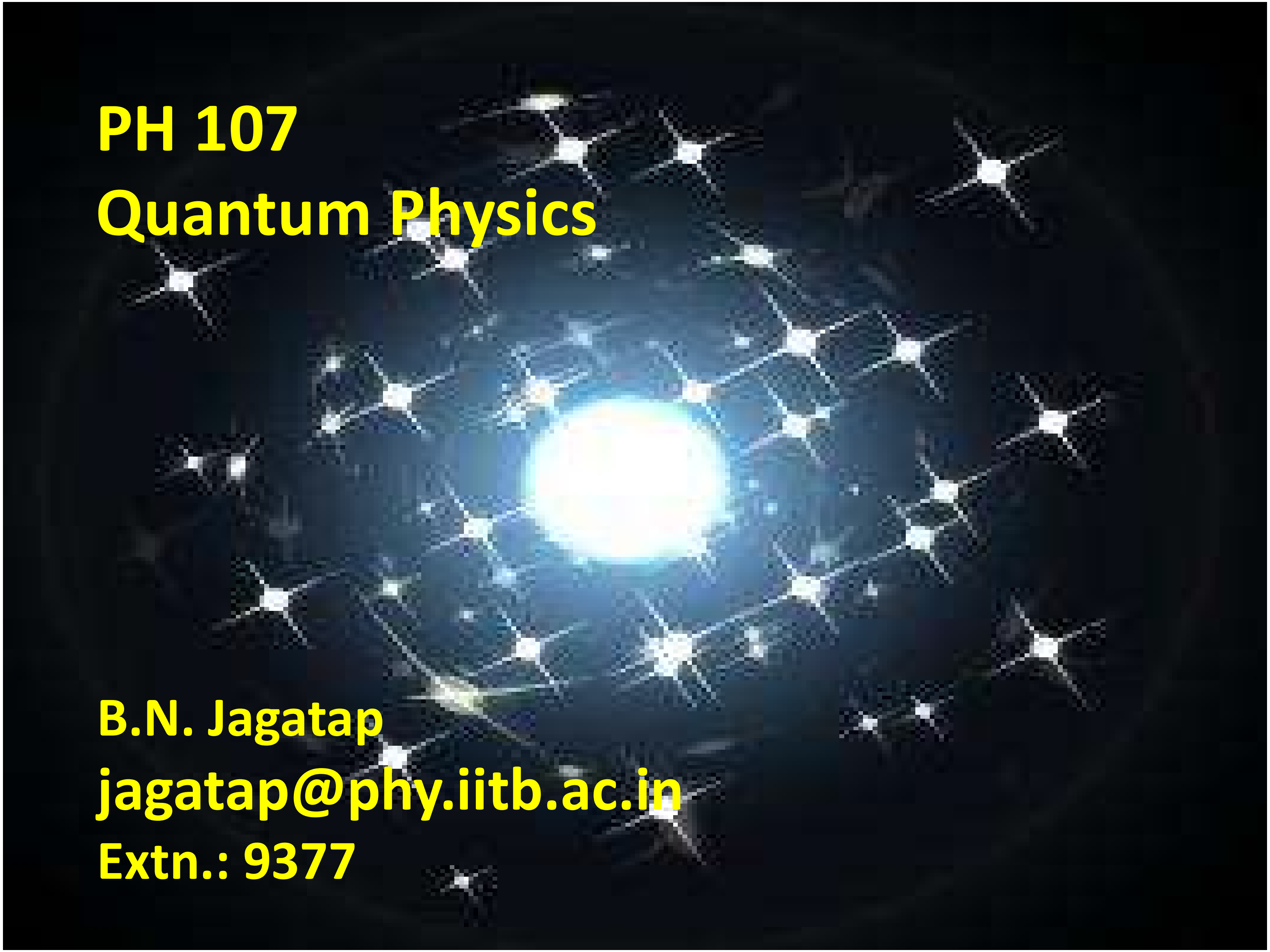

PH 107
Quantum Physics

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Extn.: 9377

A warm welcome to IIT Bombay

and to the course on Quantum Physics

❝

Don't judge each day by the harvest you reap, but by the seeds that you plant.

