DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

(Academic-PG)

Scheme for Full Time M. Tech. C&I as per NEP-2020

SEMESTER I					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I501	System Theory	4	3-0-2	24	500-599*
C&I505	Non Linear Control Theory	4	3-0-2		
C&I507	Analog and Digital Electronics	4	3-0-2		
C&I509	SCADA and EMS	4	3-0-2		
C&I531	Departmental Elective 1	4	3-1-0/3-0-2		
C&I525	Self-Study	2	-		
C&I523	Skill Enhancement Course 1	2	-		
UEC501	Audit Course	0	0-0-2		
SEMESTER II					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I502	Intelligent Control	4	3-0-2	24	500-599*
C&I504	Process Control	4	3-0-2		
C&I532	Departmental Elective 2	4	3-1-0/3-0-2		
C&I534	Departmental Elective 3	4	3-1-0/3-0-2		
UCC502	Research Methodology	4	2-0-4		
C&I546/ C&I548	Skill Enhancement Course 2/Industrial Training	4	-		
	NHEQF Level				6.5
SEMESTER III					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I601	Intelligent Instrumentation	4	3-1-0	16	600-699*
UEC601	Open Elective 1	4	3-1-0		
C&I603	Minor Project/Research Thesis/Patent	8	0-0-8		

*: Refer Draft UGC Curriculum and Credit Framework for PG Programmes

SEMESTER IV					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	
C&I602	Major Project/Research Thesis/Patent	16	-	16	-
	NHEQF Level				7.0

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-42
(Academic-PG)
Scheme for Part Time M. Tech. C&I as per NEP-202

SEMESTER I					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I501	System Theory	4	3-0-2	12	500-599*
C&I505	Non Linear Control Theory	4	3-0-2		
C&I507	Analog and Digital Electronics	4	3-0-2		
SEMESTER II					
	Type	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I502	Intelligent Control	4	3-0-2	12	500-599*
C&I504	Process Control	4	3-0-2		
C&I532	Departmental Elective 2	4	3-1-0/3-0-2		
	NHEQF Level				6.5
SEMESTER III					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I509	SCADA and EMS	4	3-0-2	12	600-699*
C&I531	Departmental Elective 1	4	3-1-0/3-0-2		
C&I525	Self-Study	2	-		
C&I523	Skill Enhancement Course 1	2	-		
UEC501	Audit Course	0	0-0-2		

*: Refer Draft UGC Curriculum and Credit Framework for PG Programmes

SEMESTER IV					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I534	Departmental Elective 3	4	3-1-0/3-0-2	12	500-599*
UCC502	Research Methodology	4	2-0-4		
C&I546/ C&I548	Skill Enhancement Course 2/Industrial Training	4	-		
	NHEQF Level				6.5
SEMESTER V					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I601	Intelligent Instrumentation	4	3-0-2	16	600-699*
UEC601	Open Elective 1	4	3-1-0		
C&I603	Minor Project/Research Thesis/Patent	8	0-0-8		
SEMESTER VI					
Code	**Type**	**Cr**	**L-T-P**	**Total Credits**	**Level**
C&I602	Major Project/Research Thesis/Patent	16	-	16	-
	NHEQF Level				7.0

List of Elective Courses

Course Name	Type	Cr	L-T-P
Departmental Elective 1 1. Modelling Identification and Control 2. Optimal Control Theory 3. Microcontroller and Embedded System 4. Soft Computing Techniques 5. Nature Inspired algorithms 6. Stochastic Control	Elective	4	**3-1-0/3-0-2**
Departmental Elective 2 1. Advanced Control System Design 2. Robust Control 3. Bio Engineering and Control 4. Special Topics in Control System 5. Robot Dynamics & Control 6. Random Processes in Control & Estimation	Elective	4	**3-1-0/3-0-2**

Departmental Elective 3 1. Networked Control System 2. Analog Filter Design 3. Digital Instrumentation 4. Instrumentation Transducers 5. Biomedical Instrumentation 6. Electrical Energy Storage Systems	Elective	4	**3-1-0/3-0-2**

List of Open Elective Courses

Course Name	Type	Cr	L-T-P
Open Elective 1 1. Machine Learning	Open Elective	4	**3-1-0**

Note: A student must earn at least 08 credits from 04 credit elective courses and at least 06 credits form 03 credit elective courses form a basket of electives specific to that programme. The remaining credits may be earned from electives offered for other programmes including Massive Open Online Course's (MOOC). In case of MOOC's only 02 credits per MOOC course will be considered.

Course Evaluation

Evaluation in each course is based on the weights assigned to the various components of the course curriculum. These components are designated as under.

