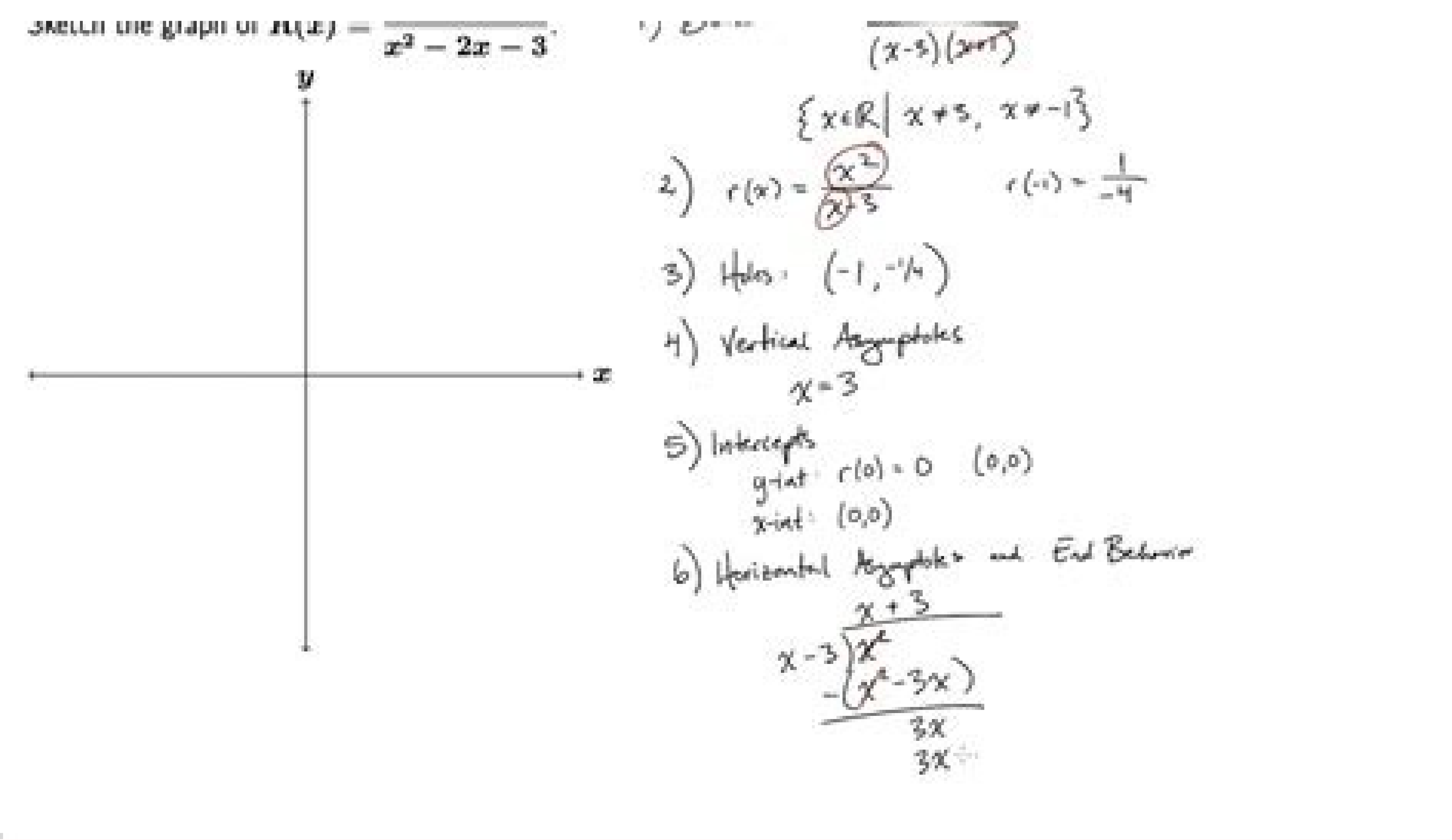
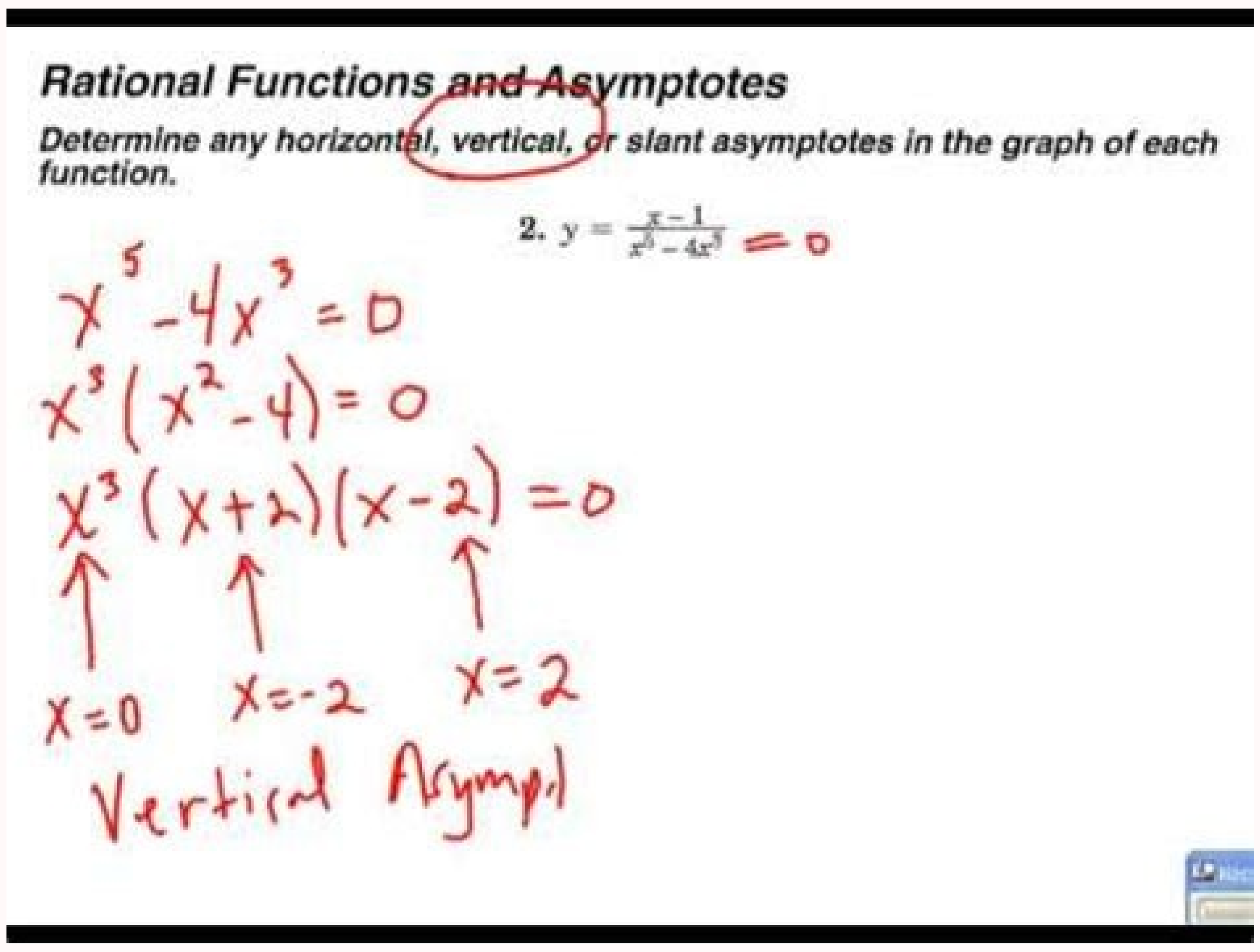
Asymptotes and holes of rational functions worksheet





$$\frac{5x+1}{x^2-2x-3}-\frac