

# Cambridge IGCSE

Computer Science  
Paper 1

## Data Storage

Unit 3: Hardware

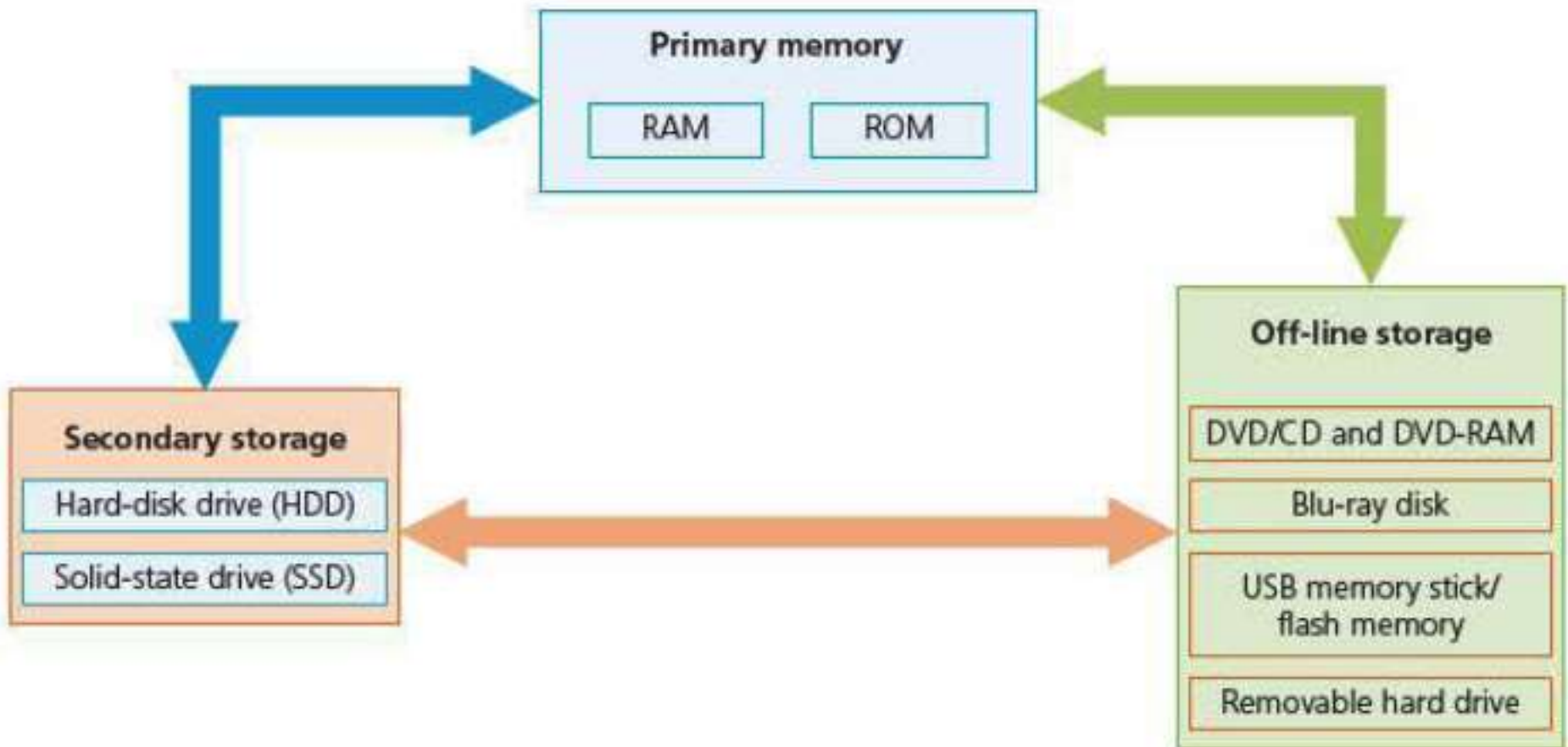
# Objectives

- Understand what is meant by **Primary** and **Secondary** storage
- Describe the operation of **magnetic**, **optical** and **solid-state** storage devices
- Describe what is meant by **virtual memory** and why it is needed
- Understand what is meant by **cloud storage** and its advantages and disadvantages compared to storing data locally

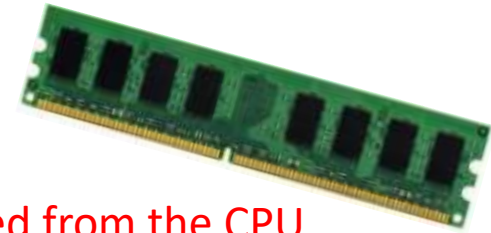
# Computer data storage

- Primary storage (Immediate Access Store)
  - RAM and ROM
- Secondary storage
  - Hard Disk Drive (HDD)
  - Solid State Drive (SSD)
- Offline secondary storage
  - Compact Disc (CD) or Digital Versatile Disc (DVD) or BluRay
  - USB Flash memory
  - Removable HDD
  - Magnetic tape

# Computer data storage



# Computer data storage



## Primary Memory

- the part of the computer memory that **can be directly accessed from the CPU**
- includes **Random Access Memory (RAM)** and **Read-Only Memory (ROM)** memory chips and **cache** memory.

