Electricity and magnetism lecture notes pdf

Please find links to class materials below, including lecture notes and additional slides, homework and quiz questions and solutions, as well as links to exams (as far as they are available). Lecture notes will appear by the next period of classes. Table Content Lecture Notes and Slides Lecture 1 (1/18/2011) Why Electricity and Magnetism? Lecture Notes: PDF Additional Slides: PDF Lecture 2 (1/20/2011) Electric Charging and Power Lecture Notes: PDF Additional Slides: PDF Lecture 3 (1/25/2011) Electric Field and Simple Charge Distribution Lecture Notes: PDF Additional Slides: PDF Lecture 4 (PDF 1/27/2011) Electric Fields and their impact on Matter Lecture Notes: PDF Additional Slides: PDF Lecture 5 (2/1/2011) Integrated Electrical Charging Distribution: Mini Lecture All Lecture is available online in 2 Parts: Part 1 and Part 2. Lecture 6 (2/3/2011) Video lecture: Electric charging movement; Electric Fields and Energy Electric Charge Movement: The entire lecture is available online in 2 parts: Part 1 and Part 2. Electric Fields and Energy: The entire lecture is available online in 2 parts: Part 1 and Part 2. Lecture 7 (2/8/2011) Potential and Energy Storage Lecture Notes: PDF Additional Slides: PDF Lecture Explained: PDF Lecture Explanations: PDF Lecture 8 (2/10/2011) Capacitors Lecture Notes: PDF Additional Slides: PDF Lecture 9 (2/15/2011) Use capacitors Lecture Notes: PDF Additional slides: PDF Lecture 10 (2/22/2011) Electric Current Lecture Notes: PDF Additional Slides: PDF Lecture 11 (2/24/2011) Resistance to Electric Current Lecture Notes: PDF Additional Slides: PDF Lecture 12 (3/1/2011) Use Resistors Lecture Notes: PDF Additional slides: PDF Lecture 13 (3/3/2011) Batteries and District Analysis Lecture Notes: PDF Additional Slides: PDF Lecture 14 (3/8/2011) RC Chain and Introduction to Magnetism Lecture Notes: PDF Additional Slides: PDF Lecture 15 (3/22/2011) Magnetic Power Lecture Notes: PDF Additional Slides: PDF Lecture 16 (3/24/2011) Origin of Magnetic Field Lecture Notes : PDF Additional Slides : PDF Lecture 17 (3/29/2011) Magnetic Power Between Currents Lecture Notes: PDF Additional Slides: PDF Lecture 18 (3/31/2011) Magnetic Dipole Moment Lecture Notes: PDF Additional Slides: PDF Lecture 19 (4/5/2011) Amper's Law Lecture Notes: PDF Additional Slides: PDF Lecture 20 (4/7/2011) Magnetic Induction Lecture Notes: PDF Additional Slides: PDF Lecture 21 (4/4/412/2011) Self-induction and Induction Lecture Notes: PDF Additional Slides: PDF Lecture 22 (4/14/2011) Nature Light Lecture Notes: PDF Additional Slide: PDF Lecture 23 (4/19/2011) Reflection and Refraction Lecture Notes: PDF Additional slides: PDF Lecture 24 (4/21/2011) Mirrors Lecture Notes: PDF Additional slides: PDF 25 (4/26/2011) Lenses Lecture PDF Additional slides: PDF Lecture 26 (4/28/2011) Human Eye Lecture Notes: PDF Additional Slides: PDF Lecture 27 (4/28/2011) Beyond Electricity and Magnetism: Creating Space and Time to Play Nice with Matter and Forces Extra Slides: PDF Homework below assigned homework and homework solutions. Information on Significant Numbers Lecturer: Masood Haq (haque@thphys.nuim.ie) Teacher: Adam Tallon (adam.tallon.2015@mumail.ie) Final Exam, Saturday May 16, 2020 Here is the final exam on May 16, available after 2:30 p.m. Important Equations of Electromagnetism Here's a list of the main equations and results we face in MP204. Practice Bank Problems ('problem set 12') Is flagged as Problem Set 12, but it's a really large collection of problems covering all module material. It should be useful for practice and for studying the material more thoroughly. Many textbooks have collections of problems and work-work exercises. Specifically, the tutorial Griffiths and that Purcell and Maureen both have a large number of excellent exercises and challenges. A set of problems set problems 11. Wednesday May 6, 8 p.m. (Partially) problem solving set 11. A set of problems 10. Wednesday, April 29, 8 p.m. (Partially) problem solving set 10. Problem set 09. Due after the Easter holidays, Wednesday April 22, 8pm. (Partly) problem solving set 09. Problem set 08. Wednesday, April 8, 8 p.m. (Partially) problem solving set 08. Problem set 07. Due Tuesday March 31, 6pm. (Partially) problem solving set 07. Problem set 06. It was due to take place on Tuesday 24 March. Extended until Thursday 26 March, 6pm for the study break; twice as many as the usual weekly problems. (Partial) solution to the problem, set 06. Problem set 05. Due Tuesday March 10, 5:30 p.m. Problem set 05. Because of Tuesday, March 