Chapter

1 Physical World

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WHAT IS SCIENCE ?

Science refers to a system of acquiring knowledge. This system uses observation and experimentation to describe and explain natural phenomena. The term science also refers to the organized body of knowledge that people have gained using that system. Less formally, the word science often describes any systematic field of study or the knowledge gained from it.

The **purpose of science** is to produce useful models of reality. Most scientific investigations use some form of the scientific method.

The **scientific method** is a logical and rational order of steps by which scientists come to conclusions about the world around them. The Scientific method helps to organize thoughts and procedures so that scientists can be confident in the answers they find. Scientists use observations, hypotheses, and deductions to make these conclusions.

Science as defined above, is sometimes called pure science to differentiate it from applied science, which is the application of research to human needs. Fields of science are commonly divided into two major categories.

1. **Natural science :** The science in which we study about the natural world. Natural science includes physics, chemistry, biology, etc.
2. **Social science :** It is the systematic study of human behavior and society.

WHAT IS PHYSICS ?

The word physics originates from a Greek word which means nature. *Physics is the branch of science that deals with the study of basic laws of nature and their manifestation of various natural phenomena*.

There are two main thrusts in physics :

1. **Unification :** In physics, attempt is made to explain various physical phenomena in terms of just few concepts and laws. Attempts are being made to unify fundamental forces of nature in the persuit of unification.
2. **Reductionism.** Another attempt made in physics is to explain a macroscopic system in terms of its microsocopic constituents. This persuit is called *reductionism*.

Keep in Memory

1. Information received through the senses is called **observation**.
2. An idea that may explain a number of observations is called **hypothesis**.
3. A hypothesis that has been tested many times is called **scientific theory**.
4. A scientific theory that has been tested and has always proved true is called **scientific law**.

SCOPE AND EXCITEMENT OF PHYSICS

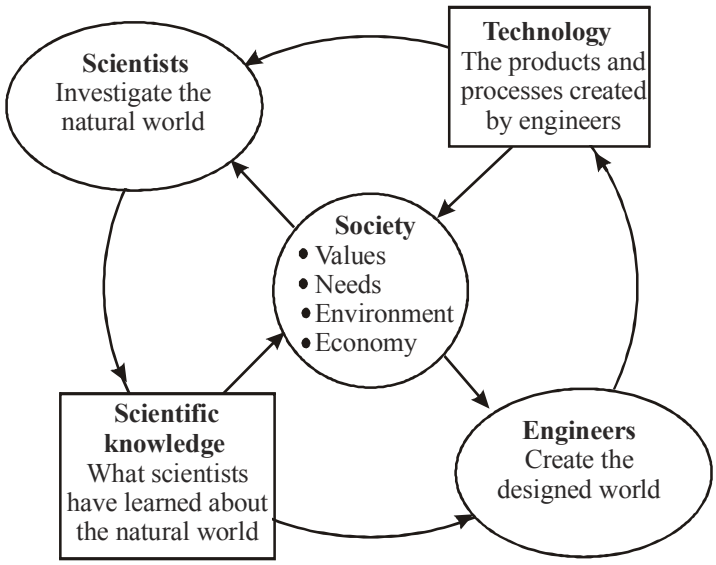
The scope of physics is very vast. It covers a tremendous range of magnitude of physical quantities like length, mass, time, energy, etc. Basically, there are two domains of interest : macroscopic and microscopic. The **macroscopic domain** includes phenomena at the laboratory, terrestrial and astronomical scales. The **microscopic domain** includes atomic, molecular and nuclear phenomena.

Classical physics deals mainly with macroscopic phenomena consisting of the study of heat, light, electricity, magnetism, optics, acoustics, and mechanics. Since the turn of the 20th century, the study of quantum mechanics and relativity has become more important. Today, physics is often divided into branches such as nuclear physics, particle physics, quantum physics, theoretical physics, and solid-state physics. The study of the planets, stars, and their interactions is known as astrophysics, the physics of the Earth is called geophysics, and the study of the physical laws relating to living organisms is called biophysics.

Physics is exciting in many ways. Application and exploitation of physical laws to make useful devices is the most interesting and exciting part and requires great ingenuity and persistence of effort.

