List of Institute wide common courses and course contents

I. List of Institute Core and Programmed linked Courses

	Course Name	*Offered for Programme*	*Offering Semester*	*Offering Department*
A. Engineering Courses				
1	Data Structures and Algorithms (Programme Core for all Depts.)	EE, CS, AI, ES	III	CS
		BB, ME, CI, CH, MT	IV	
2	Introduction to Machine Learning	BB, ME, CI, CH, MT	III	CS/EE
3	Pattern Recognition and Machine Learning	EE, CS, AI, ES	IV	CS
4	Signals and Systems	EE, CS, AI, ES, BB	III	EE
		ME, CI, CH, MT	IV	
5	Thermodynamics	EE, ME, CI, CH, MT	III	ME
		CS, AI, ES, BB	IV	
B. Programme Link Mathematics Courses				
6	Probability, Statistics and Stochastic Processes	EE, CS, AI, ES, BB, CI, CH	III	MA
7	Scientific Computations	ME, MT	III	MA
C. Programme-Linked Science Courses				
8	Condensed Matter Physics	MT	III	PH
9	Foundations of Quantum Information Processing	EE, CS, AI	III	PH
10	Metrology + Statistical Mechanics	ME	III	PH
11	Physics of Complex Liquid	CH	III	PH
12	Analytical Mechanics	CI	III	PH
13	Nanoscience	BB	III	CY
D. Additional courses for Engineering Science Double B.Tech.				
14	Modern Physics	ES	III	PH
15	Design and Analysis of Experiments	ES	IV	MA
16	Embedded Systems and IoT	ES	IV	EE
17	Modelling and Simulation	ES	IV	EE/ME
E. Non-graded HSS Course				
18	Introduction to Profession	All	III	**UCRC**

19	Professional Ethics I	All	V	HS
20	Professional Ethics II	All	VI	HS
E. Other courses common to all				
21	Environmental Science	All	VII	CI

II. List of Material Science Fractals

	Fractal Name	***Offered for***	***Offering Semester***	***Offering Department***
1	Electronic Materials	CS, AI	IV	PH
2	Magnetic Materials	EE	III	PH
3	Energy Materials	EE, CS, AI	III	MT
4	Computational Material Design	EE, CS, AI, ES	III	MT
5	Polymers	MT, CH, CI, BB, MT	IV	CH
6	Materials Selection	ME, BB, ES	IV	MT
7	Structure of Materials	ME, BB, CI, ES	IV	MT
8	Physical Metallurgy	ME, MT	IV	MT
9	Corrosion	CH, CI, MT	IV	MT
10	Suspensions and colloids	CH	IV	CY

Title	**Data Structures and Algorithms**	Course No.	**CSxxx**
Department	Computer Science and Engineering	L-T-P [C]	3–0–2 [4]
Offered for	B.Tech of all branches	Type	Compulsory
Prerequisite	Introduction to Computer Programming		

Objectives

The Instructor will:

1. To introduce and practice the implementation of various data structures used for indexing, searching, and sorting operations.
2. To introduce basic mathematical techniques for algorithm analysis and design.

Learning Outcomes

The students will have the ability to:

1. Ability to design and implement appropriate data structures for indexing, searching, and sorting operations for real-world problems.
2. Designing of new algorithms using standard data structures.
3. Analyzing the time and space complexities of standard data structures and basic algorithms.

Contents

Algorithm analysis and complexity: Big/little -Oh, Omega, Theta notation, Recurrence equations (2 Lectures)

Abstract data types: Linear data structures, Tree, Binary trees, Tree traversal, Applications (7 Lectures)

Search trees: Binary search trees, Balanced search trees, AVL trees, B-Trees (5 Lectures)

Heaps: Binary Heap, Heap order property and min/max heaps (3 Lectures)

Sets: Disjoint set ADT, Basic operations on Sets, Union/Find Algorithm (2 Lectures)

Greedy techniques for algorithm design (1 lecture)

Sorting algorithms: Bubble sort, Selection sort, Bucket sort, Insertion sort, Overview of Divide-and-conquer, Quick sort, Merge sort (6 Lectures)

Hashing: Hash tables and operations, Hash function, Open and closed hashing, External and internal hashing, Collision resolving methods, Rehashing (5 Lectures)

Dynamic programming for problem solving (3 Lectures)

Graph algorithms: Definitions, Branch and bound, Backtracking, Representation, Traversal, Shortest-path algorithms, Minimum Spanning Tree algorithm, Topological sorting (8 Lectures)

Laboratory Classes (12-13 Classes)

1. *Implementation of data structures using C programming language.*
2. *Practically verifying and comparing run-time performance and asymptotic behavior of various data structures and related algorithms.*
3. *Applications of data structures from real-life scenarios.*

Text Book

1. M. A. WEISS (2002), Data Structures and Algorithm Analysis in C, Addison-Wesley, 2nd Edition.

Reference Books

1. T. H. CORMEN, C. E. LEISERSON, R.L. RIVEST, C. STEIN (2009),Introduction to Algorithms, MIT Press, 3rd Edition.

Self-Learning Material

1. Data Structures and Algorithms, NPTEL Course Material, Department Computer Science and Engineering, IIT Delhi: https://nptel.ac.in/courses/106102064/

Course Title	**Introduction to Machine Learning**	Course No.	**CS2xx**
Department	CSE/EE	Structure (L-T-P-C)	3-0-2
Offered for	B.Tech (all other branches)	Type	Compulsory
Prerequisite	Introduction to Programming		

Objectives:

1. To familiarize with the fundamental machine learning algorithms.
2. To study applications of machine learning algorithms in different disciplines.

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Learning Outcomes:

The students are expected to have the ability to:

1. Ability to formulate a machine learning problem
2. Ability to select an appropriate machine learning algorithm for analysing different types of data.
3. Ability to apply pattern analysis tools to practical applications and detect patterns in the data.

Contents:

- Preliminaries: ML pipeline, training, testing, Learning Paradigms: Supervised, unsupervised, and reinforcement, Representation of samples, Correlation and covariance, probability, distributions, hypothesis evaluation, Data processing and normalization, Bias-Variance (8 lectures)
- Regression and Supervised Classifiers (18 lectures):
  - Logistic and Linear Regression (2),
  - Decision Tree, Boosting and Bagging, K-NN (5)
  - Bayesian Decision Theory, MLE Parameter Estimation (5)
  - EM-Algorithms (2 lectures)
  - SVM (4 lectures)
- Linear Decision boundaries, Discriminant Analysis, and Subspace Representation (PCA) (4 lectures)
- Unsupervised Learning: K-means and Graph-based Clustering (3 lectures)
- Time series: Introduction to Time Series and Stochastic Processes, HMM (3)
- Artificial Neural Networks, Autoencoder, and CNN, Regularization Techniques (6 lectures)

Lab: Programming labs on Normalization, Visualization (Visualization Tools: regression plots, scatter plot, tableau), Distribution, Evaluation, Regressions, Decision Tree, Bayes, PCA, LDA, ANN, K-means, Graph-based Clustering, HMM,

Case Studies from different departments:

1. BSB: Identification of protein secondary structure (helices, sheets, and coil), or functional categories representing binding sites, cleavage sites, or residues being posttranslationally modified using Neural networks.
2. ME: Machine Learning for Predictive Maintenance, where sensed machine data can be used in learning whether routine maintenance of the machine is required or not: Classification problem
3. Chemical Engg: Application of ML to predict life cycle of Lithium Ion Battery. (Challenge: Even with the same chemistry and same operating conditions, there is considerable variability in the life cycle of the lithium ion battery.
4. Materials: Finding unprecedentedly low-thermal-conductivity half-Heusler semiconductors via high-throughput
   materials modeling,.

Text Book

1. Machine Learning, T. M. MITCHELL, McGraw Hill Education, 2017

Reference Book

1. Pattern Recognition and Machine Learning, C. M. BISHOP, Springer-Verlag New York, 2006
2. Pattern Classification, R. O. DUDA, P. E. HART, D. G. STORK, Wiley-Blackwell, 2000

Self-learning Material

1. Introduction to Machine Learning, NPTEL Course Material, Department Computer Science and Engineering, IIT Madras: http//nptel.ac.in/courses/106106139/
2. Machine Learning, Stanford University: https://see.stanford.edu/Course/CS229

Course Title	**Pattern Recognition and Machine Learning**	Course No.	**CSL2xx**

Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-2
Offered for	B.Tech (CSE, AI&DS, EE)	Type	Compulsory
Prerequisite	Introduction to Computer Sc., Probability, Statistics and Stochastic Processes	Antirequisite	Introduction to Machine Learning

Objectives

1. To understand various key paradigms for pattern classification and machine learning approaches
2. To familiarize with the mathematical and statistical techniques used in pattern recognition and machine learning.
3. To understand and differentiate among various pattern recognition and machine learning techniques.

Learning Outcomes

The students are expected to have the ability to:

1. To formulate a machine learning problem
2. Select an appropriate pattern analysis tool for analyzing data in a given feature space.
3. Apply pattern recognition and machine learning techniques such as classification and feature selection to practical applications and detect patterns in the data.

