# TeX at the Open University

Jonathan Fine

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Slides at mathtran docs on SVN on Sourceforge

# About the OU

- Founded in 1969 (Happy 40th birthday)
- More than 2,000,000 people have studied with the OU
- About 160,000 undergraduate students, 16,000 taught postgrad, 1,500 research postgrad
- More than 8,500 hours of free learning at OpenLearn
- More than 9,000 students with disabilities each year
- The OU teaches 35% of UK part-time undergrad students
- OU professor Joycelyn Bell Burnell discovered pulsars (as a postgrad student)
- OU expenditure in 2006/7 was £363m (£212 from Funding Council grants)
- OU materials are made available to 150,000 student teachers in Nigeria, Sudan and Uganda.

# TEX at OU — getting support — 1983 to 1986

Use of TEX at OU was started in the Maths Department, in the 1980s. This slide and next based on email from Chris Rowley.

- **1983** Chris Rowley (CR) has terminal in office connected to DEC20 (PDP-10). Oxford University has a LaserComp that supports Monotype 5-line math typesetting. Academic Computing Services (ACS) has a copy of *The TEXbook*.
- **1984-5** CR learns more about TEX and LATEX. Bob Coates (at UBC Vancouver) and CR start using plain TEX plus macros to code assignment books. All printing done at Vancouver!
- ACS reluctant to obtain printers and drivers. CR and Steve Daniels (ACS) become converts to structured markup — LATEX and SGML.
- **1986** The LATEX manual arrives. Many ACS support staff see the potential. The OU decides to bring typesetting in-house, using high-end system fed with Word documents (and very limited math capabilities).

# Building the system — 1987 to 1996

By 1986 many in the OU saw the potential of TEX and its importance in the preparation of mathematical content.

- **1987** OU agrees to fund 3-year faculty project to set up LATEX system for maths and physics courses.
- The team was CR, Bob Coates, Steve Daniels, Alison Cadle (OU Publishing, later LTS) and technical typists.
- **1987-96** OU TEX developments fed into what became LATEX2e.
- Problems with integration of graphic and colour into typesetting tackled and resolved as best as possible. (Adobe released PostScript Levels 1 and 2 in 1984 and 1991.)
- From **1991** Alison Cadle manages project and OU TEX system.
- circa **1994** Student use course units produced using TEX.
- **1994** Release of new standard LATEX, called LATEX2e.

# Over time, new becomes old, solution becomes problem

The OU TEX system development was completed in about 1994. Since then, gradually, some problems built up.

- OU TEX system built using LATEX209
- LATEX2e replaced LATEX209 (a good step)
- System used proprietary (in-house) printer driver
- Faculty running TEX on PCs
- System running on Digital hardware and software
- System uses (and relies on) DEC versioning system

There was a pressing need to move the system to a modern and supported hardware/software platform, and in particular to Windows.

Not able to do this in-house, and wished to have reliable source of TEX skills.

# OU LTS hires a TEX systems expert

In 2003 the OU advertised for an expert in TEX, to solve their problems. The first problem was to move production from Alpha/VMS to Windows, MikTeX and CVS. My application was successful. Around 2005 we turned off the Alpha/VMS machine.

Running LATEX209 on Windows was quite easy, except there were 209 and 2e files with exactly the same names. So some tricks were required to ensure the correct file was picked up.

The proprietary printer driver was hard. Milton Keynes contains both the OU main campus and the Bletchley Park code-breaking centre. I instrumented the old macros, so I could record the sequences of instructions they were emitting. I then analysed these sequences and specified a map to dvips instructions.

Finally, I wrote a Finite State Automota in TEX macros that buffered old-style instructions and translated them to dvips specials.

# Today's use of TEX at the OU

- Circa 30 undergraduate mathematics courses.
- About a dozen graduate maths courses
- Four upper level physics courses
- About 500–750 main item pages per course
- Courses have long life
- Also supplementary materials
  - Course guides
  - Computer books
  - Assignment books
  - Specimen exams
  - Solutions to specimen exams
  - Real exams (confidential, secure material)
  - Tutor notes, student notes, marking schemes (also secure)
- PhDs and articles (I don't deal with that)

# M381: Number Theory and Mathematical Logic

- First presented in 1986
- Will present until at least 2015
- Indefinite life planned for this course
- Authored in LaTeX209 (of course)
- Similar courses (long-life, authored in LaTeX209)
    - M336, Groups and Geometry
    - M337 Complex analysis
    - M338 Topology
- At present, for older courses assignment books and other supps produced in LaTeX209.

