

UNIT ONE

Application of Physics in Other Fields

What is science?

Science is the collection of different types of scientific fields, or disciplines.

The general realm of science is often divided into the life sciences and the physical sciences. The life sciences include the various subfields of biology and the health related disciplines that deal with living organisms. The physical sciences deal with the behavior of matter in both living and nonliving systems. In addition to physics, the physical sciences include chemistry, geology, astronomy, oceanography, and meteorology (the study of weather). Physics underlies all of them. Physics is also generally regarded as the most quantitative of the sciences.

Physics and Other Sciences

How is physics defined?

Physics can be defined as the study of the basic nature of matter and the interactions that govern its behavior. It is the most fundamental of the sciences. The principles and theories of physics can be used to explain the fundamental interactions involved in biology, chemistry, astronomy, geology and other sciences at the atomic or molecular level.

The Major Subfields of Physics

Mechanics:- The study of forces and motion.

Thermodynamics:- The study of temperature, heat, and energy.

Electricity and Magnetism:- The study of electric and magnetic forces and electric current.

Optics:- The study of light.

Atomic Physics:- The study of the structure and behavior of atoms.

Nuclear Physics:- The study of the nucleus of the atom.

Particle Physics:- The study of subatomic particles (quarks, etc.).

Condensed-Matter Physics:- The study of the properties of matter in the solid and liquid states.

Relation of Physics with chemistry

Physics study how matter interacts but chemistry study how matter is made.

Physics and chemistry may overlap when the system under study involves matter composed of electrons and nuclei which are made of protons and neutrons.

Both physics and chemistry are concerned with matter and its interaction with energy. The physics of energy related to heat tells chemists whether a particular reaction is energetically possible in the direction in which it is written, and it gives the composition of the reaction system at equilibrium.

Spectroscopy is the study of the interaction between matter and electromagnetic radiation as a function of the wavelength or frequency of the radiation.

What physics concept is applied in separation of dissolved salt from water by evaporation method?

Answer: the physics concept applied here was energy, the form of energy is heat energy.

Relation of physics and biology

Physics law	Its application in biology
Newton's law	✓ How different animals and their body parts move. ✓ muscle movements and physical behavior of bones, lungs and the heart ✓ equilibrium of the body
Fluids law ➤ Viscosity ➤ Equation of continuity ➤ Turbulent flow	To in understanding the circulation of blood and blood pressure in the multicellular organisms.
Pascal's principles	For Soft-bodied animals body motion that lack a firm utilize such as earthworm and sea anemone

Dear students!

Define this term in physics

- I. Viscosity
- II. Equation of continuity
- III. Turbulent flow

How a blood moves against gravity from the feet to the heart or from the heart to the brain when a person stands erect?

Answer: we know blood moves in the veins. Most veins must move blood against the pull of gravity.

Subfields of physics	Its application in biology
Physics of sound wave  Sound is a mechanical wave	When the vocal cords come together and then vibrate as air passes through them during exhalation of air from the lungs. This vibration produces the sound wave for your voice.
Physics of electricity and biology	Electrical phenomena in living organisms are in living organisms are found in the nervous system of animals and Human being. When a neuron receives an appropriate stimulus, it produces electrical pulses that are propagated along its cable like structure.
Optical Physics	In photosynthesis for a plants Animals have evolved light sensitive organs like eye.

Relation of Physics and Astronomy

Astronomy is the study of everything in the universe beyond earth's atmosphere that includes object we can see with our naked eyes, like the sun the moon, the planets and the stars . It also includes object we can only see with telescope or other instruments, like faraway galaxies and tiny particles. This concept is studied sub-physics branch called astrophysics.

Newton's laws of Motion and Astronomy

- ✓ Newton's reformation of Kepler's third law is one of the most powerful concepts in astronomy.
- ✓ To describe the motion of astronomical objects around an orbit.
- ✓ Mass of astronomical objects
- ✓ When the sun pulls on planet with the force of gravity, the planet pulls on the sun with a force of equal magnitude this is newton's third law application in astronomy.

