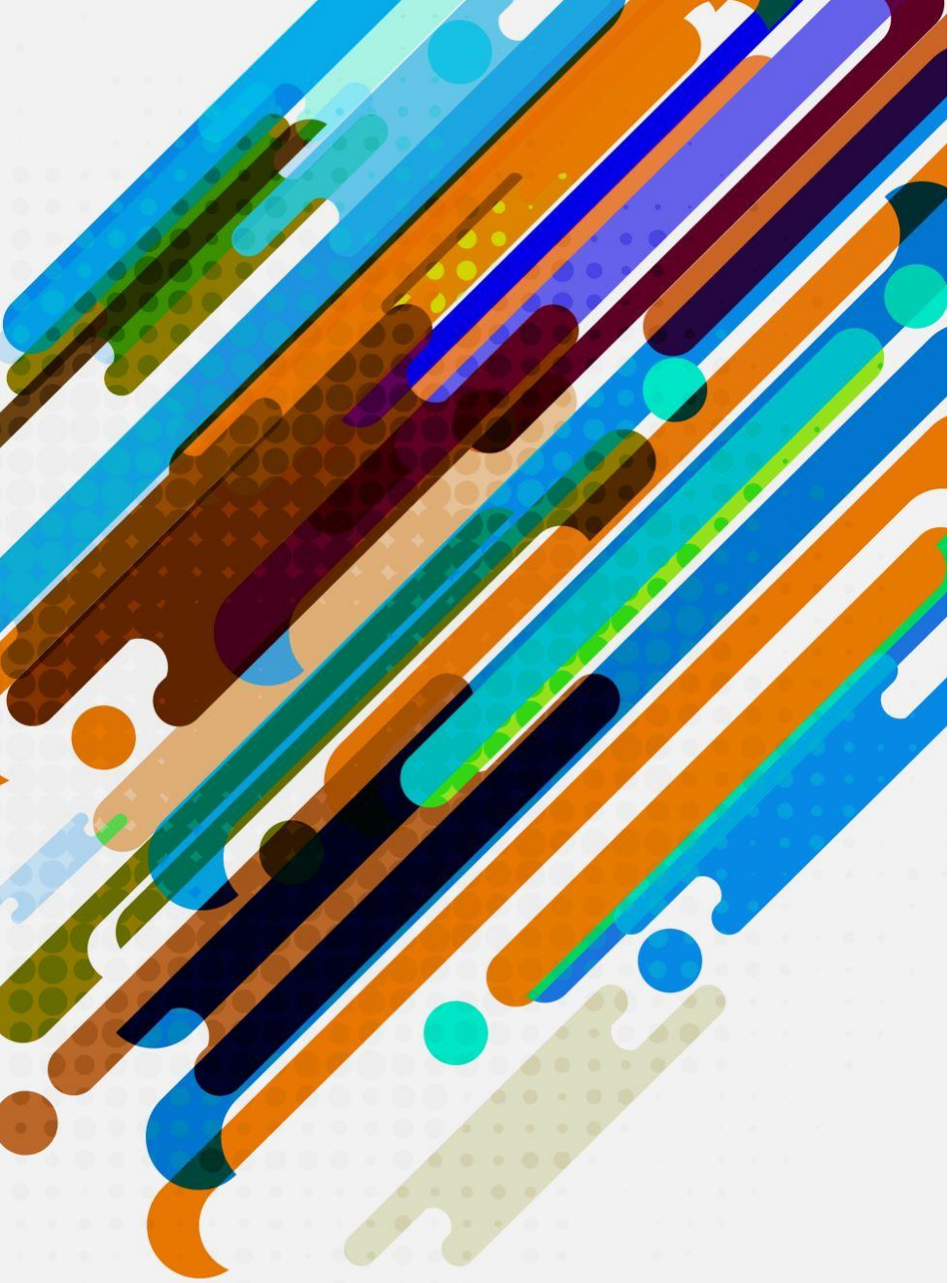
Internet of Things 1
420-420-LE

Week 1: Introduction to IoT

CHAMPLAIN COLLEGE

Rev.: January 8th, 2025



Internet of Things

(IOT)

What is the Internet of Things?

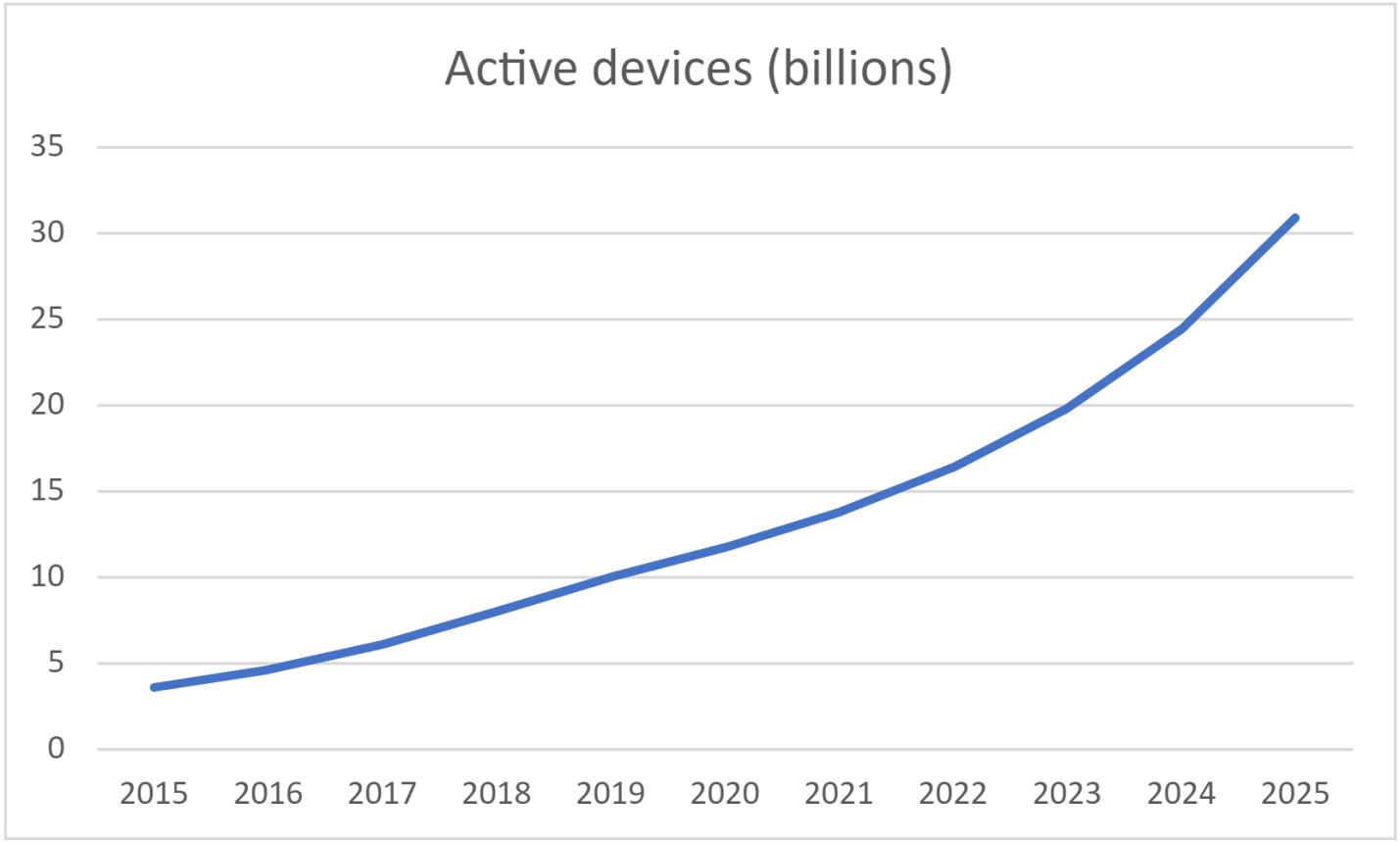
- The term 'Internet of Things' was coined by Kevin Ashton in 1999, to refer to connecting the Internet to the physical world via sensors.
- The term has been used to describe any device that interacts with the physical world around it, either by gathering data from *sensors*, or providing real-world interactions via *actuators*.
  - **Sensors** gather information from the environment, such as measuring speed, temperature or location.
  - **Actuators** convert electrical signals into real-world interactions such as triggering a switch, turning on lights or making sounds.