10. Problem set 04. Due Tuesday March 3, 5:30 p.m. Problem set 03. Due Tuesday February 25, 5:30 p.m. Problem set 02. Because of Tuesday, February 18. Problem set 01. Because of Tuesday, February 11. Problems 3 and 4 in this set of problems include finding the total charge of objects from the density of the linear charge or the density of the charge surface. This will require breaking down the object into infinitely small pieces, and then the amount of deposits of each piece that constitutes integration. We will have to do variations of this procedure many times during this module; So please practice until you are completely comfortable. The relationship between charge density and overall charge is the same as between normal (mass) density and total mass. For a guide, you can try this video, this video, this discussion, these notes. The energy flow, pointing vector Material on electromagnetic energy and vector Pointing is discussed in pages 81-83 in my handwritten notes (p.73-83). (p.73-83). you can hear someone describe this stuff for you in this video called Poynting Vector. A more enthusiastic description of the properties of EM SWAVE: video Energy density of electromagnetic waves (light); Video Light has energy and (GASP!) Momentum; Video Introduction to the polarization of filters!; Video Acceleration of charges emit electromagnetic waves. They can supplement my notes. In addition, Chapter VI of Professor Nash's records contains additional reading. Virtual Lecture on Friday April 24 In this lecture we look at the nature of electromagnetic waves. In my handwritten notes (p.73-83) we will work through the first three pages. The first page provides an example of solving wave equations that we received earlier. This decision is a bit pathological: the arguments of sinustin function are not unitary. (The argument is length-size.) We'll fix it on the next page. Now we will learn a lot by trying to visualize this decision. It's a wave travel solution. It has a pattern that moves to the right at speed (with 1/s mu_0 epsilon_0). The figure is a snapshot: it should help you visualize the direction of magnetic and electric fields. In this image, the y-axis indicates the plane, and the z-axis points upwards. A very useful exercise: consider whether to axis up, so that the z-axis points outwards from the paper. The site of the snap is electric and magnetic fields. Show that since the eletric and magnetic fields must satisfy Maxwell's equations in free space, the amplitudes of oscillations should be related as (B_0 E_0/c). The amazing thing is that we found a solution to Maxwell's equations, which involves the spread of the electromagnetic field on their own, without any charge or current or matter! Electrical and magnetic fields lead each other forward. Changing the electric field creates a magnetic field, and the change of magnetic field in turn creates an electric field. They support each other and lead each other forward. That's what an electromagnetic field is. It can travel through a vacuum, in the absence of any accusations or matter. For example, light and radiation from the Sun reach the Earth. On page 74, we note that the electrical and magnetic fields are perpendicular to each other. And also, the distribution direction is in the direction of q ('vec'E'times'vec'B). Please make sure this is true for the solution we studied on page 73. This is a common feature of electromagnetic waves. It's worth remembering. As I mentioned above, our previous decision must be corrected in such a way that the sinus function argument is ugly. This is done by introducing wavelength and frequency. Expressions can also be written in terms of wave pillowcase, q (k'2'pi'lambda) and angular frequencies, Expressions for The wave looks cumbersome after we've entered the wavelength/frequency, but you had to meet expressions like this in your vibration and wave class. On page 75 we note that the electromagnetic wave should not be sinusodia: you can also have pulses that satisfy Maxwell's wave equation and equation. Here's an example. Note that the argument exponential should be immeasurable: This is achieved by using a permanent (l_0) that should have a dimension of length. What we learn today is probably one of the 5 important things you went to university: the very nature of light! Additional reading and video: Chapter VI of Professor Nash's Records: Sections 1 and 2. In section 2, the cross-section of the fields is well proven. Subdivision 4.3.1 and the beginning of subsection 4.3.2, of these lecture notes. video describing electromagnetic waves. enthusiastic videos, including an animation of oscillating cross-field E and B. Wikipedia page on electromagnetic waves is a bit heavy, but has a good animation across the oscillating fields. 