Engineering Physics: PHY110

ELECTROMAGNETIC THEORY: UNIT-1

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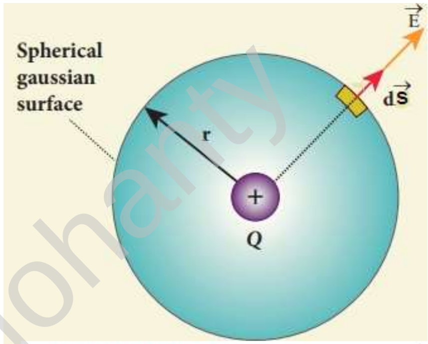
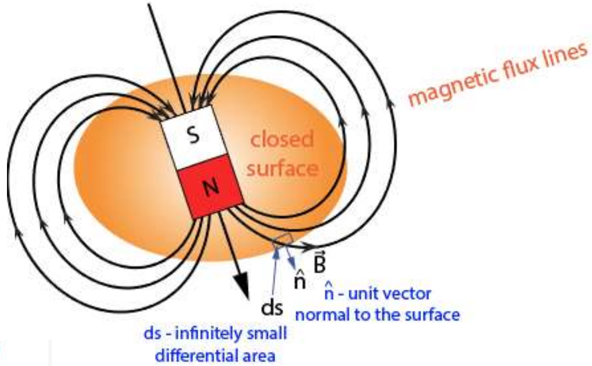
Maxwell's Equations (Integral Form)

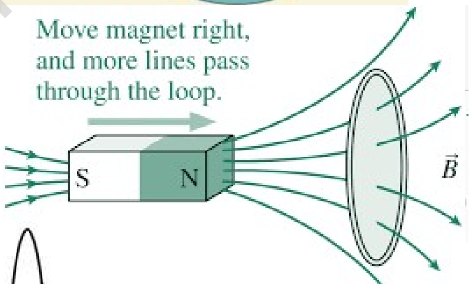
1. $\oint_S \vec{E} \cdot d\vec{s} = \dfrac{q_{enc}}{\varepsilon_0}$ (Gauss's Law in Electricity)

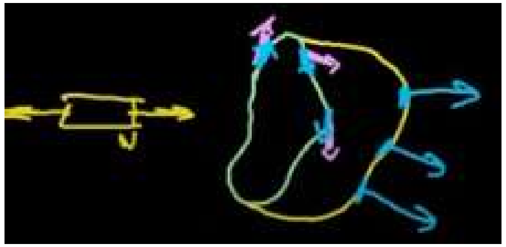




2. $\oint_S \vec{B} \cdot d\vec{s} = 0$ (Gauss's Law in Magnetism)

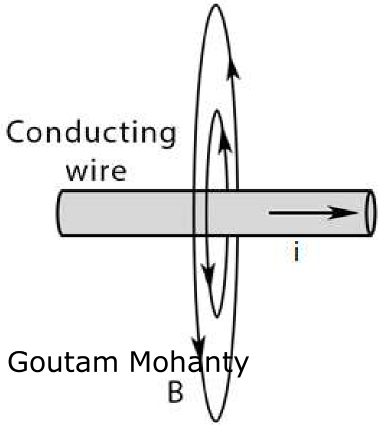
3. $\oint_l \vec{E} \cdot d\vec{l} = -\dfrac{d\Phi_B}{dt}$ (Faraday's Law of Induction)

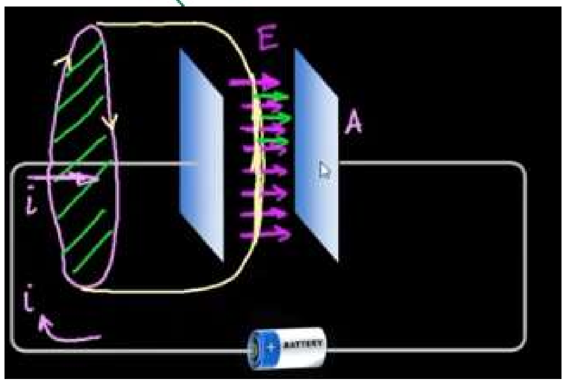




4. $\oint_l \vec{B} \cdot d\vec{l} = \mu_0 i_{enc} + \boxed{\mu_0 \varepsilon_0 \dfrac{d\Phi_E}{dt}}$