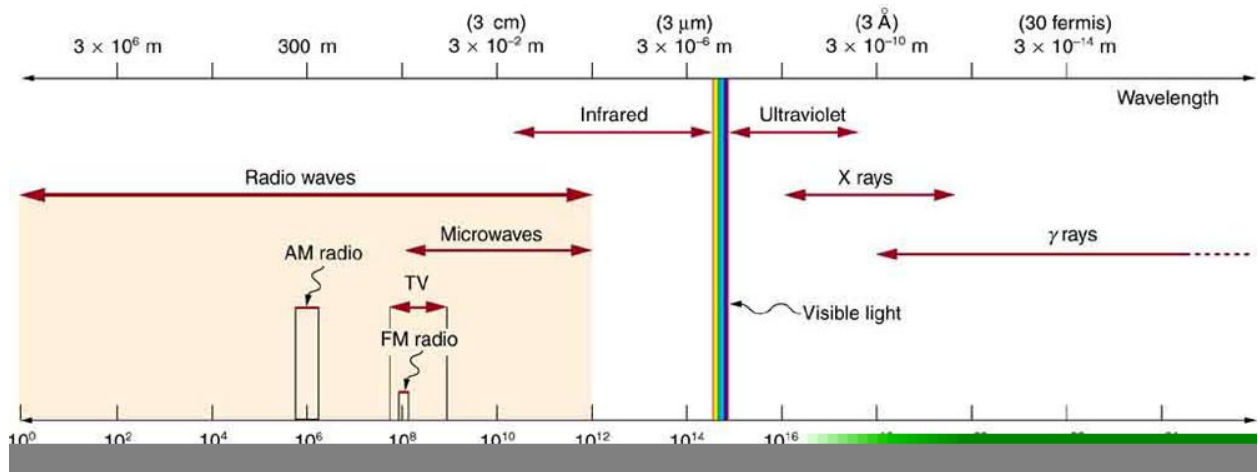
Physics of Electromagnetic wave and astronomy

Astronomers use telescopes that detect different parts of the electromagnetic spectrum.



This Figure show Detection of different components of electromagnetic radiation by telescope/

The electromagnetic spectrum, showing the major categories of electromagnetic waves. The range of frequency and wavelength is remarkable.



Note:

- High- frequency electromagnetic waves are more able to penetrate than low frequency waves.
- High- frequency electromagnetic can carry more information per unit time than low frequency waves.
- The shorter the wave wavelength of any electromagnetic waves probing a material the smaller the detail it is possible to resolve.

Astronomers use light to measure distance of astronomical objects. Measuring the apparent brightness of an object gives its distance if we know its true brightness.

$$\text{apparent brightness} \propto \frac{\text{true brightness}}{\text{distance}^2}$$

This is known as the inverse square law of apparent brightness. The true brightness is also known as the luminosity.

Luminosity is an absolute measure of radiated electromagnetic power (light). Astronomers also used light year as an alternate astronomical distance measuring unit. A light year is the distance that light travels in one year.

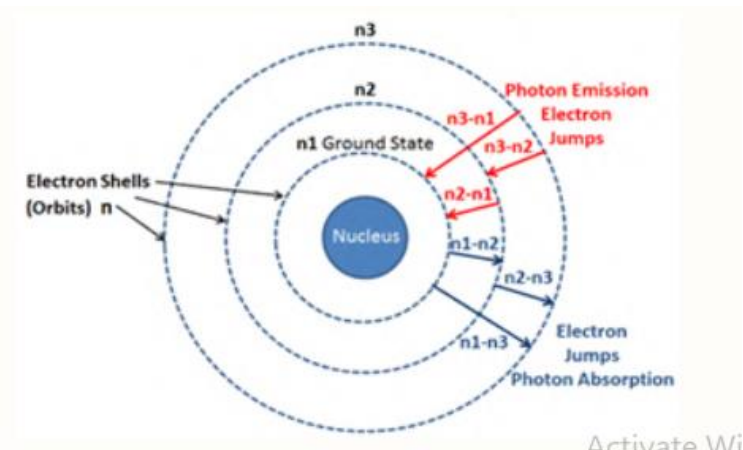
Physics of atoms and Astronomy

Atomic physics the scientific study of the structure of the atom, its energy states and its interactions with other particles and with electric and magnetic fields. The physics that explains emission and absorption of radiation is closely related to the structure and energies of individual atoms that form the astronomical objects.

- Photon is emitted if electrons of atoms jump from higher to a lower atomic orbit .
- Photon is absorbed if electron jumps from lower electron orbit to higher electron orbit.

Note: Photon is elementary particle with no charge, no resting mass and travels at the speed of light.

This figure shows the Bohr atomic structure and electron transitions



Relation of Physics with Geology

Geology is a branch of Earth science that studies the solid and liquid matter that makes up Earth and the different processes on these matters. In geology, physics concepts like force, optics, atomic structure, electromagnetic radiation, heat and heat flow, electricity and magnetism, stress and strain, waves including sound wave and fluid flow are used to study the following properties of rocks and minerals:

✚ electrical properties

✚ density

✚ magnetization

 radioactivity

 elasticity and more.

