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MPPSC

State Civil Services

Prelims

Madhya Pradesh Public Service Commission

Volume - 6

Science Technology & ICT

SIERRA INNOVATIONS

Table of Content

1 CHAPTER Basics of Everyday Science

From the moment we wake up to the time we retire, scientific principles and technological innovations shape our experiences. From the simple act of boiling water to the intricate workings of our smartphones, science permeates every aspect of modern society. By understanding the scientific underpinnings of everyday phenomena, we can gain a deeper appreciation for the world around us and make informed decisions about our lives.

Everyday Chemistry

Important Items and their chemical names and formulas

Common Name	Chemical Name	Chemical Formula
Table Salt	Sodium Chloride	$NaCl$
Baking Soda	Sodium Bicarbonate	$NaHCO_3$
Vinegar	Acetic Acid	CH_3COOH
Bleaching Powder	Calcium Hypochlorite	$Ca(OCl)_2$
Epsom Salt	Magnesium Sulfate	$MgSO_4{\cdot}7H_2O$
Gypsum	Calcium Sulfate	$CaSO_4{\cdot}2H_2O$
Ammonia	Ammonium Hydroxide	NH_4OH
Plaster of Paris	Calcium Sulfate Hemihydrate	$CaSO_4{\cdot}½H_2O$
Laughing Gas	Nitrous Oxide	N_2O
Caustic Soda	Sodium Hydroxide	$NaOH$
Washing Soda	Sodium Carbonate	Na_2CO_3

Drugs

Drugs are generally chemicals of very low molecular mass, which produce clinically beneficial effects by interacting with target bio-molecules in various biological processes in the body.

Type of Drug	Description	Example
Analgesics	Relieve pain	Aspirin, Paracetamol, ibuprofen, diclofenac.
Narcotic Analgesics (Opioids)	Relieve severe pain	Oxycodone, Morphine, Codeine, Heroin etc.

Tranquilisers	Reduce anxiety and tension Have a hypnotic effect, so used in sleeping pills.	Maprobamate, Equanil, Chlordiaze-poxide, etc.
Antibiotics (In 1929, Alexander Fleming discovered antibiotics from fungus Penicillium notatum)	Drugs to fight bacteria	Penicillin, Ofloxacin, amino glycosides, Chloramphenicol, Erythromycin, Tetracycline, etc.
Antiseptics	Drugs to reduce the growth of harmful microorganisms without affecting living tissues. They are applied to living tissues such as cuts or wounds	Bithionol (mixed in soaps), Tincture of iodine (2-3% solution of iodine in a mixture of alcohol and water), Dettol (Mix of chloroxylenol and terpineol), Dilute aqueous solution of Boric Acid, etc.
Antacids	Drugs to neutralize stomach acid, relieves heartburn.	Milk of magnesia (Magnesium hydroxide), Magnesium carbonate, Magnesium trisilicate, Aluminium phosphate, etc.
Antihistamines	Drugs to reduce/check the release of histamines and control allergic reactions.	Cetirizine, levocetirizine, desloratadine, brompheniramine, Terfenadine.
Antifertility Drug	Drugs used for preventing fertilization. Mix of estrogen and progesterone derivatives.	Norethindrone (Novestrol), Ethinylestradiol (estrogen derivative).

Chemicals in Food

I. Preservatives

Chemicals added to the food materials to prevent their spoilage and retain their nutritive value for a longer period.

Preservative	Uses
Sodium benzoate	Used in fruit juice, gem, jelly. Etc.
Sorbate	Used for preservation of milk products.
Potassium metabisulphite ($K_2S_2O_5$)	Used in lemon juice, pickles, wine, cedar, beer etc.
Parabens	Used for preservation of soft drinks, ketchup, etc.
Propionate	Used for the preservation of bread, cakes and biscuits.

2. Artificial Sweeteners

Chemicals added in food to give a sweetening effect and change its odour and flavour.