Contents

Introduction: Definitions, Datasets for Pattern Recognition, Different Paradigms of Pattern Recognition and Machine Learning, Data Normalization, Hypothesis Evaluation, VC-Dimensions and Distribution, Bias-Variance Tradeoff, Regression (Linear), Regularization (8 Lectures)
Discriminative Methods: Distance-based methods, Linear Discriminant Functions, Decision Tree, Random Decision Forest and Boosting (5 Lectures)
Bayes Decision Theory: Bayes decision rule, Minimum error rate classification, Normal density and discriminant functions, Bayesian networks (7 Lectures)
Parameter Estimation: Maximum Likelihood and Bayesian Parameter Estimation (3 Lectures)
Feature Selection and Dimensionality Reduction:PCA, LDA, SFFS, SBFS (4 Lectures)
Artificial Neural Networks*:* MLP, Backprop, and RBF-Net (4 Lectures)
Kernel Machines: Kernel Tricks, Support Vector Machines (primal and dual forms), K-SVR, K-PCA (6 Lectures)
Clustering: k-means clustering, Gaussian Mixture Modeling, EM-algorithm (5 Lectures)

Laboratory

Programming labs on Normalization, Visualization, Evaluation, Regressions, Decision Tree, Bayes, Parameter Estimation, PCA, LDA, ANN, SVM, K-means, GMM, Feature Selection

Text Book

1. R. O. DUDA, P. E. HART, D. G. STORK (2000),
2. , Wiley-Blackwell, 2nd Edition.

Reference Books

1. C. M. BISHOP (2006), Pattern Recognition and Machine Learning, Springer-Verlag New York, 1st Edition.
2. T. M. MITCHELL (2017), Machine Learning, McGraw Hill Education, 1st Edition.

Self-learning Material

3. Introduction to Machine Learning, NPTEL Course Material, Department Computer Science and Engineering, IIT Madras: http//nptel.ac.in/courses/106106139/
4. Machine Learning, Stanford University: https://see.stanford.edu/Course/CS229

Title	**Signals and Systems**	Number	EEL2XX
Department	Electrical Engineering	L-T-P [C]	3–1–0 [4]
Offered for	B. Tech.	Type	IE
Prerequisites			

Objectives

The Instructor would:

1. Familiarize students with the fundamentals of continuous-time and discrete-time linear systems, and their response analysis
2. Provide understanding frequency-domain transforms and their real-world applications
3. Discuss the applications from the area of engineering and physics

Learning Outcomes

The students would be able to:

1. Compute the response and system functions of LTI systems in various domains
2. Solve basic real-world interdisciplinary problems involving time-domain or frequency analysis of signals

Contents

Signals and Systems (Continuous and Discrete Time) [10 lectures]:
Description and Classification of signals, signal operations in time domain [4L],
Sampling, Description and Classification of LTI System, Properties of LTI system [4L],
Impulse response, Convolution and Correlation[2L].

Frequency Domain Representation of Signals [12 lectures]:
Fourier series representation of periodic signals, convergence of Fourier Series & Gibbs phenomenon [3L],
Fourier Transform, Fourier transform of periodic signals, properties of Fourier transform [3L],
Laplace Transform, Z-Transform, region of convergence & properties [3L],
Rational System functions, Inverse Laplace and Z-Transform of Rational Functions and applications [3L]

LTI systems [12 lectures] :
Difference and differential equation representation, block diagram representation [4L],
Transfer function and convolution, poles and zeros, step response [3L],
Natural Response of 1st and 2nd Order Systems, Sinusoidal steady-state and Frequency Response [5L]

Applications: [8 lectures]:
Applications from the area of condition monitoring, Predictive Operations and Maintenance, Process Control [4L],
ECG Signal Filtering and Denoising, Seismic Signal Processing, and few examples related to 2D,3D, and speech signal processing [4L]

Text Book

1. Oppenheim, A. & Wilsky, A. S., *Signals and Systems*, 2nd Edition, Prentice-Hall

Reference Books

1. Lathi, B. P., (2009), *Principles of Linear Systems and Signals*, 2nd Edition, Oxford University Press
2. Haykin, S. & Veen, B. V., (2008), *Signals and Systems*, 2nd Edition, Wiley
3. Dutta Roy, S. C., Chandra, S., (2018), Circuits, Systems and Signal Processing: A Tutorials Approach, 1st Edition, Springer

Self-Learning Material

1. Dutta Roy, S. C., Indian Institute of Technology Delhi, Signals and Systems,https://www.youtube.com/playlist?list=PLC6210462711083C4
2. Venkatesan, K. S., Indian Institute of Technology Kanpur, Signals and Systems, NPTEL, https://nptel.ac.in/courses/117/104/117104074/

Title	**Thermodynamics**	Number	MEL2XX0
Department	Mechanical Engineering	L-T-P [C]	3–1–0 [4]
Offered for	All B.Tech (ME)	Type	Compulsory
Prerequisite			

Objectives

1. To understand thermodynamics laws and various thermodynamic processes
2. To comprehend work producing and work consuming cycles
3. To inculcate the importance of change of state responsible for physical and chemical changes.
4. To introduce broader aspects of thermodynamics across disciplines and applicability of laws of thermodynamics and entropy principle in the areas ranging from design of prime movers to design of algorithms.

Learning Outcomes

1. Ability to effectively apply laws of thermodynamics in the practice of engineering.
2. Capability to assess and quantify thermodynamic efficiencies using the second law of thermodynamics.
3. Ability to conduct comprehensive and rigorous treatment of classical thermodynamics while retaining an engineering perspective

Contents

Implication of Thermodynamics and its scope in various disciplines [2 Lectures]: Mechanical engineering applications, Computer science applications, Electrical Engineering applications, Biological science applications, Chemical engineering applications.

Basic concepts [2 Lectures]: Thermodynamic system, Properties, State, Process, Thermodynamic equilibrium, Pressure measurement, Zeroth law, Temperature measurement.

Concept of energy and energy transfer[7 Lectures]: Work and Heat, Internal energy, First Law of Thermodynamics, Work transfer and its value for different processes, Heat transfer, state functions, Equation of state for ideal and real gases, Gas mixtures; Differential form of First Law, First Law and various Processes.

Thermodynamic properties of pure substance[4 Lectures]: Phase change process of pure substance and their property diagram, Use of steam table and Mollier diagram.

Energy analysis of closed and open systems [8 Lectures]: First law analysis for closed systems, Steady flow energy equation, Flow processes, Throttling process, Joule-Thomson effect, Energy analysis of open systems, and Analysis of First law for unsteady flow.

Second law of thermodynamics [4 Lectures]: Reversible and Irreversible processes, Kelvin-Planck and Clausius statement, Heat engines, Heat pumps, Carnot cycle.

Entropy [9 Lectures]: Definitions of entropy, statistical definition of pressure, temperature, entropy, Change of entropy for various processes, machine learning and coding application examples, Equilibrium, Spontaneity relations for Entropy, Helmholtz free energy, Gibbs free energy.

Thermodynamic property relations [3 Lectures]: Maxwell relations, Clausius-Clapeyron equation

Exergy *[3 Lectures]*: Definition of exergy, second law efficiency, Irreversibility, Exergy balance.

Text Book

1. Moran, M. J. & Shapiro, H. N., (2011), Fundamentals of Engineering Thermodynamics, 7th Edition, Wiley.
2. Cengel, Y. A. & Boles, M. A., (2010), *Thermodynamics: An Engineering Approach*, McGraw Hill Education
3. Sonntag, R. E. & Wylen, V., (1998), *Fundamentals of Thermodynamics*, Wiley
4. Zemansky M., (2017), *Heat and Thermodynamics*, McGrawhill

Self-Learning Material

1. Prof. Keith A. Nelson & Prof. Moungi Bawendi., Thermodynamics and Chemical Kinetics, MIT OpenCourseWare, Link: https://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/

Title	**Probability, Statistics & Stochastic Processes**	Number	MAL2XX0
Department	Mathematics	L-T-P-D [C]	3-1-0-0 [4]
Offered for	B.Tech BSBE, CSE, EE, DS&AI, CHE, CIE, ES	Type	Program Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Demonstrate the basic principles of probability theory and random variables.
2. Demonstrate the use of various families of probability distributions to model various types of data.
3. Introduce the concept of stochastic process and its application.

Learning Outcomes

The students will have the ability to:

1. Understand probability theory and develop the mathematical foundation of random variables.
2. Understand random sampling, theory of estimation and testing of hypotheses.
3. Understand the concept of stochastic processes and demonstrate the specific applications to Poisson and Gaussian processes.

Contents

Probability Spaces and Random Variables [16 lectures]: Axioms of probability, conditional probability, Independence, Bayes' rule, Random variable, Some common discrete and continuous distributions, Distribution of Functions of Random Variable, Two and higher dimensional distributions, Functions of random variables, Conditional distributions, Laws of large numbers, Central limit theorem.

Estimation and Test of Hypothesis [12 lectures]: Parameter Estimation, Maximum Likelihood Estimator [4 lecture], Confidence Interval [2 lecture], Hypothesis Testing [6 lecture].