# SMT359: Electromagnetism
# SM358: Quantum Mechanics

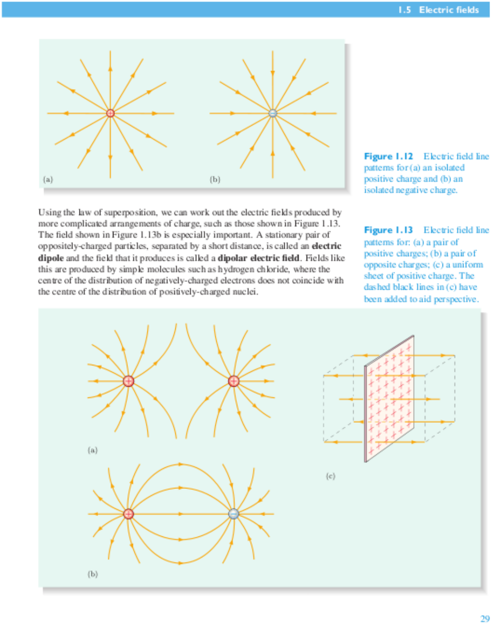
- First presented in 2006/7.
- Each course has 3 books of about 250 pages, quarto.
- Four colour, heavily illustrated, complex layout

Uses key-value syntax to pass parameters to complex figure and caption placement TEX macros.

It's a real pain to write and maintain this sort of thing in TEX.

Also some hand-code paragraph shapes and placement.

# SMT359 Book 1 page 29: Caption placement



1.5 Electric fields

**Figure 1.12** Electric field line patterns for (a) an isolated positive charge and (b) an isolated negative charge.

Using the law of superposition, we can work out the electric fields produced by more complicated arrangements of charge, such as those shown in Figure 1.13. The field shown in Figure 1.13b is especially important. A stationary pair of oppositely-charged particles, separated by a short distance, is called an **electric dipole** and the field that it produces is called a **dipolar electric field**. Fields like this are produced by simple molecules such as hydrogen chloride, where the centre of the distribution of negatively-charged electrons does not coincide with the centre of the distribution of positively-charged nuclei.

**Figure 1.13** Electric field line patterns for: (a) a pair of positive charges; (b) a pair of opposite charges; (c) a uniform sheet of positive charge. The dashed black lines in (c) have been added to aid perspective.

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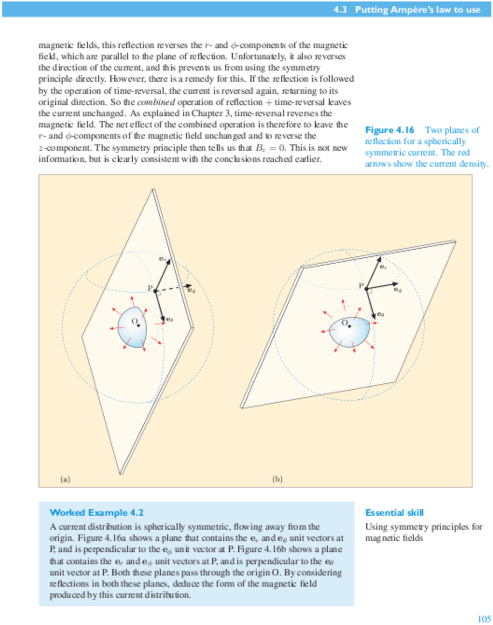
# SMT359 Book 1 page 105: Split background tint



magnetic fields, this reflection reverses the $r$- and $\phi$-components of the magnetic field, which are parallel to the plane of reflection. Unfortunately, it also reverses the direction of the current, and this prevents us from using the symmetry principle directly. However, there is a remedy for this. If the reflection is followed by the operation of time-reversal, the current is reversed again, returning to its original direction. So the *combined* operation of reflection + time-reversal leaves the current unchanged. As explained in Chapter 3, time-reversal reverses the magnetic field. The net effect of the combined operation is therefore to leave the $r$- and $\phi$-components of the magnetic field unchanged and to reverse the $z$-component. The symmetry principle then tells us that $B_z = 0$. This is not new information, but is clearly consistent with the conclusions reached earlier.

