Science and Technology Class 07

Previous Class Topic

- **Relationship among coronal holes, sunspots, and solar flares** in space technology
- **ISRO's organizational structure** under the Department of Space and introduction to agencies like NSIL, Antrix, and InSpace

ISRO's Governance and Space Agency Structure

Organizational Hierarchy

- The Department of Space operates directly under the Prime Minister, not under any ministry.
- ISRO functions under the Department of Space.
- Other major agencies under the Department include **NSIL (New Space India Limited)**, **Antrix**, and **InSpace**.

Commercial Wings of ISRO

- *Antrix Limited*is the older PSU handling ISRO's commercial deals, such as international satellite launches.
- *NSIL (New Space India Limited),* established in 2019, takes charge of manufacturing rockets (like SSLV and PSLV) and fosters private sector engagement with ISRO.

Regulatory Agency for Private Sector

- *InSpace (Indian National Space Promotion and Authorization Center)*acts as a regulator for private space sector participants.
- InSpace is directly under the Department of Space and not under ISRO.
- It ensures regulatory transparency, approval processes, and non-preferential access to ISRO facilities for private companies.

Anti-Satellite Missiles Overview

- Designed to destroy satellites.
- Countries have only destroyed their own satellites as space power demonstrations; destroying another country's satellite is considered an act of war.

Introduction to Information and Communication Technology (ICT)

- ICT is a major area comprising both communication and computing aspects.
- Key focal areas include advances in visible light communication, 5G, satellite-based Internet, artificial intelligence, blockchain, and underlying computing technologies.
- Communication and computing are closely interdependent; modern systems blend both for increased efficiency and functionality.

Fundamentals of Communication

Basic Components and Process

- Communication is the transfer of data between a transmitter and a receiver using an agreed protocol.
- Information is transmitted through a channel; both sender and receiver must understand the protocol (rules, language, or code).
- The process involves modifying a variable (like frequency or amplitude) in a systematic, meaningful way.

Real-World Analogy

Human speech uses sound waves with properties (frequency, amplitude) that the listener's brain processes and deciphers.

Importance of Protocol

Effective communication needs a pre-established agreement on the variables' interpretations (like language rules).

Introduction to Computing

Essential Features of a Computer

- Must possess input devices (keyboard, mouse) for data entry.
- Processing is central, carried out by chips or microprocessors running defined algorithms.
- Storage retains input or processed data.
- Output devices (monitors, printers) present processed information.

Binary System in Computing

- Computers use binary (0 and 1), aligning with the simplicity of representing two voltage states (low and high).
- Binary is foundational because transistors (core computing switches) can easily differentiate between two voltage levels.

Working with Number Systems

Decimal System

- Built on base 10, reflecting human counting (ten fingers).
- *Example:*The number 456.12 decomposed into units, tens, hundreds, and decimal fractions using powers of 10.

Binary Number Representation

- Uses only 0 and 1 (base 2); every number is a sequence of these digits.
- *Example:*1101 in binary equals 13 in decimal (8 + 4 + 0 + 1).

Expansion to Other Bases

- Counting and computing can be performed using bases larger than 2, but binary is optimal for electronic design.

Arithmetic in Binary

- Carrying in binary arithmetic is done by twos, compared to tens in the decimal system.

Transistors and Semiconductors

Role and Function of Transistors

- A transistor acts as an electronic switch controlled by voltage, representing binary states.
- Semiconductors allow the controlled flow of electrons, unlike conductors (always allow) or insulators (never allow).

Importance of Semiconductors

- Silicon and germanium are most common; synthetic types exist (gallium nitride, cadmium selenide).
- The semiconductor industry is pivotal for computing technology, as seen in global **chip wars** and recent investments.

Communication and Data Representation

Converting Text, Pictures, and Videos

- Text: Alphabets matched to binary strings through programming conventions.
- Images: Pixel grids, with each pixel represented in binary.
- Videos: Sequences of images, requiring increased storage and bandwidth.
- All forms of data are eventually reduced to binary form for processing and transmission.