Stochastic Processes [14 Lectures]: Definition of Stochastic process, Classification and properties of stochastic processes, Simple Markovian stochastic processes, Gaussian processes, Stationary processes, Discrete and continuous time Markov chains, ergodicity.

Textbook

1. Ross, S. M., (2010), A First Course in Probability, Pearson Prentice Hall
2. Ross, S. M., (2012), Introduction to probability and statistics for engineers and scientists, Elsevier
3. Castaneda, L.B., Arunachalam, V. and Dharmaraja, S., (2012), Introduction to Probability and Stochastic Processes with Applications, John Wiley & Sons.
4. Papoulis, A., (1991), Probability, Random Variables, and Stochastic Processes, McGraw-Hill.

Reference Books

1. Rohatgi, V. K. & Saleh, A.K.M.E., (2011), An Introduction to Probability and Statistics, Wiley
2. Casella, G. and Berger, R. (2002). Statistical Inference, Cengage Learning
3. Ross M.S., (2008), Stochastic Processes, John Wiley and Sons.
4. Hoel, P.G., Port, S.C. & Stone, C.J. (1986) Introduction to Stochastic Processes, Houghton Mifflin Company

Self-Learning Material

1. G. Srinivasan, IIT Madras, Introduction to probability and Statistics,https://nptel.ac.in/courses/111/106/111106112/
2. S. Dharmaraja, IIT Delhi, Introduction to Probability Theory and Stochastic Processes,https://nptel.ac.in/courses/111/102/111102111/

Title	**Scientific Computations**	Number	MAL2XX0
Department	Mathematics	L-T-P-D [C]	3-0-2 [4]
Offered for	B.Tech ME, MT	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Demonstrate the validity and error in the numerical results
2. Explain numerical techniques for a variety of problems
3. Introduce how to solve numerically algebraic equations, linear systems of equations, approximation and ordinary differential equations.

Learning Outcomes

The students will have the ability to

1. Develop an understanding of numerical error and applicability of a particular method.
2. Solve numerically algebraic equations, linear systems of equations and ordinary differential equations.
3. Carry out numerical interpolation, differentiation and integration.

Content

Errors in computation [2 Lecture]: Numerical Algorithms and errors, source and types of errors, error propagation, floating point representation, rounding error and floating point arithmetic.
Roots of equation [8 Lecture]: Iterative methods, order of convergence, Iterative methods for roots of nonlinear system of equations.
Linear systems of equations [8 Lecture]: Direct and iterative methods (Jacobi, Gauss Seidel), rate of convergence of iterative methods, Condition number, Power and inverse power methods for eigenvalue problems, matrix factorization schemes (LU, QR, spectral, Schur, polar, SVD).
Interpolation [7 Lecture]: Lagrange, Newton divided difference formula, Newton's interpolations, errors in interpolation.
Differentiation and Integration [7 Lecture]: Differentiation using interpolation formulas, Integration using interpolation, Newton-Cotes formulas, Gauss quadrature rules.
Ordinary differential equations [4 Lecture]: Taylor series method, Euler's Method, Modified Euler's Methods, multistep methods, Runge-Kutta Methods.
Advanced methods for Differential Equations [6 Lecture]: Adaptive methods, BVP finite difference methods and their extension to PDEs, introduction to parallel computation.

Textbook

1. S.S. Sastry, (2012) Introductory Methods of Numerical Analysis, PHI Learning.
2. E. Kreyszig, (2010) Advanced Engineering Mathematics, Wiley.
3. S.C. Chapra, (2008) Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw-Hill.
4. Golub, G.H., and Loan, C.F.V., (2000) Matrix Computation, JHU Press.

Reference Books

1. R.L. Burden and J.D. Faires, (2011) Numerical Analysis, Cengage Learning.
2. J.H Mathews and K.D. Fink, (2006) Numerical Methods using Matlab, Pearson Education.
3. R. Süli and D.F. Mayers, (2003) Introduction to Numerical Analysis, Cambridge University Press.

Self-Learning Material

1. Lal, R. and Banerjee S., Numerical Analysis, NPTEL Course Material, Department of Mathematics, IIT Roorkee,https://nptel.ac.in/courses/111107062/
2. Usha, R., Numerical Analysis, NPTEL Course Material, Department of Mathematics, IIT Madras,https://nptel.ac.in/courses/111106101/

Title	**Introductory Condensed Matter Physics**	Number	**PH2XXX**

Department	**Physics**	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech.	Type	
Pre-requisite	None		

Objectives
The Instructor will:
1. Explain the physics of condensed matter from the point of view of interatomic forces, lattice dynamics, electronic charge and spin.
2. Explain the theories governing various physical properties of materials

Learning Outcomes
The students will have the ability to:
1. understand various physical properties of solids.

Contents
Condensed Matter: Gases, Liquid, and Solid. 2D and 3D lattice, Miller indices of planes and directions, Reciprocal lattice, Brillouin zone, crystal symmetry, Atomic bonding, Condensation and Freezing (8 lectures)

Elementary Lattice Dynamics: Cohesion of solids, cohesive energy, Lattice Vibrations and Phonons, Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Einstein and Debye Theories of Specific Heat of Solids. T^3 Law. (6 lectures)

Soft Condensed Matter: Colloids, Stokes' law, Brownian motion and Einstein Equation, Forces between colloid particles, Stability of colloids, Polymer solutions and gels, Rubber elasticity (6 lectures)

Surfaces and Interfaces: Geometry of interfaces, stacking period and interplanar spacing, surface structure, observation and creation of surfaces, low energy electron diffraction, reflection high energy electron diffraction, (4 lectures)

Electrical, Thermal, and Optical Properties of Materials:charge carriers and transport, *Electrical and Thermal Conduction:* Drude model, Hall effect, *Dielectric Materials*: polarization, ferroelectrics, piezoelectrics, *Optical Properties:* Light waves, refractive index, absorption, luminescence (8 lectures)

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia – and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. B-H Curve. Hysteresis and Energy Loss. (10 lectures)

Text Books:
1. Kittel, C.., *Introduction to Solid State Physics*, John Wiley and Sons 2019.
2. Marder, M. P., *Condensed Matter Physics*, Cambridge University Press, 2010

Reference Books:
1. N. W. Ascroft and N. D. Mermin, *Solid State Physics*, (Harcourt Asia, Singapore, 2003).

Self-Learning Material:
https://www.youtube.com/watch?v=XQk25fSJkL8&list=PLaNkJORnlhZnC6E3z1-i7WERkferhQDzq

Title	**Foundations of Quantum Information Processing**	Number	**PH2XXX**
Department	**Physics/Chemistry**	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech.	Type	
Prerequisite			

Objectives

. To provide basic concepts of quantum information and computation

. To let student understand the importance of an emerging and interdisciplinary area

Learning Outcomes

1. Ability to analyze the effects of fundamental laws of quantum mechanics to information processing and computing
2. Ability to appreciate the advantages and concerns associated with theoretical as well as experimental aspects of quantum information and computation

Course Content

Mathematical formalism [12 Lecture]: Classical to quantum mechanics, bases and linear independence, wave function formalism, Interference, operators and matrices, Hermitian and Unitary operators, commuting and non-commuting observables, uncertainty and measurements in quantum mechanics, Stern-Gerlach experiment, pure and mixed states, density operators and Bloch sphere, Schrodinger's cat, Einstein-Podolsky-Rosen paradox, qubits, quantum gates and quantum circuits

Entanglement and Nonlocality [8 Lectures]: Bi-partite and multipartite states, quantum entanglement, quantum parallelism, Schrödinger's cat and Einstein-Podolsky-Rosen paradox, Bell states, Classical versus quantum correlations, Bell inequality and nonlocality, quantum steering

Quantum information [6 Lectures]: No-cloning theorem, information and entropy, von-Neumann entropy, relative entropy and interpretation, trace distance, fidelity

Quantum Information Processing [8 Lectures]: Dense coding, teleportation, entanglement swapping, quantum cryptographic protocols, quantum games

Quantum Noise and operations [6 Lectures]: Quantum operations, Kraus operators and operator-sum representation, examples and effects of noisy channels on entanglement, quantum error correction

The State of the Art [2 Lectures]: Overview and state of the art, Difficulties and open questions, Experiments, Facts versus fiction

Text Books

Nielsen, M. A. and Chuang, I. L., (2010), *Quantum Computation and Quantum Information*, 10th Anniversary addition, Cambridge University Press

Reference Books:

1. Griffiths, D. J., (2016), *Introduction to Quantum Mechanics*, Reprint edition, Pearson Prentice Hall, 2006.
2. Bouwmeester, D., Ekert, A. and Zeilinger, A., (2000), *The Physics of Quantum Information*, Reprint edition, Springer Berlin Heidelberg.
3. Bellac, M. L., (2006), *A Short Introduction to Quantum Information and Quantum Computation*, Cambridge University Press

Self-Learning Material:

1. Goswami, D., Quantum Computing, NPTEL course material, Department of Chemistry, IIT Kanpur https://www.youtube.com/watch?v=xnmpWfQKPSE&list=PLq-Gm0yRYwTj7Fs6jyzYa83HErSrpXgPQ
2. Preskill, J., Lecture Notes for Quantum Computation, Preskill Lecture Notes, California Institute of Technology

Title	**Metrology**	Number	**PH2XXX**
Department	**Physics**	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	
Prerequisite			

Objectives

The students will gain

1. Knowledge to understand the issues related to optical interferometers and its applications to various measurement techniques.