(Modified Ampere's Circuital Law)





Maxwell's Equations (Differential Form)

$$\vec{\nabla} \cdot \vec{\mathbf{E}} = \frac{\rho}{\varepsilon_o} \quad \Rightarrow \quad \vec{\nabla} \cdot \vec{\mathbf{D}} = \rho \qquad \text{Gauss' Law} \qquad (1)$$

$$\vec{\nabla} \cdot \vec{\mathbf{B}} = 0 \quad \Rightarrow \quad \vec{\nabla} \cdot \vec{\mathbf{B}} = 0 \qquad \text{Gauss' Law for magnetism} \qquad (2)$$

$$\vec{\nabla} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t} \quad \Rightarrow \quad \vec{\nabla} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t} \qquad \text{Faraday's Law} \qquad (3)$$

$$\vec{\nabla} \times \vec{\mathbf{B}} = \mu_o \vec{\mathbf{J}} + \mu_o \varepsilon_o \frac{\partial \vec{\mathbf{E}}}{\partial t} \quad \Rightarrow \quad \vec{\nabla} \times \vec{\mathbf{H}} = \vec{\mathbf{J}} + \frac{\partial \vec{\mathbf{D}}}{\partial t} \qquad \text{Ampère-Maxwell Law} \qquad (4)$$

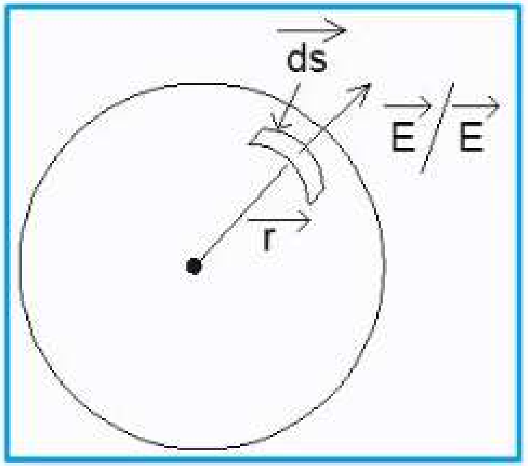
<u>Note</u>: $\vec{\mathbf{D}} = \varepsilon_o \vec{\mathbf{E}}$ and $\vec{\mathbf{B}} = \mu_o \vec{\mathbf{H}}$

Steps for Writing Maxwell's Equations

1. State the Law
2. Write the Law in Integral form
3. Use Divergence Theorem / Stokes Theorem
4. Write the Law in Differential Form

First Maxwell's Equation (Gauss Law for electric field)

Gauss law for electric field : The total electric flux passing through any closed surface is equal to the total charge enclosed by that surface.



Mathematically, It can be written as -

$$\phi = \oint_S \vec{D}\, ds = \epsilon_0 \oint_S \vec{E}\, ds = Q_{enclosed} \quad (1)$$

If ρ_v is the charge density, total charge enclosed by surface can be written as -

$$Q_{enclosed} = \int_V \rho_v \, dv \quad (2)$$

Therefore, Gauss law in integral form can be written as –

$$\oint_S \vec{D}\, ds = \epsilon_0 \oint_S \vec{E}\, ds = \int_V \rho_v \, dv \quad (3)$$

Using divergence theorem, we can write -

$$\int_V \vec{\nabla} \cdot \vec{E} \; dv = \oint_S \vec{E} \; ds \quad (4)$$

From (3) and (4), we can write –

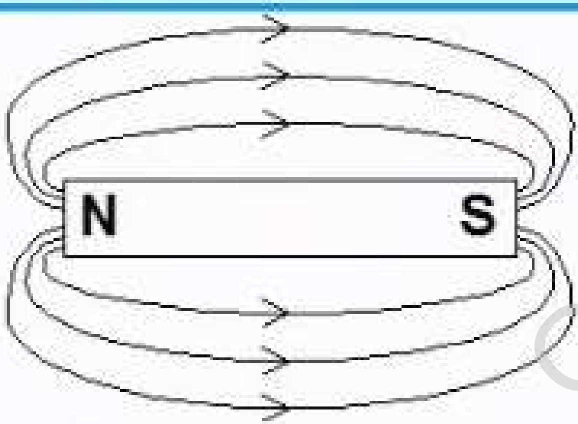
$$\epsilon_0 \int_V \vec{\nabla} \cdot \vec{E} \; dv = \int_V \rho_v \; dv$$

$$\boxed{\text{Therefore, } \vec{\nabla} \cdot \vec{E} = \frac{\rho_v}{\epsilon_0}}$$