Important Artificial Sweeteners

Artificial Sweeteners	Description
Saccharin	600 times sweeter than sucrose Remains unmetabolized in human body thus, used by diabetic patients.
Aspartame	Most commonly used artificial sweetener. Used in cold foods and soft drinks as it is unstable at cooking temperature.
Alitame	High potency sweetener. More stable than Aspartame but difficult to control its sweetness.
Sucralose	Appears and tastes like sugar. Stable at cooking temperature and does not provide calories.

3. Antioxidants

Chemicals added to prevent spoilage of foods containing substances like unsaturated oils, fats, etc. because of the exposure to the atmospheric oxygen / oxidation. Example: Butylated hydroxy anisole (BHA) and Butylated hydroxy toluene (BHT).

4. Food Colour

Chemicals used in food to impart colour to make it more visually appealing. Example: Tartrazine (Yellow colour), 1,4-di-p-toluidino anthraquinone (PTA) (Green colour).

Soaps and Detergents

- Soaps are the Sodium or Potassium salts of higher fatty acids like stearic acid, palmitic acid, oleic acid, etc.
- Detergents are obtained from the derivatives of long chain hydrocarbons and sulphuric acid. They are better cleaning agents as they do not form insoluble calcium and magnesium salts with hard water.
- Soaps are salts of weak acids and strong bases. So, their solutions are more alkaline in nature while detergents are salts of strong acids and strong bases thus, form neutral solutions.

Important Fuel Gases

Gas	Main Components	Secondary Components
CNG (Compressed Natural Gas)	Methane	Ethane, Propane, Butane, Nitrogen
LPG (Liquefied Petroleum Gas)	Propane, Butane	Ethane, Pentane, Propylene, Butylene
Biogas	Methane, Carbon Dioxide	Hydrogen, Nitrogen, Hydrogen Sulfide, Oxygen
Town Gas (Coal Gas)	Hydrogen, Methane, Carbon Monoxide	Carbon Dioxide, Nitrogen
Natural Gas	Methane	Ethane, Propane, Butane, Carbon Dioxide, Nitrogen

Physics in Everyday Life

Important Units

Quantity	Unit Name	Symbol
Length	Meter	M
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere	A
Temperature	Kelvin	K
Luminous Intensity	Candela	cd
Amount of Substance	Mole	mol
Frequency	Hertz	Hz
Force	Newton	N
Pressure	Pascal	Pa
Energy	Joule	J
Power	Watt	W
Electric Charge	Coulomb	C
Voltage	Volt	V
Electric Resistance	Ohm	Ω
Turbidity in Liquid	NTU (Nephelometric Turbidity Unit)	NTU

Everyday Equipments and Physics behind them

Equipment	Physical Phenomenon
Stethoscope	Reflection of sound
Remote Control	Infrared Radiation
Microwave oven	Electromagnetic Waves
Refrigerator	Thermodynamics
Washing Machine	Centrifugal Force
Electric Fan	Electromagnetic induction
Light Bulb	Incandescence
Smartphone	Radio Waves, Touch sensitivity
Television	Electromagnetic Waves
Air Conditioner	Refrigeration Cycle
Electric Kettle	Electrical Resistance Heating
Camera	Optics (Lens Focusing)
Speaker	Electromagnetic Induction
Hair Dryer	Convection Heating
Computer	Semiconductor Electronics
Photovoltaic cell	Solar energy (Photoelectric Effect)

Application of Physics in various fields of daily life

I. In the Field of Transportation

- Newton's Laws of Motion: These laws govern the motion of vehicles, from acceleration and deceleration to the forces acting on them during collisions.
- Friction: Understanding friction is essential for designing tires, brakes, and other components that interact with surfaces.
- Aerodynamics: The study of air flow around objects, such as cars and airplanes, helps in designing vehicles with improved fuel efficiency and stability.
- Fluid Mechanics: This field is crucial for designing ships and submarines, as well as understanding the behaviour of fluids in engines and hydraulic systems.
- Thermodynamics: The principles of thermodynamics are applied in the design of engines, which convert thermal energy into mechanical energy.

