Observation on the Evaluation of Electromagnetic Theories: A Literature Review (LR)

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Abstract
In the last decade, the classical theory of electromagnetism deals with electric and magnetic fields and their interaction with each other and with charges and currents. This usage of Electromagnetic Theories has been increased all around the world. One of the important Electromagnetic Theories. Therefore, Electromagnetic Theories has an important issue in some products and materials in the industrial world. Consequently, this research study aimed to answer the two research questions RQ1: Why Electromagnetic Theories is an important in modern and traditional methods usage. RQ2: What is the functions of the Electromagnetic Theories obtained from the Electromagnetic Theories. In addition, the result of this observational research remains presented in the Table.1.1. schematic Electromagnetic Theories. The diverse types of Electromagnetic Theories. This observational study has collected the required information from the electronic database based on more than one hundred references that is present in Table.1.2. A fundamental concepts in electromagnetic theory and outlines some basics of numerical modeling. Additionally, the results of this beneficial study are important for several domains such as the industrial world, the educational world, as well as the scientific world in addition to researchers who aimed for some investigations outcome based on Electromagnetic Theories.

Keywords: *Electromagnetic Theories, Electromagnetism, electrodynamics.*

1.1. Introduction

Nowadays, Electromagnetism is a branch of physics involving the study of the electromagnetic force, a type of physical interaction that occurs between electrically charged particles (Slater and Frank, 1969); (Bossavit, 1998). The electromagnetic force is carried by electromagnetic fields composed of electric fields and magnetic fields, and it is responsible for electromagnetic radiation such as light (Kruchinin, 2017). It is one of the four fundamental interactions or forces in nature, together with the strong interaction, the weak interaction (Bossavit, 1998), and gravitation. At high energy the weak force and electromagnetic force are unified as a single electroweak force.

Electromagnetic phenomena are defined in terms of the electromagnetic force, sometimes called the Lorentz force, which includes both electricity and magnetism as different manifestations of the same phenomenon (Kruchinin, 2017). The electromagnetic force plays a major role in determining the internal properties of most objects encountered in daily life. The electromagnetic attraction between atomic nuclei and their orbital electrons holds atoms together. Electromagnetic forces are responsible for the chemical bonds between atoms which create molecules, and intermolecular forces (Bossavit, 1998). The electromagnetic force governs all chemical processes, which arise from interactions between the electrons of neighboring atoms. There are numerous mathematical descriptions of the electromagnetic field. In classical electrodynamics, electric fields are described as electric potential and electric current. In Faraday's law, magnetic fields are associated with electromagnetic induction and magnetism, and Maxwell's equations describe how electric and magnetic fields are generated and altered by each other and by charges and currents. The theoretical implications of electromagnetism, particularly the establishment of the speed of light based on properties of the "medium" of propagation (permeability and permittivity), led to the development of special relativity by Albert Einstein in 1905.

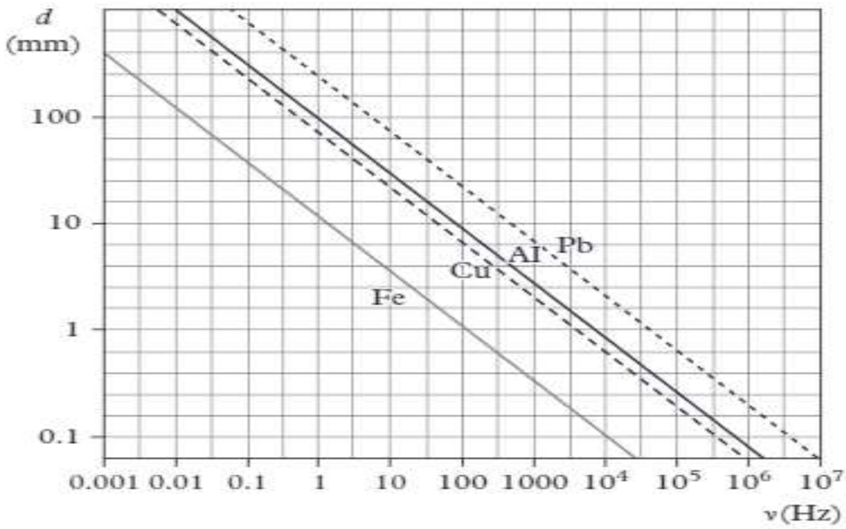

Figure. 1.1. *Skin depth for a few metals.*

Originally, electricity and magnetism were considered to be two separate forces. This view changed with the publication of James Clerk Maxwell's 1873 A Treatise on Electricity and Magnetism in which the interactions of positive and negative charges were shown to be mediated by one force (Haupt, 1995); (D'Azevedo et al., 2020); (Bao et al., 2020); (Ji et al., 2020); (Hyman et al., 2020); (Hagstrom and Lagrone, 2020). There are four main effects resulting from these interactions, all of which have been clearly demonstrated by experiments:

1. Electric charges attract or repel one another with a force inversely proportional to the square of the distance between them: unlike charges attract, like ones repel.
2. Magnetic poles has attracted one another in a manner similar to positive and negative charges and always exist as pairs: every North Pole is yoked to a south pole.
3. An electric current inside a wire creates a corresponding circumferential magnetic field outside the wire. Its direction (clockwise or counter-clockwise) depends on the direction of the current in the wire (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).
4. A current is induced in a loop of wire when it is moved toward or away from a magnetic field, or a magnet is moved towards or away from it; the direction of current depends on that of the movement (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).

Recently, while preparing for an evening lecture on (1820); (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), Hans Christian Ørsted made a surprising observation. As he was setting up his materials, he noticed a compass needle deflected away from magnetic north when the electric current from the battery he was using was switched on and off. This deflection convinced him that magnetic fields radiate from all sides of a wire carrying an electric current, just as light and heat do, and that it confirmed a direct relationship between electricity and magnetism. His findings resulted in intensive research throughout the scientific community in electrodynamics. They influenced French physicist André-Marie Ampère's developments of a single mathematical form to represent the magnetic forces between current-carrying conductors. Ørsted's discovery also represented a major step toward a unified concept of energy.

