Topic 1: Force, Motion, and Energy

L1: First Law of Motion: Law of Inertia

TYPES OF MOTION:

1. **Uniform Motion -** movement of an object in a straight line with a constant velocity.
- acceleration of the object is zero
2. **Uniform Accelerated Motion -** object's velocity changes at a constant rate, resulting in a constant acceleration
- acceleration is not zero

Dynamics (branch of Mechanics) - study of the reason why objects move the way they do.

Isaac Newton
- formulated the Three Laws of Motion
- describes the relationship between the motion of an object and forces acting on it

Force - push or pull exerted by an object or another object
- vector quantity
- SI Unit: 1 Newton (N) = 1 kgm/s^2

Net Force - vector sum of forces acting on a body (Fnet)
- *Fnet:* $\Sigma F = F_1 + F_2 + F_3 + \ldots + F_n$

Classification of Forces:

1. **Contact Force -** forces that require direct contact between objects
- Ex: Friction, Applied Force, Air Resistance, Normal Force
2. **Non-Contact Force -** applied force without physical interaction
- main characteristic: force field
- Ex: Gravitational Force, Electrostatic Force, Magnetic Force

Law of Inertia
- states an object will stay at rest or keep moving in a straight line at a constant speed unless an external force acts upon it

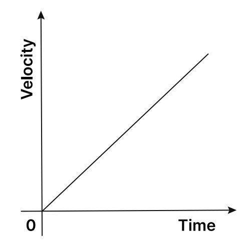
Inertia - an object's natural resistance to change its state of motion.

Mass - measurement of inertia; (higher mass = greater inertia)

First Condition of Equilibrium

Equilibrium - condition when there is no change in the state of motion.
- at rest/moving at constant velocity

Traditional Equilibrium: $\Sigma F = 0N \rightarrow a = 0\ m/s^2$
- Two Types:
  - *Static Equilibrium = at rest*
  - *Dynamic Equilibrium = moving at constant velocity*



Ex: Fast-Moving Bus Stopping Suddenly
- **The Action:** You are riding in a bus traveling at 60 km/h. The driver suddenly slams on the brakes to stop.
- **The Physics:** Your lower body is in direct contact with the bus seat, so the friction forces your legs to stop with the bus. However, your upper body has inertia of motion and wants to keep traveling at 60 km/h. Because no forward force stops your torso immediately, you lurch forward until your core muscles or the seat in front of you applies a backward force.

Ex: Car Seatbelts
- **The Action:** A car moving down the highway crashes into a barrier and stops instantly, but the passengers are held safely in place by their seatbelts.
- **The Physics**: When the car hits the wall, the stopping force is applied only to the vehicle frame. Due to inertia, your body naturally continues flying forward at the car's original speed. The seatbelt is designed to act as the missing external counter-force across your chest, safely stopping your body's forward momentum.

Topic 1: Force, Motion, and Energy

L2: Second Law of Motion: Law of Acceleration

Acceleration - rate of change with velocity over time

- non-zero net force = acceleration
- *positive velocity: right or up*
- *negative velocity: left or down*

Law of Acceleration - when a nonzero net force acts on an object, it will accelerate in the direction of the force.

- Acceleration is directly proportional to the net force and inversely proportional to the mass of the object
- Acceleration is directly proportional to force
- Acceleration is inversely proportional to mass

FORMULA: F = ma

- F: net force (1N)
- m: mass (1 kg)
- a: acceleration (1 m/s^2)

Mass

- is the quantity of matter a body contains
- SI unit: kg
- scalar quantity
- mass of a body is constant

Weight

- the force with which the body is attracted toward the center of the Earth
- SI Unit: N
- vector quantity
- changes depending on the acceleration due to gravity

FORMULA: w = mg

g = acceleration due to gravity

Examples of Everyday Applications:

- **Airplane Takeoff**
- **Skateboarding**
- **Lifting Weights**
- **Tennis Serve**
- **Braking a Vehicle**
- **Rowing a boat**

FORMULA:

$$a = \frac{F_{net}}{m} \quad F_{net} = ma \quad m = \frac{F_{net}}{a} \quad a = \frac{V_f - V_i}{t}$$

Sample Problems:

1. A 10 kg object resting on a horizontal frictionless surface is subject to two forces: F_1 = 30N directed east and F_2 = 50N directed to east. FInd its acceleration.