**Figure 4.16** Two planes of reflection for a spherically symmetric current. The red arrows show the current density.

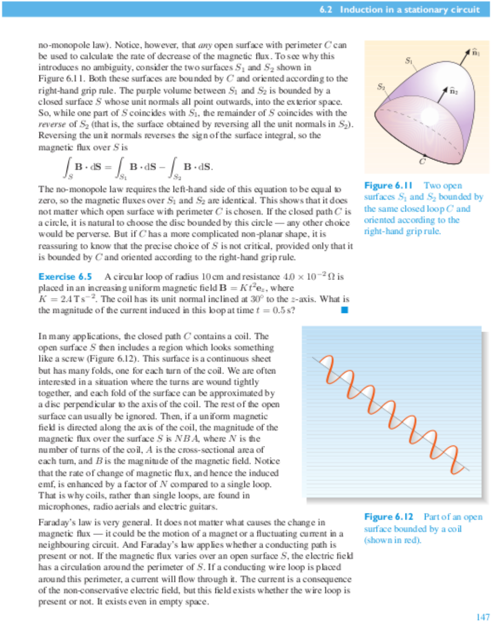
**Worked Example 4.2**

A current distribution is spherically symmetric, flowing away from the origin. Figure 4.16a shows a plane that contains the $\mathbf{e}_r$ and $\mathbf{e}_\theta$ unit vectors at P, and is perpendicular to the $\mathbf{e}_\phi$ unit vector at P. Figure 4.16b shows a plane that contains the $\mathbf{e}_r$ and $\mathbf{e}_\phi$ unit vectors at P, and is perpendicular to the $\mathbf{e}_\theta$ unit vector at P. Both these planes pass through the origin O. By considering reflections in both these planes, deduce the form of the magnetic field produced by this current distribution.

**Essential skill**

Using symmetry principles for magnetic fields

# SMT359 Book 1 page 147: Wrap figure, not caption



no-monopole law). Notice, however, that *any* open surface with perimeter $C$ can be used to calculate the rate of decrease of the magnetic flux. To see why this introduces no ambiguity, consider the two surfaces $S_1$ and $S_2$ shown in Figure 6.11. Both these surfaces are bounded by $C$ and oriented according to the right-hand grip rule. The purple volume between $S_1$ and $S_2$ is bounded by a closed surface $S$ whose unit normals all point outwards, into the exterior space. So, while one part of $S$ coincides with $S_1$, the remainder of $S$ coincides with the *reverse* of $S_2$ (that is, the surface obtained by reversing all the unit normals in $S_2$). Reversing the unit normals reverses the sign of the surface integral, so the magnetic flux over $S$ is

$$\int_S \mathbf{B} \cdot \mathrm{d}\mathbf{S} = \int_{S_1} \mathbf{B} \cdot \mathrm{d}\mathbf{S} - \int_{S_2} \mathbf{B} \cdot \mathrm{d}\mathbf{S}.$$

The no-monopole law requires the left-hand side of this equation to be equal to zero, so the magnetic fluxes over $S_1$ and $S_2$ are identical. This shows that it does not matter which open surface with perimeter $C$ is chosen. If the closed path $C$ is a circle, it is natural to choose the disc bounded by this circle — any other choice would be perverse. But if $C$ has a more complicated non-planar shape, it is reassuring to know that the precise choice of $S$ is not critical, provided only that it is bounded by $C$ and oriented according to the right-hand grip rule.

**Figure 6.11** Two open surfaces $S_1$ and $S_2$ bounded by the same closed loop $C$ and oriented according to the right-hand grip rule.

