Teaching Experience

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Contents

Space Physics I - 2021

: Teaching Assistant & Guest Lecturer | : Master | : 2021–2022
: KTH | </> : EF2240 | : link

Short Description - Content

The plasma state. Typical properties of space plasmas. The sun and the solar wind, and how they effect the Earth's space environment. The magnetosphere and the ionosphere, their origin, structure and dynamics. The aurora and geomagnetic storms and substorms. Space weather. Space environment of other celestial bodies. Interstellar and intergalactic plasma and cosmic radiation. Current research topics within space physics.

The goals of the course are that the student should be able to:

- Define what is meant by a plasma, and how different types of plasmas can be classified.
- Describe the plasma environment in space, with focus on the near-earth environment.
- Explain how certain important plasma populations in the solar system, e.g. the Earth's ionosphere and magnetosphere, get their basic properties, and how these properties may differ between the planets.
- Make order of magnitude estimates of some properties in space plasmas and space phenomena, e.g. the power dissipated in the aurora, or the amount of current floating from Earth's magnetosphere to its ionosphere.
- Model certain space physics phenomena by applying basic physical laws, using simple mathemathics (e.g. model the form of the magnetosphere or estimate the temperature of a sunspot).
- Describe current research within space physics and explain it to an interested layman.

  The references for the course are [Baumjohann and Treumann, 2012] and the notes written by Carl-Gunne Fälthammar.

Duties

- 6 Tutorials | preparation, management, and execution
- 5 Assignments | support, correction, and feedback
- 1 Lecture | Introduction to Neural Netwoorks and applications in Space Physics

Performance

Learning Experience Questionnaire (LEQ) average grade: **TBD**

Content Example - Tutorial

Tutorial 5 - Exercise 3

For a cosmic ray to be able to penetrate directly into the Earth's atmosphere close to the equator, it has to have a gyro radius at least as great as the size of the magnetosphere itself, otherwise it will begin to gyrate around a field line, and move towards the poles.

a) Estimate the energy of a cosmic ray particle for this to happen, if the particle is a proton. What about an alpha particle? For the evaluation of the gyro radius use the strongest magnetic field the particle will encounter in the equatorial plane.

b) How strong a field would you need to use if you wanted to artificially shield a spacecraft from electrons of energies less than 10^8 eV? Assume that the magnetic field is constant within a distance of 100 meters of the spacecraft.

Solution

a) The strongest magnetic field the proton will encounter is 31 μ T. The gyro radius ρ is given by:

$$\rho = \frac{p_\perp}{qB}$$

With the high energies associated with the cosmic ray particles, we need to use the relativistic expression for the momentum:

$$pc = \sqrt{E^2 - m_0^2 c^4}$$

where m_0 is the proton rest mass ($1.67 \cdot 10^{-27}$ kg). Therefore,

$$\rho = \frac{\sqrt{E^2 - m_0^2 c^4}}{cqB}$$

Solving for energy gives:

$$E = \sqrt{(\rho qB)^2 c^2 + m_0^2 c^4} = ... = \sqrt{9 \cdot 10^{-15} + 2.3 \cdot 10^{-20}} = 9.5 \cdot^{-8} \text{ J} = 5.8 \cdot 10^{11} \text{ eV}$$

Note that the rest energy of the proton ($\sim$ 1 GeV) is negligible compared to this

b) Now we have,

$$\rho = \frac{p_\perp}{qB} = L$$

Solving for the magnetic field we get:

$$B = \frac{p_\perp}{qL} = \frac{\sqrt{e^2 - m_e^2 c^4}}{eLc}$$

If we replace some typical values:

$$B = \frac{\sqrt{10^{16} \cdot (1.6 \cdot 10^{-19})^2 - (9.1 \cdot 10^{-31})^2 \cdot (3 \cdot 10^8)^4}}{1.6 \cdot 10^{-19} \cdot 100 \cdot 3 \cdot 10^8} = 3.3 \text{ mT}$$

If we want to compare this to the magnetic field found in the centre of a circular loop current, we have:

$$B = \frac{\mu_0 I}{2r} \Longrightarrow I = \frac{2Br}{\mu_0} = \frac{2 \cdot 0.003 \cdot 100}{4\pi \cdot 10^{-7}} = 0.5 \text{ MA}$$

Space Physics I - 2020

: Teaching Assistant	: Master	: 2020–2021
: KTH	</> : EF2240	: link

Short Description - Content

Same as above.

