Alex Meng's Notes

Alex Meng

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Table of contents

Preface

This is where I will store my notes for the courses I am taking, the papers I am reading, and the textbooks I am studying, starting May 2025.

Part I

COURSES

EE647 Nanophotonics (KAIST)

Youtube Playlist Self-Study: link

Instructor: Min Seok Jang

Begin Date: 6/6/2025

Expected End Date: 8/1/2025

Practical Deep Learning (fast.ai)

Source: https://course.fast.ai/

Lesson 2

Daniel on forums.fast.ai has been kind enough to create summaries of each lesson in the form of a list of questions. These summaries can be used to preview a lesson or refresh your memory afterward.

New exciting content to come

- Can there be substantial new content given we have already 4 versions and a book?

Ways of reading the book

- How many channels are available to read the book? (physical, GitHub, Colab, and others)

Extra sweets from the book

- Are there interesting materials/stories covered by the book but not the lecture?
- Where can you find questionnaires and quizzes of the lectures?

aiquizzes.com

- Where can you get more quizzes of fastai and memorize them forever?

Introducing the forum

- How to make the most out of fastai forum?

Students' works after week 1

A Wow moment

- Will we learn to put a model in production today?

Find a problem and some data

- What is the first step before building a model?

Access to the magics of Jupyter notebook

- Do you want to navigate the notebook with a TOC?
- How about collapsible sections?
- How about moving between start and end of sections fast?
- How to install Jupyter extensions?

Download and clean your data

- Why use `ggd` rather than Bing for searching and downloading images?
- How to clean/remove broken images?

Get to docs quickly

- How to get basic info, source code, full docs on fastai code quickly?

Resize your data before training

- How can you specify the resize options to your data?
- Why should we always use `RandomResizedCrop` and `aug_transforms` together?
- How do `RandomResizedCrop` and `aug_transforms` differ?

Data images instantly transformed, not copied

- When resized, are we making many copies of the image?

More epochs for fancy resize

- How many epochs do we usually go when using `RandomResizedCrop` and `aug_transforms`?

Confusion matrix: where do models get it wrong the most?

- How to create a confusion matrix on your model performance?
- When to use a confusion matrix? *(category-level practice)*
- How to interpret a confusion matrix?
- What is the most obvious thing it tells us?
- How hard is it to tell grizzly and black bears apart?

Check out images with worse predictions

- Does `plot_top_losses` give us the images with the highest losses?
- Are those images ones the model made confidently wrong predictions? *(practice)*
- Do those images include ones that the model made correct predictions unconfidently?
- What does looking at those high loss images help with? *(expert examination or simple data cleaning)*

What if you want to clean the data a little

- How to display and make cleaning choices on each of those top loss images in each data folder? *(practice)*
- Without expert knowledge on telling apart grizzly and black bears, we can at least clean images which mess up teddy bears.

Myth breaker: train model and then clean data

- How can training the model help us see problems in the dataset? *(practice)*
- Won't we have more ideas to improve the dataset once we spot the problems?

Turn off GPU when not using

- How to use GPU RAM locally without much trouble?

Watch first, then watch and code along

- What is the preferred way of lecture watching and coding by the majority of students?

A Gradio + Hugging Face tutorial

Git and GitHub Desktop

- Is GitHub Desktop a less cool but easier and more robust way to version control than git?

Terminal for Windows

- How to set up a terminal for Windows?
- Why does Jeremy prefer Windows over Mac?

Get started with Hugging Face Spaces

- Go to huggingface.co/spaces and create a new space

Get the default app up and running

- How to use git to download your space folder?
- How to open VSCode to add an `app.py` file?
- How to use VSCode to push your space folder up to Hugging Face Spaces online?
- Then go back to your space on Hugging Face to see the app running

Train and download your model

- Where is the model we are going to train and download from Kaggle notebook?
- How to export your model after training it on Kaggle?
- Where do you download the model?
- How to open a folder in terminal? `open .`
- Make sure the model is downloaded into its own Hugging Face Space folder

Predict with loaded model

- How to load the downloaded model to make predictions?
- How to make predictions with the loaded model?
- How to export selected cells of a Jupyter notebook into a Python file?
- How to see how long a code runs in a Jupyter cell?