What is the Internet of Things?

- IoT as a technology area is more than just devices - it includes:
  - Cloud-based services that can process the sensor data or send requests to actuators connected to IoT devices.
  - Devices that don't have or don't need Internet connectivity, often referred to as **edge devices**.
    - These are devices that can process and respond to sensor data themselves, usually using AI models trained in the cloud.

What is the Internet of Things?

- IoT is a fast-growing technology.
- It is estimated that by 2025, IoT devices will be gathering almost 80 trillion gigabytes.



IoT devices

Things

- "Things" in IoT: Devices that interact with the physical world via sensors (data collection) or actuators (real-world actions).
- Custom-Made Devices: Designed for specific tasks, e.g., fitness trackers, industrial controllers or smart thermostats with specialized hardware.
- Developer Kits:
  - Used for learning and prototyping IoT.
  - Two types: **Microcontrollers** & **Single-board computers**.
- Even smartphones act as general-purpose IoT devices with built-in sensors and actuators.

Microcontrollers

- A microcontroller (MCU) is a small computer in a ***single chip*** with:
  - CPU(s): The "brain" running programs.
  - Memory: Stores programs, data, and variables.
  - I/O Connections: Interfaces with sensors and actuators.
- Low-cost devices, starting as cheap as $0.50; developer kits from $4 (e.g., Arduino MKR~ US $40).
- Designed for specific tasks, not general-purpose computing like PCs.
- Features: Often include built-in sensors, actuators, and wireless connectivity (e.g., Bluetooth, WiFi).
- Programming Language: Typically programmed in C/C++.

(Avoid MCU search confusion with "Marvel Cinematic Universe!")

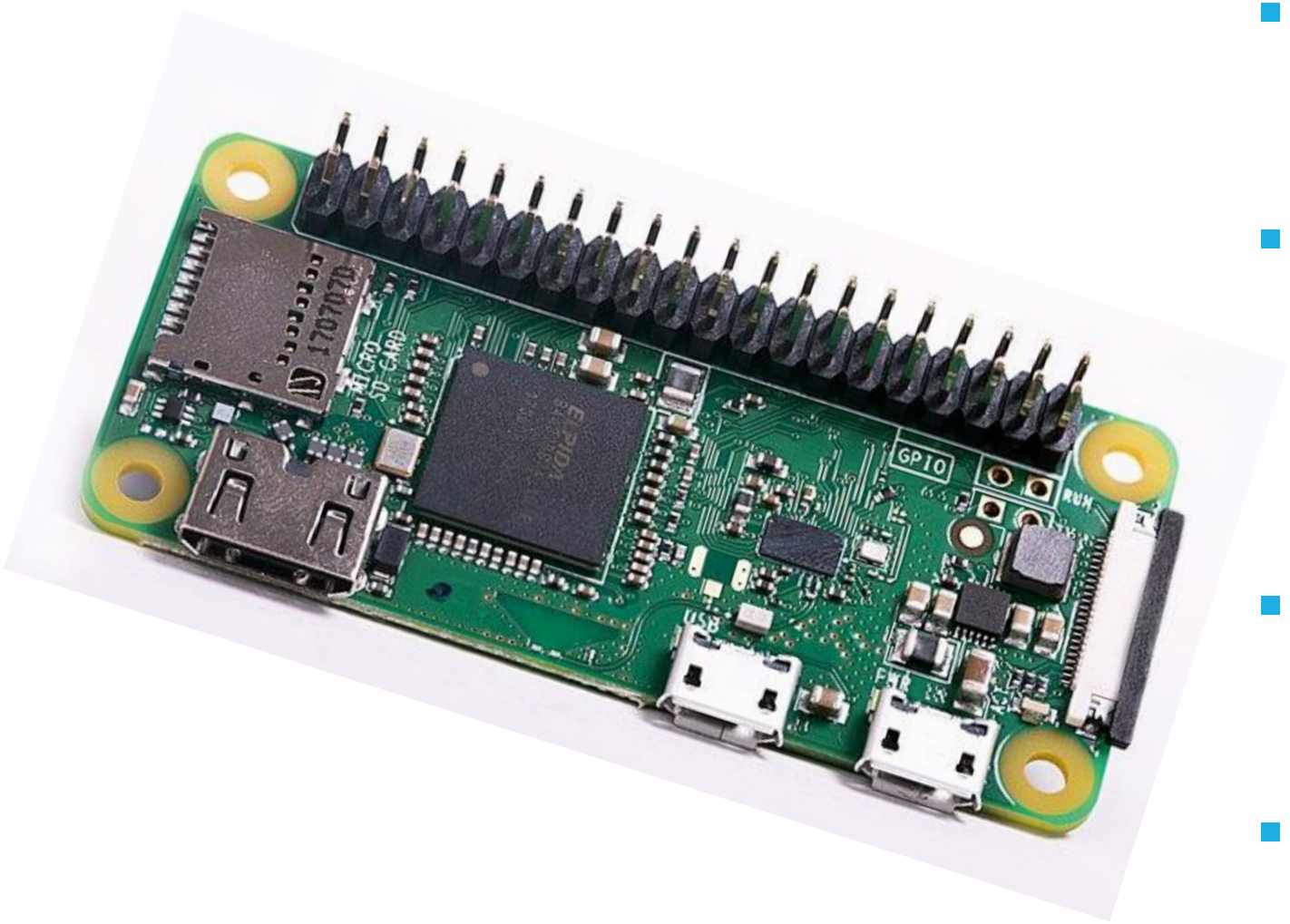
Single-Board Computers

- Compact computing devices with all components on a ***single board***.
- Run a full operating system, similar to desktops or laptops.
- Features:
  - CPU, memory, and GPIO pins for sensors/actuators.
  - Graphics chip, USB ports, and storage via SD cards or drives.
- Example: Raspberry Pi – popular, affordable, and versatile.
- Programmable in various languages, commonly **Python** for IoT applications.

Raspberry Pi Overview - Full size

- Developed by the Raspberry Pi Foundation (UK, 2009) to promote computer science education.
- Features:
  - Quad-core 1.5GHz CPU, 2/4/8GB RAM
  - Gigabit Ethernet, Wi-Fi, 2 HDMI ports (4K support)
  - USB (2x USB 2.0, 2x USB 3.0), 40 GPIO pins
  - Camera connector, SD card slot, audio/video out
  - Compact size: 88mm x 58mm x 19.5mm
  - Starts at $35
- Perfect for education and IoT projects.

Pi Zero



- Quad-core 1GHz CPU, 512MB of RAM, WiFi (in the Zero W model)
- Single HDMI port, a micro-USB port, 40 GPIO pins, a camera connector for a Raspberry Pi camera module, and an SD card slot.
- It measures 65mm x 30mm x 5mm, and draws very little power.
- The Zero is $12, with the W version with WiFi $21.