- *Electromagnetism: Electric motors and generators, which power many modern vehicles, are based on electromagnetic principles.*
- *Materials Science: The development of strong, lightweight, and durable materials is essential for building safe and efficient vehicles.*

2. In the Field of Aviation

- *Newton's Laws of Motion*
  - ✓ *First Law (Also known as law of inertia): An object at rest stays at rest, and an object in motion stays in motion unless acted upon by an external force.*
  - ✓ *Second Law: "The rate of change of momentum of any object is directly proportional to the force applied on the object in the direction of the force. "Force equals mass times acceleration (F = ma).*
  - ✓ *Third Law: For every action, there is an equal and opposite reaction.*
- *Bernoulli's Principle: This principle explains how shape of an airplane generates lift.*
- *Archimedes principle- Amount of water displaced by an object is equal to the volume of the floating object.*
- *Aerodynamics: The study of air in motion and its interaction with solid objects.*
- *Fluid Dynamics: The study of fluid flow, which is essential for understanding the behaviour of aircraft in the atmosphere.*

3. In the Field of Space Science:

- *Newton's Laws of Motion: These laws are fundamental to understanding the motion of celestial bodies and spacecraft.*
- *Kepler's Laws of Planetary Motion: Describe the motion of planets around the Sun.*
  - ✓ ***1st law -** planets move in elliptical orbits with the Sun as a focus*
  - ✓ ***2nd law**- a planet covers the same area of space in the same amount of time no matter where it is in its orbit*
  - ✓ ***3rd law**- a planet's orbital period is proportional to the size of its orbit (its semi-major axis).*
- *Celestial Mechanics: The study of the motion of celestial bodies under the influence of gravity.*
- *Electromagnetism: Used in various space technologies, such as satellite communication and plasma propulsion.*
- *Thermodynamics: Essential for understanding the behaviour of rocket engines and spacecraft propulsion systems.*
- *Quantum Mechanics: Used in the development of advanced materials and technologies for space exploration.*

4. In the Field of Technology and Computer Science

- *Mechanics: Newton's laws of motion are fundamental to understanding the motion of objects, from simple machines to complex robotic systems. Concepts like force, momentum, and energy are essential in fields like robotics, aerospace engineering, and virtual reality.*
- *Electromagnetism: Electromagnetic principles are used in devices like motors, generators, and transformers. The understanding of electromagnetic waves is crucial for wireless communication and data transmission. Electrostatics and electrodynamics are fundamental to the design of electronic circuits.*
- *Optics: The principles of optics are applied in the design of lenses, mirrors, and optical fibres. Laser technology, used in various applications from surgery to telecommunications, is based on optical principles.*
- *Thermodynamics: The laws of thermodynamics govern the efficiency of engines, refrigerators, and other thermal devices. Heat transfer and energy conservation are crucial concepts in fields like materials science and energy engineering.*
- *Quantum Mechanics: Quantum mechanics explains the behaviour of matter and energy at the atomic and subatomic level. It's essential for understanding the workings of transistors, lasers, and quantum computers.*
- *Relativity: Einstein's theory of relativity has applications in GPS systems, satellite communication, and high-energy physics.*
- *Electromagnetism and Quantum Mechanics: The combination of these two fields is crucial for understanding the behaviour of semiconductors, which are the building blocks of modern electronics.*

5. In the Field of Energy

- *Heat Transfer: Understanding heat transfer mechanisms like conduction, convection, and radiation is crucial for designing efficient thermal energy systems.*
- *Thermodynamic Laws: The laws of thermodynamics, particularly the first and second laws, govern energy conversion and efficiency in various energy systems.*
- *First Law of Thermodynamics- Energy cannot be created or destroyed, but it can be converted from one form to another. This is also known as the law of conservation of energy.*
- *Second Law of Thermodynamics- Heat flows from higher temperature to lower temperature bodies, unless an external factor is present. This means that the entropy of a closed system increases over time.*
- *Third Law of Thermodynamics- At absolute zero temperature, the entropy of a perfectly crystalline solid is zero.*