This unification, which was observed by Michael Faraday, extended by Maxwell, and partially reformulated by Oliver Heaviside and Heinrich Hertz, is one of the key accomplishments of 19th-century mathematical physics. It has had far-reaching consequences, one of which was the understanding of the nature of light. Unlike what was proposed by the electromagnetic theory of that time (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), light and other electromagnetic waves are at present seen as taking the form of quantized, self-propagating oscillatory electromagnetic field disturbances called photons. Different frequencies of oscillation give rise to the different forms of electromagnetic radiation, from radio waves at the lowest frequencies, to visible light at intermediate frequencies, to gamma rays at the highest frequencies.
A tradesman at Wakefield in Yorkshire, having put up a great number of knives and forks in a large box ... and having placed the box in the corner of a large room, there happened a sudden storm of thunder, lightning (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), &c. ... The owner emptying the box on a counter where some nails lay, the persons who took up the knives that lay on the nails observed that the knives took up the nails. On this the whole number was tried, and found to do the same, and that, to such a degree as to take up large nails, packing needles, and other iron things of considerable weight (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).

Fundamental forces
The electromagnetic force is one of the four known fundamental forces. The other fundamental forces are as following:

- The weak nuclear force, which binds to all known particles in the Standard Model, and causes certain forms of radioactive decay.
- In particle physics though, the electroweak interaction is the unified description of two of the four known fundamental interactions of nature: electromagnetism and the weak interaction;
- The strong nuclear force, which binds quarks to form nucleons, and binds nucleons to form nuclei the gravitational force.

All other forces, for instance, friction, and contact forces are derived from these four fundamental forces.
The electromagnetic force is responsible for practically all phenomena one encounters in daily life above the nuclear scale, with the exception of gravity. All the forces involved in interactions between atoms can be explained by the electromagnetic force acting between the electrically charged atomic nuclei and electrons of the atoms. Electromagnetic forces also explain how these particles carry momentum by their movement. This includes the forces we experience in "pushing" or "pulling" ordinary material objects, which result from the intermolecular forces that act between the individual molecules in our bodies and those in the objects. The electromagnetic force is also involved in all forms of chemical phenomena.

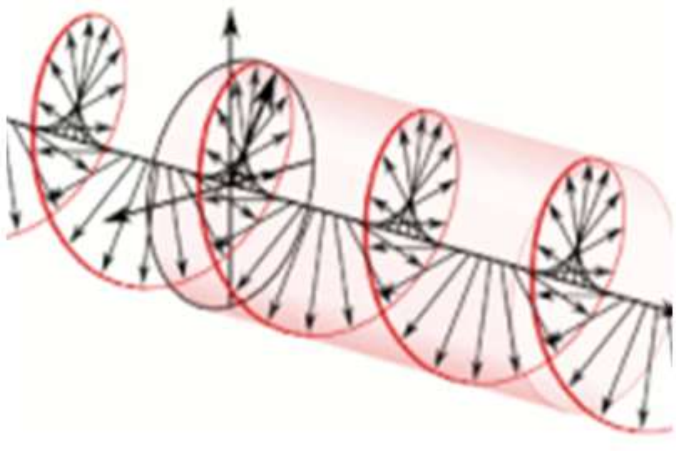

Figure.1.2. *Representation of the electric field vector of a wave of circularly polarized electromagnetic radiation.*

The electromagnetic force is responsible for practically all phenomena one encounters in daily life above the nuclear scale, with the exception of gravity (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998). Roughly speaking, all the forces involved in interactions between atoms can be explained by the electromagnetic force acting between the electrically charged atomic nuclei and electrons of the atoms. Electromagnetic forces also explain how these particles carry momentum by their movement. This includes the forces we experience in "pushing" or "pulling" ordinary material objects, which result from the intermolecular forces that act between the individual molecules in our bodies and those in the objects. The electromagnetic force is also involved in all forms of chemical phenomena (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).

A necessary part of understanding the intra-atomic and intermolecular forces is the effective force generated by the momentum of the electrons' movement, such that as electrons move between interacting atoms they carry momentum with them. As a collection of electrons becomes more confined, their minimum momentum necessarily increases due to the Pauli Exclusion Principle. The behavior of matter at the molecular scale including its density is determined by the balance between the electromagnetic force and the force generated by the exchange of momentum carried by the electrons themselves.

The relationship between classical electrodynamics and a theory of electromagnetism

In 1600, William Gilbert proposed, in his De Magnete, that electricity and magnetism, while both capable of causing attraction and repulsion of objects, were distinct effects. Mariners had noticed that lightning strikes had the ability to disturb a compass needle (Kruchinin, 2017). The link between lightning and electricity was not confirmed until Benjamin Franklin's proposed experiments in 1752. One of the first to discover and publish a link between man-made electric current and magnetism was Romagnosi, who in 1802 noticed that connecting a wire across a voltaic pile deflected a nearby compass needle. However, the effect did not become widely known until (1820) (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), when Ørsted performed a similar experiment. Ørsted's work influenced Ampère to produce a theory of electromagnetism that set the subject on a mathematical foundation (Garg, 2012); (Fritzsche et al., 2018); (Gomez-Tames et al., 2017). A theory of electromagnetism, known as classical electromagnetism, was developed by various physicists during the period between 1820 and

1873 when it culminated in the publication of a treatise by James Clerk Maxwell, which unified the preceding developments into a single theory and discovered the electromagnetic nature of light. In classical electromagnetism, the behavior of the electromagnetic field is described by a set of equations known as Maxwell's equations, and the electromagnetic force is given by the Lorentz force law. One of the peculiarities of classical electromagnetism is that it is difficult to reconcile with classical mechanics (Fritzsche et al., 2018); (Gomez-Tames et al., 2017), but it is compatible with special relativity. According to Maxwell's equations, the speed of light in a vacuum is a universal constant that is dependent only on the electrical permittivity and magnetic permeability of free space (Haupt, 1995); (D’Azevedo et al., 2020); (Bao et al., 2020); (Ji et al., 2020); (Hyman et al., 2020); (Hagstrom and Lagrone, 2020). This paper has been defined three-section, section one include Introduction, section two include research questions, section three connected to Literature review.