Duties

- 6 Tutorials | preparation, management, and execution
- 5 Assignments | support, correction, and feedback

Performance

Learning Experience Questionnaire (LEQ) average grade: **6.8/7**

Link to the full report:

LaTeX Workshop

: Lecturer & Teaching Assistant | : Bachelor | : 2019-2022
: KTH | : EF112X | : link

Short Description

At the beginning of the workshop, there will be a short introduction on the general use of the LaTeXand BibTeX environment as a comprehensive and useful tool for scientific writing. After the introduction, you will carry out a task described on the following page. In short, the task is to compile a short text with four correctly included references.

Duties

- Instructing how to correctly use bibtex and other alternative solution to reference system in LaTeX.
- Assisting the student in solving their tasks.
- Correcting the assignments of students and providing individual feedback.

Electrical Circuit Analysis

: Teaching Assistant | : Bachelor | : 2021

: KTH | : EI1110 | : link

Short Description - Content

- Basic components, voltage and current sources (independent and dependent). Ohm's law and Kirchhoff's laws. Analytical methods including nodal analysis, mesh and loop analyses, superposition and graphical methods.
- Two pole equivalents (Thevenin and Norton equivalents).
- Operational amplifiers.
- Transient switching including equilibrium and continuity. Time dependent quantities in dynamic circuits.
- Complex numbers. Alternating current and time harmonic signals analysed with the complex method (the j omega-method). Impedances.
- Complex power. Active, reactive and apparent power. The Tellegen theorem. Matching, phase compensation and power factor.
- Inductive coupling and transformers.
- Filter circuits and Bode diagrams/plots.
- Three-phase systems and balance in such systems.
- Applications. The course CDIO-elements include dimensional analysis and to design, dimension and create basic circuits, under the concept "Conceiving", with introductory elements of "Designing"

Duties

- 10 Tutorials | preparation, management and execution
- 10 Laboratories | preparation, management and execution

Content Example - Tutorial

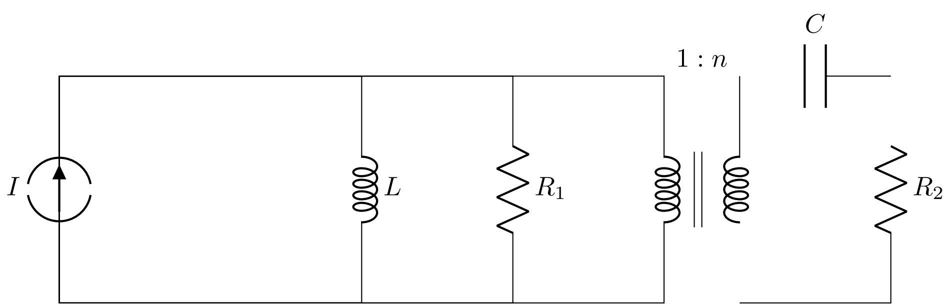
Exam 2019 question 8

Taken from : Previous Exams EI1120

The source has angular frequency ω

Component values n and C can be chosen, but other component values are fixed.

1. [3p] Determine the values of n and C that will maximise the power delivered to resistor R_2.
2. [1p] What is the value of this maximum power to R_2 ?



Solution

This is a fairly standard maximum power question: one can identify a fixed source, and a freely variable load-impedance consisting of the transformer and the components on its right.

The slight 'twist' is that as the resistor in the load is fixed, the real part of load impedance has to be varied by the transformer ratio; then the capacitor can be chosen to give the desired imaginary part.

