Course title: General Physics II

Course code: PHY 102

Course lecturer: FAREMI .A.A

Topics: Maxwell’s Equations, Electromagnetic Oscillations and Waves; Applications

**Introduction**

Maxwell’s Equations are four of the most influential equations in science. These equations can be expressed in both integral and differential forms. Gauss’s law for electric fields, Gauss’s law for magnetic fields, Faraday’s law, and the Ampere–Maxwell law give elegant explanations of these equations. These equations can be combined to produce the wave equation, the basis for the electromagnetic theory of light

**GAUSS’S LAW FOR ELECTRIC FIELDS**

** (1)**

Equation 1 holds for Gauss’s law for electric fields in integral form.

*Gauss’s law for electric fields state that Electric charge produces an electric field, and the flux of that field passing through any closed surface is proportional to the total charge contained within that surface divided by a constant called the permittivity of free space*

** (2)** Equation 2 holds for Gauss’s law for electric fields in differential form.

*State that the electric field produced by electric charge diverges from positive charge and converges upon negative charge*

**= del** meaning that partial derivative of electric field

There are three basic types of problems that you can solve using Gauss’s law

(1) Given information about a distribution of electric charge, you can find the electric flux through a surface enclosing that charge.

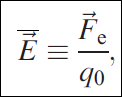
(2) Given information about the electric flux through a closed surface, you can find the total electric charge enclosed by that surface

(3) In applying Gauss’s law, it is often helpful to be able to visualize the electric field in the vicinity of a charged object.

To understand Gauss’s law, you first have to understand the concept of the electric field, surface area, enclosed charge and permittivity of free space.

**What is an electric field?**

An electric field is the electrical force per unit charge exerted on a charged object.



E is a vector quantity whose units is Newton’s per coulomb (N/C)

**Surface area** establishes a relationship between electric field and electric flux

 Electric field is uniform and perpendicular to surface area.

 Electric field is non-uniform but perpendicular to surface area.

**Enclosed charge**: this is the charge within the closed surface over which the flux is determined. Simply put, it is because any charge located outside the surface produces an equal amount of inward (negative) flux and outward (positive) flux, so the net contribution to the flux through the surface must be zero.

The charges enclosed by a surface can be determined by considering their dimension

**Total enclosed charge = ** this expression holds for discrete charges. This equation is applicable when there are many enclosed charges.

**Enclosed charge = ** where λ is linear charge density in C/m and

L= enclosed length of charged line. This equation is applicable to one dimensional enclosed charge.

**Enclosed charge = ** where σ is area charge density in C/m2 and

A= enclosed area of charged surface. This equation is applicable to two dimensional enclosed charges.

**Enclosed charge = ** where ρ is volume charge density in C/m3 and

V= enclosed portion of charged volume. This equation is applicable to three dimensional enclosed charges.

**Permittivity of free space (ε):** The constant of proportionality between the electric flux on the left side of Gauss’s law and the enclosed charge on the right side is ε, the permittivity of free space. The permittivity of a material determines its response to an applied electric field. The value of the vacuum permittivity in SI units is approximately 8.85 ˣ10-12 coulombs per volt-meter (C/Vm); you will sometimes see the units of permittivity given as farads per meter (F/m), or, more fundamentally, (C2­s2/kg m3).

Problems

1. Five point charges are enclosed in a cylindrical surface S. If the values of the charges are q1= +3nC, q2= -2nC, q3= +2nC, q4= +4nC and q5= -1nC, find the total flux through S.
2. A line charge with linear charge density λ=10-12 C/m passes through the center of a sphere. If the flux through the surface of the sphere is 1.13ˣ10-3 Vm, what is the radius R of the sphere?

**SOLUTION TO ONE**

Recall gauss’s law

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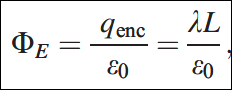
Since we have many enclosed charges, we apply discrete charge formular

That is **Total enclosed charge = =3+(-2)+2+4+(-1)=6C**

Remember permittivity value 8.85E-12

**** =****

**SOLUTION TO TWO**

****

Since L is twice the radius of the sphere that is L=2R

**=**=

**GAUSS’S LAW FOR MAGNETIC FIELDS**

** (3)**

Equation 1 holds for Gauss’s law for magnetic fields in integral form

**Gauss’s law for magnetic fields** state that the total magnetic flux passing through any closed surface is zero.

This equation holds provided there is no charge density (p). But if there is charge density, equation 1 can be re-written as: ****

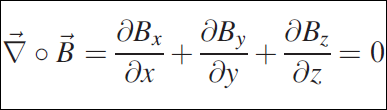
** (4)**

Equation 2 holds for Gauss’s law for magnetic fields in differential form

State that the divergence of the magnetic field at any point is zero

To understand Gauss’s law, you first have to understand the concept of the magnetic field and surface area.