- *Zeroth Law of Thermodynamics- If two systems are in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.*
- *Electromagnetic Induction: This principle is fundamental to the operation of generators, transformers, and electric motors.*
- *Electromagnetic Radiation: The study of electromagnetic waves, including visible light, infrared, and ultraviolet radiation, is essential for solar energy and other renewable energy sources.*
- *Quantum Physics: This field explains the behavior of matter and energy at the atomic and subatomic level, which is crucial for understanding nuclear energy and the development of advanced materials for energy storage and conversion.*

6. In the Field of Medicine

- *Biomechanics: The study of the mechanical principles of living organisms.*
- *Orthopedics: The use of mechanical devices like prosthetics and braces.*
- *Medical Imaging: Techniques like X-rays, ultrasound, and MRI rely on principles of wave propagation and electromagnetic radiation.*
- *Ophthalmology: The diagnosis and treatment of eye conditions using optical instruments.*
- *Laser Surgery: The use of lasers for precise surgical procedures.*
- *Electrocardiography (ECG): Measures electrical activity of the heart.*
- *Electroencephalography (EEG): Measures electrical activity of the brain.*
- *Magnetic Resonance Imaging (MRI): Uses magnetic fields and radio waves to create detailed images of the body.*
- *Nuclear Medicine: Uses radioactive isotopes for diagnosis and treatment of diseases.*
- *Radiation Therapy: Uses ionizing radiation to kill cancer cells.*
- *Medical Thermodynamics: Studies energy transfer and temperature changes in biological systems.*

7. In the field of Defence and Nuclear Science

- *Ballistics: The study of projectile motion is crucial for designing artillery and missile systems.*
- *Fluid Dynamics: Understanding fluid flow is essential for designing aerodynamics of aircraft and submarines.*
- *Radar (Radio Detection and Ranging): Using electromagnetic waves to detect and track objects.*
- *Sonar (Sound Navigation and Ranging): Using sound waves to detect objects underwater.*
- *Lasers: Used in various applications, including rangefinders, target designation, and directed-energy weapons.*

- *Nuclear Fission: The process of splitting atoms to release energy, used in nuclear power plants and nuclear weapons.*
- *Nuclear Fusion: The process of combining atoms to release energy, as in the sun and experimental fusion reactors.*
- *Radioactivity: The spontaneous emission of radiation from unstable atomic nuclei, used in nuclear weapons and medical applications.*
- *Quantum Cryptography: Using quantum mechanics for secure communication.*
- *Quantum Computing: Developing powerful computers that can solve complex problems.*
- *Optical Camouflage: Using optical illusions to conceal objects.*
- *Infrared and Thermal Imaging: Detecting objects based on their heat signature.*
- *Electronics: Designing and building electronic systems for military and nuclear applications.*

8. In the field of Entertainment

- *Lens Design: The principles of optics are used to design lenses for cameras, projectors, and virtual reality devices.*
- *Light and Colour: The understanding of light and colour is essential for creating visual effects, lighting design, and cinematography.*
- *Sound Engineering: The principles of acoustics are used to design sound systems, recording studios, and concert halls.*
- *Sound Effects: Sound engineers use their understanding of sound waves to create realistic sound effects.*
- *Animation: The laws of motion and forces are applied to create realistic and engaging animations.*

9. In the field of Sports

- *Energy Conservation: Kinetic energy is converted to potential energy during jumps and throws. Energy is transferred between objects in collisions, like in a tackle or a tennis hit.*
- *Projectile Motion: Athletes use principles of projectile motion to optimize the trajectory of objects like javelins, shot puts, and footballs.*
- *Friction: Athletes use friction to gain traction and stability, but also reduce friction to improve sliding and gliding.*
- *Fluid Dynamics: Swimmers and cyclists use principles of fluid dynamics to reduce drag and improve performance.*
- *Levers and Pulleys: Athletes use simple machines like levers and pulleys to gain mechanical advantage in lifting weights or performing exercises.*

