Comparing Electromagnetics Education in China, Hong Kong, and USA

W.C. Chew\(^1\), L.J. Jiang\(^2\), W.X. Zhang\(^3\), X.Q. Sheng\(^4\), and J. Pan\(^5\)

Abstract

We compare electromagnetics (EM) education in three regions of the world: China, Hong Kong, and USA. All three regions have varied history and hence their educational institutions are affected by their historical background.

Education in China is strongly influenced by the Soviet model due to the initial infusion of technology knowledge from Russia during the early years of modern Chinese history. Electromagnetics was under radio physics, and an entire university was devoted to an area such as the University of Electronic Science and Technology in Chengdu, China. Electrical engineering (EE) is divided into heavy current EE or weak current EE. Power engineering is under heavy current while information engineering is under weak current. The electromagnetics curricula are also influenced by such classification. Chinese team teaching is very well organized, with the use of modern technologies such as the Internet, audiovisual equipment and slides, laboratory, and software. Knowledge is often imbibed from overseas. It reflects the rapid technology advancements in China.

The education system in Hong Kong started with the UK tradition. The UK system is more laissez faire than others. Some of these traditions are apparent in Hong Kong universities. There were no course requirements for PhD students, and no weekly home-works for undergraduates, but it is changing. The lack of good technology jobs in Hong Kong has diverted good local students from engineering. Nevertheless, being the gateway to the West, Hong Kong still attracts many outstanding mainland Chinese students who excel in their classes. An old three-year bachelor degree program is now replaced with a four-year curriculum, aligning it with the world’s norm. It was hard to fit in undergraduate EM education in the old UK system, but the four-year bachelor offers more flexibility.

EM Education in US has gone on a different path. The Yankee ingenuity and the American penchant for self-criticism, openness, and soul searching has produced some of the best universities in the world: American universities lead in innovation. The curricula in US also change rapidly with time. In the postwar period, EM was very important, and many American text books were written to underscore its importance. It also correlated well with the vast resource the government had invested in research. Many universities require two undergraduate courses in EM. However, as technology evolves, with other emerging technologies, classical EM is not central to electrical engineering. Nano-electronics, photonics, computer science and computer engineering become increasingly important. Hence, it is still hotly debated as to how to teach students a difficult subject, EM, with the modern constraints.

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Introduction

- Education transforms society;
- Scotland
  - Home of James Clerk Maxwell, Sir Walter Scott, David Hume, Alexander Bell, James Watt;
- John Knox (1505-1572) promulgated education;
- Science and technology is the new source of wealth;
  - Dujiangyan of China (256 BC), by LI Bing.
Globalization of World’s Economy

- Engineers are a globalized commodity;
- The world is becoming smaller due to the ICT (information and communication technology);
- Transportation can move people around the world faster;
- Production of an airplane is outsourced to all parts of the globe to minimize the cost;
- Globalization of world’s economy;
  - Technology revolution happening worldwide.
Examples of Successful Countries

- Nordic countries like Finland, Denmark, Norway, Sweden, there is little natural resources;
- Periodic famines have historically decimated the population, despite their vast landmass;
- Now these countries are into automobile, aircraft, wireless communication, paper pulp industries;
- They used to be Vikings to raid for food;
- But now they trade high tech product for food from the rest of the world;
- Mongols and nomads in Northern China?
“Technology Revolution” in China

- China produces 600,000 engineers per year;
- Enriched 250 million people in China;
- Lifted 500 million people out of poverty;
- 50% live in 150 cities;
- 200 M bloggers;
- 700 M mobile phone users;
- 168 M motor vehicles;
- 420 M internet users;

Similar Revolution is happening in India
Future Grand Challenge Problems (NAE)

Electromagnetic engineers shall play an important role.

