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SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECT211 – ELECTROMAGNETIC FIELDS II YEAR/ IV SEMESTER

UNIT 4 – TIME VARYING FIELDS & MAXWELL'S EQUATION

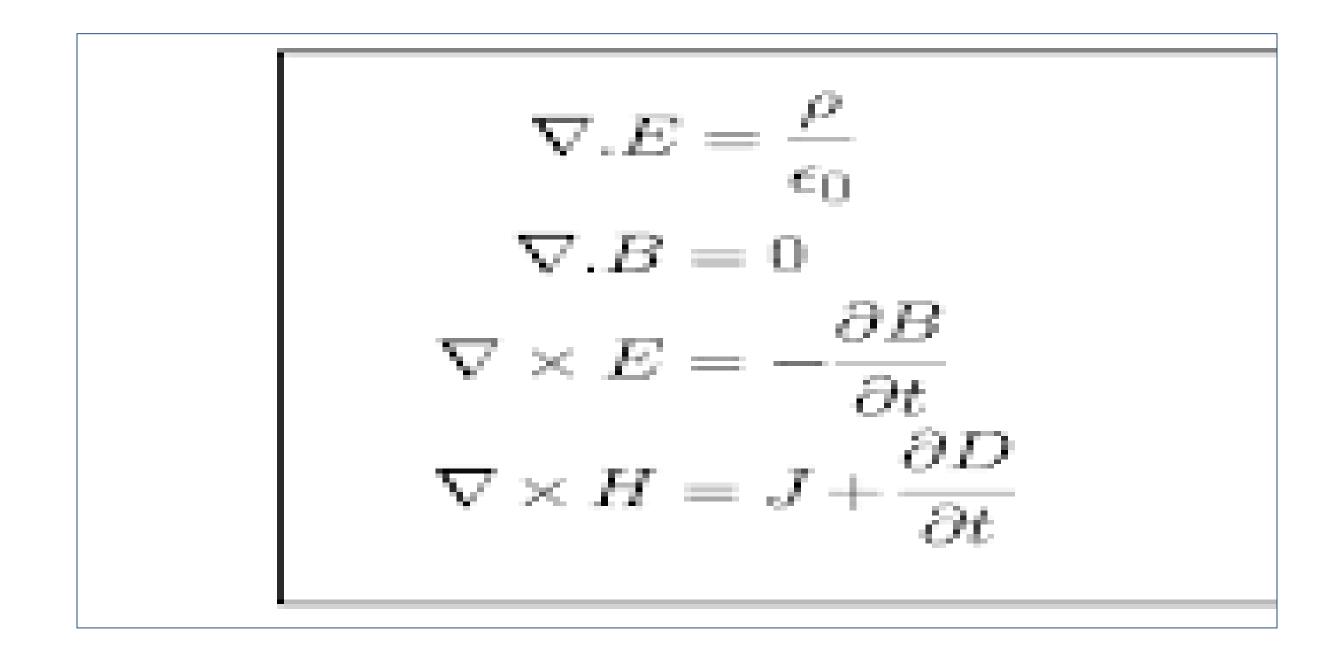
TOPIC 2 – MAXWELL'S EQUATION FOR STEADY AND TIME VARYING FIELDS







MAXWELL'S EQUATIONS



25/02/2021

MAXWELL'S EQUATION IN INTEGRAL AND DIFFERENTIAL FORM /19ECT211 - ELECTROMAGNETIC FIELDS/R.PRABHA/ECE/SNSCT





FUNDAMENTAL RELATIONS

Along with Maxwell's equations certain other fundamental relations are of importance in dealing with electromagnetic problems. Among these may be mentioned Ohm's law at a point (4-9-4)

$$\mathbf{J} = \sigma \mathbf{E}$$

the continuity relation (4-13-3)

$$\nabla \cdot \mathbf{J} = -\frac{\partial \rho}{\partial t}$$

the force relations

$$\mathbf{F} = q\mathbf{E}$$
$$d\mathbf{F} = (\mathbf{I} \times \mathbf{B}) dl$$

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(14)

(15)

(16)



MAXWELL'S EQUATION – FREE SPACE

In the preceding section, Maxwell's equations are stated in their general form. For the special case of free space, where the current density J and the charge density ρ are zero, the equations reduce to a simpler form. In integral form the equations are

$$\oint \mathbf{H} \cdot d\mathbf{l} = \int_{s} \frac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{s}$$