Given: 10 kg, 30N, 50N **Unknown: a** **Formula:** $\frac{F_{net}}{m}$

Solution: Fnet: $\frac{30N + 50N}{10\ kg} = \frac{80N}{10\ kg} = \mathbf{8 m/s^2}$

2. A toy car starts from rest and accelerates to a speed of 8.0 m/s in 2.0 seconds. If the net force acting on the toy car is 4.0N, what is the mass of the toy car?

GIven: Vi = 0 m/s Vf = 8.0 m/s t = 2.0s f = 4.0N

Unknown: m, a

Formula:

$$a = \frac{V_f - V_i}{t} \qquad m = \frac{F_{net}}{a}$$

Solution:

$$a = \frac{8.0\ m/s - 0\ m/s}{2.0s} = 4.0\ m/s^2$$

$$m = \frac{4.0N}{4.0\ m/s^2} = \mathbf{1.0\ kg}$$

L3: Third Law of Motion: Law of Interaction

Law of Interaction - for every action, there is an equal and opposite reaction

- This means that when Object A exerts a force on Object B, Object B simultaneously exerts an equal force in the opposite direction on Object A.

Examples:

Action	Reaction
Person pushes wall →	Wall pushes person ←
Foot pushes ground backward	Ground pushes foot forward
Rocket pushes gas downward	Gas pushes rock upward
Swimmer pushes water backward	Water pushes swimmer forward
Bat hits ball	Ball pushes back on bat

Topic 2: Electricity and Circuits

L1: Electric current, voltage, and resistance

Electric Circuit - closed conducting path where charges flow

Electric Current - movement of charged particles in a specific direction

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

I = Current
q = Charge
t = Time

- flow of charge
- amount of charge passing through any point in a conductor per unit time
- SI Unit: 1 Ampere (A); named after *Andre Marie Ampere*

Conventional Current - positive charges flowed (positve to negative)

Electron Current - stream of electrons (negative to positive)

Direct Current (DC) - current that flows in one direction at all

- used in battery-operated devices

Alternating Current (AC) - current that changes direction at regular intervals (60 times in a second)

- supplied by electric companies to power appliances

Resistance - opposition to the flow of electricity

- SI Unit: 1 ohm (Ω); named after *George Simon Ohm*

Resistors - are used to control or limit amount of current in a circuit

Factors Affecting Resistance of a Wire

Cross Sectional Area

- Resistance is *inversely proportional* to cross-sectional area
- thick wire has less resistance than a thin wire

Length

- Resistance is *directly proportional* to its length
- longer wire has *greater resistance* than a shorter wire

Resistivity

- Conductors: small resistivities
- Insulators: large resistivities
- Semiconductors: intermediate values of resistivity = almost zero

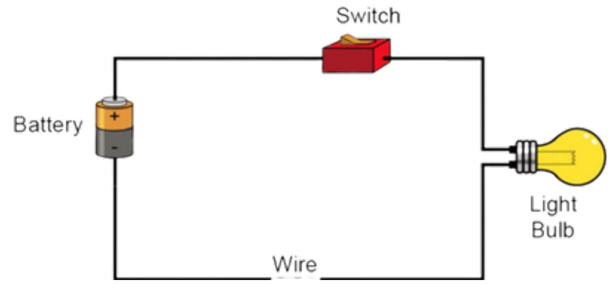
Temperature

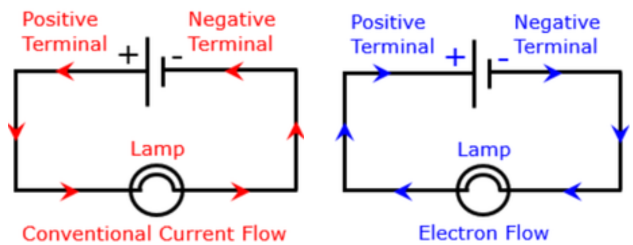
- resistance and resistivity are *directly proportional* to temperature

(temp increases, resistance increases for conductors and decreases for insulators and semiconductors)

Voltage (v)/Potential Difference

- electric pressure that causes the charges to flow
- SI Unit: Volt (V); named after Alessandra Volta





1. **Cell -** source of potential difference
2. **Positive Terminal:** longer vertical line
3. **Negative Terminal:** shorter vertical line

Positive Terminal is at a higher potential than Negative Terminal

cathode (positive), anode (negative)

