B.Sc.(Hons)Mathematics,Semester-IV,DSE-Courses

DISCIPLINESPECIFICELECTIVECOURSE–2(i):BIOMATHEMATICS

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle&Code	Credits	Creditdistributionofthecourse			Eligibility criteria	Pre-requisiteof the course (ifany)
		Lecture	Tutorial	Practical/ Practice		
Biomathematics	4	3	1	0	ClassXIIpass with Mathematics	DSC-6:Ordinary DifferentialEquations

LearningObjectives: Themainobjectiveofthiscourseis to:

- Developandanalysethemodelsofthebiologicalphenomenonwithemphasisonpopulation growth and predator-prey models.
- Interpret first-order autonomous systems of nonlinear differential equations using the Poincaré phase plane.
- Applythebasicconceptsofprobabilitytounderstandmolecular evolutionandgenetics.

LearningOutcomes: Thiscoursewillenablethestudents to:

- Tolearnandappreciatestudyoflong-termbehaviorarisingnaturallyinstudyofmathematical models and their impact on society at large.
- Tounderstandspreadofepidemictechnicallythroughvariousmodelsandimpactof recurrence phenomena.
- Learn what properties like Chaos and bifurcation means through various examples and their impact in Bio-Sciences.

SYLLABUSOFDSE-2(i)

UNIT – I: Mathematical Modeling for Biological Processes (15hours)

Formulation a model through data, A continuous population growth model, Long-term behavior and equilibrium states, The Verhulst model for discrete population growth, Administration of drugs, Differential equation of chemical process and predator-prey model (Function response: Types I, II and III).

UNIT – II: Epidemic Model: Formulation and Analysis (15hours)

Introductiontoinfectiousdisease,TheSIS,SIRandSEIRmodelsofthespreadofanepidemic, Analyzing equilibrium states, Phase plane analysis, Stability of equilibrium points, Classifying the equilibrium state; Local stability, Limit cycles, Poincaré-Bendixson theorem.

UNIT–III:Bifurcation,ChaosandModelingMolecularEvolution (15hours)

Bifurcation,Bifurcationofalimitcycle,Discretebifurcationandperiod-doubling,Chaos,

Stability of limit cycles, Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

EssentialReadings

1. Robeva,RainaS.,et al.(2008).AnInvitationto Biomathematics.Academicpress.
2. Jones,D.S.,Plank,M.J.,&Sleeman,B.D.(2009).DifferentialEquationsand Mathematical Biology (2nd ed.). CRC Press, Taylor & Francis Group.
3. Allman,ElizabethS.,&Rhodes,JohnA.(2004).MathematicalModelsinBiology:An Introduction. Cambridge University Press.

SuggestiveReadings

- LindaJ.S.Allen (2007).An IntroductiontoMathematicalBiology.Pearson Education.
- Murray,J.D.(2002).MathematicalBiology:An Introduction(3rded.).Springer.
- Shonkwiler,RonaldW.,&Herod,James.(2009).MathematicalBiology:AnIntroduction with Maple and MATLAB (2nd ed.). Springer.

DISCIPLINESPECIFICELECTIVECOURSE–2(ii):MATHEMATICALMODELING

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle&Code	Credits	Creditdistributionofthecourse			Eligibility criteria	Pre-requisiteof the course (ifany)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Modeling	4	3	0	1	ClassXIIpass with Mathematics	DSC-6:Ordinary Differential Equations

LearningObjectives: Primaryobjectiveofthiscourseistointroduce:

- Mathematicalmodelingastherepresentationofasystembyasetofmathematical relations or equations.
- Mathematicalepidemiologicalmodelssusceptible-infectious-recovered(SIR)andits variant SEIR (S-Exposed-IR) for the spread of diseases.
- MonteCarlosimulationtechniques,andsimplexmethodforsolvinglinearprogramming problems.

LearningOutcomes: Thiscoursewillenablethestudents to:

- UnderstandthemethodologyofsolvingSIRmodelsfordisease spread.
- Learnsignificanceofdietingmodelthatprovidesimportantinsightsandguidestoa biomedical issue that is of interest to the general public.
- Understandnonlinearsystemsandphenomenawithstabilityanalysisrangesfromphase plane analysis to ecological and mechanical systems.

- UseMonteCarlo simulation technique to approximatearea under a givencurve, and volume under a given surface.