Compute Module 4

- Broadcom BCM2711 quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 1GB, 2GB, 4GB or 8GB LPDDR4-3200 SDRAM
- Options for 0GB ("Lite"), 8GB, 16GB or 32GB eMMC Flash memory
- 2.4 GHz, 5.0 GHz IEEE 802.11 b/g/n/ac wireless;
- Bluetooth 5.0, BLE

Applications for IoT

Consumer IoT (aka smart devices)

- Devices used at home (e.g., smart speakers, heating systems, robotic vacuums).
- Empowerment: Especially beneficial for people with disabilities by offering:
  - Automated Cleaning: Robotic vacuums for users with mobility issues
  - Voice-Controlled Appliances: Ovens for those with limited vision or motor control
  - Health Monitors: Regular and detailed tracking of chronic conditions

Applications for IoT

Commercial IoT: The use of IoT in the workplace.

- **Office:** Optimize lighting and heating using occupancy sensors to reduce costs and carbon emissions.
- **Factory:** Enhance safety by detecting hazards like missing protective gear or excessive noise levels.
- **Retail:** Monitor cold storage temperatures and shelf stock levels to ensure product quality and availability.
- **Transport:** Track vehicle locations, mileage, driver compliance, and prepare for depot operations efficiently.

Applications for IoT

Industrial IoT (IIoT): The use of IoT devices to control machinery on a large scale:

- Factories:
  - Monitor machinery (temperature, vibration, rotation speed) to prevent failures by shutting down equipment outside tolerances.
  - Use predictive maintenance with AI to anticipate and prevent breakdowns.
- Agriculture:
  - Use sensors for temperature and soil moisture to optimize harvest timing and automate watering.
  - Leverage drones, satellite data, and AI to monitor crop growth, disease, and soil quality over large areas. monitor crop growth, disease and soil quality over huge areas of farmland.

Applications for IoT

Infrastructure IoT is monitoring and controlling the local and global infrastructure that people use every day.

- **Data-Driven Management:** IoT devices optimize transport, parking, and pollution control through data collection and collaboration between governments, academia, and businesses.
- **Smart Power Grids:** Analyze energy usage at home levels to improve power demand management, guide infrastructure planning, and provide cost-saving insights for users (e.g., charging EVs at night).

IoT on the Edge

- Edge devices connect to local gateway devices instead of the Internet, enabling faster data processing.
- Offline Capability: Operate without Internet access, ideal for areas with slow or no connectivity.
- Cloud-Enhanced AI: Use cloud-trained AI models running locally to process and respond to data (e.g., smart home devices like Alexa or Google Home).

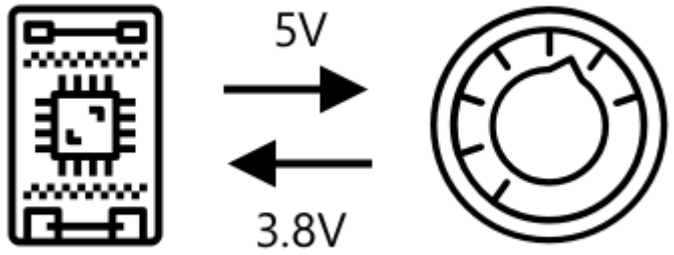
Sensors and Actuators

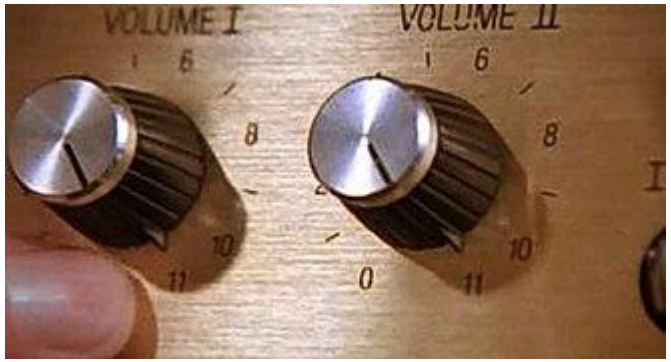
What are sensors?

- Sensors are hardware devices that sense the physical world - they measure one or more properties around them and send the information to an IoT device.
- Sensors cover a huge range of devices as there are so many things that can be measured, from natural properties such as air temperature to physical interactions such as movement:
  - Temperature sensors - these sense the air temperature or the temperature of what they are immersed in.
  - Buttons - these sense when they have been pressed.
  - Light sensors - these detect light levels and can be for specific colors, UV light, IR light
  - Cameras - these sense a visual representation of the world by taking a photograph or streaming video.
  - Accelerometers - these sense movement in multiple directions.
  - Microphones - these sense sound, either general sound levels or directional sound.

Analog sensors

- Some of the most basic sensors are analog sensors. These sensors receive a voltage from the IoT device, the sensor components adjust this voltage, and the voltage that is returned from the sensor is measured to give the sensor value.





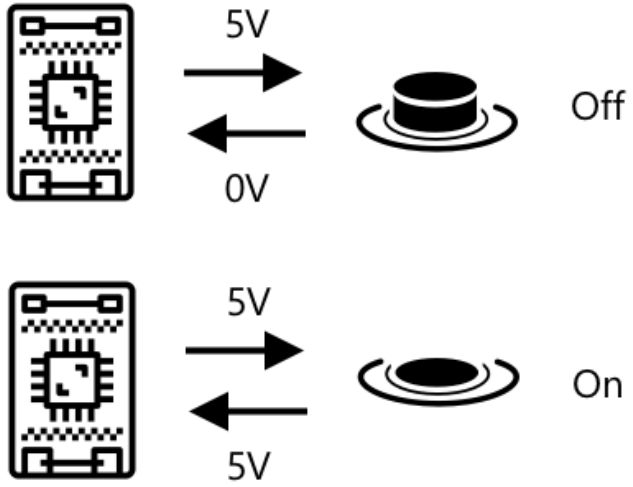
- When the potentiometer is in the full off position (0) then 0V (0 volts) will come out. When it is in the full on position (11), 5V (5 volts) will come out.

Analog to digital conversion

- IoT devices are digital - they can't work with analog values, they only work with 0s and 1s.
- So, analog sensor values need to be converted to a digital signal before they can be processed. Many IoT devices have analog-to-digital converters (ADCs) to convert analog inputs to digital representations of their value.
- One example is the Seeed Grove light sensor which outputs values from 0 to 1,023. For this sensor running at 3.3V, a 1V output would be a value of 300. An IoT device can't handle 300 as an analog value, so the value would be converted to **0000000100101100**, the binary representation of 300 by the Grove hat. This would then be processed by the IoT device.

