Biyani's Think Tank

Concept Based Notes

Electromagnetism

(B.Sc. Semester-II)

Dr. Yogesh Kumar

Assistant professor
Department of Physics
Biyani Girls College, Jaipur

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Published by:
Think Tanks
Biyani Group of Colleges

Sector-3, Vidhyadhar Nagar,
Jaipur-302 023 (Rajasthan)
Ph : 0141-2338371, 2338591-95
Fax : 0141-2338007
E-mail: acad@biyanicolleges.org
Website: www.gurukpo.com; www.biyanicolleges.org

Edition: 2025

Leaser Type Setted by: Biyani College Printing Department

Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the "Teach Yourself" style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, Chairman & Dr. Sanjay Biyani, Director (Acad.) Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this endeavor. They played an active role in coordinating the various stages of this endeavor and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

Author

SYLLABUS

SYLLABUS		
S. NO.	UNIT	TOPICS
1	**Scaler and Vector Fields.** **Electric Field and Potential Energy**	Concept of field and Scalar and Vector Fields Gradient of Scalar Field, Physical Significance. Formalism of Gradient,Divergence of a Vector Field, Curl of a Vector Field Gradient, ,Curl ,Divergence in cartisian system Concept of Solid Angle, Stokes and Gauss theorem Gauss law from inverse square law, Differential form of Gauss law Charge invarience, Potential Energy of System For discrete charges, For continuous charges system Energy required to built a uniformly charges sphere Classical radius of electron, Electric field due to a short electric dipole Interaction of Electric dipole with External uniform and Non uniform field Potential due to a uniformly charged Spherical Shell Poission and laplace Equation in cartisian system Applications of Poission and Laplace Equation Electric field measure in moving frames.Electric field due to a point charge moving with constant velocity
2	**2. Electric field in matter**	Multipole Expansion Definition of moment of charge distribution, Dielectrics Induced dipole moment, Polar and non Polar molecules, Free and Bound charges Polarization, Atomic Polarizabilty,Electric Displacement vector Electric Susceptibility, Dielectric constant and relation between them. Electric Potential and Electric field due to uniformly polarized sphere Case 1: Outside the sphere, Case 2: at the surface of

		sphere, Case 3: Inside the sphere Electric field due to a dielectric sphere placed in a uniform electric field Case 1: Outside the sphere, Case 2: at the surface of sphere. Electric field due to charge placed in a dielectric medium and Gauss law Clausius-Mossotti relation in Dielectrics.
3	**3.Magnetostatics and Magnetic field in matter**	Lorentz force, properties of Magnetic Fields , Ampere law Field due to a current carrying solid conducting cylinder Case 1: Outside the surface, Case 2 : At the surface, Case 3 : Inside the cylinder Ampere law in differential form,Introduction of Magnetic Vector Potential, Poission Equation for Vector Potential Deduction of Bia Savart law using Magnetic Vector Potentials Differential form of Bio Savart law, Atomic magnet, Gyro magnetic ratioBohr Magneton, Larmor Frequency,Indused magnetic moment and Dia magnetism.Spin magnetic moment, Para and Ferromagnetism .Intensity of Magnetisation, Magnetic Permeability and Susceptibility Free and Bound current densities. Magnetic fields due to a uniform Magnetised or non uniform Magnetised Material
4	**4.Maxwell's Equations and Electromagnetic waves:**	Displacement current and Maxwell Equations Electromagnetic waves, Electromagnetic waves in isotropic medium. Properties of EM waves Energy density of Electromagnetic waves,Pointing vector, Radiation Pressure of Free space ,Electromagnetic waves in dispersive medium Spectrum of Electromagnetic Waves.

Short Questions:

QUESTION 1: What is a scalar and vector fields?

ANSWER: A scalar field means we take some space, say a plane, and measure some scalar value at each point. Say we have a big flat pan of shallow water sitting on the stove. If the water is shallow enough we can pretend that it is two-dimensional. Each point in the water has a temperature; the water over the stove flame is hotter than the water at the edges. But temperatures have no direction. There's no such thing as a north or an east temperature. The temperature is a scalar field: for each point in the water there is a temperature, which is a scalar, which says how hot the water is at that point.

A vector field means we take some space, say a plane, and measure some vector value at each point. Take the pan of water off the stove and give it a stir. Some of the water is moving fast, some slow, but this does not tell the whole story, because some of the water is moving north, some is moving east, some is moving northeast or other directions.

QUESTION 2: Write the concept of solid angle?

ANSWER: An object's solid angle in steradians is equal to the area of the segment of a unit sphere, centered at the apex that the object covers. Giving the area of a segment of a unit sphere in steradians is analogous to giving the length of an arc of a unit circle in radians. Just like a planar angle in radians is the ratio of the length of an arc to its radius, a solid angle in steradians is the ratio of the area covered on a sphere by an object to the area given by the square of the radius of said sphere.

QUESTION 3: What is dipole?

ANSWER: An electric dipole deals with the separation of the positive and negative electric charges found in any electromagnetic system.

QUESTION 4: What are Laplace and Poisson equations?

ANSWER:

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$$

E = electric field
ρ = charge density
ε_0 = permittivity

Poisson equation

$$\nabla^2 V = 0$$

Laplace equation

QUESTION 5: What is electric field and magnetic fields?

ANSWER: Electric field - Electric field or electric field intensity is the force surrounding an electrically charged particle. We can also say that it is the area where the line of force exists and these lines of force surround the electric field. These lines of force are imaginary lines that are used to define the area of influence around the electric charge. It is a vector quantity as it has both direction and magnitude. The symbol used to express the electric field is the letter **E**. It's unit of measurements is Newton/Coulomb.

Magnetic field - The area around the magnet where attractive forces or repulsive forces are exhibited by the poles of the magnet is called magnetic field. When electric charges move across space or an electrical conductor, a magnetic field is induced due to its motion.

QUESTION 6: What is Atomic Polarizability?