**= del** meaning that partial derivative of magnetic field



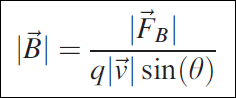
**The magnetic field**

Magnetic field can be defined as the magnetic force experienced by a moving charged particle. As you may recall, charged particles experience magnetic force only if they are in motion with respect to the magnetic field, as shown by the Lorentz equation for magnetic force:

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Recall vector cross-product

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**** holds for magnetic flux

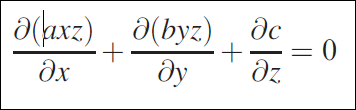
**PROBLEM**

A magnetic field is given by the expression



Show that a=- b

**Solution**





Then, a=-b

**FARADAY’S LAW OF INDUCTION**

**** (5)

Equation 5 holds for Faraday’s Law of induction in integral form

****

The minus sign mean an induced emf oppose the changing of flux

FARADAY’S LAW state that changing magnetic flux through a surface induces an **emf** in any boundary path of that surface, and changing magnetic field induces a circulating electric field. (summary: the change in magnetic flux induces an emf and the change in magnetic field induces electric field.)

**** (6)

This equation show the differential form of Faraday’s law

State that a circulating electric field is produced by a magnetic field that changes

with time.

The importance of faraday’s law

1. Given information about the changing magnetic flux, find the induced emf.
2. Given the induced **emf** on a specified path, determine the rate of change of the magnetic field magnitude or direction or the area bounded by the path.

**Problem**

The magnetic flux through a loop increases according to the relation ****in milliweber and in seconds. Find the magnitude of the emf induced in the loop when t=2seconds.

**Solution**

****

****

**AMPERE’S LAW FOR ELECTRICITY**

**** (7)

Equation 7 holds for Ampere’s law for electricity in integral form

**** (8)

Equation 7 holds for Ampere’s law for electricity in differential form

**AMPERE’S LAW FOR ELECTRICITY state** that the line integral of magnetic field around a closed path is equal to the net current enclosed multiply by the permeability of material.

It should be noted that from Maxwell equation, we can derive wave equation

**** (9)

Equation 9 holds for wave equation for electric field

**** (10)

Equation 9 holds for wave equation for magnetic field

**ELECTROMAGNETIC OSCILLATIONS AND WAVES**

What is electromagnetism? Electromagnetism is the study of electric field and magnetic field interaction or different facets between electricity and magnetism.

recall that a static distribution of charges produces an electric field while charges in *motion* (an electrical current) produce a magnetic field. A *changing* magnetic field produces an electric field, moving charges.

Similarity and difference between Electric and Magnetic fields

1. Electric and Magnetic fields produce forces on charges
2. Both electric and magnetic fields can transport energy
3. Electric field energy used in electrical circuits & released in lightning
4. Magnetic field carries energy through transformer

An *accelerating* charge produces electromagnetic waves (radiation)

Classification of electromagnetic radiation

* AM and FM radio waves (including TV signals)
* Microwaves
* Infrared radiation
* Light
* X-rays
* Gamma rays

These different types of radiation can be differentiated using their respective wavelength and frequency.

The Electromagnetic Spectrum is the relationship between frequency, speed and wavelength



The frequency of electromagnetic radiation such as a radio wave determines its propagation characteristics through various media.

Radio waves are classified into Amplitude Modulation (AM) and Frequency Modulation (FM):

The difference between AM and FM:

1. Amplitude Modulation (AM) uses changes in the signal *strength* to convey information while Frequency Modulation (FM) uses changes in the wave’s *frequency* to convey information.
2. The frequency of FM is lesser than AM
3. FM is superior in immunity to environmental influences than AM
4. Converting back to sound, FM is more sophisticated than AM.

**What does electromagnetism have to do with waves?**

Both can be described by mathematical functions that are oscillation functions of space, and oscillating functions of time. They can both be described mathematically by spatially varying and time varying (scalar or vector) fields.

**Oscillation**

Oscillation shows how waves, electricity and magnetism are related. When object moves back and forth we say it is oscillating. The motion of such an object is called oscillatory or periodic motion. There are three properties of oscillatory motion which are amplitude define as a maximum displacement, period defined as time taken to complete one oscillation and frequency define as number of oscillation complete in one second.

**** (1)

For one revolution, distance is ****

From this you can find angular velocity, period and frequency

**Wave**

Wave is a disturbance from equilibrium that travels from one region of space to another. There are two types of wave namely mechanical wave which require a medium or material for propagation. Under this type of wave, we have transverse wave which is the one in which the particle displacement is perpendicular to the direction of propagation of wave and longitudinal wave in the particle displacement is parallel to the direction of wave propagation. And electromagnetic wave which require no medium for propagation.

**THANKS FOR LISTENING**