Dry Cell

- electrolyte in paste/gel or semi-solid form
- Ex: AA battery

Wet Cell

- electrolyte is a liquid
- Ex: car battery

Primary Cell

- cannot normally be recharged; used once and replaced
- Ex: Alkaline AA battery

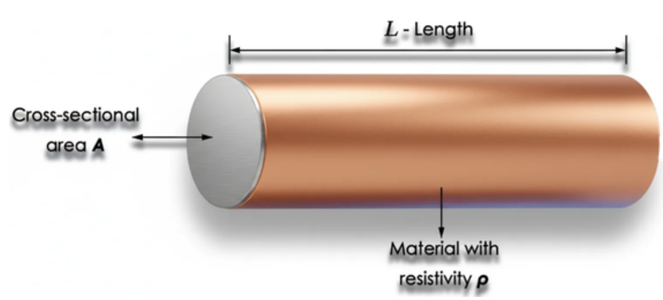
Secondary Cell

- can be recharged and used repeatedly
- Ex: rechargeable lithium-ion battery

Electromotive Force (E) - potential difference across its terminals when no current is flowing

Terminal Voltage ($V_{terminal}$) - potential difference across its terminals when current flows

Potential difference - is the "push" that makes electricity flow through a circuit.



Topic 2: Electricity and Circuits

L1: Electric current, voltage, and resistance (Ohm's Law)

Ohm's Law

- formulated by Georg Simon Ohm in 1872
- states that current (*I*) is *directly proportional* to (*V*) and *inversely proportional* to (*R*)

FORMULA: *I = V /R*

- Voltage and current are ***directly proportional*** when resistance stays the same.
- Current and resistance are ***inversely proportional*** when voltage stays the same.

It is essential for designing and analyzing circuits, as it helps determine how much current will flow for a given voltage and resistance.

Sample Problems:

1. How much current flows through a lamp with a resistance of 90.0 Ω when it is connected to a 220.-V outlet?

G: R = 90.0 Ω
V = 220.-V

U: I = ?

E: $I = \frac{V}{R}$

S: $I = \frac{220.\ V}{90\Omega}$

A: 2.44 A

2. What is the resistance of a lamp which allows 0.80A of current when 110 V is applied to it?

G: I = 0.80 A
V = 110 V

U: R = ?

E: $R = \frac{V}{I}$

S: $\frac{110\ V}{0.8\ A}$

A: R = 137.5 Ω = 140 Ω

3. **A CD player with a resistance of 40 Ω has a current of 0.1 A flowing through it. How many volts supply the CD player?**

G: 1 = 0.1 A
R = 40 Ω

U: V = ?

E: V = IR

S: V = (0.1 A)(40 Ω)

A: 4V

Quantity	Symbol	Unit of Measurement	Unit Abbreviation
Current	I	Ampere (Amp)	A
Resistance	R	Ohm	Ω
Voltage	E or V	Volt	V

L2: Series and Parallel Circuits

Measuring Current, Voltage, and Resistance

Ammeter - is used to measure current in amperes.

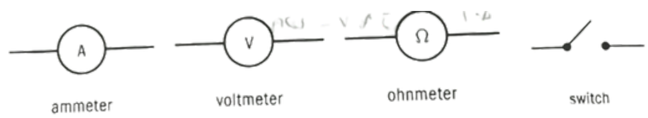
Ohmmeter - is used to measure resistance in ohms.

Voltmeter - is used to measure voltage in volts.

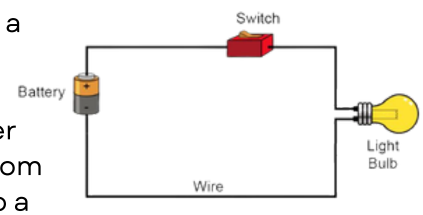
Multimeter - is a handheld tester used to measure electrical voltage, current, resistance, and other values.

Switch - circuit that either allows current to flow or stops it

- Closed: current flows through it
- Open: circuit is broken and no current flows



Electric Circuit - is a closed conducting loop in which a current can transfer electrical energy from a suitable source to a useful load.

