New Curriculum for M.Tech. in Control and Automation

Overall credit structure

Category	PC	PE	PE/OE	Total
Credits	24	18	6	48

Semester wise distribution of credits

Semester	Courses					Lecture Courses	Contact hours/week				Credits
							L	T	P	Total	
I	(PC) ELL700 *Linear Systems Theory* **(3-0-0)**	(PC) ELL701 *Mathematical Methods in Control* **(3-0-0)**	(PC) ELL702 *Nonlinear Systems* **(3-0-0)**	(PC) ELP800 *Control Systems Lab* **(0-0-3)**	PE / OE **(3-0-0)**	3/4	9/12	0	3	12/15	10.5/13.5
II	(PC) ELL703 *Optimal Control Theory* **(3-0-0)**	(PC) ELL705 *Stochastic Filtering and Identification* **(3-0-0)**	(PC) ELP801 *Advanced Control Lab* **(0-0-3)**	PE / OE **(3-0-0)**	PE / OE **(3-0-0)**	4/3	12/9	0	3	15/12	13.5/10.5
Summer											
III (Project based)	(PC) ELD801 *Major Project Part I* **(0-0-12)**		PE / OE **(3-0-0)**	PE / OE **(3-0-0)**		2	6	0	12	18	12
III (Course based)	PE **(3-0-0)**	PE **(3-0-0)**	PE / OE **(3-0-0)**	PE / OE **(3-0-0)**		4	12	0	0	12	12
IV (Project based)	(PE) ELD802 *Major Project Part II* **(0-0-24)**					0	0	0	24	24	12
IV (Course based)	(PC) ELD801 *Major Project Part I* **(0-0-12)**		PE / OE **(3-0-0)**	PE / OE **(3-0-0)**		2	6	0	12	18	12

Program Core (PC)

S. No.	Course Number	Title	L-T-P	Credit
1.	ELL700	Linear Systems Theory	3-0-0	3
2.	ELL701	Mathematical Methods in Control	3-0-0	3
3.	ELL702	Nonlinear Systems	3-0-0	3
4.	ELP800	Control Systems Laboratory	0-0-3	1.5
5.	ELL703	Optimal Control Theory	3-0-0	3
6.	ELL705	Stochastic Filtering and Identification	3-0-0	3
7.	ELP801	Advanced Control Laboratory	0-0-3	1.5
8.	ELD801	Major Project Part I	0-0-12	6

Program Elective (PE)

S. No.	Course Number	Title	L-T-P	Credit
1.	ELL704	Advanced Robotics	3-0-0	3
2.	ELL707	Systems Biology	3-0-0	3
3.	ELL708	Selected Topics in Systems and Control	3-0-0	3
4.	ELL709	Design Aspects in Control	3-0-0	3
5.	ELL800	Numerical Linear Algebra and Optimization in Engineering	3-0-0	3
6.	ELL801	Nonlinear Control	3-0-0	3
7.	ELL802	Adaptive and Learning Control	3-0-0	3
8.	ELL803	Model Reduction in Control	3-0-0	3
9.	ELL804	Robust Control	3-0-0	3
10.	ELL805	Networked and Multi-Agent Control Systems	3-0-0	3
11.	ELL806	Modeling and Control of Distributed Parameter Systems	3-0-0	3
12.	ELL807	Stochastic Control	3-0-0	3
13.	ELL808	Advanced Topics in Systems and Control	3-0-0	3
14.	ELD800	Minor Project (EEA)	0-0-6	3
15.	ELD802	Major Project Part II	0-0-24	12
16.	ELV700	Special Module in Systems and Control	1-0-0	1
17.	ELL787	Embedded Systems and Applications	3-0-0	3
18.	ELL796	Signals and Systems in Biology	3-0-0	3
19.	ELL784	Introduction to Machine Learning	3-0-0	3
20.	ELL789	Intelligent Systems	3-0-0	3
21.	ELL797	Neural Systems and Learning Machines	3-0-0	3

22.	ELL793	Computer Vision	3-0-0	3
23.	ELL888	Advanced Machine Learning	3-0-0	3
24.	ELL795	Swarm Intelligence	3-0-0	3
25.	ELL883	Embedded Intelligence	3-0-0	3
26.	ELL893	Cyber-Physical Systems	3-0-0	3
27.	ELL890	Computational Neuroscience	3-0-0	3
28.	ELL720	Advanced Digital Signal Processing	3-0-0	3
29.	ELL776	Power System Dynamics and Control	3-0-0	3
30.	ELL714	Basic Information Theory	3-0-0	3
31.	ELL779	Dynamic Modeling And Control of Sustainable Energy Systems	3-0-0	3
32.	ELL767	Mechatronics	3-0-0	3
33.	ELL762	Intelligent Motor Controllers	3-0-0	3
34.	ELL850	Digital Control of Power Electronics and Drive Systems	3-0-0	3
35.	ELL765	Smart Grid Technology	3-0-0	3
36.	MEL745*	Advanced Robotics	3-0-2	4
37.	MEL783*	Automation in Manufacturing	3-0-2	4
38.	MAL704*	Numerical Optimization	3-0-2	4
39.	MAL731*	Introduction to Chaotic Dynamical Systems	3-1-0	4
40.	IDL711*	Instrumentation Transducers	3-0-0	3

* These courses are from outside the department and may have changed after the curriculum review.