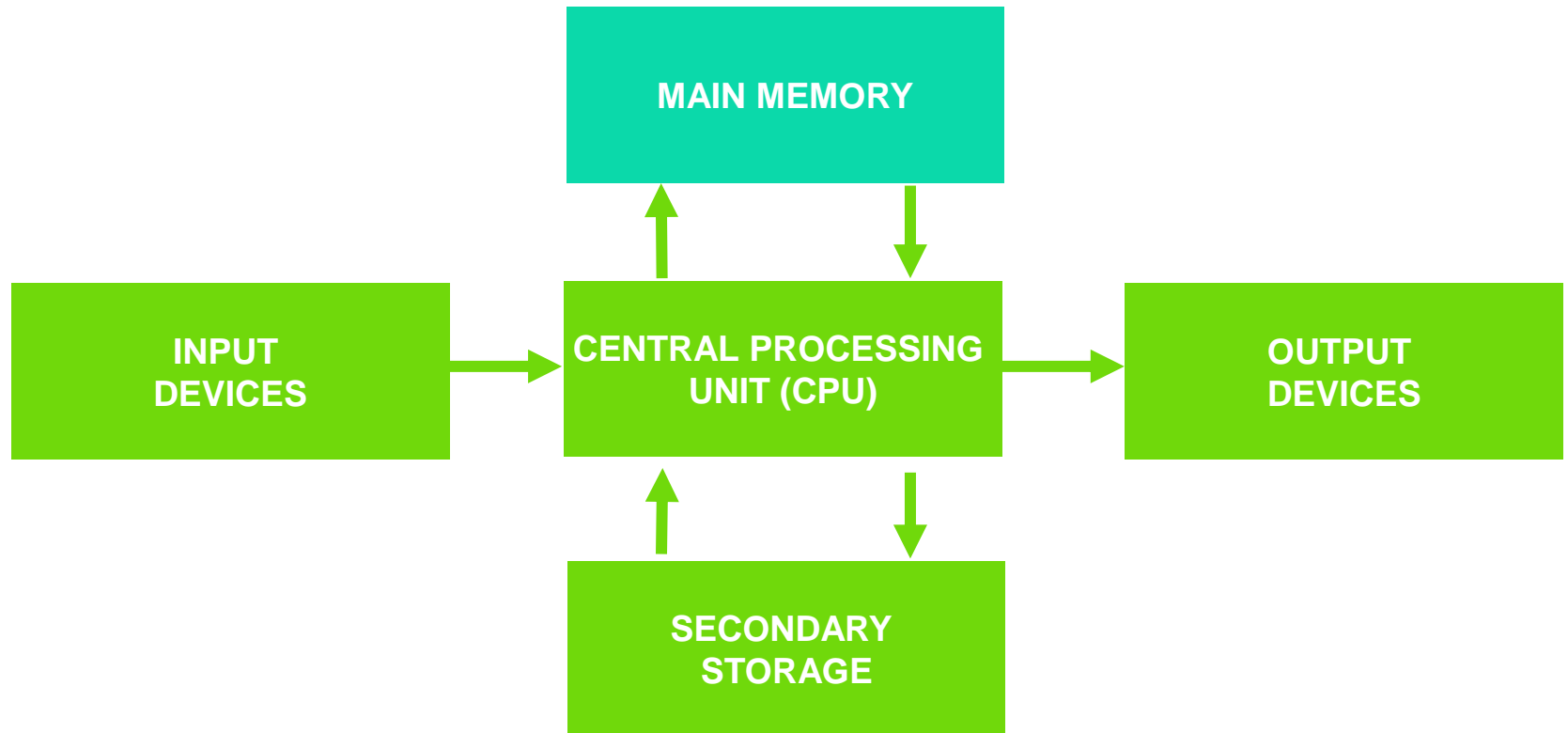
## Secondary Storage

- storage devices that are **not directly accessible by the CPU**
- they are **non-volatile devices** -> when you turn off the computer, the data remains there, so data can be stored as long as required by the user
- can **store more data than primary memory**, but **data access time is a lot longer** than with RAM or ROM
- all applications, the operating system, device drivers and general user files (documents, music, photos etc) are stored on secondary storage.



# Primary storage / memory

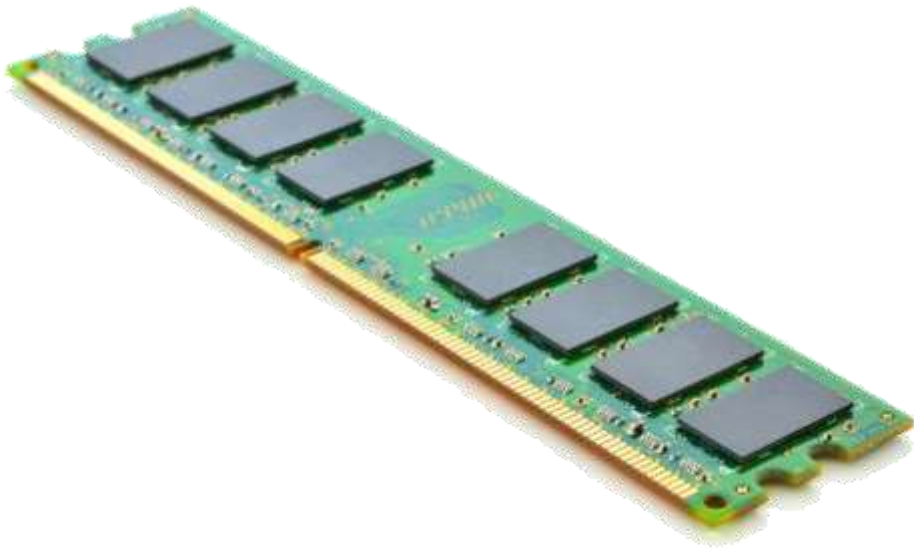
- What do you already know about memory and its role within computer systems?



# Primary storage / memory

- There are two types of primary storage (*Immediate Access Store*) used in computers

## RAM - Random Access Memory



## ROM - Read-Only Memory





# Primary storage / memory

RAM and ROM are close to the CPU, and can be accessed much more quickly than data on secondary storage such as a hard disk.





# Read Only Memory (ROM)

- Some data needs to be permanently held in memory, even when a computer is off
- **ROM** is used to store the instructions to start-up a computer, also known as the bootstrap / bootup program.

# Read Only Memory (ROM)

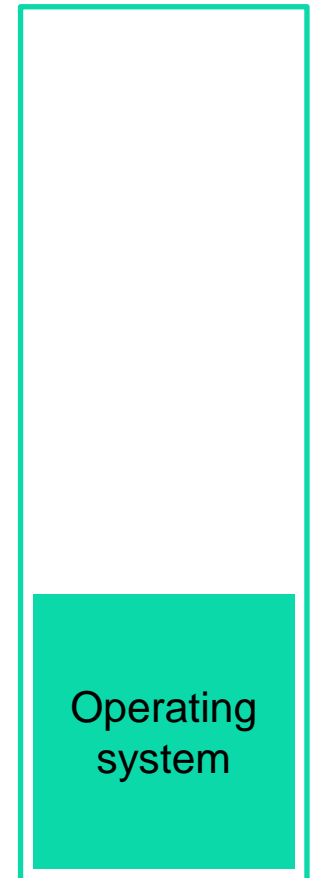
- When a computer is switched on, the **start-up instructions** held in ROM automatically load the Operating System (MS Windows, MacOS, Android ...) from the hard disk into RAM



Hard Disk



RAM



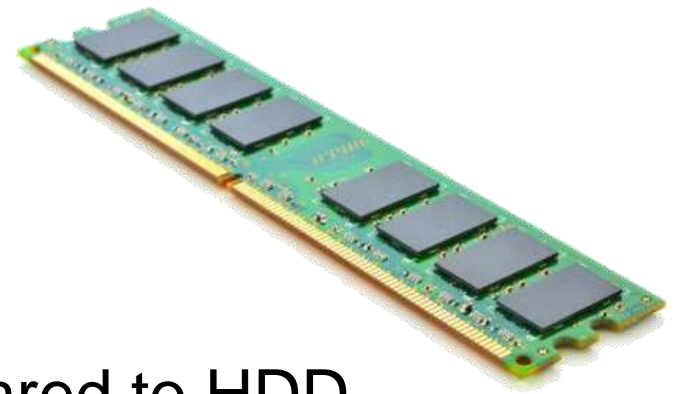
# Embedded systems

- Household devices with **embedded systems** such as washing machines, microwave ovens as well as cameras, vehicles and aircraft, **have programs held in ROM** which cannot be changed.