Digital Sensors

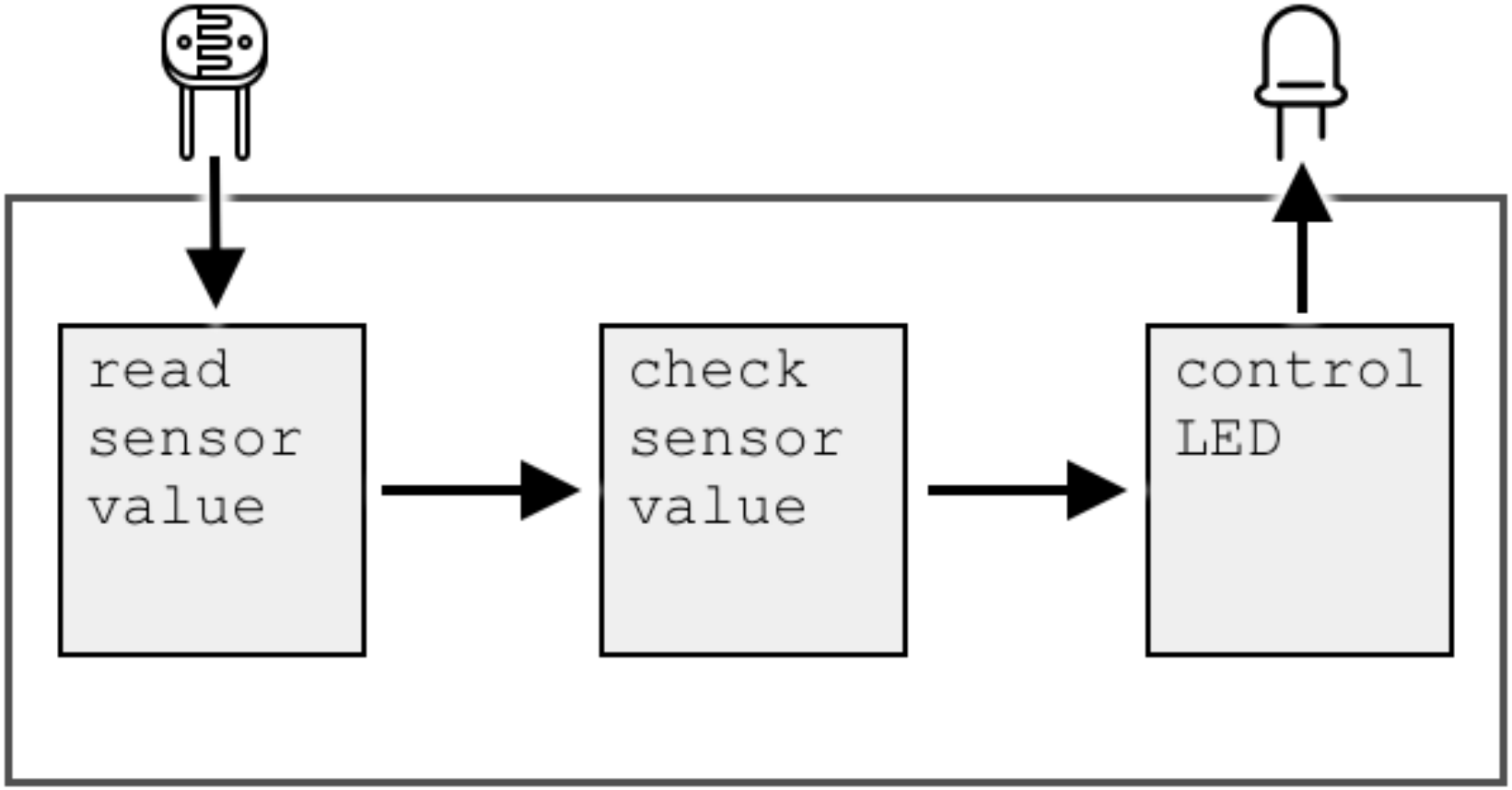
- Digital sensors detect the world around them using changes in electrical voltage.
- The difference is they output a digital signal, either by only measuring two states or by using a built-in ADC.
- The simplest digital sensor is a button or switch. This is a sensor with two states, on or off.



What are actuators?

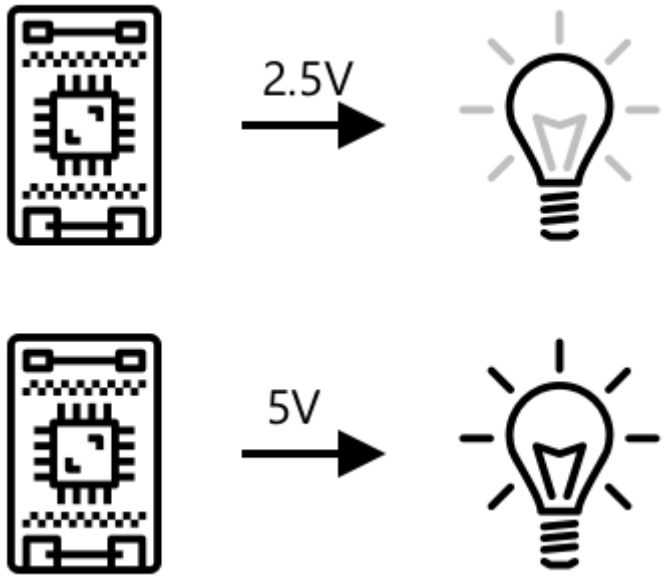
- Actuators are the opposite of sensors - they convert an electrical signal from your IoT device into an interaction with the physical world such as emitting light or sound or moving a motor.
  - LED - these emit light when turned on
  - Speaker - these emit sound based on the signal sent to them, from a basic buzzer to an audio speaker that can play music
  - Stepper motor - these convert a signal into a defined amount of rotation, such as turning a dial 90°
  - Relay - these are switches that can be turned on or off by an electrical signal. They allow a small voltage from an IoT device to turn on larger voltages.

Use an actuator



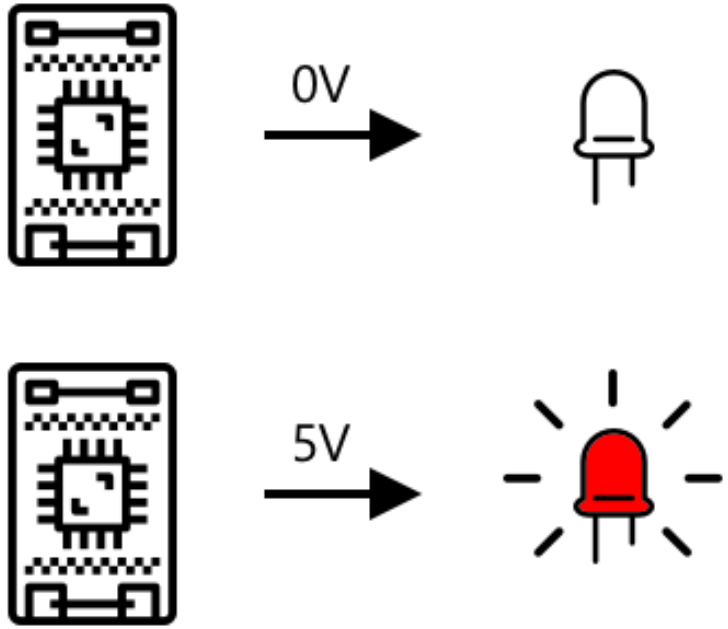
Analog actuators

- Analog actuators take an analog signal and convert it into some kind of interaction, where the interaction changes based off the voltage supplied.
- One example is a dimmable light: The amount of voltage supplied to the light determines how bright it is.



Digital actuators

- Digital actuators either have two states controlled by a high or low voltage or have a DAC built in so can convert a digital signal to an analog one.
- One simple digital actuator is an LED. When a device sends a digital signal of 1, a high voltage is sent that lights the LED. When a digital signal of 0 is sent, the voltage drops to 0V and the LED turns off.



What is Reinforced Learning?

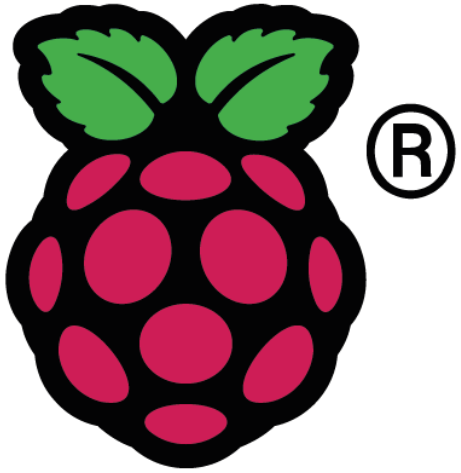
- Reinforcement learning is a way for computers to learn by trying things out and getting feedback.
- It works like this:
  - The computer is given a goal (like winning a game).
  - It tries different actions.
  - If an action gets it closer to the goal, it gets a "reward”.
  - If not, it gets "punished" or no reward.
- Over time, the computer learns which actions work best to reach the goal, just like how we learn from trial and error.

