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| Course Number & Title: **RA604 & Advanced Engineering Dynamics** |
| L-T-P-C: **3-0-0-6** |
| Course Content/ Syllabus Overview of Vector operations and Newtonian Mechanics. Particle Kinematics: curves in space and kinematical descriptions; Relative Motion: Coordinate transformations, displacement analysis, velocity and acceleration analysis in moving reference frames. Rigid Body Motion Kinematics: Eulerian angles, interconnections and linkages, rolling, Euler Parameters. Rigid Body Geometry. Newton-Euler equations of motion. Introduction to Analytical Mechanics. Constrained Generalized coordinates. Advanced concepts in rigid body dynamics: modified Eulers equations, moment equations about an arbitrary point, quasi-coordinates and velocities, Gibbs-Appells equations, Kane’s equations. Gyroscopic effects. Application case studies for multi-body, aerospace and underactuated system problems. |
| References:  |
| 1. | J.H. Ginsberg, Advanced Engineering Dynamics, 2nd Edition, Cambridge University Press, 1998. |
| 2.  | D.T. Greenwood, Advanced Dynamics, Cambridge University Press, 2003. |
| 3. | H. Baruh, Analytical Dynamics, International Edition, McGraw-Hill, 1999. |

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| Course Number & Title: **RA603 & CAD/CAM** |
| Course Content/ Syllabus:  Introduction and components of Computer aided design (CAD)/Computer aided manufacturing (CAM)/Computer aided engineering (CAE) systems; Basic concepts of graphics programming; Transformation matrix; Rendering; Graphical user interface; Computer aided drafting systems; Geometric modeling systems – wireframe, surface and solid modeling systems; Nonmanifold systems; Assembly and web-based modeling systems; Representation and manipulation of conic sections; Hermite, Bezier, and B-spline curves and surfaces; Introduction to optimization; CAD/CAM integration; Numerical control – Concepts for manual and computer assisted part programming; Virtual engineering – components and applications; Extensive laboratory work on CAD (Solid modeling software), CAM (manufacturing software), and CAE (Finite element analysis software)  |
| **Texts:**  |
| 1. | Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison Wesley, 1999. |
| 2. | Zeid, Ibrahim, *CAD/CAM theory and practice*, McGraw-Hill Higher Education, 1991. |
| **References** |
| 1. | Mark E. Coticchia, George W. Crawford, and Edward J. Preston, CAD/CAM/CAE systems: justification, implementation and productivity measurement, 2nd edition, New York, Marcel Dekker, 1993. |
| 2.  | Chris Macmahon and Jimmie Browne CADCAM: principles, practice and manufacturing management, 2nd edition, Addison Wesley, 1998. |
| 3. | Mikell P. Groover and Emory W. Zimmers ,CAD/CAM: Computer aided design manufacturing, Prentice Hall, 1996. |
| 4. | P. Radhakrishnan, S. Subramanyan, and V. Raju, CAD/CAM/CIM , 2nd edition, New Age, 2000. |

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| Course Number & Title: **RA605 & Deep Learning for Robotics** |
| Course Content/ Syllabus:  Machine Learning: Fundamentals; Neural Network: Perceptrons, Back Propagation, Over-fitting, Regularization. Deep Networks: Definition, Motivation, Applications; Principal Component Analysis; Restricted Boltzmann Machine; Sparse Auto-encoder; Deep Belief Net; Hidden Markov Model. Convolution Neural Network (CNN): Basic architecture, Activation functions, Pooling, Handling vanishing gradient problem, Dropout, Greedy Layer-wise Pre-training, Weight initialization methods, Batch Normalization; Different CNN Models: Alex Net, VGG Net, Google Net, Res Net, Dense Net, MIL, Highway Network, Fractal Network, Siamese Net; Graphical Model: Bayes Net, Variational Auto-encoders. Sequence Learning: 1D CNN, Recurrent Neural Network (RNN), Gated RNN, Long short-term memory (LSTM). Generative Modeling: Generative adversarial network. Zero Shot Learning. Applications. Case studies in Robotics |
| **Texts:** |
| 1. | Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press, 2016 |
| **References:**  |
| 1. | Michael A. Nielsen, Neural Networks and Deep Learning, Determination Press, 2015 |
| 2.  | Yoshua Bengio, Learning Deep Architectures for AI, now Publishers Inc., 2009 |