PHYSICS, TECHNOLOGY AND SOCIETY

Physics generates new technologies and these technologies have made our lives comfortable and materially prosperous. We hear terms like science, engineering , technology all in same context though they are not exactly same.



Science:

- A body of knowledge
- Seeks to describe and understand the natural world and its physical properties
- Scientific knowledge can be used to make predictions
- Science uses a process--the scientific method--to generate knowledge

Engineering:

- Design under constraint
- Seeks solutions for societal problems and needs
- Aims to produce the best solution from given resources and constraints
- Engineering uses a process–the engineering design process–to produce solutions and technologies

Technology:

- The body of knowledge, processes and artifacts that result from engineering
- Almost everything made by humans to solve a need is a technology
- Examples of technology include pencils, shoes, cell phones, and processes to treat water

In the real world, these disciplines are closely connected. Scientists often use technologies created by engineers to conduct their research. In turn, engineers often use knowledge developed by scientists to inform the design of the technologies they create.

Link between technology and physics

Technology	Scientific principle(s)
Aeroplane	Bernoulli's principle in fluid dynamics
Bose-Einstein condensate	Trapping and cooling of atoms by laser beams and magnetic fields
Computers	Digital logic
Electric generator	Faraday's laws of electromagnetic induction
Electron microscope	Wave nature of electrons
Fusion test reactor (Tokamak)	Magnetic confinement of plasma
Giant Metrewave Radio Telescope (GMRT)	Detection of cosmic radio waves
Hydroelectric power	Conversion of gravitational potential energy into electrical energy
Lasers	Light amplification by stimulated emission of radiation
Non-reflecting coatings	Thin film optical interference
Nuclear reactor	Controlled nuclear fission
Optical fibres	Total internal reflection of light
Particle accelerators	Motion of charged particles in electromagnetic fields
Photocell	Photoelectric effect
Production of ultra high magnetic fields	Superconductivity
Radio and television	Generation, propagation and detection of electromagnetic waves
Rocket propulsion	Newton's laws of motion
Sonar	Reflection of ultrasonic waves
Steam engine	Laws of thermodynamics

Some physicists from different countries of the world and their major contributions

Name of physicists	Major contribution/discovery	Country of origin
Abdus Salam	Unification of weak and electromagnetic interactions	Pakistan
Albert Einstein	Explanation of photoelectric effect; Theory of relativity	Germany
Archimedes	Principle of buoyancy; Principle of the lever	Greece
C.H. Townes	Maser; Laser	U.S.A.
Christiaan Huygens	Wave theory of light	Holland
C.V. Raman	Inelastic scattering of light by molecules	India
Edwin Hubble	Expanding universe	U.S.A.
Enrico Fermi	Controlled nuclear fission	Italy
Ernest Orlando Lawrence	Cyclotron	U.S.A.
Ernest Rutherford	Nuclear model of atom	New Zealand
Galileo Galilei	Law of inertia	Italy
Heinrich Rudolf Hertz	Generation of electromagnetic waves	Germany
Hideki Yukawa	Theory of nuclear forces	Japan
Homi Jehangir Bhabha	Cascade process of cosmic radiation	India
Issac Newton	Universal law of gravitation; Laws of motion; Reflecting telescope	U.K.
James Clark Maxwell	Electromagnetic theory; Light - an electromagnetic wave	U.K.
James Chadwick	Neutron	U.K.
J.C. Bose	Ultra short radio waves	India
J.J. Thomson	Electron	U.K.
John Bardeen	Transistors; Theory of super conductivity	U.S.A.
Lev Davidovich Landau	Theory of condensed matter; Liquid helium	Russia
Louis Victor de Broglie	Wave nature of matter	France
Marie Sklodowska Curie	Discovery of radium and polonium; Studies on natural radioactivity	Poland
Michael Faraday	Laws of electromagnetic induction	U.K.
M.N. Saha	Thermal ionisation	India
Niels Bohr	Quantum model of hydrogen atom	Denmark
Paul Dirac	Relativistic theory of electron; Quantum statistics	U.K.
R.A. Millikan	Measurement of electronic charge	U.S.A.
S. Chandrashekhar	Chandrashekhar limit, structure and evolution of stars	India
S.N. Bose	Quantum statistics	India
Victor Francis Hess	Cosmic radiation	Austria
Werner Heisenberg	Quantum mechanics; Uncertainty principle	Germany
W.K. Roentgen	X-rays	Germany
Wolfgang Pauli	Exclusion principle	Austria

Example 1. Does imagination play any role in physics?