'Virtual Lecture' on Tuesday April 21 Today we (1) look at the physical manifestations of current displacement density, (2) will begin our study of electromagnetic waves. The density of the movement is now introduced by the density of the bias as a correction of Maxwell's law to Amper. Please see how this correction allows Ampere's law to fit the continuity equation. We have not thought about any physical consequences of this law. It's time to do it. In my handwritten notes (p. 61-72) this material begins halfway through page 66. Please go through example 1, which lasts until the end of page 67. You can add to the reading of Professor Nash's 36-37 notes, which analyzes the same situation. Example 2 is optional; You can skip it so we can go to electromagnetic waves. Electromagnetic waves start at p.70 in my handwritten notes (p.61-72), halfway down the page. First, we write down Maxwell's equations in free space or in a vacuum. This means that there is no charge or current: you can set the charge density (zro) and the current density (Vec)J) to zero. Note that the combination (mu_0 epsilon_0) is set to be equal (frak{1} 'c'2), where the constant (c) later turn out to be the speed of light. In the first half of page 71, the wave equation and the shape of its solutions are briefly considered. Please show that: any form function (x-vt) is the solution to the wave equation. Here (fi) is an arbitrary function. Convince yourself that (x-vt) is a form that travels to the right at speed (v). This is followed by the withdrawal of wave equations of electric and magnetic fields, starting with Maxwell's equations. (p.71-72) These are wave equations, but they are for vectors and They also depend on three spatial dimensions, not one. So they're more complex than the wave equations you might have seen in your Vibrations and Waves class. We will think about solutions to these equations (electromagnetic waves) in the following lectures. Here's a video of someone working to pull wave equations out of Maxwell's equations. Of course, this conclusion is also developed in almost any textbook on electromagnetism, for example, try section 4.3 (p. 82) of these lecture notes. 'Virtual Lecture' on Tuesday April 7th Today we look at vector potential and scalable potential, and the freedom sensor is taking advantage of these capabilities. In my handwritten notes (p.61-72), this material starts at page 63 and ends at page 66, about a third on page 66. The magnetic field can be written as a curl of vector potential, because the divergence of the magnetic field is zero. In electrostatics, the electric field can be written as a gradient of scalable function, which is a negative of electrical (large-scale) potential. This was because the elbow of the electric field is zero in electrostatics. But, since for non-static situations, as you know from faraday's law, is not zero. So we need a correction to (Vec-E'-'vec'abla'V)! The term of correction is explained in page 63. At the top of p.64 are important equations that express fields in terms of potentials. Adding certain types of terms to potential can keep fields unchanged. They are known as calibration transformations. Please make sure that you show yourself that the fields remain the same when the potentials change this way. Freedom may be limited by the choice of sensor. Two popular options are the Coulomb sensor and the Lorenz sensor, page 65. Also shown what the equations of the 1st and 4th Maxwell look like in the case of these two sensors. If the fields are derived from potentials, the equations of the 2nd and 3rd Maxwell are automatically satisfied. Please make sure you convince yourself in this statement. Of course, scalable and vector potential is described in many tutorials and notes. As an additional reading, you can try - lecture notes describing Maxwell's equations and then describing the potentials. (uses instead of V for scalal potential, which is quite common). There is also a page describing the sensor conversions. - Section 3.4 (p.22-23) of these notes. 