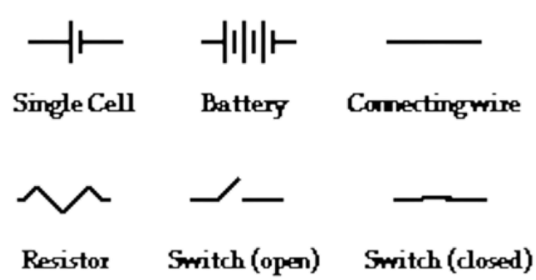


Source/Supply - provides the voltage needed to force current through the circuit. (e.g., battery)

Conductors - it is where the current can travel (e.g., copper wire, metals)

Load - is a device that converts electrical energy into some other useful form (e.g., light bulb)

Switch/control device - a device that continues or discontinues the flow of electric current through the circuit



Series Circuit - components connected one after another along a single path

Parallel Circuit - components connected side by side, creating multiple paths for current

Analysis Rules for Series Circuits:

The *current* that flows through each resistance is the same as the total current throughout the circuit.

$$I_T = I_1 = I_2 = I_3 = I_4 = ... = I_n$$

The *total resistance* is equal to the sum of the individual resistances.

$$R_T = R_1 + R_2 + R_3 + R_4 + ... + R_n$$

The sum of all the individual *voltages* is the same as the applied voltage.

$$V_T = V_1 + V_2 + V_3 + V_4 + ... + V_n$$

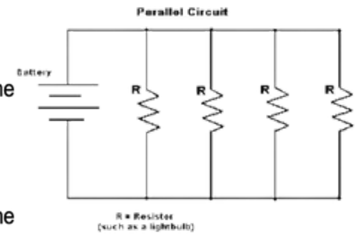
Topic 2: Electricity and Circuits

L2: Series and Parallel Circuits

Analysis Rules for Parallel Circuits:

The *total current* that flows through the circuit is equal to the sum of the current in separate resistances.

$$I_T = I_1 + I_2 + I_3 + I_4 + \dots + I_n$$



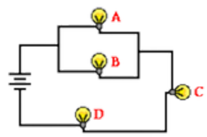
The *individual voltages* in each resistor is the same as the applied voltage.

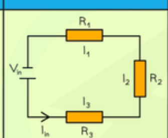
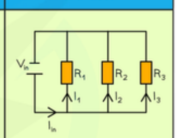
$$V_T = V_1 = V_2 = V_3 = V_4 = \dots = V_n$$

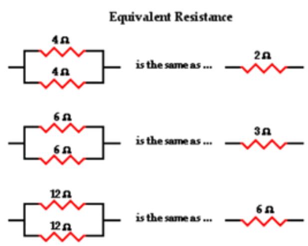
The *reciprocal of the total resistance* is equal to the sum of the reciprocals of the separate resistances.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

Combination Circuit - dual use of series and parallel connections in a circuit.



	Series	Parallel
Circuit		
Voltage	$V_{in} = V_1 + V_2 + V_3$	$V_{in} = V_1 = V_2 = V_3$
Current	$I_{in} = I_1 = I_2 = I_3$	$I_{in} = I_1 + I_2 + I_3$
Resistance	$R_{total} = R_1 + R_2 + R_3$	$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$



Breadboards - simple & reusable platform for testing and modifying circuits without the need for soldering

- all holes in each row are electrically connected, while adjacent rows are not.
- columns (power rails) have connected holes, which are mainly used fro attaching the power supply.

Short Circuit - happens when electricity takes an unintended path with very little resistance, causing a large amount of current to flow.

L3 & L4: Safe Use of Electricity

Human Bodies

- are made up of 60% of water = Good conductor for electricity

Electric Shock

- happens when current from external source passes through the body

Effects of Electric Shock

- Burns, damage to internal organs
- Heart rhythm problems - ventricular fibrillation
- Death

Overloading

- happens when too many devices use one circuit, causing too much current to flow and the wires to overheat.
- The *circuit breaker* trips to stop the flow and prevent damage or fire.
- *Fuse:* consists of a high-resistance strip of alloy that melts readily when too much current flows through it

Two-pronged plug - two principal flat wires (live and neutral) allow electricity to flow and power it

Three-pronged plug - third prong (earth pin) is a safety feature.

- it is grounded to prevent electric shock in case live wire accidentally touches a metal part of the appliance

Ground Fault Circuit Interrupter (GFCI)

- protects people from electric shock
- It breaks the circuit when there is a difference in current entering and leaving electrical equipment.

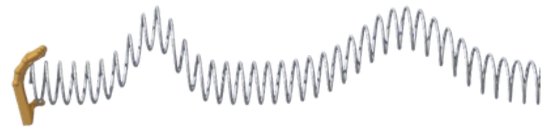
Topic 3: Electromagnetic Spectrum

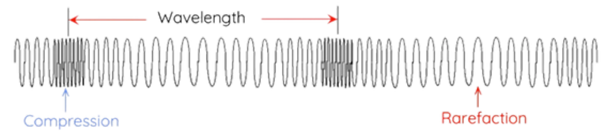
L1: The Nature of Electromagnetic Waves

Wave - is a <u>disturbance that carries energy from one place to another</u> without the particles moving along with it.