Solution : Yes, imagination has clayed an important role in the development of physics. Huygen's principle, Bohr's theory, Maxwell equations, Heisenberg's uncertainty principle, etc. were the imaginations of the scientists which successfully explained the various natural phenomena.

Example 2. How is science different from technology?

Solution : Science is the study of natural laws while technology is the practical application of these laws to the daily life problems.

FUNDAMENTAL FORCES IN NATURE

We come across several forces in our day-to-day lives eg., frictional force, muscular force, forces exerted by springs and strings etc. These forces actually arise from four fundamental forces of nature.

Following are **the four fundamental forces in nature.**

1. *Gravitational force*
2. *Weak nuclear force*
3. *Electromagnetic force*
4. *Strong nuclear force*

Among these forces gravitational force is the weakest and strong nuclear force is the strongest force in nature.

Fundamental forces of nature

Name	Relative strength	Range	Exchange particles	Major role	Important properties
Gravitational force (Force of attraction between any two boies by virtue of their masses)	10^{-39}	Infinite	Gravitons	Large-scale structure	Universal attractive, weakest, long range, central, conservative force.
Weak nuclear force (Changes quark types as in Beta-decay of nucleus	10^{-13}	Very short, sub-nuclear size (on 10^{-16}m)	Weak bosons	Nuclear reactions	Govern process involving neutrino and antineutrino, operates only through a range of nuclear size.
Electromagnetic force (Force between particles with charge/magnetism)	10^{-2}	Infinite	Photons	Chemistry and Biology	Either attractive or repulsive, long range, central, conservative force.
Strong nuclear force (Strong attractive force which binds together the protons and neutrons in nucleus)	1	Very Short, nuclear size (on 10^{-15}m)	Gluons	Holding nuclei together	Basically an attractive becomes repulsive (when distance between nucleons < 0.5 fermi) strongest, short range, non-central, non-conservative force.

Physicists are trying to derive a unified theory that would describe all the forces in nature as a single fundamental law. So far, they have succeeded in producing a unified description of the weak and electromagnetic forces, but a deeper understanding of the strong and gravitational forces has not yet been achieved. Theories that postulate the unification of the strong, weak, and electromagnetic forces are called **Grand Unified Theories** (often known by the acronym GUTs). Theories that add gravity to the mix and try to unify all four fundamental forces into a single force are called **Superunified Theories**. The theory that describes the unified electromagnetic and weak interactions is called the **Standard Electroweak Theory**, or sometimes just the **Standard Model**.

Progress in unification of different forces/domains in nature

Name of the physicist	Year	Achievement in unification
Issac Newton	1687	Unified celestial and terrestrial mechanics; showed that the same laws of motion and the law of gravitation apply to both the domains.
Hans Christian Oersted	1820	Showed that electric and magnetic phenomena are inseparable aspects of a unified domain : electromagnetism.
Michael Faraday	1830	
James Clark Maxwell	1873	Unified electricity, magnetism and optics; showed that light is an electromagnetic wave.
Sheldon Glashow, Abdus Salam, Steven Weinberg	1979	Showed that the 'weak' nuclear force and the electromagnetic force could be viewed as different aspects of a single electro-weak force.
Carlo Rubia, Simon Vander Meer	1984	Verified experimentally the predictions of the theory of electro-weak force.