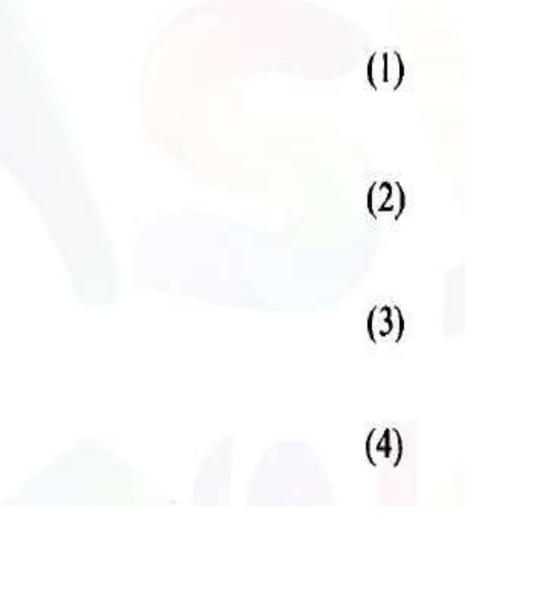
$$\oint \mathbf{E} \cdot d\mathbf{l} = -\int_{s} \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{s}$$

$$\oint_{s} \mathbf{D} \cdot d\mathbf{s} = 0$$

$$\oint_{s} \mathbf{B} \cdot d\mathbf{s} = 0$$

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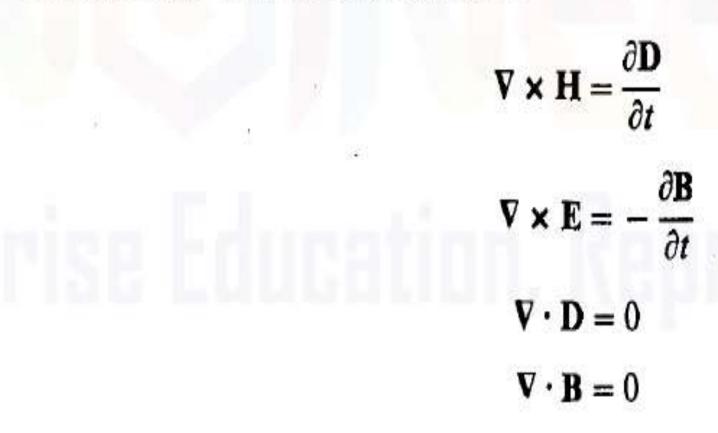






MAXWELL'S EQUATION – FREE SPACE

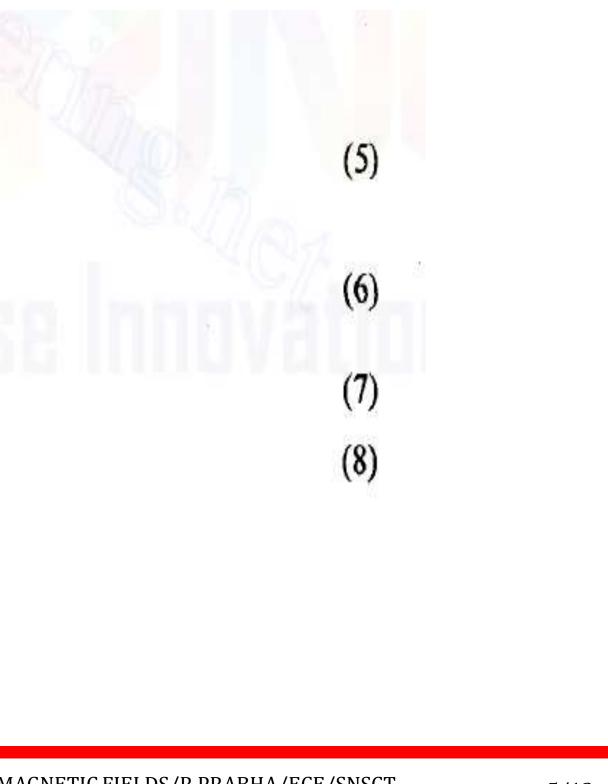
In differential form the equations are



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MAXWELL'S EQUATION – HARMONICALLY VARYING FIELDS

If we assume that the fields vary harmonically with time, Maxwell's equations can be expressed in another special form. Thus, if D varies with time as given by

 $\mathbf{D} = \mathbf{D}_0 e^{j\omega t}$

$$\frac{\partial \mathbf{D}}{\partial t} = j\omega \mathbf{D}_0 \, e^{j\omega t} = j\omega \mathbf{I}$$



(1)