Learning Outcomes

The students are expected to have the ability to:

1. Show a basic familiarity with the science and technology of various optical interferometers.

Contents

Introduction to Metrology: Concepts of measurements, Standards and Measurements (3 Lectures)

Optical Interferometry and measurements: Introduction to wave optics, Coherence theory, Imaging systems, Spectral and polarization effects on interferometry, Various interferometers: Michelson, Mach-Zehnder interferometer, Speckle Interferometer, Sagnac interferometer, Shadowgraphy, Schlieren, Shearing interferometers and its applications, Recording and analysis of interferogram, Standard of length, Refractive index Measurement and testing of optical systems and components (9 Lectures)

New directions in metrology/ Modern trends in metrology and measurements standards (2 lectures)

Textbook

1. Steel, W. H., Interferometry, Cambridge University Press (1967)

Self-Learning Material

1. https://nptel.ac.in/courses/112106179/, NPTEL course by K. Sadashivappa, Dept. of Mechanical Engineering, IIT Madras

Preparatory Course Material

1. Malacara-Hernández, D., and Malacara-Hernández, Z., Handbook of Optical Design, Third Edition CRC press (2013)

2. Basics of Interferometry, P. Hariharan, Academic Press (1992)

Title	**Statistical Mechanics**	Number	**PHL2XXX**
Department	**Physics**	L-T-P [C]	2–0–0 [2]
Offered for	B.Tech.	Type	
Prerequisite			

Objectives

The students will gain

1. Deep understanding of kinetic theory of gases and fundamentals of statistical physics.

Learning Outcomes

The students are expected to have the ability to:

1. Demonstrate a detailed understanding of kinetic theory of transport in gases.
2. Discuss the behavior of non-interacting ideal systems using statistical physics.

Contents

Kinetic Theory of Gases: Kinetic theory of gases, Maxwell-Boltzmann Distribution of molecular velocities, Equipartition theorem, Basic kinetic theory of transport in gases, Molecular collisions, Mean free path, Diffusion, van der Waal's equation of state (9 Lectures)

*Statistical Mechanics:*Phase space and Liouville's theorem, Ensembles, Non-interacting ideal systems, Partition function for various systems (11 Lectures)

Quantum statistics: Bose-Einstein and Fermi-Dirac distributions; Fermi Energy, Black body radiation (8 Lectures)

Textbook

1. Statistical Mechanics, Donald A McQuarrie, Viva Books Pvt. Ltd, (2005)
2. Chandler, D., Introduction to Modern Statistical Mechanics, Oxford University Press, 1987

Self-Learning Material

1. Statistical Mechanics :https://www.youtube.com/watch?v=ckUyxmwaC5E
2. https://nptel.ac.in/courses/115106111/, NPTEL course by A. Joy, Dept. of Physics, IIT Madras

Preparatory Course Material

1. Huang, K., Statistical Mechanics, John Wiley and Sons, 1987

Title	**Physics of Complex Fluids**	Number	**PHL2XXX**
Department	**Physics**	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech.	Type	
Prerequisite			

Objectives

The students will gain

1. Basic understanding of the physics of simple and complex fluids/liquids.
2. Advanced knowledge in applying the concepts to industrially relevant practical applications.

Learning Outcomes

The students are expected to have the ability to:

1. Demonstrate deep understanding of basic concepts related to liquid matter.
2. Exploit the physics of complex fluids to a wide variety of consumer goods.

Contents

PHL2XX1 Fundamentals of Fluid Matter (1-0-0):

States of matter, Simple fluids, Molecular liquids, Intermolecular forces, Model interaction potentials, Experimental techniques for liquid structure, Pair correlation functions, Static and dynamic structure factor, Introduction to X-ray and Neutron scattering (14 lectures)

PHL2XX2 Theory of Complex Liquids (1-0-0):

Theory of elasticity and viscosity, Stokes-Einstein relation, Linear response theory, Green-Kubo relations, Viscoelasticity, Master equation, Stress-strain behavior, Rouse theory, Kremer-Grest model (14 lectures)

PHL2XX3 Advanced Topics in Complex Liquids (1-0-0):

Supercooled fluids, Glasses, Glass transition temperature, Time correlation function, Breakdown of Stokes-Einstein relation, Gels, Polymer melts, Colloidal suspensions, Microemulsions, Rheology and Rheometer, Microfluidic devices, Physics of soft material consumer goods & cosmetics (14 lectures)

Textbook

1. Hansen, J.-P. and McDonald, I. R., *Theory of Simple Liquids: With Applications to Soft Matter*, 4th Edition, Elsevier, 2013.

2. Chandler, D., *Introduction to Modern Statistical Mechanics*, 1st Edition, Oxford University Press, 1987.

Self-Learning Material

1. *Transport Phenomena of Non-Newtonian Fluids*, NPTEL course by Prof. Nanda Kishore, IIT Guwahati
https://nptel.ac.in/courses/103/103/103103146/#

2. *Statistical Thermodynamics of Complex Liquids*, MIT Open Course Ware Number 22.52J / 8.575J / 10.44J by Prof. Sow-Hsin Chen https://ocw.mit.edu/courses/nuclear-engineering/22-52j-statistical-thermodynamics-of-complex-liquids-spring-2004/syllabus/

Preparatory Course Material

1. Macosko, C. W., *Rheology: Principles, Measurements, and Applications*, Wiley-VCH, 1993.

2. Chaikin, P. M. and Lubensky, T. C., *Principles of Condensed Matter Physics*, Cambridge University Press, 2004.

Course Title	**Introduction to Analytical Mechanics**	**Course No**	**PHL2XXX**
Department	Physics	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech	Type	
Pre-requisite	None		

Objectives

The Instructor will:

1. Provide concepts and problem solving approach related to Newtonian and Lagrangian formulation in Mechanics.

Learning Outcomes:

The students are expected to have the ability to:

1. Solve problems in Newtonian, Lagrangian and Hamilton formalism

Course Contents

Introduction to Newtonian and Lagrangian mechanics, constraints, D'Alembert's principle, Problems solving approach in Newtonian and Lagrangian formalism (12 Lectures)

Central force problem: The equation of motion, the equivalent one-dimensional problem, classification of orbits, Virial theorem, Differential equation for the orbit, inverse square law of force, scattering in the central force field. (10 Lectures)

Variational Principles and Lagrange's equations: calculus of variations, Hamilton's principle, derivation of Lagrange's equation from Hamilton's principle, its application, conservation and symmetry property. (8 Lectures)

Rigid body motion: orthogonal transformation, the Eulerian angles, Euler's theorem, infinitesimal rotation, Rodrigues formula, quaternion, the heavy symmetrical top, Gyroscope, Foucault Pendulum (8 Lectures)

Hamilton's equation of motion: Legendre transformations and Hamilton's equation (4 Lectures)

Text books:

1. Simon, Keith. R., Mechanics Second Edition Addison -Wesley publication (1960).
2. Analytical Mechanics, L. N. Hand and J. D. Finch Paperback (1998)

Reference Books:

1. Goldstein, H., *Classical Mechanics*, Pearson India Limited, New Delhi (2011).
2. Landau, L.D. and Lifshitz, E.M., *Mechanics*, Pergamon Press, (1960).

Self-Learning Material:

1. Prof. Harbola. M. K. , Engineering *Mechanics*, Indian Institute of Technology -Kanpur, https://nptel.ac.in/syllabus/115/104/115104094/

Title	***Nanoscience***	Number	CYL2XX0
Department	Chemistry	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech.	Type	SLE
Prerequisite	None		

Objectives

The aim of this course is to provide

1. Strong foundation and basic knowledge of nanoscience.
2. Greater understanding of the underlying theory of material behaviour at nanoscale.

Learning Outcomes

The students will enable to:

1. Appreciate the science involved in the nanoscale phenomena.
2. Design a strategy for nanoscale synthesis.
3. Select nanomaterials for specific applications.

Contents

Fundamentals of Nanoscience [14 Lectures]: Nanoscale processes, nanosystems, nanostructures, important nanomaterials (clusters, nanocrystals, nanotubes and nanowires)

Size-dependent properties [7 Lectures]: Quantum confinement, Band gap, Surface effects in nanosystems, Optical, mechanical, electronic and magnetic properties along with surface reactivity

Principles involved in the synthesis of nanomaterials [7 Lectures]: Top-down and bottom-up, soft versus hard methods, chemical and physical methods, hybrid methods for synthesis of nanomaterials

Analysis of nanoscale phenomena [7 Lectures]: X-ray and electron diffraction, gas adsorption and porosity analysis and zeta-potential analysis

Applications of nanomaterials [7 Lectures]: Bio-nanomaterials, electronic nanomaterials, nanomaterials for energy and environmental applications

Textbooks

1. Lindsay, S. (2009), *Introduction to Nanoscience*, 1st edition, OUP Oxford, 2009
1. Pradeep,T. (2007) Nano: The Essentials Understanding nanoscience and nanotechnology, Tata McGrawHill Publishing Company Limited.