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Minor Project (EEA)
3.	**L-T-P structure**	0-0-6
4.	**Credits**	3
5.	**Course number**	ELD800
6.	**Status** (*category* for *program*)	M.Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	None

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supersedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, M. Nabi, S. Janardhanan, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To do an introductory project in systems and control.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To be decided by the project supervisor.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
	COURSE TOTAL *(14 times 'L')*	

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
	To be decided by the project supervisor.	
		84

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Major Project Part I
3.	**L-T-P structure**	0-0-12
4.	**Credits**	6
5.	**Course number**	ELD801
6.	**Status** (*category* for *program*)	M.Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supersedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, M. Nabi, S. Janardhanan, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To do project work in systems and control.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To be decided by the project supervisor.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
	COURSE TOTAL *(14 times 'L')*	

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
	To be decided by the project supervisor.	
		168

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Major Project Part II
3.	**L-T-P structure**	0-0-24
4.	**Credits**	12
5.	**Course number**	ELD802
6.	**Status** (*category* for *program*)	M.Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELD801

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supersedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, M. Nabi, S. Janardhanan, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To do advanced project work in systems and control.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To be decided by the project supervisor.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
	To be decided by the project supervisor.	
		336

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Linear Systems Theory
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL700
6.	**Status** (*category* for *program*)	M. Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	ELL 225 or equivalent

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☒1stsem ☐2ndsem ☐Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** Introduce the basic and fundamental concepts of modern control theory, controller and observer design based on linear algebra.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Review of matrix algebra, state variable modelling of continuous and discrete time systems, linearization of state equations, solution of state equations of linear time-invariant and time-varying systems, Controllability and observability of dynamical systems, Minimal realization of linear systems and canonical forms, Liapunov's stability theory for linear dynamical systems, State Feedback controllers, Observer and Controller design.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of matrices and vector spaces	5
2	State variable modeling of continuous and discrete-time systems	4
3	Linearization of state equations	3
4	Solution of LTI and LTV systems	4
5	Controllability and Observability	4
6	Minimal realization	3
7	Canonical forms and their computational aspects	4
8	Lyapunov Stability	4
9	State Feedback and Controller Design	5
10	Duality and Observer Design	3
11	Functional Observers and their algorithmic aspects	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments on Linearization of state equations	3
2	Solution of LTI and LTV systems – Numerical Problems	2
3	Lyapunov Stability – Numerical Problems	2
4	State Feedback and Controller and Observer Design	4
5	Functional Observers and their algorithmic aspects	3
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Chi-Tsong Chen : Linear System Theory and Design,Oxford
2. Thomas Kailath : Linear Systems, Prentice-Hall
3. Biswa Nath Dutta: Numerical Methods for Linear Control Systems (Academic Press, Elsevier)
4.J. P. Hespanha : Linear Systems Theory, Princeton University Press

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	20%
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Mathematical Methods in Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL701
6.	**Status** (*category* for *program*)	M. Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	B. Tech.

10.	**Frequency of offering**	☐Every sem ☒1stsem ☐2ndsem ☐Either sem -

11.	**Faculty who will teach the course** I. N. Kar, Shaunak Sen, M. Nabi, S. Janardhanan, S. Bhasin

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To give the students an understanding of foundational concepts linear algebra and random processes for use in control systems.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Linear Spaces – Vectors and Matrices, Transformations, Norms - Vector and Matrix norms, Matrix factorization, Eigenvalues and Eigenvectors and Applications, Singular Value Decomposition and its Applications, Projections, Least Square Solutions. Probability, Random Variables, Probability distribution and density functions, Joint density and Conditional distribution, Functions of random variables, Moments, characteristic functions, sequence of random variables, Correlation matrices and their properties, Random processes and their properties, Response of Linear systems to stochastic inputs, PSD theorem

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Linear Spaces – Vectors and Matrices	4
2	Transformations, Norms	3
3	Matrix Factorization	2
4	Eigenvalue, Eigenvectors and Applications	4
5	SVD and Applications	4
6	Projections and Least Square Solutions	3
7	Probability, Random variables	3
8	Probability distribution and density functions	3
9	Joint density and conditional distribution	3
10	Functions of random variables and random vectors	3
11	Characteristic functions and correlation matrices	3
12	Random Processes and properties	3
13	Response of Linear systems to stochastic inputs, PSD theorem	4
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments on Matrix Factorization	2
2	SVD, Projections and Least Square Solutions - Assignments	3
3	Assignments on Probability, Random Variables, Probability distribution and density functions	4
4	Assignments on Random variables functions and correlation matrices	2
5	Assignments on Response of Linear systems to stochastic inputs	3
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. G. Strang, "Introduction to Linear Algebra", 4 th Edition, Wellesley-Cambridge Press, 2009.
2. Papoulis & Pillai, Probability, random variable and stochastic processes, Mcgraw Hill, 2002.
3. H. Stark & J.W. Woods, Probability and random processes with application to signal processing, Pearson Education Asia, 2002.
4. J A Gubner: Probability and Random processes for Electrical and Computer engineers, Cambridge Univ. Press. 2006

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	SciLab, MATLAB
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	

20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Nonlinear Systems
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL702
6.	**Status** (*category* for *program*)	M.Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	ELL225 or equivalent

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	-

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, S. Sen, S. Bhasin, S. Janardhanan, M. Nabi

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** Introduce fundamental concepts of nonlinear dynamical systems. It covers basic tools for mathematical analysis as well as applications.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Introduction to nonlinear systems: Examples of phenomena, models & derivation of system equations. Fundamental properties: Existence & uniqueness, Dependence on initial conditions & parameters. Phase plane analysis. Limit cycles & oscillations. Describing function method and applications. Circle criterion. Lyapunov stability of autonomous systems. Perturbation theory & Averaging. Singular perturbation model and stability analysis. Basic results on Lie algebra. Controllability and Observability of nonlinear systems. Bifurcations. Chaos. Synchronization.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to nonlinear systems: Examples of phenomena, models & derivation of system equations.	3
2	Fundamental properties: Existence & uniqueness, Dependence on initial conditions & parameters.	3
3	Phase plane analysis.	3
4	Limit cycles & oscillations. Describing function method and applications. Circle criterion.	8
5	Lyapunov stability of autonomous systems.	6
6	Perturbation theory & Averaging. Singular perturbation model and stability analysis.	7
7	Basic results on Lie algebra. Controllability and Observability of nonlinear systems.	6
8	Bifurcations. Chaos. Synchronization.	6
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Introduction to nonlinear systems: Examples of phenomena, models & derivation of system equations. – Background Reading, Assignment	1
2	Fundamental properties: Existence & uniqueness, Dependence on initial conditions & parameters. - Assignment	1
3	Phase plane analysis. - Assignment	1
4	Limit cycles & oscillations. Describing function method and applications. Circle criterion. – Literature Survey, Assignment, Potential topic for project and/or term paper	3
5	Lyapunov stability of autonomous systems. – Assignment, Potential topic for project and/or term paper	2
6	Perturbation theory & Averaging. Singular perturbation model and stability analysis. – Assigned reading, Potential topic for project and/or term paper	2
7	Basic results on Lie algebra. Controllability and Observability of nonlinear systems. – Assigned reading, Assignment	2
8	Bifurcations. Chaos. Synchronization. – Background Reading, Assignment with numerical computations, Potential topic for project and/or term paper	2
COURSE TOTAL		14