1.2. Aim and objective of the study

This study aimed for the following points

- To understand *Electromagnetic Theories* which were utilized as well as why the utilizes of *Electromagnetic Theories* industrialized over time.
- To understand the usage according to differ period amongst modern backgrounds.
- To know the common Electromagnetic Theories and it is important in industries.
- To observe some Electromagnetic Theories based on the objective effect of physics domain.

1.3. The research signification

This observational study aimed to review *Electromagnetic Theories* all over the world; also, the important and alternatives modern usage which is related and has been reported from 2000 years ago specifically in China. Furthermore, not only Electromagnetic Theories used for functional Theories; it is also used in the manufacturing world as a source of preparing some techniques. Therefore, it is widely used in manufacturing and research domain.

1.4. Research questions

- **RQ$_1$:** Why *Electromagnetic Theories* is an important in manufacturing usage?

Rational$_1$: Because *Electromagnetic Theories* has contains a huge number of Electromagnetic Theories that presented in table 1.2.

- **RQ$_2$:** What is the Electromagnetic Theories that has impacted some manufacturing domains?

Rational$_2$: there are several studies that concerned about Electromagnetic Theories and the effect of the Electromagnetic Theories on physics manufacturing, Electromagnetic manufacturing domains, Electrical manufacturing domains, which has been reviewed in Table 1.2.

- **RQ$_{2-1}$:** What is functions of Electrical manufacturing domains has been obtained from *Electromagnetic Theories*?

Rational$_{2-1}$: there are many researches that concerned about Electromagnetic Theories on physics manufacturing, of *Electromagnetic Theories* effect of Electromagnetic Theories and the effect of the Electromagnetic Theories on physics manufacturing (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), Electromagnetic manufacturing domains, Electrical manufacturing domains, which has been reviewed in Table 1.2.

1.5. The research methods

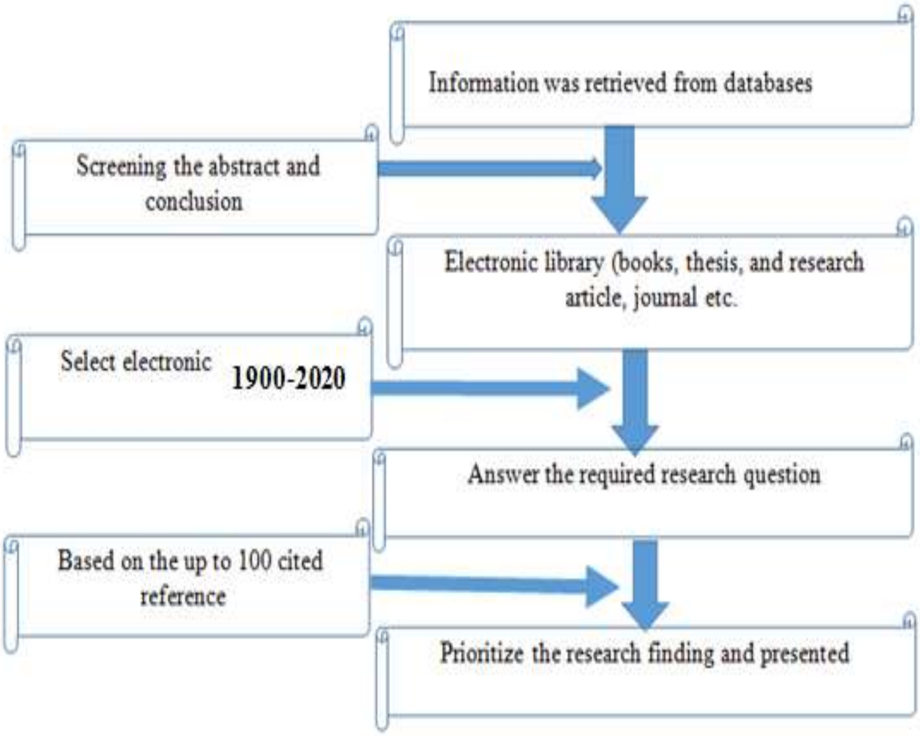

Figure. 1. 3. The research methods that used in this research

1.6. Literature review

- **History of electromagnetic theory**

The history of electromagnetic theory begins with ancient measures to understand atmospheric electricity, in particular lightning. People then had little understanding of electricity, and were unable to explain the phenomena. Scientific understanding into the nature of electricity grew throughout the eighteenth and nineteenth centuries through the work of researchers such as Coulomb, Ampère, Faraday and Maxwell (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).

In the 19th century it had become clear that electricity and magnetism were related, and their theories were unified: wherever charges are in motion electric current results, and magnetism is due to electric current. The source for electric field is electric charge, whereas that for magnetic field is electric current (charges in motion). The knowledge of static electricity dates back to the earliest civilizations, but for millennia it remained merely an interesting and mystifying phenomenon, without a theory to explain its behavior and often confused with magnetism. The ancients were acquainted with rather curious properties possessed by two minerals

- **List of electromagnetism equations**

Electromagnetic units are part of a system of electrical units based primarily upon the magnetic properties of electric currents (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998), the fundamental SI unit being the ampere. The units are:

- Ampere (electric current)
- Coulomb (electric charge)
- Farad (capacitance)
- Henry (inductance)
- Ohm (resistance)
- Siemens (conductance)
- tesla (magnetic flux density)
- volt (electric potential)
- Watt (power)
- Weber (magnetic flux)

In the electromagnetic cgs system, electric current is a fundamental quantity defined via Ampère's law and takes the permeability as a dimensionless quantity relative permeability whose value in a vacuum is unity (Bossavit, 1998). As a consequence, the square of the speed of light appears explicitly in some of the equations interrelating quantities in this system (Garg, 2012); (Fritzsche et al., 2018); (Gomez-Tames et al., 2017); (Gaynutdinov and Chermoshentsev, 2016).