Electromagnetic Spectrum

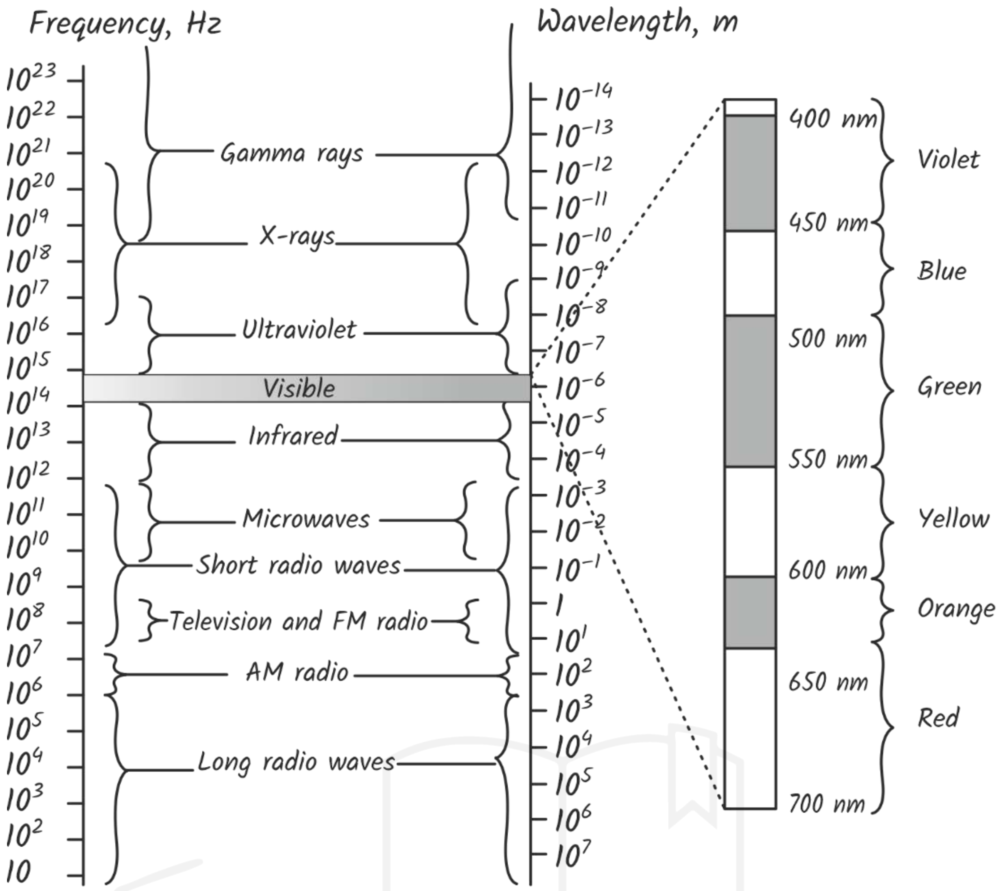


Figure: The electromagnetic spectrum, with common names for various part of it. The various regions do not have sharply defined boundaries.

Radio Waves	Used in radio (AM and FM bands) and television communications systems. Cellular phones use them to transmit voice communication in UHF band.
Microwaves	Suitable for radar systems used for aircraft navigation, speed guns used to time fast balls, tennis-serves and automobiles. Microwave oven use selective frequency of microwaves to match the resonant frequency of water molecules to efficiently transfer wave energy to kinetic energy of molecules. It raises the temperature of food containing water.
Infrared Waves	Infrared lamps used in physical therapy Maintains earth's average temperature through Greenhouse effect Infrared detectors are used in Earth Satellites Semiconductor light emitting diodes, emitting infrared lights are used in TV/AC remotes, video recorders and hi-fi systems. Snakes can detect infrared waves
Visible rays	Helps us see different objects and different colours

Ultraviolet rays	Sun is an important source of UV-rays and most of it gets absorbed by the Ozone Layer in the atmosphere Exposure to UV radiations induces production of more melanin, causing skin tanning (Ordinary glass absorbs UV-rays thus, protect from tanning) UV is produced by welding arcs thus; welders wear special glass goggles or face masks for protection Used in LASIK eye surgery UV lamps used to kill germs in water purifiers
X-rays	Used as a diagnostic tool in medicine and treatment of cancer
Gamma rays	Used in medicine to destroy cancer cells