ROBERT LOUIS STEVENSON

About this course

PH 107
Quantum Physics

Quantum Theory is the theoretical basis of **modern physics** that explains the nature and behaviour of *matter and energy* at *atomic and sub-atomic level*.

Also called as Modern Physics

How Modern?

Not really so modern!

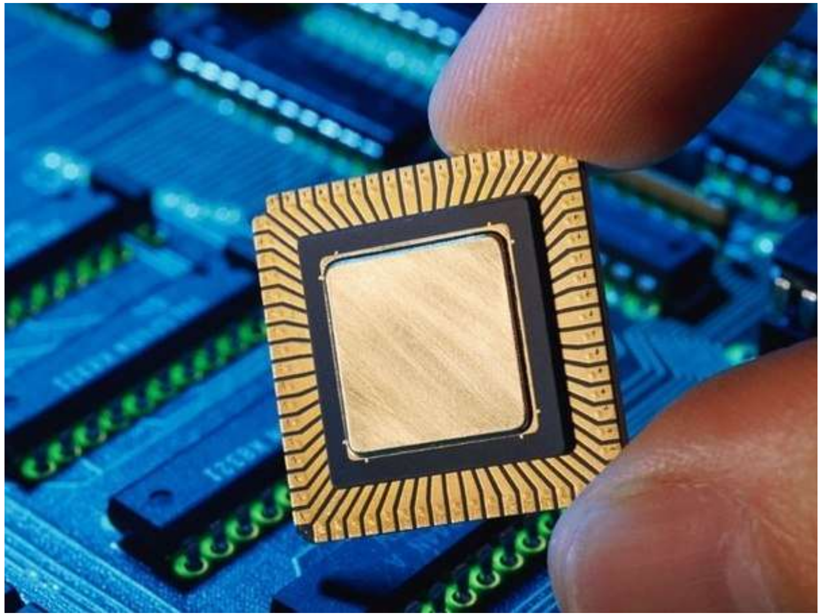
Seeds were planted more than a century ago….

Why do I learn Quantum Physics?

- Every student and practitioner of science and engineering needs it

- You cannot afford to ignore it.

- If you understand it well, you can participate in the science and technology endeavours of 21st century.



Electrical & Electronics Engineering

- Semiconductor devices
- Nanoelectronics: Nanometer sized quantum tunnelling devices
- Spintronics: Devices based on electron spin
- Photonics: Devices based on photons