ANSWER: Atomic Polarizability is defined as the dipole moment induced in the atom in response to application of electric field, $X = \alpha E$.

QUESTION 7: What is Di- Electric material?

ANSWER: A dielectric (or dielectric medium) is an electrical insulator that can be polarized by an applied electric field. When a dielectric material is placed in an electric field, electric charges do not flow through the material

QUESTION 8: Write the Clausius- Mosotti relation?

ANSWER:

$$\frac{\varepsilon - 1}{\varepsilon + 2} = \frac{N}{3\varepsilon_0}\alpha.$$

QUESTION 9: Write down the properties of magnetic field?

ANSWER:

Properties of magnetic field:

- They form closed loops.
- They never intersect each other.
- The magnetic field lines are crowded near the pole where the field is strong and spread apart from each other where the field is weak.
- They flow from the south pole to the north pole within a magnet and north pole to south pole in outside.

QUESTION 10: What is Magnetic Vector Potential?

ANSWER: Magnetic vector potential (A) is the vector quantity defined so that its curl is equal to the magnetic field: ∇ XA = B. Together with the electric_potential φ, the magnetic vector potential can be used to specify the electric_field E as well.

QUESTION 11: What is Bohr- Magneton?

ANSWER: In atomic physics, the Bohr magneton (μB) is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by its orbital or spin angular momentum**.**

QUESTION 12: What is dia- magnetic, paramagnetic and ferro-magnetic material?

ANSWER: **Diamagnetic** materials have a weak, negative susceptibility to magnetic fields. Diamagnetic materials are slightly repelled by a magnetic field and do not retain the magnetic properties when the external field is removed. **Paramagnetic** materials have a small, positive susceptibility to magnetic fields. These materials are slightly attracted by a magnetic field and do not retain the magnetic properties when the external field is removed. **Ferromagnetic** materials have a large, positive susceptibility to an external magnetic field**.** They exhibit a strong attraction to magnetic fields and are able

to retain their magnetic properties after the external field has been removed.

QUESTION 13: What is Current decay?

ANSWER: In the Decay of current, the source EMF is removed from the circuit. The current flowing in the circuit will be maximum at the time of this connection of the source.

QUESTION 14: Write the Maxwell's Equations?

ANSWER:

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

QUESTION 15: What are the electromagnetic waves?

ANSWER: Electromagnetic waves- These are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include radio waves, infrared, visible light, ultraviolet, X-rays, and gamma rays

ANSWER BRIEFLY :

QUESTION 1: Derive the expression for Stokes-Curl theorem?

ANSWER: The Stoke"s theorem states that "the surface integral of the curl of a function over a surface bounded by a closed surface is equal to the line integral of the particular vector function around that surface."

$$\oint_C \vec{A} \cdot \vec{dl} = \iint_S (\vec{\nabla} \times \vec{A}) \cdot \vec{dS}$$

Let A vector be the vector field acting on the surface enclosed by closed curve C. Then the line integral of vector A vector along a closed curve is given by

$$\oint_C \vec{A} \cdot \vec{dl}$$

where dl vector is the length of a small element. Now let us divide the area enclosed by the closed curve C into two equal parts by drawing a line Therefore, the line integral of vector A vector along a closed curve C can be written as.

$$\oint \vec{A}.d\vec{l} = \oint_{C1} \vec{A}.d\vec{l} + \oint_{C2} \vec{A}.d\vec{l} \quad \ldots \quad \ldots \quad \ldots \ldots (1)$$

If the area enclosed by the curve C is divided into a large number of small areas such as dS1, dS2, dS3…… dSn bounded by the curves C1, C2 .....Cn

$$\oint_{C} \vec{A}.d\vec{l} = \sum \oint_{Cn} \vec{A}.d\vec{l} \ldots \ldots \ldots \ldots (2)$$

According to the definition of curl

$$\oint_{Cn} \vec{A}.d\vec{l} = Curl\ \vec{A}.d\,\overrightarrow{S_n} \ldots \ldots \ldots \ldots (3)$$

Put this value in (2), we get

$$\oint_{C} \vec{A}.d\vec{l} = \sum \oint_{Cn} \vec{A}.d\vec{l} = \sum Curl\ \vec{A}.d\overrightarrow{S_n} \ldots \ldots \ldots \ldots (4)$$

$$dS \to 0, \sum Curl\ \vec{A}\,.d\overrightarrow{S_n} = \iint_{S} Curl\ \vec{A}.d\vec{S}$$

Hence eqn. (4) can be written as

$$\oint \vec{A}.d\vec{l} = \iint Curl\ \vec{A}.d\vec{S} \ \ or \ \oint \vec{A}.d\vec{l} = \iint (\vec{\nabla} \times \vec{A})\,.d\vec{S} \ldots \ldots \ldots (5)$$

which is the Stokes Theorem.

QUESTION 2: **Draw a table comparing electric and magnetic field?**

ANSWER:

Electric field	Magnetic field
It is the force around the electrical charge particle	The region around the magnetic where poles exhibits a force of attraction or repulsion
It is perpendicular to the magnetic field.	It is perpendicular to the electric field.
Electric field lines do not form a closed loop.	Magnetic line forms a closed loop
Negative or positive charge.	North or south pole.
Exist in two dimensions	Remain in three dimensions
Repulsion force on like charges and attraction force on unlike charges.	Repulsion force on like poles and attraction force on unlike poles.

QUESTION 3: Write is the Ampere's law? Derive the differential form of this.

ANSWER: **Ampere's law:** "The magnetic field created by an electric current is proportional to the size of that electric current with a constant of proportionality equal to the permeability of free space."

