Alignment of Student Activities, through Exercises, Quizzes, Demonstrations, and Lectures, Applied to Electromagnetic Teaching

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PIERS, Guangzhou, 25-28 of August, 2014

Abstract— My teaching in electromagnetic theory consists of several different parts, aiming in the direction of the constructive alignment (Biggs 2007). The course goals are described as specific active verbs (required at KTH). The underlying assumption in my course design is that the students own work is the basis for his/her learning. Thus my designing of lectures, homework, quizzes and mid-term exams are aiming to direct the students own activities to be in course alignment, while focusing them to the key areas. I will illustrate my interpretation of course alignment by two examples, lectures with quizzes and with the homework/class-room demonstration exam chain.

The classes in electromagnetic theory, begins with 2 × 45 minute lectures on electromagnetic theory, each such a lecture is interrupted by 2–4 class-room Mazur (1996) inspired quizzes. These quizzes are directly focused on what was just taught in the class, and often requires the student to apply, test, or use the recently demonstrated theory or demonstrated experiment. These quizzes are rather informal. A quiz is stated as a short question, with a (3–4) multiple choice answers. The students are requested to select an answer, through a quick show of hands. This is followed by a subsequent student-to-student discussion for a few additional minutes, ended with a new show of hands. Often but not always it converges to the right answer. An important feedback loop for me is that I circulate among the students to engage in a short discussion with probing questions and encouragements during the work with the quiz. These few-to-one students to teacher interaction often indicate weak and strong points of the students initial understanding of the theory. The quiz ends with a demonstration of a method to arrive to the correct answer.

The above quizzes as a teaching element were introduce in the response of that a high level attention of the students are typically limited to 10–15 minutes (Bligh 1972). What was also clear from the study was that a high level attention can return if the students are engaged in another activity. This other activity tested here is the student-to-student discussion and problem solving during the quizzes. The quizzes are aligned with the course, by focusing on applying the just illustrated electromagnetic ideas and theories.

The homework, demonstrations and exam-chain of alignment begins with using old exams as training material. Apart from the above described lectures, we have class-room demonstrations on problem solving. The problems are both introductory problems, and exam-level questions. The demonstrations apply and exemplify the methods used to solve electromagnetic problems. They illustrate only a few of the recommended tasks per class. There is a large amount of old- exam questions available to the students. They are used as homework problems and training material along the course, and in particular for the two mid-term exams. These 2 h class-room exams on problem solving can yield a small bonus for the student towards the final exam. However they are mainly used to provide feedback both to the lecturer and to the student on the student knowledge and problem solving ability at the present stage of the course.

The electric engineering students taking the course are, at the end of the course, requested to provide feedback. This feedback shows that the quizzes and the experimental demonstrations are the most appreciated activities during the course. For me as a lecturer, the quizzes and mid-term exams provide a direct feedback of their present level knowledge, which enables me to make adjustment during the subsequent teaching in response to the observed level of understanding. This may include additional information focusing on a problem area and when it is required we insert additional classes focused on the students own problem-solving often through a small group student-to-student discussion, with a teacher circulating between several such small groups, to help along the discussion.

One of the key important parts in a successful teaching of electromagnetic theory is that the prerequisite mathematics is well integrated. To further this observation we have across courses discussion between mathematic and electromagnetic lecturers about mutual requirements and observed results of the present knowledge. In preparation for autumn 2014 and an updated electromagnetic course, such mutual exchange between vector algebra and electromagnetic has been emphasized, and we look forward to evaluating the result.

Undergraduate electromagnetic theory at KTH

Courses for Electrical Engineers, year 2

- Electromagnetic Field Theory (7.5hp) until spring 2014
- Wave propagation and Antennas (7.5hp) until spring 2014

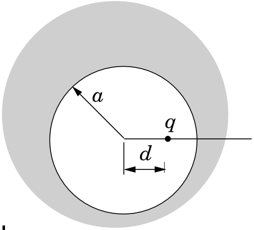
... we use Cheng 'Field and Wave Electromagnetics'

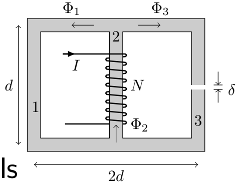
Courses for Electrical Engineers autumn 2014 and onwards

- Electromagnetic Theory E (10.5hp)
- Electromagnetic Theory, Continuation Course (6hp), elective.