SYLLABUSOFDSE-2(ii)

UNIT – I: Mathematical Epidemiological and Dieting Models (15hours)

Modeling concepts and examples, Scaling of variables, and approximations of functions; SIR and SEIR models for disease spread: Methodology, Standard and solvable SIR models, Basic reproduction number; Dieting model with analysis and approximate solutions.

UNIT – II: Modeling with Nonlinear Systems and Phenomena (15hours)

Stability and the phase plane, Almost linear systems; Ecological models: Predators and competitors, Critical points, Oscillating populations, Survival of single species, Peaceful coexistenceoftwospecies,Interactionoflogisticpopulations,Wildlifeconservationpreserve; Nonlinear mechanical systems: Hard and soft spring oscillations, Damped nonlinear vibrations.

UNIT – III: Simulation and Optimization Modeling (15hours)

Monte Carlo simulating deterministic, and probabilistic behavior, Generating random numbers; Linear programming model: Geometric and algebraic solutions, Simplex method and its tableau format, Sensitivity analysis.

EssentialReadings

1. Mickens,RonaldE.(2022).MathematicalModellingwithDifferentialEquations. CRC Press, Taylor & Francis Group.
2. Edwards,C.Henry,Penney,DavidE.,&Calvis,DavidT.(2023).DifferentialEquations and Boundary Value Problems: Computing and Modeling (6th ed.). Pearson.
3. Giordano,FrankR.,Fox,WilliamP.,&Horton,StevenB.(2014).AFirstCoursein Mathematical Modeling(5thed.). Brooks/Cole, Cengage Learning IndiaPvt. Ltd.

SuggestiveReadings

- Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modeling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
- Ross,ShepleyL.(2014).DifferentialEquations(3rd ed.).WileyIndiaPvt.Ltd.
- Simmons,GeorgeF.(2017).DifferentialEquationswithApplicationsandHistoricalNotes (3rd ed.). CRC Press. Taylor & Francis Group.

Practical(30hours)- Practicalworktobeperformedin ComputerLab:Modelingofthe following problems using: R/Python/SageMath/Mathematica/MATLAB/Maxima/Scilab etc.

1. a)SimulationofSIRmodeland itsvariantsusingsomeinitialparametervalues,and finding basic reproduction number for analysis.
   b)Analysisofthedietingprocess,whichincludesbothbody-masslossand gain.
2. NonlinearSystemsand Phenomena.
   a) Plotphaseplaneportraitsandsolutionsof first-order equations.
   b) Obtaininterestingand complicatedphaseportraitsforalmostlinearsystems.

c) Discuss large wildlife conservation preserve model and obtain (i) The period of oscillation of the rabbit and fox populations, (ii) The maximum and minimum numbers of rabbits and foxes.
d) DiscusstheRayleigh andvan derPol models.

3. (i)Randomnumbergenerationandthenuseitfor the following:
   a) Simulateareaunder agiven curve.
   b) Simulatevolumeunderagivensurface.

   (ii)[2]Chapter7(Projects7.4and7.5).

DISCIPLINESPECIFICELECTIVECOURSE–2(iii):MECHANICS

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle&Code	Credits	Creditdistributionofthecourse			Eligibility criteria	Pre-requisiteof the course (ifany)
		Lecture	Tutorial	Practical/ Practice		
Mechanics	4	3	1	0	ClassXIIpass with Mathematics	DSC-5: Calculus DSC-6:Ordinary Differential Equations

LearningObjectives: Themainobjectiveofthiscourseis to:

- StartingNewtonianlaws,learningvarioustechnicalnotionswhichexplainsvarious states of motion under given forces.
- Dealswiththekinematicsandkineticsoftherectilinearandplanarmotionsofaparticle including constrained oscillatory motions of particles, projectiles, and planetaryorbits.
- Understandhydrostaticpressureandthrustonplane surfaces.

LearningOutcomes: Thiscoursewillenablethestudents to:

- Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces.
- Applytheconceptsofcenterofgravity,lawsofstatic andkineticfriction.
- Learn that aparticle moving undera centralforcedescribesaplanecurveand know the Kepler's laws of the planetary motions.
- Evaluate the hydrostatic pressure at any given depth in a heavy homogeneous liquid at rest under gravity.