1. **Determine the values of n and C that will maximise the power delivered to resistor R_2.**

If we see the 'source' as everything to the left of the transformer, then the source impedance is

$$Z_s = \frac{j\omega L R_1}{R_1 + j\omega L} = \frac{\omega^2 L^2 R_1 + j\omega L R_1^2}{R_1^2 + \omega^2 L^2}$$

The remainder of the circuit is then the load. The branch on the right of the transformer has an impedance of $R_2 + \frac{1}{j\omega C}$. What the source 'sees' at the transformer's left terminals is therefore this impedance scaled,

$$Z_1 = \frac{R_2}{n_2} - j\frac{1}{n^2\omega C}$$

Now that the source and load impedances are both expressed with real and imaginary parts separated, it is easy to use the AC maximum power theorem:

$$Z_1 = Z_s^* \Longrightarrow \frac{R_2}{n^2} - j\frac{1}{n^2\omega C} = \frac{\omega^2 L^2 R_1 - j\omega L R_1^2}{R_1^2 + \omega^2 L^2}$$

Equating real and imaginary parts separately, we notice that the real parts have only n as a free variable, so we set this first,

$$\frac{R_2}{n^2} = \frac{\omega^2 L^2 R_1}{R_1^2 + \omega^2 L^2} \Longrightarrow n = \sqrt{\frac{R_1^2 + \omega^2 L^2}{\omega^2 L^2 R_1 / R_2}}$$

With n set, it is just C that is free to set the imaginary part of the load impedance,

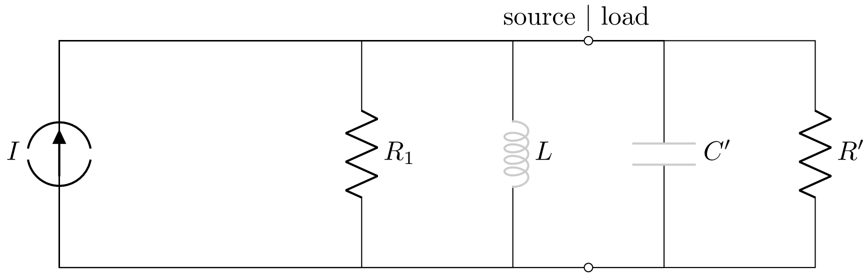
$$\frac{1}{n^2\omega C} = \frac{\omega L R_1^2}{R_1^2 + \omega^2 L^2} \Longrightarrow C = \frac{R_1^2 + \omega^2 L^2}{n^2\omega^2 L R_1^2}$$

To be the ideal solution, one should try to express each of the two sought quantities in terms only of the known ones. The above expression for C requires a solution of n, so we can substitute the expression for n into it. This results in a large simplification,

$$C = \frac{R_1^2 + \omega^2 L^2}{\frac{R_1^2 + \omega^2 L^2}{\omega^2 L^2 R_1 / R_2}\omega^2 L R_1^2} = \frac{L}{R_1 R_2}$$

It's nice if you did that, but as we didn't say absolutely clearly that each separate expression in the solution shall not depend on the other, we won't deduct any points for leaving C in terms of n. A note about choices of 'source' and 'load'. We made probably the most obvious choice, by including the transformer in the load as its value n was one of the free variables. But the dividing line between source and load doesn't matter as long as one does not include any components in the 'load' that can consume or produce active power: remember that the maximum power theorem is about maximising active power to the load impedance, so if the original task is to maximise the active power to a particular component or set of components then the 'load impedance' chosen for the solution must have the same active power as those components. The transformer, capacitor and inductor cannot consume or produce any active power, so they could be included either in the load or in the source, and the condition $Z_1 = Z_s^*$ would still be valid.

2. **What is the value of this maximum power to R_2?**



A long way to approach this is to solve the whole circuit with the chosen values of n and C from the previous part It's not very recommended. After much work, it should reduce to the expression below.

A shorter way is to consider that the maximum power is a property of the source. If we know that the load is chosen to extract the maximum power from the source, then we don't need to consider the details of the load any more, but just to find the source's maximum power. That could be done for example by studying the case with the simplest possible form of load that is the complex conjugate of the source's impedance.

With the definition of 'source' that we have chosen the simplest load would be a parallel combination of $R' = R_1$ and a capacitor C' that 'cancels' L by having $\omega^2 LC' = 1$.

Then the capacitor and inductor in parallel become an infinite impedance (open circuit), and so half the short-circuit current of the source passes in the load resistor.

Thus, since the short-circuit current is the current-source current,

$$P_{max} = \frac{I^2 R_1}{4}$$

Notice that it would be even simpler if we moved the inductor to be part of the 'load' for finding the source's maximum power: that is valid, as the inductor does not consume or produce active power.