CWS	Class work sessional
MTE	Mid-term examination
ETE	End term Examination
PRS	Practical sessional
PRE	Practical Examination

Total credits	**L**	**T**	**P**	**TH**	**PR**	**CWS**	**MTE**	**ETE**	**PRS**	**PRE**
4	3	0	2	Yes	Yes	10	25	50	-	15
3	3	0	0	Yes	No	20	30	50	-	-
2	2	0	0	Yes	No	20	30	50	-	-
24	0	0	24	No	Yes	0	0	60	40	0
12	0	0	12	No	Yes	0	0	100	-	0

Syllabus of Core Courses

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 501	System Theory	4	3	0	2	10	15	25	50	-

Concept of state, state variable and state vectors. State variable modelling of Electrical, Mechanical & Electromechanical Systems. Sampler & Zero-order hold device, Discrete time response of sampled- data control systems, Z-Transform and its properties, Jury's stability test, stability via Z-plane and bi-linear transformation. Phase variable, canonical variable forms, evaluation of state transition matrix, properties of state transition matrix, solution of state equations of linear time invariant and time variant continuous and discrete time systems. Concepts of controllability and observability, controllability test, observability test, observer design, observer-based controller design, reduced order observer design. Ackermann's formula, Pole assignment by state feedback using Ackermann's formula.

Suggested Readings:

1. J.P. Hespanha, " Linear Systems Theory", Second Edition, Princeton University Press, 2018.
2. C. T. Chen," Linear System Theory and Design", Third Edition, Oxford University Press.
3. M.Gopal, "Digital Control and State Variable Methods", McGraw Hill Education (India) Private Limited, 2015.
4. P.J. Antsaklis and Anthony N. Michel, "A Linear Systems Primer", Birkhauser, 1997.
5. R. W. Brockett, "Finite Dimensional Linear Systems", John Wiley and Sons, 1970.
6. T.M Apostol, "Mathematical Analysis", Second Edition, Narosa Publishing House, 1996.
7. Michael Spivak, "Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus", CRC Press, 1971.
8. P.R. Halmos, D Van Nostrand Company, "Finite-dimensional Vector Spaces", Princeton University Press, 1942.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5303	Nonlinear Control Theory	3	3	0	0	20	-	30	50	-

Introduction to non-linear systems and their behavior, multiple equilibrium points, limit cycles. nonlinear system analysis, phase-plane analysis, isoclines method and delta method. Concept of singular points and their analysis, existence of limit cycles. Describing function analysis, describing function of common non-linearities. Stability analysis of nonlinear system using describing function, dual input describing function, perturbation theory and perturbation dynamics. Lyapunov's methods, krasovski method, variable gradient method. advanced stability criterion, Lyapunov analysis of non-autonomous systems. Lyapunov's direct method of stability, absolute stability and Popov's criterion.

Suggested Readings:

1. D.P. Atherton, "Nonlinear control Engineering", First Edition, Van Nostrand Reinhold, 1975.
2. D.P. Atherton, "Stability of Nonlinear system", First Edition, John Wiley & Sons, 1981.
3. W.J. Cunningham, "Introduction to Nonlinear Analysis", First Edition, McGraw-Hill, 1958.
4. J.E. Gibson, "Nonlinear, Automatic Control", First Edition, Tata McGraw-Hill, 1964.
5. W. Hahn, "Theory and Application of Lyapunov's Direct Method", First Edition, Prentice-Hall, Englewood Cliffs, 1963.
6. R.R. Mohler, "Nonlinear Systems: Dynamics and Control", Prentice-Hall, Englewood Cliffs, 1990.
7. Mark W. Spong, and M. Vidhyasagar, "Robotic Dynamics and Control", Prentice Hall, Englewood Cliffs, 2008.
8. M. Vidhyasagar, "Nonlinear System Analysis", Second Edition, Prentice-Hall, Englewood Cliffs, 2002.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5401	Analog and Digital Electronics	4	3	0	2	10	15	25	50	-

Linear circuits: Basic circuits using op-amps like non-inverting/inverting amplifiers, differential and instrumentation amplifiers, integrator, practical integrators, differentiator, current sources for floating and grounded loads, negative impedance converter, generalized impedance converter. Real op-amp performance parameters, static limitations, dynamic limitations, input-output swing limitations, compensation techniques. Applications in Non-linear circuits , Comparators, Schmitt trigger, precision rectifier. log/antilog amplifiers, analog multipliers, ADC and DAC circuits, combinational circuits, Latches, racing, master salve flip-flops,D-flip flop, characteristic equations, sequential circuits, multiplexer, demultiplexer

Suggested Readings:

1. Sergio Franco, "Design with Operational Amplifiers and Analog Integrated Circuits", Third Edition, Tata McGraw-Hill, 2017
2. George Clayton and Steve Winder, "Operational Amplifiers", Fifth Edition, EDN Series foe design Engineers, 2003.
3. John F. Wakerly, "Digital design", Fourth Edition, Prentice Hall, 2000.
4. Sedra and Smith, "Microelectronic circuits", Seventh Edition, Oxford Publication, 2017.
5. Donald A Neamen, "Electronic circuit analysis and design", Third Edition, Tata McGraw-Hill, 2006.
6. Ramon Pallas Areny, "Analog signal processing", Wiley Publications, 2011.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 509	SCADA & EMS	4	3	0	2	15	25	20	40	-

Evolution of SCADA, SCADA Architecture, SCADA components (MTU, RTU, Communication system, Field devices), Communication technologies, communication networks, Message format, IEEE C.37, Error detection and correction, Transmission media for SCADA. RTU Components, Data Acquisition, Data Processing, Data Monitoring, Time Tagged Data, Alarms and Event Processing, Regulatory Functions, Intelligent Electronics Devices (IED), PLC, Transducers, Voltage to current/ current to voltage converters. Operator Interface, VDU Displays and its Uses, Alarms and their Treatment at MTU, Process Configuration in MTU (Pipe line system, Transmission system etc) Master Station Performance, Reliability, Typical SCADA Configuration, Database Management System, Real Time Operational Requirements. OSI seven-layer model, TCP/IP model, Ethernet, CSMA/CD, SMTP, HTTP, Field bus protocol, DNP3, Modbus -ASCII/ RTU, Profibus-DP/AP, CAN, IEC-61850, security aspects. Overview of Power System, General hierarchical structure of power system. Generation, Transmission and Distribution Functions performed at the centralized management system, Regional Grid in India- overview, Real time network modeling, Security management, Production control, Training simulator.