{5x-3}{x^2-x-6}=\frac{5x+1}{(x-3)(x+1)}-\frac{5x-3}{(x-3)(x+2)}=$$

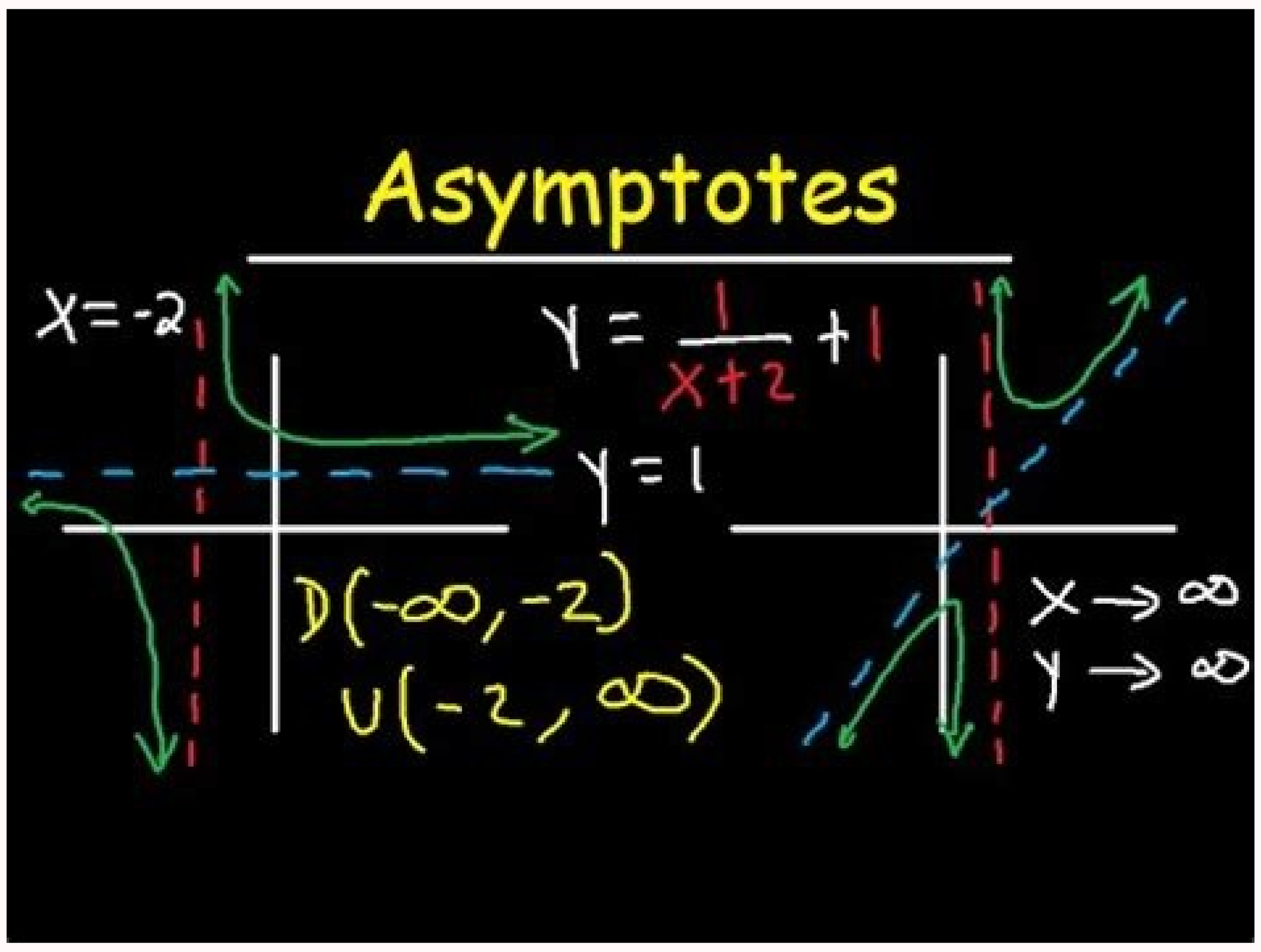
$$=\frac{(5x+1)(x+2)}{(x-3)(x+1)(x+2)}-\frac{(5x-3)(x+1)}{(x-3)(x+2)(x+1)}=$$