1. Make solar energy economical
2. Provide energy from fusion
3. Develop carbon sequestration methods
4. Manage the nitrogen cycle
5. Provide access to clean water
6. Restore and improve urban infrastructure
7. Advance health informatics
8. Engineer better medicines
9. Reverse engineer the brain
10. Prevent nuclear terror
11. Secure cyberspace
12. Enhance virtual reality
13. Advance personalized learning
14. Engineer the tools of scientific discovery
Commonality of EM Education

- Electromagnetics is important in many high tech industries;
- Electromagnetic education is difficult;
  - Abstract, math, physics, derivations;
  - Broad physical phenomena, applications, wide gap between theory and applications;
- Difficult to cover topics to meet society needs;
- Multi-media classrooms and materials;
- Competing with other disciplines drain students away;
- Competing with the finance and banking industry occurs in Hong Kong, Singapore, and the USA.
# UG EM Course Requirements

<table>
<thead>
<tr>
<th>Institution</th>
<th>REQUIRED EM COURSES</th>
<th>WEAKLY REQUIRED EM COURSES</th>
<th>ELECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKU</td>
<td>1</td>
<td></td>
<td>Several (optics, EM)</td>
</tr>
<tr>
<td>SEU, CHINA</td>
<td>1</td>
<td></td>
<td>4 (microwave, antenna, EMC, CEM)</td>
</tr>
<tr>
<td>UESTC, CHINA</td>
<td>1 big course (&gt;50 hrs)</td>
<td></td>
<td>many</td>
</tr>
<tr>
<td>BIT, CHINA</td>
<td>1</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>UIUC, USA</td>
<td>1 (Waves &amp; Fields I)</td>
<td>1 (3 out of 5) (Waves &amp; Fields II)</td>
<td>4 (optics, MIC, Antennas, RF)</td>
</tr>
<tr>
<td>NTU, Taiwan</td>
<td>2</td>
<td></td>
<td>4 (EMW, RF, MIC, Antennas)</td>
</tr>
<tr>
<td>NUS, S’PORE</td>
<td>1</td>
<td></td>
<td>2 (Micro. Engg)</td>
</tr>
<tr>
<td>NTU, S’PORE</td>
<td>1</td>
<td></td>
<td>1 (Microwave RF Engineering)</td>
</tr>
<tr>
<td>NIHON, JAPAN</td>
<td>2 (Electric, Magnetic)</td>
<td></td>
<td>2 (Intro EM Wave, EM Wave)</td>
</tr>
</tbody>
</table>
Teaching EM is like an industry here;
One of the most sophisticated EM education center in the world;
Ways to nurture a first class teaching team, teaching method, visualization, hands-on experiments, teaching conditions;
35 members in a EM team teaching (leading team in China)
18 hours in big class (fundamental concepts), 52 hours in small class (detail works), and 10 hours in big class (special topic workshop); 80 hours class;
• Experimental class;
  • 3 fundamental experiments;
    • Sensor design; EM wave propagation and characteristics; EM polarization experiments;
  • 13 elective experiments;
    • Travelling wave; frequency; attenuation; reflections; double slit interferometer; Wilkinson divider etc;
  • 9 free experiments;
    • Frequency mixer; oscillators; amplifiers, filters, Yagi-Uda antennas;
A typical outline for undergraduate EM-course
《Electromagnetic Fields & Waves》
for School of Information Sci. & Eng.
SEU

Pre-studied Courses:
《University Physics》with Electromagnetism, Optics.
《Mathematical analysis》with Vector analysis, Fourier series,
Differential equations, Complex variables

Content Abstract:
- Basic laws in the electromagnetic fields
- Static electric fields
- Steady magnetic field
- Solutions of the static electromagnetic field
- Time-varying electromagnetic fields
- Plane electromagnetic waves
- Guided electromagnetic wave
- Electromagnetic radiation

Further Courses
For undergraduate
《Microwave Engineering》
Required 3 Credits
《Antenna Technology》
Selected 2 Credits
《EM Compatibility》
Selected 2 Credits
《Computational EM》
Seminar 2 Credits
**EM Education Course-Series for Graduate Program on Electromagnetic & Microwave Technology in SEU**