$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

The integral form of Amperes" Circuital Law (ACL) for Magnetostatics relates the magnetic field along a closed path to the total current flowing through any surface bounded by that path. In mathematical form:

$$\oint H \cdot dl = I_{encl}$$

where H is magnetic field intensity, C is the closed curve, and Ienc is the total current flowing through any surface bounded by C. In this section, we derive the differential form of this equation. In some applications, this differential equation, combined with boundary conditions associated with discontinuities in structure and materials, can be used to solve for the magnetic field in arbitrarily complicated scenarios. A more direct reason for seeking out this differential

equation is that we gain a little more insight into the relationship between current and the magnetic field, disclosed at the end of this section

$$\int (\nabla \times H) \cdot ds = \oint H \cdot dl$$

where S is any surface bounded by C, and ds is the differential surface area

Which is combined with the unit vector in the direction determined by the right-hand rule from Stokes‟ Theorem.

$$I_{encl} = \int_S J \cdot ds$$

Then $$\int_S (\nabla \times H) \cdot ds = \int_S J \cdot ds$$

The above relationship must hold regardless of the specific location or shape of S. The only way this is possible for all possible surfaces in all applicable scenarios is if the integrands are equal. Thus, we obtain the desired expression - $\nabla \times H = J$

QUESTION 4: Derive the formula for Biot- savart law?

ANSWER: The Biot Savart Law is an equation describing the magnetic field generated by a constant electric current. It relates the magnetic field to the magnitude, direction, length, and proximity of

the electric current. Biot–Savart law is consistent with both Ampere‟s circuital law and Gauss‟s theorem Let us consider a long wire carrying a current I and also consider a point p in the space. The wire is presented in the picture below, by red color. Let us also consider an infinitely small length of the wire dl at a distance r from the point P as shown. Here, r is a distance-vector which makes an angle θ with the direction of current in the infinitesimal portion of the wire. As the current through that infinitesimal length of wire is the same as the current carried by the whole wire itself, we can write

$$dB \alpha I \text{ …..(i)}$$

It is also very natural to think that the magnetic field density at that point P due to that infinitesimal length dl of wire is inversely proportional to the square of the straight distance from point P to the center of dl. Mathematically we can write this as

$$dB \; a \; 1/r2\text{…..(ii)}$$

As θ be the angle between distance vector r and direction of current through this infinitesimal portion of the wire, the component of dl directly facing perpendicular to the point P is dl sinθ,

$$dB \; a \; dl \sin\theta \quad \text{…..(iii)}$$

From (i) (iii) &(iii) $dB \; a \; I \, dl \sin\theta / r^2$

QUESTION 5: Explain the Electron spin and magnetic moment?

ANSWER: **ELECTRON SPIN**: S.A. Goudsmit and G.E. Uhlenbeck, in 1925, recommended that an electron has an inherent angular momentum that is a magnetic moment that is recognised as spin. In atomic physics, the inherent angular momentum of a particular particle is parametrized by spin quantum numbers. The spin quantum number is the fourth number. The rest three are a principal quantum number, azimuthal, and magnetic quantum number. The spin quantum number explains the unique quantum state of an electron. This is nominated as„s". The spins play a noteworthy role in quantum mechanics in computing the characteristics of elementary units like electrons. Magnetic Moment is defined as magnetic strength and orientation of a magnet or other object that produces a magnetic field.

QUESTION 6: Compare various magnetic properties of different materials?

ANSWER: Five basic **types of magnetism** have been observed and classified on the basis of the magnetic behavior of materials in response to magnetic fields at different temperatures.

Diamagnetic Material- Diamagnetic materials are those that some people generally think of as non-magnetic. Diamagnetic materials are repelled by a magnetic field; an applied magnetic field creates an **induced magnetic field** in them in the **opposite direction**, causing a repulsive force. Diamagnetism results from changes in electron orbital motion that are induced by an external field. Diamagnetic materials include water, wood, most organic compounds such as petroleum and some plastics,

Paramagnetic Materials- Paramagnetic materials are those having permanent atomic dipoles, which are acted on individually and **aligned in the direction of an external field**. Diamagnetic and paramagnetic materials are considered nonmagnetic because the magnetizations are relatively small and persist only while an applied field is present. If χ (**magnetic susceptibility**) is positive, a material can be paramagnetic

Ferromagnetic Materials- Ferromagnetism is the basic mechanism by which a material form permanent magnet (i.e. materials that can be magnetized by an external magnetic field and remain magnetized after the external field is removed). Ferromagnetism is the strongest type and is responsible for this common phenomenon. Ferromagnetic, ferromagnetic, or antiferromagnetic materials possess permanent magnetization even without external magnetic field and do not have a well-defined zero-field susceptibility.

Antiferromagnetic Materials- In an antiferromagnetic, unlike a ferromagnetic, there is a tendency for the intrinsic magnetic moments of neighboring valence electrons to point in opposite directions. When all atoms are arranged in a substance so that each neighbor is anti-parallel, the substance is antiferromagnetic.

Ferromagnetic Materials- The macroscopic magnetic characteristics of ferromagnets and ferrimagnetism are similar, the distinction lies in the source of the net magnetic moments. A ferromagnetic material is one that has populations of atoms with opposing magnetic moments, as in antiferromagnetism; however, in ferrimagnetic materials, the opposing moments are unequal and a spontaneous magnetization remains

QUESTION 7: **What are electric oscillations?**

ANSWER: An **electronic oscillator** is an

An electronic oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave or a triangle wave. Oscillators convert direct current (DC) from a power supply to an alternating current (AC) signal. They are widely used in many electronic devices ranging from simplest clock generators to digital instruments (like calculators) and complex

computers and peripherals etc.[3] Common examples of signals generated by oscillators include signals broadcast by radio and television transmitters, clock signals that regulate computers and quartz clocks, and the sounds produced by electronic beepers and video games.

Oscillators are often characterized by the frequency of their output signal:

A low-frequency oscillator (LFO) is an electronic oscillator that generates a frequency below approximately 20 Hz. This term is typically used in the field of audio synthesizers, to distinguish it from an audio frequency oscillator.

An audio oscillator produces frequencies in the audio range, about 16 Hz to 20 kHz.[2]

An RF oscillator produces signals in the radio frequency (RF) range of about 100 kHz to 100 GHz.