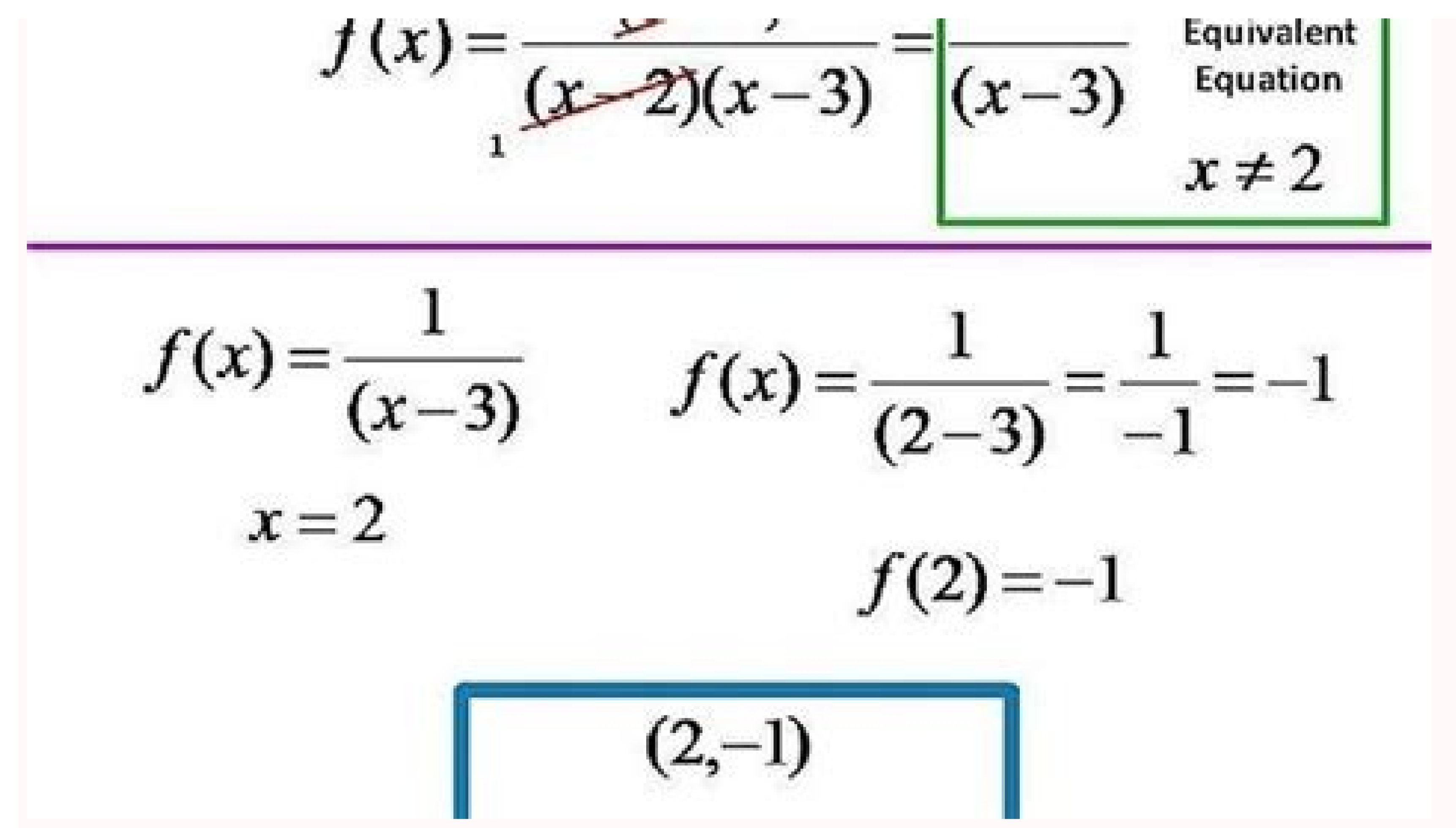
$$=\frac{(5x+1)(x+2)-(5x-3)(x+1)}{(x-3)(x+1)(x+2)}=$$

$$=\frac{(5x^2+10x+x+2)-(5x^2+5x-3x-3)}{(x-3)(x+1)(x+2)}=$$

$$=\frac{5x^2+10x+x+2-5x^2-5x+3x+3}{(x-3)(x+1)(x+2)}=$$

$$=\frac{9x+5}{(x-3)(x+1)(x+2)}$$





Finding asymptotes and holes of rational functions worksheet.