Physics and Engineering

It is difficult to solve many of the complex engineering problems without understanding the concepts of physics.

Sub-Engineering branch	The required physics concepts
Civil Engineering It concerns designing and building skyscrapers, roads, bridges, dams, and railways.	○ Forces ○ fluid pressure ○ gravity and others.
Mechanical Engineering engines, manufacturing equipment, vehicles, aircraft, watercraft, engines, robotics, weapons, cars, hydraulics and others	mechanics, dynamics, thermodynamics, forces, stresses and aerodynamics
Electrical engineering Electrical engineering involves designing electrical circuits including motors, electronic appliances, optical fiber networks, computers, and communication links.	❖ electromagnetism, ❖ mechanics, ❖ Thermodynamics and others.
Chemical Engineering It involves the production of products through chemical processes. This includes designing equipment, systems, and processes for refining raw materials and for mixing, compounding, and processing chemicals.	✓ Molecular physics ✓ concept of energy changes ✓ deriving from thermodynamic considerations

Technology Generating New Physics

There is a fundamental connection between physics and technology. Without knowledge of physics, most of the technologies we know well today could not be available for the society.

The contributions of technology in the development of physics are:-

Technology has played an enormous role to reach atomic scales as well as huge and distant astronomical objects to create physics there.

- ✓ Technology produced instruments, like particle accelerator, electron microscopes, different types of X-ray machines, highly helped the development of physics in the atomic scales.
- ✓ Space technology has opened to do physics in space and astronomical objects. Computer-based Technology helps us to analyze huge data within short period of time.
- ✓ Analyzing data is the core process in physics. Knowledge of physics can be generated by analyzing data.

Medical physics

Medical physics is a branch of physics that deals the applications of principles of physics to medical diagnosing and treating abnormal tissues. The modern medical equipment like X-ray, MRI, CT scan, ultrasound and others are developed by the application of physics knowledge.

- **Thermometer**:- uses the thermal physics and reads temperature of a body
- Stethoscope: - use the physics of sound wave and reads the heart beats.
- **X-ray(CT scan)**:- uses physics of electromagnetic wave (X-ray) and examines the injuries in the tissues.

Basic difference between the conventional X-ray and CT scan as table below.

X-ray	CT Scan
Creates 2D images	Creates 3D images
Used primarily to see bones and to detect cancer and pneumonia	Used primarily to diagnose conditions in organs and soft tissues
Most common and widely available	More powerful than X-ray
Use radiation to produce image	Take 360-degree image
Has fixed detector	Has rotating detector

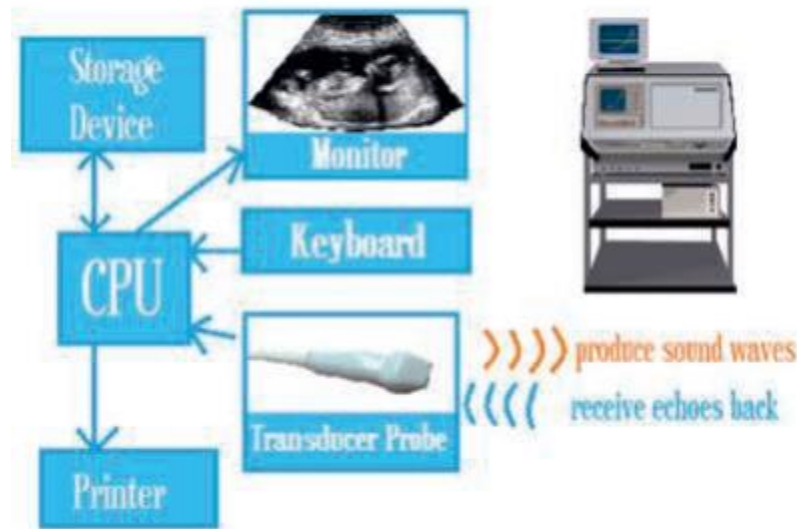
Magnetic Resonance Imaging (MRI)

- Magnetic resonance is absorption or emission of electromagnetic radiation by electrons or atomic nuclei in response to the application of certain magnetic fields.
- MRI is based on technology that excites and detects the change in the direction of the rotational axis of protons found in the water that makes up living tissues.
- image formation is to define the spatial location of the sources that contribute to the detected signal (hydrogen spin moment).

- MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field.
- The spatial information of the proton pools (nuclear magnetic moments) contributing MR signal is determined by the spatial frequency and phase of their magnetization.
- When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field.
- When the radiofrequency field is turned off, the MRI sensors are able to detect the energy released as the protons realign with the magnetic field.
- Gradient coils generate spatially varying magnetic field so that spins at different location precess at frequencies unique to their location, allowing us to reconstruct 2D or 3D images.
 - The time it takes for the protons to realign with the magnetic field, as well as the amount of energy released, changes depending on the environment and the chemical nature of the molecules.
 - Physicians are able to tell the difference between various types of tissues based on these magnetic properties.

Ultrasound: - uses the physics of sound wave and examines the nature of the sound reflected by different tissues.

- If the frequency of sound is higher than 20 KHz (0.02 MHz), it is called ultrasonic or ultrasound. Typical frequencies used in medical ultrasound are 3.5-10 MHz.
- An ultrasound machine sends an ultrasound wave into a body tissue and detects the reflected wave.



This figure shows:- Major parts of an ultrasound machine and workflow

Radiation Therapy

- ✓ Radiation Therapy (irradiation or radiotherapy) is the use of high energy radiation, primarily x-rays, to kill cancer cells.
- ✓ In high doses, radiation causes damage to cells by interfering with the cell's ability to grow and reproduce.
- ✓ In controlled doses radiation can be used therapeutically.

Physics and Defense Technology

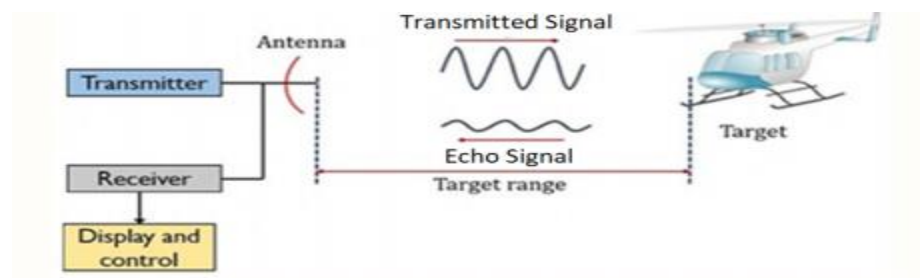
The modern defense force has different branches like Air Force, Army, Navy and most recently Space Force.

- All of these defense forces demand different knowledge and advancement of physics like laser guidance and satellite technology
- modern electronics, optics, sensing systems
- high-energy-density physics
- atomic and nuclear physics
- hydrodynamics, and physics of advanced materials.

Radar Technology

- ✚ Radar detects a target by sending a radio wave and receiving the reflected wave from the target.

- ✚ A radar system has such components as: a magnetron to generate radio waves, antenna to send them out into space and also to receive them, and screen to display.
- ✚ The basic principle behind radar is simple - radio wave energy, traveling at the speed of light are transmitted, reflected off a target and then returned as an echo. Radar makes use of the echo principle.
- ✚ A radar system uses a relation, $R = \frac{ct}{2}$ to determine the distance of the target where R is a distance, c is speed of light, t is time taken by the radar wave for transmission from the source to the target and reflect back to the radar.
- ✚ Radar system can be used in defense and air traffic controlling.
- ✚ Additional Radar can also be utilized in civilian applications particularly in controlling air traffic, observation of weather, navigation of ship, environment, sensing from remote areas, observation of planetary



This figure shows Basic principles of radar

Military applications of Radar

Military is the major application of radar and is one of the most important parts of the air defense system.

Missiles

- ✓ A missile is a weapon propelled by either a rocket or a jet.
- ✓ Cruise missiles are jet-propelled throughout their flights. Ballistic missiles are rocket powered only in the initial phase of flight.
- ✓ There is continuous radio communication between the internal missile controlling unit and the launch controller to track the target and the proper functioning of each unit of the missile.

Infra-red wave detection for night vision

Human eyes are sensitive to visible light: red, orange, yellow, green, blue, and violet light. Infrared, is just out of range of what the human eye can detect.

The infrared wave detection for night vision:-

- ❖ All people, places, and things give off infrared light in an amount proportional to their temperature
- ❖ Infrared devices will typically use heat emissions to identify objects that cannot be detected using available light sources.
- ❖ Thermal imaging systems create an electronic image based on the temperature differences in the radiating object; hotter objects appear brighter than cooler objects.
- ❖ Temperature difference in the target is represented by different colors that are not related to the actual color of the target.

Physics in communication

Communication is transferring of information from one point to another using wire or without wire.

- ✓ Most of the communication technology uses the electromagnetic radiation physics like Reflection, refraction, diffraction, interference, rarefaction, propagation, transmission and compression.
- ✓ Fiber optics uses the law of complete internal reflection of light.
- ✓ Wireless communication needs no wire however wire communication demands wire or fiber optics cable.