two points of device, to determine whether the equipment (wire in this case) can tolerate this temperature difference, and can still work properly.

This is one sample application of the gradient function. Now depending on the physical parameter, sometimes the line integral of the gradient over a 2D area may provide more useful observations, specifically in weather monitoring, over an area.

* SIGNIFICANCE OF GRADIENT FOR COMPUTATIONAL ENGINEERS:
In present times, where the society and industry is expecting software for each and every small application, the knowledge of the "gradient" is the actual core concept that you need to know. The efficiency of your software when compared to others depends on the exact identification of the gradient vector. Particularly, this is evident in the immense number of freeware available for predicting stock market performance and associated financial activities.

Gradient description is your actual "patent" or the intellectual property right. The issue of providing intellectual property rights for software is still an issue.

LECTURE 23 - COMPUTE NUMERICAL INTEGRATION

Let us start by taking an example -

$$\oint \vec{H} \cdot dl = I$$

magnetic field around a current carrying conductor is numerically to the current.

We can measure 'H' and arrive at an expression which may be complicated or, simply we may have numerical values. In that case, how to calculate I?

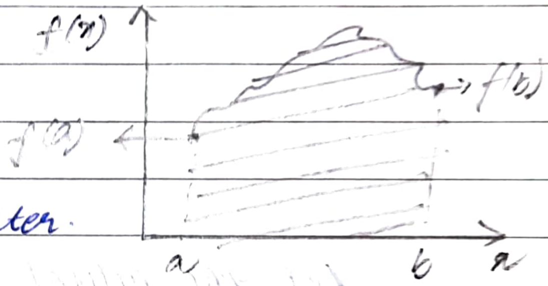
This apart, we have already seen on how to calculate $\sin x$ in a computer. Now, our challenge is -

$$\int \sin x \, dx = \int_a^b \left(x - \frac{x^3}{3!} + \frac{x^5}{5!} \cdots \right) dx$$

Here is the requirement of numerical integration. How to implement integration in computers?

* NEWTON- COTES FORMULA:

It is the simplest numerical integration technique, we'll be seeing three more formulaes later.



[1D Integration]

The fundamental idea is replace any function with a polynomial and evaluate it.

According to Newton,

$$\int f(x) \simeq \int \text{polynomial} + \text{error associated}$$

Approximate any function with a polynomial and the errors can be reduced by increasing the order of the polynomial. Cotes is credited for the algorithm works

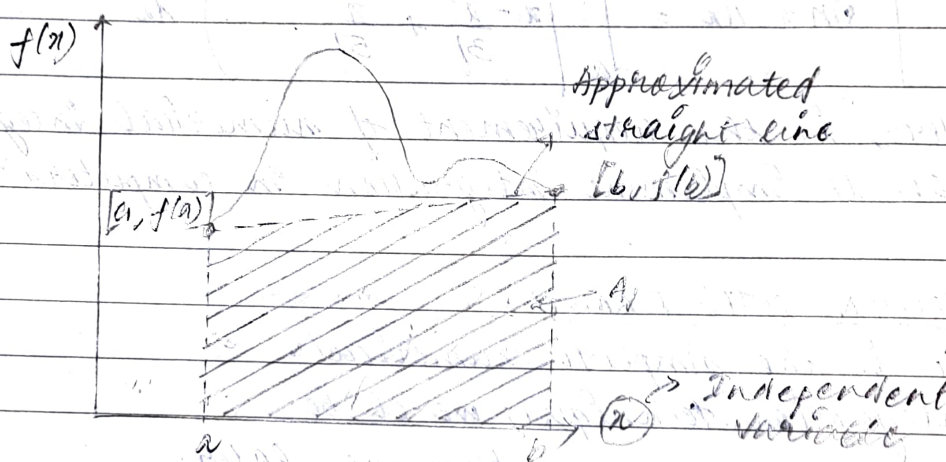
Let $f(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \dots + a_n x^n$

we can approximate using -

1. First order polynomial, $f(x) = a_0 + a_1 x$ [Trapezoidal Rule]
2. Second Order polynomial, $f(x) = a_0 + a_1 x + a_2 x^2$ [Simpson's 1/3 Rule]
3. Third Order polynomial, $f(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$ [Simpson's 3/8 Rule]

Geometrically,
① First order polynomial is a line.
② Second order polynomial is a parabola.