This is first Maxwell's Equation in differential form

Second Maxwell's Equation (Gauss Law for Static Magnetic Field)

Gauss Law for Static Magnetic Field states that – "In a magnetic field, the magnetic lines of force are closed on themselves as shown -



Total outgoing flux is zero.

$$\oint_S \vec{B}\ ds = 0 \quad (1)$$

This is called Gauss Law for magnetic field in integral form

Using divergence theorem, we can write -

$$\int_V \vec{\nabla} \cdot \vec{B}\ dv = \oint_S \vec{B}\ ds = 0 \quad (2)$$

Thus, $\boxed{\vec{\nabla} \cdot \vec{B} = 0}$

This is second Maxwell's Equation in differential form

Third Maxwell's Equation (Faraday's Law)

A changing magnetic field induces an electric field.

Faraday's law states that "Whenever there is a change in magnetic flux linked with the circuit, an emf is induced in that circuit. The magnitude of induced emf is equal to the rate of change of the flux."

Therefore, the work done in moving a test charge from one point to the other point is given by –

$$\oint_P \vec{E}\ dl = -\frac{d\phi}{dt} = -\oint_S \frac{\partial \vec{B}}{\partial t}\ ds$$

This is integral form of the Faraday's law.

Using Stoke's theorem, we can write –

$$\oint_P \vec{E}\ dl = \int_S (\vec{\nabla} \times \vec{E})\ ds = -\oint_S \frac{\partial \vec{B}}{\partial t}\ ds$$

Therefore, $\boxed{\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}}$

This is third Maxwell's equation in differential form

Third Maxwell's Equation (Faraday's Law)

In static field, the work done in moving a test charge around a closed path is zero as ϕ is constant.

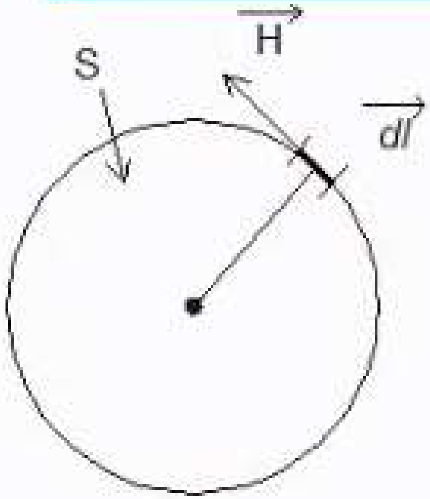
$$\oint_P \vec{E}\ dl = 0$$

So, in static field,

$$\oint_P \vec{E}\ dl = \int_S (\vec{\nabla} \times \vec{E})\ ds = 0 \quad \text{and} \quad \boxed{\vec{\nabla} \times \vec{E} = 0}$$

Fourth Maxwell's Equation(Ampere's Circuital law for Static Magnetic field)

Ampere's circuital law states that-
"The line integral of magnetic field intensity $\vec{H}$ around a closed path is equal to the current enclosed by that path."



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

This is integral form of Ampere's law

As, current density, $J = \frac{I}{ds}$

$$\oint \vec{H}\, dl = I = \int_S \vec{J}\, ds$$

Using Stoke's theorem, we can write –

$$\int_S (\vec{\nabla} \times \vec{H})\, ds = \oint \vec{H}\, dl = \int_S \vec{J}\, ds$$

Therefore, $\vec{\nabla} \times \vec{H} = \vec{J}$

As $\vec{B} = \mu_0 \vec{H}$ in free space,

$$\boxed{\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}}$$

This is fourth Maxwell's equation in differential form

➔ But This is incomplete equation.