QUESTION 8: What is Faraday's law?

ANSWER:

Faradey's first law:

Any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called induced emf and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current.

Method to change the magnetic field:

1. By moving a magnet towards or away from the coil
2. By moving the coil into or out of the magnetic field
3. By changing the area of a coil placed in the magnetic field
4. By rotating the coil relative to the magnet

Faradey's second law:

It states that the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil. The flux linkage of the coil is the product of the number of turns in the coil and flux associated with the coil.

QUESTION 9: Derive the Ist and IInd Maxwell's equations?

ANSWER:

Maxwell's first equation in differential form

The value of total charge in terms of volume charge density is $q=\int \rho dv$ So equation (3) becomes

$$\int \vec{E}.d\vec{A}=\frac{1}{\epsilon 0}\int \rho dv$$

Applying divergence theorem on left hand side of above equation we have

$$\int(\vec{\nabla}.\vec{E})d.V=\frac{1}{\epsilon 0}\int \rho dv$$

$$\int(\vec{\nabla}.\vec{E})d.V-\frac{1}{\epsilon 0}\int \rho dv=0$$

$$\int[(\vec{\nabla}.\vec{E})-\frac{\rho}{\epsilon 0}]\,dv=0$$

$$(\vec{\nabla}.\vec{E})-\frac{\rho}{\epsilon 0}=0$$

$$(\vec{\nabla}.\vec{E})=\frac{\rho}{\epsilon 0}$$

he magnitude of the magnetic field at any point is directly proportional to the strength of the current and inversely proportional to the distance of the point from the straight conductors is called Ampere‟s law.

Maxwells fourth equation

$\int \vec{B}.\overrightarrow{dA}=0$ ..... (4)

It is the integral form of Maxwell's second equation.

Applying divergence theorem

$\int(\vec{\nabla}.\vec{B})dV=0$

This implies that:

$\vec{\nabla}.\vec{B}=0$

It is called differential form of Maxwell's second equation.

QUESTION 10: Derive the IIIrd and IVth Maxwell's equations?

ANSWER: According to Faraday"s law of electromagnetic induction

$\varepsilon = -N\frac{d\emptyset_m}{dt}$ ..... (5)

Since emf is related to electric field by the relation

$\varepsilon = \int \vec{E}.\overrightarrow{dA}$

Also $\emptyset_m=\int \vec{B}.\overrightarrow{dA}$

Put these values in equation (5) we have

$\int \vec{E}.\overrightarrow{dA} = -N \int \vec{E}.\overrightarrow{dA} \int \vec{B}.\overrightarrow{dA}$

For N=1 ,we have

$\int \vec{E}.\overrightarrow{dA} = -\frac{d}{dt}\int \vec{B}.\overrightarrow{dA}$ ..... (6)

It is the integral form of Maxwell's 3rd equation.

Applying Stokes Theorem on L.H.S of equation (6) we have

$\int(\vec{\nabla}\times\vec{E})d\vec{A} = -\frac{d}{dt}\int \vec{B}.\overrightarrow{dA}$

$\int(\vec{\nabla}\times\vec{E})d\vec{A} + \frac{d}{dt}\int \vec{B}.\overrightarrow{dA}=0$

$(\vec{\nabla}\times\vec{E})+\frac{d\vec{B}}{dt}=0$

$(\vec{\nabla}\times\vec{E})=-\frac{d\vec{B}}{dt}$

he magnitude of the magnetic field at any point is directly proportional to the strength of the current and inversely proportional to the distance of the point from the straight conductors is called Ampere‟s law.

Maxwells fourth equation

$\int \vec{B}.\overrightarrow{ds} = \mu_0 i$ ..... (7)

It is the integral form of Maxwell's 4th equation.

The value of current density

$i = \int \vec{j}.\overrightarrow{dA}$

Now the equation (7) Become

$\int \vec{B}.\overrightarrow{ds} = \mu_0 \int \vec{j}.\overrightarrow{dA}$

Applying Stoke's theorem on L.H.S of above equation, we have

$\int (\vec{\nabla} \times \vec{B}) d\vec{A} = \mu_0 \int \vec{j}.\overrightarrow{dA}$

$\int [(\vec{\nabla} \times \vec{B}) d\vec{A} - \mu_0 j].\, dA = 0$

$(\vec{\nabla} \times \vec{B}) = \mu_0 j$

QUESTION 11: What is energy density of electromagnetic waves?

ANSWER: Energy Density is defined as the total amount of energy in a system per unit volume. For example, the number of calories per gram of food. Foodstuffs that has low energy density provide less

energy per gram of food which means that you can eat more of them since there are fewer calories. It is denoted by letter U.

Magnetic and electric fields can also store energy.

In the case of the electric field or capacitor, the energy density formula is given by

$$u = \frac{1}{2} \mathrm{G}E^2$$

E = E is the electric field ε0 = permittivity of free space. The energy density formula in case of magnetic field or inductor is given by,

$$\mathrm{u} = \frac{1}{2\mu} B^2$$

B =Magnetic field μ0 =permeability of free space

Regarding electromagnetic waves, both magnetic and electric field are equally involved in contributing to energy density. Therefore, the formula of energy density is the sum of the energy density of the electric and magnetic field.