# RAM (Random Access Memory)

- Is often referred to as:
  - main memory
  - Immediate access store
- It can be read from and written to
- Access to RAM is very fast compared to HDD
- At any one time (when the computer is on) it will normally contain:
  - The Operating System (or the part currently in use)
  - The software (apps) currently in use
  - The data which the software is using

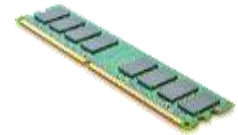


# RAM memory

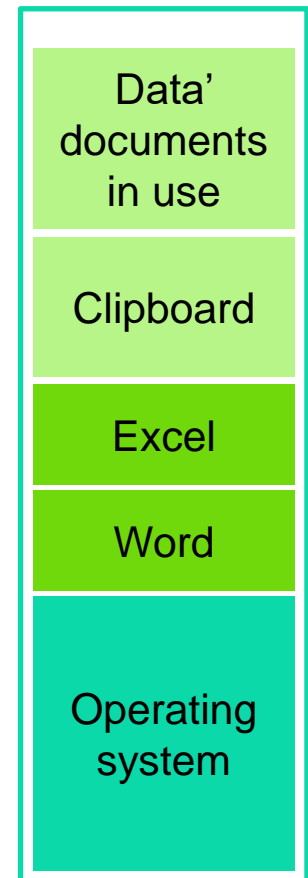
- When the computer is on, the **programs and data that are currently being used**, are copied into RAM from the HDD / SSD
  - RAM starts to fill up



Hard Disk



RAM

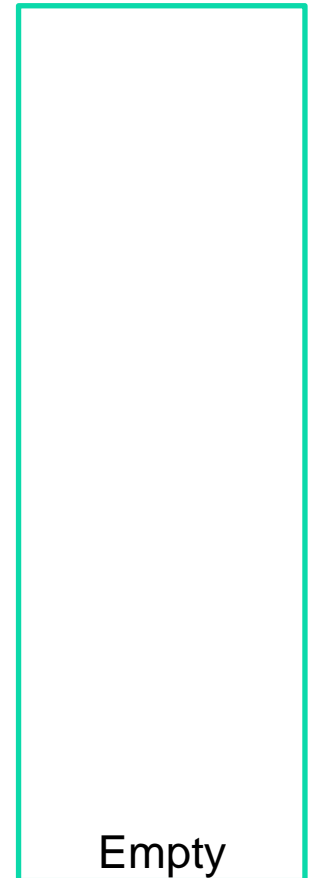


# RAM – Random Access Memory

- When the computer is off, RAM is empty as it is **volatile** storage - **it does not keep any data when the computer is off.**



RAM



Empty



# RAM

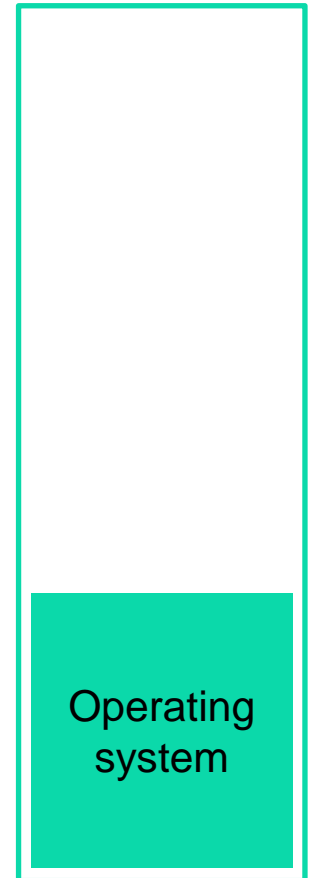
- When you switch on your computer, the start-up instructions held in ROM automatically load the Operating System from your hard disk into RAM



Hard Disk



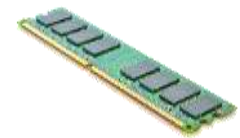
RAM



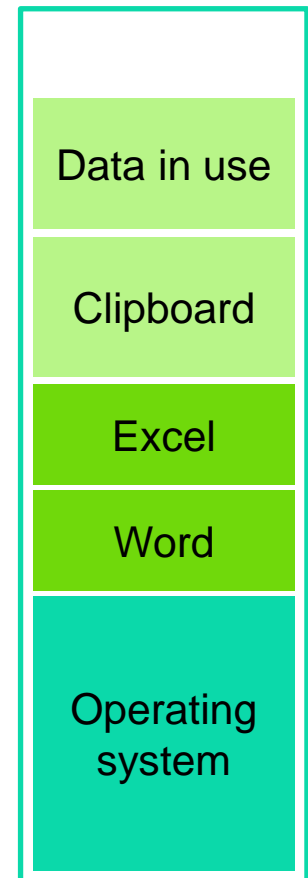
# Running out of space

- You now want to open a browser to search the Internet
- The browser software needs more memory than you have free in RAM
  - What happens?

Browser



RAM

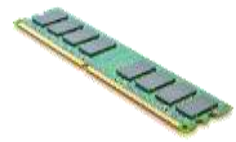


# Virtual memory

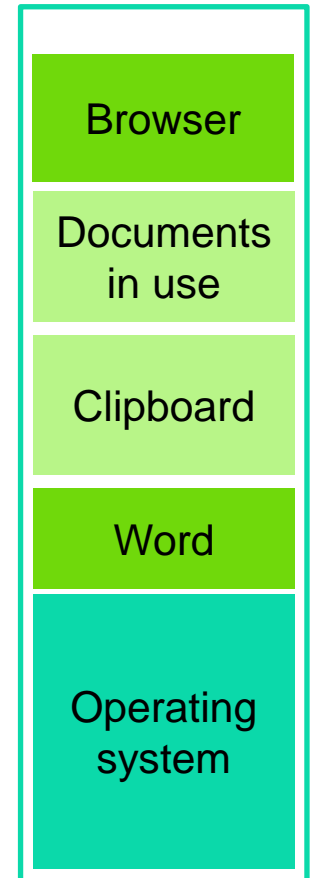
- A program that is in RAM, but not currently being executed, is moved out to hard disk to make room for the browser
- When RAM is almost full, programs and data are constantly being swapped out to the hard disk and back into RAM as soon as the user needs them
- Hard disk space used in this way is called **virtual memory**



Hard Disk



RAM

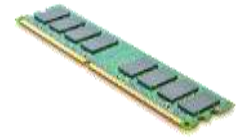


# Virtual memory

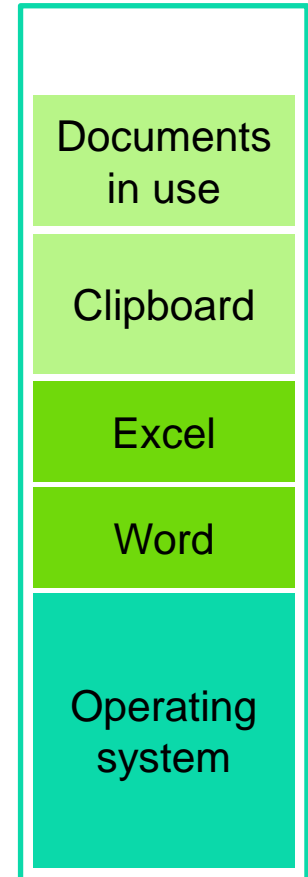
- Virtual memory is the part of the hard drive that is used as an extension to RAM
- 虚拟内存是硬盘驱动器的一部分，用作RAM的扩展
  - What are the advantages and disadvantages of using part of the hard disk in this way?