➔ As Div (Curl **H**) = Div **J = 0 ---** **It violates the Equation of Continuity.**

Fourth Maxwell's Equation(Ampere's Circuital law for Time Varying field)

- Ampere's law is completely valid for the closed surface through which Electric field doesn't change with time (i.e. for static fields).
- For closed surfaces through which Electric field changes with time, displacement current density must also be considered.
- Changing electric field must also produce a magnetic field. Further, since magnetic fields have always been associated with currents, Maxwell postulated that this current was proportional to the rate of change of the electric field and called it displacement current.
- Displacement current density is defined in terms of the rate of change of electric displacement field. The units of displacement current are same as that of electric current density.
- Displacement current is not an electric current caused due to moving of charges, but it is caused by a time varying electric field

Fourth Maxwell's Equation(Ampere's Circuital law for Time Varying field)

Time Varying Electric Field → Induced Magnetic Field → Displacement Current

Total current density is given by - $\left(\vec{J} + \frac{\partial \vec{D}}{\partial t}\right)$

Therefore, the fourth Maxwell equation for time varying fields becomes -

$$\vec{\nabla} \times \vec{B} = \mu_0\left(\vec{J} + \frac{\partial \vec{D}}{\partial t}\right)$$

(or) $$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

→ Maxwell modified that total current density = $\mathbf{J} + \mathbf{J_d}$

So, Curl $\mathbf{H} = \mathbf{J} + \mathbf{J_d}$

→ Div Curl $\mathbf{H}$ = Div $(\mathbf{J} + \mathbf{J_d})$

→ Div $\mathbf{J}$ + Div $\mathbf{J_d} = 0$

→ $-\frac{\partial \rho}{\partial t} + \text{Div } \mathbf{J_d} = 0$

→ $-\frac{\partial (div\ D)}{\partial t} + \text{Div } \mathbf{J_d} = 0$

→ $-\text{div } \frac{\partial D}{\partial t} + \text{Div } \mathbf{J_d} = 0$

→ $\mathbf{J_d} = \frac{\partial D}{\partial t}$

Introduction to touch screen

- A touch screen is a computer display screen that is sensitive to human touch, allowing a user to interact with the computer by touching pictures or words on the screen.
- A touch screen is an input device that allows users to operate a PC by simply touching the display screen which has a sensitive glass overlay placed on it .
- A touch screen accepts direct onscreen inputs.
- In 1971, the first "touch sensor" was developed by Doctor Sam Hurst (founder of Elographics) while he was an instructor at the University of Kentucky.
- In 1974, the first true touch screen incorporating a transparent surface came.

Function and Working

Function:

- Pressure sensitive activation-by finger or stylus.
- Emulates mouse functions-click, double click, & drag.
- Touch screen & mouse can be used concurrently.
- Durable & scratch resistant coated surface.
- Compatible with Windows 95,98,NT,2000,XP,Macintosh,Linux.

Basic Components:

A basic touch screen has three main components:

- Touch sensor
- Controller
- software driver

Basic Components

TOUCH SENSOR:

A touch screen sensor is a clear glass panel with a touch responsive surface which is placed over a display screen. The sensor generally has an electrical current or signal going through it and touching the screen causes a voltage or signal change. This voltage change is used to determine the location of the touch to the screen.

CONTROLLER:

The controller is a small PC card that connects between the touch sensor and the PC. It takes information from the touch sensor and translates it into information that PC can understand.

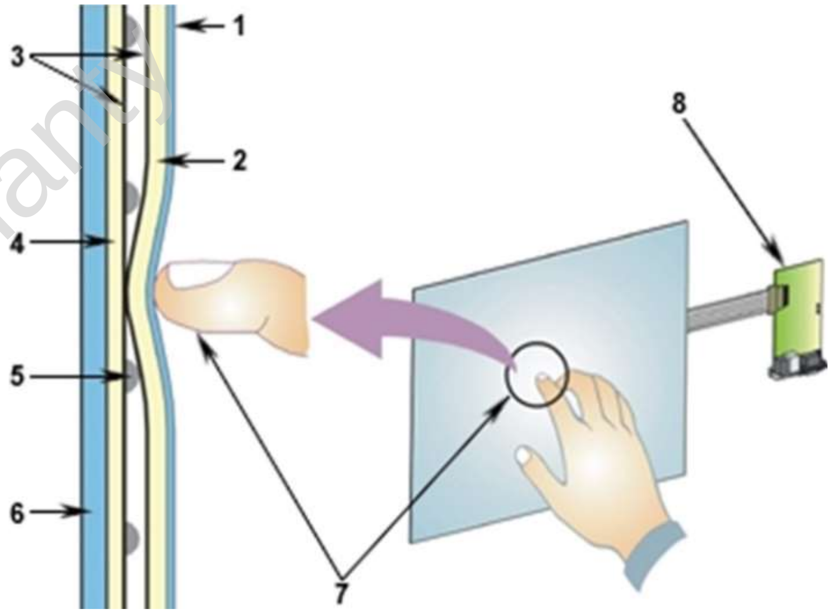
SOFTWARE DRIVER:

The driver is a software that allows the touch screen and computer to work together. It tells the operating system how to interpret the touch event information that is sent from the controller. Most touch screen drivers today are mouse-emulation type drivers. This makes touching the screen the same as clicking your mouse at the same location on the screen.

RESISTIVE TOUCH SCREEN TECHNOLOGY

Number significance in figure:

1. Polyester Film,
2. Top Resistive Layer,
3. Conductive Transparent Metal Coating,
4. Bottom Resistive Layer,
5. Insulating Dots,
6. Glass Substrate
7. Pressing the flexible top sheet creates electrical contact with the coating on the glass.
8. The touch screen controller gets the alternating voltages between the two layers and converts them into the digital X and Y coordinates of the activated area.



Advantages:

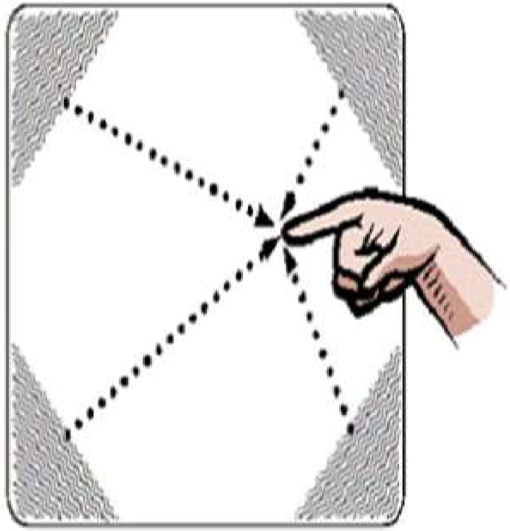
- Can be activated with any device,
- Low cost solution,
- Low power consumption

Disadvantages:

- Poorer durability compared to other technologies,
- Very short life, especially considering cosmetic wear

CAPACITIVE TOUCH SCREEN TECHNOLOGY

- In the capacitive system, a layer that stores electrical charge is placed on the glass panel.
- When a user touches, some of the charge is transferred to the user, so the charge on the capacitive layer decreases.
- This decrease is measured in electrodes located at each corner of the monitor.
- The computer then calculates the coordinates, from the relative differences in charge at each corner.
- A finger touch draws current from each corner.
- Then the controller measures the ratio of the current flow from the corners and calculates the touch location.

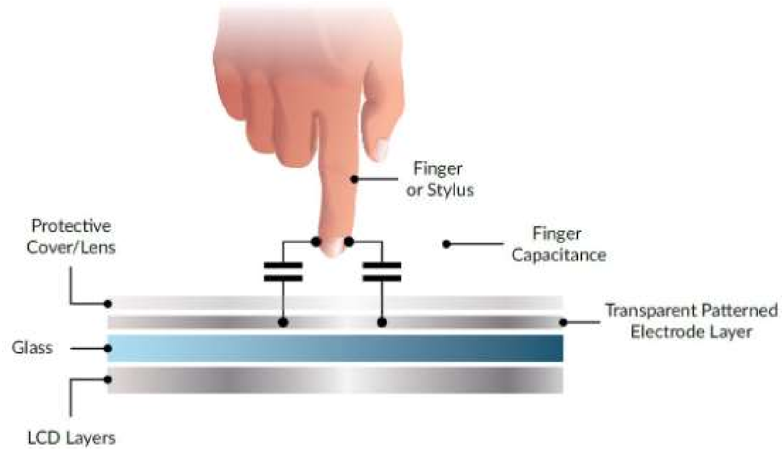


Advantages:

- More durable than resistive
- Higher transmittance than resistive

Disadvantages:

- Costlier than resistive touchscreen
- Accepts input from finger only.
- Accuracy is dependent on capacitance of person



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