Lecture 1

General

Outline of the first part

- Introduction of the instructor and teaching assistants
- Duties and obligations of the teacher
- Duties and obligations of the TA’s
- Duties and obligations of the students
- The JI Honor code
- Class rules
- Homework's rules
- Quiz rules
- Exam rules
- Grading policy
- Schedule (tentative)
- Teaching evaluation

VE230: Electromagnetism I

Professor

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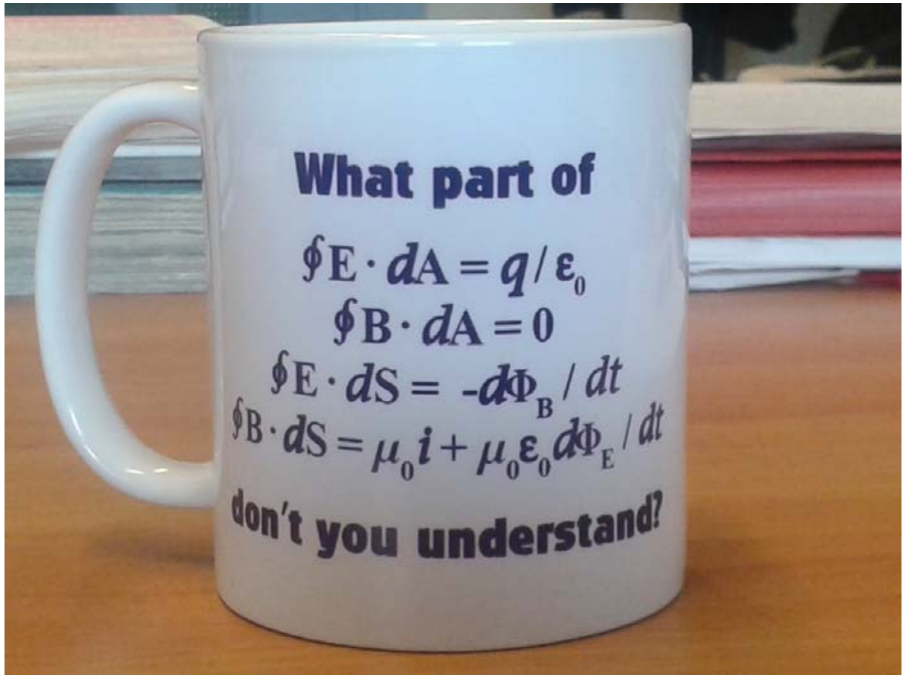


This is my daily Coffee mug

Duties and obligations of the teacher

- Will give his best to let you <u>learn</u>, <u>understand</u>, and <u>enjoy</u> Ve230… May be even fall in <u>love with physics</u>

- Does all what he could to remain concerned by your process of <u>understanding</u>

- Office hours will be dedicated to your questions: be aware that these office hours **WILL NOT** be dedicated to help solving problems **BUT** to discuss conceptual questions that have been treated in class and not well understood

Duties and obligations of the TA's

- Hold recitation classes and office hours: **You are highly advised to attend !**

- Solve HW problems and help you strengthening your understanding of the concepts learned during classes

- Grade quizzes and exam and release scores in Canvas:
  In case of any conflict or complain quizzes and exam copies will be checked by the instructor

Recitation classes and office hours

TA's

Office hours: at JI

- SUN Shangquan: Tuesday 18.00 – 20.00
- CHEN Ychen: Thursday 18.00 – 20.00

Recitation classes: F Dongxiayuan

- SUN Shangquan: Monday 18.20 – 20.00
- CHEN Ychen: Wednesday 18:20 – 20:00

Instructor

Office hours: Room 435C, JI building

- Tuesday 10:00 to 12:00 am

Duties and obligations of the Students

- Work <u>hard</u>, <u>enjoy</u> and <u>show</u> that the instructor and TA’s are not wasting their time

- Do your best to make China, JI, the teacher and the TA’s proud of you

The JI Honor Code

Personal integrity as students and professionals

Respect other people and their work

Respect yourself and your own efforts

Mutual trust

Applicable to all your academic activities here, including homework, quizzes, projects and exams