★ TRAPEZOIDAL RULE :
Approximating the function as a straight line.



Let the actual integral value be A
approximated value be A_1.
The equation of the straight line connecting a and b is given as -

$$\boxed{\text{straight line} = f(a) + \frac{f(b) - f(a)}{(b-a)}(x-a)}$$

The above expression is derived from the basic formulae of straight line joining two points (x_1, y_1) and (x_2, y_2) -

$$\frac{x - x_1}{y - y_1} = \frac{x_2 - x_1}{y_2 - y_1}$$

Here, $x \to x$ $\quad x_1 \to a$ $\quad x_2 \to b$
$y \to f(x)$ $\quad y_1 \to f(a)$ $\quad y_2 \to f(b)$

Therefore, the actual function to be integrated,

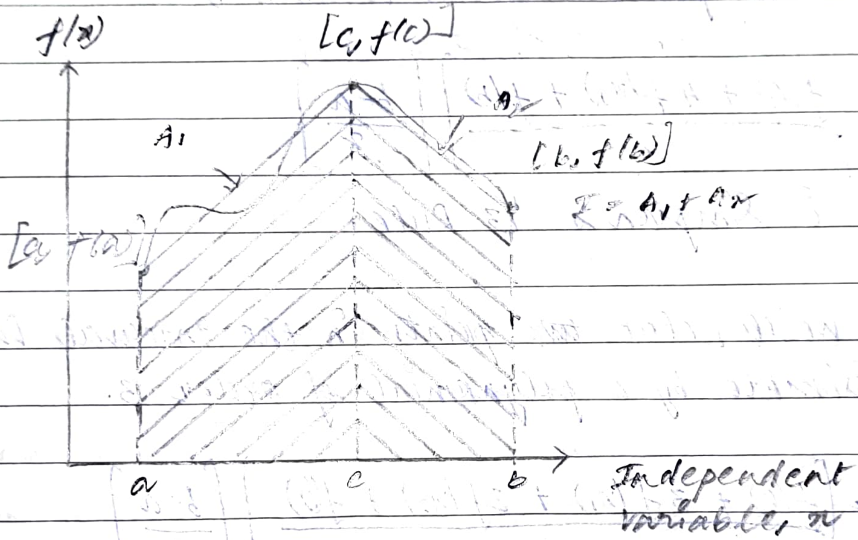
$$I = \int_a^b f(x)\, dx \simeq \int_a^b (\text{straight line})\, dx$$

$$\Rightarrow I \approx \int_a^b \left\{ f(a) + \frac{f(b) - f(a)}{(b-a)} (x-a) \right\} dx$$

$$\Rightarrow \boxed{I = \frac{f(a) + f(b)}{2} \{(b-a)\}}$$

This expression is obtained after a very long simplification of the previous expression.

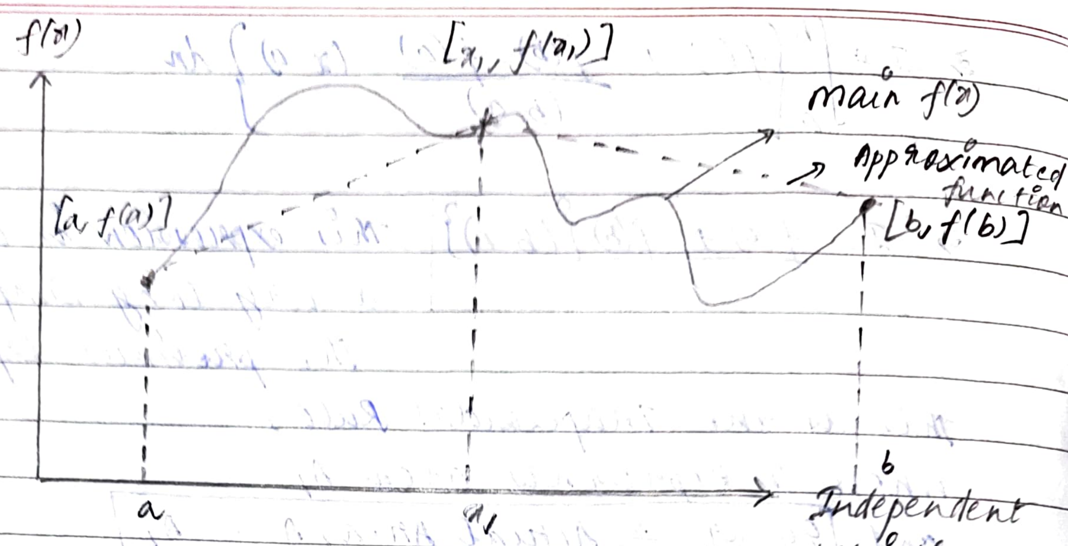
This is the Trapezoidal Rule,
where I represents area A_1
and $\boxed{\text{Error} \approx \text{Actual Area}, A - A_1}$