Haupt, (1995) Electromagnetics is fundamental in electrical and electronic engineering. Electromagnetic theory based on Maxwell's equations establishes the basic principle of electrical and electronic circuits over the entire frequency spectrum from dc to optics. It is the basis of Kirchhoff's current and voltage laws for low-frequency circuits and Snell's law of reflection in optics (Xu et al., 2020); (Kuester, 2020). For low-frequency applications, the physics of electricity and magnetism are uncoupled. Coulomb's law for electric field and potential and Ampere's law for the magnetic field govern the physical principles. Infrared and optical applications are usually described in the content of photonics or optics as separate subjects. This section emphasizes the engineering applications of electromagnetic field theory that relate directly to the coupling of space and time-dependent vector electric and magnetic fields, and, therefore, most of the subjects focus on microwave and millimeter-wave regimes. The eleven chapters in this section cover a broad area of applied electromagnetics, including fundamental electromagnetic field theory, guided waves, antennas and radiation, microwave components, numerical methods, and radar and inverse scattering (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998).

Maxwell-Lorenz theory

The standard equations of the classical Maxwell-Lorenz theory of electrodynamics relate four material sources to four EM fields in the Minkowski spacetime (r, t). The sources are the free charge density ρ_{free}, free current density J_{free}, polarization P, and magnetization M, while the fields are the electric field E, magnetic field H, displacement D, and magnetic induction B. In the SI system of units, where the free space (or vacuum) has permittivity ε0 and permeability μ0, the displacement is defined as D $=_{\varepsilon 0}$E + P, and the magnetic induction as B $=_{\mu 0}$H + M. Let the total charge-density ρ(r, t) and total current-density J(r, t) be defined as

$$\rho(r,t) = \rho_{free}(r,t) - \nabla \cdot P(r,t).$$

3.1 Electromagnetic Waves

Dobkin, (2013) recent estimates by cosmological folks suggest that around 95% of the mass in the universe is composed of dark matter and more-recently-minted dark energy, about which essentially nothing is known. Dark matter and dark energy don't appear to interact with our alternately glowing and dusty stuff except through gravitational means. Folks made of dark matter couldn't watch reruns of American Idol even if forced them: they don't have any means of interacting with the broadcast signal, and probably don't want to pay for cable.
Electromagnetic waves are a fact of life. In most textbooks on electromagnetic theory, through Maxwell's equations and possibly laborious arguments on mysterious exchanges between the electric and magnetic fields launching self-supporting structures with little Poynting vectors pointing out of them (Haupt, 1995); (D'Azevedo et al., 2020); (Bao et al., 2020); (Ji et al., 2020); (Hyman et al., 2020); (Hagstrom and Lagrone, 2020) all true but unnecessarily obscure. Introducing the relevant terminology and techy of radio, let's share a little secret, implicit but not readily apparent in the standard texts, which the author has found to considerably simplify his view of electromagnetic radiation. It goes like this: **Electric currents rise to a magnetic vector potential in the direction of the current flow**

Dobkin, (2013) Everything radiates, on the other hand, most things cancel. To expand a bit: every object in the world that has an electric charge creates an electrostatic potential, which falls inversely as the distance. The potential sensed at some distance r corresponds to what the charged object was doing at an earlier time (r/c), for the reason that signals move at the speed of light $c=3\times10^8$ m/s. The total electric potential in the space between your nose and the pages of the book you're reading depends on the amount of charge on the fur of a cat in Bulgaria. However, almost never care, because electric charge comes in two flavors, positive and negative, and the amount of energy associated with an isolated charge of only one type is enormous: a microgram of hydrogen, split into its constituent protons and electrons and separated by (1) meter, could support a mass of 8 million kilograms against the gravitational attraction of the entire earth. Subsequently, in almost every case, adjacent to each electron with a negative charge is a proton with a positive charge, such that the two cancel, and have no net effect on your cellphone conversation. Electric currents similarly give rise to a magnetic vector potential in the direction of the current flow, which again exists everywhere with amplitude decreasing with distance, at a correspondingly delayed time. Similar arguments show that most currents don't have any effect on distant objects: if a current is flowing in one direction, with no compensating countercurrent, charge must be accumulating somewhere, leading after a while to enormous energies (voltages). Most electric currents flow in a balanced loop: the potential from current flowing up cancels that from current flowing down, and again no net effect results on distant observers. These points are made pictorially in Figure 3.1, where also introduce a bit of the mathematical terminology associated with the subject.