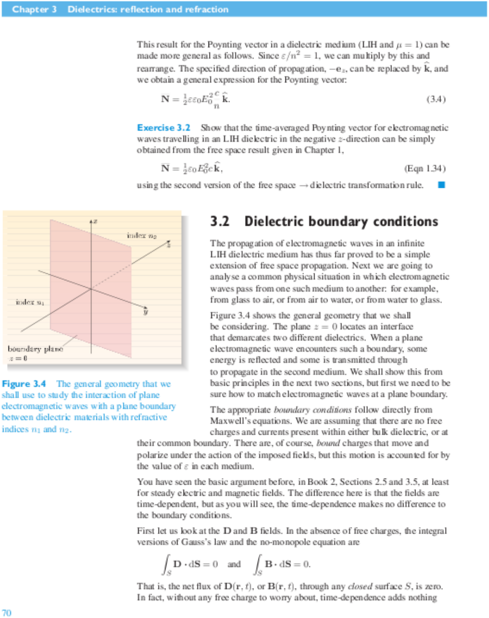
**Exercise 6.5** A circular loop of radius 10 cm and resistance $4.0 \times 10^{-2}\,\Omega$ is placed in an increasing uniform magnetic field $\mathbf{B} = Kt^2\mathbf{e}_z$, where $K = 2.4\,\mathrm{T\,s^{-2}}$. The coil has its unit normal inclined at 30° to the $z$-axis. What is the magnitude of the current induced in this loop at time $t = 0.5\,\mathrm{s}$? ■

In many applications, the closed path $C$ contains a coil. The open surface $S$ then includes a region which looks something like a screw (Figure 6.12). This surface is a continuous sheet but has many folds, one for each turn of the coil. We are often interested in a situation where the turns are wound tightly together, and each fold of the surface can be approximated by a disc perpendicular to the axis of the coil. The rest of the open surface can usually be ignored. Then, if a uniform magnetic field is directed along the axis of the coil, the magnitude of the magnetic flux over the surface $S$ is $NBA$, where $N$ is the number of turns of the coil, $A$ is the cross-sectional area of each turn, and $B$ is the magnitude of the magnetic field. Notice that the rate of change of magnetic flux, and hence the induced emf, is enhanced by a factor of $N$ compared to a single loop. That is why coils, rather than single loops, are found in microphones, radio aerials and electric guitars.

**Figure 6.12** Part of an open surface bounded by a coil (shown in red).

Faraday's law is very general. It does not matter what causes the change in magnetic flux — it could be the motion of a magnet or a fluctuating current in a neighbouring circuit. And Faraday's law applies whether a conducting path is present or not. If the magnetic flux varies over an open surface $S$, the electric field has a circulation around the perimeter of $S$. If a conducting wire loop is placed around this perimeter, a current will flow through it. The current is a consequence of the non-conservative electric field, but this field exists whether the wire loop is present or not. It exists even in empty space.

# SMT359 Book 3 page 70: Wrap figure, title and text



This result for the Poynting vector in a dielectric medium (LIH and $\mu = 1$) can be made more general as follows. Since $\varepsilon/n^2 = 1$, we can multiply by this and rearrange. The specified direction of propagation, $-\mathbf{e}_z$, can be replaced by $\widehat{\mathbf{k}}$, and we obtain a general expression for the Poynting vector:

$$\overline{\mathbf{N}} = \tfrac{1}{2}\varepsilon\varepsilon_0 E_0^2 \frac{c}{n}\,\widehat{\mathbf{k}}. \tag{3.4}$$

**Exercise 3.2** Show that the time-averaged Poynting vector for electromagnetic waves travelling in an LIH dielectric in the negative $z$-direction can be simply obtained from the free space result given in Chapter 1,

$$\overline{\mathbf{N}} = \tfrac{1}{2}\varepsilon_0 E_0^2 c\,\widehat{\mathbf{k}}, \qquad \text{(Eqn 1.34)}$$

using the second version of the free space → dielectric transformation rule. ■

**Figure 3.4** The general geometry that we shall use to study the interaction of plane electromagnetic waves with a plane boundary between dielectric materials with refractive indices $n_1$ and $n_2$.

## 3.2 Dielectric boundary conditions

The propagation of electromagnetic waves in an infinite LIH dielectric medium has thus far proved to be a simple extension of free space propagation. Next we are going to analyse a common physical situation in which electromagnetic waves pass from one such medium to another: for example, from glass to air, or from air to water, or from water to glass.