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. H. K. Khalil, *Nonlinear systems*, 3rd edition, Prentice Hall, 2001.
2. J. J. E. Slotine and W. Li, *Applied nonlinear systems*, Prentice Hall, 1991.
3. A. Nijemjer and A. van der schaft, *Nonlinear dynamical control systems*, Springer, 1989.
4. M. Vidyasagar, *Nonlinear Systems Analysis*, Society for Industrial and Applied Mathematics, 2002.
5. S. Strogatz, *Nonlinear Dynamics and Chaos*, Westview Press, 2001.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Optimal Control Theory
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL703
6.	**Status** (*category* for *program*)	M. Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	ELL700 or ELL333

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	NO

13.	**Course objectives** *(about 50 words)***:** Introduce the basic and fundamental concepts of optimal control theory, controller design and the computational aspects of optimal control.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	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 and state inequality constraints, Minimum time problems, Minimum control effort problems, Linear quadratic regulator problems, Riccati Equation, Singular intervals in optimal control problems, The principle of optimality, Application of the principle of optimality to decision making, Dynamic programming applied to routing problems, Solving optimal control problems using dynamic programming, Discrete linear regulator problem, Hamilton -Jacobi -Bellman Equation, Numerical Techniques to determine optimal trajectories.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of Matrix Computations	3
2	Maximization of functionals of a single and several functions using calculus of variations, Constrained extremals	3
3	Euler-Lagrange Equation, Necessary conditions for optimal control	3
4	Pontryagin's minimum principle and state inequality constraints,	4
5	Minimum time problems, Minimum control effort problems	4
6	Linear quadratic regulator problems, Riccati Equation, Singular intervals in optimal control problems	5
7	The principle of optimality, Application of the principle of optimality to decision making, Dynamic programming applied to routing problems	5
8	Solving optimal control problems using dynamic programming	4
9	Discrete linear regulator problem, Hamilton -Jacobi -Bellman Equation	4
10	Numerical Techniques to determine optimal trajectories	4
11	Numerical Aspects of Optimization	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. M. Athans and P. L. Falb, “Optimal Control: An Introduction to the Theory and Its Applications”, Dover Books on Engineering, 2006.
2. D. S. Naidu, “Optimal Control Systems”, CRC Press, 2002.
3. D. Liberzon, "Calculus Of Variations and Optimal Control Theory: A Concise Introduction", Princeton University Press, Dec 2011
4. Frank L. Lewis, Draguna Vrabie, Vassilis L. Syrmos, Optimal Control, 3rd Edition, Wiley, 2012

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos,	

	etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Advanced Robotics
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL704
6.	**Status** (*category* for *program*)	M.Tech. (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL 225 or equivalent

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** Prof. I.N. Kar, Dr. M. Nabi, Dr. S. Janardhanan, Dr. S. Sen, Dr. S. Bhasin

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** This course gives an in-depth view into the mathematical methods for modeling and control of robotic manipulator and mobile robots.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Review of Coordinate Transformations, D-H parameters and kinematics. Velocity kinematics and Jacobian, Singularity analysis, Robot Dynamics ,. Motion planning, Robot control: linear methods – feedforward control, state feedback, observers; Nonlinear Control methods – Computed Torque Control, Feedback linearization, Sliding Mode control; Vision based Robotic Control. Holonomic and Non-Holonomic Systems, Mobile Robots : Modeling and Control, Odometry Analysis, Navigation problems with obstacle avoidance, motion capturing systems.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of Transformations, DH Convention and Kinematics	5
2	Velocity kinematics and Jacobian	3
3	Robot Dynamics	3
4	Motion Planning	3
5	Robot control – Linear Control Techniques	5
6	Nonlinear Control Techniques	5
7	Holonomic and Non-holonomic Systems	2
8	Vision based Robotic Control	4
9	Mobile Robots - Modeling	3
10	Odometry Analysis	2
11	Navigation with Obstacle Avoidance	4
12	Motion Capturing Systems	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Robot Dynamics – Modeling Assignments	3
2	Assignments on Trajectory planning	2
3	Robot control - Assignments	3
4	Segmentation and Thresholding Assignments	3
5	Mobile Robots – Dynamic Modeling	3
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Mark W. Spong, Seth Huchinson and M. Vidyasagar, "Robot Modeling and Control", John Wiley and Sons, Inc., 2005

2. John J. Craig, "Introduction to Robotics: Mechanics & Control", 3rd Edition, Prentice Hall, 2004

3. Richard Murray, A. Lee, S. Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 1994.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	MATLAB, SciLab, Mathematica
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	15%
21.2	Open-ended problems	
21.3	Project-type activity	10%
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Stochastic Filtering and Identification
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL705
6.	**Status** (*category* for *program*)	M.Tech. (PC for EEA)

7.	**Pre-requisites** (course no./title)	ELL701 or ELL333

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	-

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, S. Sen, S. Bhasin, S. Janardhanan, M. Nabi