In class discussion

- How many/what sensors do you think is using the box in the video?
  - Describe your assumptions for each one
- How many actuators do you think is using the box in the video?
  - Describe your assumptions for each one
- Why it is important to feed the birds randomly during the training period ?
- What do you think you will need to be changed if we want to train the birds to collect more diverse litter (not just metallic caps)
  - Hits: What if it's not metallic? What if it has different shapes? Think also in software requirements not just hardware…

In class discussion

Watch the video in Moodle and answer:



Raspberry Pi

Raspberry Pi

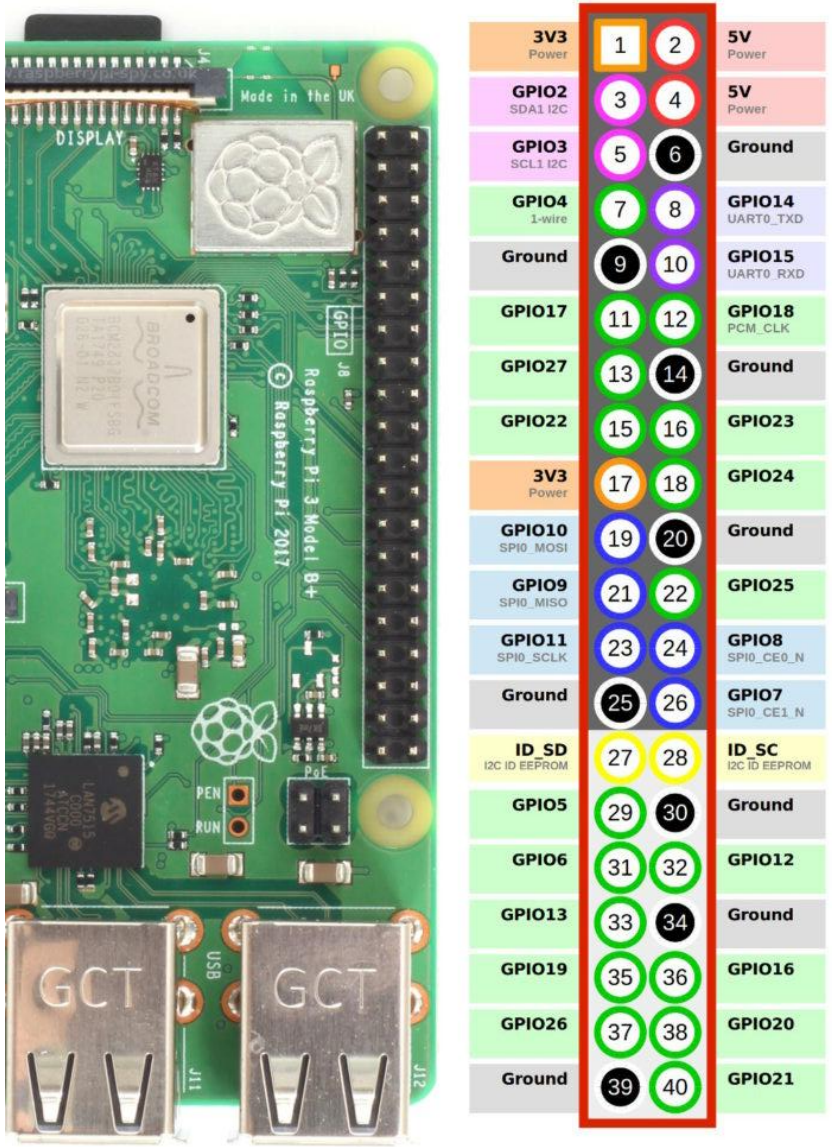
- The Raspberry Pi is a credit card-sized ARM-processor single-board nano computer.
- It was designed by professors in the computer science department at Cambridge University.
- The Raspberry Pi allows the execution several operating systems.
- The first commercial version, the Raspberry Pi 1 Model A, was offered in early 2012 for around US$ 35

Raspberry Pi

- The Raspberry Pi is indeed a nano-computer and not an electronic card as proposed by Arduino.

Raspberry Pi

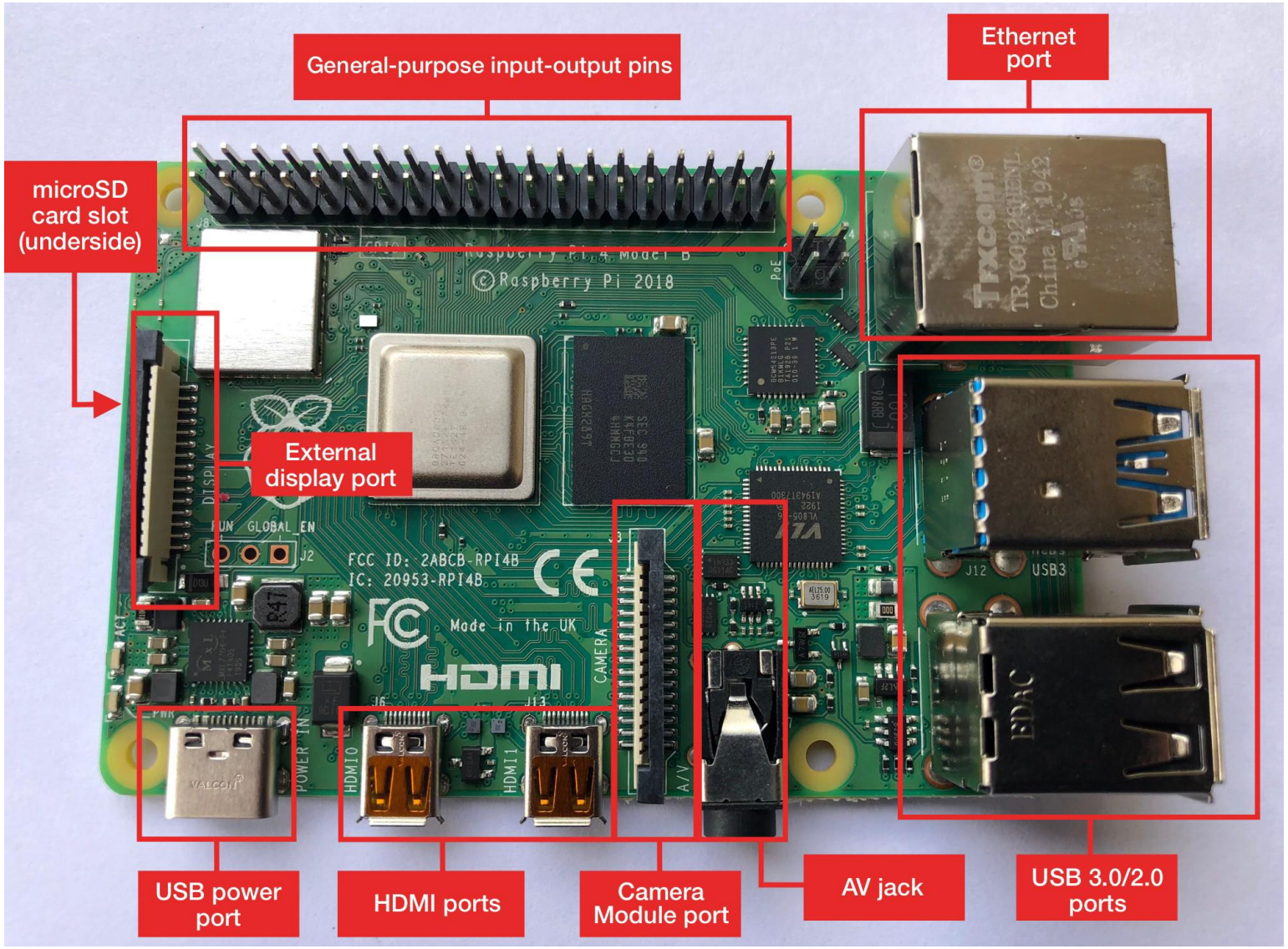
- The Raspberry Pi has GPIO (General Purpose Input Output) pins that allow the connection of expansion boards or other electronic components to make mounts..