Violations will be reported to the Honor Council

- Copy other student’s homework, quizzes, exams
- Illegal copy of online resource and academic literatures
- Helping other on the abovementioned activities
- Fake ID for exams

Class rules

- No food is allowed inside class. Anyone coming with food should stay outside until finished eating
- Soft drink may be allowed

- Please do not arrive late and do not get up to leave until the class is dismissed or during the break.
  Action will be taken if a recurrent perturbation becomes obvious

- You are responsible for all material covered in class, whether or not it is in the books. According to teacher's experience there is no dedicated book as any reference depends on the student "taste"

Books suggested by teacher and JI

- Field and Electromagnetics(2nd Edition): **David K. Cheng**
- Introduction to Electrodynamics(3rd Edition): **David J.Griffiths**
- Fundamentals of Applied Electromagnetics (5th): **Fawwaz T. Ulaby**
- Electricity and Magnetism(3rd Edition): **Edward M. Purcell, David J. Morin**

Interaction in Class

Physics is an interactive science → Requires live questions and comments

Teacher & TA's ⟷ Students

- There is **NO** stupid question: everybody should feel free to ask questions and make comments

- The questions can be asked along different forms
  - ✓ Directly during class allowing everybody to benefit
  - ✓ By email for those who are shy: both the questions and answers will be given during next class (for confidentiality purposes, the name of the student asking the questions will not be cited)

Gathering around the blackboard at the end of the lecture to ask questions and make comments prevent other students to benefit

About "star" questions

- During each class some questions graded 1, 2 or 3 stars will be asked.
- The students who are volunteer and willing to answer are welcome to do so. Class will be lively

Vp260 versus Ve230

- Is it worth reminding some basic concepts learned in Vp260 while teaching Ve230? **YES**
- During the first 3 lectures questions refereeing to Vp260 will be asked
- Is it worth mentioning the names of the physicists who are at the origin of a concept? **YES**
- In other words, is a brief historical touch, as an approach to understanding physics, pertinent? **YES**

Major advice

- If you encounter understanding difficulties don't wait until a week before the final exam to start worrying

Canvas

- Why the lecture will not be posted **BEFORE** given in class?

    1) Because I will be asking questions for which the response are given in the slides
    2) Because I want to make sure that the students are concentrated during the lecture

- It thus becomes useless to open the laptop during the class and it is highly **NOT RECOMMENDED** to do so

- **You are advised to take notes whenever I stress a particular point. This may have some incidence on the exams**

Homework rules

- Homework will be assigned online on Canvas

- Students should complete the home works independently
  They **MUST** make sure that they are able to solve the problems by their own

- Solutions will be given by TA's during recitation classes:

  - Solutions will **NOT** be released in Canvas
  - Students are **INVITED** to attend recitation classes

  - Homeworks will **NOT** be **GRADED: Why?**

HW 1	HW 2	HW 3	Midterm 1	Midterm 2	Final
100	98	100	59	71	40
92	98	95	73	26	73
100	98	96	70	42.5	70
100	100	95	73	32	81
100	100	100	71	66	87
100	98	100	40	35	86
100	100	100	83	75	98
98	95	100	45	46	76
100	98	100	79	59	101
100	86	100	68	72	92
100	98	95	59	49	79
98	98	100	76	71	117
97	100	100	52	48	56
100	90	89	72	65	88
95	98	100	40	40	71
72	88	100	52	16	76
100	100	95	42	62	86
97	98	100	53	49	95
99	88	100	62	31	88
99	98	100	58	26	74
100	98	100	33	33	58

Here are some samples taken from fall 2017 showing the reason

Most of the students got around 100% at the HW’s **BUT** many got bad scores at the exams and quizzes

Can anybody guess the reason?

It is so easier to search in internet !