Utility of electro-magnetic waves based on their frequency

Frequency Band	Frequency Range	Mode of Travel	Examples
Low Frequency (LF)	30 KHz-300 KHz	Ground Waves	Am Radio
Medium Frequency (MF)	300 KHz-3 MHz	Ground and sky Waves	Am radio broadcasting
High frequency (Hf)	3 MHz-30 MHz	Sky Waves	Shortwave radio
Very high Frequency (VHF)	30 MHz-300s MHz	Space waves	Fm radio, television broadcasts
Ultra High Frequency (UHF)	300 Mhz-3 GHz	Space waves	Television Broadcasts, Mobile phones
Super High Frequency (SHF)	3 GHz-30 GHz	Space waves	Satellite communications, radar
Extremely High Frequency (EHF)	30 GHz-300 GHz	Space waves	Advanced radar Systems, experimental communications

Gravitation

Universal law of gravitation

The force of attraction between any two particles in the universe is directly proportional to the product of the masses and inversely proportional to the square of the distance between them. If the two masses m_1 and m_2 are at a distance of d. The force of attraction between them is-

$F = G(m_1m_2/d^2)$

G is the universal gravitational constant = 6.673×10^{-11} Nm^2/kg^2

Acceleration Due to Gravity

The acceleration due to gravity is the rate of increase of velocity of a body falling freely towards the earth. It does not depend on the shape, size and mass of the object. It is denoted by the letter g.

Escape Velocity

The minimum velocity of projection of a body for which it will escape the gravitational attraction of earth is known as escape velocity. Escape velocity of earth (v_e)= 11.2 km/s

Weightlessness

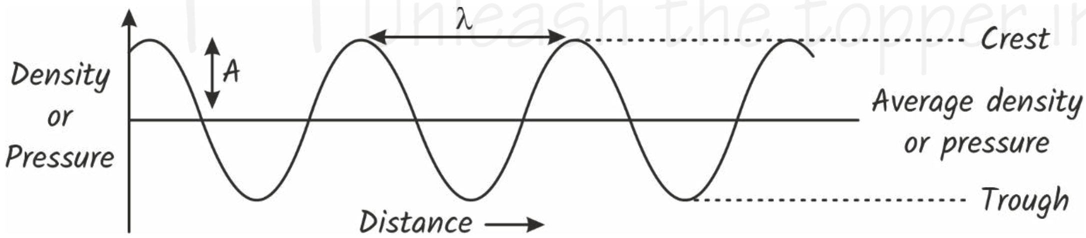
Weightlessness is a term used to describe the sensation of a complete or near-complete absence of weight. The weight of the body is due to the reactionary force applied to the body. If, for a certain condition, the reactionary force applied becomes zero, we will then feel as our weight is zero. This is called weightlessness. If the rope of a descending lift is broken then the people inside will feel weightless. Also felt by the people in an artificial satellite.

Sound

Sound is a form of energy which produces a sensation of hearing in our ears. Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation. It cannot travel through vacuum.

Important terms related to sound-

1. **Wavelength (Lemda)**-*The distance between two consecutive compressions (C) or two consecutive rarefactions (R).*
2. **Frequency**-*The number of oscillations per unit time is the frequency of the sound wave*



3. **Sonic boom -** *When a sound, producing source(Bullets, Jets) moves with a speed higher than that of sound, it produces shock waves in air. These shock waves carry a large amount of energy. The air pressure variation associated with this type of shock waves produces a very sharp and loud sound called the "sonic boom". The shock waves produced by a supersonic aircraft have enough energy to shatter glass and even damage buildings.*
4. **Reverberation-** *The repeated reflection that results in the persistence of sound is called reverberation. Stethoscope works on this principle.*