Last year question papers of Rajasthan University –

Printed Pages : 4

B.Sc. (Part – I) Examination, 2022

(Three -Year Scheme)

(10+2+3)

(Faculty of Science)

PHYSICS

Paper-II

(Electromagnetism)

Time : 3 Hours

Maximum Marks : 33

Note : (1) No supplementary answer-book will be given to any candidate. Hence the candidates should write the answer precisely in the main answer book only.
किसी भी परीक्षार्थी को पूरक उत्तर-पुस्तिका नहीं दी जायेगी । अतः परीक्षार्थियों को चाहिये कि वे मुख्य उत्तर-पुस्तिका में ही समस्त प्रश्नों के उत्तर सही ढंग से लिखें ।

(2) All the parts of one question should be answered at one place in the answer-book. One complete question should not be answered at different places in the answer-book.
किसी भी एक प्रश्न के अंतर्गत पूछे गए विभिन्न प्रश्नों के उत्तर, उत्तर-पुस्तिका में अलग-अलग स्थानों पर हल करने के बजाय एक ही स्थान पर हल करें ।

(3) This Paper is divided into 9 questions, candidates are required to attempt five questions, first question will be compulsory of nine marks comprising of six parts of short answer type with answer not exceeding half a page. In remaining part of paper two questions will be set from each unit with internal choice. Each question will carry six marks.
इस प्रश्न-पत्र में 9 प्रश्न हैं । विद्यार्थी को 5 प्रश्न हल करने हैं । प्रथम प्रश्न 9 अंकों का है जो अनिवार्य है जिसके 06 भाग हैं जिनका उत्तर आधे पृष्ठ से अधिक नहीं होना चाहिए । सभी 06 भाग समान अंक के हैं । प्रश्न-पत्र के शेष भाग में प्रत्येक यूनिट से दो प्रश्न हैं जिनमें से प्रत्येक यूनिट से एक प्रश्न हल करना है । इन सभी प्रश्नों के अंक समान हैं जो 6 अंकों के हैं ।

1. Answer the following questions. The answer to each question should not exceed half a page. $1\frac{1}{2} \times 6$

निम्नलिखित प्रश्नों के उत्तर दीजिए । प्रत्येक प्रश्न का हल आधे पृष्ठ से अधिक नहीं होना चाहिए ।

(a) Explain Physical importance of gradient of scalar field.
अदिश क्षेत्र की प्रवणता के भौतिक महत्त्व को समझाइये ।

(b) What is field ? How many type it is ? Give one example of each.
क्षेत्र किसे कहते हैं ? यह कितने प्रकार का होता है ? प्रत्येक का एक-एक उदाहरण दें ।

(c) What is electric dipole and dipole moment ?
विद्युत द्विध्रुव क्या है व द्विध्रुव आघूर्ण क्या है ?

(d) State the Ampere's law and explain it.
ऐम्पियर के नियम का कथन कीजिये तथा इसे समझाइये ।

(e) A radio wave of intensity 10 w/m^2 is reflected from a surface. Find the value of pressure exerted on the surface.
10 वाट/मी^{2} तीव्रता की एक रेडियो तरंग किसी पृष्ठ से परावर्तित होती है । पृष्ठ पर आरोपित दाब का मान ज्ञात कीजिए ।

(f) Explain Induced electric dipole and atomic polarizability.
प्रेरित वैद्युत द्विध्रुव तथा परमाण्विक ध्रुवणता को समझाइये ।

UNIT – I / इकाई – I

2. (a) Define divergence of a vector field. Deduce a relation of divergence of a vector field in Cartesian coordinates. Explain Physical significance. $1 + 2 + 1$
किसी सदिश क्षेत्र के डाइवर्जेन्स की परिभाषा दीजिए । कार्तीय निर्देशांकों में सदिश क्षेत्र के डाइवर्जेन्स के सम्बन्ध का व्यंजक प्राप्त कीजिए । इसका भौतिक महत्त्व समझाइये ।

(b) Prove that for a position vector $\vec{r} = i\hat{x} + \hat{j}y + \hat{k}z$ 2

$$\nabla (\ln r) = \frac{\vec{r}}{r^2}$$

सिद्ध कीजिए कि स्थिति सदिश $\vec{r} = i\hat{x} + \hat{j}y + \hat{k}z$ के लिए

$$\nabla (\ln r) = \frac{\vec{r}}{r^2}$$

OR/अथवा

3. (a) Define Curl of a vector field. Deduce a relation of curl of a vector field in cartesian coordinates. Explain Physical significance. 1 + 2 + 1

किसी सदिश क्षेत्र के कर्ल की परिभाषा दीजिए। कार्तीय निर्देशांकों में सदिश क्षेत्र के कर्ल का व्यंजक ज्ञात कीजिए। इसका भौतिक महत्व समझाइये।

(b) Prove that : $\text{Curl}\,\frac{\hat{k}}{r} = \frac{-\hat{i}y + \hat{j}x}{r^3}$ 2

सिद्ध कीजिए : $\text{Curl}\,\frac{\hat{k}}{r} = \frac{-\hat{i}y + \hat{j}x}{r^3}$

UNIT – II / इकाई – II

4. (a) Show that the potential at a distance R due to an arbitary charge distribution can be expressed as

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{P_0}{R} + \frac{P_1}{R^2} + \frac{P_2}{R^3} + \ldots\ldots\right)$$ 4

प्रदर्शित कीजिए कि स्वैच्छ आवेश वितरण से R दूरी पर स्थित बिन्दु पर विभव निम्न व्यंजक द्वारा दिया जाता है :

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{P_0}{R} + \frac{P_1}{R^2} + \frac{P_2}{R^3} + \ldots\ldots\right)$$

(b) Differentiate between insulators and dielectric materials. 2

कुचालक व परावैद्युत पदार्थ में अन्तर स्पष्ट कीजिए।

OR/अथवा

(a) Calculate the potential and electric field due to a polarised sphere at points inside and outside the sphere. 4

ध्रुवित गोले के कारण गोले के अन्दर व बाहर स्थित बिन्दुओं पर विभव एवं विद्युत क्षेत्र की गणना कीजिए।

(b) Find the value of atomic polarizability of hydrogen atom assuming it as a uniformily negatively charged sphere. 2

हाइड्रोजन परमाणु में ऋणावेश को गोले पर समान मात्रा में वितरित मानते हुए परमाण्विक ध्रुवणता ज्ञात कीजिए।

P.T.O.