HW 1	HW 2	HW 3	Midterm 1	Midterm 2	Final
92	70	100	63	29	103
100	100	100	41	46	47
97	93	95	81	61	70
100	83	95	52	38	95
100	100	100	61	40	84
100	100	100	90	62	87
97	100	100	39	8	44
85	88	100	59	49	107
100	98	100	50	39	67
98	98	93	48	26	92
72	98	100	47	44	86
100	98	100	44	28	64
100	88	100	57	34.5	96
97	98	100	67	59	97
100	98	97	53	33	40
100	98	95	82	64	98
100	98	100	70	54.5	75
99	98	100	62	26	82
100	100	100	58	35	81
100	80	100	51	57	85

New protocol for fall 2018

Quiz rules

- There will be a number of in-class quizzes over the term: <u>Between 6 and 10</u>
- Students should complete the quiz independently. No talk and collaboration are allowed
- No electronic devices will be allowed except basic calculators

Reminder about quizzes

- ***Unlike the exams, the dates for quizzes will not be announced !***
- ***The quizzes will be <u>closed books AND closed doors</u>: Once the quiz is decided during the class NO STUDENT is allowed to get in !***

Exam rules

- There will be two mid-term exams and one final exam. Each lasts **1:40** minutes
- **Closed books: 1 double sided sheet for each exam**
- No electronic devices will be allowed except basic calculators

WARNING

- Between 20% and 30% of the problems are directly picked up from the home works without changing any word. The HW's containing such problems will be indicated in the exam sheet
- Between 20% and 30% of the problems are based on the questions asked and solved during class
- Between 20% and 30% of the problems are new **BUT** related to the material covered during class
- One or two problems are given to outstanding students

Grading Policy

Midterm I + II	25% + 25%
Final	30%
Quizzes	20%

A very important point

How to solve problems during the exams

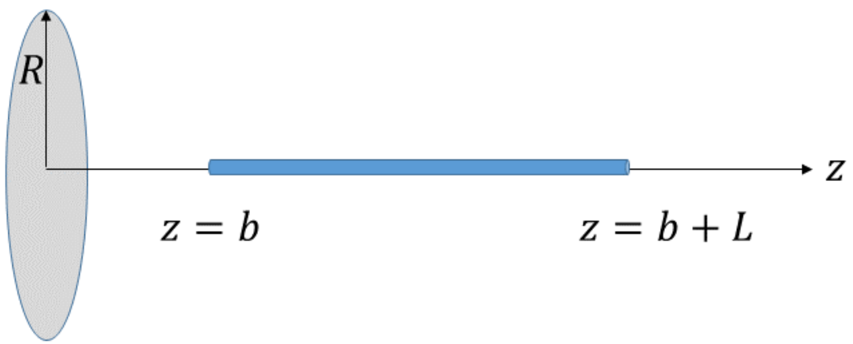
The way a problem is solved tells about the student's skill and his/her ability to be didactic

Example of a problem given during summer term 2016

Problem 5 (15 pts)

A uniformly charged (thin) non-conducting rod is located on the central axis a distance b from the center of a uniformly charged non-conducting disk. The length of the rod is L and has a linear charge density λ. The disk has a radius R and a surface charge density σ.

- Calculate the total force between these two objects.
- What if the disk has an infinite diameter?



Student A

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{1}{\sqrt{R^2/_{z^2} + 1}}\right]\vec{k}$$

$d\vec{F} = dq\vec{E}$ $\quad dq = \lambda dz$

$$\vec{F} = \int_b^{b+L} \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{1}{\sqrt{R^2/_{z^2} + 1}}\right]\vec{k}.dq$$

$$\vec{F} = \frac{\lambda\sigma}{2\varepsilon_0}\left(L - \sqrt{R^2 + (b+L)^2} + \sqrt{R^2 + b^2}\right)\vec{k}$$

$R = \infty, \vec{E} = \frac{\sigma}{2\varepsilon_0}\vec{k}$

$$\vec{F} = \frac{\lambda\sigma L}{2\varepsilon_0}\vec{k}$$

Student B

We saw in class that the electric field created at any point along the central axis is given by

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{1}{\sqrt{R^2/_{z^2} + 1}}\right]\vec{k}$$

It has only one component, along z −axis. Breaking up the rod into an infinite number of infinitesimally small point charges dq, We have that the net force on each tiny charge is $d\vec{F}$ = $dq\vec{E}$. Summing up all these contributions, and using the fact that $dq = \lambda dz$ gives

$$\vec{F} = \int_b^{b+L} \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{1}{\sqrt{R^2/_{z^2} + 1}}\right]\vec{k}.dq$$