5. **Refraction of Sound Waves -** *When a sound wave bends due to changes in its speed as it passes through a medium. The density of a gas decreases with the rise in temperature, inversely proportional.*
6. **Diffraction of Sound Waves -** *Ability of the sound waves to bend around obstacles is known as diffraction. For example, sound waves diffract around walls and door openings to carry sound from one room to another.*

Miscellaneous-

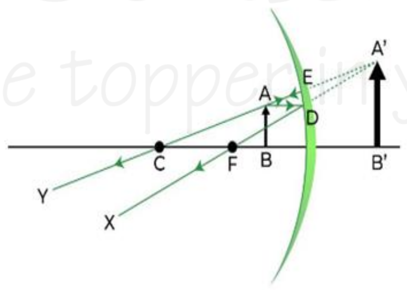
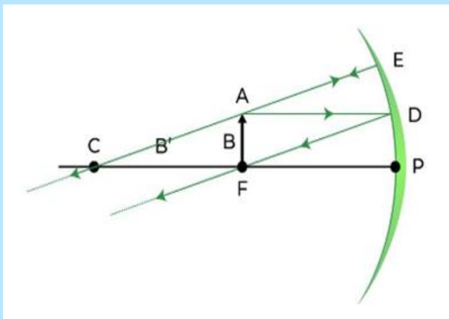
a. **Dispersion** *of light occurs when light passes through a prism.*

b. **Scattering** *of light is the phenomenon in which light rays deviate from their original path upon striking an obstacle like dust, gas molecules, or water vapours. Example blue colour of sky.*

c. **Tyndall effect** *- Scattering of light by particles in a colloid or suspension, which makes the light beam visible. Example-Smoke or dust in a room, making a light beam entering a window visible.*

Optics

Image formation by Concave Mirror

Position of Object	Position of Image	Image Size	Nature of Image	Ray Diagram
Within focus (Between P and F)	Behind the mirror	Enlarged	Virtual and erect	
At focus	At infinity	Highly Enlarged	Real and Inverted	

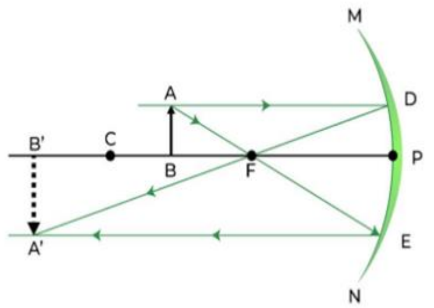
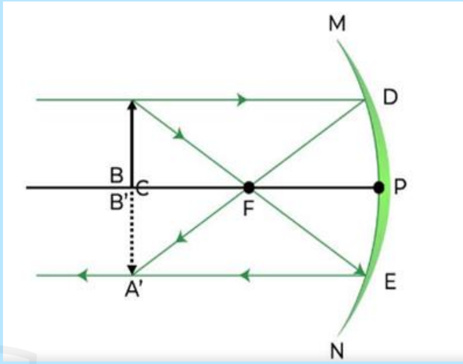
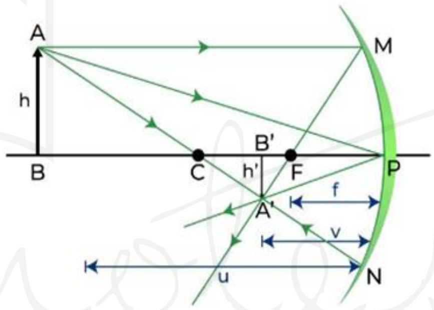
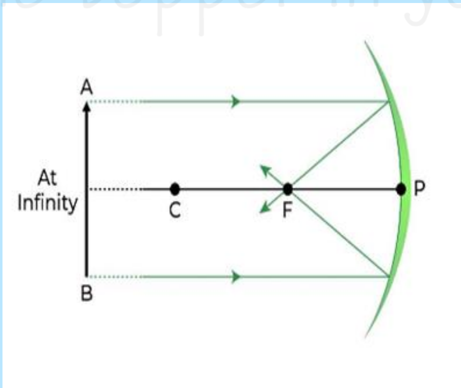
Between F and C	Beyond C	Enlarged	Real and Inverted	
At C	At C	Equal to object	Real and Inverted	
Between Infinity and C	Between F and C	Diminished	Real and Inverted	
At Infinity	At focus (F)	Highly Diminished	Real and Inverted	