Turn your model into a Gradio app locally

- How to prepare your prediction result into a form Gradio prefers? *(code)*
- How to build a Gradio interface for your model?
- How to launch your app with the model locally?
- *(Not in video: run the code on Kaggle in cloud)*

Push this app onto Hugging Face Spaces

- Make sure to create a new space first (e.g., `testing`)
- How to turn the notebook into a Python script?
- How to push the folder up to GitHub and run app in cloud?
- *(Not in Video: if stuck, check out Tanishq's tutorial – shooting)*

Additional questions

- How many epochs are ideal for fine-tuning?
- How to save model from Colab?

How to install fastai properly

- How to download `github/fastai/fastsetup` using git?
  `git clone https://github.com/fastai/fastsetup.git`
- How to download and install mamba?
  `./setup_conda.sh`
- *(Not in Video: problem of running `./setup_conda.sh`)*
- How to download and install fastai?
  `mamba install -c fastchan fastai`
- How to install nbdev?
  `mamba install -c fastchan nbdev`
- How to start using Jupyter Notebook?
  `jupyter notebook --no-browser`
- *(Not in Video: other problem related to Xcode)*

The workflow summary

HuggingFace API + Gradio + JavaScript = real app

How easy does HuggingFace API work?

How easy to get started with JS + HF API + Gradio?

App example of having multiple inputs and outputs

App example of combining two models

How to turn your model into your own web app with fastpages

How to fork a public fastpages for your own use

Part II

PAPERS

Optical Computing

Wetzstein, G., Ozcan, A., Gigan, S. et al. Inference in artificial intelligence with deep optics and photonics. Nature 588, 39–47 (2020). https://doi.org/10.1038/s41586-020-2973-6

General Optical computing is not practical yet, but using optics for inference for visual computing applications is practical. This paper is a review on recent work on optical computing for AI.

Motivation 1: Edge devices (cameras, cars, robots, headsets, IoT) need leaner (low latency, light, small, low power) computational imaging systems.

Optical computing systems promise small form factor, massive parallelism, little to no power consumption. Optical interconnects are already widely used in data centers today.

Linear optical elements can calculate convolution, fourier transforms, random projections, as a byproduct of light-matter interaction. These operations are what's needed for DNNs.

"Incorporating all-optical nonlinearities into photonic circuits is one of the key requirements for truly deep photonic networks. Yet, the challenge of efficiently implementing photonic nonlinear activation functions at low optical signal intensities was one of the primary reasons that interest in ONNs waned in the 1990s. Creative approaches from the last decade, such as nonlinear thresholders based on all-optical micro-ring resonators35, saturable absorbers29,36, electro-absorption modulators37, or hybrid electro-optical approaches38, represent possible solutions for overcoming this challenge in the near future."

Although programmability has traditionally been more difficult with photonic systems, first steps towards simplifying the process have recently been demonstrated

"One direction that seems particularly well suited for optical and photonic processing is **optical inference with incoherent light to rapidly process scene information under ambient lighting conditions**. Such an approach presents many exciting opportunities for autonomous vehicles, robotics and computer vision, which we discuss next."

Part III

TEXTBOOKS

Maxwell's Equations - Dan Fleisch

Website: Official Website

1 Gauss's law for electric fields

Introduction

Expand

- What are the two kinds of Electric Fields in Maxwell's Equation?

Answer

- Electrostatic Fields (from electric charge)
- Induced Electric Field (from changing magnetic field)

- What type of fields does Gauss's law deal with?

Answer

Electrostatic Fields (from electric charge)

Integral Form of Gauss's Law

Expand

Electric charge produces an electric field. The flux of that field passing through any closed surface is proportional to the total charge contained within that surface.

$$\oint_S \vec{E} \cdot \hat{n} da = \frac{q_{enc}}{\epsilon_0}$$

Expand To Learn About Left Hand Side

- What does the left hand side represent?