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| Course Number & Title: **RA607 & Underactuated Systems** |
| Pre-Requisite: **RA602 (Control Engineering for Robotics) or equivalent** |
| Course Content/ Syllabus:  Underactuated systems: acrobots, cart-poles, quadrotors, walking robots; Dynamic Programming; Lyapunov Analysis and Stability Theory; Underactuated System Dynamics and Controller Design; Trajectory Optimization; Feedback Motion Planning; Underwater Robots: working principles and their control. Case studies on overhead cranes and drones. |
| **Texts:**  |
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| **References:**  |
| 1. | Tedrake, R., Underactuated Robotics: Algorithms for Walking, Running, Swimming, Flying and Manipulation, MIT Opencourseware. <https://underactuated.mit.edu/> |
| 2. | Qian D., Anti-Sway Control for Cranes: Design and implementation using MATLAB, De Grutyer, 1st Ed., 2017. |
| 3. | Huang A.C., Chen Y.F. and Kai C.Y., Adaptive Control of Underactuated Mechanical Systems, World Scientific, 2015. |
| 4. | G. Antonelli, Underwater Robots, Springer Tracts in Advanced Robotics, Springer Cham, 2014. |
| 5. | Fantoni, I. and Lozano, R., Non-linear Control for Underactuated Mechanical Systems, Communications and Control Engineering, Springer, London, 2022. |
| 6.  | Sebbane Y.B., A First Course in Aerial Robots and Drones, 1st Edition, Chapman and Hall/CRC, New York, 2022. |
| 7. | S. Wadoo and P. Kachroo, Autonomous Underwater Vehicles: Modeling, Control Design and Simulation, CRC Press, 2011. |

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| Course Number & Title: **RA608 & Design, Simulation and Programming Lab** |
| Course Content/ Syllabus:  Computer Aided Design: Introduction to SOLIDWORKS, Demonstrations on Mechanisms and their design. Introduction to PowerShape and PowerMILL with examples. MATLAB Programming: Review of C/C++, numerical differential and integration, plotting functions, working of Simulink with examples. Robot Operating System: Installation and working with case studies. Introduction to Python: why Python, ecosystem: installation, workflow, data types, control flow, functions, scripts and modules, input, output, standard library, Numpy arrays, Pandas Basic, Generators, List Comprehensions, Multiple Function Arguments, Regular Expressions, Exception Handling, Sets, Serialization, Partial functions, Code Introspection, Closures, Decorators, Map, Filter, Reduce, Visualization with Matplotlib, Libraries for AI. |
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| **References:**  |
| 1. | Zeid, Ibrahim, *CAD/CAM theory and practice*, McGraw-Hill Higher Education, 1991. |
| 2. | Rudra Pratap, *Getting Started with Matlab*, Oxford University Press, 7th edition, 2016. |
| 3. | Python Data Science Handbook, O’REILLY <https://jakevdp.github.io/PythonDataScienceHandbook/> |
| 4. | M. Lombard, *Mastering SOLIDWORKS*, Sybex, John Wiley & Sons, 2019. |
| 5. | L. Joseph, Robot Operating System for Absolute Beginners, APress, 2018. |
| 6. | Nnaji B.O., *Computer-aided Design, Selection and Evaluation of Robots*, Manufacturing Research & Technology, Elsevier Science Ltd, 1986. |
| 7.  | G.C. Onwubolu, *Introduction to Solidworks: A Comprehensive guide with applications to 3D Printing*, CRC Press, 2017. |
| 8. | B. Gottfried and J. Chhabra, *Programming with C*, Tata Mcgraw Hill, 4th Edition, 2018. |
| 9. | Stormy Attaway, Matlab: *A Practical Introduction to Programming and Problem Solving*, Butterworth-Heinemann Elsevier, 5th edition, 2018. |

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| Course Number & Title: **RA609 & Robotics Lab** |
| Course Content/ Syllabus:  Modelling of Mobile Robots and Navigation. Robot SLAM. Robot Path Planning with examples using PowerShape and PowerMILL. Robotics System Toolbox: Installation and Working with examples, Case studies in Robot Planning and Control. Drone control and navigation |
| **References:**  |
| 1. | Siegwart R. andNourbakhsh I.R., Introduction to Autonomous Mobile Robots, MIT Press, Cambridge, MA, 2004. |
| 2. | P. Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, 2nd Edition, Springer, 2017 |
| 3. | Hover F. and Chin H., Design of Electromechanical Robotic Systems, MIT Opencourseware, <https://ocw.mit.edu/courses/2-017j-design-of-electromechanical-robotic-systems-fall-2009/> |
| 4.  | Robotics System Toolbox, <https://in.mathworks.com/help/robotics/> |
| 5. | Madrigal J.A.F. and Claraco J.L.B., Simultaneous Localization and Mapping for Mobile Robots: Introduction and Methods, Information Science Reference, IGI Global, 2013. |
| 6. | S. Wadoo and P. Kachroo, Autonomous Underwater Vehicles: Modeling, Control Design and Simulation, CRC Press, 2011. |
| 7. | Sebbane Y.B., A First Course in Aerial Robots and Drones, 1st Edition, Chapman and Hall/CRC, New York, 2022. |
| 8. | Joseph L., Mastering ROS for Robotics Programming, Packt Publishing, Birmingham, 2015. |