Suggested Readings:

1. Stuart A. Boyer, “SCADA: Supervisory Control and Data Acquisition”, ISA Publisher, 2010
2. Torsen Cegrell, “Power System Control Technology”, Prentice- Hall, 1986
3. Behrouz A. Forouzan, “Data Communication and Networking”, Mc- Graw Hill, 2007
4. Krishna Kant , “Computer based Industrial Control”, PHI, 2004
5. George L. Kusic, “Computer Aided Power System Analysis”, CRC Press, 1986
6. Mini S. Thomas, John D.McDonald, “Power System SCADA and Smart Grids”,CRC Press, 2015
7. Terry Bartelt, “Industrial Control Electronics: Devices, Systems and Applications”, Delmar, Thomson Learning, 2002

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 502	Intelligent Control	4	3	0	2	10	15	25	50	-

Norms of signals, vectors and matrices, positive definite, negative definite, positive semi definite and negative semi definite functions. Nonlinear control strategies, State feedback linearization systems. Crisps & Fuzzy sets, Fuzzy logic, Types of Membership function, Basic fuzzy set operation, Fuzzification, Defuzzification, Rule Base, & Fuzzy Inference System, Fuzzy logic control using Mamdani model. Implementation of fuzzy logic controller using Matlab, fuzzy-logic toolbox. Stability analysis of fuzzy control systems. Biological neuron, Artificial neuron, types of activation function, training of NN, Feedforward NN, ANFIS, Neural Networks in system identification and control, control of non linear system using neural network toolbox, inverse neural network control, and adaptive control using neural networks.

Suggested Readings:

1. B. Kosko, “Neural Networks and Fuzzy Systems: A Dynamical Approach to Machine Intelligence”, First Edition, Prentice-Hall of India Pvt. Ltd, 1991.
2. J.S.R Jang, C.T. Sun, E. Mizutani, “Neuro-fuzzy and soft Computing”, First Edition, Pearson Education, 1997.
3. L. Behera, I. Kar, “Intelligent Systems and Control”, Oxford Higher Education, 2009.
4. Omid Omidvar and L. Elliott David, “Neural Systems for control”, First Edition, Academic Press Limited, 1997.
5. C.T. Lin and C.S.G. Lee, “Neural Fuzzy Systems”, First Edition, Prentice Hall PTR, 1996.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 504	Process Control	4	3	0	2	10	15	25	50	-

Introduction to process control, models of industrial process, hydraulic tanks, fluid flow systems, mixing process, chemical reactions, thermal systems-heat exchangers and distillation column. Basic control action-on/off, P, P+I, P+I+D, floating control, pneumatic and electronic controllers, controller tuning, time response and frequency response methods , non-linear controllers, inverse time response of system, effect of pole and Zero on right hand side of s-plane, feed forward and multivariable control. Evolution of PLC, sequential and programmable controllers, architecture, Programming of PLC, relay logic and ladder logic, functional blocks, communication networks for PLC, field bus such as profi-bus, mod-bus etc.

Suggested Readings:

1. Stephanopolus George, “Chemical Process control: An Introduction to Theory and Practice”, First Edition, Prentice Hall India, 1983.
2. P. Harriot, “Process control”, Tata McGraw-Hill, 2012.
3. Norman A Anderson, “Instrumentation for process measurement and control”, Third Edition, CRC Press LLC, 1998.
4. Dale E. Seborg, Thomas F Edgar, Duncan A Mellichamp, “Process dynamics and control”, Third Edition, Wiley John and Sons, 2011.
5. T.E. Marlin, “Process control”, Second edition, McGraw hill, 2000.
6. M.P Lucas, “Distributed Control System”, First Edition, Van Nostrand Reinhold Co. 1986.
7. Pertrezeulla, “Programmable Controllers”, Fourth Edition, McGraw-Hill, 2016.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5402	Intelligent Instrumentation	4	3	0	2	10	15	25	50	-

Transducers & its classifications, Fiber optics sensors, measurement of pressure, temperature, current, voltage, liquid level and strain. Laser for measurement of distance, length, velocity, acceleration, current, voltage, atmospheric effect. Telemetry: General telemetry system, land line & radio frequency telemetering system, transmission channels and media, receiver & transmitter. Data Acquisition System: A/D and D/A converters, Analog data acquisition system,

digital data acquisition system, modern digital data acquisition system and signal conditioning. Microprocessor Based Instrumentation, Hardware and firmware components of a microprocessor system – micro controllers – multiple processors, calibration and correction, computer interface, embedded programming issues. Virtual Instrumentation, Block diagram and architecture of the virtual instrumentation. Smart sensors, smart transmitters, process instrumentation diagrams.