UNIT - III / इकाई - III

5. (a) What do you mean by magnetic vector potential ? With the help of this, derive Biot-Savart's law.
चुम्बकीय सदिश विभव से आप क्या समझते हो ? उसकी सहायता से बायो-सावर्ट नियम व्युत्पन्न कीजिए। 4

(b) Compute angular frequency of a moving charge in perpendicular direction to the Uniform magnetic field.
एकसमान चु. क्षे. के लम्बवत् गतिशील आवेश की कोणीय आवृत्ति ज्ञात कीजिए। 2

OR/अथवा

(a) Using the relation $\vec{J}_m = (\vec{\nabla} \times \vec{M})$; establish the relation
(i) $\vec{B} = \mu_e (\vec{H} + \vec{M})$
(ii) $\mu = \mu_e (1 + \chi)$

$\vec{J}_m = (\vec{\nabla} \times \vec{M})$ का उपयोग करते हुए निम्न संबंधों को व्युत्पन्न कीजिए :
(i) $\vec{B} = \mu_e (\vec{H} + \vec{M})$
(ii) $\mu = \mu_e (1 + \chi)$ 4

(b) Magnetic susceptibility of paramagnetic substance at −253 °C is $\chi = 75 \times 10^{-4}$ then calculate the value at −173 °C temp.
किसी अनुचुम्बकीय पदार्थ के लिए −253 °C पर चुम्बकीय प्रवृत्ति $\chi = 75 \times 10^{-4}$ है, − 173 °C पर चुम्बकीय प्रवृत्ति का मान ज्ञात कीजिए। 2

UNIT - IV / इकाई - IV

6. (a) Describing Physical Laws related to electromagnetism. Obtain differential form of Maxwell's equations.
विद्युत-चुम्बकत्व से संबंधित भौतिक नियमों का उल्लेख करते हुए मैक्सवेल के समीकरणों को अवकल रूप में प्राप्त कीजिए। 4

(b) Explain Displacement current.
विस्थापन धारा की व्याख्या कीजिए। 2

OR/अथवा

(a) Prove that in Electromagnetic waves electric vector $\vec{E}$ and magnetic vector $\vec{B}$ are in same phase but in wave propagation they lie mutually perpendicular plans. 4
सिद्ध कीजिए कि वि.चु. तरंगों में विद्युत सदिश $\vec{E}$ तथा चु.सदिश $\vec{B}$ समान कला में परन्तु परस्पर लम्बवत् तल में तरंग संचरण करते हैं।

(b) What is Poynting Vector ? Write its value. 2
पायंटिंग सदिश क्या होता है ? इसका मान लिखिए।

2017-

PHYSICS

SECOND PAPER

(Electromagnetism)

Time Allowed: Three Hours **Maximum Marks:** 33

Answer All questions.

सभी प्रश्न हल कीजिये।

Write your roll number on question paper before start writing answers of questions.

प्रश्नों के उत्तर लिखने से पूर्व प्रश्न पत्र पर रोल नम्बर अवश्य लिखें।

1. Answer the following questions. The answer to each question should not exceed half a page. 1½×6=9

निम्नलिखित प्रश्नों के उत्तर दीजिये। प्रत्येक प्रश्न का हल आधे पेज से अधिक नहीं होना चाहिये।

(a) State Gauss's Law and Deduce its equation in the differential form. 1½

गाउस के नियम का उल्लेख करके अवकल रूप में उसके समीकरण का व्यंजक प्राप्त कीजिये।

(b) Assuming the electron being an uniformly charged sphere. Calculate the classical radius of an electron. 1½

इलेक्ट्रॉन को समआवेशित गोले के रूप में मानकर इलेक्ट्रॉन की चिरसम्मत त्रिज्या की गणना कीजिये।

(c) Derive Laplace's and Poisson's equations starting from the differential form of Gauss's Law. 1½

गाउस के नियम के अवकल रूप का उपयोग करते हुये लाप्लास तथा प्वासों के समीकरण ज्ञात कीजिये।

(d) What is the significance of negative sign in the relation $dU = -q_0 \vec{E}.\vec{dr}$?1½

संबंध $dU = -q_0 \vec{E}.\vec{dr}$ में ऋणात्मक चिन्ह का क्या महत्व है?

(e) Write the relation between electrical susceptibility and atomic polarizability or Clausius Mossotti relation. 1½

विद्युत प्रवृत्ति एवं परमाणविक ध्रुवणता में संबंध या क्लासियस–मोसोटी संबंध को लिखिये।

(f) Define Bohr magneton. Find its value.

बोर मेगनेटॉन को परिभाषित कीजिये। इसका मान ज्ञात कीजिये।

2. (a) Prove that the curl of a conservative field is zero 3

सिद्ध कीजिये कि संरक्षी क्षेत्र का कर्ल सदैव शून्य होता है।

(b) Show that $\vec{\nabla} \times \vec{E} = 0$ 3

Where $\vec{E}$ is Intensity of Electric field.

सिद्ध कीजिये कि $\vec{\nabla} \times \vec{E} = 0$

जहाँ $\vec{E}$ विद्युत क्षेत्र की तीव्रता है।

OR / अथवा

Prove the Identity:

$$\nabla \times \nabla \times \vec{E} = \nabla\left(\nabla.\vec{E}\right) - \nabla^2 \vec{E}$$

i.e. curl curl $\vec{E}$ = grad div $\vec{E} - \nabla^2 \vec{E}$

निम्न सदिश सम्मिका को सिद्ध कीजिये:

$$\nabla \times \nabla \times \vec{E} = \nabla\left(\nabla.\vec{E}\right) - \nabla^2 \vec{E}$$

अर्थात् curl curl $\vec{E}$ grad div $\vec{E} - \nabla^2 \vec{E}$

3. (a) Prove that the magnitude of the electric field of a charge moving with constant velocity is: 3

सिद्ध कीजिये कि नियत वेग से गतिशील आवेश के विद्युत क्षेत्र का मान होता है:

$$E_{(r,\theta)} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^{12}} \frac{\left(1 - \frac{V^2}{C^2}\right)}{\left(1 - \frac{V^2}{C^2}\sin^2\theta^1\right)^{3/2}}$$

Where the symbols have their usual meanings.