'Virtual Lecture' on Friday April 3 Here are pages 61 to 72 of my handwritten notes. They contain materials for this lecture and the next few lectures. Today's lecture will be reviewed: (1) electromagnetic induction (2) of Maxwell's equations. Electromagnetic Induction Review: Faraday's Law and Lenz's Law Please review how the change in magnetic fields creates curly electric fields. Look up or say to yourself: - Faraday's law gives gives EMF around the chain; - How Faraday's law can be expressed as a holistic equation that can be used even when no chain wire is physically present; - How can you get Maxwell's third equation, which is Faraday's law in a differentiated form, from Faraday's law in a holistic way; - As the Law of Lenz gives you the direction of an induced current or induced electric field. You can use the material that I have posted or pointed to during the last two lectures. Or, if you want something fresh, you can try one/some of the following. Chapter 8 of these notes (shows many good examples with diagrams); - The last 4 pages (23-26) of these lecture slides; Section 4.1 and subsection 4.1.1 of these notes; - Chapter 16 Feynman II. Review of Maxwell's Equations This is the first 2'1/2 pages of my handwritten notes (p.61-72), i.e. up to the first paragraph of page 63. Now you have to be very familiar with these equations. Please go through them again. Make sure you know exactly where each equation comes from. Please also make sure that you can go from an integral form to a differential form, for each equation. The current density of the displacement (Maxwell's correction into the Ampere equation) is now given its own symbol, (Vec'J'_D). Next time we will look at large-scale and vector potentials. They are closely related to the structure of Maxwell's equations. Virtual Lecture on Tuesday March 31 Here are my handwritten notes on March 31. For this lecture, we want (1) a review of the Faraday Law; (2) Assess that there are two types of electric fields; (3) Generalize and consider Maxwell's equations; (4) Introduce and study the law of Lenz. Review of electromagnetic induction, faraday law electromagnetic induction is a phenomenon that changing the magnetic field can create a curly electric field. We will rely on electromagnetic induction and Faraday's law; So please review. Make sure you are familiar with both the integral form and the differential form of Faraday's law. On page 55, we note that Faraday's law has a holistic shape of Ampere's law in a holistic way. The Amper Act quantifies how a curly magnetic field is created due to current density (mu_0'vec'J). In contrast, Faraday's law tells you how a curly electric field is created by a change in magnetic field, ((left (-Frac'partial-vec'vec'B't't'right).). In electrostatics we had electric fields created by charges pointing directly or directly from the charges. But electric fields can also be created by induction, i.e. by changing the magnetic field. Around. The electric field, created in this way, curls around. The curl is certainly not zero. Maxwell Time Time Equations all of Maxwell's equations. Please name or describe to yourself the law or phenomenon leading to each equation. The exception is the last term in the 4th equation. This did not come from the observed phenomenon. Rather, Maxwell brought it out theoretically to ensure that Ampere's law corresponded to the continuity equation. Please make sure you can repeat that conclusion. This term (Maxwell correction) is known for historical reasons as the current bias. Lenz's Law After all the reviews, we are now adjoining the new part of this lecture. Lenz's law helps determine the direction of the induced electric field. Please go through the examples. The law is a little tricky and clumsy to say, so it will take some effort. Note that you don't need a physical wire loop to have electromagnetic induction. An example with solenoid discusses this. If the magnetic field inside the solenoid changes (due to a change in current through the solenoid), there will be electric fields generated from the outside (and inside) the solenoid. You can calculate the value using Faraday's law in a holistic way. You can draw a conclusion about the direction by imagining the wire loop surrounding the solenoid. You can see how someone goes through the geomert of several examples of Lenz's law, in this video, in this video, in this video. Virtual Lecture on Friday 27 March In this lecture we present the phenomenon of electromagnetic induction and learn the law of Faraday. Here are my on-machine notes on March 27. That's enough on your own. Please let me know if you notice a typographical or spelling error, or something seems unclear. Several examples of induction situations are described and sketched in notes. However, there are many other thought experiments (or real experiments) you can think of that leads to electromagnetic induction. It can