Answer
The number of electric field lines (AKA electric flux) passing through a closed surface S.

- What is Electric field?

Answer
The electrical force exerted on one coulomb of charge at that point in space is the electric field at that location.

$$\vec{E} = \frac{\vec{F}_e}{q_0}$$

$\vec{E}$ has units of $\frac{N}{C} = \frac{V}{m}$
Spacing of electric field lines tells you the strength of it.

- Electric field lines go from positive to negative
- Electric field lines vector sums, so they never cross

- Why do physicists and engineers always talk about small test charges?

Answer
Because the job of this charge is to test the electric field at a location, not to add another electric field into the mix (although you can't stop it from doing so). Making the test charge infinitesimally small minimizes the effect of the test charge's own field.

- What is the dot product? Why are we taking the dot product between $\vec{E}$ and $\hat{n}$ in Gauss's Law?

Answer
Consider vectors $\vec{A}$ and $\vec{B}$ in space.
What is the projection of $\vec{A}$ onto $\vec{B}$? From trig, it's $|A|\cos\theta$.
Now the dot product is that projection, multiplied by the magnitude of $\vec{B}$.

$$\vec{A} \cdot \vec{B} = |A||B|\cos\theta$$

- What is $\hat{n}$?

Answer
It is the unit normal vector, which has a length of one, and points in the direction perpendicular to the surface.
Note that since da is the tiny amount of area we are considering

$$\hat{n} da = d\vec{a}$$

- What is the difference between closed surface and open surface?

Answer

- Open Surface - any surface for which it is possible to get from one side to the other without going through the surface
- Closed Surface - a surface that divides space into an "inside" and "outside". Unit Normal Vector $\hat{n}$ always points outwards, away from the volume enclosed by the surface.

- What does $\vec{E} \cdot \hat{n}$ represent?

Answer
The component of the electric field vector that is perpendicular to the surface.

$$\vec{E} \cdot \hat{n} = |\vec{E}| \cos \theta$$

- How do you find the mass of a surface with varying density function $\sigma(x, y)$?

Answer
Since mass is density times volume, we can write:

$$Mass = \sigma \cdot Area$$

$$Mass_S = \Sigma_{i=1}^{N} \sigma_i \cdot Area_i$$

If we let Areas to become infinitesimally small dA, we get

$$Mass = \int_S \sigma dA$$

This is a *surface intergal*.

- What does $\int_S \vec{A} \cdot \hat{n} da$ represent?

Answer
It represents the flux of a vector field.
What's a vector field?
It is magnitude and direction quantities distributed in space.

- Scalar Field - something like temperature distribution in a room, where at each point theres a number
- Vector Field - something like flow of fluid, there at every point it has a speed and direction

- What's flux Φ?

Answer
Flux Φ of a field over a surface is the amount of flow through that surface.

$$\Phi = \vec{A} \cdot \hat{n} \times (SurfaceArea)$$

Expand To Learn About Right Hand Side

- What is the right hand side in words?

Answer
The total amount of enclosed charge normalized by the permittivity of free space.

- What is ϵ_0 and why is it there?

Answer
It is called the permitivity of free space or "vacuum permitivity".

$$\epsilon_0 = 8.854 \times 10^{-12} \frac{F}{m}$$

When we say the permitivity of a material, when are referring to its reponse to an electric field. It is also the key parameter in determining the speed at which an electromagnetic wave propagates through that medium.
High permitivity means it provides higher capacitance.
In Gauss's Law, ϵ_0 acts as a proportionality constant that relates electric flux to enclosed charge.

Exercises

- Five point charges are enclosed in a cylindrical surface S. If the values of the charges are $q_1 = +3nC$, $q_2 = -2nC$, $q_3 = +2nC$, $q_4 = +4nC$, and $q_5 = -1nC$, find the total flux through S.