Therefore, the computational aspect is create many small areas and keep on approximating the actual function with as many straight lines.

LECTURE 24 - NUMERICAL INTEGRATION EXTENDED

Now, we'll look to approximate using a second order polynomial. The basic idea is approximating a function with a parabola.



Select 'one' point between 'a' and 'b'.

$$I = \left[\frac{f(a) + 4f(x_1) + f(b)}{3}\right]\left[\frac{b-a}{2}\right]$$

This is Simpson's 1/3 Rule.

Now, we'll select ~~two~~ points in the interval [a,b] and approximate by a polynomial of order 3.

$$I = \left[\frac{f(a) + 3f(x_1) + 3f(x_2) + f(b)}{4}\right]\left[\frac{b-a}{2}\right]$$

This is Simpson's 3/8 Rule.
Here x_1 and x_2 are the ~~two~~ points chosen in the interval [a,b].

* FUNDAMENTAL IDEA ~~BETWEEN~~ BEHIND NEWTON - COTES ALGORITHM:

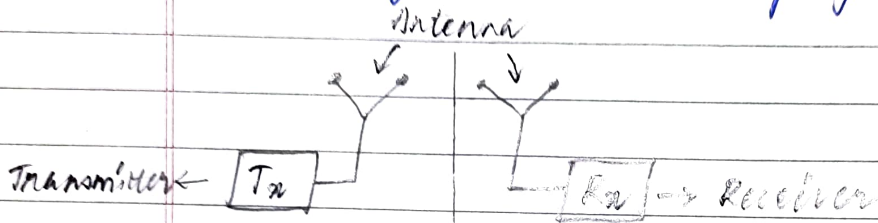
1. It is meant for complex mathematical functions.
2. We need a f(x) closed loop expression.
3. We also have operate Newton-Cotes formulae for numerical data, where no f(x) type expressions are possible.
4. Keep on doing; it is considered that even Simpson's 1/3 is more than enough with very very small error.

LECTURE 25 - BASICS OF ELECTROMAGNETICS

Communication is transferring information using electrical energy between two points. This can happen in two ways-

① Physical Wired System

② Wireless system [Waves - concept of EM field]



electronics and Communication

electronics and communication

↓

EM field in the atmosphere

↓

Study of EM Field [CCE]

Modelling EM in this region is quite challenging. The primary reason behind this is the geometry being too BIG, thereby resulting in no clear boundary conditions.

EM is used in many areas-

① Microphone

② Generator / Motor

③ X-Ray / Biomedical Diagnosis

④ Chemical Reactions

⑤ Cooking - Microwave oven / Induction stove

⑥ Geographic studies

The field of wireless communication demands a constant research in EM. This is why communication and electronics engineers study this subject. We (CCE) are more required to have a basic idea and concentrate on problem solving in EM with computers.

In other fields such as Electrical and Civil, most of the things are "standardized" and do not possess big scope for research and development.

Computational techniques are mainly used in three areas-
① Electromagnetics
② Thermodynamics
③ Structure Analysis.

Based on the current scenario of the application, we chose between wired and wireless communication.

Let us take the internet connection as an example, present in our campus. There are modems placed symmetrically in a wired form, say 10 m apart. The things that can be taken into consideration are-
① Power level of the modem
② Frequency of operation
③ How will the wave travel through the cement wall?

Modelling field/wave propagation in such scenarios is a very BIG task. The advent of 5G is one such example, i.e, the speed at which Information is shared. These are just EM fields travelling in space.

LECTURE 26 - FIELD AND WAVES

Maxwell, Faraday and Ampere have given formulas to solve the frequency and power levels required to solve problems in various applications, where we use computational techniques to process the scenario of obtained differential equations.