Types of Waves:

- <u>Transverse</u> - particles of the medium move at right angles (perpendicular) to the direction the wave travels.
- <u>Longitudinal</u> - particles of the medium move back and forth (parallel) in the same direction to the wave travels.





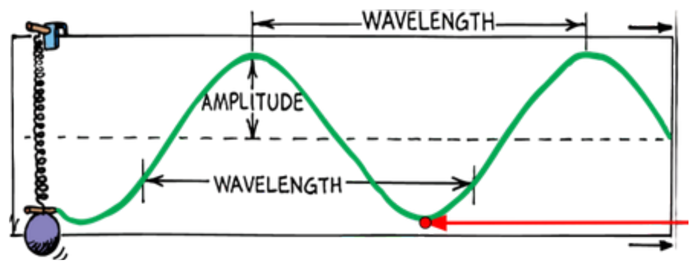
Mechanical Waves

- requires a medium
  - <u>Longitudinal Waves: sound waves, ultrasound waves, seismic P-waves</u>

Electromagnetic Waves

- can move in a medium or vacuum
  - <u>Transverse Waves: radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, gamma rays</u>

Characteristics of Waves



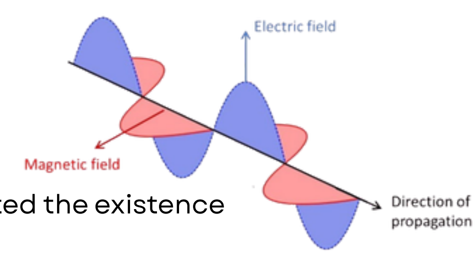
1. **Crest -** the highest point of a wave
2. **Trough -** the lowest point of a wave
3. **Amplitude (A) -** the distance from the midpoint to the crest (or trough) of the wave (*SI UNIT: meters (m)*)
4. **Wavelength (λ) -** distance between two successive crests or identical points in a wave (SI UNIT: meters (m))
5. **Frequency (f) -** the number of wave cycles that pass a fixed point per second (SI UNIT: Hertz (Hz))
6. **Period (T) -** the time for one complete vibration/cycle to occur (SI UNIT: seconds (s))

$$\text{Frequency} = \frac{1}{\text{period}}$$

$$\text{Period} = \frac{1}{\text{frequency}}$$

Electromagnetic Waves

- are produced by vibrating electric charges.
- Electric and magnetic fields oscillate perpendicular to each other and to the wave's direction.
- are **<u>transverse waves</u>** that can move through matter, in a space or in a vacuum.



James Clerk Maxwell (1860s) - a Scottish scientist that predicted the existence of electromagnetic waves.

Properties of EM Waves

EM waves follow the <u>wave equation</u> which related speed (v), wavelength (λ), and frequency (f):

V = λf

At constant speed: <u>Higher frequency = shorter wavelength</u>

In vacuum and air, all EM waves travel at the same speed:

c = 300,000,000 m/s or 3 x 10^8 m/s

c = speed of light in air or vacuum

The energy of an EM wave is *dependent* on its <u>intensity</u> and the energy carried by the photons that constitute.

Photon - carries a discrete amount of energy depending on the frequency of the EM wave

Higher frequency = Higher photon energy/EM wave

Topic 3: Electromagnetic Spectrum

L2: The Electromagnetic Spectrum

Electromagnetic (EM) Spectrum - is the full range of EM waves that are organized by frequency and wavelength

1. **Radio Waves**
- longest wavelength and lowest frequency
- used for: radio and tv broadcasting, communication, and cell phones
- ex: radio signals

2. **Microwaves**
- subcategory of radio waves
- used for: microwave ovens, wi-fi, radar
- ex: Wi-fi signals

3. **Infrared (IR)**
- associated with heat
- used for: remote controls, thermal cameras
- ex: heat from the Sun

