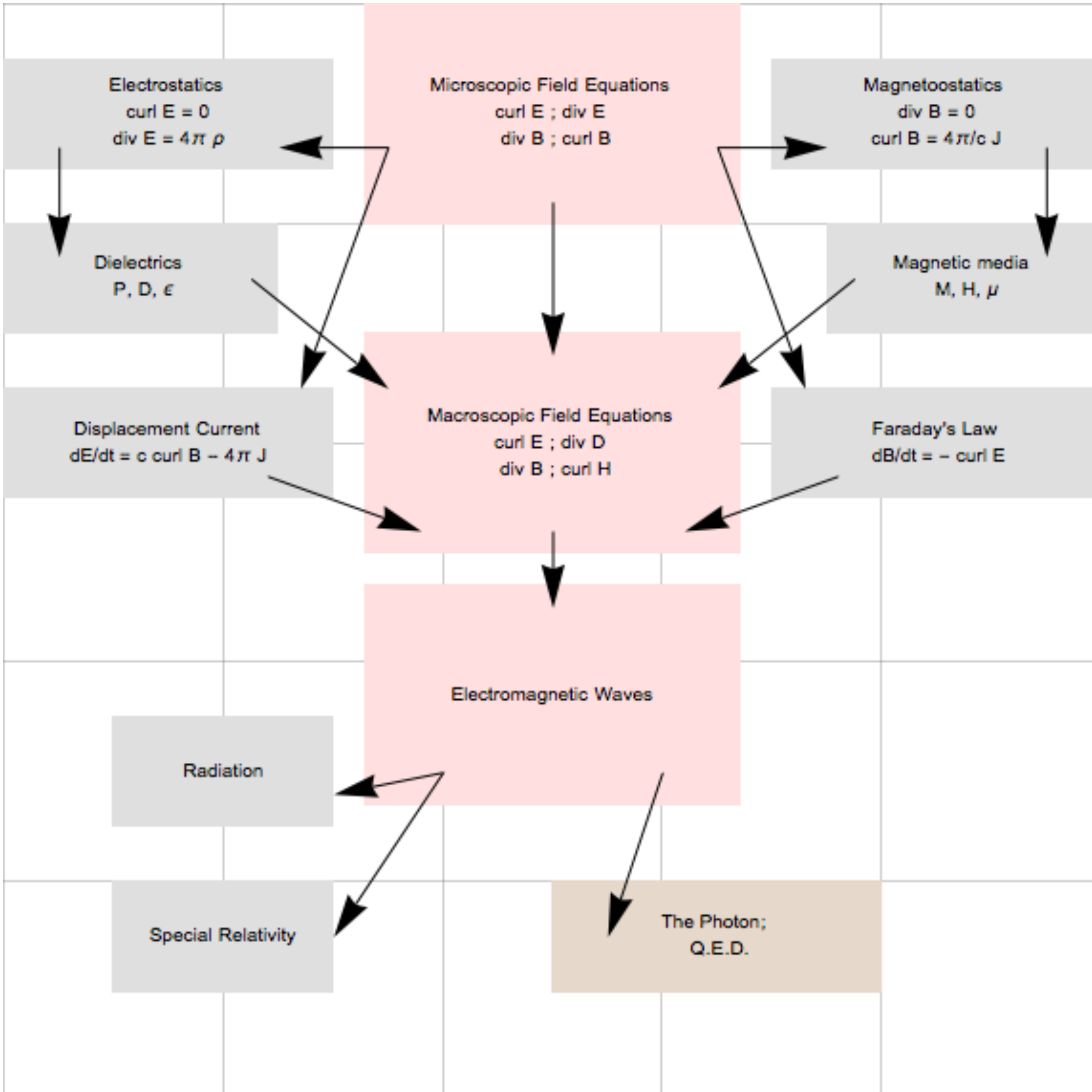
In[ ]:=

```
SetDirectory[
  "/Users/OurMacBookAir/Documents/Teaching.2018.current/introduction
    .current"];
FileNames[];
map = Import["map.png"];
```