Reference Books

1. Lourtioz, J., Lahmani, M., Dupas-Haeberlin, C. (2015), *Nanosciences and Nanotechnology*, 1st edition, Springer Nature, 2015

Self Learning Material

1, Anandh Subramaniam, *Nanostructures and Nanomaterials: Characterization and Properties,* NPTEL Course, Material, Department of Materials Science and Engineering, IIT Kanpur, Link https://nptel.ac.in/courses/118/104/118104008/

Course Title	**Modern Physics**	Course No	**PH2XXX**
Department	Physics	L-T-P-C	3-0-0 [3]
Offered for	B. Tech	Type	
Pre-requisite			

Objectives

This course aims to:

1. Provide the basic understanding and concepts of modern physics
2. Deliver comprehensive knowledge of various fundamental effects of modern physics which has revolutionized the technologies in the 21st century.

Learning Outcomes

The students will develop the ability to understand the fundamental physics behind various effects and phenomena covered in the syllabus.

Course Contents

Relativity: Special Relativity, Time Dilation, Length Contraction, Lorentz transformations, Relativistic Mass and Energy, Energy and Momentum, General Relativity. (6 lectures)

Quantum theory of light: EM Waves, Blackbody radiation, Photoelectric effect, X-rays, X-ray Diffraction, Compton-Effect, Stern Gerlach experiment, two-level systems, Pair Production, De-Broglie Waves, Phase and Group Velocities, Uncertainty Principle. (8 lectures)

Quantum Mechanics: Wave Equation, Schrodinger's wave equation (Time-Dependent Form), Linearity and Superposition, Expectation Values, Operators, Schrodinger's wave equation (Steady State), Particle in a Box, Finite potential well. (10 lectures)

Statistical Mechanics: Statistical Distribution, Maxwell-Boltzmann Statistics, Quantum Statistics: Fermi-Dirac Statistics and Bose-Einstein Statistics. (6 lectures)

Atomic structure: Energy of Hydrogen Atom, Atomic spectra, Orbital Electron Wavelength, Atomic Excitation, Einstein's phenomenological theory, lifetime of a state, Lasers, Introduction to single photon interference and to coherence. (12 lectures)

Text Books:

1. Beiser,A., (2009), *Concepts of Modern Physics*, McGraw Hill.
2. Verma, H. C., (2017), *Quantum Physics*, Surya Publication, India.
3. Feynman R., Leighton R, and Sands M. (1965), *The Feynman Lectures on Physics*, Volume III (Addison Wesley, MA).

Reference books:

1. Eisberg, R., and Resnick, R., (1985), *Quantum Physics*, 2nd edition, John Wiley, New York.
2. Shankar. R., (1994), *Principles of Quantum Mechanics*, 2nd edition, Plenum Press, New York.
3. Griffiths. D. J.,(2005), *Introduction To Quantum Mechanics*, 2nd edition, Pearson Education India.

Self-Learning Material:

1. NPTEL Course Material, Prof. V. Balakrishnan, Department of Physics, IIT Madras https://nptel.ac.in/courses/ 122106034/.

Preparatory Course Material

1. Susskind, L., *Foundations of Modern Physics*, https://www.courses.com/stanford-university/foundations-of-modern-physics.

Title	**Design and Analysis of Experiments**	Number	MAL4X00
Department	Mathematics	L-T-P [C]	3-0-0
Offered for	B.Tech.	Type	Compulsory
Prerequisite	Basic Probability & Statistics		

Objectives

The Instructor will:

1. Provide background in the area of Design and Analysis of Experiments
2. Provide sufficient knowledge of how to plan and conduct experiments in the engineering, physical and chemical sciences
3. Explain different methods to analyze the resulting data so that valid and objective conclusions are obtained

Learning Outcomes

The students will have the ability to

1. Use different design techniques, namely, randomized block designs, Latin squares, factorial designs, Taguchi methods and response surface methodology, in different practical scenarios.
2. Conduct scientific experiments in their own domains.
3. Use different methodologies in order to analyze the experiment

Contents

Introduction to Design of Experiments [2 Lectures]: Why Designed Experimentation? Concept of Experimental Error, Fundamental Principles of Experimentation.
Statistical Preliminaries: [2 Lectures]: F- distribution, Theory of random sampling.
ANOVA [6 Lectures]: One-Way Analysis of Variance, Analysis of the fixed effects models, Model Adequacy checking, Practical interpretation of results, Multiple comparisons tests, Two-Way Analysis of Variance.
Randomized Blocks, Latin squares, and Related Designs [6 lectures]: Statistical Analysis of the RCBD, Model Adequacy Checking, Estimating model parameters and general regression significance test, The Latin Square Design, Statistical Analysis of Balanced Incomplete Block Designs, Least square estimation of the parameters, Recovery of interblock information in the BIBD.
Introduction to Factorial Designs [6 Lectures]: Basic Definitions and Principles, The Advantage of Factorials, Two-Factor Factorial Design: Statistical Analysis of the fixed effects model, model adequacy checking, Estimating the model parameters, Choice of sample size, The assumption of no interaction in a two-factor model; The 2^k Factorial Design: the 2^2 and 2^3 designs, the general 2^k designs, A single replicate of 2^k design, the addition of centre point to the 2^k design.
Taguchi Methods [5 lectures]: Designing Experiments using Orthogonal Arrays, Multi-Level and Dummy-Level Designs, Signal to Noise Ratio Analysis, Dynamic Signal to Noise Ratio Analysis.Response Surface Methodology [6 lectures]: Method of Steepest Ascent, Analysis of Second Order Response Surface: Location of the stationary point, Characterising the response surface, Ridge systems, Multiple responses; Designs for fitting Response Surfaces: Designs for fitting the first and the second order models, Blocking in response surface designs, Computer generated designs.
Optimality [3 lectures]: Concepts of Design Optimality, Multiple Response Optimization Methods.
Tutorial Session [6 classes]: Using R/ Python/ SPSS/ other.

Textbooks

1. Montgomery, D.C., (2001), Design and Analysis of Experiments, Wiley and Sons
2. Toutenburg, H., and Shalabh, (2009), Statistical Analysis of Designed Experiments, Springer
3. Roy, R.K., (2001), Design of Experiments Using the Taguchi Approach, Wiley and Sons

Reference Books

1. Casella, G., (2008), Statistical Design, Springer

2. Morris, M.D., (2011), Design of Experiments: An Introduction Based on Linear Models, CRC Press

Online Course Material

1. Maiti, J., Design and Analysis of Experiments, NPTEL Course Material, Department of Industrial and System Engineering, Indian Institute of Technology Kharagpur,https://nptel.ac.in/courses/110105087/#

Title	**Embedded Systems and IoT**	Number	**EEL2XXX**
Department	Electrical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	B.Tech. ES	Type	Compulsory
Prerequisite	Basic Electrical Engineering		

Objectives

The Instructor will:

1. Provide knowledge of embedded processors and IoT architecture.
2. Provide knowledge of programming of Embedded Processors.

Learning Outcomes

The students are expected to have the ability to:

1. Use IDEs for writing software for embedded processors.
2. Design embedded systems for different applications including IoTs.

Contents

Introduction to Embedded Processors [07 Lectures]:
Concept of Processors; Arduino Platform; [4L]
Microprocessors and Microcontrollers, Memory Interfacing [3L]
Architecture of Processors [08 Lectures]:
Architecture of ARM M0 processors, ISA of 8-bit and 32-bit microcontrollers,[5L]
Memory mapped peripherals, peripherals like GPIOs, Timers, analog inputs. [3L]
Internet of Things [07 Lectures]:
Sensors and actuators, Architecture of IoT, working principle of IoT devices, Edge, Fog and Cloud computing,[4L]
IBM Watson IoT—Bluemix, Microsoft Azure IoT Suite [3L]
Communication Protocols and Enabling Technologies for IoT[06 Lectures]:
FID and Near Field communication, ZigBee, Bluetooth, [4L]
HTTP, WebSocket, Constrained Application Protocol (CoAP)[2L]
Platform for IoT Development [10 Lectures]:
Introduction to Arm Mbed development environment, use of Arm Mbed for programming Embedded processors, digital I/Os and analog I/Os interface. *[5L]*
Networking and communication, control applications, debugging application, use of high level language like C for programming embedded processors *[5L]:*
Application of IoT in healthcare, infrastructure and industry 4.0 [4 lectures]

Laboratory

The laboratory has experiments on interfacing with different sensors i.e. temperature, force, current and their readout circuits. Experiments on different communication protocols like Bluetooth, Zigbee. Experiments on Cloud platforms like Microsoft Azure and other available cloud platforms with the institute. Experiments from reading the signal to analyzing acquired data on cloud platforms.

Textbook

1. Perry Xiao., (2018), Designing Embedded Systems and the Internet of Things (IoT) with the ARM® Mbed™, John Wiley & Sons Ltd.
2. Mohit Arora, (2016), Embedded Systems Design, Learning Bytes Publication.

Reference Book

1. Marilyn Wolf (2012) "Computers as Components: Principles of Embedded Computing System Design" Third Edition, Elsevier .