SYLLABUSOFDSE-2(iii)

UNIT–I:Statics (15hours)

Fundamental laws of Newtonian mechanics, Lawof parallelogram of forces, Equilibrium ofa particle, Lamy's theorem, Equilibrium of a system of particles, External and internal forces, Couples,Reductionofaplaneforcesystem,Work,Principleof virtualwork,Potentialenergy and conservative field, Mass centers, Centers of gravity, Friction.

UNIT–II:Dynamics (18hours)

Kinemetics of a particle, Motion of a particle, Motion of a system, Principle of linear momentum,Motionofmasscenter,Principleofangularmomentum,Motionrelativetomass center, Principle of energy, D'Alembert's principle; Moving frames of reference, Frames of reference with uniform translational velocity, Frames of reference with constant angular velocity;Applicationsinplanedynamics-Motionofaprojectile,Harmonicoscillators,General motion under central forces, Planetary orbits.

UNIT–III:Hydrostatics (12hours)

Shearingstress,Pressure,Perfectfluid,Pressureatapointinafluid,Transmissibilityofliquid pressure, Compression, Specific gravity, Pressure of heavy fluid- Pressure at all points in a horizontal plane, Surface of equal density; Thrust on plane surfaces.

EssentialReadings

1. Synge,J.L.,&Griffith,B.A.(2017).PrinciplesofMechanics(3rded.).McGraw-Hill Education. Indian Reprint.
2. Ramsey,A.S.(2017).Hydrostatics.CambridgeUniversityPress.IndianReprint.

SuggestiveReadings

- Roberts,A.P.(2003).StaticsandDynamicswithBackgroundMathematics.Cambridge University Press.
- Ramsey,A.S.(1985).Statics(2nded.).CambridgeUniversityPress.

B.Sc.(Hons)Mathematics,Semester-V,DSE-Courses

DISCIPLINESPECIFICELECTIVECOURSE–3(i):MATHEMATICALDATASCIENCE

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle&	Credits	Creditdistributionofthecourse			Eligibility	Pre-requisiteof
Code		Lecture	Tutorial	Practical/ Practice	criteria	thecourse (if any)
Mathematical Data Science	4	3	0	1	ClassXIIpass with Mathematics	Basicknowledgeof R/Python DSC-3:Probability & Statistics

LearningObjectives: Themainobjectiveofthiscourseis to:

- Introducevarioustypesofdataandtheirsources,alongwithstepsinvolvedindatascience case-study, including problems with data and their rectification and creation methods.
- Coverdimensionalityreductiontechniques,clusteringalgorithmsandclassificationmethods.

LearningOutcomes: Thecoursewillenablethestudentsto:

- Gain a comprehensive understanding of data science, its mathematical foundations including practical applications of regression, principal component analysis, singular value decomposition, clustering, support vector machines, and *k*-NN classifiers.
- Demonstrate data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation and regularization using R/Python.
- Use real-world datasets to practice dimensionality reduction techniques such as PCA, SVD, and multidimensional scaling using R/Python.

SYLLABUSOFDSE-3(i)

UNIT-I: Principles of Data Science (12 hours)

Types of Data: nominal, ordinal, interval, and ratio; Steps involved in data science case-study: question, procurement, exploration, modeling, and presentation; Structured and unstructureddata:streams,frames,series,surveyresults,scaleandsourceofdata–fixed, variable,highvelocity,exactandimplied/inferred;Overviewofproblemswithdata–dirty and missing data in tabular formats – CSV, data frames in R/Pandas, anomaly detection, assessing data quality, rectification and creation methods, data hygiene, meta-data for inline data-description-markups such as XML and JSON; Overview of other data-source formats – SQL, pdf, Yaml, HDF5, and Vaex.

Unit-II: Mathematical Foundations (15hours)

Model driven data in R^n, Log-likelihoods and MLE, Chebyshev, and Chernoff-Hoeffding inequalitieswithexamples,Importancesampling;NormsinVectorSpaces–Euclidean,and metric choices; Types of distances: Manhattan, Hamming, Mahalanobis, Cosine and angular distances, KL divergence; Distances applied to sets– Jaccard, and edit distances; Modeling text with distances; Linear Regression: Simple, multiple explanatory variables, polynomial, cross-validation, regularized, Lasso, and matching pursuit; Gradient descent.