* DEFINITIONS IN EM:

Electric Field	Magnetic Field	Electromagnetic Field

Field ⟷ Wave

Field is anything that is stationary, for our understanding.

$\boxed{\text{source}}$ → effect is felt

Travelling field is known as a wave. It is here, that the field becomes a wave. When the field is felt at large distances, we assume the field is travelling. When the field starts varying, the effects were felt at huge distances. This is now meant by a wave.

earth
$\boxed{\text{source}}$

It is giving out two components, namely-
(a) stationary component
(b) time varying component
[felt at far away distances]

When the electromagnetic field is used for transporting information, it becomes an electromagnetic wave. The field begins to vary in time. This effect begins to be felt over large distances. For communication purposes, this term began to be called as a wave.

The wave component is what communication engineers are concerned about. We should try to artificially develop the wave over the present stationary field to transmit information over large distances.

LECTURE 27 - MEANING OF ELECTRIC FIELD

Now, we are going to study about:-

① electric field - How it can be created?
(E-field) How it can be maintained in an area?

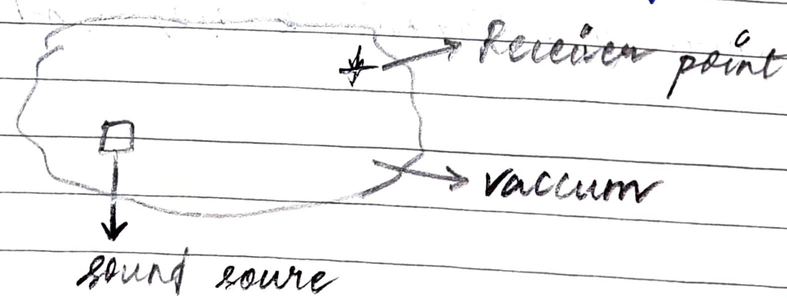
② Magnetic field - How it can be created?
(H-field) How it can be maintained?

③ Under what conditions, an electromagnetic field is formed? How it can be maintained in an area?

* NOTE: When an EM field is formed, the field starts to travel, and mostly EM wave terminology is used. This EM wave concept is used in wireless communication. Whereas, the individual electric and magnetic field concepts are used in industrial applications.

④ Along with the above three conditions, medium study (space where the field exists) is also important because the medium should support the existence of E, H and EM-fields.

No medium,
no sound,
no field



The main source of E, H and EM-fields is current. Creating EM fields using current proved to be very easy, flexible and adjustable. It is because of this that EM studies of Ampere, Faraday, Maxwell, Oersted and Hertz became very popular.

Current Source → Creating EM Fields → Convenient and Popular

Scientists who studied EM relation with other sources (except current) were not so popular. As mentioned earlier, for wireless-based communications, current-based EM field creation is employed. For example,

I/P current → $\boxed{\text{Antenna}}$ → O/P EM wave

In opposition, a piece of magnet also creates a magnetic field. But, we are not worried about this much. We are more concerned about magnetic field creation using current.

Q. What is a charged particle?
A. A particle that has excess or less of one type of charge. Charge is the base of all electrical activity. It is difficult to isolate a charge.

Q. Define electric field.
A. A force that is experienced only by a charged particle is called as an electric field.

* ELECTRIC FIELD AND CHARGE RELATIONS:
According to the definition of electric field,

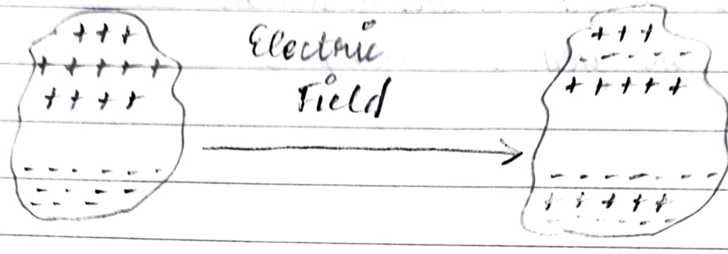
$$E = \frac{F}{q} = \frac{N}{C} \text{ (or) } \frac{V}{m} \text{ units}$$

This is the force experienced by a unit charge.

Though we deal with charge, a more workable quantity is charge density [C/m^3, C/m^2, C/m].

most popular

In real-world scenarios, all bodies are neutral at macro-level. But, within the body, there is a huge charge presence. For example, when you walk below an electric rail line, you may not get affected physically but charge density inside your body varies. Re-orientation of charges take place.