Quantum tunnelling is how flash drives erase their memory

Giant magnetoresistance is what allows hard disk drives to function

Quantum wells are what allow lasers and photonics

From Electrical Engineering to Quantum Physics: The Case of Nishina Yoshio

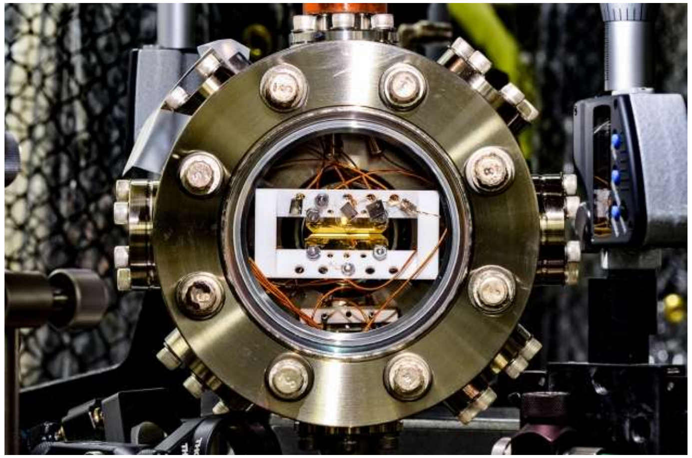
Kenji Ito

Sokendai University

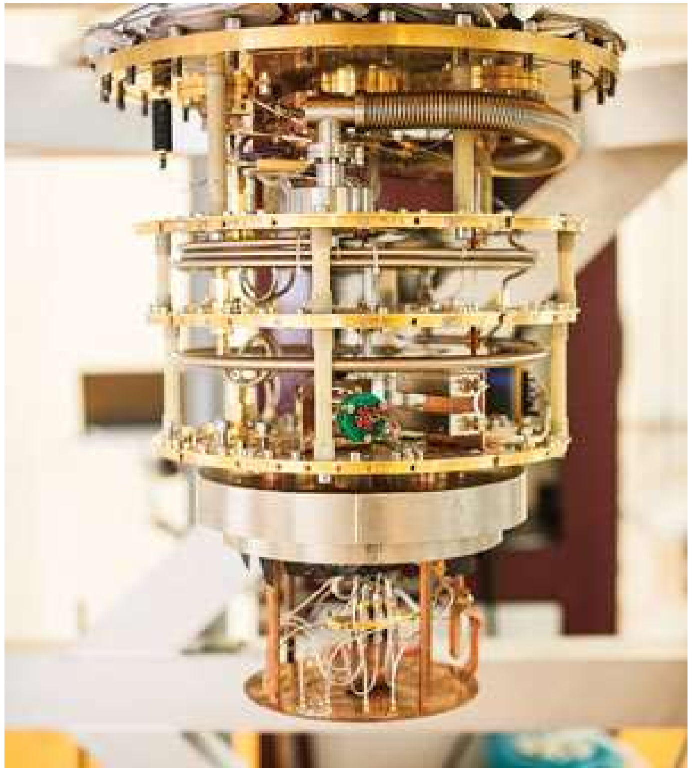
In this paper, I examine connections between electrical engineering and quantum physics research in Japan. Japan was one of the countries that have successfully developed quantum physics research relatively early outside Europe and North America. This paper is a part of a larger project to aim to explain how this happened. I claim that electrical engineering was one of the bases for quantum physical research to be motivated, legitimized, and sustained. It also prepared at least one important figure in quantum physics research in Japan through its conceptual affinity.

"In this paper, I examine connections between **electrical engineering and quantum physics research** in Japan. Japan was one of the first countries that have successfully developed quantum physics research relatively early outside Europe and North America.

I claim that electric engineering was one of the bases for quantum physical research to be **motivated, legitimized and sustained**."



Computer Sciences & Engineering



Quantum Computer & Quantum Information Processing

Cool Quantum Tech: This dilution refrigerator can cool quantum dots to less than 5 millikelvins for experiments in quantum computing.

THE HINDU

Quantum Cryptography &
Quantum Communication

ECONOMY

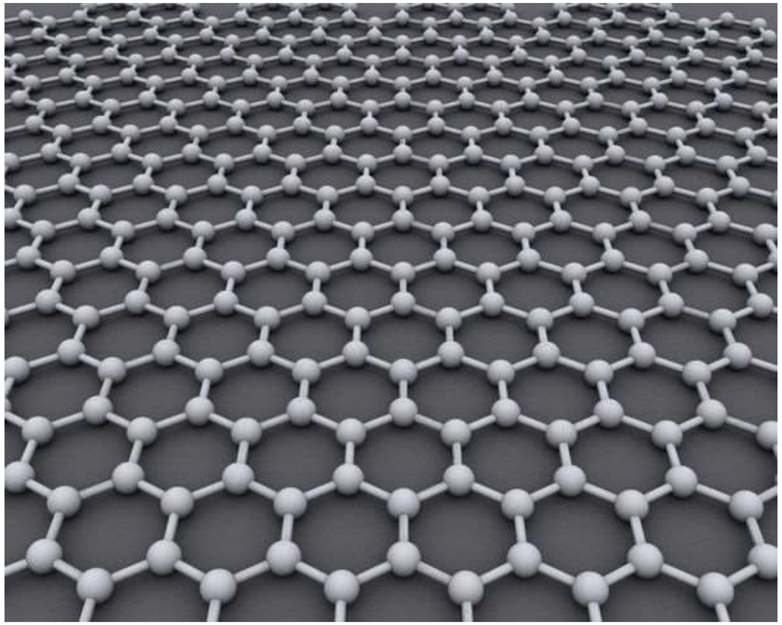
Russia offers technology to keep hackers at bay