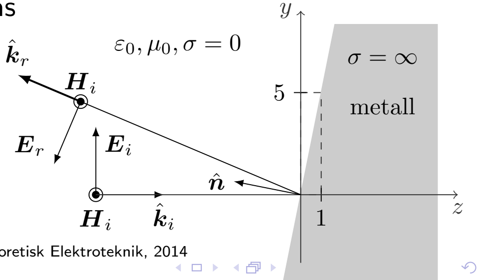
- A years study correspond to 60hp.
- There are about 70 electrical engineering students per year.
- In addition there are teaching electromagnetic theory for engineering physics-students (about 100 students).

- Coulombs law, electric fields, potentials
- Gauss law, Capacitance, Work
- Electric dipole moment, polarization, $\boldsymbol{D}$-field
- Electrostatic forces, torque
- Laplace and Poisson's equations, boundary problems
- Mirroring in plane, sphere, and cylinder.
- DC-currents, Resistance, Joules law
- Magnetic dipole moment, magnetization, $\boldsymbol{H}$-field
- Scalar magnetic potential, forces, torques
- Magnetic flux, magnetic circuit, magnetic materials
- Induction, inductance, mutual inductance
- Energy, iron-transformer





- Maxwell's equations, Poynting's theorem
- Wave equation, complex vectors, plane waves
- Reflection; planar and oblique, PEC or lossy media
- Introduction to transmission lines
- Introduction to wave-guides, rectangular cross section
- Gauge-theory, retarded potentials,
- electric and magnetic antenna dipoles, wire-antennas, impedance
- Introduction to Array antennas



Figures: From KTH exams and also from G. Petersson: Teoretisk Elektroteknik, 2014

Teaching facts and tools

Attention span, and concentration

- Attention span in lectures, writing is about 15 minutes
- Attention/learning level can be restored by rest, change of activity
- Review/Consolidation at end of lecture, improves retention.

Ref: Bligh 1972, What's the use of lectures?m Biggs & Tang 2007

Methods

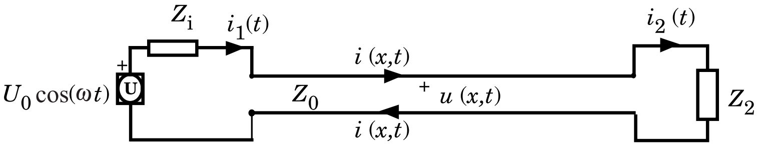
- Class-room lectures
- Quizzes
- Demonstrations
- Exercise sessions
- Homework, Mid-term and final exams.

Goal: To use enthusiasm and required work as a leverage to encourage students to work the right kind of work at home.

Most people learn...

- 10% of what they read
- 20% of what they hear
- 30% of what they see
- 50% of what they see and hear
- 70% of what they talk over with others
- 80% of what they use and do in real life
- 95% of what they teach someone else

Attributed to William Glasser; quoted by Biggs & Tang Teaching for Quality learning at University, 2007



How do we learn?

Most people learn...

- 10% of what they read
- 20% of what they hear
- 30% of what they see
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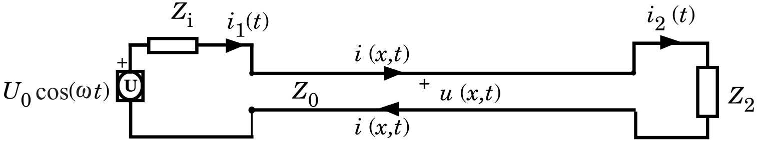


Mazur style Quizzes

Eric Mazur – concept

- Read before – specific reading tasks, written statement
- Feedback: Difficult and or most interesting part of lecture
- Quizzes: Multiple choice questions in class
- Recollection of today's subject (by teacher or student - one-minute essay): What was the main point left unanswered in today's session?

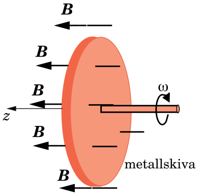
Implemented tools:

- Insist that they read before (at start of course, repeated a few times)
- Lecture in short block's $\sim$15 minutes
- Use quizzes as active learning tool
- Collect and Review main results of today's class.
- Use old exams as training home-work training tasks.