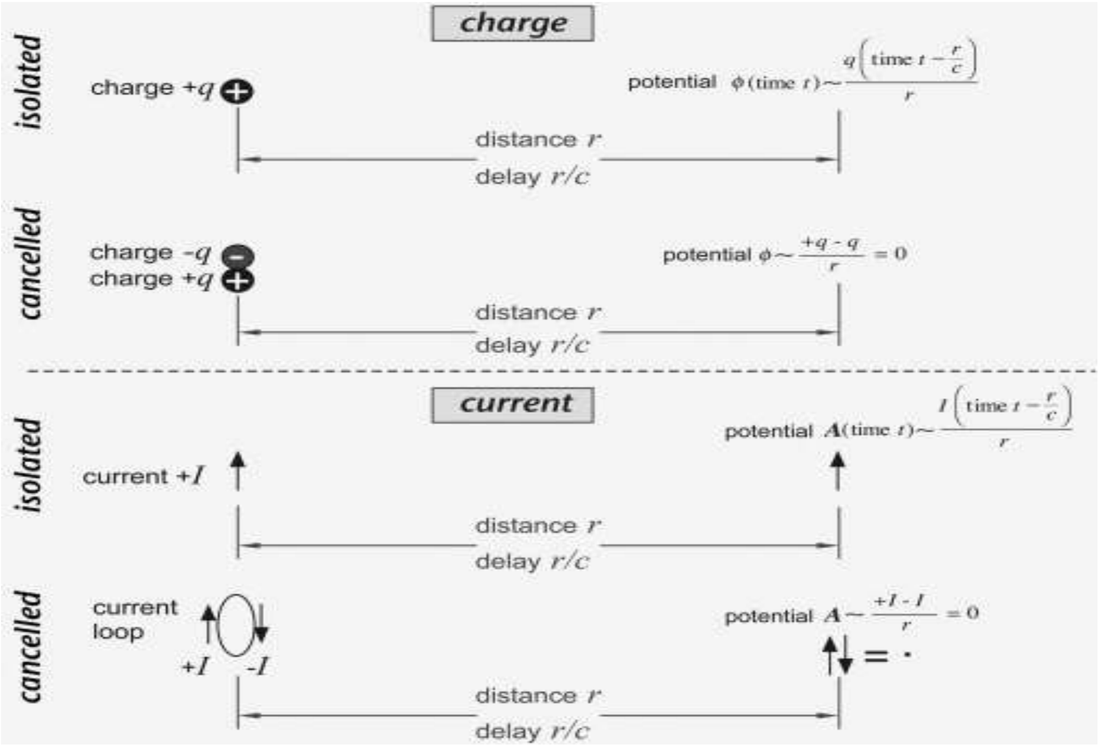

Figure .1.4. Potentials from charges and currents usually cancel.

Dobkin, (2013), at first glance, we're left with no potentials and no waves, but of course this is not correct. For example, we can run an uncompensated current for a little while before charge accumulation causes too much voltage to build up, and then turn it around. This uncompensated current will lead to a detectable signal at a distance (Fritzsche et al., 2018); (Gomez-Tames et al., 2017).
(Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020) nounced that anhad Einstein-Maxwell theory of coupled electromagnetic fields to gravity is one of the most firmly established classical relativistic field theories of nature. In perturbative QED, a whole range of interesting new phenomena arises in curved space-times. In the weak field approximation we would have a quantum field theory of massless spin-1 photons that are minimally coupled to massless spin-2 gravitons. At the tree level, we know that the photon propagation takes place along null geodesics of the metric. On the other hand, vacuum polarisation is a 1-loop quantum effect in which a photon exists during a very short time interval as a virtual electron-positron pair. Such virtual transitions confer a size. A case of non-minimal couplings between gravity and electromagnetic fields is presented (Slater and Frank, 1969); (Monnai et al., 2020); (Chikhachev, 2020); (Dereli and Senikoglu, 2020); (Bossavit, 1998). The field equations are worked out in the language of exterior differential forms. A class of exact charge screening solutions is given with a specific discussion on the polarisation and magnetisation of spacetime. The consequences of non-minimal couplings to gravity are examined.

(Kamata et al., 2020); (Wardoyo et al., 2020) The magnetic fields produced by an electromagnet depends on the amount of current and voltage. A single current source can produce multi-field magnetic fields, the position of the solenoid connected to the electric current source, where there are multi connectors that can be switched based on the composition of the helical coil and from the data obtained that this can proved. This research was carried out in a helical and design of copper plates forming solenoid windings, each part of the partition plate numbered 10, 15, 20, and 30 connected to electric currents of 1.5, 3, and

4.5 Ampere and the switch functioned to flow electric current to the partition based on the number of electromagnet plates. The experimental results obtained that the number of plates can produce multi magnetic field with a single current source with a range 0 to 8 mT which is measured using Gaussmeter. The benefits of this research will have impact on physical and engineering research related to the use of electromagnets that are portable and concise but with a single electric current source with multi magnetic fields, besides the next research has the potential to be developed in order to produce high magnetic fields.
(Krizsky et al., 2020) Design of cathodic protection systems of the trunk pipeline is regulated by current standards, based on the condition of uniformity and constancy of the electric conductivity of the multilayered half-space surrounding the pipeline. The current mathematical models of such systems also use an average value of the medium electric conductivity, which does not fully reflect the actual characteristics of the soil, in which the pipeline is laid. The authors present a method that accounts for the thickness and electrical conductivity of individual beds in a vertically-inhomogeneous, horizontally layered medium (the most practically appropriate case). Using method of computational experiment, the authors showed the importance of accounting for the effect of the medium layers structure and electrical resistivity on the protective voltage of the electric current in the cathodic protection system for underground trunk pipeline and studied the magnetic field sensitivity dependence on the insulation resistance of the pipeline defect-containing segments and on the altitude of data acquisition.
According to Smith et al., (2020) Thermodynamic properties of Ca–Pb alloys are investigated by electromotive force (emf) measurements to determine equilibrium cell potentials and phase properties for their application in energy storage systems such as liquid metal batteries. Using the electrochemical cell Ca(s) | CaF_2(s) | Ca(in Pb) at 700–1060 K, cell emf is measured for thirteen Ca–Pb alloys at mole fractions, x_{Ca} = 0.06–0.80. At 873 K, the equilibrium potentials of liquid Ca–Pb alloys are 0.57–0.62 V versus Ca and the activity values are as low as $a_{Ca} = 6.2 \times 10^{-8}$ at $x_{Ca} = 0.06$. In addition, the emf values as a function of temperature provide partial molar quantities (entropy and enthalpy) as well as phase transitions which are corroborated by determining transition temperatures and phase constituents using differential scanning calorimetry (DSC) and powder X-ray diffraction (XRD). This work establishes the fundamental data necessary for the design of Pb-containing liquid metal electrodes through the integration of electrochemical, thermal, and structural properties of Ca–Pb electrodes.
Zhang et al., (2020) has reported that An acoustic switch permits or forbids sound transmission through a partition, and its performance is governed by the stiffness and mass laws at low and high frequencies, respectively. The mechanism of artificial mass and stiffness, either positive or negative, is required to break these laws. The switch consists of a suspended diaphragm with electric moving coil and a magnetic field, shunted by an essentially passive analog circuit. Electrically mediated damping is extremely large, and its mechanism as a powerful wave stopper can be very broadband, which contrasts with most resonance-based devices in the literature. We also show that a serial shunt capacitor introduces a mechanical mass that softens the diaphragm spring at low frequencies, while a shunt inductance is an electromagnetic spring that pacifies mechanical inertia at high frequencies. By manipulating the dynamic mass, stiffness, and damping electronically to enhance or defy the mass law and stiffness law, a switch effective in over one octave and working at a deep subwavelength scale is realized, and the maximum switch ratio is as high as 28 dB. As circuits can be miniaturized and easily tuned, these illustrated physics point to a versatile tool for digital control of sound waves.