Peerzada Abrar

DECEMBER 25, 2016 21:58 IST
UPDATED: DECEMBER 26, 2016 01:02 IST

SHARE ARTICLE | 2.26K | 6 | PRINT | A | A | A

Russian Quantum Center (RQC) said that it is ready to collaborate with India and offer its quantum technology that will prevent hackers from breaking into bank accounts. RQC plans to offer 'quantum cryptography' that could propel India to the forefront of hack proof communication in sectors such as banking and national and homeland security.



Material Engineering, Chemical Engineering

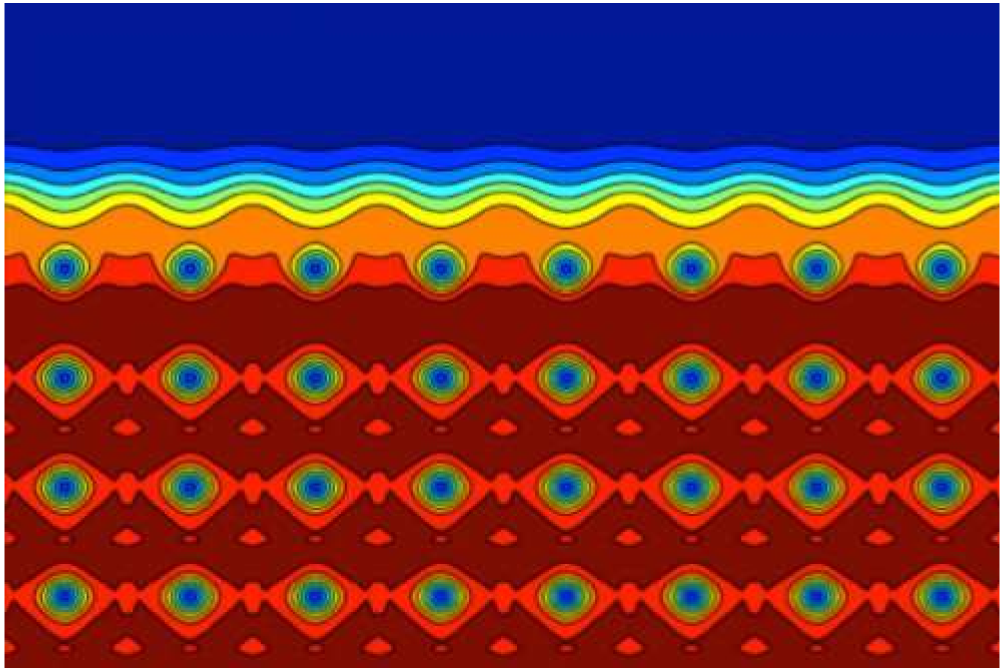
- Novel materials, graphene, topological insulators

- Molecular and thermodynamic properties based on molecular structure that have large potential for optimization and design of processes

Combustion, ignition, lubricants, fuel injection, design of solvents, drugs etc.