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental Mathematics <em>for EM Engineering</em> (3)</td>
<td></td>
</tr>
<tr>
<td>Functional Methods <em>for EM Boundary-value Problems</em> (2)</td>
<td></td>
</tr>
<tr>
<td>Numerical Techniques <em>for EM Boundary-value Problems</em> (2)</td>
<td></td>
</tr>
<tr>
<td>Integral Equation Methods <em>in Computational EM</em> (2)</td>
<td></td>
</tr>
<tr>
<td>Advanced EM Theory (3)</td>
<td></td>
</tr>
<tr>
<td>Antenna Theory (3)</td>
<td></td>
</tr>
<tr>
<td><em>Modern Topics in EM</em> (2/each)</td>
<td></td>
</tr>
<tr>
<td>EM Seminars <em>(invited)</em></td>
<td></td>
</tr>
</tbody>
</table>
Features of EM Education in BIT

XQ Sheng’s View

- **Regard EM as a masterpiece in Human Civilization**
  Elaborate how EM Theory is established to demonstrate the methodology of constructing theory, which is invented by Western society and play a fundamental role in human civilization.

- **Regard EM as a foundation of Wireless Communication**
  Elaborate how to employ EM theory to solve three fundamental problems in communication system: EM propagation and transmission problem, EM radiation problem, EM scattering problem.
• Hong Kong was deeply influenced by British Colonial culture
• It is financially boosted and dependent on mainland China and the nearby “World Factory” Shenzhen.
• Its education system is migrating from British system to American system
  • 3+4+3 versus 3+3+4.
UNIVERSITIES IN HONG KONG

- There are 8 government funded universities in Hong Kong

* Numbers are the local ranking from Hong Kong people’s point of view.
FINANCIAL RESOURCES IN HONG KONG

- Hong Kong is an international finance center.
- A giant real estate market with astronomical housing price.
- Few local industries.

  - Local students do no favor engineering.
  - Quality students from mainland China.
  - Competition with finance and banking.
  - Mphils and PhDs seek jobs elsewhere.
ELECTROMAGNETICS IN HONG KONG

- City University of Hong Kong--top research center on electromagnetics and antenna technologies.
- University of Hong Kong--Electromagnetics and Optics group with heavy focus on electromagnetics, computational electromagnetics, and multiphysics.
- Chinese University of Hong Kong--RF and microwave technologies and EM modeling.
- Other Hong Kong universities have meta materials, antennas, and other relevant topics.

- Optics is being actively pursued as interdisciplinary area.
ELECTROMAGNETIC COURSE IN HONG KONG

*Using the education at the University of Hong Kong as the example*

- The electromagnetics introduction course is compulsory only for EcomE at the University of Hong Kong.
- It is taught in the second semester of the first year.
- But the mathematics background is poor for many students.
- These made EM teaching extremely difficult.
ELECTROMAGNETIC COURSE IN HONG KONG

- There are many brilliant students who want to learn as much as possible.
- One example:
  - A Hong Kong local student has read through most EM master pieces including Rao, Balanis, Kong, Jackson, Stratton, etc in his 2nd year.
  - A mainland student moved forward to learn Quantum Mechanics at Physics based on after school recommendations and then finished reading the book by Datta on Non Equilibrium Green’s Function.
  - Students are eager to team up for international competitions on mathematics and EM.
- Few graduate level courses on EM.
EM RESEARCH IN HONG KONG

- Most researchers (RPG, PDF, and RA) are from mainland China.
- All teachings and official communications are in English.
- Mainland students are obsessed with key profile indicators.
EM RESEARCH IN HONG KONG

- It also serves as a regional training center to nurture young talents for scientific and engineering society.
- Mainland China provides a big human resource pool and job market for Hong Kong. Many EM graduates from Hong Kong went back to mainland as academic scholars.
- Hong Kong aims to be the educational center of the region.
ECE Curriculum, UIUC

Fields & Waves I

Fields & Waves II
EM at UIUC

- Many grad courses in EM and Optics available;
  - Intro graduate course in electromagnetics
  - Waves and fields in inhomogeneous media;
  - Theory of microwave and optical waveguides;
  - Computational electromagnetics;
  - Advanced antenna theory;
  - Microwave circuits;
  - Nonlinear optics;
  - Nano-photonics;
- Many students are encouraged to take mathematical physics courses as well as quantum mechanics courses;
Other Asian Universities (NUS)

(1) Undergraduate: A core module ('Engineering Electromagnetics')--compulsory for all ECE Year 2 students (about 250);
   - Major in EM: ('Introduction to RF and Microwave Systems and Circuits'), plus other electives;