MAXWELL'S EQUATION – HARMONICALLY VARYING FIELDS

When the same assumption is made for B, Maxwell's equations in integral form reduce to

$$\oint \mathbf{H} \cdot d\mathbf{l} = (\sigma + j\omega\epsilon) \int_{s} \mathbf{E} \cdot d\mathbf{s}$$
$$\oint \mathbf{E} \cdot d\mathbf{l} = -j\omega\mu \int_{s} \mathbf{H} \cdot d\mathbf{s}$$

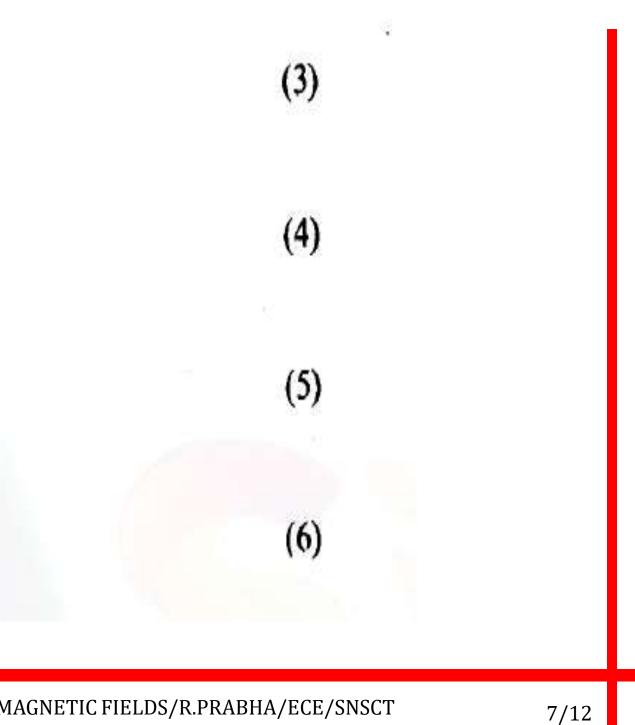
ρ dv

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 $\mathbf{D} \cdot d\mathbf{s} =$

 $\mathbf{B} \cdot d\mathbf{s} = 0$







MAXWELL'S EQUATION – HARMONICALLY VARYING FIELDS

In differential form they are

 $\nabla \times \mathbf{H} = (\sigma + j\omega\epsilon)\mathbf{E}$

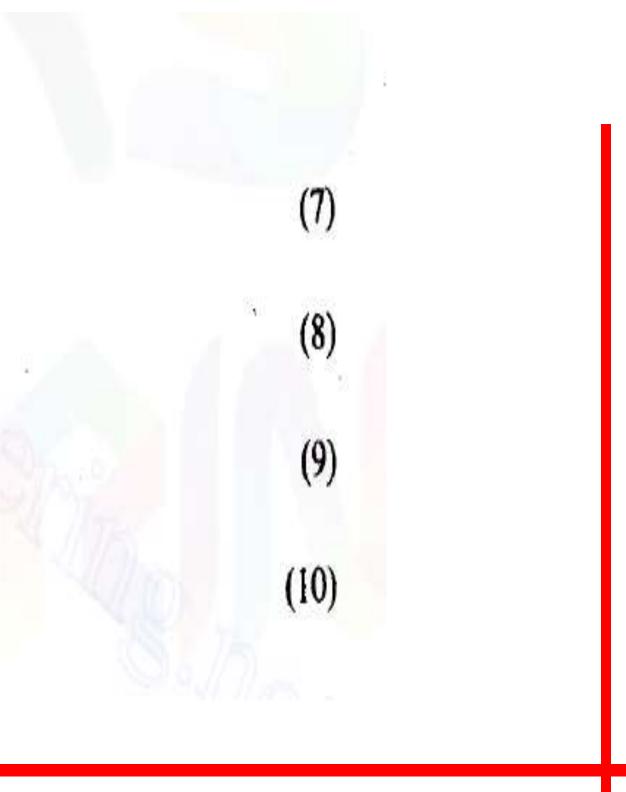
 $\nabla \times \mathbf{E} = -j\omega\mu\mathbf{H}$

 $\nabla \cdot \mathbf{D} = \rho$

 $\nabla \cdot \mathbf{B} = 0$

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STATIC & STEADY FIELDS

A static electric field (also referred to as electrostatic field) is created by charges that are fixed in space; A static magnetic field is created by a magnet or charges that move as a steady flow (as in appliances using direct current).

Steady fields does not vary with time.