Caltech: Department of Mechanical and Civil Engineering

Quantum Mechanics at the Macroscopic Scale:
Coarse-graining Density Functional Theory



Multiscale Modelling

What has **Architecture** to do with **Quantum Physics**: About Buildings and Systems

"Building is part of a dynamical system. Although those systems that matter to a building can be described reasonably accurately with classical Newtonian knowledge, to understand the bigger context and its systems, a less 'mechanical' knowledge is required. Quantum Mechanics, phase transitions, tipping points and emergence could indeed help us to be useful in solving even more complex problems and dynamical issues"

— **Neri Oxman**

Europe Will Spend €1 Billion to Turn Quantum Physics Into Quantum Technology

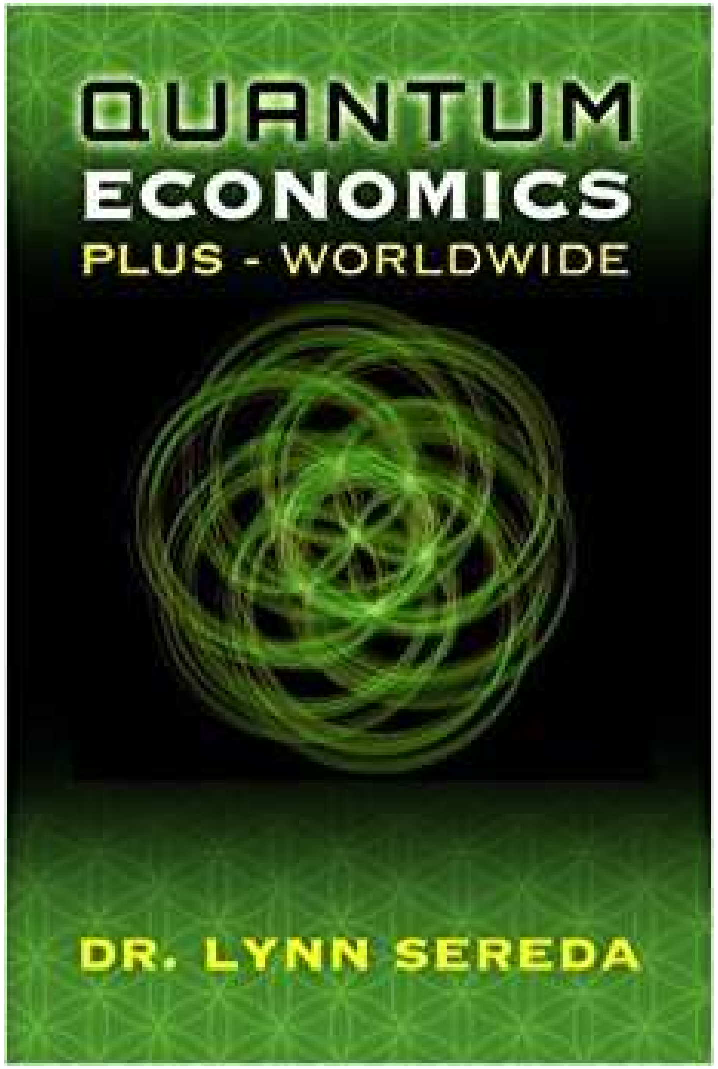
A 10-year-long megaproject will go beyond quantum computing and cryptography to advance other emerging technologies