Nature of Waves and Their Use in Communication

Types of Waves

- **Transverse waves:** Oscillation is perpendicular to the direction of propagation (e.g., light, ripples on water).
- **Longitudinal waves:** Oscillation is parallel to propagation (e.g., sound).

Wave Properties

Wave Property	Description	Independence
Frequency (f)	Number of oscillations per second; higher frequency = shorter wavelength	Interdependent with wavelength
Wavelength (λ)	Distance covered per wave cycle; λ = speed/frequency	Interdependent with frequency
Amplitude	Maximum displacement from the mean; determines energy/intensity of wave	Independent
Phase	Relative alignment of wave crests/troughs; distinguishes two otherwise identical waves	Independent

Speed of wave = Frequency × Wavelength

Intensity: Energy transmitted per unit time per unit area, linked to amplitude.

Interference

- Defined as the superposition of two or more waves at the same place and time.
- Types:
- *Constructive interference*: Amplitudes add, resulting in brighter/darker regions (as seen in Young's double-slit experiment).
- *Destructive interference*: Waves cancel out each other, causing darkness/no sound (noise cancellation headphones).

Diffraction

- Wave property where waves bend around obstacles or through slits, giving rise to interference patterns.

Nature of Light

Particle vs. Wave Debate

- Newton: Light as particles.
- Huygens: Light as waves, suggesting the existence of a medium (**ether**) for wave propagation.

Disproof of Ether

- The Michelson-Morley experiment failed to detect ether, showing light doesn't need a medium.

Maxwell’s Theory

- Demonstrated that light is an electromagnetic wave (oscillating electric and magnetic fields travel together).
- Electric fields arise from charged particles; changing electric fields produce magnetic fields, and vice versa.
- Electromagnetic waves (light) propagate perpendicular to both fields, even in a vacuum.

Electromagnetic Induction and Its Applications

Inductive Phenomena

- Changing a magnetic field induces an electric field and vice versa.
- Practical example: Moving a magnet through a wire loop produces an electric current.

Technological Applications

- *Wireless charging*: Uses electromagnetic induction, where changing magnetic fields induce current in a device without direct electrical contact.
- Proposed wireless charging for electric vehicles utilizes this principle.

Electro Magnetic Waves :-

-> Vibration of electric and magnetic field are perpendicular to each other and wave propagation is perpendicular to both electric and magnetic field.
-> Depending upon frequency and wavelength it can be divided into -
-> Gamma rays
-> X-Rays and so on

Electromagnetic Spectrum

Classification by Frequency and Wavelength

Type	Wavelength	Frequency	Uses/Notes
Gamma Rays	<0.01 nm	>10^19 Hz	Nuclear technology, medical imaging
X-Rays	0.01–10 nm	10^16–10^19 Hz	Medical diagnostics
Ultraviolet	10–400 nm	8x10^14–10^16 Hz	Sterilization, photolithography
Visible Light	380–700 nm	4x10^14–7x10^14 Hz	Human vision
Infrared	700 nm–1 mm	3x10^11–4x10^14 Hz	TV remotes, thermal imaging
Microwaves	1 mm–30 cm	1x10^9–3x10^11 Hz	Communication, cooking
Radio Waves	30 cm–>1 km	<1x10^9 Hz	Broadcasting, communication

- Visible light is detectable by the human eye; other types require special instruments.
- The energy of electromagnetic waves is proportional to frequency ($E = h \cdot f$; h is Planck's constant).
- High-frequency waves (gamma, X-ray, UV) are ionizing and potentially hazardous.
- Modern communication systems use radio waves and microwaves due to ease and efficiency of generation, modulation, and wireless propagation.
- *C*denotes speed of light (3 x 10^8 m/s): $c = f \cdot \lambda$.

Modern Data Transmission

Wired and Wireless Media

- Electromagnetic waves (microwave/radio) allow for wireless data communication.
- Wired communication, now often using optical fiber cables, transmits data as light pulses, increasing speed and reducing losses.