Answer

$$\sum_{i=1}^{5} q_i = 3 - 2 + 2 + 4 - 1 = 6nC = 6 \times 10^{-9}C$$

$$\Phi_E = \frac{q_enc}{\epsilon_0} = \frac{6 \times 10^{-9}C}{8.854 \times 10^{-12} \frac{C}{V \cdot m}} = \boxed{678\ Vm}$$

Differential Form of Gauss's Law

Expand

The electric field produced by electric diverges from positive charge and converges upon negative charge.

$$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

Expand To Learn About Left Hand Side

- What does the left hand side represent?

Answer
The tendency of electric field to flow away from a point in space - AKA the divergence.

- What is the difference between differential and integral form of Gauss's Law?

Answer
Differential deals with individual points in space, whereareas integral deals with a closed surface.

- What is $\vec{\nabla}$?

Answer
It is called "del" or "nabla". It tells you to take the derivative of what ever quantity comes after it.

$$\vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$$

It is an *mathematical operator*, which just means that it needs something to act on and cannot just appear by itself.
$\vec{\nabla}$ is gradient, $\vec{\nabla}\cdot$ is divergence, and $\vec{\nabla}\times$ is curl.

- What is $\vec{\nabla}\cdot$ specifically?

Expand
Oliver Heaviside suggested the word "divergence" to describe the rate at which electric field flow outwards from a positive charge.

- source - diverge from that point (positive charge for electric field)
- sink - converge to that point (negative charge for magnetic field)

Expand To Learn About Right Hand Side

- What is the right hand side in words?

Answer

Exercises

- Five point charges are enclosed in a cylindrical surface S. If the values of the charges are $q_1 = +3nC$, $q_2 = -2nC$, $q_3 = +2nC$, $q_4 = +4nC$, and $q_5 = -1nC$, find the total flux through S.

Answer

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Advanced Engineering Electromagnetics - C. Balanis

Link: Internet Archive

1 Time-Varying and Time-Harmonic Electromagnetic Fields

Maxwell's Equations

Expand

- Who is James Clerk Maxwell?