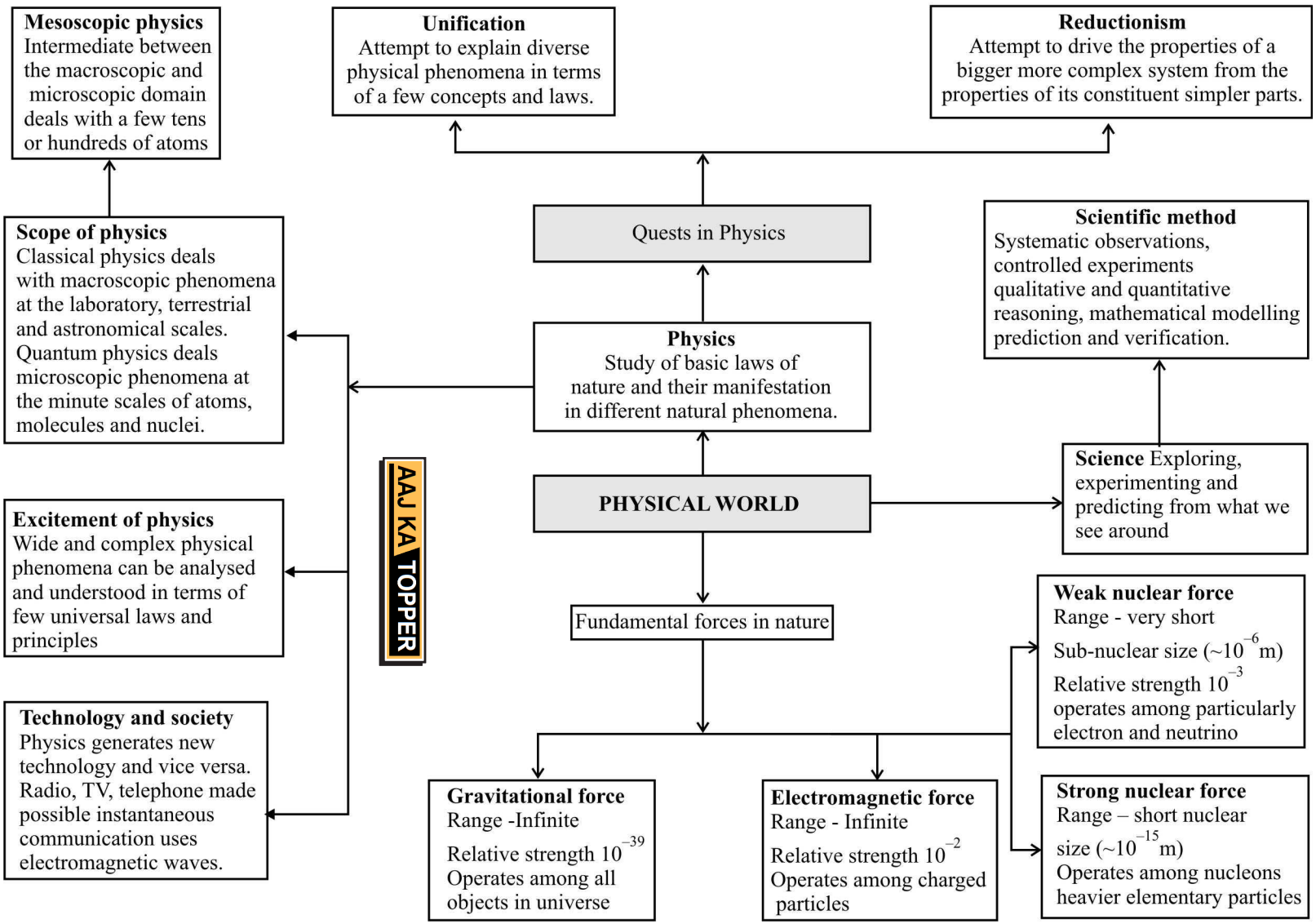
Example 3 . What is electromagnetic force?

Solution : It is the force due to interaction between two moving charges. It is caused by exchange of photons (γ) between two charged particles.

NATURE OF PHYSICAL LAWS

A physical law, scientific law, or a law of nature is a scientific generalization based on empirical observations of physical behavior. Empirical laws are typically conclusions based on repeated scientific experiments and simple observations over many years, and which have become accepted universally within the scientific community. The production of a summary description of nature in the form of such laws is a fundamental aim of science. Physical laws are distinguished from scientific theories by their simplicity. Scientific theories are generally more complex than laws. They have many component parts, and are more likely to be changed as the body of available experimental data and analysis develops. This is because a physical law is a summary observation of strictly empirical matters, whereas a theory is a model that accounts for the observation, explains it, relates it to other observations, and makes testable predictions based upon it. Simply stated, while a law notes that something happens, a theory explains why and how something happens.

