Online and certifiable spectroscopy courses using information and communication tools: A model for classrooms and beyond

Mangala Sunder Krishnan*
Department of Chemistry
Indian Institute of Technology Madras
Chennai, Tamil Nadu, India
mangal@iitm.ac.in; mangalasunderk@gmail.com

NPTEL stands for National Programme on Technology Enhanced Learning*

- Teaching-learning programmes through the Internet using ICT tools.

- More than 900 full, Semester-long courses with problem sets and modularisation of curriculum derived from major academic bodies in India and abroad.

- About 450 of them in full video format (18000+ one-hour videos online and freely accessible/downloaded)

- One hundred or more of these in mathematics, chemistry and physics at honours level. To complete the programme of contents for M. Sc., about 60 more to be added soon.

* Joint programme of seven Indian Institutes of Technology and Indian Institute of Science, Bangalore

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NPTEL and NMEICT (National Mission on Education through ICT)

- Creation of technical and non-technical courses, arts, science, humanities, engineering and technology, medicine, law and agriculture course contents online and certification in each area.

- Creation of Virtual, online labs and simulation tools in many areas

- Creation of certification programmes using aspects of Massive Open Online Courses (MOOCs) with proctoring and industry/government support

- Offer proctored exams and identity-verified certificates for credit transfer and choice-based credit system in Universities;

- Offer mentor-training for teachers to design courses using sound course pedagogy and taxonomy of learning (BENJAMIN BLOOM)
Spectroscopy teaching in India using NPTEL and MOOCs

Component topics

**Quantum mechanics**
- up to Hydrogen atom (Course I)
- Perturbation and variation, time independent (course II)
- Time dependent perturbation and scattering; angular momentum coupling (Course III)

**Spectroscopy theory and experimental, along with simulations**
- Introductory spectroscopy and lasers
- Microwave, infrared and electronic spectra, matrix elements and intensities
- Theoretical molecular spectra: Eckart frame, Watson Hamiltonian, effective Hamiltonians

**Group theory**
- Symmetry operations and elementary groups, character tables (Course I)
- Normal modes, point group classification, selection rules (course II)
- Molecular symmetry groups and Wigner-Eckart theorem (course III)

Monday, 22 June 15
Quantum part and introductory molecular spectra in a MOOC format being offered from July 1 this year (Open to all and animation-rich)

http://onlinecourses.nptel.ac.in

Videos (between 15 and 30 minutes each; a topic may have more than one video)

Unit I:

✈️ Particle in a one-dimensional box; two and three dimensional boxes with infinite barriers
✈️ Particle on a ring and on a spherical surface: angular momentum and spherical harmonics
✈️ Harmonic oscillator
✈️ Electron in a hydrogen atom: the Schrödinger equation and solutions
✈️ Pictorial / animated representations of wave functions, spherical harmonics (real and imaginary part)
✈️ Calculation of average values and eigenvalues
Unit 2:

- Introduction to electromagnetic radiation; interaction with dipole moments
- Semiclassical description; Lab practices
- Molecular vibrations through harmonic oscillator models; triatomic molecules
- Elementary electronic spectra, Born-Oppenheimer potential energy surfaces and Franck-Condon principle

Advanced topics:

- The more advanced courses follow clear pedagogy, however lecture videos are NOT limited by 20-30 min duration.
- Duration is a Semester-long, 40 plus hours of recording with additional learning materials as pdf.
- Advanced courses are problem-rich and require discussions/elaboration of concepts; flipped class model is being used.

Elementary courses are animation-rich with numerous multiple-choice questions.
p shapes

d shapes
f shapes
Group theory and spectroscopy

Simple animations for complex operations: Tetrahedron $S_4$
Group Theory- Simple animations for complex operations
Octahedron-- $S_6$
Group Theory - Simple animations for complex operations
Dodecahedron-- $15 \ C_2$  Icosahedral Symmetry
Spectroscopy-rigid rotors, normal modes and beyond

Several video and text based lecture contents under NPTEL

Suggested mode: Flipped Class by teachers for intermediate to advanced courses.

MOOC format with proctored exams for introductory courses with large registrations: use short videos and plenty of online assessments. In class, engage them with brief lecturing and intermittent clicker-based or similar instant responses to quiz.
Current topics under recording: video based online content (for supplementary online teaching-learning by a large number of post-graduate /honours students)

★ Elementary introduction to interaction of radiation with matter.
★ Time dependent perturbation theory and intensity via dipole moment matrix elements.
★ Angular momentum and matrix elements of various operators associated with rotation.
★ Symmetric and Asymmetric top Hamiltonians. Solutions for symmetric top
★ Normal Modes and anharmonicity- Introduction to perturbation matrix elements using harmonic oscillator raising and lowering operators.
Current ADVANCED topics under recording: video based online content

- Euler rotations and molecule-fixed angular momenta
- Energy levels of asymmetric rotor and labeling transition frequencies
- Anharmonic corrections: Morse oscillator
- Rotation-vibration coupling and centrifugal distortion constants
- General ro-vibrational Hamiltonian: The Watson Hamiltonian
- Contact transformation and effective rotational Hamiltonians for each vibrational degree of freedom

Expected date for release as open source: December 2015
NPTEL Phases II/III (contents being developed as 4 quadrants, integrated in the final form)

<table>
<thead>
<tr>
<th>Content--web based lecture notes / video lectures in an organized form</th>
<th>Animations/ visuals / illustrations, video demonstrations/ documentaries and interactive simulations wherever required</th>
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</thead>
<tbody>
<tr>
<td>Supplementary reading/Wiki Development on the course, other resources /open content in the internet, <strong>Case studies, anecdotal information, historical development</strong> of the subject</td>
<td><strong>Problems, quizzes, assignments and solutions</strong>, online feedback through discussion forums and setting up the FAQ</td>
</tr>
</tbody>
</table>

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NPTEL, Virtual Labs, Online Curricula by NMEICT, OpenCourseware of MIT, Stanford, Yale, Open University, Curricula tailored from OERs worldwide: AN ENORMOUS OPPORTUNITY

✴ Offers opportunities for cross-disciplinary learning independent of time, geography and social needs for anyone.
✴ Professionals can update their knowledge while being on the job, without interrupting their service.
✴ Industry-academia partnership in training and re-training.

Teaching is short-duration delivery; Learning is a lifelong experience; Access the classroom, therefore, on demand.
I think, however, that there isn’t any solution to this problem of education other than to realize that the best teaching can be done only when there is a direct individual relationship between a student and a good teacher—a situation in which the student discusses the ideas, thinks about the things and talks about the things. It’s impossible to learn very much by simply sitting in a lecture, or even by simply doing problems that are assigned. But in our modern times we have so many students to teach that we have to try to find some substitute for the ideal. Perhaps my lectures can make some contribution. Perhaps in small place where there are individual teachers and students, they may get some inspiration or some ideas from the lectures. Perhaps they will have fun thinking them through—or going on to develop some of the ideas further.

**Richard Feynman, Foreword to Lectures on Physics.**
Thank you
References


4. The URL for details of all courses published so far: http://nptel.ac.in (The number of channel views of NPTEL and YouTube Mirror for videos combined, is over 240 million (May 31, 2015) since the launch in 2006 (NPTEL) and 2007 (YouTube). all videos are downloadable in mp4, flv and 3gp format.