Answer

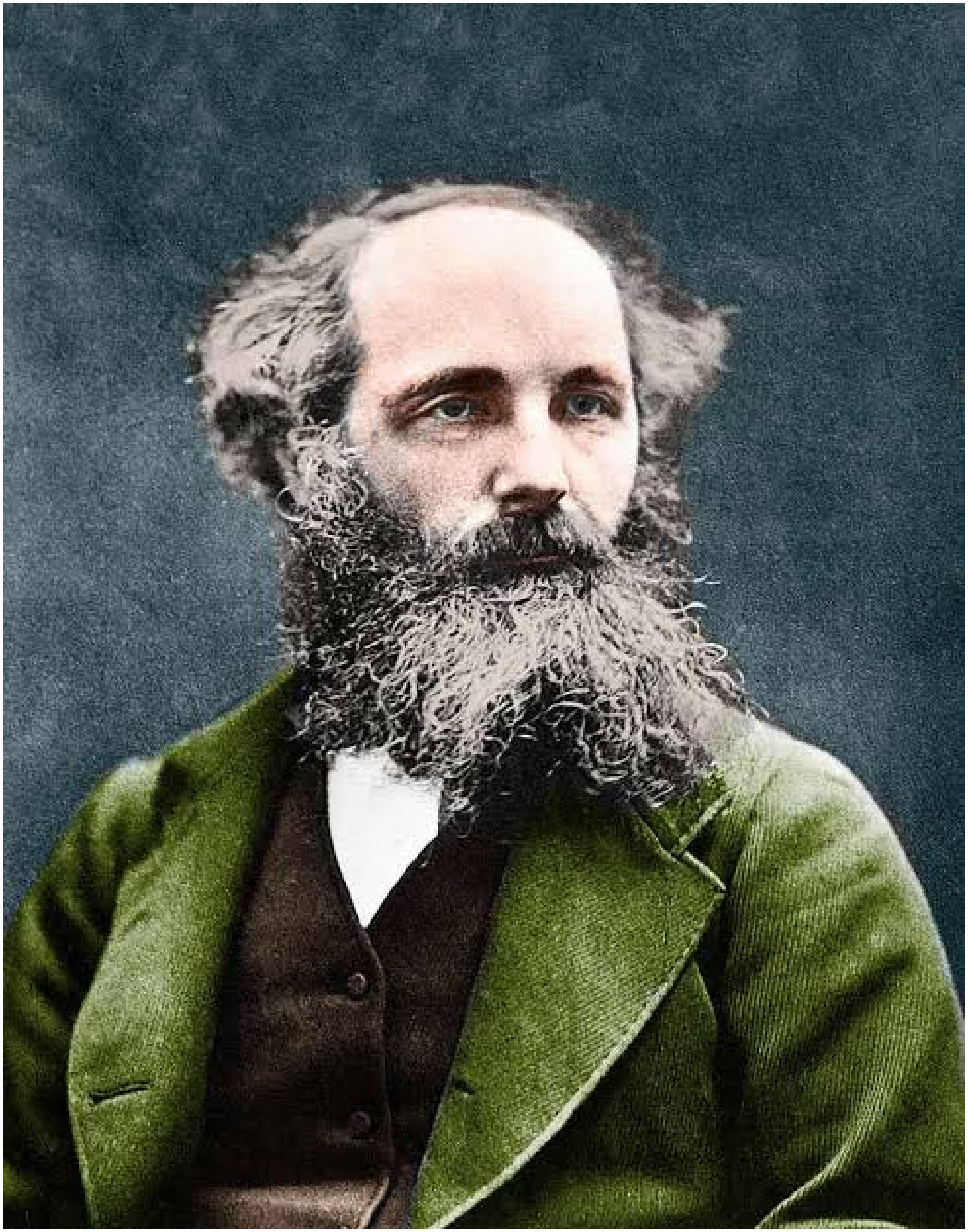

Figure 1: James Clerk Maxwell

A Scottish physicist and mathematician that lived from 1831 to 1879.

The Father of Modern Physics

See my notes on Dan Fleisch's A student's guide to Maxwell's Equations for detailed explanation of the differential and integral forms of the four maxwell's equations.

Constitutive Parameters and Relations

Expand

Circuit-Field Relations

Expand

- What is Circuit Theory?

Answer

A special case of electromagnetic theory, when the physical dimensions of the circuit are small compared to the wavelength.

KVL

KCL

Element Laws

Boundary Conditions

Expand

Finite Conductivity Media

Infinite Conductivity Media

Sources Along Boundaries

Power and Energy

Expand

Time-Harmonic Electromagnetic Fields

Expand

Maxwell's Equations in Differential and Integral Forms

Boundary Conditions

Power and Energy

Exercises

Expand

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2 Electrical Properties of Matter

Introduction

Expand

Dielectrics, Polarization, and Permittivity

Expand

Magnetics, Magnetization, and Permeability

Expand

Current, Conductors, and Conductivity

Expand

Current

Conductors

Conductivity

Semiconductors

Expand

Superconductors

Expand

Metamaterials

Expand

Linear, Homogeneous, Isotropic, and Nondispersive Media

Expand

Exercises

Expand

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3 Wave Equation and Its Solutions

Introduction

Expand

Time-Varying Electromagnetic Fields

Expand

Time-Harmonic Electromagnetic Fields

Expand

Solution to the Wave Equation

Expand

Rectangular Coordinate System

Cylindrical Coordinate System

Spherical Coordinate System

Exercises

Expand

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4 Wave Propagation and Polarization

Introduction

Expand

Transverse Electromagnetic Modes

Expand

Transverse Electromagnetic Modes in Lossy Media

Expand

Polarization

Expand

Exercises

Expand

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5 Reflection and Transmission

Introduction

Expand

Normal Incidence - Lossless Media

Expand

Oblique Incidence - Lossless Media

Expand

Perpendicular Polarization

Parallel Polarization

Total Transmission - Brewster Angle

Total Reflection - Critical Angle