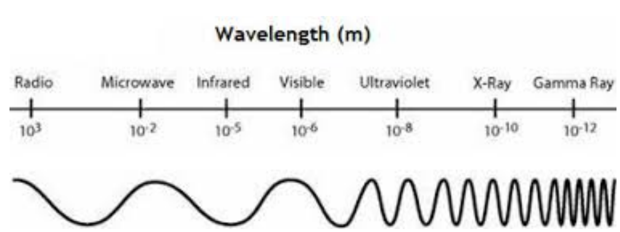
4. **Visible Light**
- only part of the EM spectrum that humans can see
- used for: lighting, photography & vision
- ex: colors of the rainbow

5. **Ultraviolet (UV)**
- higher energy than visible light
- used for: sterilization and detecting certain materials
- ex: UV rays from the Sun

Have three categories based on its wavelength:
- UV-A (longest) - 95% of all UV reaching Earth
- UV-B - mostly absorbed by the ozone
- UV-C (shortest) - the most dangerous due to it being energetic

6. **X-rays**
- very high frequency
- used for: medical imaging and checking bones
- discovered by Wilhelm Roentgen (1895)
- ex: hospital x-ray machines
- Soft x-rays - have limited penetrating power; absorbed by soft tissues and thin materials
- Hard x-rays - have more penetrating power and are used in medical imaging

7. **Gamma Rays**
- shortest wavelength and highest frequency
- used for: cancer treatment and sterilizing medical equipment
- ex: radiation from nuclear reactions



L3: Effects of EM Radiation on Earth

Effects of EM Radiation

- **Radio Waves**
  - low energy
  - generally not harmful at normal exposure levels
  - can cause heating at very high intensities
- **Microwaves**
  - can heat body tissues
  - high exposure can cause burns or tissue damage
- **Infrared (IR)**
  - produces heat
  - too much exposure can cause burns
- **Visible Light**
  - allows us to see
  - very intense light can damage the eyes
- **Ultraviolet (UV)**
  - can cause sunburn
  - too much exposure can damage skin and eyes
- **X-rays**
  - high-energy radiation
  - too much exposure can damage cells and increase health risks
- **Gamma Rays**
  - highest energy
  - can damage cells and DNA
  - high exposure can be very harmful

Classifications of EM Radiation

Non-ionizing Radiation – EM radiation with lower energy that does not have enough energy to remove electrons from atoms.
- It includes radio waves, microwaves, infrared, and visible light. It mainly causes heating when exposure is very high.

Ionizing Radiation – EM radiation with higher energy that has enough energy to remove electrons from atoms.
- It includes ultraviolet, X-rays, and gamma rays. It can damage cells and DNA with enough exposure.

In short:
Non-ionizing = lower energy
Ionizing = higher energy

Environmental Effects of EM Radiation

- **Radio & Microwaves** – can interfere with communication and may affect wildlife at high exposure.
- **Infrared** – can increase heating in the environment.
- **Visible Light** – artificial light can disrupt animals' natural behaviors.

Topic 3: Electromagnetic Spectrum

L3: Effects of EM Radiation on Earth

- **Ultraviolet (UV) –** can harm plants, animals, and aquatic organisms.
- **X-rays & Gamma Rays –** high exposure can damage living cells and genetic material.

Overall: The effects depend on the type, energy, and amount of exposure.

Radiation Protection

ALARA (As Low As Reasonably Achievable)

Principles:

- Time - reduce exposure duration
- Distance - stay as far from the source as possible
- Shielding - use protective barriers when necessary

Topic 4: The Solar System and Space Technologies

L1: Minor Members of the Solar System

Minor Members of our Solar System:

- asteroids
- comets
- meteoroids
- dwarf planets

1. **Asteroids**

Composition: Mostly rock and metal
Origin: Leftover material from the formation of the Solar System
Location: Mostly in the Asteroid Belt between Mars and Jupiter
Size: Usually a few meters to hundreds of kilometers wide
Shape: Usually irregular, but some are more rounded
Example: Vesta, Pallas, Ceres

2. ***Comets***

Composition: Ice, dust, rock, and frozen gases
Origin: Leftover material from the early Solar System
Location: Mainly from the Kuiper Belt and Oort Cloud
Size: Nucleus is usually a few kilometers wide
Shape: Nucleus is generally irregular
Special feature: Forms a glowing coma and tail when near the Sun

Parts of a Comet:

- **Nucleus –** the solid center made of ice, dust, and rock.
- **Coma –** a cloud of gas and dust surrounding the nucleus when the comet gets close to the Sun.
- **Hydrogen Envelope –** a large, invisible cloud of hydrogen gas surrounding the coma.
- **Ion Tail –** made of electrically charged gas; always points away from the Sun.
- **Dust Tail –** made of dust particles; usually curves away from the Sun.