Constructive alignment – Biggs and Tang 2007

Alignment

- Alignment between, teaching goals, lectures, student tasks, and exams
- Important to direct attention to right task:
  - "I've studied every line of the solution book, but when you change the shape of the circuit, I can't solve it"
  - "I appreciate the homework since they direct my attention to the right problems"
- Use exams as training task. They define how we measure the goals.
- Tie quizzes direct to lectured materials.
- Use student discussion to improve knowledge



Quizzes – set up and implementation

Elements of a quiz

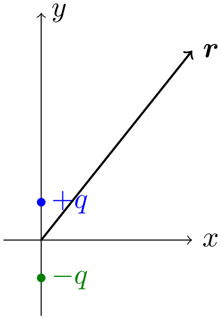
1. Introduce the material (part of what was lectured today)
2. Formulate the problem, should be easy enough that it can be solved in 5 minutes
3. Let the students work on it (about) 5 minutes
4. Ask for a quick show of hands (or clickers, poll-applications)
5. Evaluate, if 80% or more know the right answer, continue with class, otherwise, let the students discuss it for 2-5minutes; teacher participate in discussion by circulating
6. Quick show of hands, discuss the solution.
7. (when using quick-hands, colored paper, or similar, explain that you do not remember answers from individuals).

Quiz – Coulomb's law

The charge here is $q > 0$. The electric field from a single charge is

$$\boldsymbol{E}(\boldsymbol{r}) = \frac{q}{4\pi\varepsilon_0}\frac{\boldsymbol{r}-\boldsymbol{r}'}{|\boldsymbol{r}-\boldsymbol{r}'|^3} \qquad (1)$$

where $\boldsymbol{r}'$ is a vector to q, and $\boldsymbol{r}$ is the vector to the observation point. The electric field from q corresponds to $\boldsymbol{E}_1$ and the electric field from $-q$ corresponds to $\boldsymbol{E}_2$.



Quiz: Draw $\boldsymbol{E}_1(\boldsymbol{r})$ and $\boldsymbol{E}_2(\boldsymbol{r})$, and determine the net $\boldsymbol{E}_{tot}(\boldsymbol{r})$-direction.

Answer on demand, by standing up, and let your arm point in $\boldsymbol{E}_{tot}$-direction

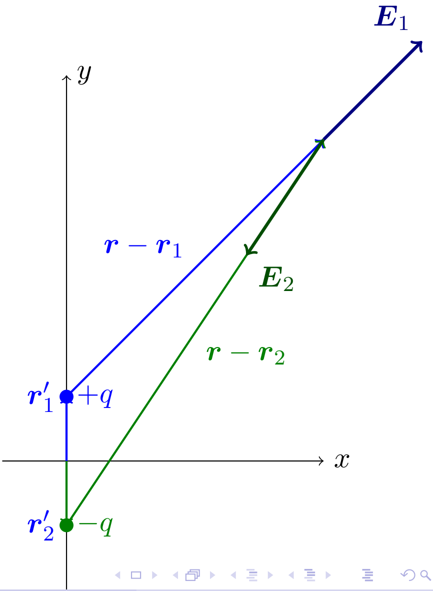
Answer – Coulomb's law

$$\boldsymbol{E}_1(\boldsymbol{r}) = \frac{q}{4\pi\varepsilon_0}\frac{\boldsymbol{r}-\boldsymbol{r}_1'}{|\boldsymbol{r}-\boldsymbol{r}_1'|^3}$$

$$\boldsymbol{E}_2(\boldsymbol{r}) = \frac{-q}{4\pi\varepsilon_0}\frac{\boldsymbol{r}-\boldsymbol{r}_2'}{|\boldsymbol{r}-\boldsymbol{r}_2'|^3}$$

Quiz: Draw $\boldsymbol{E}_1(\boldsymbol{r})$ and $\boldsymbol{E}_2(\boldsymbol{r})$, and determine the net $\boldsymbol{E}_{tot}(\boldsymbol{r})$-direction.