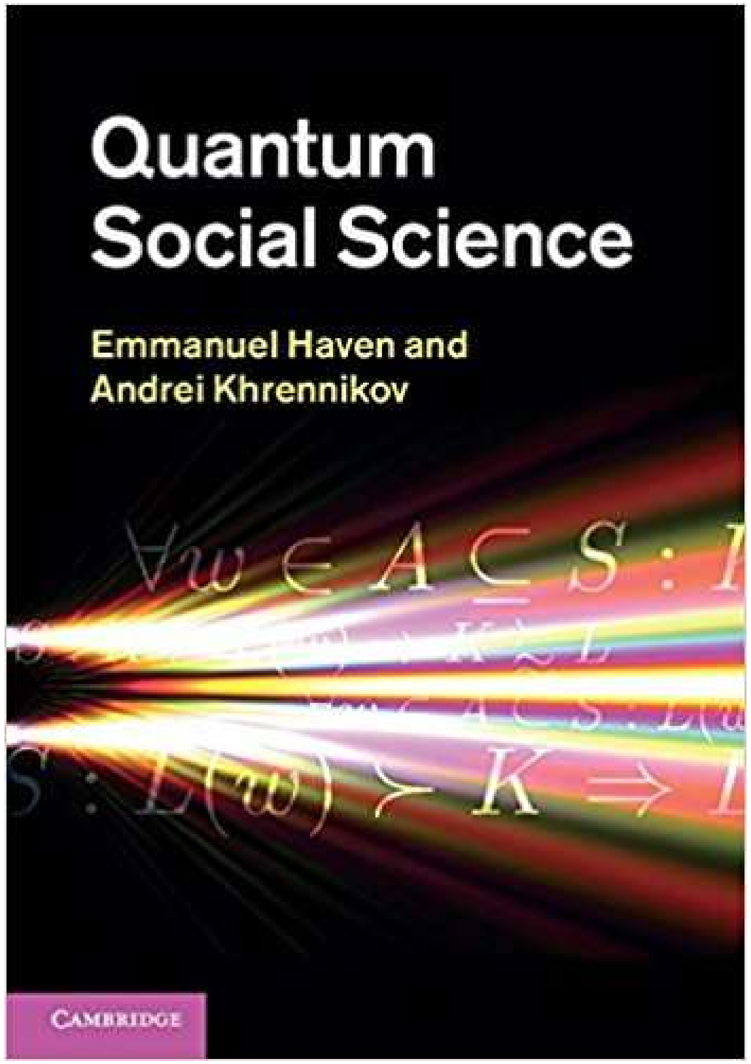
By Alexander Hellemans

Posted 22 Jun 2016 | 15:00 GMT

“Many areas of quantum mechanics are no longer problems of physics; they are now engineering problems.”

Even the financial markets need knowledge of Quantum Physics!





This Course

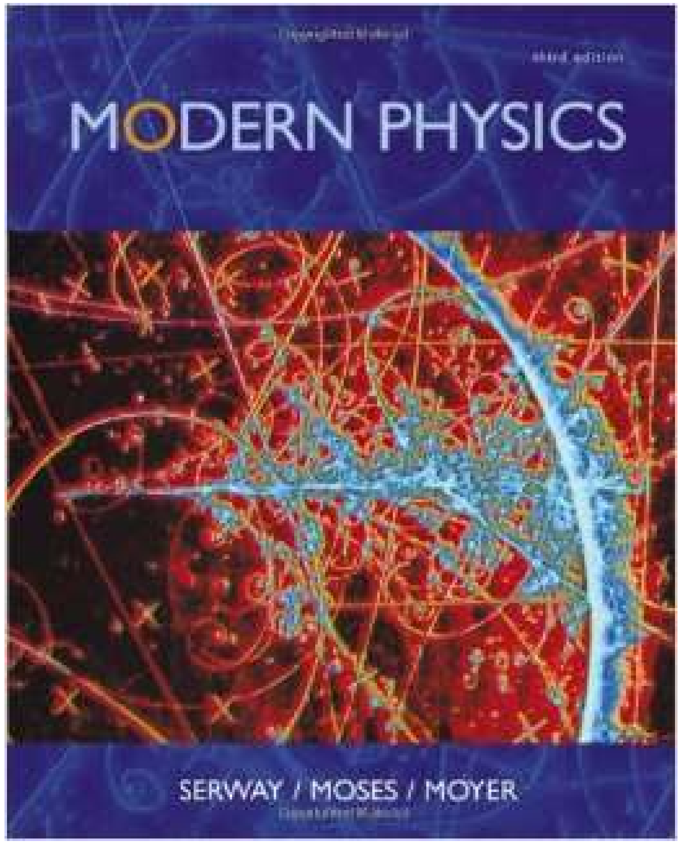
- Covers developments leading to birth of Quantum Physics

- Provides a flavour of Quantum Physics and its applications to Solid State Physics

- **Gives some insight into how well established theories in physics gave way to newer theories**