Figure 3.4 shows the general geometry that we shall be considering. The plane $z = 0$ locates an interface that demarcates two different dielectrics. When a plane electromagnetic wave encounters such a boundary, some energy is reflected and some is transmitted through to propagate in the second medium. We shall show this from basic principles in the next two sections, but first we need to be sure how to match electromagnetic waves at a plane boundary.

The appropriate *boundary conditions* follow directly from Maxwell's equations. We are assuming that there are no free charges and currents present within either bulk dielectric, or at their common boundary. There are, of course, *bound* charges that move and polarize under the action of the imposed fields, but this motion is accounted for by the value of $\varepsilon$ in each medium.

You have seen the basic argument before, in Book 2, Sections 2.5 and 3.5, at least for steady electric and magnetic fields. The difference here is that the fields are time-dependent, but as you will see, the time-dependence makes no difference to the boundary conditions.

First let us look at the $\mathbf{D}$ and $\mathbf{B}$ fields. In the absence of free charges, the integral versions of Gauss's law and the no-monopole equation are

$$\int_S \mathbf{D}\cdot d\mathbf{S} = 0 \quad \text{and} \quad \int_S \mathbf{B}\cdot d\mathbf{S} = 0.$$

That is, the net flux of $\mathbf{D}(\mathbf{r},t)$, or $\mathbf{B}(\mathbf{r},t)$, through any *closed* surface $S$, is zero. In fact, without any free charge to worry about, time-dependence adds nothing

# S382: Astrophysics
# S383: The relativistic Universe

- First presentation 2010.
- Reused styles from SMT359 and SM358.
- Each course has 3 books of about 250 pages, quarto.
- Four colour, heavily illustrated, complex layout

# M347: Mathematical Statistics

Background

- First presentation planned for 2012
- Experiment: web delivery of main teaching materials
- We use Moodle VLE, with XML schema for content
- Course in first draft stage, using LaTeX
- Have decided to use plasTeX to convert to schema XML
- May revisit this decision

Problems

- Author defined commands and macros
- Resistance to change vs. needless innovation
- LaTeX does not map well to XML
- OU LaTeX markup vs. OU XML schema
- Fear of cost and dependencies

# Student authored mathematics

Most courses accept/encourage/require electronic submission of Tutor Marked Assignments (TMAs).

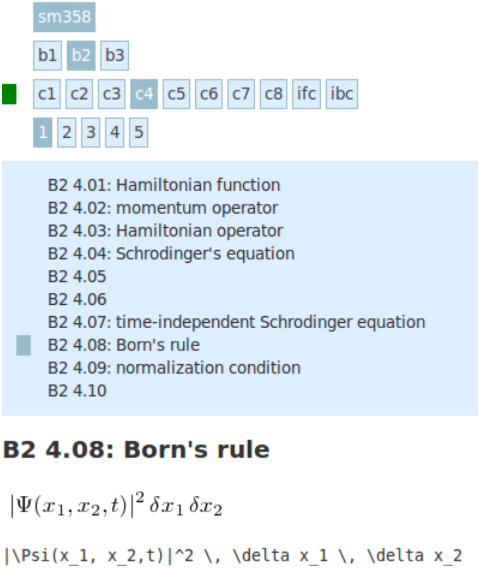
Encouraging students to use forums (Moodle Virtual Learning Environment) and on-line conferencing (Elluminate).

Mathematical content is big problem in this area.

*How do I get formulas into a whiteboard?*

Obtained funding from JISC and the OU to hold one-day workshop on technical problems in mathematical content.

# Browsers formulas with ‘Miller Columns’



B2 4.01: Hamiltonian function
B2 4.02: momentum operator
B2 4.03: Hamiltonian operator
B2 4.04: Schrodinger's equation
B2 4.05
B2 4.06
B2 4.07: time-independent Schrodinger equation
B2 4.08: Born's rule
B2 4.09: normalization condition
B2 4.10

**B2 4.08: Born's rule**

$$|\Psi(x_1, x_2,t)|^2 \, \delta x_1 \, \delta x_2$$

`|\Psi(x_1, x_2,t)|^2 \, \delta x_1 \, \delta x_2`