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** Introduce fundamental concepts of stochastic filtering, prediction, control and system identification.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** MMSE estimation including LMS, Gaussian case. Wiener filtering & prediction. Kalman filtering & prediction. Extended Kalman filtering. Predictors for difference equation based models including ARMA, Box Jenkins & others. Statistical properties of Least Squares estimation and its relationship with Bayes estimation (ML, MAP), convergence analysis, CR bound. Recursive Least Squares, Iterative methods for nonlinear Least Squares. Identification problem: Different approaches for linear dynamical systems. Offline identification methods including Least Squares, Prediction error framework, Pseudo-linear regression (PLR) & Instrument variable methods. Recursive Identification of linear dynamical system: RLS, PLR, Prediction error framework & its application to ARMA & Innovations representation. Convergence Analysis of Recursive Identification methods: Associated ODE, Martingale. Nonlinear system identification. Subspace based method of system identification. Applications including LQG and adaptive control.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Parameter Estimation and System Identification	1
2	MMSE estimation including LMS, Gaussian case	3
3	Wiener filtering & prediction	2
4	Kalman filtering & prediction	4
5	Extended Kalman filtering and its variations	3
6	Predictors for difference equation based models including ARMA, Box Jenkins & others	3
7	Statistical properties of Least Squares estimation and its relationship with Bayes estimation (ML, MAP), convergence analysis, CR bound	4
8	Recursive Least Squares, Iterative methods for nonlinear Least Squares	3
9	Identification problem: Different approaches for linear dynamical systems	2
10	Offline identification methods including Least Squares, Prediction error framework, Pseudo-linear regression (PLR) & Instrument variable methods	3
11	Recursive Identification of linear dynamical system: RLS, PLR, Prediction error framework & its application to ARMA & Innovations representation	5
12	Convergence Analysis of Recursive Identification methods: Associated ODE, Martingale	2
13	Nonlinear system identification	2
14	Subspace based method of system identification	3
15	Applications including LQG and adaptive control	2
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Introduction to Parameter Estimation and System Identification – Background reading	1
2	MMSE estimation including LMS, Gaussian case - Assignment	0.5
3	Wiener filtering & prediction - Assignment	0.5
4	Kalman filtering & prediction - Assignment	0.5
5	Extended Kalman filtering – Assignment with numerical computations, potential topic for project and term paper	1.5
6	Predictors for difference equation based models including ARMA, Box Jenkins & others – Literature Survey	0.5
7	Statistical properties of Least Squares estimation and its relationship with Bayes estimation (ML, MAP), convergence analysis, CR bound – Assignment, potential topic for project and term paper	1.5
8	Recursive Least Squares, Iterative methods for nonlinear Least Squares – Assignment with numerical computations, potential topic for project and term paper	2
9	Identification problem: Different approaches for linear dynamical systems – Background reading	1

10	Offline identification methods including Least Squares, Prediction error framework, Pseudo-linear regression (PLR) & Instrument variable methods – Assignment with numerical computation	1
11	Recursive Identification of linear dynamical system: RLS, PLR, Prediction error framework & its application to ARMA & Innovations representation – Assignment with numerical computation, potential topic for project and term paper	2
12	Convergence Analysis of Recursive Identification methods: Associated ODE, Martingale – Background reading	0.5
13	Nonlinear system identification – Assigned reading	0.5
14	Subspace based method of system identification – Assigned reading	0.5
15	Applications including LQG and adaptive control – Assigned reading	0.5
COURSE TOTAL		**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Papoulis & Pillai, Probability, random variable and stochastic processes, McGraw Hill, 2002.
2. T. Soderstrom and P. Stoica: System Identification, Prentice-Hall, 1989.
3. Lennart Ljung: System Identification, Prentice-Hall, 2nd edition, 1999.
4. S. Thomas Alexander: Adaptive Signal processing, Theory and applications, Springer-Verlag, 1986.
5. R. Isermann and M. Munchhof: Identification of Dynamic Systems, Springer-Verlag, 2011.
6. B. D. O. Anderson and J. B. Moore: Optimal Filtering, Dover Books on Electrical Engineering, 2005.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Systems Biology
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL707
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL225 or equivalent

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	-

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** S. Sen, I. N. Kar, K. K. Shah, S. Agarwal

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** The course will provide an introduction to systems biology, and a discussion on future outlook.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	MODELS : Variables and parameters, Law of mass action, Representations : Deterministic vs stochastic, Spatial aspects, Examples of core processes: Gene expression, Protein degradation, Phosphorylation. DYNAMICS : Equilibrium solutions, Bifurcations, Switches, Bistability, Pulses and Oscillations, Circadian Rhythms and Clocks, Spatial patterns. Morphogenesis and Development. CONTROL MECHANISMS : Performance Goals, Integral Feedback Control, Homeostasis and Perfect Adaptation, Bacterial Chemotaxis , Feedforward Loops, Fold Change Detection, Robustness to Perturbations, Tradeoffs, Internal Model Principle.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Mathematical models and frameworks: Law of mass action, Master equation; Deterministic vs stochastic, Spatial aspects	6
2	Examples of core processes: Gene expression, Protein degradation, Phosphorylation	3
3	Equilibrium solutions & their Bifurcations	3
4	Switches & Bistability	5
5	Pulses and Oscillations, Circadian Rhythms and Clocks	6
6	Spatial patterns. Morphogenesis and Development	4
7	Robustness to Perturbations, Integral Feedback Control, Homeostasis and Perfect Adaptation	6
8	Feedforward Loops, Fold Change Detection	5
9	Fundamental Tradeoffs, Internal Model Principle	4
COURSE TOTAL *(14 times 'L')*		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Mathematical models and frameworks: Law of mass action, Master equation; Deterministic vs stochastic, Spatial aspects - Assignment	2
2	Examples of core processes: Gene expression, Protein degradation, Phosphorylation – Background Reading	1
3	Equilibrium solutions & their Bifurcations – Assignment with numerical computations	1
4	Switches & Bistability – Assignment, potential topic for protect and/or term paper	2
5	Pulses and Oscillations, Circadian Rhythms and Clocks – Assignment, potential topic for protect and/or term paper	2
6	Spatial patterns. Morphogenesis and Development – Assignment, potential topic for protect and/or term paper	1
7	Robustness to Perturbations, Integral Feedback Control, Homeostasis and Perfect Adaptation – Assignment, potential topic for protect and/or term paper	2
8	Feedforward Loops, Fold Change Detection – Assignment, potential topic for protect and/or term paper	1
9	Fundamental Tradeoffs, Internal Model Principle – Assigned reading, potential topic for project and/or term paper	2
COURSE TOTAL		14

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. N. G. van Kampen, Stochastic Processes in Physics and Chemistry, North-Holland 3rd edition, 2007.
2. U. Alon, An Introduction to Systems Biology, Chapman & Hall/ CRC Mathematical and Computational Biology, 2006.