In[∘]:= map

Out[∘]=


Electrostatics
curl E = 0
div E = 4π ρ
Microscopic Field Equations
curl E ; div E
div B ; curl B
Magnetoostatics
div B = 0
curl B = 4π/c J
Dielectrics
P, D, ϵ
Magnetic media
M, H, μ
Displacement Current
dE/dt = c curl B − 4π J
Macroscopic Field Equations
curl E ; div D
div B ; curl H
Faraday's Law
dB/dt = − curl E
Electromagnetic Waves
Radiation
Special Relativity
The Photon;
Q.E.D.

PHY 842 - Lecture 1

Why are you taking PHY 842?

2

At MSU we have 7 semester-long courses on electromagnetism.

PHY 184 = Physics for Scientists and Engineers II (fresh/soph) ✓

PHY 431 = Optics (jr/sr) ✓

PHY 481 = Electricity and Magnetism I (jr/sr) ✓

PHY 482 = Electricity and Magnetism II (jr/sr) ✓

PHY 841 = Classical Electrodynamics I (grad) ✓

PHY 842 = Classical Electrodynamics II (grad)

PHY 855/955 = Quantum Field Theory and Relativistic QFT (grad)

You have already taken 5 courses on electro-magnetism. Why are you taking another one?

3

All physicists must understand electromagnetism, because

- Electromagnetism is one of the 4 fundamental interactions;
  - gravity,
  - electromagnetism,
  - strong interactions (QCD),
  - weak interactions (standard model; EWSB)
- Electromagnetism is the simplest of the four fundamental interactions.
- QCD and the electroweak standard model are extensions of QED.

(QED, QCD, and the standard model are all gauge-invariant field theories.)

- Gravity is different.

(It's like a field theory on steroids.)

If you don't learn electromagnetism, then you won't understand the other interactions.

4

Mastering electromagnetism is a long process because each course requires a step higher in mathematical techniques.

PHY 184:

$$\oint \vec{E} \cdot d\vec{A} = Q_{\text{enclosed}} / \epsilon_0$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{through}} \qquad \text{etc}$$

PHY 481/2:

$$\text{div}\,\vec{D} = \rho_{\text{free}}$$

$$\text{curl}\,\vec{H} = \vec{J}_{\text{free}}$$

$$\vec{D} = \epsilon\,\vec{E} \quad , \quad \vec{H} = \vec{B}\,/\mu \qquad \text{etc}$$

PHY 841/2: same equations in Gaussian units; plus E.M. waves

PHY 855/955: the fields are quantized; i.e, a Hilbert space of photons

5

Electromagnetism has both

- quantum effects (photons) = QED
- macroscopic effects = CED

The macroscopic effects are important in electrical engineering, design of experimental apparatus, applications to condensed matter physics and many other examples;

CED is the subject of PHY 841 and 842.

6

Outline of Jackson

(1,2,3) Electrostatics in “vacuum”

(4) Dielectrics; $\vec{P}$ and $\vec{D}$

(5) Magnetostatics in “vacuum” and magnetic materials; $\vec{M}$ and $\vec{H}$

(6) Time-dependent fields; Maxwell’s equations and field theory

(7) Electromagnetic waves (waves in "infinite volume")

(8) Wave guides and resonant cavities (fields in "finite volumes")

(9) Scattering of E.M. waves

(10) Radiation of E.M. waves

(11,12) Special Relativity ⇐ derived by Einstein from Maxwell’s field theory

(13,14,15) Various advanced topics

(16) Limitations of classical physics

Which chapters do you already know?

Which chapters do you need to learn?

The first homework assignment is due Friday.

7

Homework Assignment #1 due Friday

We are not going to use Jackson as the primary textbook.

We'll use Wilcox and Thron as the required textbook!