CONCEPT MAP


Mesoscopic physics
Intermediate between the macroscopic and microscopic domain deals with a few tens or hundreds of atoms
Unification
Attempt to explain diverse physical phenomena in terms of a few concepts and laws.
Reductionism
Attempt to drive the properties of a bigger more complex system from the properties of its constituent simpler parts.
Scope of physics
Classical physics deals with macroscopic phenomena at the laboratory, terrestrial and astronomical scales. Quantum physics deals microscopic phenomena at the minute scales of atoms, molecules and nuclei.
Quests in Physics
Scientific method
Systematic observations, controlled experiments qualitative and quantitative reasoning, mathematical modelling prediction and verification.
Physics
Study of basic laws of nature and their manifestation in different natural phenomena.
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Excitement of physics
Wide and complex physical phenomena can be analysed and understood in terms of few universal laws and principles
PHYSICAL WORLD
Science Exploring, experimenting and predicting from what we see around
Fundamental forces in nature
Technology and society
Physics generates new technology and vice versa. Radio, TV, telephone made possible instantaneous communication uses electromagnetic waves.
Weak nuclear force
Range - very short
Sub-nuclear size (~10^-6 m)
Relative strength 10^-3
operates among particularly electron and neutrino
Gravitational force
Range -Infinite
Relative strength 10^-39
Operates among all objects in universe
Electromagnetic force
Range - Infinite
Relative strength 10^-2
Operates among charged particles
Strong nuclear force
Range – short nuclear
size (~10^-15 m)
Operates among nucleons heavier elementary particles

EXERCISE - 1
Conceptual Questions

1. The man who has won Nobel Prize twice in physics is
(a) Einstein (b) Bardeen
(c) Heisenberg (d) Faraday

2. Prof. Albert Einstein got nobel prize in physics for his work on
(a) special theory of relativity
(b) general theory of relativity
(c) photoelectric effect
(d) theory of specific heats

3. Which of the following is wrongly matched ?
(a) Barometer-Pressure
(b) Lactometer-Milk
(c) Coulomb's law-charges
(d) Humidity-Calorimeter

4. C.V. Raman got Nobel Prize for his experiment on
(a) dispersion of light (b) reflection of light
(c) deflection of light (d) scattering of light

5. A scientific way of doing things involve
(a) identifying the problem
(b) collecting data
(c) hypothesising a possible theory
(d) All of the above

6. The scientific principle involves in production of ultra high magnetic fields is
(a) super conductivity (b) digital logic
(c) photoelectric effect (d) laws of thermodynamics

7. Which of the following has infinite range?
(a) Gravitational force (b) Electromagnetic force
(c) Strong nuclear force (d) Both (a) and (b)

8. Which of the following is the correct decreasing order of the strengths of four fundamental forces of nature ?
(a) Electromagnetic force > weak nuclear force > gravitational force > strong nuclear force
(b) Strong nuclear force > weak nuclear force > electromagnetic force > gravitational force
(c) Gravitational force > electromagnetic force > strong nuclear force > weak nuclear force
(d) Strong nuclear force > electromagnetic force > weak nuclear force > gravitational force

9. The exchange particles for the electromagnetic force are
(a) gravitons (b) gluons
(c) photons (d) mesons

10. Louis de-Broglie is credited for his work on
(a) theory of relativity
(b) electromagnetic theory
(c) matter waves
(d) law of distribution of velocities

11. Madam Marie Curie won Nobel Prize twice which were in the field of
(a) Physics and chemistry (b) Chemistry only
(c) Physics only (d) Biology only

12. The man who is known as the Father of Experimental Physics is
(a) Newton (b) Albert Einstein
(c) Galileo (d) Rutherford

13. The person who has been awarded the title of the Father of Physics of 20th century is
(a) Madame Curie (b) Sir C.V. Raman
(c) Neils Bohar (d) Albert Einstein

14. Which of the following is true regarding the physical science?
(a) They deal with non-living things
(b) The study of matter are conducted at atomic or ionic levels
(c) Both (a) and (b)
(d) None of these

15. The branch of science which deals with nature and natural phenomena is called
(a) Sociology (b) Biology
(c) Civics (d) Physics