Suggested Readings:

1. P W Chapman, "Smart sensors", First Edition, ISA Publications, 1996.
2. John F Ready, "Industrial applications of Lasers", Second Edition, Academic press, 1997.
3. Jasprit Singh, "Semiconductor optoelectronics: Physics and Technology", First Edition, McGraw Hill, 1995.
4. Clyde F. Coombs, "Electronic instrument handbook", Third Edition, McGraw Hill, 1994.
5. Lisa K.Wells & Jeffery Travis, "Lab view for every one", Third Edition, Prentice Hall, 2006.
6. Sokoloff, "Basic concepts of Lab view 4", First Edition, Prentice Hall, 1998
7. A.K. Sawhney, "Advanced Measurements & Instrumentation", 4th Edition, Dhanpat Rai & Sons, 2010.

Syllabus of Departmental & Open Elective Courses

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5406	Modelling, Identification and Control	4	3	0	2	10	15	25	50	-

Random variables and process, stochastic processes, properties, mean, variance, correlation, spectral density. Problem formulation for identification & estimation. Review and realization of continuous and discrete, state space and input-output, disturbance models, inverse response system dynamics. Parameter estimation, linear regression models, multiple regression model, ARMA models, experimental techniques. Online identification techniques, development of 'Least Squares' regression, exponentially mapped estimates. Discrete design methods, Functional models of computer process control systems, RTOS, input-output systems, functions of the computer process control system, techniques for developing physical process models, Position, velocity, dead beat, ringing and Dahlin algorithms.

Suggested Readings:

1. Ljung, “System Identification theory for the user”, Fifth Edition, Prentice Hall of India, 2001.
2. Rolf. Johansson, “System Modelling and Identification”, First Edition, Prentice Hall of India, 1993.
3. Astrom and Wittenmark, “Adaptive Control”, Second Edition, Prentice Hall of India, 1995.
4. Willam S.Levine, “Control Hand Book”, Second Edition, CRC Press, 2010.
5. Narendra and Annasamy, “Stable Adaptive Control System”, Dover Publications, 2005.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5308	Optimal Control Theory	3	3	0	0	20	-	30	50	-

Introduction, Statement of optimal control problem, problem formulation and forms of optimal control, selection of performance measures. Maximization of functionals of a single and several functions using calculus of variations, Constrained extremals, Euler-Lagrange Equation, Necessary conditions for optimal control, Pontryagin’s minimum principle, state inequality constraints, minimum time problem, minimum control effort problem, LQR problems and dynamic programming. Linear optimal regulator problem, matrix Riccatti equation and solution method, linear tracking problem, – LQG problem, dynamic programming, application to discrete and continuous systems, – Hamilton Jacobi Bellman equation, numerical Techniques for Optimal Control.

Suggested Readings:

1. D.E. Kirk, “Optimal Control Theory: An Introduction”, First Edition, Dover Publications Inc., 2004
2. D.S. Naidu, ”Optimal Control Systems”, CRC Press, 2002.
3. A.P. Sage, “Optimum System Control”, Second Edition, Prentice Hall, 1997.
4. BD.O. Anderson and J.B. Moore, “Optimal Filtering”, Second Edition, Dover Publications, 2005.
5. S.M. Bozic, “Digital and Kalman Filtering”, First Edition, Edward Arnould, London, 1979.
6. D. Liberzon, "Calculus Of Variations and Optimal Control Theory: A Concise Introduction", 1Princeton University Press, Dec 2011.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I6405	Microcontroller & Embedded Systems	4	3	0	2	10	15	25	50	-

Organization of a microprocessor, register organization, C.P.U. Description of timing and control units, interfacing memory & I/O devices Synchronous & Asynchronous data transfer,

Interrupt, Polling, DMA, Introduction to Pentium and Pro-Pentium microprocessor. Basic organization of 8051, 8097, MC68HC11, PIC16CXX, SLK-51 microcontrollers, instruction set- timing diagram, address modes, simple program and applications. Embedded system and their components, categories of embedded systems. Stand alone, Real time Networked and Mobile etc., Requirements of embedded systems. Reliability, cost effectiveness, low power consumption, efficient use of processing power, efficient use of memory, approximate execution time, challenges and issues in embedded software development. Co design operating system, efficient I/O testing and debugging. Hardware Architecture for embedded systems. Embedded Applications.

Suggested Reading:

1. D.V. Hall, "Microprocessors-Principles & Applications", Second Edition, TMH, 2005.
2. Ramesh Gaonkar, "Microprocessor Architecture, Programming and Applications with 8085", Sixth Edition, Penram Publications, 2013.
3. John B. Peatman, "Design with PIC Microcontrollers", First Edition, Pearson Education, Asia, 1987.
4. Michael Kheir, "The M68HC11 Microcontrollers", Application in control, Instrumentation and communication", First Edition, Prentice Hall, New Jersey, 1996.
5. John B. Peatman, "Design with Microcontrollers", First Edition, McGraw Hill, 1988.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5407	Soft Computing Techniques	4	3	0	2	10	15	25	50	-

Introduction to neural network, Learning schemes, supervised, unsupervised learning, incremental and batch training, backpropagation algorithm, the perceptron neural network, multilayer perceptron, radial basis function networks, self-organizing map, Elman networks, Jordan networks etc., & applications of neural network.