Hard Disk



RAM

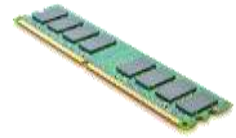
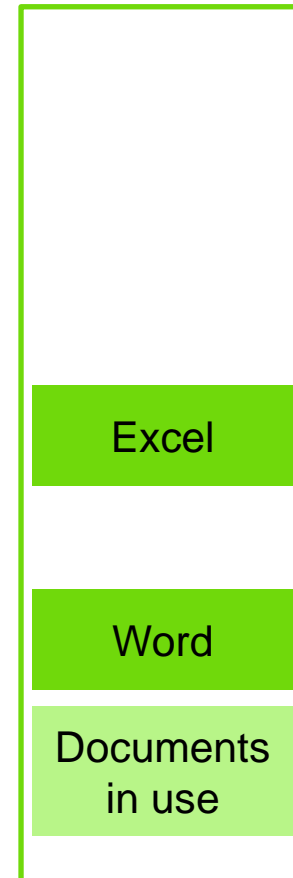


# Virtual memory

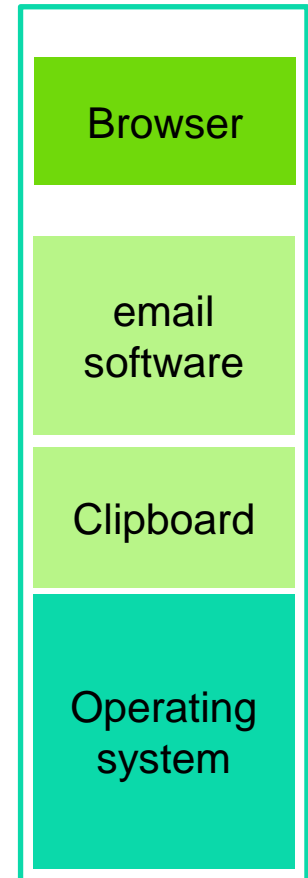
- It takes time to copy files in and out of RAM, and so the computer becomes a lot **slower**
- When RAM is really full and the user keeps swapping between tasks, the computer spends more time moving files around than getting on with processing
  - This is called **thrashing**



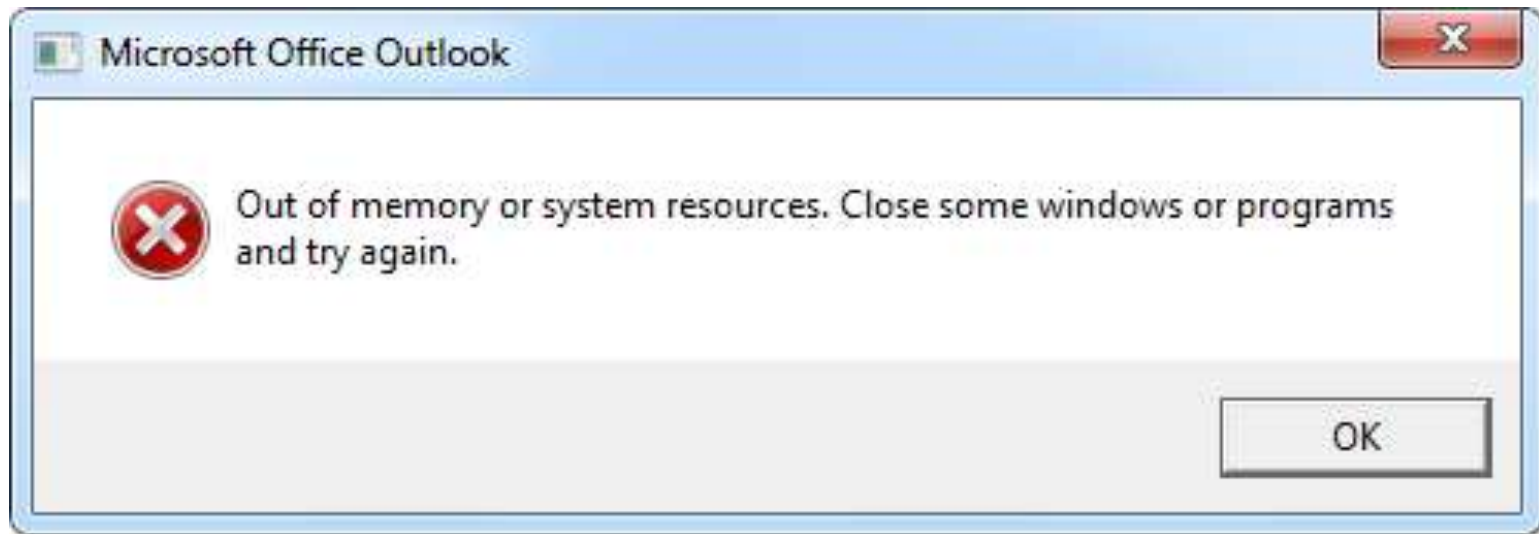
Hard Disk



RAM



# What happens when memory space completely fills up?





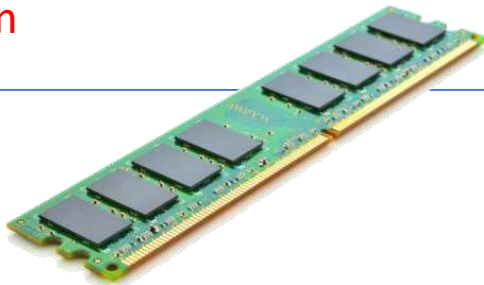
## RAM

### **Volatile** -

data is lost when the power is turned off

Stores user data / programs / part of operating system which is **currently in use**

Memory can be **written to or read from**



## ROM

### **Non-volatile** -

data is not lost when the power is turned off

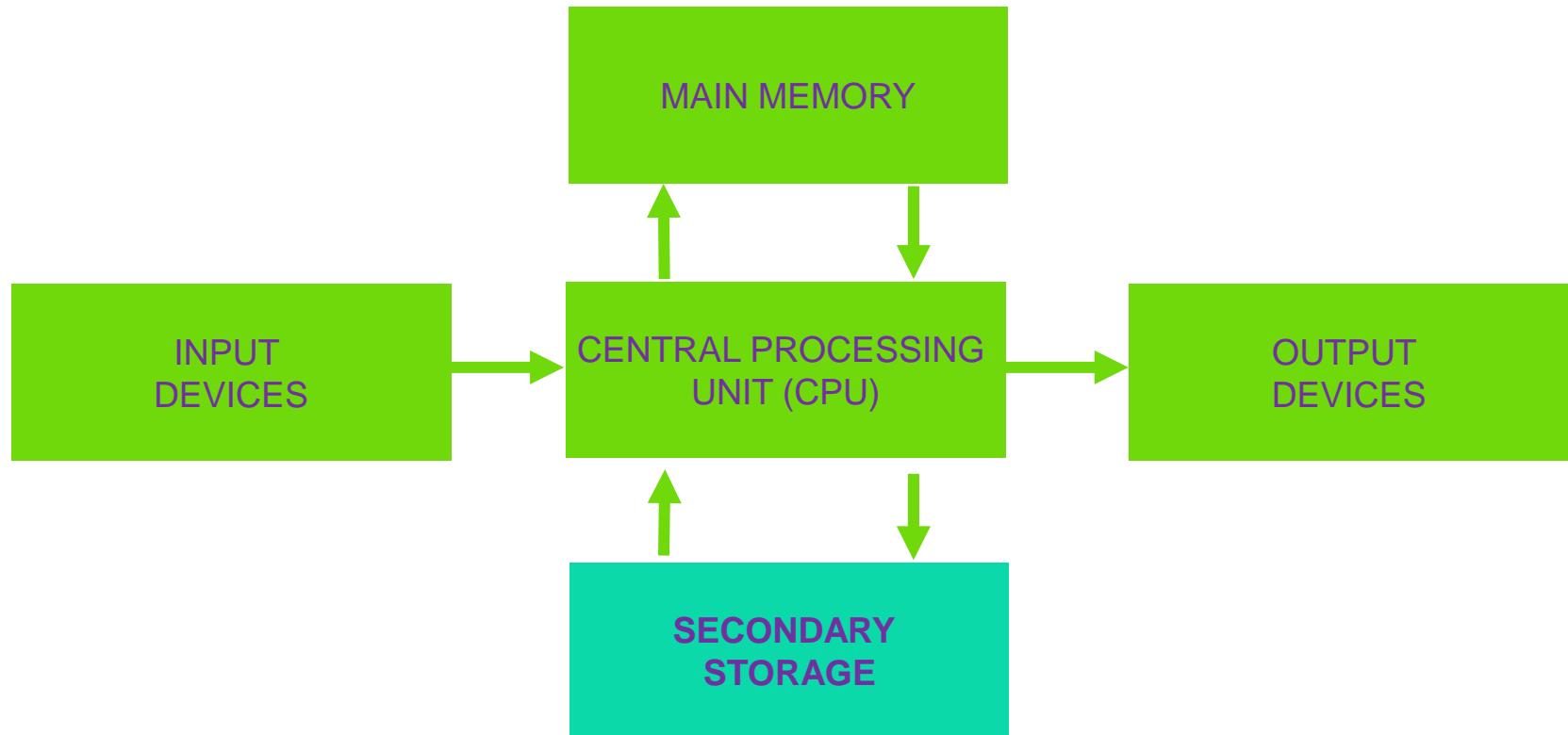
Used to store the BIOS and bootstrap loader (**instructions**) required to **start-up the computer**