As far as electric field is concerned, the parameters of interest are:-

① Electric field
② Sources - charge / charge density
③ Medium parameter - permittivity (medium's capacity to hold on to electric field)

We will be discussing laws of the empirical form,

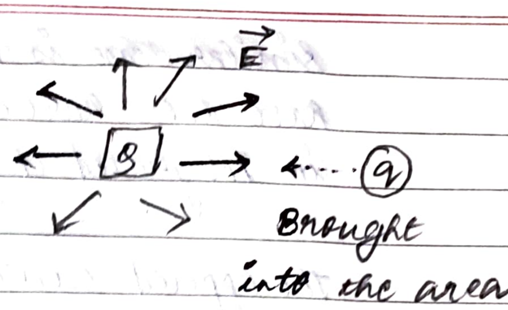
$$E = f(q, \rho, \epsilon)$$
$$= f(\text{charge, density, permittivity})$$

The terms such as dipole help in explaining the phenomena although they either don't actually exist or rather exist for momentarily.

LECTURE 28 - STUDY OF MEDIUM

We have accepted that charge creates an electric field. But, how is an electric field defined?

Bring a small infinitesimal charge into the area from infinity. The force experienced by the charge is the description of the electric field. Here, the infinitesimal test charge, q <<< Q, the source charge.



$\vec{E} = \frac{\vec{F}}{q}$, where q tends to be a small charge

or $\boxed{\vec{F} = q\vec{E}}$, where $\vec{F}$ is the force experienced by q and $\vec{E}$ is the field generated by Q.

\+ CHARGE DENSITY : (ρ)

Depends on area, $\frac{C}{m^3}$ (or) $\frac{C}{m^2}$ (or) $\frac{C}{m}$

For a cell phone, ρ is high compared to that of a human body. Think of the railway line example that we discussed earlier ?! A cell phone when taken near an electric railway line does not blast because the experienced field is not strong enough to cause any mechanical problems. There may be a voice interference when you are on a call.

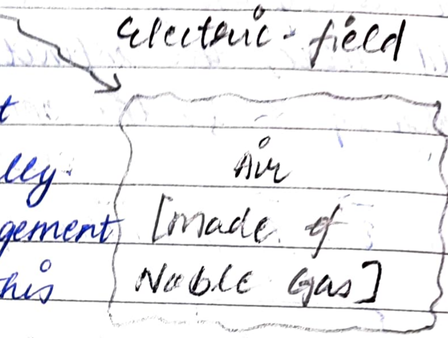
Medium is essential to support electric field existence. It is a numerical explaination and any field study involves the study of medium.

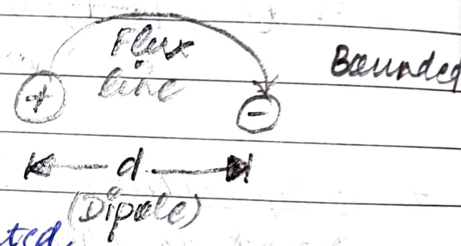
Q. What happens when an electric field is applied to a medium?

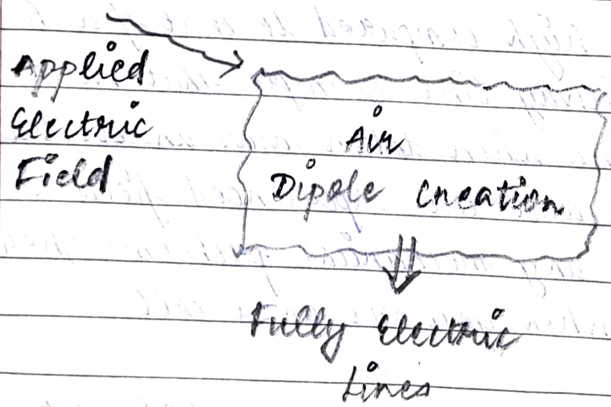
A. To explain this, we need to look into chemistry. A medium is made up of atoms which have an electronic configuration. If the atom has outermost shell completely packed (noble gases), they are non-reactive and inert in nature. They are available plenty in air (rare gases) but you cannot isolate them.