LectureSectionTopicsIntroduction and Basic Principles of ModelingDiscrete Dynamical SystemsDiscrete Stochastic ModelsStages, States, and ClassesContinuous Dynamical SystemsContinuous Dynamical Systems (continued) and Related TopicsContinuous Stochastic ModelsMathematical Contest in Modeling: Student Discussions and Projects Math 61: Introduction to Discrete Structures Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 31A, 31B. Not open for credit to students with credit for course 180 or 184. Discrete structures commonly used in computer science and mathematics, including sets and relations, permutations and combinations, graphs and trees, induction. P/NP or letter grading.The following schedule, with textbook sections and topics, is based on 26 lectures. The remaining classroom meetings are for two midterm exams and review. These are scheduled by the individual instructor. Often there are midterm exams about the beginning of the fourth and eighth weeks of instruction.R. Johnsonbaugh, Discrete Mathematics (8th Edition) , Prentice-Hall.LectureSectionTopicsEquivalence relations, matrices of relationsBasic counting principlesPermutations and combinationsGeneralized permutations and combinationsSolving recurrence relations (including material in exercises 40-46)Decision trees, sorting (including merge sort from 7.3) Math 70: Introduction to Probability Course Description(4) Lecture, 3 hours; Discussion, 1 hour. Requisites: courses 31A, 31B. Introduction to probability through applications and examples. Topics include laws of large numbers, statistics, chance trees, conditional probability, Bayes? rule, continuous and discrete random variables, jointly distributed random variables, multivariate normal and conditional distributions. In depth discussion of betting schemes in gambling, occurrence of rare events, coincidences and statistical predictions. P/NP or letter grading. The course introduces a list of standard probabilistic problems and analyzes them in detail within the formalism of probability as a mathematical discipline. At the end of the course, the students will be able to demonstrate their understanding of the foundations and basic facts of probability as a mathematical discipline and apply them to resolve questions with probabilistic content.

solution to one dimensional heat equation.Separation of variables solution to Laplace's equation in a disk.Sturm-Liouville problems.Calculus of Variations: Introduction.Euler's differential equation for an extremal. Math 136: Partial Differential Equations Course DescriptionLecture, three hours; discussion,one hour. Prerequisites: courses 33A, 33B. Linear partial differential equations, boundary and initial value problems; wave equation, heat equation, and Laplace equation; separation of variables, eigenfunction expansions; selected topics, as method of characteristics for nonlinear equations.W.A. Strauss, Partial Differential Equations, 2nd Edition, John Wiley and Sons.The course covers Chapters 1, 2, parts of 3, and most of 4-6.LectureSectionTopicsThe notion of a partial differential equation (PDE), the order of a PDE, linear PDE, examples. First order linear PDE.Homogeneous first order linear PDE with constant coefficients. The method of characteristics (geometric method) and the coordinate method. First order linear PDE with variable cofficients. Characteristic curves and the geometric method in the case of variable cofficients. The solvability of the Cauchy problem for a first order linear PDE (the statement only).PDE from Physics. Examples: the heat equation (derivation using Fourier's law), vibrating strings and drumheads, the wave equation and the Laplace equation. Schrodinger's equation.Initial and boundary conditions for PDE. Classification of second order linear PDE with constant coefficients. Elliptic and hyperbolic PDE.The wave equation on the real line.Traveling waves. The Cauchy problem for the wave equation and the d'Alembert formula. Examples.The causality principle for the wave equation. The domain of dependence and the domain of influence. Conservation of energy.The diffusion/heat equation on the real line. The maximum principle and the uniqueness of the Dirichlet problem for the heat equation. The heat kernel and the solution of the initial value problem for the heat equation on the real line. The smoothing property of the heat flow and the comparison of the main properties of the wave and heat equations.The heat equation on the half-line. The Dirichlet and Neumann boundary conditions. The method of reflections.The wave equation on the half-line. Reflected waves. (The first part of Section 3.2).The inhomogeneous heat equation on the real line. The inhomogeneous wave equation on the real line and the operator method. Duhamel's principle. (Section 3.4: the proof of Theorem 1 using the operator method)Review before the midterm.Spectral methods for boundary problems on finite intervals. Separation of variables and the wave equation with Dirichlet boundary conditions. The eigenvalues and eigenfunctions on a bounded interval with Dirichlet boundary conditions. The heat equation with Dirichlet boundary conditions. Formal eigenfunction expansions.The Neumann boundary conditions for the wave and the heat equations. The eigenvalues and eigenfunctions of on a bounded interval with Neumann boundary conditions.The eigenvalues and eigenfunctions on a bounded interval with Robin boundary conditions: a cursory discussion.Fourier series and Fourier coefiicients of periodic functions in real and complex form. Fourier series expansions for functions defined on an interval of the form via even and odd extensions. Since and cosine expansions. Examples.Symmetric boundary conditions and the orthogonality of eigenfunctions. Convergence theorems for Fourier series, the notions of uniform and L^2-convergence. The least square approximation, Bessel's inequality, and Parseval's identity. One word about the pointwise convergence of Fourier series.The Laplace equation and harmonic functions. The maximum principle and the uniqueness of the Dirichlet problem. The Laplace operator in polar coordinates and the Newtonian potential in 2D and 3D.The Laplace equation and separation of variables in a rectangle. (Section 6.2, may be omitted due to time constraints).The Dirichlet problem in the disc and Poisson's formula. The mean value property for harmonic functions and their differentiability properties. Math 142: Mathematical Modeling Course DescriptionLecture, three hours; discussion, one hour. Prerequisites: courses 32B, 33B. Introduction to fundamental principles and spirit of applied mathematics. Emphasis on manner in which mathematical models are constructed for physical problems. Illustrations from many fields of endeavor, such as the physical sciences, biology, economics, and traffic dynamics.Haberman, R., Mathematical Models, Society for Industrial and Applied Mathematics. Math 146: Methods of Applied Mathematics Course DescriptionLecture, three hours; discussion, one hour. Prerequisite: courses 32B, 33B. Integral equations, Green's function, and calculus of variations. Selected applications from control theory, optics, dynamical systems, and other engineering problems.Troutman, J., Variational Calculus and Optimal Control: Optimization with Elementary Convexity, 2nd Ed., Springer. Math 151A: Applied Numerical Methods Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 32B, 33B, 115A, Program in Computing 10A. Introduction to numerical methods with emphasis on algorithms, analysis of algorithms, and computer implementation issues. Solution of nonlinear equations. Numerical differentiation, integration, and interpolation. Direct methods for solving linear systems. Matlab programming. Letter grading.R. Burden and J. Faires, Numerical Analysis, 10th Ed., Brooks/Cole.LectureSectionTopicsGeneral course overview and machine numbersAlgorithms and convergenceSecant method, and method of False PositionConvergence order. Multiple rootsZeros of polynomials. Horner's methodDeflation and Lagrange polynomialsLagrange polynomials and Neville's methodInterpolation nodes and finite differenceCubic spline interpolationForward/backward differenceFinite-difference formulasRichardson's extrapolation. Interpolation based numerical integrationNewton-Cotes formulas. Composite integration formulasSpecial types of matricesReview of matrix algebra. Jacobi's method Math 151B: Applied Numerical Methods Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 151A. Introduction to numerical methods with emphasis on algorithms, analysis of algorithms, and computer implementation. Numerical solution of ordinary differential equations. Iterative solution of linear systems. Computation of least squares approximations. Discrete Fourier approximation and the fast Fourier transform. Matlab programming. Letter grading.R. Burden and J. Faires, Numerical Analysis, 10th Ed., Brooks/Cole.LectureSectionTopicsHigher-order Taylor methods. Error analysis of one-step methodsStability of one-step methods. Taylor Theorem in two variablesButcher tableau. Design a Runge-Kutta methodRunge-Kutta-Fehlberg method.Adams-Bashforth/Adams-Moulton multistep methodsPredictor-corrector methods. Analysis of general multistep methodsStability of multistep methods. Stiff differential equationsRegion of absolute stabilityHigh-order differential equations. Systems of differential equationsBoundary value problems. Linear shooting methodNonlinear shooting method. Finite difference methods for linear BVPFinite-difference methods for nonlinear BVPSolving nonlinear