But everything is in Jackson, so we'll sometimes refer to Jackson.

8

Units of Measurement in Electromagnetism

Read the Appendix!

The two most common systems of units are "SI units" and "Gaussian esu units".

■ Jackson uses SI units in some chapters and Gaussian esu units in other chapters.

■ Elementary textbooks (PHY 184 level) always use SI units.

■ Most intermediate textbooks (PHY 481/2) use SI units.

●● Wilcox and Thron use Gaussian (esu) units.

■ Electrical engineering: SI

■ Theoretical physics: Gaussian esu (CED) or Gaussian emu (QED)

If we're going to calculate numbers then we need to know the units.

Example: What is the charge of an electron?

In SI units, $e = 1.602 \times 10^{-19}$ C (coulomb)

In esu units, $e = 4.803 \times 10^{-10}$ esu (or, statcoulomb)

1.602e-19 × 2.998e8 = 4.803e-10

Example: What is the magnetic field at distance $r = 1$ cm from a long straight current-carrying wire, with $I = 1$ amp?

In SI units, $B = 2 \times 10^{-5}$ T $\Longleftarrow \mu_0 I/(2\pi r)$ SI

In esu units, $B = 2$ nG $\Longleftarrow 2I/(cr)$ gaussian

"Gaussian units" are more difficult than a simple change of units. The field equations are different for Gaussian and SI units. (Homework problem 1.)

9. Microscopic Electrostatics of Point Charges

Gaussian

$\vec{F} = q_1 \vec{E}_2$

$\vec{F}_{12} = q_1 q_2 (\vec{x}_1 - \vec{x}_2) / |\vec{x}_1 - \vec{x}_2|^3$

$\vec{E}(\mathrm{q}) = \mathrm{q} (\vec{x} - \vec{x}') / |\vec{x} - \vec{x}'|^3$

Systeme Internationale

$\vec{F} = q_1 \vec{E}_2$

$\vec{F}_{12} = (q_1 q_2) / (4 \pi \epsilon_0) (\vec{x}_1 - \vec{x}_2) / |\vec{x}_1 - \vec{x}_2|^3$

$\vec{E}(\mathrm{q}) = q / (4 \pi \epsilon_0) (\vec{x} - \vec{x}') / |\vec{x} - \vec{x}'|^3$

Microscopic Magnetostatics of Wire Elements

Gaussian

$d\vec{F} = (I_1 / c)\ \vec{dl}_1 \times \vec{B}_2$

$d\vec{F}_{12} = (I_1\ I_2\ /\ c^2)\ \vec{dl}_1\ \times \{ \vec{dl}_2 \times (\vec{x}_1 - \vec{x}_2) \} /$

$|\ \vec{x}_1 - \vec{x}_2\ |^3$

$d\vec{B}(\vec{x}) =\ (\ I/c\ )\ \ \vec{dl}' \times (\ \vec{x} - \vec{x}'\ ) / |\ \vec{x} - \vec{x}'\ |^3$

Systeme Internationale

$d\vec{F} =\ I_1\ \vec{dl}_1 \times \vec{B}_2$

$d\vec{F}_{12} = (\ \mu_0\ I_1\ I_2)/(4\pi)\ \ \vec{dl}_1\ \times \{ \vec{dl}_2 \times (\vec{x}_1 - \vec{x}_2) \}$

$/\ \ |\ \vec{x}_1 - \vec{x}_2\ |^3$

$d\vec{B}(\vec{x}) =\ (\mu_0\ I\ )/(4\pi)\ \ \vec{dl}' \times (\ \vec{x} - \vec{x}'\ ) / |\ \vec{x} - \vec{x}'$

$|^3$

10.

Pick up the handouts

—Syllabus for PHY 842

—Homework Assignment #1

Hand in the quiz.

Quiz question:

Why are you taking PHY 842?
The answer "Because it is required" will not be accepted.
Why is it required? Or, give another answer.