(2) Graduate Students: one out of three directions: Computation/theory; Antenna; RF circuit. Each direction consists of one advanced module and three regular modules. The size of class varies, but it is somewhere between 10 and 30;
   - (data from X. Chen).
NTU (Nanyang Technology U)

- One course on EM in undergraduate program.
  - It was 26 hours for the course and is going to be extended to 39 hours.
  - Elective course on "Microwave & RF Engineering" for final-year students;
- Master of Science Program: Two more EM-related courses: Microwave Circuits and Antennas;
- (data from ZX Shen).
National Taiwan U (K.Y. Lin and R.B. Wu)

GICE Curriculum - EM Group

Electromagnetics (I)(II)

- Electromagnetic Waves Lab
- Rf Microwave Wireless Systems
- Microwave Engineering
- Antennas and Propagation

Electronics

- Engineering
- Mathematics

- Monolithic Microwave Integrated Circuit (mmic) Engineering
- Power Amplifier Design for Wireless Communications

Mathematics

- Electromagnetics Theory
- Applied Electromagnetics
- Theory of Guided Waves
- Computational Electromagnetics
- Theory of Microwave Circuits and Devices
- Electromagnetic Compatibility
- Wireless Communication Laboratory
- Antenna
- Mathematical Physics
- Antenna

- Microwave Circuit Laboratory
- Transmission-Line Modes and Microwave Circuits
- Microwave Filter Design
- Special Topics on Antennas
- Differential Geometry and Applied Electromagnetics
- Special Topics on Microwaves Integrated Circuits
Renovation Program for Electromagnetics Education in Taiwan

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¹ National Taiwan University of Science and Technology
² National Taiwan University
³ Yuan Ze University

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Nihon U, Japan

- Undergraduate:
  - Introduction to Electromagnetics (required),
  - Electromagnetics I(required), II(required)
  - Introduction to Electromagnetic Waves,
  - Electromagnetic Waves
- Graduate:
  - Advanced Electromagnetic Theory
  - Advanced Electromagnetics (Computational EM)
  - (data from S. Ohnuki)
### Competition between New and Old

<table>
<thead>
<tr>
<th>Classical technology and knowledge (Electromagnetics, circuits, signals and systems, electrical machinery)</th>
<th>Emerging technology and knowledge (nano-optics, quantum optics, nano-electronics, bio-tech, bio-medicine, computer science)</th>
</tr>
</thead>
</table>

- To save EM education, we need to combine EM education with emerging technologies;
- Opportunities lie in nano-optics, nano-electronics, bio-medicine etc;
- Quantum mechanics has induced many new technologies: lasers, masers, semi-conductor devices, etc;
- One day, quantum electromagnetics will be as important as quantum optics;
- PIERS is a place where emerging EM technologies meets old EM technologies.
Thank You for Listening!
ありがとうとうございます。
謝謝 Tack så mycket
Korean Univ.—UG EM Courses (Taek-Kyung Lee)

- Seoul National U : (3) EM Fields I (required),
  EM Fields II (elective), Microwave Engineering (elective)
- KAIST : (6 including optics) EM, EM Waves & Anten., Rad. Engg,
  Intro to Fiber Optic Comm., Systems, Fund. Photonics
- POSTECH : (4) Intro EM, EM Fields, RF Electron. Lab., Microwave
  Engineering Lab.
- Korea University : (4) EM (required), EM Fields and Waves, TL
  Theory, Microwave Engineering
- Yonsei University : (6 including optics) EM I, EM II, Microw. Engg.,
  Antenna Engineering, Advanced Microw. & Optics, Microw. & Optics
  Lab.
- Korea Aerospace University : (6 including Radar) EM I (required), EM
Korean U—Graduate EM Courses

- Seoul National University: Advanced EM I, Advanced EM II, Antenna Engineering
- EM Compatibility, Special Topic in EM
- Yonsei University: (13 courses) Advanced EM Field Theory, Microwave Active Circuits, Microwave System Design, Emi/Emc, etc.

In summary, for undergraduate, most universities in Korea offers 3 or 4 EM courses, Electromagnetics I and II, Microwave Engineering, and in some universities Antenna Engineering is provided.