Electrostatics

Since classical physics, it has been known that some materials, such as amber, attract lightweight particles after rubbing. The electron, was thus the source of the word 'electricity'. Electrostatic phenomena arise from the forces that electric charges exert on each other. Such forces are described by Coulomb's law. Even though electrostatically induced forces seem to be rather weak, some electrostatic forces such as the one between an electron and a proton, that together make up a hydrogen atom, is about 36 orders of magnitude stronger than the gravitational force acting between them.

Coulomb's law

It has been found experimentally that the force interaction between stationary, electrically charged bodies can be described in terms of two-body mechanical forces. Based on these experimental observations, Coulomb postulated, in and can be formulated as below

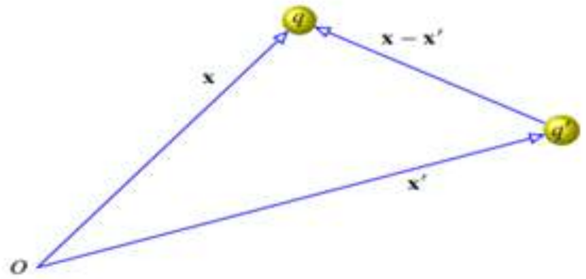

Figure.1.5. Electrically charged bodies can be described in terms of two-body mechanical forces.

mathematics as

$$\mathbf{F}^{es}(\mathbf{x}) = \frac{qq'}{4\pi\varepsilon_0}\frac{\mathbf{x}-\mathbf{x}'}{|\mathbf{x}-\mathbf{x}'|^3} = -\frac{qq'}{4\pi\varepsilon_0}\boldsymbol{\nabla}\left(\frac{1}{|\mathbf{x}-\mathbf{x}'|}\right) = \frac{qq'}{4\pi\varepsilon_0}\boldsymbol{\nabla}'\left(\frac{1}{|\mathbf{x}-\mathbf{x}'|}\right) \quad (1.1)$$

.

1.1.2 The electrostaisic field

$$\mathbf{E}^{stat}(\mathbf{x}) \stackrel{\text{def}}{\equiv} \lim_{q\to 0}\frac{\mathbf{F}^{es}(\mathbf{x})}{q} \quad (1.2)$$

$$\mathbf{E}^{stat}(\mathbf{x}) = \frac{q'}{4\pi\varepsilon_0}\frac{\mathbf{x}-\mathbf{x}'}{|\mathbf{x}-\mathbf{x}'|^3} = -\frac{q'}{4\pi\varepsilon_0}\boldsymbol{\nabla}\left(\frac{1}{|\mathbf{x}-\mathbf{x}'|}\right) = \frac{q'}{4\pi\varepsilon_0}\boldsymbol{\nabla}'\left(\frac{1}{|\mathbf{x}-\mathbf{x}'|}\right) \quad (1.3)$$

$$\mathbf{E}^{stat}(\mathbf{x}) = \frac{1}{4\pi\varepsilon_0}\sum_i q'_i \frac{\mathbf{x}-\mathbf{x}'_i}{|\mathbf{x}-\mathbf{x}'_i|^3} \quad (1.4)$$

$$d\mathbf{E}^{stat}(\mathbf{x}) = \frac{1}{4\pi\varepsilon_0} dq' \frac{\mathbf{x}-\mathbf{x}'}{|\mathbf{x}-\mathbf{x}'|^3} \quad (1.5)$$

$$d\mathbf{E}^{stat}(\mathbf{x}) = \frac{1}{4\pi\varepsilon_0} d^3x'\,\rho(\mathbf{x}')\frac{\mathbf{x}-\mathbf{x}'}{|\mathbf{x}-\mathbf{x}'|^3} \quad (1.6)$$

$$= -\frac{1}{4\pi\varepsilon_0}\int_{V'} d^3x'\,\rho(\mathbf{x}')\boldsymbol{\nabla}\left(\frac{1}{|\mathbf{x}-\mathbf{x}'|}\right) = -\frac{1}{4\pi\varepsilon_0}\boldsymbol{\nabla}\int_{V'} d^3x'\,\frac{\rho(\mathbf{x}')}{|\mathbf{x}-\mathbf{x}'|} \quad (1.7)$$

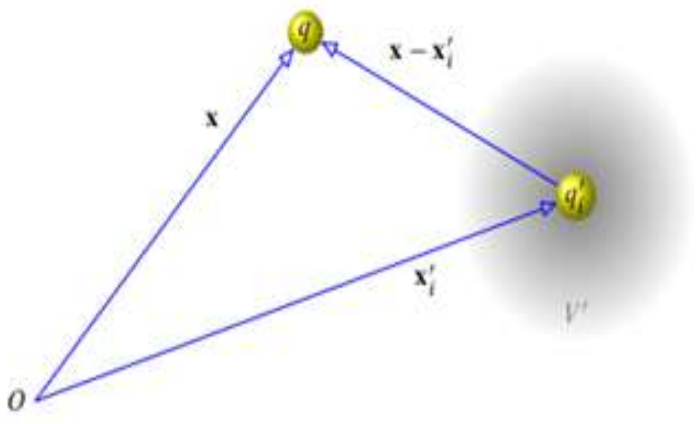

Figure 1.6: Coulomb's law for a continuous charge density *p*(x)' within a volume V' 0 of limited extent.