systems of equations. Newton's methodQuasi-Newton method – Broyden's methodHomotopy and continuation methodsLinear algebra, Eigenvalues, orthogonal matrices and similarity transformationsPower method. Inverse Power methodHouseholder's transformation. Householder's methodQR factorization. QR algorithmDiscrete least squares approximation. Linearly independent functionsOrthogonal polynomials and least squares approximationContinuous and discrete trigonometric polynomial approximation.Fast Fourier transform II Math 151AH: Numerical Analysis Part 1 (Honors) Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 32B, 33B, 115A, 131A, Programming in Computing 10A or equivalent. Rigorous introduction to numerical algorithms including necessary skills to apply algorithms in statistics, imaging, data science, engineering and related fields. Root Finding, solving linear systems, interpolation, quadrature and finding eigenvalues. MatLab programming. P/NP or letter grading.Textbook:L. Ridgway Scott, Numerical Analysis, Princeton University Press.General Course Outline/Schedule of Lectures:WeekChapterTopics11, 18Introduction to finite precision arithmetic and algorithms. Convergence and Stability. Floating point numbers, their arithmetic and errors. Big "O" notation.22Fixed-point algorithms. Applications to root-finding. Newton's method and the secant method. Connections with optimization. Error analysis.35, 6Review of linear algebra. Vector spaces and norms. Infinite dimensional vector spaces. Operators and operator norms. Inner products. Powers and convergence of matrices.43Basic numerical methods for linear systems. Guassian elimination. Triangular matrices and the LU decomposition. Pivoting rules. Cholesky decomposition. Application to banded matrices.58Iterative methods for linear systems. Jacobi and Gauss-Seidel methods. Convergence analysis for these algorithms. Application to sparse linear systems. Matrix splittings in general.67System of nonlinear equations. Functional iteration. Newton's method and quasi-Newton's method. Bi-level procedures for fixed point problems.710, 11Polynomial interpolation. Connection to linear systems. Relationship between Taylor polynomials and Lagrange polynomials. Higher order interpolation schemes such as Hermite polynomials. Approximation with trigonometric series.812Introduction to approximation theory. Lebesgue and Sobolev spaces of functions. Weierstrass Thoerem. Bernstein polynomials. Splines. Connection between polynomials approximation and least squares.913Numerical quadrature. "Basic" schemes such as trapezoidal and Simpson's. Gaussian quadrature. Composite schemes.1014Introduction to eigenvalue problems. Some sample applications. Gershgorin's disks. Finding all vs. finding highest eigenvalue. Power method. Hessenberg factorizations and finding all eigenvalues. Math 151BH: Numerical Analysis Part 2 (Honors) Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 115A or 115AH, 131A or 131AH, 151A or 151AH, Computer Science 31 or Programming in Computing 10A, with grades of B or better. Rigorous introduction to numerical algorithms including necessary skills to apply algorithms in statistics, imaging, data science, engineering and related fields. Finding eigenvalues, finding numerical solutions to ordinary differential equations, the least squares problem and the fast Fourier transform. MatLab programming. Honors course parallel to course 151B. P/NP or letter grading.Course Objectives1. Students will acquire an understanding of the background theory, the derivation, and the implementation, of foundational methods of numerical approximation.2. Students will learn to analyze concrete problems that arise in practice, and choose and implement appropriate numerical methods for their solution.3. Students will learn how to assess the accuracy of approximations as function of the algorithms employed and the data used.4. Areas covered in 151BH include numerical methods for finding eigenvalues and eigenvector/eigenvalue pairs, methods for numerical solution of ordinary differential equations, including systems and boundary value problems, solution of least squares problems, and elementary Fourier theory, including the Fast Fourier Transform and some of its applications. Textbook:L. Ridgway Scott, Numerical Analysis, Princeton University Press. (LSR)R. Burden and J. Faires, Numerical Analysis, 10th Ed., Cengage. (BF)Grade policy:Homework 40% Midterm 25% Final exam 35%General Course Outline/Schedule of Lectures:WeekChapterTopics1BF: 8.1 – 8.5Brief review of linear algebra. The least squaresproblem. QR decompositions, Householder trans-formations.2BF: 8.1 – 8.5LSR: 9The conjugate gradient method. The Kacsmarzmethod. Ridge regression and LASSO.3LSR: 14Introduction to eigenvalue problems. Some sample