Basic concept of Genetic algorithm and detailed algorithmic steps. Solution of typical control problems using genetic algorithm. Concept of some other search techniques like tabu search, ant-colony search, etc.

Support Vector Machine, SVM Classifier, Objectives, function and characteristics of SVM. Advantages and Disadvantages of SVM. Deep Learning, Convolutional Neural Network, LSTM networks & Recurrent Neural Network.

Suggested Readings:

1. D.K Pratihar, "Soft Computing Techniques", First Edition, Alpha Publications, 2013
2. Jacek M. Zuarda, "Introduction to Artificial Neural Systems ", Jaico Publishing House, 1997.
3. Sudarshan K. Valluru, T.N Rao, "Neural Networks, Fuzzy Logic and Genetic Algorithms", First Edition, Jaico Publishing House, 2010.
4. G.J. Klir & T.A. Folger, "Fuzzy sets, uncertainty and information", First Edition, Prentice-Hall of India, 1988.
5. H.J. Zimmerman, "Fuzzy set theory-and its Applications", Fourth Edition, Kluwer Academic Publishers, 2001.

6. Driankov, Hellendron, “Introduction to Fuzzy Control”, Second Edition, Narosa Publishers, 1996.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5202	Nature Inspired Algorithms	2	2	0	0	20	-	30	50	-

Introduction to single and multi-objective optimization, multi agent artificial life worlds, particle Swarm optimization, ant colony optimization, evolutionary computation, genetic algorithms, simulated annealing, evolution strategies, bacterial foraging algorithm, Teaching-Learning Based Optimization(TLBO), evolution and adaptation of intelligent agents. Applications of nature inspired algorithms in control and optimization. Recent trends in Nature Inspired algorithms.

Suggested Readings:

1. L de Castro, “Fundamentals of Natural Computing”, First Edition, CRC Press. Chapman & Hall, 2006ISBN1-58488-643-92, 2006.
2. A. Eiben & J Smith, Introduction to Evolutionary Computing, Springer, 2015.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 6303	Stochastic Control	3	3	0	0	20	-	30	50	-

Random variables, Stochastic Processes and their properties, Probability density functions. Moments Ergodic hypothesis and ensemble averages, correlation functions and power spectral density functions. M.S.E. minimization, Filtering and prediction problems, Wiener-Hopf equation, Frequency domain system design.

Suggested Readings:

1. A.P. Sage, “Optimal System Control”, Second Edition, Prentice Hall, 1977.
2. J.H. Laning and R.H. Batin, “Random Signals in Automatic Controls”, Tata McGraw Hill
3. G.C.Newton, L.A. Gonld, J.F. Kaiser, “Analytical design of feedback control systems”, First Edition, John Wiley, 1957
4. J.S. Meditch, “Stochastic Optimal Linear Estimation & Control”, First Edition, Tata McGraw Hill, 1969.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 6309	Advanced Control System Design	3	3	0	0	20	-	30	50	-

Review of sample and hold devices, Reconstruction, Z transform – Properties – Pulse transfer function and state variable approach – Review of controllability and observability. Pole

placement design. Full order observer, Reduced order observer. Computer Based Control, Mechanization of control algorithms – PID control, tuning methods of PID controller. Optimal Controller Design, Statement of optimal control problem- Solution using variational approach- Ricatti equation- -Infinite time problems, Linear regulator Problem, ARE equation, Introduction to robust control, Slide mode control, H ∞ and H-2 control, Model reference control and Adaptive control.

Suggested Readings:

1. Gopal. M., "Digital control Engineering", Wiley Eastern Ltd.
2. G.F. Franklin, J.David Powell, Michael Workman, "Digital control of Dynamic Systems", 3rd Edition, Addison Wesley.
3. Paul Katz, "Digital control using Microprocessors", Prentice Hall.
4. Forsytheand. W. Goodall. R.N., "Digital Control", McMillan.
5. Chesmond, Wilson, Lepla, "Advanced Control System Technology", Viva – low price edition.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5207	Robust Control	2	2	0	0	20	-	30	50	-

Classical control, root locus, Nyquist plots, Modelling of uncertain systems(structured and unstructured), Signals & Norms, Robustness and Disturbance rejection in SISO systems. Multivariable linear systems, continuous time state space models, discrete time state models. Transfer functions, frequency response, poles, zeros and modes. Stability, change of basis, controllability, observability and observer feedback. Performance measures, general models of feedback control systems. Robustness, internal stability, robustness analysis of structured and unstructured uncertainty models. H∞ control, Mixed-sensitivity control, H∞ estimation, h∞ output feedback, finite time control, steady state control and μ synthesis, LMI for robust control, Ricatti equations through LMI,

Suggested Readings:

1. J. B. Burl, Linear Optimal Control H2 and H∞ Methods, Addison Wesley, California, US, 1999.
2. K. Zhou, J. C. Doyle and K. Glover, Robust and Optimal Control, Prentice-Hall, 1999.
3. S. Skogstad and I. Postlethwaite, Multivariable Feedback Control, John Wiley and Sons, 2005.
4. T. Glad and L. Ljung, Control Theory: Multivariable and Non-linear methods, Taylor and Francis, London, 2009.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE

C&I 5203	Bio Engineering & Control	2	2	0	0	20	-	30	50	-

Basic components of bio-medical instruments, bio-electric signals & recording electrodes, transducers, recording and display devices. Patient care and monitoring systems, cardiovascular measurements-blood pressure, blood flow, cardiac output, and heart sounds etc. Instrumentation for respiratory and nervous systems, analysis of EEG, ECG, EMG, EOG and action potentials, non-invasive diagnostic measurements- temperature, ultrasonic diagnosis, CAT scan techniques, sensory measurements motor response, analysis of behavior etc. biotelemetry, biofeedback, clinical laboratory instruments and X-ray diagnosis. Recent advances in biomedical instrumentation microprocessor based system, lasers & optical fiber based systems.

Suggested Readings:

1. R. S. Khandpur, "Handbook of Analytical Instruments", Third Edition, Tata McGraw-Hill, 2015.
2. D.E. Dean, A. Marre, "Bio-Electronic Measurements", First Edition, Prentice Hall, 1983.
3. A li Evans, "The Evaluation of Medical Images", First Edition, CRC Press, 1981
4. John G. Webster, "Medical Instrumentation application and design", Fourth Edition, John Wiley and Sons, 2009.
5. L. Cromwell., Fred J. Weibell, "Bio medical Instrumentation and measurements", Second Edition, Prentice Hall, 1990.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5208	Special Topics in Control Systems	2	2	0	0	20	-	30	50	-

Introduction to advanced control techniques, Norms of vectors & matrices, Linear quadrature regulator (LQR), Kalman Filter, LQG, H-2 Control, H-Infinity Control, Mixed Sensitivity Control, Glover-Macfarlane 2-DOF Control, mu-synthesis control, Model based control, direct synthesis control, internal model control (IMC), generic model control, model reference adaptive control(MRAC), model reduction techniques.

Suggested Readings:

1. D.E. Kirk, "Optimal Control Theory: An Introduction", First Edition, Dover Publications Inc., 2004
2. J. B. Burl, Linear Optimal Control H2 and H∞ Methods, Addison Wesley, California, US, 1999.
3. K. Zhou, J. C. Doyle and K. Glover, Robust and Optimal Control, Prentice-Hall, 1999.
4. S. Skogstad and I. Postlethwaite, Multivariable Feedback Control, John Wiley and Sons, 2005.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 6301	Robot Dynamics & Control	3	3	0	0	20	-	30	50	-

Introduction, Geometric configuration of robots. Robot arm Kinematics: Direct and inverse kinematics – Rotation Matrices – Composite rotation matrices – Euler angle representation – Homogenous transformation – Denavit Hattenberg representation and various arm configuration. Robot Arm Dynamics, Lagrange – Euler formulation, joint velocities – Kinetic energy – Potential energy and motion equations – Generalised D'Alembert equations of motion. Planning of Manipulator Trajectories, General consideration on trajectory planning joint interpolation & Cartesian path trajectories. Control of Robot Manipulators, PID control computed torque technique – Near minimum time control – variable structure control – Non-linear decoupled feedback control – Resolved motion control and adaptive control.

Suggested Readings:

1. Fu, K.S. Gonazlez, R.C. and Lee, C.S.G., "Robotics (Control, Sensing, Vision and Intelligence)", First Edition, McGraw-Hill, 1987.
2. Wesley, E. Snyder, "Industrial Robots: Computer interfacing and Control", First Edition, PHI, 1985.
3. Asada and Slotine, "Robot Analysis and Control", First Edition, John Wiley and Son, 1986.
4. Philippe Coiffet, "Robot Technology" Vol. II (Modelling and Control), First Edition, Prentice Hall INC, 1983.
5. Saeed B. Niku, "Introduction to Robotics, Analysis, systems and Applications", First Edition, Pearson Education, 2001.
6. Groover M.P. Mitchell Wesis., "Industrial Robotics Technology Programming and Applications", First Edition,Tata McGraw-Hill, 1986.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5301	Random Processes in Control & Estimation	3	3	0	0	20	-	30	50	-

Random variables and processes, Weiner's theory of optimization. Basic concepts of estimation and various types of estimates, applications of Weiner's theory of compensator design for feedback control system. Gauss-Markov model for vector random Processes, Kalman filtering, minimum variance Introduction, Statement of optimal control problem-Problem formulation and forms of optimal control-Selection of performance measures.

Suggested Readings:

1. D.E. Kirk, "Optimal Control Theory: An Introduction", First Edition, Dover Publications Inc., 2004
2. A.P. Sage, "Optimum System Control", Second Edition, Prentice Hall, 1997.
3. BD.O. Anderson and J.B. Moore, "Optimal Filtering", Second Edition, Dover Publications, 2005.

4. S.M. Bozic, “Digital and Kalman Filtering”, First Edition, Edward Arnould, London, 1979.
5. K.J. Astrom, “Introduction to Stochastic Control Theory”, 56.52 Edition, Academic Press, 2006.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5205	Networked Control System	2	2	0	0	20	-	30	50	-

Overview of Networked Control System (NCS), Communication Systems Models, Control Systems Models, Models of NCS, Applications, Analysis and design of simple NCS, Discussion and analysis of current state-of-the-art approaches in NCSs, Trends in NCS.