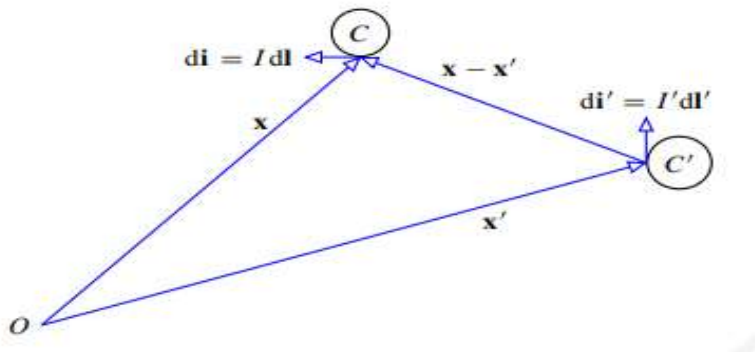

Figure. 1.7: Ampère's law postulates how a small loop C, carrying a static electric current I directed along the line element dl at x.

Discussion

Discussion

Formulas for physical laws of electromagnetism such as Maxwell's equations need to be adjusted depending on what system of units one uses as presented in Table.1.1. . This is because there is no one-to-one correspondence between electromagnetic units in SI and those in CGS, as is the case for mechanical units. Furthermore, within CGS, there are several plausible choices of electromagnetic units, leading to different unit "sub-systems", including Gaussian, "ESU", "EMU", and Heaviside Lorentz. Among these choices, Gaussian units are the most common today, and in fact the phrase "CGS units" is often used to refer specifically to CGS-Gaussian units.

.3)

In the presence of several field producing discrete electric charge ted at the point as presented in (1.3). including discrete charges, in which case (x) is expressed in terms of Dirac delt. (1.7) on the facing page is valid for an arbitrary distribution of electric charges. Emphasise that under the assumption of linear superposition, equation as presented in (1.8.) equation. Maxwell's (Haupt, 1995); (D'Azevedo et al., 2020); (Bao et al., 2020); (Ji et al., 2020);

(Hyman et al., 2020); (Hagstrom and Lagrone, 2020) displacement current will be explored in future study.

Jones Vector

Guenther, (2015) has declared that there is one other representation of polarized light, complementary to the Stokes parameters, developed by Jones (1916–2004) in 1941 and called the Jones vector. Its superior to the Stokes vector in that it handles light of a known phase and amplitude with a reduced number of parameters. It is inferior to the Stokes vector in that, unlike the Stokes representation, which is experimentally determined, the Jones representation cannot hand leunpolarized or partially polarized light. The Jones vector is a theoretical construct that can only describe light with a well-defined phase and frequency. The density matrix formalism can be used to correct the shortcomings of the Jones vector, but then the simplicity of the Jones representation is lost (Guenther, 2015). It was shown earlier that if it is assumed that the coordinate system is such that the electromagnetic wave is propagating along the z-axis, then any polarization can be decomposed.

Table 1.1.1. Jones and Stokes vectors adapted from (Guenther, 2015).

Jones vector		Stokes vector
	Horizontal polarization	
$\begin{bmatrix}1\\0\end{bmatrix}$		$\begin{bmatrix}1\\1\\0\\0\end{bmatrix}$
	Vertical polarization	
$\begin{bmatrix}0\\1\end{bmatrix}$		$\begin{bmatrix}1\\-1\\0\\0\end{bmatrix}$
	+45° polarization	
$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$		$\begin{bmatrix}1\\0\\1\\0\end{bmatrix}$
	−45° polarization	
$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$		$\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$
	Right-circular polarization	
$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\i\end{bmatrix}$		$\begin{bmatrix}1\\0\\0\\1\end{bmatrix}$
	Left-circular polarization	
$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-i\end{bmatrix}$		$\begin{bmatrix}1\\0\\0\\-1\end{bmatrix}$

Conclusion

This research deals with fundamental concepts in electromagnetic theory and outlines some basics of numerical modeling. Thus, the research starts with The relationship between classical electrodynamics and a theory of electromagnetism, List of electromagnetism equations, Maxwell equations, continuity equation and Coulomb's law. Then, electromagnetic wave equations and potentials are derived, and finally, fundamentals of radiation are presented. The first part of the research ends with both analytical analysis of Electric currents rise to a magnetic vector potential in the direction of the current flow and electromagnetic theory differential equation approach. The second part of the research yields some introductory aspects of electromagnetic theory methods. A brief description of electromagnetic theory and numerical solution of integral equations over sources is given. Some simple electromagnetic theory computational examples are given, as well.

Table 1.1. SI electromagnetism units and

Symbol	Name of quantity	Unit name	Symbol	Base units	Authors and years
Q	electric charge	coulomb	C	A.S	(Slater and Frank, 1969) (Monnai et al., 2020) (Chikhachev, 2020) (Dereli and Senikoglu, 2020) (Bossavit, 1998)
I	electric current	ampere	A	A (= W/V = C/s)	(Kruchinin, 2017) (Kamata et al., 2020); (Wardoyo et al., 2020)
J	electric current density	ampere per square metre	A/m2	$A·m^{-2}$	(Garg, 2012) (Krizsky et al., 2020) (Papachristou, 2020)
U, ΔV, Δφ; E	potential difference; electromotive force	volt	V	J/C = $kg·m^2·s^{-3}·A^{-1}$	(Zuza et al., 2020) (Smith et al., 2020) (Merkle et al., 2020)
R; Z; X	electric resistance; impedance; reactance	ohm	Ω	V/A = $kg·m^2·s^{-3}·A^{-2}$	(Garg, 2012) (Zhang et al., 2020) (Imura, 2020)
ρ	resistivity	ohm metre	Ω·m	$kg·m^3·s^{-3}·A^{-2}$	(Bossavit, 1998) (Garg, 2012)
P	electric power	watt	W	V·A = $kg·m^2·s^{-3}$	(Garg, 2012) (Wentrup, 2020) (Conversano et al., 2020)
C	capacitance	farad	F	C/V = $kg^{-1}·m^{-2}·A^2·s^4$	(Ward, 1988) (Yan et al., 2020) (Zhengzhi et al., 2020)
Φ_E	electric flux	volt metre	V·m	$kg·m^3·s^{-3}·A^{-1}$	(Terao et al., 2020) (Wu et al., 2019) (Zhao et al., 2019)
E	electric field strength	volt per metre	V/m	N/C = $kg·m·A^{-1}·s^{-3}$	(Gomez-Tames et al., 2017) (Gaynutdinov and Chermoshentsev, 2016)