3. J. D. Murray, Mathematical Biology parts I & II, Springer 3rd edition, 2007.
4. E. Klipp et. al, Systems Biology, Wiley-Blackwell, 2009.
5. S. Strogatz, Nonlinear Dynamics and Chaos, Westview Press, 2001.
6. D. D. Vecchio & R. M. Murray, Biomolecular Feedback Systems, Princeton University Press, 2014.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Selected Topics in Systems and Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL708
6.	**Status** (*category* for *program*)	M.Tech. (PE for EEA)

7.	**Pre-requisites** (course no./title)	To be decided by Instructor when floating this course

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	- NONE
8.2	Overlap with any UG/PG course of other Dept./Centre	- NONE -
8.3	Supersedes any existing course	- NONE -

9.	**Not allowed for** (indicate program names)	- NONE -

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** S. Janardhanan, M. Nabi, I. N. Kar, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	- NO -

13.	**Course objectives** *(about 50 words)*: To introduce the emerging new and interesting topics in systems and control engineering, over and above the established courses.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To be decided by the Instructor when floating this course: It can be anything that is related to systems and control engineering, but is not covered in any of the established courses.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
	To be decided by the Instructor	
	COURSE TOTAL *(14 times 'L')*	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	COURSE TOTAL *(14 Hrs)*	**14**

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. description of module-wise activities pertaining to self-study component

(mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be decided and announced by Instructor

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	Scilab or MATLAB
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	

21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Design Aspects in Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL709
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL 225 and ELL 333

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** The student is introduced to the tools and techniques of control system design and the various aspects of controller design philosophy.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	System Modeling – model structures (Process model, ARX model), Review of concepts of stability, feedback and feedforward control. Classical control – First-Order Plus Dead-Time model (FOPDT), process reaction curves, Second-Order Plus Dead-Time model (SOPDT), relay feedback process identification; Smith Predictor and its variations, PID controllers and their tuning, Ziegler-Nichols and Cohen-Coon techniques. Reliable State Feedback design – pole placement, eigenstructure assignment, region based eigenvalue assignment, eigenstructure-time response relationships. Controller gain selection – noise sensitivity. Controller robustness. Disturbance rejection. Frequency Domain Loop Shaping. Output feedback control – compensator design, review of Lead, Lag and Lag-Lead compensators, Zero dynamics – significance in servo control design, design for unstable zero dynamics. Observers – concept and design philosophy. Applications in practical controller design scenarios.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	System Modeling, review of concepts	4
2	FOPDT and SOPDT systems and identification	3
3	Smith Predictor and its variations	2
4	PID Controllers - review	2
5	PID Tuning – Ziegler Nichols, Cohen-Coon techniques	3
6	State feedback review – pole placement	3
7	Eignestructure assignment, eigenstructure – time response relation	3
8	Controller gain selection, controller robustness, disturbance rejection	3
9	Frequency Domain Loop Shaping	3
10	Lag, Lead and Lag-lead compensators	3
11	Zero dynamics in servo control	2
12	Unstable zero dynamics – control design	3
13	Observer – concept and design	3
14	Case studies - Applications	5
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Classical Control Case Studies	3
2	State Feedback Control Case Studies	3
3	Output feedback Case Studies	4
4	Nonlinear System Case Studies	4
5		
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Karl J. Astrom, Richard M. Murray, “Feedback Sytems : An Introduction for Scientists and Engineers”, Princeton University Press, 2010.
2. Thomas Kailath : Linear Systems, Prentice-Hall

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos,	

	etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	40%
21.2	Open-ended problems	30%
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Numerical Linear Algebra and Optimization in Engineering
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL800
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	-None-

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** S. Janardhanan, M. Nabi, I. N. Kar, S. Sen. S. Bhasin

12.	**Will the course require any visiting faculty? (yes/no)**	NO

13.	**Course objectives** *(about 50 words)***:** To introduce the application of linear algebra concepts to solve engineering problems

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Basics of Linear Algebra; Matrix decompostion - LU, LDU, QR and Cholesky factorization; Householder reflection, Givens rotation; Numerical implications of SVD; Numerical Solution for Linear Systems; Algorithm Stability; Problem Conditioning; Pivoting and scaling; Least Square Solutions; Numerical Matrix eigenvalue methods; Sparse Systems; Iterative methods for large systems; Krylov, Arnoldi, Lanczos methods; Numerical Optimization techniques - Conjugate gradient method, Linear and quadratic programming, Spectral and Pseudo-spectral methods

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Basics of Linear Algebra	2
2	Matrix Factorization – LU, LDU, QR and Cholesky	5
3	Householder reflection and Givens rotation	2
4	SVD – Numerical implications	2
5	Numerical solution of linear systems	2
6	Algorithm stability and problem conditioning	2
7	Pivoting and Scaling	2
8	Least square solutions to linear systems	4
9	Numerical matrix eigenvalue problems	3
10	Iterative methods for large, sparse systems	3
11	Krylov, Arnoldi, Lanczos methods	4
12	Numerical optimization – conjugate gradient method	3
13	Linear and Quadratic Programming	4
14	Spectral and Pseudo-spectral methods	4
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	TOTAL	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. G. Strang, "Introduction to Linear Algebra", 4 th Edition, Wellesley-Cambridge Press, 2009.
2. B. N. Dutta, "Numerical Linear Algebra and Applications", SIAM, 2010
3. G. W. Stewart, "Introduction to Matrix Computations", Academic Press, 1973
4. L. N. Trefethen and D. Bau, "Numerical Linear Algebra", SIAM, 1997
5. S. S. Rao, "Engineering Optimization : Theory and Practice", John Wiley & Sons, 1996.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	MATLAB, SciLab
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	15-20% (Coding of factorization and MOR algorithms)
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Nonlinear Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL801
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA),