Title	**Modelling and Simulation**	Number	**ESXX0**
Department	Electrical Engineering, Mechanical engineering, Computer Science Engineering	L-T-P [C]	3–0–2[3]
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

Impart the concepts of various mathematical modelling and solution techniques for engineering problems

Learning Outcomes

The students will have the ability to:

1. Mathematical modelling of engineering problems and their solutions using computer simulations
2. Use different simulation tools for solving problems

Contents

Introduction: Concept ofSystem, Concept of model, Input and output variables, Static and Dynamic systems; Review of conservation laws and the governing equation for heat, mass and momentum transfer, Introduction to different types (i.e. Analytical, Graphical) of models. [5 L]

Deterministic Systems Modelling: Differential equation, Difference equation, Linear and nonlinear equations, linearization, [5 L] Transfer function, State-space representation [3L] Examples like Battery and fuel cell , LRC circuit, Inverting Amplifier, DC Motor Inverted pendulum, Mass-spring-damper model [4 L]

Stochastic Systems Modelling: Review of probability theory, continuous-time stochastic differential equations for modelling uncertain system, Random process, Markov-chain [5 L]

Modelling of Agent-based interconnected systems: Distributed systems and tools to model; introduction to basic notions of Graph theory, associated matrices; use of graph theory to model distributed agent-based systems. [5L]

Finite State Machine and Hybrid System: Hybrid system modelling, Examples: Bouncing ball systems, Automated Highway System. [3L] Finite state machine; Extended state machines [5 L]

*Simulation:*Introduction to numerical integration technique to solve differential equations; Concept of solution, different numerical algorithms to solve algebraic differential equations; [4L] different error bounds of solution; selection of numerical algorithm to solve given problem; [3L]

Laboratory class: Laboratory class would involve simulation of the systems modelled in the course of the above using Matlab, Ansys, and other simulation software which include solving ordinary differential equations, differential-algebraic equations, solving partial differential equations, Simulation of continuous and discrete processes with suitable examples from engineering problems, The laboratory will also use COMSOL-multi-physics modeling tools.

Textbook

1. Zeigler B.P. Praehofer. H. and Kim I.G. (2000) "Theory of modeling and simulation", 2 nd Edition, Academic press.
2. Bungartz H., Zimmer, S., Buchholz, M and Pfluger, D. (2014), Modelling and Simulation, Springer.
3. Ogata K. (2009) Modern Control Engineering 5th edition PHI.

Title	**Professional Ethics I**	Number	

Department	Humanities and Social Sciences	L-T-P [C]	0-1-0[1]
Offered for	UG	Type	Compulsory
Prerequisite	Nil		

Objectives

The course will:

1. Foster awareness of ethical responsibilities associated with professions
2. Assist students in identifying, assessing and resolving ethical dilemmas in professional contexts
3. Help students becoming responsible professionals

Learning Outcomes

The students are expected to have the ability to:

1. Understand the responsibilities linked to professions
2. Identify normative commitments of technological knowledge and artifacts
3. Think analytically and critically

Contents

Professional Ethics: Basic Notions: Thinking Like an Engineer; Moral Conflicts and Dilemmas; What Morality Is and What Morality Is Not; Structure of Moral Reasoning; Ordinary Morality and Professional Ethics; Tools and Techniques in Ethics; Professionalization and Normative Commitments (7 classes)

Major Moral Problems in Professional Contexts (case study based):Rights, Duties, and Violations; Conflicts of Interests; Corruption; Contracts; Obligations in Special Relations; Deception and Puffery; Paternalism; Consent and Dissent; Whistleblowing (7 classes)

Textbook

1. Callahan, J.C. (1988), *Ethical Issues in Professional Life*, New York: Oxford University Press.

Reference Books

1. Meijers, A. (2009). *Philosophy of Technology and Engineering Sciences*, Amsterdam: Elsevier.
2. Fleddermann, C.B. (2012). *Engineering Ethics* (4th edition). Boston: Prentice Hall.

Online Resources

1. Sanders, J., *Professional Ethics*, Rochester Institute of Technology, www.openculture.com/philosophy_free_courses
2. Illinois Institute of Technology, Center for the Study of Ethics in the Professions, ethics.iit.edu/library/ethics-resources-online

Title	**Professional Ethics II**	Number	
Department	Humanities and Social Sciences	L-T-P [C]	0-1-0[1]
Offered for	UG	Type	Compulsory
Prerequisite	Nil		

Objectives

The course will:

1. Foster awareness of ethical responsibilities associated with professions
2. Assist students in identifying, assessing, and resolving ethical dilemmas in professional contexts
3. Help students becoming responsible professionals

Learning Outcomes

The students are expected to have the ability to:

1. Understand the responsibilities linked to professions
2. Identify normative commitments of technological knowledge and artifacts
3. Think analytically and critically

Contents

Ethical Issues in Professional Contexts (case study based): Why Should One be Moral; Fairness in Discharging Professional Roles; Fair Competition, Hiring Process; Allocation of Burdens and Benefits; Risk Assessment; Privacy and Confidentiality; Obligations to Vulnerable Populations (9 classes)

Character, Integrity, and Accountability: Trust, Respect, and Justice as Foundational Values; Role of Conscience and Personal Values; Professional Integrity; Laws, Norms, and Professional Codes; Social Responsibility; Responsibility to the Environment (5 classes)

Textbook

1. Callahan, J.C. (1988), *Ethical Issues in Professional Life*, New York: Oxford University Press.

Reference Books

1. Meijers, A. (2009). *Philosophy of Technology and Engineering Sciences*, Amsterdam: Elsevier.
2. Fleddermann, C.B. (2012). *Engineering Ethics* (4th edition). Boston: Prentice Hall.

Online Resources

1. Sanders, J., *Professional Ethics*, Rochester Institute of Technology, www.openculture.com/philosophy_free_courses
2. Illinois Institute of Technology, Center for the Study of Ethics in the Professions, ethics.iit.edu/library/ethics-resources-online

Title	**Introduction to Profession**	Number	XX2XX
Department	All	L-T-P [C]	0–0–2 [1]
Offered for	B. Tech.	Type	IE
Prerequisites			

Objectives
The Instructor would:
1. Introduce students to the profession of engineering
2. Familiarize students with discipline of their engineering programme

Learning Outcomes
The students would be able to:
1. Appreciate the significance of Engineering in solving real life problems
2. Ability to appreciate problem specific to discipline of the programme

Contents

Introduction to Engineering [4 Sessions]: Broad introduction to Engineering in general

Introduction to Programme [8 Sessions]: Introduction to respective Programme of studies

The above session may include:
- Lectures by successful industrialists, alumni and entrepreneurs about their journey.
- Screening of videos that bring out the strong relation between science / engineering and societal needs.
- Understanding engineering through product dissection and reverse engineering.
- Hands-on exercises in laboratories including use of breadboard circuits, Lego sets, robot kits, balsa bridge engineering kits, fibre optics kits, mobile apps etc.
- Interesting demonstrations in laboratories.
- Industry visits
- Conducting design and innovation contests among students.
- Solving science / engineering puzzles in the class.
- Some interesting demonstrations in laboratories
- Exposure to successful research cases from the Institute/Department and the impact of the same.
- Exposure to successful products / innovations from the Institute/Department which have reached people/ industry/ society.
- Do-it-yourself projects in teams
- Lectures by faculty, visitors, on some exciting topics.

Title	**Environmental Science**	Number	CIL4XX0
Department	Civil and Infrastructure Engineering	L-T-P [C]	2-0-0[2]

Offered for	B.Tech.	Type	
Pre-requisite			

Objectives

1. To inculcate basics of environmental science in students
2. To address issues of environmental health and policies related to it

Learning Outcomes

1. To be able to understand basic environmental phenomena and to assimilate values of environmental laws and policies
2. To effectively understand different aspects of pollution in the environment

Contents

Introduction [6 Lectures]: Earth, its composition and structure, Orogeny, Matter, Energy and life; Natural resources and issues; Chemistry and the atmosphere; The role ofchemistry in environmental studies,

Ecosystem, Evolution and Population [12 Lectures]: Ecosystem and cycles, Aut-ecology and syn-ecology components and classification; Food chain, webs and ecological pyramids; Biomes; Renewable and non-renewable energy; Energy plantation and bio energy; Examples of ecosystems; Evolution and diversity; Population growth, species interactions and its impact

Pollution and Environmental Health [10 Lectures]: Types of pollution (Water, Soil, Air, Noise, Nuclear etc.)and their effects on environment; Toxicology of pollutants and environmental health; Solid waste generation, disposal and associated risks; Mechanisms for minimizing the effects and risk assessment in soil and water management

Food, Agriculture and Climate [8 Lectures]: Green revolution; Sustainable agriculture;Food production and food security; Nutrition and Health; Irrigation and fertilizers; Climate changes and solutions

Environmental Policy and Sustainable development [6 Lectures]: Environmental policies in India; Implementation; A glance of International laws and policies; Public awareness and social responsibility towards clean future

Text Book

1. Friedland, A., Relyea, R., and Courard-Hauri, D. (2012), *Essentials of Environmental Science*, 1st edition, New York: Freeman and Company, 2012