D	electric displacement field	coulomb per square metre	C/m^2	A·s·m−2	(Garg, 2012) (Rozov and Grinchenko, 2017)
ε	permittivity	farad per metre	F/m	$kg^{-1}·m^{-3}·A^2·s^4$	(Lu et al., 2019) (Garg, 2012) (Abdulhameed et al., 2018)
χe	electric susceptibility	(dimensionless)	1	1	(Blackburn et al., 2016) (Gaynutdinov and Chermoshencev, 2018)
G; Y; B	conductance; admittance; susceptance	siemens	S	$\Omega^{-1} = kg^{-1}·m^{-2}·s^3·A^2$	(Garg, 2012) (Caccami and Marrocco, 2018)
κ, γ, σ	conductivity	siemens per metre	S/m	$kg^{-1}·m^{-3}·s^3·A^2$	(Garg, 2012) (Schnepf, 2017)
B	magnetic flux density, magnetic induction	tesla	T	$Wb/m^2 = kg·s^{-2}·A^{-1} = N·A^{-1}·m^{-1}$	(Fritzsche et al., 2018)
Φ, ΦM, ΦB	magnetic flux	weber	Wb	$V·s = kg·m^2·s^{-2}·A^{-1}$	(Garg, 2012)
H	magnetic field strength	ampere per metre	A/m	$A·m^{-1}$	(Garg, 2012) (Fritzsche et al., 2018) (Gomez-Tames et al., 2017) (Gaynutdinov and Chermoshentsev, 2016)
L, M	inductance	henry	H	$Wb/A = V·s/A = kg·m^2·s^{-2}·A^{-2}$	(Peyton et al., 1996) (Engel et al., 2006) (Lallart and Lombardi, 2020)
μ	Permeability	henry per metre	H/m	$kg·m·s^{-2}·A^{-2}$	(Henze and Uhlhorn, 2020) (Aladadi and Alkanhal, 2020) (Zhou et al., 2020)
χ	Magnetic susceptibility	(dimensionless)	1	1	(Garg, 2012)

Table.1.2. A fundamental concepts in electromagnetic theory and outlines some basics of numerical modeling.

The method bases	Description	Limitations	
Kirchhoff's current and voltage laws for low-frequency circuits and Snell's law of reflection in optics.	Electromagnetics is fundamental in electrical and electronic engineering. Electromagnetic theory based on Maxwell's equations establishes the basic principle of electrical and electronic circuits over the entire frequency spectrum from dc to optics.	1.Low-frequency applications, the physics of electricity and magnetism are uncoupled. 2.Coulomb's law for electric field and potential and Ampere's law for the magnetic field govern the physical principles. 3.Infrared and optical applications are usually described in the content of photonics or optics as separate subjects. 4.Engineering applications of electromagnetic field theory that relate directly to the coupling of space and time-dependent vector electric and magnetic fields 5.Fundamental electromagnetic field theory, guided waves, antennas and radiation, microwave components, numerical methods, and radar and inverse scattering.	(Haupt, 1995) (Xu et al., 2020) (Kuester, 2020)
Electromagnetic Waves	A cosmological folks suggest that around 95% of the mass in the universe is composed of dark matter and more-recently-minted dark energy, about which essentially nothing is known. Dark matter and dark energy don’t appear to interact with our alternately glowing and dusty stuff except through gravitational means. Folks made of dark matter couldn’t watch	1.To expand a bit: every object in the world that has an electric charge creates an electrostatic potential, which falls inversely as the distance. 2.The potential sensed at some distance r corresponds to what the charged object was doing at an earlier time (r/c), because signals move at the speed of light c=3×108 m/s.	(Dobkin , 2013) (Haupt, 1995) (Banis et al., 2020)

	reruns of American Idol even if you forced them: they don’t have any means of interacting with the broadcast signal, and probably don’t want to pay for cable.	3.The total electric potential in the space between nose and the pages of the book reading depends on the amount of charge on the fur of a cat in Bulgaria 4.Electric charge comes in two flavors, positive and negative, and the amount of energy associated with an isolated charge of only one type is enormous: 5.A microgram of hydrogen, split into its constituent protons and electrons and separated by 1 meter, could support a mass of 8 million kilograms against the gravitational attraction of the entire earth. 6.A negative charge is a proton with a positive charge, such that the two cancel, and have no net effect on your cellphone conversation. 7. Electric currents rise to a magnetic vector potential in the direction of the current flow, which again exists everywhere with amplitude decreasing with distance, 8.Electric currents flow in a balanced loop: the potential from current flowing up cancels that from current flowing down, and again no net effect results on distant observers.	
Maxwell's equations	A basic principle of electrical and electronic circuits over the entire frequency	1.The engineering applications of electromagnetic field theory that	(Haupt, 1995) (D’Azevedo et al., 2020).

	spectrum from dc to optics.	relate directly to the coupling of space and time-dependent vector electric and magnetic fields. 2.Focus on microwave and millimeter-wave regimes.	(Bao et al., 2020) (Ji et al., 2020) (Hyman et al., 2020) (Hagstrom and Lagrone, 2020)
Coulomb's law	law for electric field and potential		(Haupt, 1995) (Immel et al., 2020)
Ampere's law	Ampere's law for the magnetic field govern the physical principles.	Infrared and optical applications are described in the content of photonics or optics as separate subjects.	(Haupt, 1995) (Luo and Feng, 2020) (OK, 2020)

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