Image formed by Convex Mirror

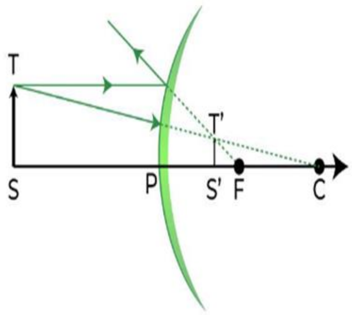
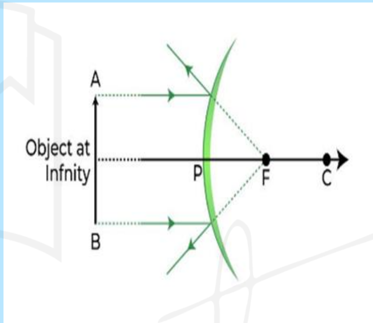
Position of Object	Position of Image	Image of Size	Nature of Image	Ray Diagram
Anywhere between pole P and Infinity	Behind the mirror between P and F	Diminished	Virtual and erect	
At infinity	Behind the mirror at Focus (F)	Highly Diminished	Virtual and erect	

Image formation by Concave Lens

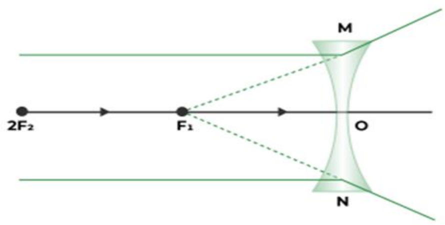
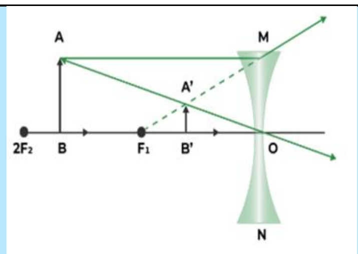
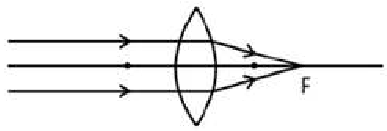
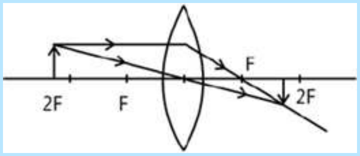
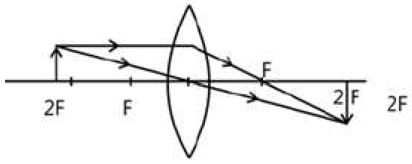
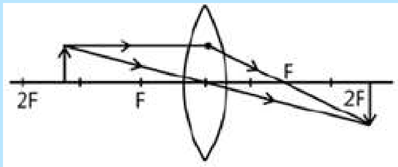
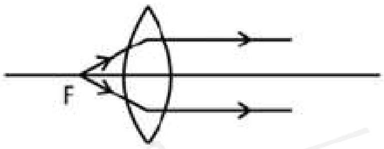
Object Position	Image Position	Nature and Size of Image	Ray Diagram
At Infinity	At Focus (F)	Highly diminished, Virtual, Upright	
finite distance	Between Focus (F) and Optical Centre	Diminished, Virtual Upright	

Image formation by Convex Lens

Object Position	Image Position	Nature of the Image	Ray Diagram
Infinity	On Focus F2	Real and Inverted, Highly Diminished	
Beyond 2F1	Between F1 and F2	Real and Inverted, Diminished	
At 2F1	At 2F2	Real and Inverted, of same size	
Between F1 and 2F1	Beyond 2F2	Real and Inverted, enlarged	
At Focus F1	At infinity	Real and Inverted	
Between F1 and Optical Centre O	On the same side of the lens as the object	Real and Inverted, enlarges