Reference Book

1. Baird, C. et al. (2008), *Environmental chemistry,* 4th edition, W. H. Freeman and Company, New York, 2008

Self-learning Material

1. C. V. Sastri, Environmental Chemistry, NPTEL Course Material, Department of Chemistry, IIT Guwahati, Link https://nptel.ac.in/courses/122106030/

Title	**Energy Materials**	Number	MTL2XX0
Department	Metallurgical and Materials Engineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	Not Required		

Objectives

The Instructor will:

1. Introduce various methods of energy storage and conversion
2. Explain the mechanisms of energy storage and conversions for various processes

Learning Outcomes

The students are expected to:

1. Understand how materials influence the energy storage and conversion process

Contents

Introduction: [2 lectures] Importance of energy storage, classification of processes for energy storage and conversion, basics of electrochemistry, Nernst Equation

Electrochemical and Photoelectrochemical Energy Storage and Conversion: [5 lectures] Electrolytic capacitor, electrochemical cell, supercapacitor, materials for primary and rechargeable batteries, fuel cells, artificial photosynthesis- semiconductor based and dye-synthesized solar cells

Hydrogen Harvesting and Storage: [2 lectures] Hydrogen economy, Hydrogen harvesting, Hydrogen storage- mechanical, compressed, and liquid hydrogen storage, metal hydrides

Thermal and Mechanical Energy Conversion: [2 lectures] Thermoelectric materials, piezoresistive materials

Carbon Materials for Energy: [3 lectures] Carbon nanoparticle/nanotube/graphene/graphene oxide, functionalization of carbon materials, carbon nanomaterials for energy conversion and storage

Textbook

1. Lu, K., (2014) *Materials in Energy Conversion*, Harvesting, and Storage, 3rd Edition, John Wiley and Sons

Reference Books

1. Kumar, A., Das, S.K., (2017), *Energy Storage and Conversion: Materials and Devices*, Narosa Publishing House

Online Course Material

1. Pal, K., Selection of Nanomaterials for Energy Harvesting and Storage Application, Department of Mechanical and Industrial Engineering, IIT Roorkee,http://nptel.ac.in/courses/112/107/112107283

Title	**Computational Materials Design**	Number	MTL2XX0
Department	Metallurgical and Materials Engineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Create awareness of the opportunities of traditional and emerging computational methods for materials design
2. Introduce the molecular dynamics simulation for studying materials, and the concept of materials intelligence

Learning Outcomes

The students will have the ability to:

1. Analyze structural and dynamical properties using molecular dynamics simulation
2. Identify the applications of machine learning for accelerating materials design

Contents

Computational techniques for Materials design: [3 lectures] Introduction and need for computational techniques in materials design, techniques, current and potential applications

Molecular dynamics: [8 lectures]

Basic concepts and Potential energy functions (3 lectures)
Integration algorithms (2 lectures)
Initialization and equilibration (3 lectures)

Materials Intelligence: [3 lectures] Data relevant to Materials Engineering, Material Informatics, Machine learning to create knowledge from materials data and for accelerated materials design

Laboratory Classes

NA

Text Book

1. Lee, J., *Computational Materials Science: An Introduction*, 2nd Edition, CRC Press 2016.

Reference Books

1. Frenkel, D., Smit, B., Understanding Molecular Simulation: From Algorithms to Applications, 2nd Edition, Elsevier 2001.

Self-Learning Material

1. Ceder, G., and Marzari, N., 3.320 *Atomistic Computer Modeling of Materials* (SMA 5107). Spring 2005. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Polymers**	Number	CHL2XX0
Department	Chemical Engineering	L-T-P [C]	1-0-0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Provide basic background to structure and properties of polymeric materials

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basic classifications and synthesis of polymers
2. Correlate the structure of polymers with properties

Contents

Background: [3 lectures] Terminologies, classification of polymers, Amorphous & semi-crystalline polymer, biopolymers, Functional group reactivity, classification of polymerization reactions

Structure-Property in Bulk Polymer: [6 lectures] Glass transition, crystal structure, crystallinity and melting in polymer, mechanical properties-stress-strain relationship, Electrical properties: Dielectric properties, conduction in polymers

Introduction to Viscoelasticity: [3 lectures] Mechanical models for stress-strain relationships-Kelvin model, Maxwell model, Voigt model

Applications: [2 lectures] Polymer composites, polymers for electronic packaging

Textbook

1. Young, R.J., and Lovell, P.A. (2011), *Introduction to Polymers*, 3rd Edition, CRC Press

Reference Books

1. BillMeyer, F.W., (2007), *Textbook of Polymer Science*, 3rd Edition, Wiley

Online Course Material

1. Adhikari, B., *Science and Technology of Polymers,* NPTEL Course Material, Department of Metallurgical & Materials Engineering, Indian Institute of Technology Kharagpur, http://nptel.ac.in/courses/113105028/

Title	**Materials Selection**	Number	MTL2XX0

Department	Metallurgical and Materials Engineering	L-T-P [C]	1-0-0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Provide basic background to systematically approach for selection of materials for a wide range of products in engineering applications

Learning Outcomes

The students are expected to have the ability to:

1. Correlate between material properties with component design
2. Apply the method of materials selection, material data and knowledge sources for computer-aided selection of materials

Contents

Background: [2 lecture] The need for material selection in design, the evolution of Engineering materials

The Design Process and Materials Data: [2 lectures] Types of design, design tools and materials data, processes of obtaining materials data, materials databases

Engineering Materials and Their Properties: [2 lectures] The classes of engineering materials and their structure, material properties: mechanical properties, functional properties

Material Selection Charts: [4 lectures] Selection criteria for materials, material property Charts, deriving property limits and material indices, materials indices which include shape

Computer Aided Selection of Materials: [4 lectures] Application of GRANTA Edupack for material selection: Case studies based on material properties

Textbook

1. Ashby, M.F. (2010), *Materials Selection in Mechanical Design*, 4th Edition, Butterworth-Heinemann

Reference Books

1. Jones, D.R.H., and Ashby,M.F., (2011), *Engineering Materials 1:* An Introduction to Properties, Application and Design, 4th Edition, Butterworth-Heinemann
2. Jones, D.R.H., and Ashby,M.F., (2012), *Engineering Materials 2:* An Introduction to Microstructure and Processing, 4th Edition, Butterworth-Heinemann

Online Course Material

1. Bhattacharya,B., *Materials Selection and Design,* NPTEL Course Material, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, http://nptel.ac.in/courses/112104122/

Title	**Structure of Materials**	Number	MTL2XX0

Department	Metallurgical and Materials Engineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Introduce the concept of crystal structure, atomic planes and directions
2. Introduce the concept of atomic packing, coordination, and symmetry elements
3. Introduce imperfections in solids

Learning Outcomes

The students are expected to have the ability to:

1. Understand the atomic arrangement in crystalline materials
2. Describe the periodic arrangement of atoms in terms of unit cell parameters
3. Identify various kinds of defects

Contents

Introduction: [3 lectures] Classification of materials, crystalline and non-crystalline solids, atomic bonding

Geometrical Crystallography: [3 lectures] Symmetry elements: the operation of rotation, Proper and Improper rotation axes, Screw axes, Glide planes

Crystal Structure: [4 lectures] Crystal Lattice, Unit Cell, Planes and directions in a lattice, Planar Atomic Density, packing of atoms and packing fraction, Classification and Coordination of voids, Bragg's Law

Imperfections in Solids: [3 lectures] Types of imperfections, Point defects: vacancies, interstitials, line defects, 2-D and 3-defects, Concept of free volume in amorphous solids.

Textbook

1. Azaroff, L.V., (2001) *Introduction to solids*, 1st Edition, McGraw Hill Book Company

Reference Books

1. Callister Jr, W.D., Rethwisch, D.G., (2018), *Materials Science and Engineering: An Introduction*, 10th Edition, Hoboken, NJ: Wiley

Online Course Material

1. Prasad, R., Introduction to Materials Science and Engineering, NPTEL Course Material, Department of Materials Science and Engineering, Indian Institute of Technology Delhi, http://nptel.ac.in/courses/113102080/
2. Subramaniam, A., Structure of Materials, NPTEL Course Material, Department of Material Science and Engineering, Indian Institute of Technology Kanpur,https://nptel.ac.in/courses/113104014/

Title	**Physical Metallurgy**	Number	MTL2XX0
Department	Metallurgical and Materials Engineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Introduce phase stabilities and phase diagrams
2. Teach mechanism of phase transformations
3. Introduce various heat treatment methods

Learning Outcomes

The students are expected to have the ability to:

1. Understand the importance of phase diagrams
2. Understand the phase transformations
3. Know various heat treatment methods for controlling the microstructure

Contents

Alloy Systems: [1 lecture] Classification of Solid solutions, Hume-Rothery Rules

Phase Diagrams: [4 lectures] Gibbs Phase Rule, Solubility limit, phase equilibria and Phase Diagrams: Isomorphous systems, Invariant Binary Reactions, Lever Rule; important phase-diagrams

Diffusion: [2 lectures] Diffusion-Fick's Laws, Role of imperfections in diffusion

Nucleation and growth: *[1 lecture]* Introduction to homogeneous and heterogeneous nucleation, critical radius for nucleation

Plastic Deformation: [2 lectures] Slip, Twinning; Recovery-Recrystallization-Grain Growth, Introduction to Strengthening mechanisms

Heat treatment: [4 lectures] Annealing, normalizing, hardening and tempering; TTT diagram, microstructural effects brought about by these processes and their influence on mechanical properties

Textbook

1. Avner, S.H., (2017), *Introduction to Physical Metallurgy*, 2nd Edition, McGraw Hill Education.

Reference Books

1. Abbaschian, R., Abbaschian, L., Reed-Hill, R. E., (2009), *Physical Metallurgy Principles*, 4th Edition, Cengate Learning.