7.	**Pre-requisites** (course no./title)	ELL702

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** Prof. I N Kar, Dr. M Nabi, Dr. S. Janardhanan, Dr. S Bhasin, Dr. S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To study concepts and techniques for stability analysis and control design of nonlinear systems.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Overview of nonlinear control, Lyapunov stability for autonomous and non-autonomous systems, Input-Output Stability and Input-to-State Stability, Passivity analysis and applications, Absolute Stability, Incremental stability analysis, Lyapunov-based feedback control design, Feedback linearization and backstepping, Sliding mode control, Nonlinear observer design.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of nonlinear control	2
2	Lyapunov stability for autonomous and non-autonomous systems	7
3	Input-Output Stability and Input-to-State Stability	5
4	Passivity analysis and applications to control design	4
5	Absolute Stability	2
6	Lyapunov-based feedback control design	3
7	Feedback linearization and backstepping	6
8	Sliding mode control	5
9	Incremental stability analysis	5
10	Nonlinear observer design	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. H. K. Khalil, *Nonlinear Systems*, 3rd edition, Prentice Hall, 2001.
2. H. K. Khalil, *Nonlinear Control*, Pearson, 2015.
3. J. J. E. Slotine and W. Li, *Applied nonlinear systems*, Prentice Hall, 1991.
4. A. Nijemjer and A. van der schaft, *Nonlinear dynamical control systems*, Springer, 1989.
5. M. Vidyasagar, *Nonlinear Systems Analysis*, Society for Industrial and Applied Mathematics, 2002.
6. Alberto Isidori, Nonlinear Control Systems, Third Edition, Springer, 1995

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	20%
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Adaptive and Learning Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL802
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL702

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To introduce adaptive and learning techniques for control design for uncertain dynamical systems.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Introduction to adaptive control, Review of Lyapunov stability theory, Direct and indirect adaptive control, Model reference adaptive control, Parameter convergence, persistence of excitation, Adaptive backstepping, Adaptive control of nonlinear systems, Composite adaptation, Neural Network-based control, Repetitive learning control, Reinforcement learning-based control, Predictive control, Robust adaptive control

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to adaptive control	2
2	Review of Lyapunov stability theory	2
3	Direct and indirect adaptive control	2
4	Model reference adaptive control	4
5	Parameter convergence, persistence of excitation	2
6	Adaptive backstepping	4
7	Adaptive control of nonlinear systems	5
8	Composite adaptation	2
9	Neural Network-based control	5
10	Repetitive learning control	3
11	Reinforcement learning-based control	5
12	Predictive control	4
13	Robust adaptive control	2
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. H. K. Khalil, Nonlinear Systems, 3rd edition, Prentice Hall, 2002
2. S. Sastry and M. Bodson, Adaptive Control, Prentice-Hall, 1989
3. K. S. Narendra and A. M. Annaswamy, Stable Adaptive Systems, Prentice-Hall, 1989
4. J.J.E. Slotine, and W. Li, Applied Nonlinear Control, Prentice-Hall, 1991
5. P. Ioannou & B. Fidan, Adaptive Control Tutorial, SIAM, Philadelpia, PA, 2006.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	20%
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Model Reduction in Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL803
6.	**Status** (*category* for *program*)	M.Tech. (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL700, ELL701

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	-NONE-
8.2	Overlap with any UG/PG course of other Dept./Centre	- NONE -
8.3	Supersedes any existing course	- NONE -

9.	**Not allowed for** (indicate program names)	- NONE -

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** S. Janardhanan, M. Nabi, I. N. Kar, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	- NO -

13.	**Course objectives** *(about 50 words)*: To introduce the concept of model reduction of large scale dynamics models which from various engineering disciplines.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Introduction to Model Reduction; Sources of Large Models - Circuits, Electromagnetic Systems, Mechanical Systems; Discretization Methods - Finite Difference Method (FDM), Finite Element Method (FEM); Classical Model Reduction Methods - Pade Approximation, Moment matching, Routh Approximants; Modern Methods - Modal Model Reduction Methods, SVD (Grammian) based methods, Krylov based methods, SVD-Krylov based methods; MOR for Nonlinear Systems – SVD & POD Methods; Model Reduction in Control; Control Design on Reduced Models – Sub- optimal control; Sliding Mode Control as model reducing control - First Order SM, Higher Order Sliding Mode

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Model Reduction	2
2	Source of Large Models – Circuits, EM systems, Mechanical Systems	5
3	Classical Model Reduction Methods – Modal reduction	3
4	Pade approximation and moment matching	3
5	Routh Approximants	2
6	Modern Methods - SVD (Grammian) based methods	4
7	Krylov based methods	4
8	SVD-Krylov based methods	2
9	MOR for Nonlinear Systems – SVD & POD Methods	4
10	Model Reduction in Control	3
11	Sliding Mode Control - Review	2

12	SMC as model reducing control	4
13	Higher Order Sliding Mode	4
	COURSE TOTAL *(14 times 'L')*	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
1	Introduction to Model Reduction	0
2	Source of Large Models – Circuits, EM systems, Mechanical Systems	2
3	Classical Model Reduction Methods – Modal reduction	2
4	Pade approximation and moment matching	1
5	Routh Approximants	0
6	Modern Methods - SVD (Grammian) based methods	2
7	Krylov based methods,	2
8	SVD-Krylov based methods	1
9	MOR for Nonlinear Systems – SVD & POD Methods	1
10	Model Reduction in Control	0
11	Sliding Mode Control - Review	0
12	SMC as model reducing control	2
13	Higher Order Sliding Mode	1
	COURSE TOTAL *(14 Hrs)*	**14**

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. description of module-wise activities pertaining to self-study component

(mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. A. C. Antoulas, “Approximation of Large Scale Dynamical Systems”, SIAM, 2005

2. Ed. Alfio Quarteroni & Gianluigi Rozza, “Reduced Order Methods for Modeling and Computational Reduction”, Springer, 2014

3. M. Jamshidi, “Large-scale systems: modeling & control”, North Holland, New York, 1983.

4. C. Edwards and S. Spurgeon, “Sliding Mode Control : Theory and Applications”, CRC Press, 1998

5. B. Bandyopadhyay, S. Janardhanan and S. Spurgeon, “Advances in Sliding Mode”, Springer, 2013.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	Scilab or MATLAB
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	

20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Robust Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL804
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL700 and ELL701