Reference Books

Modern Physics by Serway, Moses and Moyer
3rd Edition



- Indian edition available
- PDF version available on internet

- **Modern Physics** : K.S. Krane; John Wiley 1998, 2nd Edition
- **Introduction to Modern Physics** : F.K. Ritchmyer, E.H. Kennard, John N. Cooper; Tata McGraw Hill, 1976, 6th Edition
- **Concepts of Modern Physics**: Arthur Beiser, McGraw Hill, 1987, 4th Edition
- **Quantum Physics**: R. Eisberg and R. Resnik, John Wiley, 2002, 2nd Edition

Moodle

- Lecture slides will be uploaded on Moodle within a week

- These slides are for **personal use** of the students **registered in this course** only.

- **Lecture slides cannot be put on any other server, shared on the internet or mailed to anyone not registered for this course**

Good to Remember

- One hour class 11.35-12.30 Hrs (Monday) and 09.30-10.25 Hrs (Thursday) every week

- Tutorials will start from soon (August 01, 2017).

- The first tutorial will contain some problems which are expected to be known to you. It would be part of examination but would not be taught in the class

- **It will be presumed that any announcement made in the class will reach everyone. No additional notice may be circulated.**

Evaluation Scheme

- **In-semester (60%)**
  Quiz-1 in August (15%), Quiz-2 in October (15%)
  Mid-sem n September (30%)

- **End-semester in November** (40%)

- All quizzes/exams are compulsory. No re-exam or compensation in any form will be given on any ground whatsoever.

Attendance Policy

- 80% attendance is mandatory
- Each lecture will be developed based on the ideas developed in the previous lecture(s)
- Attendance is helpful in understanding the subject
- Students with poor attendance find it difficult to cope with tests and often land up with poor grades or **even fail in the course**

Classical Physics

Physics before 20th century, i.e., physics before the birth of Quantum Mechanics

- **Mechanics**
- **Electrodynamics**
- **Thermodynamics**

Mechanics

Newton's first law:

Law of inertia

Newton's second law:

Introduces force ($\vec{F}$) as responsible for the change in linear momentum ($\vec{p} = m\vec{\mathrm{v}}$)

$$\vec{F} = m\vec{a}$$

$$\vec{F} = d\vec{p}/dt$$

Newton's second law:

Law of action and reaction

$$\overrightarrow{F_{21}} = -\overrightarrow{F_{12}}$$

Newton's law of gravitation:

$$\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

Electrodynamics

Maxwell's Equations

Gauss's law (Electric field) $\vec{\nabla} \bullet \vec{E} = \rho / \varepsilon_0$

Gauss's law (Magnetic field) $\vec{\nabla} \bullet \vec{B} = 0$

Faraday's law $\vec{\nabla} \times \vec{E} = -\partial \vec{B} / \partial t$

Ampere's law $\vec{\nabla} \times \vec{B} = \mu_0 \varepsilon_0 \partial \vec{E} / \partial t$

Wave equation $$\nabla^2 E = \frac{1}{c^2} \frac{\partial^2 E}{\partial t^2}$$

Light is an electromagnetic wave with velocity $c = \dfrac{1}{\sqrt{\varepsilon_0 \mu_0}}$

Thermodynamics

Zeroth Law: This is the game

Two systems in thermal equilibrium with a third system are in thermal equilibrium with each other.

First Law: You cannot win

You cannot get something out of nothing, because matter and energy are conserved. $\Delta E=Q+W$

Second Law: You cannot break even

Any transfer of energy will result in some wastage (disorder) unless temperature of absolute zero is achieved.

$\Delta S_{total} = \Delta S_{surrounding} + \Delta S_{system}$

Third Law: You cannot get out of the game

Absolute zero is unattainable.

Thinking of Physicists towards the end of 19th century

“The more important fundamental laws and the facts of physical science have all been discovered and they are so firmly established that the possibility of their ever being supplanted in consequence of the new discoveries is exceedingly remote…. Our future discoveries must be looked for in sixth place of decimal”

Michelson (1899)