Online Course Material

1. Schuh, C., 3.40J Physical Metallurgy. Fall 2009. Massachusetts Institute of Technology: MIT Open Course Ware, https://ocw.mit.edu. License: Creative Commons BY-NC-SA.
2. Ghosh, R.N., Principles of Physical Metallurgy, IIT Kharagpur, http://nptel.ac.in/syllabus/113105024/

Title	**Corrosion**	Number	MTL2XX0
Department	Metallurgical and Materials Engineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Institute Core (IE)
Prerequisite	-		

Objectives

The Instructor will:

1. Introduce to different forms of corrosion
2. Elucidate thermodynamics and kinetics of corrosion
3. Teach different protection mechanisms against corrosion

Learning Outcomes

The students are expected to:

1. Understand corrosion under different environments
2. Understand the thermodynamics and kinetics of corrosion
3. Know protection methods against corrosion

Contents

Introduction and Motivation: [2 lecture] Economics, forms of corrosion, design, basics of Electrochemistry,

Thermodynamics and Kinetics: [6 lectures] Nernst equation, Pourbaix diagram, Rate expression, Exchange current density, Polarization, Tafel Equation, Mixed Potential Theory-Galvanization, Passivation, corrosion measurement

Forms of Corrosion: [5 lectures] Major forms of corrosion (e.g. uniform, galvanic, crevice corrosion, stress corrosion, Hydrogen embrittlement, sulphate attack, etc.), Oxidation, Pilling Bedworth ratio, corrosion of steel, Al, and concrete, microbial corrosion

Corrosion Protection: [1 lecture] Cathodic and anodic protection, Inhibitors, coatings

Textbook

1. Fontana, M.G., (2017) *Corrosion Engineering*, 3rd Edition, McGraw Hill

Reference Books

1. Ahmad, Z., (2006), *Principles of Corrosion Engineering and Corrosion Control*, Elsevier
2. Revie, W.R., Uhlig, H.H., (2008) *Corrosion and Corrosion Control*, 4th edition, Wiley

Online Course Material

1. Natarajan, K.A., Advances in Corrosion Engineering, Department of Materials Engineering, IISc Bangalore,http://nptel.ac.in/courses/113108051/
2. Mondal, K., Corrosion I, Department of Material Science and Engineering, Indian Institute of Technology, Kanpur,https://nptel.ac.in/courses/113/104/113104082/

Title	**Electronics Materials**	Number	**PHL2XXX**
Department	Physics	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Elective
Prerequisite	Basic knowledge of Electromagnetism		

Objectives

The Instructor will:

1. Introduce materials used for application in electronics
2. Demonstrate importance of semiconductor materials in operation of computers
3. Provide brief description of novel materials designed for future applications

Learning Outcomes

The students will have the ability to:

1. Understand the role of materials in Electronics and Computer Engineering applications
2. Learn the process of Material selection in specific applications

Contents

Fractal1:PHL2XX1 Electronics Materials (1-0-0)

Classification of Materials [2 Lectures]: Materials fordevices (Electrical, Electronics, Magnetic, Optical and
Mechanical properties); Electronics materials (diodes, transistors, FET (MOSFET, MESFET) and IC)

Microprocessor Material [5 Lectures]: Moore's law, Early development of Transistor and IC, CMOS Technology,
Device scaling, Why silicon (Structural, Electronic, Mechanical, Thermal and Chemical properties), III-V and II-VI
semiconductors for transistors, Advantages and disadvantages over Si, High electron mobility transistors (HEMT)

Materials for GATE oxide and interconnects [5 Lectures]: Dielectric constant and GATE oxide, Silicon dioxide, Silicon
Oxynitride, Scaling, Oxide reliability and leakage, High k-Dielectrics, Issues with high k-dielectrics, Au, Al, Al alloys
and Cu interconnects, Silicide and Nitrides

Future electronics materials [2 Lectures]: Carbon nanostructures (nanotubes, graphene), 2D materials.

Text Book

1. Miller, L. S. and Mullin, J.B. (Editors), Electronic Materials from Silicon to Organics, Springer Science 1991
2. Gupta, K.M. and Gupta, N., Advanced Electrical and Electronics Materials, Scrivener Publishing, 2005

Reference Books

1. Huff, H.R. and Gilmer, D. C. (Editors), High Dielectric constant materials, Springer 2005
2. Lallert, M. (Editor), Ferroelectrics - Application, Intech Web, 2011

Self-Learning Material

Swaminathon, P., IIT Madras, Fundamental of Electronics Materials and Devices,NPTEL course https://nptel.ac.in/courses/113106062/

Title	**Magnetic Materials**	Number	**PHL2XXX**
Department	Physics	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Elective
Prerequisite	Basic knowledge of Electromagnetism		

Objectives

The Instructor will:

1. Introduce materials used for application in magnetism
2. Demonstrate importance of magnetic materials in operation of computers and electrical devices
3. Provide brief description of novel materials designed for future applications

Learning Outcomes

The students will have the ability to:

1. Understand the role of materials in Electronics and Computer Engineering applications
2. Learn the process of Material selection in specific applications

Contents

Fractal1:PHL2XX2 Magnetic Materials (1-0-0)

Classification of Magnetic Materials [5 Lectures]: Dia, Para, Ferro-, Antiferro- and Ferrimagnetic materials, Hysteresis and Susceptibility, Domains and domain walls, Magnetism in metals, semiconductors, amorphous materials, alloys and composites, soft and hard magnets, Transformers and Permanent magnets

Materials for Data storage [4 Lectures]: Evolution of Magnetic Data storage, Magnetic Read and Write head, Magnetic sensor materials, Giant and Tunnel magnetoresistance, Density of storage and scaling, Superparamagnetism, Future trends in magnetic data storage

Emerging Magnetic and Superconducting materials [5 Lectures]: Spintronics materials and application, Magnetic shape memory alloys, Superconductivity, Meissner effect, Type -I and Type-II superconductors, Ceramic superconductors, Superconducting magnets, Levitation, Superconducting qubits, Josephson junction

Text Book

1. Lacheisserie, E., Gignoux, D. and Schlenker, M., Magnetism Materials and Application Vol II, Springer, 2005
2. Gupta, K.M. and Gupta, N., Advanced Electrical and Electronics Materials, Scrivener Publishing, 2005

Reference Books

1. Coey, J. M. D., Magnetism and Magnetic Materials, Cambridge University Press 2009
2. Kittel, C., Introduction to Solid State Physics, Wiley 2007
3. Cullity, B. D., Graham, C. D., Introduction to Magnetic Materials, Wiley 2008

Self-Learning Material

1. O'Handley, R. MIT Course Number 3.45, Magnetic Materials https://ocw.mit.edu/courses/materials-science-and-engineering/3-45-magnetic-materials-spring-2004/readings/

Title	***Colloids and Suspensions***	Number	CYL2XX1
Department	Chemistry	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objectives

1. To teach relevant theories and methodological tools in interfacial science

Learning Outcomes

1. Understanding the properties and composition of colloids and suspensions
2. Applications of colloids

Contents

Introduction to Colloids and surfactants (5 lectures): Classification, properties and stabilities of colloids, Brownian motion, Osmotic pressure, characterization of colloids; properties and classification of surfactants, micelles, Bilayers, liposomes and vesicles, Hydrophilic-lipophilic balance.

Surface and Interfacial Tension (4 lectures): Concepts of surface and interfacial energies and tensions; measurement-techniques, Stability of equilibrium solutions, Contact angle analysis on solid and liquid surfaces, free energies of adhesion

Intermolecular andSurface Forces (5 lectures): van der Waals force between macroscopic bodies in electrolyte solutions, charged interaction between surfaces , Gouy Chapman Theory, charge Density, forces between two particles, Zeta potential

Textbooks

1. Hunter, R. J., *Foundations of Colloid Science,* (2001), 2nd Edition, Oxford University Press, 2001

Reference Books

1. Babick, F.,*Suspensions of Colloidal Particles and Aggregates*, (2016), 2nd edition, Springer International Publishing, 2016
2. Hiemenz, P. C., and Rajagopalan, R*., Principles of Colloid and Surface Chemistry*, (2016), 3rd edition., CRC Press, 2016

Self Learning Material

1. Bhaskarwar, A. N., Interfacial Engineering, NPTEL Course Material, Department of Chemical Engineering, IIT Delhi, Link https://www.youtube.com/watch?v=pAY-sfMs2h4&list=PLbMVogVj5nJSDFd-zudqQUyhJI0ZNdkC-