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** Introduction to control techniques with greater emphasis on robustness to modeling uncertainty, parameter variations, and presence of disturbances and noise.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Modeling of uncertain systems, Signals and Norms, Lyapunov theory for LTI systems Passive systems – frequency domain, Passive systems – time domain, Robust Stability and performance, Stabilizing controllers – Coprime factorization, LQR, LQG problems Ricatti equations and solutions, H-infinity control and mu-synthesis, Linear matrix inequalities for robust control, Ricatti equation solution through LMI

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Modeling of uncertain systems	3
2	Signals and Norms	3
3	Lyapunov theory for LTI systems	4
4	Passive systems – frequency domain	3
5	Passive systems – time domain	3
6	Robust Stability and performance	3
7	Stabilizing controllers – Coprime factorization	4
8	LQR, LQG problems	4
9	Ricatti equations and solutions	2
10	H-infinity control and mu-synthesis	6
11	Linear matrix inequalities for robust control	4
12	Ricatti equation solution through LMI	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Kalman decomposition	3
2	Linear Quadratic regulator	4
3	H-infinity controllers	3
4	LMI based control design	4
5		
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. L. Fortuna, M. Frasca (Eds.), “Optimal and Robust Control”, CRC Press, 2012
2. K. Zhou, J. C. Doyle and K. Glover, “Robust and Optimal Control”, Prentice Hall, 1996.
3. J. C. Doyle, B. A. Francis and A. R. Tannenbaum, “Feedback Control Theory”, Macmillan, 1992.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	10%
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Networked and Multi-Agent Control Systems
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL805
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL700, ELL 701

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To analyze and design control systems for networked and multi-agent systems.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Overview of networked systems, Graph Theory Fundamentals, Graph-based Network Models, Network Optimization, Consensus Problem: cooperative control, leader-follower architecture. Control under Communication Constraints, Formation Control, Swarming and Flocking Collision Avoidance, Game Theoretic Control of Multi-Agent Systems, Applications: Multi-robot/vehicle coordination, Sensor Networks, Social Networks, Smart Grids, Biological Networks

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of networked systems	1
2	Graph Theory Fundamentals	4
3	Graph-based Network Models	4
4	Network Optimization	3
5	Consensus Problem: cooperative control, leader-follower architecture	5
6	Control under Communication Constraints	4
7	Formation Control	4
8	Swarming and Flocking	5
9	Collision Avoidance	2
10	Game Theoretic Control of Multi-Agent Systems	5
11	Applications: Multi-robot/vehicle coordination, Sensor Networks, Social Networks, Smart Grids, Biological Networks	5
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. C. Godsil and G. Royle, *Algebraic Graph Theory*, Springer, 2001.
2. M. Mesbahi and M. Egerstedt , *Graph Theoretic Methods in Multi-Agent Networks*, Princeton University Press, 2010.
3. F. Bullo, J. Cortes, and S. Martinez, Distributed Control of Robotic Networks, Princeton, 2009.
4. Wei Ren, Randal W. Beard, *Distributed Consensus in Multi-vehicle Cooperative Control,* Communications and Control Engineering Series, Springer-Verlag, London, 2008.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	MATLAB
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	30%
21.2	Open-ended problems	5%
21.3	Project-type activity	40%
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Modeling and Control of Distributed Parameter Systems
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL806
6.	**Status** (*category* for *program*)	M. Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL700, ELL701

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I N Kar, M Nabi, S. Janardhanan, S Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** Introduction to modeling, analysis and control of distributed parameter systems.

14.	**Course contents (about 100 words) (Include laboratory/design activities):**
	Overview: Motivation and examples (wave propagation, fluid flow, network traffic, electromagnetism), Modeling of Distributed Parameter Systems (DPS): Parabolic and Hyperbolic PDEs, Analytic and Numerical Solution of PDEs, Lyapunov stability of DPS Boundary control and Observer Design of DPS, Discretization of Distributed Parameter Models: Finite Difference, Finite Element and Boundary Elements, Reduction of FEM models, Applications: Control of systems with time delays, control of fluid flow, network control

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview: Motivation and examples (wave propagation, fluid flow, network traffic, electromagnetism)	4
2	Modeling of Distributed Parameter Systems: Parabolic and Hyperbolic PDEs	5
3	Analytic and Numerical Solution of PDEs	5
4	Lyapunov stability of DPS	3
5	Boundary control and Observer Design of DPS	7
6	Finite Difference discretization of DPS	4
7	Finite Element discretization of DPS	4
8	Boundary Elements discretization of DPS	4
9	Reduction of discretized models	3
10	Applications: Control of systems with time delays, control of fluid flow, network control	3
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Miroslav Krstic and Andrey Smyshlyaev, Boundary Control of PDEs: A Course on Backstepping Designs, SIAM, 2008
2. Nonlinear and Robust Control of PDE Systems", Panagiotis D. Christofides, Birkhauser 2001
3. Nonlinear Systems", by Hassan K. Khalil, Third Edition, Prentice Hall 2002

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Stochastic Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL807
6.	**Status** (*category* for *program*)	M.Tech. (PE for EEA)

7.	**Pre-requisites** (course no./title)	ELL700, ELL701

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	-

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** I. N. Kar, S. Sen, S. Bhasin, S. Janardhanan, M. Nabi

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To understand dynamics of stochastic systems and their control strategies.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Overview of stochastic systems with examples, Modeling of Stochastic Systems: Continuous and discrete-time models subjected to noise, Markov Decision Processes, Introduction to Stochastic Calculus and Stochastic Differential Equations, Stochastic Stability, Stochastic Optimal Control with complete and partial observations, finite and infinite horizon problems, Linear and nonlinear Filtering, Separation Principle, Linear quadratic Gaussian Problem, Stochastic Dynamic Programming, Stochastic Adaptive Control, Applications: Finance, operations research, biology

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Overview of stochastic systems with examples	1
2	Modeling of Stochastic Systems: Continuous and Discrete-time models subjected to noise, Markov Decision Processes.	3
3	Introduction to Stochastic Calculus and Stochastic Differential Equations	6
4	Stochastic Stability	3
5	Stochastic Optimal Control with complete and partial observations, finite and infinite horizon problems	5
6	Linear and Nonlinear Filtering	4
7	Separation Principle	3
8	Linear quadratic Gaussian Problem	3
9	Stochastic Dynamic Programming	6
10	Stochastic Adaptive Control	4
11	Applications: Finance, operations research, biology	4
COURSE TOTAL *(14 times 'L')*		**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	COURSE TOTAL	**14**