जहाँ संकेतों का सामान्य अर्थ है।

(b) An electric field produced by stationary charge in a system S is given by:

$$\vec{E} = \left(4\hat{i} + 5\hat{j} + 9\hat{k}\right) V/cm$$

Deduce the field in a frame S' moving with velocity 0.6 C along common x-ais.

UNIT - II / इकाई - II

3. (a) Find the expression for Resolving Power of a plane Transmission Grating.2
समतल पारगमन ग्रेटिंग की विभेदन क्षमता का सूत्र ज्ञात कीजिये।

(b) Describe the Fresnel's Diffraction produced due to a circular aperture for axial and non-axial points with necessary theory. 2+2
वृत्ताकार द्वारक द्वारा उत्पन्न फ्रेनेल विवर्तन का अक्षीय एवं अनाक्षीय बिन्दुओं के लिये आवश्यक सिद्धान्त सहित वर्णन कीजिये।

OR / अथवा

In double slit Fraunhoffer Diffraction pattern discuss the effect of: 2½+½+½+½
(i) Width of slit
(ii) Gap between slit .
(iii) Wavelength of light
द्विरेखाछिद्र के फ्राउनहॉफर विवर्तन प्रतिरूप पर:
(i) रेखा छिद्र की चौड़ाई
(ii) रेखाछिद्रों के बीच का अन्तराल तथा
(iii) प्रकाश के तरंगदैर्ध्य का क्या प्रभाव पड़ता है वर्णन कीजिये।

UNIT - III / इकाई - III

4. (a) Write the applications of Holography. 2
होलोग्राफी के अनुप्रयोग लिखिये।

(b) Explain the analysis of plane, circularly and elliptically polarised light. 1½+1½+1
समतल, वृत्त तथा दीर्घवृत्त ध्रुवित प्रकाश के विश्लेषण को समझाइये।

OR / अथवा

Explain the construction and working of Ruby Laser. 2+2
रूबी लेसर की संरचना एवं कार्यविधि को समझाइये।

UNIT - IV / इकाई - IV

5. (a) Analyse square wave using Fourier Theorem. 3
फोरियर प्रमेय की सहायता से वर्गाकार तरंगों का विश्लेषण कीजिये।

(b) Prove that the velocity of longitudinal wave in a solid rod depend upon the Young's Modulus and density of material. 2½+½
सिद्ध कीजिये कि किसी ठोस छड़ में अनुदैर्ध्य तरंग का वेग उस पदार्थ के यंग प्रत्यास्थता गुणांक एवं घनत्व पर निर्भर करता है।

OR / अथवा

Derive an expression for the velocity of longitudinal wave in gas and explain Laplace correction. 2+1
गैसों में अनुदैर्ध्य तरंगों के वेग का व्यंजक ज्ञात कीजिये तथा लाप्लास संशोधन की विवेचना कीजिये।

फ्रेम S में स्थिर आवेश से उत्पन्न विद्युत क्षेत्र निम्न है:

$$\vec{E} = \left(4\hat{i} + 5\hat{j} + 9\hat{k}\right) V/cm$$

x- अक्ष के अनुदिश $0.6\,C$ वेग से गतिमान फ्रेम S' में विद्युत क्षेत्र के मान की गणना कीजिये।

OR / अथवा

Find electric field due to dipole at a point (r,θ). Show that electric field decreases on going from axial to equatiorial position.

किसी ध्रुवीय बिन्दु (r,θ) पर द्विध्रुव के कारण विद्युत क्षेत्र की तीव्रता की गणना कीजिये। दर्शाइये कि बिन्दु के अक्षीय से निरक्षीय स्थिति में परिवर्तन से विद्युत क्षेत्र की तीव्रता का मान घटता है।

4. (a) The electric field intensity between the plates of a parallel plate capacitor without dielectric is $\vec{E_0}$. A sphere of dielectric k is placed between the plates. If $\vec{p}$ is the density of polarization of the sphere, show that it is expressed as: 3

समान्तर प्लेट संधारित्र की प्लेटों के बीच माध्यम की अनुपस्थिति में विद्युत क्षेत्र की तीव्रता $\vec{E_0}$ है। एक गोला जिसका परावैद्युतांक k है, को प्लेटों के बीच रखा जाता है। यदि गोले के ध्रुवण का घनत्व $\vec{p}$ है, तो सिद्ध कीजिये कि:

$$\vec{P} = 3\epsilon_0\left(\frac{k-1}{k+2}\right)\vec{E_0}$$

(b) A dielectric sphere is placed in a uniform electric field. If the sphere is uniformly polarized and the field inside it is just half the externally applied field. Calculate the dielectric constant of the sphere. Also find the electric susceptibility. 3

एक परावैद्युत गोले को एक समान विद्युत क्षेत्र में रखा गया है। यदि गोला एक समान ध्रुवित है तथा इसके अन्दर क्षेत्र बाह्य आरोपित क्षेत्र का आधा है तो गोले के पराविद्युतांक की गणना कीजिए। विद्युत प्रवृत्ति का मान भी ज्ञात कीजिए।

OR / अथवा

Derive the relation $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$ where the symbols have usual meaning. 3

सिद्ध करो $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$ जहाँ संकेतों के सामान्य अर्थ है।

5. (a) Using Biot - Savart's Law show that divergence of Magnetic Induction $\vec{B}$ is zero. 3

बायो–सावर्ट नियम को प्रयुक्त करके यह सिद्ध कीजिये कि चुम्बकीय प्रेरण $\vec{B}$ का डाइवर्जेन्स शून्य होता है।

2016-

PHYSICS

SECOND PAPER

(Electromagnetism)