MAXWELL'S EQUATION – INTEGRAL FORM TABLE

Table 9-1 MAXWELL'S EQUATIONS IN INTEGRAL FORM

	From Ampère mmf, A	From Faraday emf, V	From Gauss		
Dimensions and SI Case units			Electric flux, C	Magnetic flux, Wb	
General	$F = \oint \mathbf{H} \cdot d\mathbf{l} = \int_{s} \left(\mathbf{J} + \frac{\partial \mathbf{D}}{\partial t} \right) \cdot d\mathbf{s} = I_{\text{total}}$	$\mathfrak{V} = \oint \mathbf{E} \cdot d\mathbf{I} = -\int_{s} \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{s}$	$\psi = \oint_{s} \mathbf{D} \cdot d\mathbf{s} = \int_{v} \rho dv$	$\psi_m = \oint_s \mathbf{B} \cdot d\mathbf{s} = 0$	
Free space	$F = \oint \mathbf{H} \cdot d\mathbf{l} = \int_{s} \frac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{s} = I_{\text{disp}}$	$\mathfrak{V} = \oint \mathbf{E} \cdot d\mathbf{I} = -\int_{s} \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{s}$	$\psi = \oint_{s} \mathbf{D} \cdot d\mathbf{s} = 0$	$\psi_m = \oint_s \mathbf{B} \cdot d\mathbf{s} = 0$	
Harmonic variation	$F = \oint \mathbf{H} \cdot d\mathbf{l} = (\sigma + j\omega\epsilon) \int_{s} \mathbf{E} \cdot d\mathbf{s} = I_{\text{total}}$	$\mathfrak{V} = \oint \mathbf{E} \cdot d\mathbf{l} = -j\omega\mu \int_{s} \mathbf{H} \cdot d\mathbf{s}$	$\psi = \oint_{s} \mathbf{D} \cdot d\mathbf{s} = \int_{v} \rho dv$	$\psi_m = \oint_s \mathbf{B} \cdot d\mathbf{s} = 0$	
Steady	$F = \oint \mathbf{H} \cdot d\mathbf{l} = \int_{s} \mathbf{J} \cdot d\mathbf{s} = I_{\text{cond}}$	$V = \oint \mathbf{E} \cdot d\mathbf{l} = 0$	$\psi = \oint_{s} \mathbf{D} \cdot d\mathbf{s} = \int_{v} \rho dv$	$\psi_m = \oint_s \mathbf{B} \cdot d\mathbf{s} = 0$	
Static	$U = \oint \mathbf{H} \cdot d\mathbf{I} = 0$	$V = \oint \mathbf{E} \cdot d\mathbf{l} = 0$	$\psi = \oint_{s} \mathbf{D} \cdot d\mathbf{s} = \int_{v} \rho dv$	$\psi_m = \oint \mathbf{B} \cdot d\mathbf{s} = 0$	

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MAXWELL'S EQUATION – DIFFERENTIAL FORM TABLE

Table 9-2 MAXWELL'S EQUATIONS IN DIFFERENTIAL FORM

	From Ampère	From Faraday	From Gauss	
Case Dimen- sions	Electric current area	Electric potential area	Electric flux volume	Magnetic flux volume
General	$\nabla \mathbf{X} \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$	$\nabla \mathbf{x} \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\nabla \cdot \mathbf{D} = \boldsymbol{\rho}$	$\nabla \cdot \mathbf{B} = 0$
Free space	$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t}$	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\nabla \cdot \mathbf{D} = 0$	$\nabla \cdot \mathbf{B} = 0$
larmonic variation	$\nabla \mathbf{x} \mathbf{H} = (\sigma + j\omega\epsilon)\mathbf{E}$	$\nabla \mathbf{x} \mathbf{E} = -j\omega\mu \mathbf{H}$	$\nabla \cdot \mathbf{D} = \boldsymbol{\rho}$	$\nabla \cdot \mathbf{B} = 0$
Steady	∇×H=J	$\nabla \times \mathbf{E} = 0$	$\nabla \cdot \mathbf{D} = \boldsymbol{\rho}$	$\nabla \cdot \mathbf{B} = 0$
Static	$\nabla \mathbf{X} \mathbf{H} = 0$	$\nabla \times \mathbf{E} = 0$	$\nabla \cdot \mathbf{D} = \rho$	$\nabla \cdot \mathbf{B} = 0$

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REFERENCES

- John.D.Kraus, "Electromagnetics ",5th Edition, Tata McGraw Hill, 2010
- W. H.Hayt & J A Buck: "Engineering Electromagnetics" Tata \bullet McGraw-Hill, 7th Edition 2007

THANK YOU

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