Raspberry Pi

- The Raspberry Pi gives you a "System on a Chip" (SoC) which has memory, GPIO I / O, internal storage, the ability to accommodate a keyboard / mouse and other peripherals through USB ports and more.

Raspberry Pi – The components



Raspberry Pi – Micro SD Card

- The Raspberry Pi doesn't have internal storage by default, so it doesn't have a place to store the Operating System.
- The microSD card is used as storage media. This is where the Operating System is saved and executed.
- Card size may vary, recommended minimum is 32 GB.

Raspberry Pi – Power supply

- The Raspberry Pi does not have a built-in power cable.
- It has a female micro–USB C power port.
- You must use 5 volts 700 mA - 1200 mA (1.2 A)
- You can use a phone charger or a backup battery for the Cell phone but verify the current range before !

Raspberry Pi – Video output

- The Raspberry Pi 4 offers the possibility of connecting 2 screens
- The card has 2 micro-HDMI port.
- Warning!!!
  - The card doesn't offer much power!

Raspberry Pi – Network Connection

- The Raspberry Pi 4 offers communication:
  - Wireless
  - RJ45 wired network
  - Bluetooth

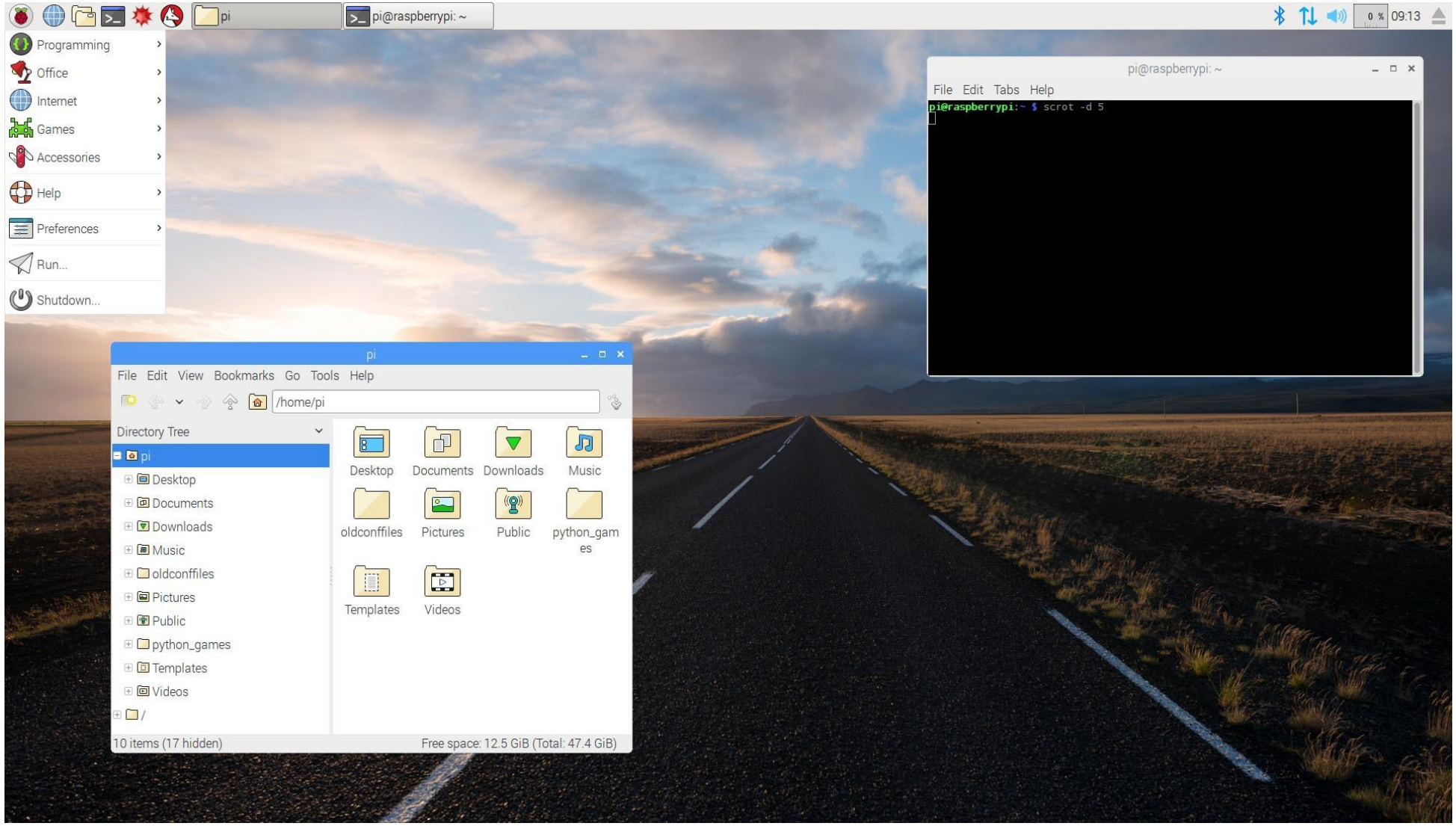
Raspberry Pi – System Startup

- It is necessary to install an Operating System on your microSD card for your system to work.
- Raspberry Pi OS (previously called Raspbian) is the official supported operating system.
- Raspberry Pi Imager is the quick and easy way to install Raspberry Pi OS and other operating systems to a microSD card.
- The Raspberry Pi Foundation used to offer a "New Out Of Box Software" (NOOBS) – ***now deprecated***