Example: Halley's Comet

3. **Meteoroids**

Composition: Rock, metal, or a mixture of both
Origin: Often broken pieces of asteroids or comets
Location: Found throughout space
Size: Usually smaller than asteroids, ranging from tiny grains to about 1 meter
Shape: Usually irregular
Important: In space = meteoroid → in atmosphere = meteor → reaches the ground = meteorite

4. **Dwarf Planets**

Composition: Rock, ice, or both
Origin: Leftover material from the formation of the Solar System
Location: Found in different regions, especially the Kuiper Belt
Size: Large enough to become nearly round, but smaller than the eight planets
Shape: Nearly spherical due to their own gravity
Special feature: Orbit the Sun but have not cleared their orbital neighborhood
Examples: Pluto, Eris, Haumea, Makemake, and Ceres

How a Meteor Shower Works:

A meteor shower happens when Earth passes through a trail of dust and small rocks left behind by a comet or asteroid. As these particles enter Earth's atmosphere at high speed, they heat up and glow, creating bright streaks of light called meteors. Most of the particles are small enough to burn up completely in the atmosphere.

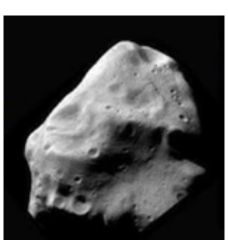
Topic 4: The Solar System and Space Technologies

L2: Cosmic Clues to the Solary System

Three Types of Asteroids:

Classification	Composition	Appearance	Location in the Asteroid Belt	Clues:
C-type (Carbonaceous) 	Clay and silicate materials, organic carbon	Dark in color	Outer layer of the asteroid belt	Earliest objects in the Solar System
				They are found in the outer asteroid belt, where it is colder, and may preserve some of the oldest materials from the early Solar System.

Classification	Composition	Appearance	Location in the Asteroid Belt	Clues:
S-type (Stony) 	Rocks and metals; iron and nickel, magnesium silicates	Lighter in color	Inner asteroid belt	Found in the crust and mantle of Earth
				Their materials are similar to Earth's crust and mantle, showing that they contain rocks similar to those that formed the inner planets.

Classification	Composition	Appearance	Location in the Asteroid Belt	Clues:
M-type (Metallic) 	Iron andd nickel and some stones	Partially molten	Middle of the asteroid belt	Formed closer to the sun where heat partially melted the metals
				They may be fragments of larger early objects whose metals melted and sank to the center, later broken apart by collisions, exposing their metal-rich interiors.

Topic 4: The Solar System and Space Technologies

L2: Cosmic Clues to the Solary System

Three Types of Meteorites:

Classification	Composition	Commonality	Appearance
Stony 	Mostly hard minerals called silicates, while some also include trace amounts of iron	Most common (about 95%)	With black **fusion crust** (because of intense heat); Many have **chondrules** (small glassy spheres)
			Some contain chondrules, tiny round particles formed early in the Solar System. They preserve some of the oldest unchanged materials that helped form the planets.

Classification	Composition	Commonality	Appearance
Iron 	Almost entirely iron-nickel alloy	Less common (about 5%)	Very dense and metallic; when cut and polished, they show Widmanstätten patterns formed as the metal cooled slowly over millions of years.
			Iron meteorites came from the metallic cores of large asteroids, where heavy metals sank to the center before collisions broke them apart.

Classification	Composition	Commonality	Appearance
Stony-Iron 	A mixture of stony silicate material and iron-nickel material	Rarest (<1%)	Some stony-iron meteorites, called **pallasites,** contain green crystals of the mineral olivine surrounded by metal.
			Scientists think they came from the boundary between an asteroid's metallic core and rocky mantle, helping us understand the interior of early planet-like bodies.

Topic 4: The Solar System and Space Technologies

L3: Space Technologies

Space Probes - unmanned spacecraft sent to explore objects such as asteroids, comets, dwarf planets, and distant regions of the Solar System
Camera/telescope - separates light into different wavelengths to identify minerals, gases, water, ice & organic materials
Spectrometer - separates light into different wavelength to identify minerals, gases, water, ice and organic materials
Thermal Imager - detects infrared radiation to measure surface temperature
LIDAR or LASER altimeter - sends laser pulses to measure distance, height and surface shape
Magnetometer - detects magnetic fields
Dust/particle detector - measures dust grains, solar wind, and charged particles
Sample collector - gathers soil, dust, or rocks for study
Lander/rover - examines an object directly from its surface

OSIRIS-REx

- Destination: Asteroid Bennu
- Main Goal: Study Bennu and collect a sample of its rocks and dust.