Replacing dq *by* λdz and integrating gives,

$$\vec{F} = \frac{\lambda\sigma}{2\varepsilon_0}\left(L - \sqrt{R^2 + (b+L)^2} + \sqrt{R^2 + b^2}\right)\vec{k}$$

If the disk has an infinite diameter, the electric field simplifies and is now given by $\vec{E} = \frac{\sigma}{2\varepsilon_0}\vec{k}$ and the force is simply,

$\boxed{\vec{F} = \frac{\lambda\sigma L}{2\varepsilon_0}\vec{k}}$ or $\vec{F} = \frac{Q\sigma}{2\varepsilon_0}\vec{k}$ or $\vec{F} = Q\vec{\mathrm{E}}$,

where Q is the charge of the rod ($Q = \lambda L$) and $\vec{\mathrm{E}}$ the field created by the infinite disk

Which way of solving do you like ?

Be aware !

Problem 5 (15 pts)

Student A

-10%

Student B

Full mark

A student who does not explain what he/she is doing will **NOT get the full mark** even though the solution is correct

Schedule (Tentative)

Course Description: Vector calculus; Electrostatics; Magnetostatics; Energy and elementary circuits; Maxwell's equations; Plane waves.

Tentative Teaching Schedule:

Lecture 1. General consideration and learning versus understanding	
Lecture 2. Introduction I: General overview of electromagnetism	**HW1**
Lecture 3. Introduction II: Defining concepts and principles	
Lecture 4. Position of the problem and Vector Analysis I	
Lecture 5. Vector Analysis II	**HW2**
Lecture 6. Static Electric Fields: Gauss law and applications	**HW3**
Lecture 7. Static Electric Fields: Dipole	
Lecture 8. Static Electric Fields: Conductor	**HW4**
Lecture 9. Static Electric Fields: Dielectric I	
No lecture, Midterm Exam 1	
Lecture 10. Static Electric Fields: Dielectric II	**HW5**
Lecture 11. Static Electric Fields: Electrostatic energy, work and force	
Lecture 12. Steady Electric Currents: Ohm's and Kirchhof's law	
Lecture 13. Steady Electric Currents: Joule's law	**HW6**

Lecture 14. Magnetostatics I: Basic of magnetic field force and its applications
Lecture 15. Magnetostatics II: Ampere’s law and its applications **HW7**
Lecture 16. Magnetostatics III: Vector potential and its applications
Lecture 17. Magnetostatics IV: Faraday's emf induction **HW8**
Lecture 18. Static Magnetic Fields: Electrostatic versus magnetostatics
No lecture, Midterm Exam 2
Lecture 19. Maxwell’s Equations I: Electromagnetic waves
Lecture 20. Solving Maxwell’s equations in free space
Lecture 21. Solving Maxwell’s equations with current and charges **HW9**
Lecture 22. Plane Electromagnetic Waves I
Lecture 23: Plane Electromagnetic Waves II
Lecture 24. Plane Electromagnetic Waves III
Lecture 25. Plane Electromagnetic Waves IV **HW10**
Lecture 26. Plane Electromagnetic Waves V
Review
No lecture, Final Exam

Schedule (Tentative)

Introduction and Vector analysis	1 weeks
Electrostatics	3 weeks
Steady Electric Currents	1 weeks
Magnetostatics	3 weeks
Maxwell's equations	2 weeks
Plane wave propagation	1 weeks
Review and exams	1 weeks

2 lectures and a half per week

Teaching Evaluation

"The IDEA Center is a nonprofit organization whose mission is to serve colleges and universities committed to improving learning, teaching, and leadership performance. The Center supports the evaluation and development of both programs and people."

Insight.Improvement.Impact.®

A NON-PROFIT ORGANIZATION

My job: to participate this program to improve my teaching.

Your job: to fill out some forms as requested over the semester.