be instructive to go through a few. For more examples, you can try: Also, here's a web page covering similar material like mine on typical notes. Virtual Lecture on Tuesday March 24Th For this lecture, we want (1) to go through the application of the Ampere Law, (2) Introduce magnetic vector potential. Application of the Ampere Act: Long Current Wire It's in page 43-44 of my handwritten notes on March 13. These calculations are somewhat reminiscent of what we did using Gauss's law. In this case, we found electrical fields outside and inside charged objects, using surface integrals over closed surfaces, which we called Gaussian surfaces. Now we find magnetic fields outside and inside the current wire using linear integrals along closed curves. These closed curves, which use the Ampere law, are called Amperian loops. If you want to watch/listen to someone discuss it: you can try two videos: off-wire and inside the wire. It's a video. Applying the Ampere Law: Solenoid It's in page.45 of my handwritten handwritten March 13. This page is not as clearly written/drawn as I would like. So please supplement this with reading the argument in the tutorial or print the notes! You can try Feynman Lecture II: Section 13-5, Chapter IV Of Professor Nash's Notes, These Notes. The result is that if the current flows through a long solenoid, it creates a magnetic field that is zero outside of the solenide, and uniform everywhere inside the selenoid. Please make sure you are able to get this result and the value of the magnetic field. Vector Potential Here's a scan of my handwritten notes about vector potential. You can find roughly equivalent material stuff stuffed in these notes, on this page, Feynman Lecture II: Section 14-I, this video. Virtual Lecture on Friday March 13Th Lecture March 13, we planned (1) to introduce the Ampere Law; (2) revise the basic equations/laws that we've learned so far; (3) start with the application of the Ampere Act. Here's a scan of my handwritten notes. Please work through pages 39 to 44. Most of my handwriting has to be legible. If not, please ask. Ampere's Law: The Ampere Act is another way of expressing how currents create magnetic fields. (In electrostatics, Gauss's law complements the law of coulon and expresses the same physics more elegantly. My handwritten notes don't always have full sentences. For a textual discussion of material on ampere law, you can try working through: Feynman Lectures II: Sections 13-4 and 13-5. Chapter IV Of Professor Nash's Notes. This material is also discussed in many other books and lecture notes. For example, here are the records of the application of the Ampere Act and the application of the Biot-Savart Act Review of Equations/Laws and extension of the Ampere Law: In my handwritten notes, on page 40 and 41, I will bring a list of all the equations and laws we encountered in electrostatics and magnetostatics. Please make sure you go through all of them and explain to yourself the meaning of each one. It is good practice to draw the relevant situation on a case-by-case basis. You have already completed almost all of these equations, with the exception of the equation expressing the magnetic field as a curl of so-called vector potential. More on this in later lectures. Page 42 of the Ampere Act states that it does not correspond to the continuity equation when the system is not in a stable condition. In this case, a correction is needed. It's called Maxwell's correction. In Feynman II, this is discussed at the beginning of Chapter 18. Please make sure you understand and can explain the discrepancy. In addition, you should understand and be able to explain how the term correction resolves the discrepancy. Finally, if you to have someone explain some of this on the board, you can try: this video, it's this it's a video, it's a video. (Decisions) Previous exams - Sample exams Here is an exam sample for practice: Sample Exam 1, for 2018-2019 Here is the 2019 May exam, and here is the 2019 Repeat (August) exam. (Decisions are not available; sorry.) Below are the solutions for some past exams. (The length of exams has changed since 2017.) 