Time Allowed : Three Hours **Maximum Marks :33**

1. Answer the following questions. The answer to each question should not exceed half a page.
निम्नलिखित प्रश्नों के उत्तर दीजिये। प्रत्येक प्रश्न का हल आधे पेज से अधिक नहीं होना चाहिए। 1½×6=9

(a) Show that the Gauss law can be derived from Coulomb's law.
प्रदर्शित कीजिये कि कूलॉम के नियम से गॉस का नियम व्युत्पन्न किया जा सकता है।

(b) Three charges $2q$, $-q$ and $-q$ are arranged on the vertices of an equilateral triangle. Find the dipole moment of the combination.
एक समबाहु त्रिभुज के तीन शीर्षों पर तीन आवेश $2q$, $-q$ व $-q$ रखे गये हैं। इस संयोजन का द्विध्रुव आघूर्ण ज्ञात कीजिये।

(c) Explain free and bound charges.
मुक्त तथा बद्ध आवेशों को समझाइये।

(d) Explain the Ampere's circuital law.
ऐम्पियर का परिपथीय नियम समझाइये।

(e) If $\phi(x,y,z) = x^2 + y^2 + z^2$ then find out grad ϕ at the point (1,2,3).
यदि $\phi(x,y,z) = x^2 + y^2 + z^2$ है तो grad ϕ का मान बिन्दु (1,2,3) पर ज्ञात कीजिये।

(f) Define orbital gyromagnetic ration and Bohr magneton. Calculate the value of Bohr magneton.
कक्षीय घूर्ण-चुम्बकीय निष्पत्ति तथा बोर मैग्नेटॉन को परिभाषित कीजिये। बोर मैग्नेटॉन के मान की गणना कीजिये।

2.(a) Define curl of a vector. Derive an expression for the curl of a vector in cartesian coordinates.
किसी सदिश के कर्ल को परिभाषित कीजिये। किसी सदिश के कर्ल के व्यंजक को कार्तीय निर्देशांकों के रूप में व्युत्पन्न कीजिये। 3

(b) Determine the curl and divergence of a vector field given by-
दिये हुए सदिश क्षेत्र के कर्ल तथा डाइवर्जन्स ज्ञात कीजिये- 3

$\vec{E} = i(x+y) + j(x+y) - k2z$ Or $\vec{E} = iy + j(x^2 + y^2) + kz(x+y)$

3.(a) Find out potential due to a uniformly charged spherical shell at any external and internal point of a spherical shell.
एकसमान आवेशित गोलीय कोश के कारण गोलीय कोश के बाहर व अंदर किसी बिन्दु पर विभव का मान ज्ञात कीजिये। 3

(b) An electron of 30 BeV energy passes near the nucleus of an atom at a distance of 10^{-7} cm. Calculate the maximum value of the electric field due to the moving electron at the nucleus at the atom. The rest mass energy of the electron is 0.5 MeV.
एक 30 BeV ऊर्जा का इलेक्ट्रॉन किसी परमाणु के नाभिक से 10^{-7} सेमी. की दूरी से गुजरता है। इस गतिमान इलेक्ट्रॉन के कारण परमाणु के नाभिक पर उत्पन्न अधिकतम विद्युत क्षेत्र की गणना कीजिये। इलेक्ट्रॉन की विराम द्रव्यमान ऊर्जा 0.5MeV है। 3

 Or (अथवा)

Using Laplace equation find the potential difference and electric field between the two parallel plates charged to potentials ϕ_1 and ϕ_2.

लाप्लास समीकरण का उपयोग करते हुए किन्हीं ϕ_1 तथा ϕ_2 विभव से आवेशित दो समान्तर प्लेटों के मध्य अन्तराल में विभव तथा विद्युत क्षेत्र की तीव्रता ज्ञात कीजिये। 3

UNIT II (इकाई II)

4.(a) Show that the potential at a distance R due to an arbitrary charge distribution can be expressed as-

प्रदर्शित कीजिये कि एक स्वैच्छिक आवेश वितरण से R दूरी पर स्थित बिन्दु पर विभव को निम्नलिखित व्यंजक द्वारा दिया जाता है-

$$\phi = \frac{1}{4\pi\epsilon_0}\left(\frac{p_0}{4\pi\epsilon R} + \frac{p_1}{4\pi\epsilon R^2} + \frac{p_n}{4\pi\epsilon R^3} + \ldots\ldots\ldots\right)$$ 3

(b) Explain electric polarization, electric susceptibility and electric displacement vector.

विद्युत ध्रुवण, विद्युत प्रवृत्ति तथा विद्युत विस्थापन सदिश को समझाइये। 3

Or (अथवा)

Find the value of atomic polarisability of hydrogen atom by assuming it as a uniformly negative charged sphere.

हाइड्रोजन परमाणु में ऋण आवेश गोले पर समान मात्रा में वितरित मानते हुए इसकी परमाणुविक ध्रुवणता ज्ञात कीजिये।

5.(a) What do you understand by magnetic vector potential? Derive Biot-Savart's law using magnetic vector potential.

चुम्बकीय सदिश विभव से आप क्या समझते हैं? इसकी सहायता से बिओ-सार्वत नियम व्युत्पन्न कीजिये। 3

(b) Prove that $J_m = \vec{\nabla} \times \vec{m}$, where symbols have their usual meaning.

सिद्ध कीजिये $J_m = \vec{\nabla} \times \vec{m}$, जहाँ प्रतीकों का सामान्य अर्थ है। 3

Or (अथवा)

In hydrogen atom the electron is revolving around the nucleus in a circular orbit of radius 5×10^{-11} m. Calculate the orbital magnetic dipole moment associated with the electron.

हाइड्रोजन परमाणु में इलेक्ट्रॉन नाभिक के चारों ओर 5×10^{-11} मीटर की त्रिज्या के वृत्ताकार कक्ष में चक्कर लगा रहा है। इस इलेक्ट्रॉन से संबंधित कक्षीय चुम्बकीय द्विध्रुव आघूर्ण की गणना कीजिये। 3