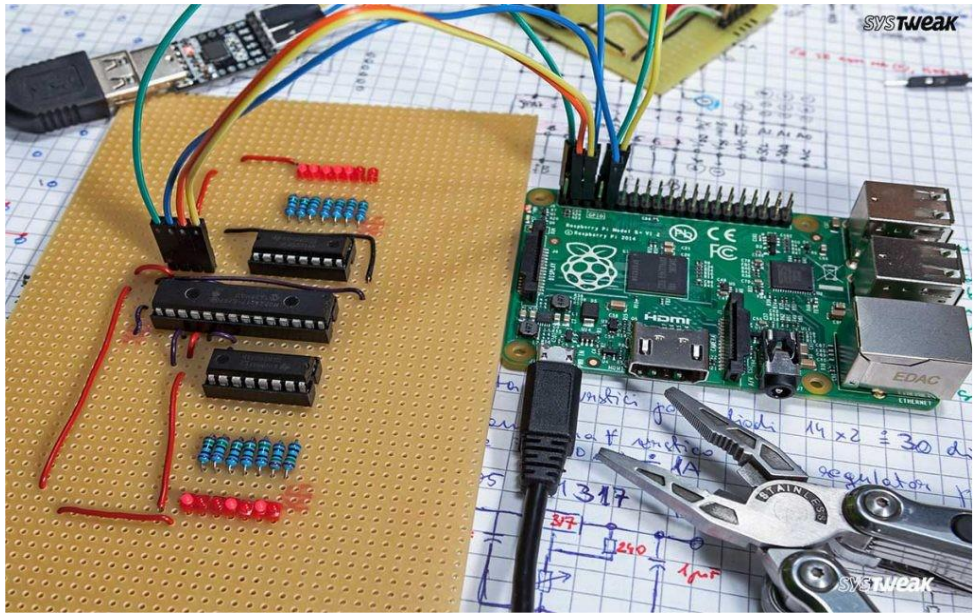
Raspberry Pi – The Operating System

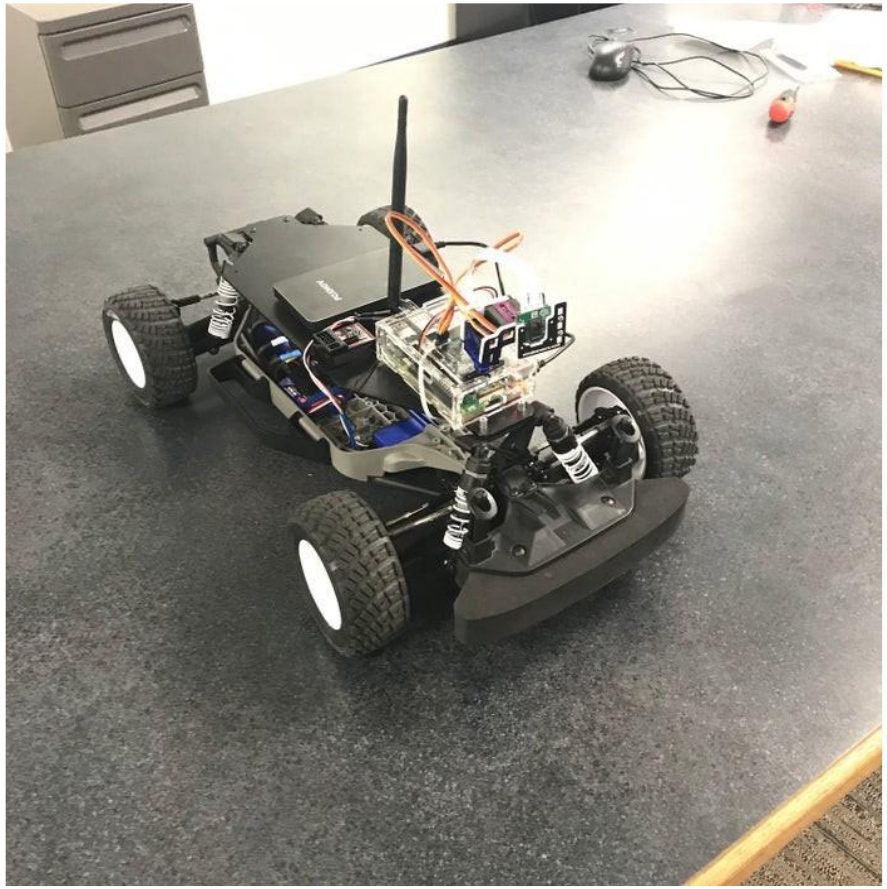
- Raspberry Pi OS (formerly named Raspbian) is a free Debian-based open-source operating system optimized to run on Raspberry Pi.
- Given the limited resources of the nano computers, it integrates software known to be light and not very resource-intensive:
  - The default desktop environment is PIXEL, which stands for "Pi Improved Xwindows Environment Lightweigh, which is composed of a modified LXDE and Openbox.
  - The default web browser is Chromium

Raspberry Pi – The Operating System



Raspberry Pi – What You Can Do?