Memory can **only be read** from and not written to



# Secondary storage

- What do you already know about secondary storage and its role within computer systems?



# Secondary storage – what's it for?

- Are secondary storage devices volatile or non-volatile?
- Why do we need secondary storage?
- Why are there so many different types of secondary storage?

# Secondary storage

- Secondary storage is **non-volatile** – it keeps its data even when the power is switched off
- It has many different uses – for example:
  - Programs and data are stored on **hard disk or solid state drive**
  - **CDs and DVDs** may be used to distribute software, music, and movies etc.
  - **Memory sticks** may be used to transport data from one place to another
  - **External hard drives** may be used for backup
  - What other uses are there for secondary storage devices?

## Off-line secondary storage

**Offline storage** - any device which can permanently hold data that is **not** permanently connected to a computer.

These storage devices are often used for **backing up** (making a copy of the data that is on a computer system).



# Storage technology

- **Magnetic:** Mechanical parts move over the disk's surface to read and write data magnetically
- **Solid State:** Data is recorded onto solid memory chips without any moving parts
- **Optical:** Lasers read and write data





# Magnetic storage: hard disks

- Fixed hard disk drives (HDD) are built into many PCs and laptops
  - They have a very large storage capacity compared to other media
- Portable hard drives can be connected to a computer through a USB port
  - They are used for backing up or transporting data
- Some portable music players have tiny hard drives no bigger than a small coin
  - They can store several GB of data



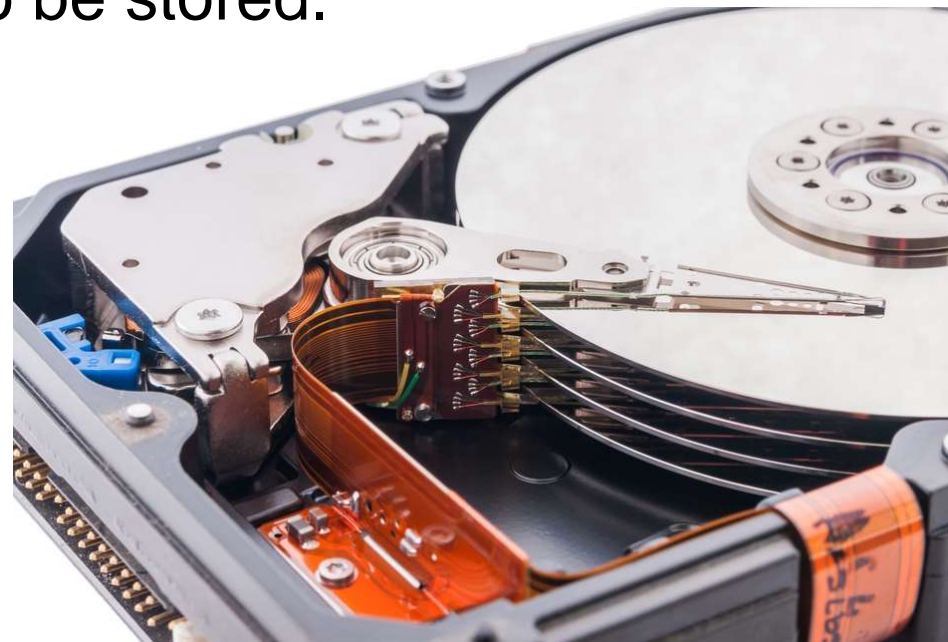
# Inside a hard disk



# Hard disk drives - HDD

Basic features:

- The metal disks (**platters**) are covered in tiny **magnets**
- Each magnet is **polarised** as either north or south (**1 or 0**) -> allowing data to be stored.
- The **read-write head** can read and change the data that is stored on the platters.

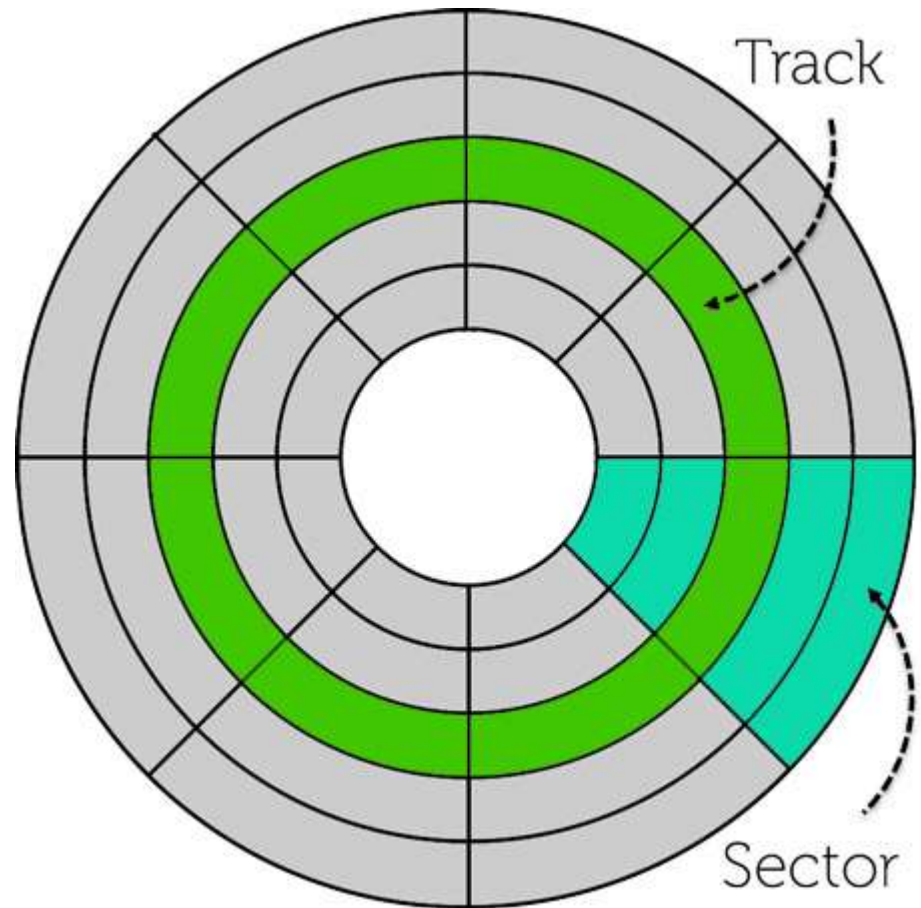




# Hard disk drives - HDD

Basic features:

- Disk contains concentric circles called **tracks**
- Each track is divided into **sectors**
- **Disk head** mounted on mechanical arm reads and writes the data



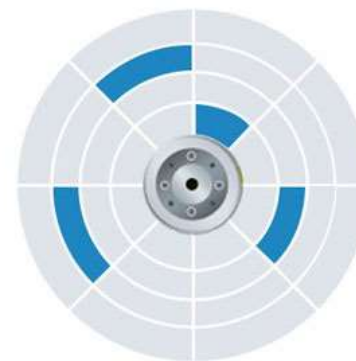
# Magnetic disks

## Latency

The time it takes for a specific block of data on a data track to rotate around to the read-write head.

## Fragmentation 数据是碎片化的

Files are not stored in adjacent sectors and are often fragmented all over the disk -> slower performing disk.



Fragmented Disk



Defragmented Disk

# Hard disk drives

- Advantages:
  - Cheap per GB storage than SSD
  - large storage capability
- Disadvantages:
  - Lots of mechanical / moving parts -> cannot shake or move around, and must avoid magnetic fields
  - not as fast as a SSD to read and write data
- Uses:
  - Personal computers, servers, mainframes, data centres
- Capacity:
  - 500GB - 20TB or greater



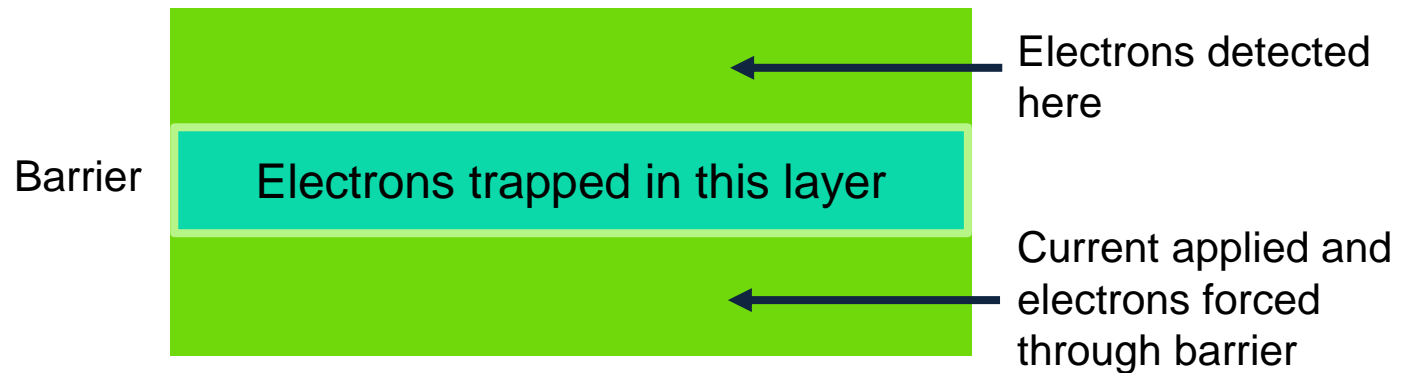
# Solid State Drives (SSD)

- Basic features:
  - Solid-state storage use **non-volatile flash memory** to store information
  - **Very fast read/write speeds** due to data being physically close and easy to recover
  - **No mechanical or moving parts** - > less chance of damage
  - Use **NAND** or **NOR** technology
  - **Transistors** are used as **gates**



# How flash memory works

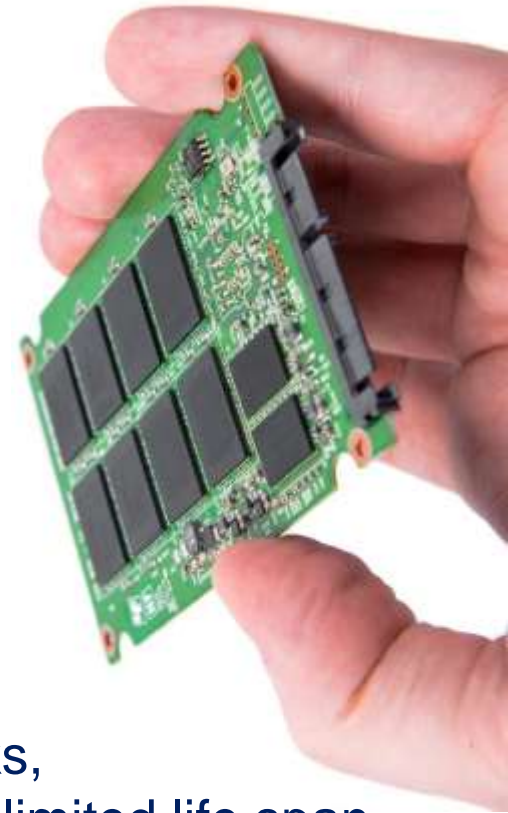
- Large electric current used to force electrons through a barrier and trap them on the other side



- They remain on the other side until “flushed” with a new current, hence the name
- Trapped (charged) or not trapped = 0 or 1

# Solid State Drives (SSD)

- Advantages:
  - No moving parts -> highly durable 耐用
  - Very fast read/write speeds
  - Faster start up times than HDD
  - Compact / small in size
- Disadvantages:
  - More expensive than HDD (per GB storage)
  - Less storage capacity than traditional hard disks,
  - Have a limited number of read / write cycles -> limited life span
- Uses:
  - Hand held devices, portable computers, personal computers
- Capacity:
  - 100GB – 10TB or more



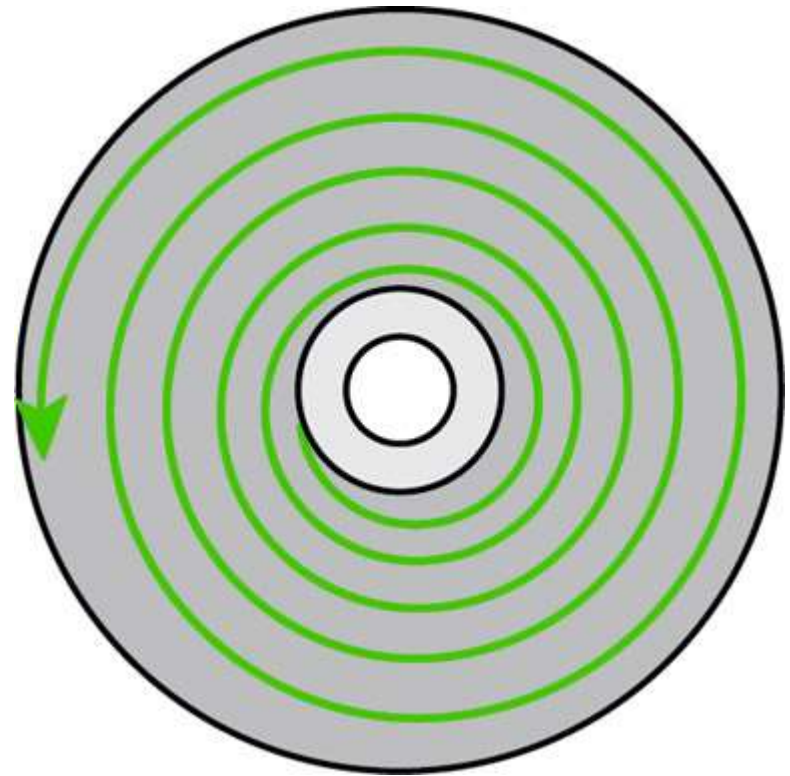
# Flash memory

- Ideal for a range of offline devices:
- Low cost, portable, no moving parts, durable
  - Cameras
  - Mobile phones
  - USB memory sticks