16. Who gave general theory of relativity?
(a) Einstein (b) Marconi
(c) Ampere (d) Newton

17. Who discovered X-rays?
(a) Chadwick (b) Roentgen
(c) Thomson (d) Madam Curie

18. Which of the following is the weakest force?
(a) Nuclear force (b) Gravitational force
(c) Electromagnetic force (d) None of these

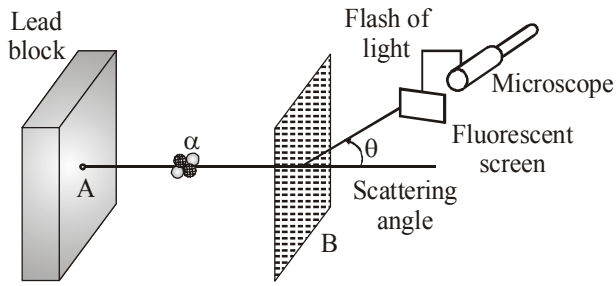
19. The field of work of S. Chandrashekar is
(a) theory of black hole (b) Cosmic rays
(c) theory of relativity (d) X-rays

20. Two Indian born physicists who have been awarded Nobel Prize in Physics are
(a) H. J. Bhabha and APJ Kalam
(b) C.V. Raman and S. Chandrasekhar
(c) J.C. Bose and M.N. Saha
(d) S. N. Bose and H. J. Bhabha

21. Science is exploring, ...x... and ...y... from what we see around us. Here, x and y refer to
(a) qualitative, modify (b) experiment, predict
(c) verification, predict (d) reasoning, quantitative

22. Macroscopic domain includes
(a) phenomena at the laboratory
(b) terrestrial scales
(c) astronomical scales
(d) All of the above

23. In Rutherford, alpha particle scattering experiment as shown in given figure, A and B refer to



(a) polonium sample and aluminium foil

(b) polonium sample and gold foil

(c) uranium sample and gold foil

(d) uranium sample and aluminium foil

DIRECTIONS for Qs. (24-25) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following

(a) Statement -1 is false, Statement-2 is true

(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1

(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1

(d) Statement -1 is true, Statement-2 is false

24. **Statement-1 :** The concept of energy is central to Physics and expression for energy can be written for every physical system.
Statement-2 : Law of conservation of energy is not valid for all forces and for any kind of transformation between different forms of energy.

25. **Statement-1 :** Electromagnetic force is much stronger than the gravitational farce.
Statement-2 : Electromagnetic force dominates all phenomena at atomic and molecular scales.

Hints & Solutions AAJ KA TOPPER

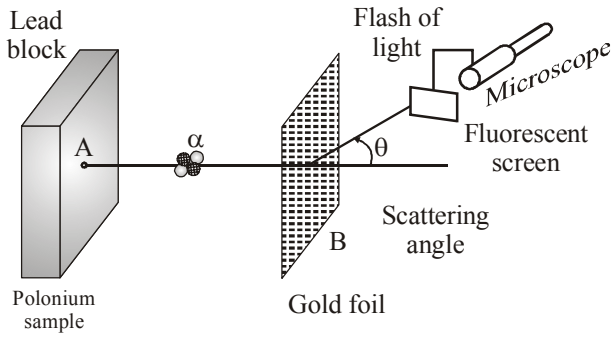
EXERCISE - 1

1.	(b)	2.	(c)	3.	(d)	4.	(d)	5.	(d)
6.	(a)	7.	(d)	8.	(d)	9.	(c)	10.	(c)
11.	(a)	12.	(c)	13.	(d)	14.	(c)	15.	(d)
16.	(a)	17.	(b)	18.	(b)	19.	(a)	20.	(b)

21. (b) Science is exploring, experimenting and predicting from what we see around us.

22. (d) The macroscopic domain includes phenomena at the laboratory, terrestrial and astronomical scales.

23. (b) The alpha particle scattering experiment of Rutherford gave the nuclear model of the atom as shown in figure



24. (d) The concept of energy is central to Physics and the expressions for energy can be written for every physical system. When all forms of energy e.g., Heat, mechanical energy, electrical energy etc., are counted, it turns out that energy is conserved. The general law of conservation of energy is true for all forces and for any kind of transformation between different forms of energy.

25. (b) It is mainly the electromagnetic force that governs the structure of atoms and molecules, the dynamics of chemical reactions and the mechanical, thermal and other properties of materials.