Reasons for being concerned by Teaching evaluation

- In any institution and in any society, the goal is to improve the conditions for a better life
- Our grandparents and parents worked hard to allow us get educated: They paved the way to us
- It is crucial today to feel concerned by the coming generations, your brothers, sisters, neighbors and friends
- My presence here cost money to China, therefore to your parents. That is why, you need to make sure and claim whether my teaching is relevant or not to the future of China
- You are not allowed to miss the possibility to participate in evaluating your teacher, whether Chinese or foreigner

Feeling concerned makes you real citizens

This is the only way for JI to continue offering a high standard education to Chinese pupils

Some useful information regarding my way of lecturing

Highlighting, underlying and **bold writing**

The line integral of $\vec{\nabla} f$ **does not depend** on the path but only on end points a and b.

Highlighting

$$f(\mathrm{x,y,z}) = -\int_a^b \vec{\nabla} f(x,y,z).\,d\vec{l}$$

Along any open path from a to b

Two consequences of the fact that the field is conservative

There is no circulation around any loop

$$f(\mathrm{x,y,z}) = -\oint \vec{\nabla} f(x,y,z).\,d\vec{l} = 0$$

Along a closed path

Stokes theorem

$$\vec{\nabla} \times \vec{U}(x,y,z) = -\vec{\nabla} \times \vec{\nabla} f(x,y,z) = \vec{0}$$

Learning versus understanding

Why is it so important that you understand something instead of just learning a thing?

- **Learning** = act of memorization of a set of supposed facts

⇨ Apply them in a very limited and focused manner to solve problems

- **Understanding** = Makes us able to correlate a whole bunch of concepts in order to come up with a holistic comprehension

Holistic: Characterized by the fact that the parts of something are intimately interconnected and explicable only by reference to the whole.

- It is up to you to decide whether physics is right or wrong
- Anyone who tries to convince you that physics is beyond question is someone who truly does not ‘understand’ what he or she is talking about
- Physics could be partly right and partly wrong, it could also be totally doubtful to you
- Your subjective world is as important as any objective truth that is expounded by anyone else.

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<u>Understanding</u> is the act of questioning what you have <u>learned</u>

Without this act…

- ***Planck would not have come up with quantum physics***
- ***Maxwell would not have come up with his theory of electromagnetism***
- ***Einstein would have come up with his relativity theory***

⬇

Learning makes you <u>knowing</u> ***BUT*** *<u>understanding</u> makes you <u>skilled</u>*

Understanding physics

The understanding process is settled in a logical order following somehow the historical path

- Nowhere the students start by learning <u>relativity theory</u> or <u>quantum physics</u> before getting acquainted with <u>classical Newtonian mechanics</u>

- **Are the concepts learned in classical mechanics obsolete in learning another field (electromagnetism)?**

NO

✓ Force and acceleration
✓ Potential and kinetic energy
✓ Conservation laws: Energy – linear and angular momentum etc…

- The concept of **Force** was still used in Bohr's atom model **BUT** no longer in quantum mechanics
- All other concepts are not only valid! **They have been strengthened**

In electromagnetism all what has been learned in Classical mechanics is crucial

The physical word is very broad

Great principles apply to **ALL** different kinds of phenomena

- Conservation laws
- Principle of least action,
- Principle of superposition

⋮

Many seemingly complicated phenomena may reduce to understanding what happens at the atomic scale

- Electricity may help understanding compression of solids

⋮

The most remarkable thing

- Equations for <u>many different physical situations have exactly the same form</u> ⇨ lead to the same solution
- Understanding one situations may greatly facilitate understanding others

**Question #1

<u>Example 1:</u> What is common to the following physical situations?