Similar case is with lanthanides. Countries such as China have these rare-earth elements in plenty, which is used in Integrated Chip (IC) manufacturing

The applied electric field tries to break the shell but it doesn't break mechanically. The nucleus-electron arrangement gets disturbed. To describe this process, we have a concept called dipole. It explains how an electric field exists in air. This creates the electric lines of force. Once when a dipole is created, it creates or induces additional dipoles around it.







* Receiver
You will be able to detect the field even at a distance.

If the medium is made of atoms that have only one electron in its outermost shell, the electron becomes free and it is the flow of this free electron that generates a current.

* TYPES OF MEDIUM: [BASED ON E-FIELD]
① Insulator (or) Perfect Dielectric [Air/vaccum]
② Lossy Dielectric (or) Dielectric casually [Others, human body]
③ Conducting Medium [Metals]
(Lossy)

classmate

Date 03/12/2021

Page 47

① Insulator - Dipole creation

Field is maintained as Field → observer able to get the field.

② Conducting - Free electrons are created

Field becomes current → observer can get current but not the field.

Electrical Energy

Depending on medium

Field | Current

③ Lossy Dielectric - Both field and current, co-exist.

Field is maintained and current is created.

~~Observer can get field, material gets heated~~

For example, when it rains, our television antenna loses connection. This is because the medium initially was an insulator (air) has suddenly became lossy dielectric (air and water).

LECTURE 29 - MORE DISCUSSION ON MEDIUM

75% of field studies are based on description of the media. Dipole describes charge-field effect in dielectrics whereas the free electron describes the effect in conducting medium.

* PERMITTIVITY :

$$D_{induced} = \varepsilon \, E_{applied}$$

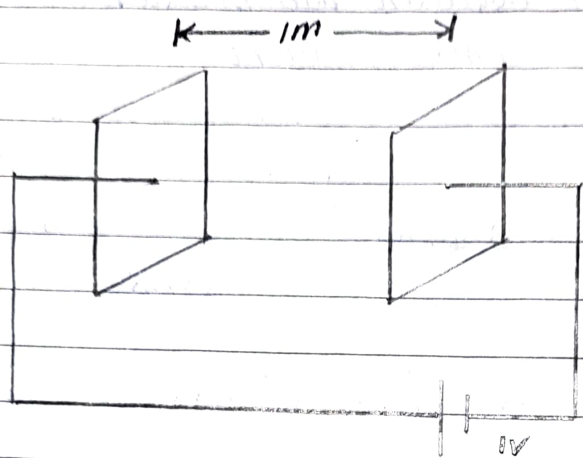
ε → Not defined for conducting medium

$D_{induced}$ → How many electric flux lines (dipoles) are created?

From experiments, we have found that $\varepsilon_{air} = 8.854 \times 10^{-12}$ F/m

What is the meaning of the above statement?

$$1F = \frac{1C}{1V} \Rightarrow \frac{1F}{m} = \frac{1C}{1V} \times \frac{1}{m}$$



In the area between the plates, 8.854×10^{-12} C of charge will be created. To express the above quantity in terms of number of electrons –

$$1.6 \times 10^{-19}\, C = 1e^-$$
$$8.854 \times 10^{-12}\, C = ? = \frac{8.854 \times 10^{-12}}{1.6 \times 10^{-19}} = 55.3375 \times 10^{6}\, e^-$$

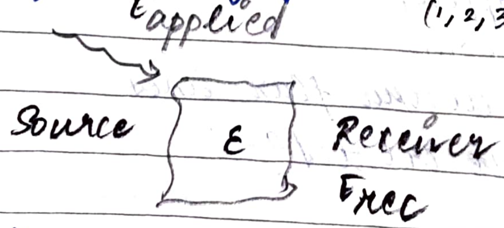
Similarly, in a perfect insulator,

$$6.25 \times 10^{18}\, e^- = 1A$$
$$55.3375 \times 10^{6}\, e^- = ? = \frac{55.3375 \times 10^{6}}{6.25 \times 10^{18}} = 8.854 \times 10^{-12}\, A$$

For air, $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

For others, $\varepsilon = \varepsilon_r \varepsilon_0 \Rightarrow \boxed{\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}}$

As the value of ε_r increases, the medium becomes conducting, starting from insulating to lossy.
(1, 2, 3, 4)



Our main goal is to express (formula) the received electric field (E_{rec}) in terms of $E_{applied}$ and ε.