2018 Repeat exam - Decisions 2018 May exam - decision 2017 Retest - Decision 2017 May Exam - Solutions Below are the old sample exams for practice. They are in the style of previous (2017-2018) exams. Exams 2018-2019 were structured slightly differently (divided into 4 questions instead of 3), but the material covered and the level of complexity should be similar. Sample Exam 1, for 2017-2018 Sample Exam 2, for 2017-2018 Sample Exam 3, for 2017-2018 Material covered in The Class I'm Pumping Relevant Chapters in Professor Nash Notes and in Vol. Feynman's SECOND lectures (called Feynman II below). Of course, equivalent material is available in many other tutorials, or in online materials such as those that are associated with further down on this page. Electromagnetic induction; Faraday's Law. Chapters 16 and 17 in Feynman II. Nash notes: Chapter V. Vector Potential. Chapter 15 in Feynman II. Unfortunately, Nash notes, don't discuss vector potential. Magnetic field. Chapters 13 and 14 in Feynman II. Nash notes: Chapter IV. Electric Currents. Chapter 13 of Feynman II. Nash notes: Chapter III. In Feynman II, Chapter 5 is highly recommended reading. Nash notes that this is Chapter 2. The electric flow. The theorem of the Gauss dielectric flow (aka Gauss Law). In Feynman II, the thread discussion begins in Chapter 4 of Section 5 and continues through Chapter 5. Nash Notes covers this material in Chapter 2. Continuous distribution of charges. In class, we figured out how to calculate the potential and electric field through continuous charge distribution, first calculating the contribution from an infinite element and then integrating (adding up. This is an important method that will be repeated throughout this module; Please make sure you are able to create integrals like this yourself. Coulomb law, Electric Fields, Electrical Potentials. Chapter 1 Nash notes. The introduction to electrical potential in Nash Notes Chapter 1 Section 3 is more detailed than we had time for in class; You can read this carefully. In Feynman's Tom II lectures, you'll find similar material in the first four sections of Chapter 4. Review and background. In Feynman's lectures, Volume II, Chapter 1 gives an overview of what we learn this semester. Chapters 2 and 3 introduce hail-dive-twisted and vector integration. You should know most of this stuff already. Working through them will be a great undergvam for MP204. Premise: The Calculus Vector This module requires that familiar with Vector Calculus. You should be comfortable with the hail/div/curl, Stokes theorem and theorem divergence, and of course the vector additions and components. If you need a review, you can try working through some of the following. I highly recommend taking the time to do so at the beginning of the semester. Material, sources of the Lecture notes from the previous teacher MP204 lecture notes Professor Charles Nash --- this is about the material that will be covered in the module, with some additions. It is recommended to work through these notes, and also to spend considerable time working at least one tutorial. There are many, many tutorials on introductory electromagnetism or electrodynamics. You are strongly encouraged to read one or more textbooks. In particular, I suggest working through Feinman's lectures (Tom II) that will be free to read on this site. The material that we will cover in MP204 is basically contained in the first 20 chapters of Volume II. (In particular: Chapter 1, 4--6, 13--18, 20.) It will be very close to what we will cover. However, the material is very standard and you will find the same themes in many other texts. Other texts: Fleisch, Student Guide to Maxwell's Equations. Student friendly, as the name suggests. Griffiths, Introduction to Electrodynamics. A little more advanced than the level of this module, but reading this text and work off the exercises is very worthwhile. Purcell and Maureen, Electricity and Magnetism. Slightly more advanced than the level of this module. Edminister and Nahvi, Shauma's Electromagnetic Energy Scheme. Many well-worked examples. Panofsky and Phillips, classical electricity and magnetism. Grant and Phillips, Electromagnetism. Shankar, Basics of Physics II: Electromagnetism, Optics and quantum mechanics. Material is available online: Lecture notes from different places. Of course, I don't check in the details for correctness and/or how closely these notes are aligned with the question we cover in MP204, so please use on your own. Please let me know if any of the links don't work. Note We use SI (also called MKS or MKSA) units. Note that many equations look very different when written in Gaussian (or CGS) units. When reading a tutorial, be sure to keep an eye on what units that text uses. Notations vary. I will basically try to use the same notations as Professor Nash's notes, but not always succeed. You should in any case be able to read and learn from multiple sources using different notations for the same physical quantities. Quantities.