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Dimitri P. Bertsekas, Dynamic Programming and Optimal Control, Vol I (2005) , Vol II (2012), Athena Scientific
2. Karl J. Astrom, Introduction to Stochastic Control Theory, Dover, 2006.
3. B. Oeksendal, Stochastic Differential Equations: An Introduction with Applications, 2003.
4. P.R. Kumar, P. Varaiya, Stochastic Systems: Estimation, Identification and Adaptive Control, Prentice Hall, 1986.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	

20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Advanced Topics in Systems and Control
3.	**L-T-P structure**	3-0-0
4.	**Credits**	3
5.	**Course number**	ELL808
6.	**Status** (*category* for *program*)	M.Tech. (PE for EEA)

7.	**Pre-requisites** (course no./title)	To be decided by Instructor when floating this course

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	- NONE
8.2	Overlap with any UG/PG course of other Dept./Centre	- NONE -
8.3	Supersedes any existing course	- NONE -

9.	**Not allowed for** (indicate program names)	- NONE -

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** S. Janardhanan, M. Nabi, I. N. Kar, S. Bhasin, S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	- NO -

13.	**Course objectives** *(about 50 words)*: To introduce the advanced emerging topics in systems and control engineering, over and above the established courses.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To be decided by the Instructor when floating this course: Can be anything that is related to systems and control engineering but is not covered in any of the established courses.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
	To be decided by the Instructor	
	COURSE TOTAL *(14 times 'L')*	**42**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	COURSE TOTAL *(14 Hrs)*	

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. description of module-wise activities pertaining to self-study component

(mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be decided and announced by Instructor

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	Scilab or MATLAB
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	

21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Control Systems Laboratory
3.	**L-T-P structure**	0-0-3
4.	**Credits**	1.5
5.	**Course number**	ELP800
6.	**Status** (*category* for *program*)	M. Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	None
8.3	Supersedes any existing course	None

9.	**Not allowed for** (indicate program names)	B. Tech

10.	**Frequency of offering**	☐Every sem ☒1stsem ☐2ndsem ☐Either sem -

11.	**Faculty who will teach the course** Prof. I N Kar, Dr. M Nabi, Dr. S. Janardhanan, Dr. S Bhasin, Dr. S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	NO

13.	**Course objectives** *(about 50 words)***:** To familiarize with the practical aspects of Control Engineering.

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Basics of Sensors and Actuators, Study of AC and DC Motors, Linear Systems, Analog and Digital Motors, Synchros, Temperature Control.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours
1	Introduction	3
2	Study of AC and DC Motor Control Characteristics	3
3	Sensors and Transducers	3
4	Temperature Control of a Process	6
5	Study of Linear Systems through hardware	3
6	Analog Motor Control	3
7	Digital Control System	3
8	Modular Servo Systems and Control	3
9	Position Control System	3
10	Synchro-set : Study and Control	3
11	Make-up Turn	3
12	Lab Viva and Quiz	6
	Total	42

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Department of Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Advanced Control Laboratory
3.	**L-T-P structure**	0-0-3
4.	**Credits**	1.5
5.	**Course number**	ELP801
6.	**Status** (*category* for *program*)	M. Tech (PC for EEA)

7.	**Pre-requisites** (course no./title)	ELP800

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	NONE
8.2	Overlap with any UG/PG course of other Dept./Centre	NONE
8.3	Supersedes any existing course	NONE

9.	**Not allowed for** (indicate program names)	--

10.	**Frequency of offering**	☐Every sem ☐1stsem ☒2ndsem ☐Either sem -

11.	**Faculty who will teach the course** Prof. I. N. Kar, Dr. M. Nabi, Dr. S. Janardhanan, Dr. S. Bhasin and Dr. S. Sen

12.	**Will the course require any visiting faculty? (yes/no)**	No

13.	**Course objectives** *(about 50 words)***:** To familiarize with the practical aspects of Modern Control Engineering

14.	**Course contents (about 100 words) (Include laboratory/design activities):** Magnetic Levitation System, Twin Rotor MIMO System, Gyroscope, Ball and Beam System, Embedded Control System, Mobile Robotic System.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
COURSE TOTAL *(14 times 'L')*		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
1	Introduction	3
2	Study of Magnetic Levitation System	3
3	Control of Twin Rotor MIMO System	3
4	Study of Gyroscope	3
5	Nonlinear Control of Ball and Beam System	3
6	Embedded Control System	3
7	Mobile Robot Systems	3
8	Make-up Turn	3
9	Lab Viva and Quiz	3
10	Project Activity and Evaluations	15
	TOTAL	**42**

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)

COURSE TEMPLATE

1.	**Department/Centre proposing the course**	Electrical Engineering
2.	**Course Title** *(< 45 characters)*	Special Module in Systems and Control
3.	**L-T-P structure**	1-0-0
4.	**Credits**	1
5.	**Course number**	ELV700
6.	**Status** (*category* for *program*)	M.Tech (PE for EEA)

7.	**Pre-requisites** (course no./title)	To be decided by the instructor

8.	**Status vis-à-vis other courses** *(give course number/title)*	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supersedes any existing course	

9.	**Not allowed for** (indicate program names)	

10.	**Frequency of offering**	☐Every sem ☐1stsem ☐2ndsem ☒Either sem -

11.	**Faculty who will teach the course** Invited faculty/researcher

12.	**Will the course require any visiting faculty? (yes/no)**	Yes

13.	**Course objectives** *(about 50 words)***:** To provide exposure in specialized topics in systems and control

14.	**Course contents (about 100 words) (Include laboratory/design activities):** To provide exposure in specialized topics in systems and control

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
	To be decided by the instructor	
COURSE TOTAL *(14 times 'L')*		**14**

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	
20.2	Hardware	
20.3	Teaching aides (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: (Signature of the Head of the Department)