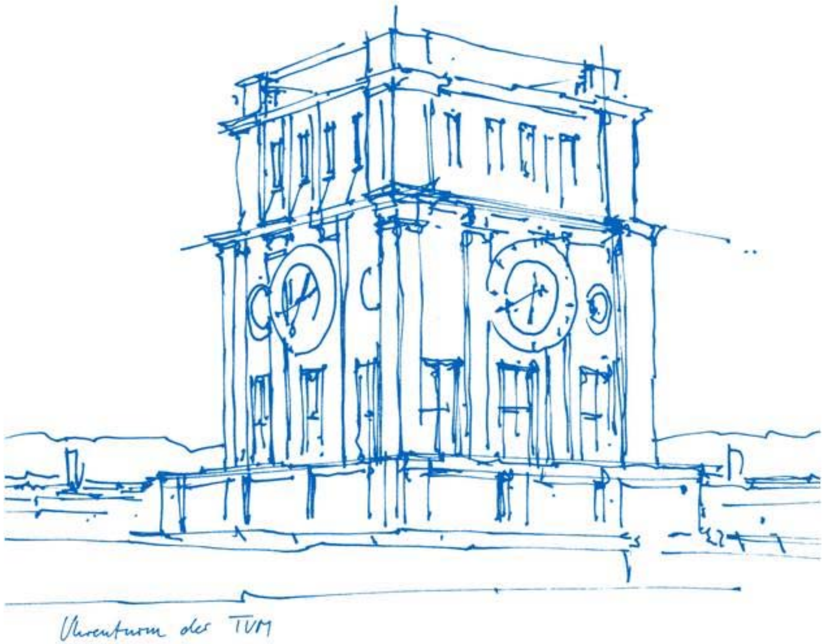
Lecture

Electricity and Magnetism

The Grand Final – Electromagnetic Field Equations (Maxwell‘s equations)



4.4 Electromagnetic Field Equations – Maxwell‘s Equations (Fundamental physical equations, natural laws)

(4.14) $$div\vec{D} = \rho$$

Gauss‘s law

(4.15) $$div\vec{B} = 0$$

Solenoidality of $\vec{B}$-Field

(4.16) $$curl\vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Faraday‘s law of induction

(4.17) $$curl\vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$$

Ampère-Maxwell‘s circuital law

4.4 Electromagnetic Field Equations – Maxwell's Equations

(4.14) $div\vec{D} = \rho$

Gauss's law

Electric fields are generated by electric charges (quasi-static)
$\Leftrightarrow$ sources of $\vec{D}$ are electric charges (for conservative electric fields)

or

(4.16) $curl\vec{E} = -\dfrac{\partial\vec{B}}{\partial t}$

Faraday's law of induction

Electric fields are generated by rapidly time-varying $\vec{B}$-Fields

These fields are then not conservative ($curl\vec{E} \neq 0$).

4.4 Electromagnetic Field Equations – Maxwell's Equations

There are no magnetic charges/ magnetic monopoles, at which $\vec{B}$ lines start/end, hence ⟺ field lines of magnetic fields are always closed

(4.15) $$div\vec{B} = 0$$

Solenoidality of $\vec{B}$-Field

Magnetic fields are generated by

- Electric currents (quasi-stationary)
- Rapidly time-variant electric fields (electric displacement current)

(4.17) $$rot\vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$$

Ampère-Maxwell's circuital law

4.4 Electromagnetic Field Equations – Maxwell‘s Equations

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Gauss‘s law

(4.15) $$div\vec{B} = 0$$

Solenoidality of $\vec{B}$-Field

(4.16) $$rot\vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Faraday‘s law of induction

(4.17) $$rot\vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$$

Ampère-Maxwell‘s circuital law

Material laws, which supplement the Maxwell‘s equations (4.14 – 4.17)

(4.18) $$\vec{D} = \varepsilon \vec{E}$$

(4.19) $$\vec{B} = \mu \vec{H}$$

(4.20) $$\vec{j} = \sigma \vec{E}$$

These are no natural laws, but phenomenological model equations. In this lecture: linear material laws (polarisation, magnetization, Ohm‘s law)

4.4 Electromagnetic Field Equations – Maxwell's Equations

(Fundamental physical equations, natural laws)

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Gauss's law

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Solenoidality of $\vec{B}$-Field

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Ampère-Maxwell's circuital law

Coupling between electric and magnetic fields (electromagnetic fields); also in vacuum (-> electromagnetic field theory)