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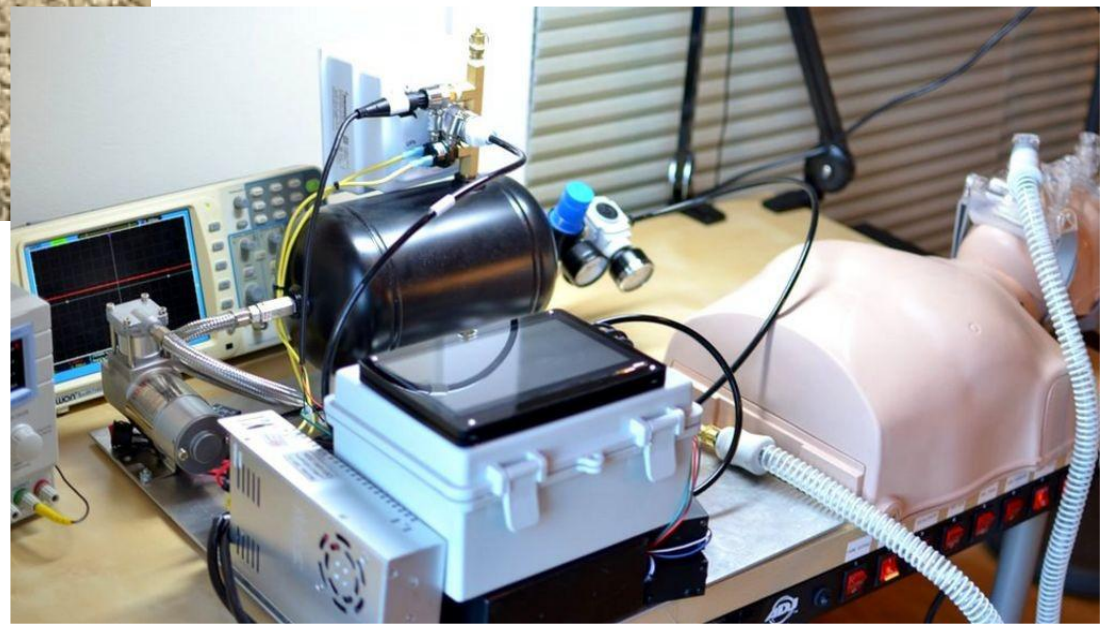
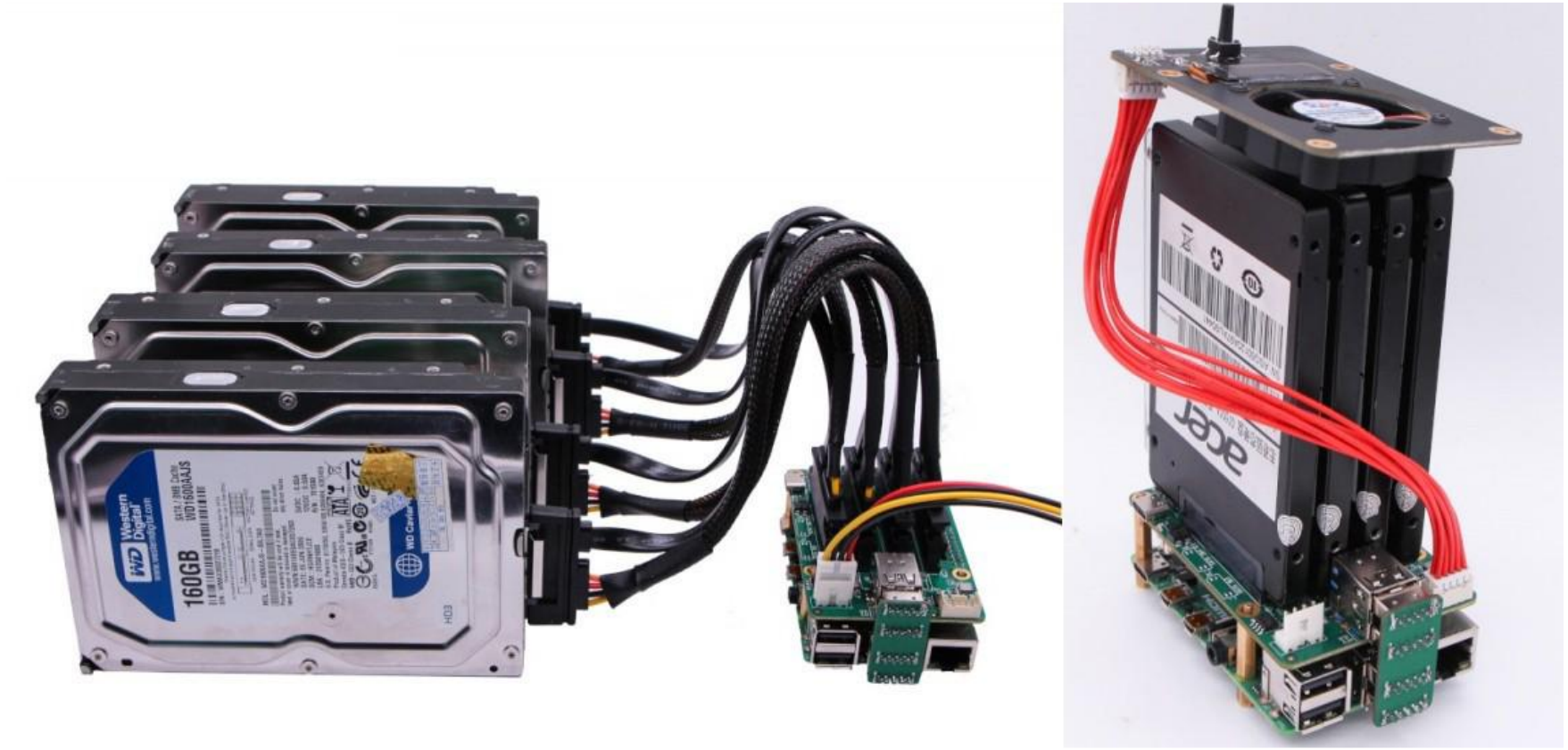
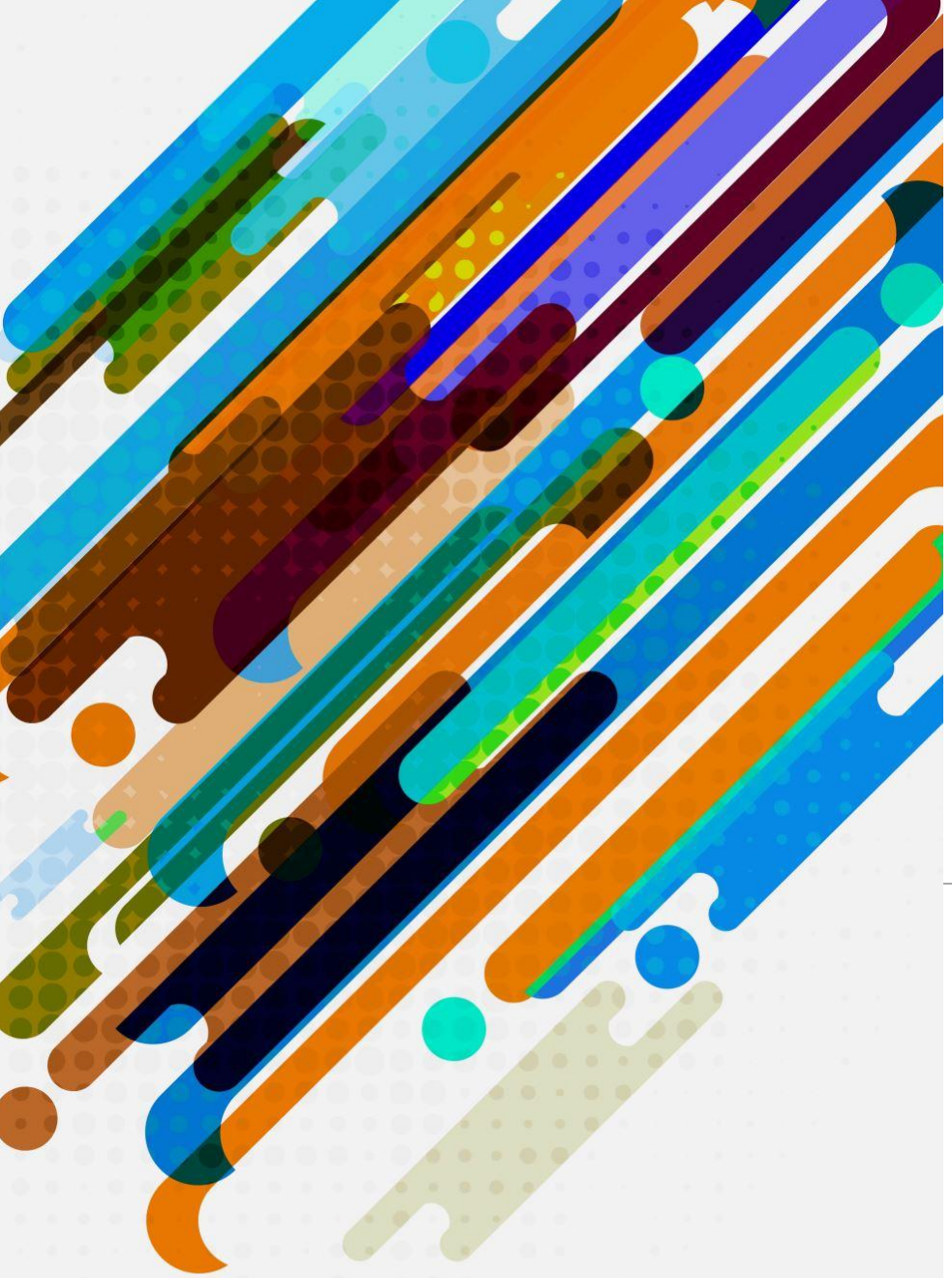


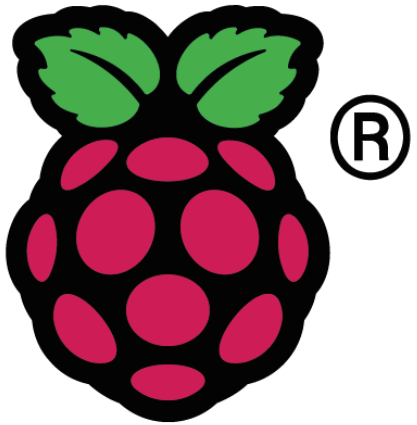
Raspberry Pi – What You Can Do?



Raspberry Pi – The Operating System

- *https://all3dp.com/2/raspbery-pi-drone-simply-explained/*
- *https://towardsdatascience.com/deeppicar-part-1-102e03c83f2c*
- *https://www.bbc.com/news/technology-52251286*
- *https://www.electronicsforu.com/electronics-projects/hardware-diy/turn-raspberry-pi-into-low-cost-nas-wifi-wireless-pendrive*





Raspberry Pi - Python

Raspberry Pi – The Operating System

- Python is a powerful programming language that's easy to use (easy to read and write) and, with Raspberry Pi, lets you connect your project to the real world.
- Python syntax is very clean, with an emphasis on readability, and uses standard English keywords.

Lab 1

- Goals:
  - Mount, Install and Configure the Raspberry Pi 4.
  - Install Raspberry Pi OS.
  - Connect the Raspberry Pi to your PC network.
  - Use MobaXterm to access the Raspberry Pi from your PC using SSH (terminal)
  - Use VNC to access the Raspberry Pi from your PC (graphical interface)

Lab 1

Exercise 1. Mounting the Raspberry Pi

1. If your Raspberry Pi has a case, and its not mounted yet, it’s the time to do it!
2. Be sure to mount correctly. You can help yourself by looking for tutorials or videos to guide you.
3. Be sure that each connector is well aligned in the case.
4. Be careful with the handling of your Raspberry Pi card, the electrical circuits are very fragile. You must be careful and not touch it.
5. Connect your system to an external monitor with keyboard and mouse so that you can use it.

Lab 1

Intro

Course description

Policies

Intro to IoT

Intro to RPi

RPi setup

For the rest of the Lab, review the document on moodle