Practical Implementation

- Optical fiber cables use total internal reflection, enabling light to travel vast distances with negligible attenuation.
- Physical layering in cables (core, cladding) is designed for efficient light confinement.

Communication Technology: Key Concepts

Basic Terms associated with communication technology -

Transducer

- A device converting one form of energy to another, such as microphones converting sound waves to electrical signals.

Signal

- The representation of information for transmission, which can be analog (continuous) or digital (binary/discrete).

Noise

- Any unwanted signal that disrupts message transmission.
- Originates from within or external to the communication system.
- Good systems ensure the signal-to-noise ratio remains high.

Attenuation and Amplification

- **Attenuation:** Loss of signal strength as it traverses a medium.
- **Amplification:** Boosting signal strength using a power source to counteract attenuation.

Repeaters

- Devices acting as both receivers and transmitters to extend the range by amplifying and retransmitting signals over long distances.
- Modern repeaters include mobile towers and satellites.

Bandwidth

- *Definition:*Range of frequencies a medium can carry; determines data-carrying capacity.
- The quality and type of medium (optical fiber, copper cable) directly impact available bandwidth.
- Data types require varying bandwidth: text < images < videos.

Modulation

- *Process:*Encodes a low-frequency message signal onto a high-frequency carrier wave.
- **Types:**
- **Amplitude Modulation (AM):** Varies amplitude according to the message signal.
- **Frequency Modulation (FM):** Alters carrier frequency to transmit information.
- **Phase Modulation:** Changes phase to represent data.
- *Purpose:*Increases range, enables multiple signals on a network, allows for suitable antenna sizes, and reduces interference.

Analog vs. Digital Signals

Analog Signals	Digital Signals
Continuous, variable representation of information	Discrete, represented in binary (0's and 1's)
Susceptible to noise and distortions	Noise-resistant, compatible with modern digital systems
*Example:*Traditional audio signals	*Example:*Computer data, modern voice communication

Optical Fiber Cables and Total Internal Reflection

Structure and Principle

- Composed of a core and cladding with different refractive indices.
- Uses the phenomenon of total internal reflection: When light travels from a denser to a rarer medium at specific angles, it reflects internally without loss.

Advantages

- Practically no signal absorption; enables data to travel over long distances.
- Capable of handling vast amounts of data due to minimal attenuation.

Real-World Analogy and Applications

- A mirage (inverted image on a hot road) results from total internal reflection in atmospheric layers, analogous to how optical fibers work.

Internet and Mobile Communication: Physical and Logical Flow

Mobile Communication

Process Overview

- User’s voice is captured by the microphone and converted into binary data (zeros and ones).
- Data is transmitted as electromagnetic waves from the phone to a cell tower.
- Cell towers process signals and forward them via optical fibers to destination towers.
- Destination towers send electromagnetic waves to the recipient phone, reconstructing the original signal.

Cellular Structure

- Geographic areas divided into hexagonal cells, each with a tower and specific frequency slots.
- Towers are interconnected by optical fiber cables for high-speed, low-loss transmission.

Internet Communication

Data Routing and Addressing

- All Internet devices have unique IP addresses.
- Domain names (e.g., youtube.com) link to IP addresses via DNS servers for ease of use.
- Major websites may be hosted on dedicated data center infrastructure.

Data Transfer Pathway

- User requests sent via cellular data or Wi-Fi eventually link to a vast optical fiber network.
- Data packets traverse complex global optical cable networks, including oceanic and terrestrial routes.
- Signals are transformed into light in optical fibers, then converted back into electrical signals for routers and end devices.
- Routers and switches direct data to the correct IP-based destination, employing sophisticated engineering.

Frequency Bands for Daily Technologies

- Wi-Fi operates at 2.4, 5, and 6 GHz frequency bands.
- Bluetooth also uses the 2.4 GHz frequency.
- Optical fiber cables provide the backbone for global Internet connectivity, linking every household to the wider web.

Topic to be Discussed in the Next Class

- Overview and key components of **5G technology**, including enabling sub-technologies
- Exploration of **visible light communication (Li-Fi)** as an alternative to radio-based methods