- A stone thrown in a lac
- A loud speaker emitting sound
- A light source emitting light
- A beam of material particles hitting a crystal
- An electron orbiting in an atom

Answer to **Question #1

They all obey a wave equation and produce interferences

We can see a mechanical wave but nobody has ever seen a light wave

**Question #2

How did we came to the facts that:

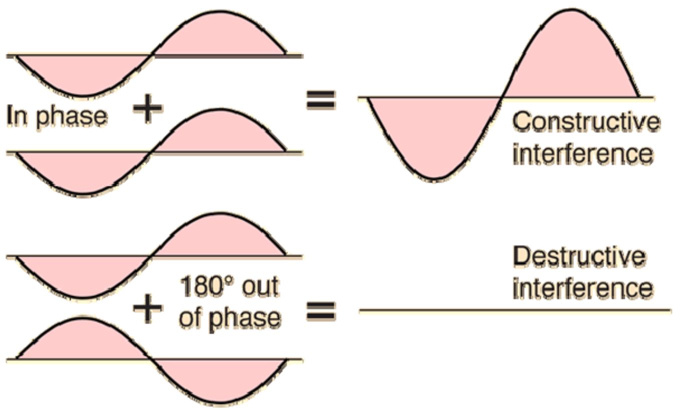
- Light is a wave
- Light is made of particles called photons?

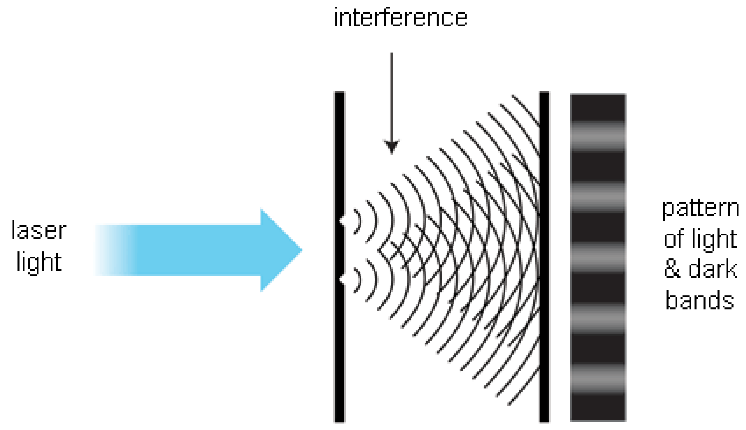
Answer to **Question #2

Light as a wave: Classical electromagnetism (Maxwell's theory)

- Interference = distribution in space of constructive and destructive patterns $\Rightarrow$ adding things :

  ✓ Enforced
  ✓ Weakened





Light as a particle: Quanta exchange between light and matter
Photoelectric effect (Hertz experiment vs Einstein explanation)

Example 2: Electrostatic versus other things

Electrostatic

$$\vec{\nabla}.(\varepsilon_r \vec{E}) = \frac{\rho}{\varepsilon_0} \qquad \vec{\nabla} \times \vec{E} = 0 \qquad \vec{E} = -\vec{\nabla}\varphi \qquad \vec{\nabla}.(\varepsilon_r \vec{\nabla}\varphi) = -\frac{\rho}{\varepsilon_0}$$

$\vec{E}$ Electric field
φ Electric potential
ε_r, ε_0 Dielectric constants
ρ charge density

Flow of heat

$$\vec{\nabla}.\vec{h} = s \qquad \vec{h} = -K\vec{\nabla}T \qquad \vec{\nabla}.(K\vec{\nabla}T) = -s$$

$\vec{h}$ heat flow
s heat energy/unit volume
K thermal conductivity

Stretched membrane

$$\vec{\nabla}.(\tau\vec{\nabla}u) = -f$$

τ Surface tension
u vertical displacement of the membrane
f = upward force per unit area

Diffusion of neutrons

$$\vec{\nabla}.\vec{J} = S - \frac{\partial N}{\partial t} \qquad \vec{J} = -D\vec{\nabla}N \qquad \vec{\nabla}.(D\vec{\nabla}N) = \frac{\partial N}{\partial t} - S$$

$N(x, y, z, t)$ = number of neutrons in volume element
S rate of neutron generation
D diffusion constant

Important thing

Rate of change of physical quantity with position and time

- Function
- Scalar field
- Vector field

Fundamental laws

Tool box #1

- Differential equations
- Integral equations

Tool box #2

- Derivative
- Gradient
- Divergence
- Curl

... require specific mathematical <u>tools</u> and <u>spatial</u> representation

+ An important ingredient : **<u>Symmetry</u>**
+ An important principle : **<u>Superposition</u>**

⬇

Understanding and solving equations

⬇

What does it really mean “Understanding an equation” ?