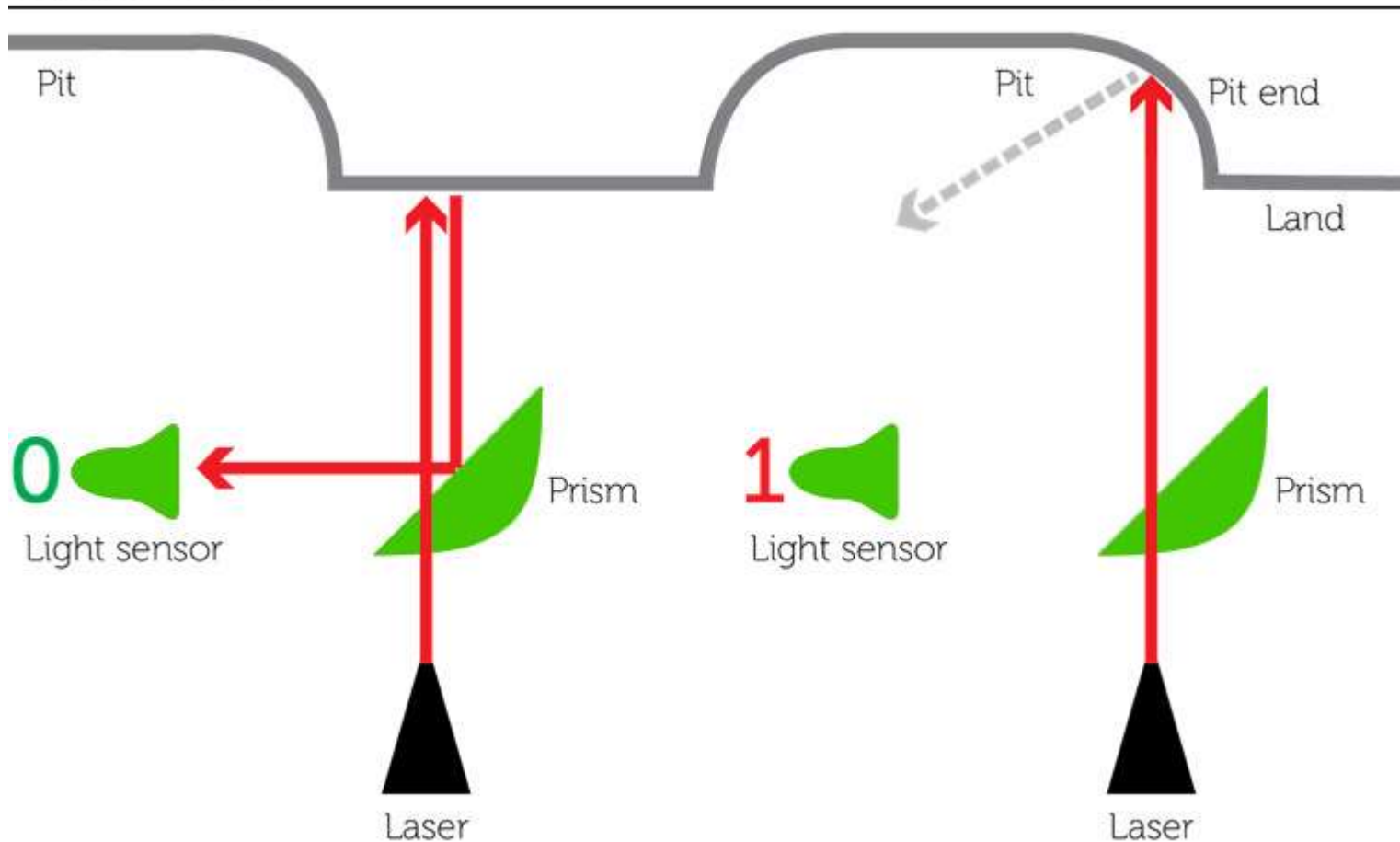
# Optical storage (CDs and DVDs)

- Data is stored as **pits** and **lands** burnt into a **spiral track** circulating outwards from the centre
- A **laser beam** passes over the **pits and lands** the level of **reflection is measured**
- From this signal, 0s and 1s can be calculated from reflections or no reflections



# How CDs work

Top of CD ROM



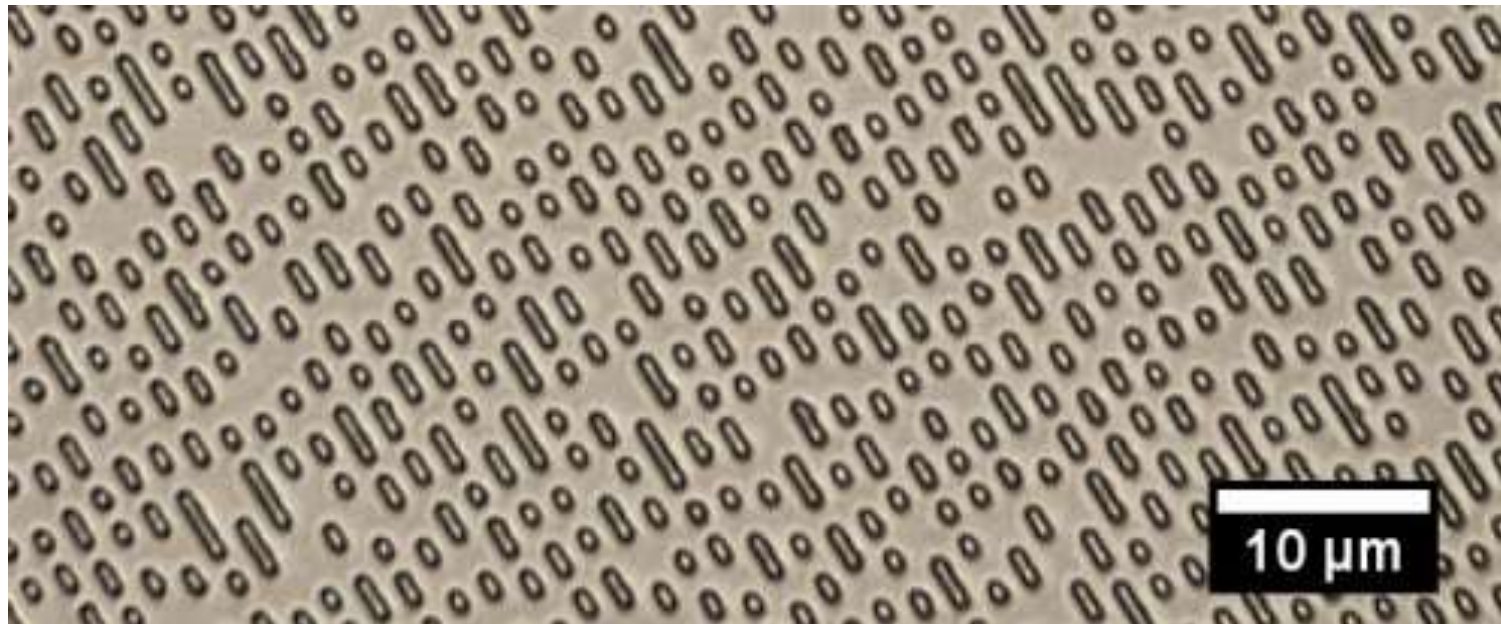
# Optical storage (CDs / DVDs)