Suggested Readings

1. Analysis and Design of Networked Control Systems (Chapters 1-8)
2. Communication and Control for Networked Complex Systems (Chapters 1,2)
3. Distributed Decision Making and Control (Chapter 3)
4. [Journal paper] The Wireless Control Network- A New Approach for Control Over Networks
5. Handbook of Networked and Embedded Control Systems (Parts I,IV)

1Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5306	Analog Filter Design	3	3	0	0	20	-	30	50	-

Introduction to modern active building blocks used in Analog Filters: Current Conveyors, Operational Transconductance Amplifiers, Current Feedback Amplifiers, OTRAs, CDBAs and other modern devices. First order filters, Realization with passive elements, realization with active elements, cascaded design, Second order active filters, design parameters, the 2nd order circuits, KHN, Bi quads, S & K Biquads, SAB biquads and GIC circuits. LP filters with maximally flat and equal ripple response, inverse chebyshev and cauer filter. Frequency transformation: LP-HP, LP-BP, LP-BE, etc. LG, Ladder filters, Ladder Simulation by element replacement, GP embedding technique, FDNR technique, creation of negative components, Gm-C & switched capacitor filters, sensitivity considerations.

Suggested Readings:

1. R. Schaumann & M.E. Vanvalkenburg, “Design of Analog Filters”, First Edition, Oxford, 2001.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE

C&I6407	Digital Instrumentation	4	3	0	2	10	15	25	50	-

Signals from process instrumentation, signal conditioning for the control computer, signal transmission, time division multiplexing, signal termination. Digital control loop, analysis of block diagrams, stability systems with dead time. The computer control system. CPU, relationship of word length to performance, peripheral devices, optimization/control of a distillation column, control algorithms, Dahlin's method, and standard algorithms. PC based industrial process measurements like flow, temperature, pressure and level – PC based instruments development system. Concept of Supervisory control & Data Acquisition System, Component and types of SCADA systems, CT, PT, Voltage to current, current to voltage converters, RTUs etc.

Suggested Readings:

1. Kevin M. Daugherty, "Analog – to – Digital conversion – A Practical Approach", First Edition, McGraw Hill International Editions, 1993.
2. N. Mathivanan, "Microprocessors, PC Hardware and Interfacing", Prentice – Hall of India Pvt. Ltd, 2003.
3. Krishana Kant, "Computer-based Industrial Control", Second Edition, PHI Publication, 2011.
4. H.S. Kalsi, "Electronic Instrumentation", Third Edition, Technical Education Series (TES)/TMH, 2017.
5. Buchanan, "Computer busses: Design and Applications", First Edition, Butterworth-Heinemann, 2000.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 6307	Instrumentation Transducers	3	3	0	0	20	-	30	50	-

Transducers and their characteristics, Definition of terminologies Generalized performance characteristics range resolution linearity overload factor accuracy precision static and dynamic rise time fall time settling time slew rate frequency response bandwidth modelling Classification ingress protection vibration isolation passive active. Resistive Transducers, Resistance potentiometer noise resolution signal conditioning strain gauges associated electrical circuitry temperature compensation load cells torque and pressure measurement using strain gauges resistive temperature device (RTD) three-lead arrangement thermistors linearization - hot-wire anemometers time constant improvement measurement of direction of flow peizo resistive transducers. Inductive Transducers, signal conditioning circuits choice of components linear variable differential transducer (LVDT) lead and lag compensation. Parasitic effects solutions, miscellaneous transducers, Peizo electric signal conditioning thermo couples' theory mass-spring accelerometer force-balance. Applications of transducers, Measurement of displacement (linear and angular) velocity acceleration force torque pressure flow-temperature.

Suggested Readings :

1. Neubert, H. K. “Instrument Transducers-An introduction to their performance and design”, Second edition, Oxford University press, 2003.
2. Doeblin, E. O. “Measurement Systems Application and Design”, Fifth Edition, McGraw - Hill Publications, 2004.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5405	Biomedical Instrumentation	4	3	0	2	10	15	25	50	-

Basic concepts of Bio-medical instrumentation, terminology, generalized medical instrumentation system, measurement constrains, classification, Interfacing and modifying inputs, Bio statistics, static and dynamic characteristic, regulation of medical devices, electrical safety in medical environment. Basic sensors and signal processing, displacement measurements, resistive sensors, bridge circuits, inductive, capacitive and piezo electric sensor, temperature measurements, thermocouples radiation thermometry fiber optic temperature sensors, optical measurements, opamp circuits, Microcomputers in bio-medical instrumentation. Bio potentials and measurements, electric activity and excitable cells. Functional organization of peripheral nervous system. ENG, EMG, ECG, EEG & MEG, Bio-potential electrodes, electrolyte interface. Bio potential amplifiers. Direct and indirect blood pressure measurement and analysis

Suggested Readings:

1. Khandpur R.S., “Handbook of Bio-medical Instrumentation”, Third Edition, Tata McGraw-Hill, 2014.
2. Dean D.E., Marre A., “Bio electronic Measurements”, Prentice Hall.
3. A li Evans, “The Evaluation of Medical Images”, First Edition, CRC Press, 1981.
4. John G. Webster, “Medical Instrumentation application and design”, Fourth Edition, John Wiley and Sons, 2009.
5. L. Cromwell., Fred J. Weibell, “Bio medical Instrumentation and measurements”, Second Edition, Prentice Hall, 1990.