OCAMS Camera Suite

PolyCam: A telescope-like camera that photographed Bennu from a distance and took detailed close-up images.
MapCam: Mapped the asteroid in different wavelengths.
SamCam: Recorded the collection of the sample.
OLA-OSIRIS-REx Laser Altimeter: used laser pulses to create a three-dimensional map of Bennu
OVIRS: a visible & infrared spectrometer that searched for minerals, water-related substances, and organic materials
OTES: measured infrared heat & helped determine the minerals & temperatures on Bennu
REXIS: used X-rays to identify chemical elements on the asteroid
TAGSAM: the robotic sampling arm that briefly touched Bennu and collected dust and rocks

New Horizons

- Destination: Arrokoth in the Kuiper Belt
- Main Goal: Conduct close flybys and study distant icy worlds.

LORRI: powerful telescope and black-and-white camera that took highly detailed photographs
Ralph: Mapped surface colors, minerals, ice, and temperature using cameras and infrared.
Alice: an ultraviolet spectrometer used to examine gases and atmospheres
REX: used radio waves to study atmospheric pressure and temperature
SWAP: measured the solar wind, a stream of particles coming from the Sun
PEPSSI: detected high-energy charged particles
Student Dust Counter: counted tiny dust particles encountered during the journey

Psyche

- Destination: Asteroid 16 Psyche
- Main Goal: investigate a metallic asteroid that may resemble the exposed interior of an early planetary body

Multispectral Imager: pair of telescope-equipped cameras that photograph Psyche in visible and near-infrared light
Gamma-Ray & Neutron Spectrometer: identifies chemical elements by detecting gamma rays and neutrons emitted from the surface
Magnetometer: searches for evidence that Psyche once had a magnetic field
X-band Radio Science System: Uses radio waves to study the asteroid and measure its properties.
DSOC-Deep Space Optical Communications: Uses lasers to send data between spacecraft and Earth.

Lucy

- Destination: Jupiter's Trojan asteroids
- Main Goal: study ancient asteroids

L'LORRI: high-resolution telescope and black-and-white camera used to photograph surface features
L'Ralph: map out surface geology
MVIC: takes color photographs
LEISA: an infrared spectrometer that searches for ice, minerals, and organic compounds
L'TES: A thermal infrared instrument that measures surface temperature and heating/cooling rates.
T2CAM Tracking Cameras: help the spacecraft follow & locate an asteroid

Hayabusa 2

- Destination: Asteroid Ryugu
- Main Goal: map ryugu & deploy small surface vehicles

ONC-T-Optical Navigation Camera-Telescopic: has several color filters to navigate around Ryugu
NIRS3-Near-Infrared Spectrometer: looks for water-bearing/hydrated minerals
TIR-Thermal Infrared Imager: measures surface temp. & helps understand physical condition of rocks

Topic 4: The Solar System and Space Technologies

L3: Space Technologies

LIDAR: uses laser light to measure distance
SCI-Small Carry-on Impactor: created an artificial crater to expose less-weathered material underneath
DCAM3: a separate camera that observed the impact from a safe distance
Minerva-II Rovers and Mascot Lander: took close-up photographs and measured the surface directly
Sampler and Re-entry Capsule: collected material and safely transported it to Earth

Rosetta

- Destination: Comet 67P/Churyumov-Gerasimenko
- Main Goal: orbit a comet to observe how it changes as it approaches the Sun, and place the Philae lander on its surface

OSIRIS: a camera and telescope system that photographed the comet's nucleus, jets, gas, and dust
VIRTIS: a visible and infrared spectrometer that mapped surface minerals, ice, temp, and organic substances
MIRO: Used microwave radiation to measure gases, gas movement, and temperature beneath the comet's surface
ROSINA: a mass spectrometer that identified gases surrounding the comet
GIADA: measured the speed, size, and movement of dust grains
COSIMA: collected and chemically analyzed comet dust
MIDAS: produced microscopic images of very small dust particles
CONSERT: sent radio waves between Rosetta and Philae to investigate a comet's internal structure
Ground-based telescopes helped scientists discover, track, and study an object from a distance. They provide information about its orbit, brightness, size, and possible composition. A space probe can then travel closer and obtain much more detailed measurements.