- Advantages:
  - Cheap, very easily portable, takes up little space physically
- Disadvantages:
  - Less storage capacity compared to other types of secondary
  - Easily damaged / scratched
  - Requires a CD / DVD reader
  - Slow write speeds
- Uses:
  - Songs, videos and other multi-media storage, backup of data
- Capacity:
  - CD-ROM – up to 720Mb
  - DVD – up to 8.4Gb
  - Blu-Ray – up to 50Gb



# CDs, DVDs and BluRay

- Why are the capacities of these discs different given they are all the same physical size?
  - Microscopic view of the surface of a CD Rom

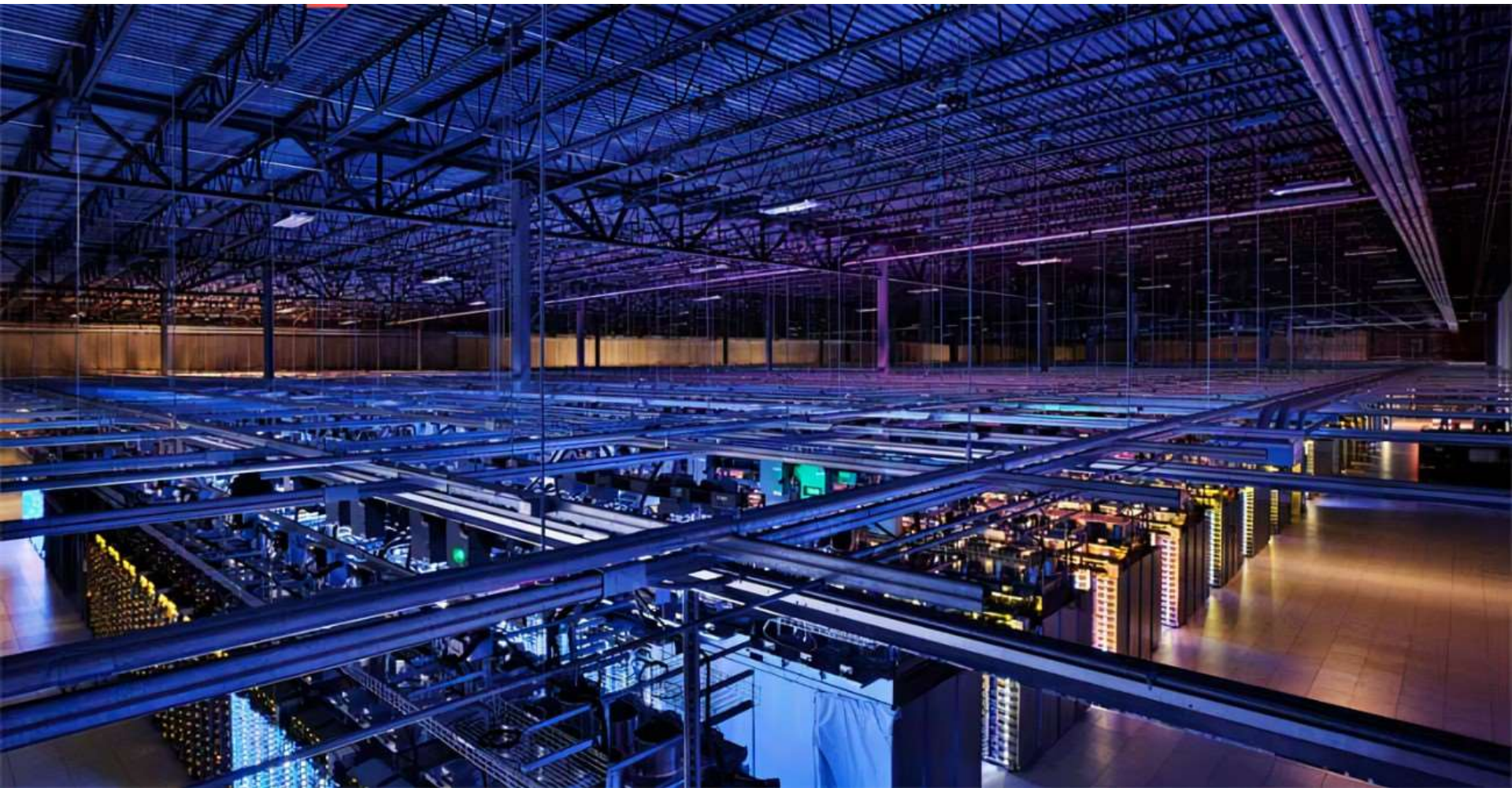


# Pit size and laser wavelength





# Cloud Storage



# Cloud Storage

Cloud storage is a method of data storage where **data is stored on remote servers** 服务器.

Instead of storing data **locally**, for example on the hard disk drive, a user can save their data into the cloud.

**Data can be accessed remotely**, from anywhere and from any device, as long as there is an **internet connection**.

Physical servers are needed to store data in cloud storage.





# Cloud Storage

A collection of servers

... that store data in a remote location // that allows data to be accessed remotely

... that are accessed using an internet connection



# Cloud Storage

## Advantages

- Data stored on the cloud can be accessed at **any time**, from **any device**, from **anywhere** in the world, as long as there is **internet access**
- No need to carry an external storage device, or even use the same computer
- Can be used as a remote **back-up of data** - a **copy of your data**. In case of data loss, the cloud storage will allow recovery of data
- Offers almost **unlimited data storage capacity**

# Cloud Storage

## Disadvantages

- If the **internet connection is slow or unstable**, there will be problems accessing or downloading data
- **Costs** can be high / expensive if large storage capacity is required
- Risk of **data loss** if the cloud storage company stops working
- **Security** is a much bigger issue and there is a risk that **important** or **personal data** may be lost or stolen, through mistakes by the cloud company, or the activities of **hackers** 黑客



# Summary: Memory

- There are two types of primary storage: **Random Access Memory (RAM)** and **Read Only Memory (ROM)**
- **Immediate Access Store (IAS)** is another name for primary storage
- **ROM** has its contents written at the time of manufacture and they cannot be changed
- **RAM** holds the data and instructions that are currently being processed
- **Virtual memory** is disk storage used as an extension of RAM - controlled by the operating system. Pages of data are transferred between RAM and virtual memory when needed.

# Summary: Secondary Storage

- **Not directly accessed** by the CPU
- Required for **permanent storage of data - non-volatile**
- Magnetic storage uses **platters** which are divided into **tracks** and **sectors**. Data is read and written using **electromagnets**.
- Optical storage uses **lasers** to create and read **pits** and **lands**
- Solid state uses **NAND** or **NOR** technology.  
**Transistors** are used as **control** and **floating gates**.