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I	Electrical Energy Storage Systems	4	3	0	2	20	-	30	50	-

Battery: Energy Storage Parameters; Lead–Acid Batteries-Constructional Features, Charge–Discharge Cycles, Operating Limits, Maintenance and Sizing, Types, Applications; Performance measurement, storage density, energy density, and safety issues in Lead-Acid, Nickel-Cadmium, Zinc Manganese dioxide batteries, Modern batteries as Zinc-Air, Nickel Hydride, Lithium Battery, Flow Batteries. Ultracapacitors/Supercapacitors: Double-Layer Ultracapacitors, High-Energy Ultracapacitors, Rating, Size & Applications; Supercapacitors - Basic components, Types of electrodes and electrolytes, Advantages and Disadvantages, Comparison with battery systems, applications in public transport vehicles, private vehicles, and consumer electronics; Aspects of energy density, power density, price, and market.

Fuel Cell: Fuel cells for direct energy conversion, physical interpretation of the Carnot efficiency factor, electrochemical energy converters, power outputs, maximum intrinsic efficiency of an electrochemical converter. Types of fuel cells: Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, Alkaline fuel cell and Phosphoric fuel cell; Advantages and Disadvantages Other Storages: Pumped Hydroelectric Energy Storage, Storage Capabilities of Pumped Systems, Compressed Air Energy Storage, Storage Heat, Energy Storage as an Economic Resource.

Flywheels: Advanced Performance of Flywheels, Applications of Flywheels, Design Strategies, Superconducting Magnetic Storage System, SMES System Capabilities, Developments in SMES Systems. Power Electronics For Charging Control -Basic operation and modeling of power electronic devices applied in power transmission and distribution systems for electrical vehicles, various types of power electronics circuits used in energy processing; analysis and design of power converter circuits such as AC- DC, AC-AC, DC-DC and DC-AC converters; applications of power electronics circuit in electrical vehicles charging; methods of protection of power semiconductor devices and calculation of power device losses.

Suggested Readings:

1. M. Broussely and G. Pistoia, Eds, Industrial Applications of Batteries: From Cars to Aerospace and Energy Storage, Elsevier, Amsterdam, 2007.

2. M. Broussely, G.A. Nazri and G. Pistoia,Eds., Lithium Batteries – Science and Technology, Kluwer Academic Publishers, Boston, USA, 2004.

3. Rand D.A.J., Moseley P.T., Garche J. and Parker C.D. , " Valve regulated Lead–Acid Batteries", Elesevier 2004

4. Osaka T., Datta M. , "Energy Storage Systems in Electronics-New Trends in Electrochemical Technology" , CRC Press 2000

5. Nazri G. A. and Pistoia G., "Lithium Batteries – Science and Technology", Kluwer Academic Publishers 2004

6. Larminie J., Dicks A. and Wiley-Blackwell , "Fuel Cell Systems Explained", 2nd edition 2003

Course Code	Course Name	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
C&I 5204	Machine Learning	2	2	0	0	20	-	30	50	-

Introduction to machine learning, unsupervised, supervised, reinforcement, hybrid models. decision boundaries, crisp, and non-crisp, optimisation problems. Unsupervised Learning, K-Means, gaussian mixture models, EM. ML-estimation, the simple case of one 1-D Gaussian, to the general case of K dimensional gaussians. Eigen analysis,PCA, LDA and subspaces. linear models for regression, classification. The basic SVM optimisation, the primal and the dual problems

Suggested Readings:

1. C. M. Bishop. "Pattern Recognition and Machine Learning". First Edition. Springer, 2006. (Second Indian Reprint, 2015).
2. P. Flach. "Machine Learning: The Art and Science of Algorithms that Make Sense of Data". First Edition, Cambridge University Press, 2012.
3. S. J. Russell, P. Norvig." Artificial Intelligence: A Modern Approach." Third Edition, Prentice-Hall, 2010.
4. Y. S. Abu-Mostafa, M. Magdon-Ismail, H.-T. Lin. "Learning from Data: A Short Course." First Edition, 2012.
5. P. Domingos. "A Few Useful Things to Know about Machine Learning". *Communications of the ACM,* vol. 55, no. 10, pp. 78 - 87, 2012.
6. C. Stauffer, W. E. L. Grimson, "Adaptive Background Mixture Models for Real-Time Tracking. *Proc. IEEE Computer Society Conference on Computer Vision and Pattern Recognition",* vol. 2, pp. 246 - 252, 1999.
7. C. Stauffer, W. E. L. Grimson. "Learning Patterns of Activity Using Real-Time Tracking." *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 22, no. 8, pp. 747 - 757, 2000.
8. P. N. Belhumeur, J. P. Hespanha, D. J. Kiregman. Eigenfaces vs. Fisherfaces: "Recognition using Class Specific Linear Projection". *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 19, no. 7, pp. 711 - 720, 1997.