Classical Electrodynamics

: Teaching Assistant   : Bachelor   : 2019
: KTH   </> : EI2405   : link

Short Description - Content

- Green's theorems
- Green functions to Poisson's equation
- Expansions of Green functions in orthogonal bases
- Electrostatic and magnetostatic boundary value problems
- Multipole expansions of electrostatic and magnetostatic fields
- Magnetic diffusion
- Maxwell's equations
- Green functions to the wave equation
- Calculation of retarded fields from continuous sources and point charges
- Application of the conservation laws for energy, linear momentum and angular momentum.
- Analysis of propagation, reflection and transmission of plane waves
- Decomposition of fields into plane waves
- The covariant formulation of Maxwell's equations
- Application of the Lorentz transformation on 4-vectors and the field tensor.

  The reference for the course is [Griffiths, 2013].

Duties

- 5 Tutorials | preparation, management and execution

Content Example - Tutorials

Tutorial 15 | Exam 01-06-2011 - Exercise 3

In a magnetostatic case, the stored magnetic energy is:

$$W_m = \frac{1}{2\mu_0} \int_R^3 B^2 d\tau$$

Show that:

$$W_m = \frac{1}{2} \int \vec{J} \cdot \vec{A} d\tau$$

Solution

By using $\vec{B} = \vec{\nabla} \times \vec{A}$, we can re-write:

$$W_m = \frac{1}{2\mu_0} \int \vec{B} \cdot (\vec{\nabla} \times \vec{A}) d\tau$$

Which can be re-written:

$$W_m = \frac{1}{2\mu_0} \int \left[\nabla \cdot (\vec{A} \times \vec{B}) + \vec{A} \cdot (\vec{\nabla} \times \vec{B})\right] d\tau$$

Note

$$\vec{\nabla} \cdot (\vec{A} \times \vec{B}) = \vec{B} \cdot (\vec{\nabla} \times \vec{A}) - \vec{A}(\vec{\nabla} \times \vec{B})$$
$$\Rightarrow \vec{B} \cdot (\vec{\nabla} \times \vec{A}) = \vec{\nabla} \cdot (\vec{A} \times \vec{B}) - \vec{A}(\vec{\nabla} \times \vec{B})$$

Taking the integral for both terms we get:

$$W_m = \frac{1}{2\mu_0} \int \vec{A} \cdot (\vec{\nabla} \times \vec{B}) d\tau + \frac{1}{2\mu_0} \int \vec{\nabla}(\vec{A} \times \vec{B}) d\tau$$

Now using the identity $\vec{\nabla} \times \vec{B} = \mu_0 \cdot \vec{J}$ for the first term, and the Gauss divergence theorem for the second, we get:

$$W_m = \frac{1}{2} \int \vec{J} \cdot \vec{A} d\tau + \frac{1}{2\mu_0} \oint_{S_\infty} \vec{A} \times \vec{B} \cdot d\vec{A}$$

But $\vec{A} \propto \frac{1}{r^2}$, $\vec{B} \propto \frac{1}{r^3}$, $d\vec{a} \propto r^2$

So we know that in the limit of infinity, the second term goes to zero,

$$\oint_{S_\infty} \vec{A} \times \vec{B} \cdot d\vec{A} \to 0$$

Thus, the relationship is shown:

$$W_m = \frac{1}{2} \int \vec{J} \cdot \vec{A} d\tau$$

Specialized Physics - Mechanics/Oscillations/Waves

: Organizer/Teacher
: High School
: 2013–2015
: Social Tuition Center of City of Athens
: Specialized Physics
: link

Short Description

Special topics in physics is a course required for the national exams to allow entry to higher education (e.g., universities).

The content of the course include the most important topics of classical physics. The focus is primarily on classical dynamical systems, mechanics, mechanical and electrical oscillations, and waves.

Duties

- Preparation for university entry exams.
- Organization and teaching of three different groups of student.

Performance Metrics

Certifications by the City of Athens:

2013 – 2014: (Greek)

2014 – 2015: (Greek)

Bibliography

[Baumjohann and Treumann, 2012] Baumjohann, W. and Treumann, R. A. (2012). *Basic space plasma physics.* World Scientific Publishing Company.

[Griffiths, 2013] Griffiths, D. J. (2013). *Introduction to electrodynamics; 4th ed.* Pearson, Boston, MA. Re-published by Cambridge University Press in 2017.