Answer on demand, by standing up, and let your arm point in $\boldsymbol{E}_{tot}$-direction



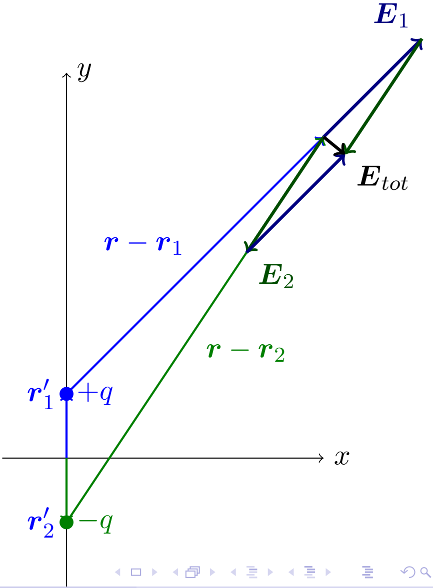
$$\boldsymbol{E}_1(\boldsymbol{r}) = \frac{q}{4\pi\varepsilon_0}\frac{\boldsymbol{r}-\boldsymbol{r}_1'}{|\boldsymbol{r}-\boldsymbol{r}_1'|^3}$$

$$\boldsymbol{E}_2(\boldsymbol{r}) = \frac{-q}{4\pi\varepsilon_0}\frac{\boldsymbol{r}-\boldsymbol{r}_2'}{|\boldsymbol{r}-\boldsymbol{r}_2'|^3}$$

$$\boldsymbol{E}_{tot} = \boldsymbol{E}_1 + \boldsymbol{E}_2$$

Quiz: Draw $\boldsymbol{E}_1(\boldsymbol{r})$ and $\boldsymbol{E}_2(\boldsymbol{r})$, and determine the net $\boldsymbol{E}_{tot}(\boldsymbol{r})$-direction.

Answer on demand, by standing up, and let your arm point in $\boldsymbol{E}_{tot}$-direction



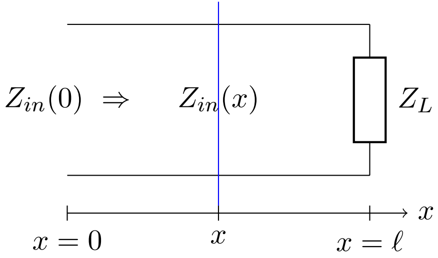
Outline of a quiz

Lecture about transmission line impedance

$$Z_{in}(x) = Z_0 \frac{Z_L + Z_0 \tanh(\gamma(\ell - x))}{Z_0 + Z_L \tanh(\gamma(\ell - x))}$$

Special case of no losses $\gamma = \mathrm{j}k$.

Z_0 is the characteristic impedance.



Quiz: Given $\ell = \lambda/4$, and loss-less transmission line, what is $Z_{in}(0)$?

1. Z_0^2/Z_L
2. Z_0
3. Z_L
4. something else.

Solution

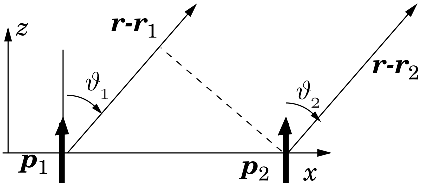
Key observation is

1. $\tanh(jk\ell) = j\tan(k\ell)$ (from Eulers formula of cos/sin)
2. $k = 2\pi/\lambda$ and $\ell = \lambda/4 \Rightarrow k\ell = \pi/2)$
3. $\tan\pi/2 = \infty$, i.e. think of large value of $\tan k\ell$.
4. $$Z_{in} = Z_0 \frac{\cancel{Z_L} + jZ_0 \cancel{\tan k\ell}}{\cancel{Z_0} + jZ_L \cancel{\tan k\ell}} = \frac{Z_0^2}{Z_L} \qquad (2)$$

   The right answer was number 1.

This quiz is on the tougher side, it requires several steps of thoughts, e.g. allow more time.

- Align goal and training; use old exams as training tool
- Concentration lasts max 15 minutes, use quizzes to reactivate students
- Teach others, and discussions are high powered learning tools
- "Brought over" and "Gone through" are not teaching, learning requires using, talking about, working with the subject.
- Demonstrations, quizzes, 1 minute essay, all can be used to learn more.
- Reading before helps – encourage it.



Ref: Illustrative pictures comes from my exam questions and our exercise books by G. Petersson, reprinted 2014.