<u>Dirac:</u> *“I understand what an equation means if I have a way of figuring out the characteristics of its solutions without actually solving it”*

***Question #3

What do these two equations describe and what do they tell us about physics?

Answer to ***Question #3

Wave equation $$\frac{\partial^2 u}{\partial t^2} = v^2 \frac{\partial^2 u}{\partial x^2}$$

Heat equation $$\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$$

1) Both indicate that something propagates ⇔ changes position with time

2) The first equation says that energy is conserved and time is reversible

3) The second equation tells that energy dissipates and time is irreversible

$$t \rightarrow -t$$

Historical timeline to key discoveries leading to Maxwell's equations

Electro/magneto/statics — Electrodynamics — time

Coulomb (1785)

$$\vec{E} \propto \frac{q}{r^2}\vec{u}_r$$

$\boldsymbol{\vec{E} \,//\, \vec{u}_r}$

$\propto \frac{1}{r^2}$

Poisson (1813)

$$\vec{E} = -\vec{\nabla} V$$

$$\nabla^2 V = -\frac{\rho}{\varepsilon_0}$$

Orsted (1820)

$$\vec{J} \rightarrow \vec{B}$$

Biot and Savart (1820)

$$\vec{J} \rightarrow \vec{v} \times \vec{r} \rightarrow \vec{B}$$

Ampere (1820)

$$\vec{\nabla} \times \vec{B} = \frac{1}{c^2}\frac{\vec{J}}{\varepsilon_0}$$

$\propto \frac{1}{r^2}$ $\boldsymbol{\vec{B} \perp \vec{u}_r}$

Faraday (1821)

$$\frac{\partial B}{\partial t} \rightarrow E(t) \rightarrow \vec{J}$$

$$\vec{\nabla} \times \vec{E}(t) = -\frac{\partial \vec{B}}{\partial t}$$

Perfect symmetry far from the source

Gauss (1831)

Concept of flux

$$\vec{\nabla}.\vec{E}(t) = \frac{\rho(t)}{\varepsilon_0}$$

$$\vec{\nabla}.\vec{B}(t) = 0$$

Maxwell (1873)

$$D = \varepsilon_0 E \rightarrow \frac{\partial E}{\partial t} \rightarrow \frac{\partial D}{\partial t} = j$$

Displacement current

Ampere + Maxwell

$$\vec{\nabla} \times \vec{B}(t) = \cancel{\frac{1}{c^2}\frac{\vec{J}}{\varepsilon_0}} + \frac{1}{c^2}\boxed{\frac{\partial \vec{E}}{\partial t}}$$

EM waves

$\boldsymbol{\vec{E} \perp \vec{B} \perp \vec{u}_r}$ $\propto \frac{1}{r}$

Discovery of Maxwell letting him to the Electromagnetic wave equation

- At his time physics seemed complete
  ⇨ Was he to refrain from asking questions to himself?
  and therefore concentrate just on **learning** instead of **understanding**?

- The equations of electrostatic and magnetostatic where mutually inconsistent when put together

- Maxwell added a new term to Ampere's law

⇓

An amazing thing appeared

Part of electric and magnetic fields fall off as $\mathbf{1/r}$ **AND** $\vec{E} \perp \vec{B} \perp \vec{u}_r$

Much slowly than $\mathbf{1/r^2}$ law of Coulomb and Biot & Savart law

⇓

Electromagnetic waves were predicted

Breakthrough

time

Maxwell (1873)

EM wave theory

Hertz (1887)

Experimental proof of Maxwell's theory

Hertz (1887)

First experiment killing Maxwell's theory as the only possible way of representing an EM Wave.

The photoelectric effect

Prelude to wave-particle theory

Continuity

Planck (1900)

Birth of quantum physics:
Light – matter interaction
is discontinuous !

Einstein (1905)

Explanation of the photoelectric effect: Concept of photon for light

Duality wave-particle becomes reality

Special theory of relativity: New triumph for Maxwell

- No need to correct Maxwell's theory
- Need to correct Newton's theory
- Lorentz transformations replace Galileo's

Discontinuity