applications. Gershgorin's disks. Finding all vs. finding highest eigenvalue. Power method. Hessenberg fact-orizations and finding all eigenvalues.4LSR: 15Eigenvalue algorithms. Power method, inverse iteration and deflation. Singular Value Decomposition. Finding all eigenvalues using QR decomposition and using Jacobi iteration.5BF: 5.9LSR: 16Ordinary differential equations. Existence and uniqueness of solutions. Euler and implicit Euler methods. Error estimates.6BF: 5.4LRS: 17Systems of differential equations and higher order differential equations. Higher order solvers for initial value problems. Runge-Kutta.7BF: 5.6, 5.10, 5.11Stability for numerical ODE solvers. Implicit schemes such as Adams-Moulton. Multi-step and predictor corrector schemes. Stability.8BF: 11.1 – 11.4Boundary value problems. Linear and nonlinear shooting methods. Finite difference methods.9BF 8.5, 8.6Trigonometric polynomial approximation. Elementary Fourier theory. The fast Fourier trans-form.10Review and catch-up. Math 155: Mathematical Imaging Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 32B, 33B, 115A, Program in Computing 10A. Imaging geometry. Image transforms. Enhancement, restoration, and segmentation. Descriptors. Morphology. P/NP or letter grading.R. Gonzalez and R. Woods, Digital Image Processing, New edition, Prentice-Hall. Book is Subject to Change Without Notice.LectureSectionTopicsIntroduction: A Simple image model (2.2); Sampling and Quantization (2.3)Introduction to the Fourier TransformThe Discrete Fourier TransformSome Properties of the Two-Dimensional Fourier TransformSome Properties of the Two-Dimensional Fourier TransformThe Fast Fourier TransformOther Separable Image TransformsOther Separable Image TransformsEnhancement by Point ProcessingEnhancement by Point ProcessingEnhancement in the Frequency DomainImage Restoration: Degradation ModelDetection of DiscontinuitiesEdge Linking and Boundary DetectionRegion-Oriented SegmentationThe Use of Motion in Segmentation Math 156: Machine Learning Course DescriptionLecture, three hours; discussion, one hour. Requisite: course 115A, 164, 170E (or 170A or Statistics 100A) and Programming in Computing 10A of Computer Science 31. Strongly recommended requisite: Program in Computing 16A or Statistics 21. Introductory course on mathematical models for pattern recognition and machine learning. Topics include parametric and nonparametric probability distributions, curse of dimensionality, correlation analysis and dimensionality reduction, and concepts of decision theory. Advanced machine learning and pattern recognition problems, including data classification and clustering, regression, kernel methods, artificial neural networks, hidden Markov models, and Markov random fields. Projects in MATLAB to be part of final project presented in class. P/NP or letter grading.?Pattern Recognition and Machine Learning?, by Christopher M. Bishop, Springer, 2006 (ISBN-13: 978-0387-31073-2), plus complementary sources where necessary (?n/a?).LectureSectionTopicsIntroduction, Definitions, Pre-requisites. Course Introduction, recap on Linear Algebra, probabilities. Gaussian, exponential pdf; Learning parametric pdf. Learning non-metric pdf.Correlation Analysis, dimensionality reduction, PCA. PCA: maximum variance, minimum error, high-dimensional PCA. Probablilistic PCA (ML-PCA, EM, Bayesian PCA). Non-linear latent variable models: ICA, kPCARegression. Linear Basis Function Models, least squares and maximum likelihood. Bayesian linear regression. Evidence Approximation.Classification. Disriminant functions; least squares. Logistic regression. Mixture of linear classifiers: Boosting and Bagging.Clustering. K-Means, Gaussian mixture model, Expectation-Maximization, Spectral clustering.Kernel methods. Dual representation, kernel trick; Constructing kernels. Gaussian processes, GP regression, GP classification. Support vector machines, k-SVM.Artificial neural networks. Biological motivation; the perceptron; Feed-forward Network. Single Layer network training. Multi-layer perceptron training: Backpropogation.Markov models. Bayesian Networks. Markov Random Fields; Iterated conditional modes (SA, graph-cuts). Hidden Markov Models; forward-backward, Viterbi algorithm.Advanced Topics (optional). Reinforcement learning, Bellman optimality. Vapnik-Chervonenkis (VC) dimension; overfit and underfit. Probably approximately correct (PAC) learning.Leeway (to accommodate midterm and holidays in the preceding weeks). Review. Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 115A, 131A. Not open for credit to students with credit for Electrical Engineering 136. Fundamentals of optimization. Linear programming: basic solutions, simplex method, duality theory. Unconstrained optimization, Newton's method for minimization. Nonlinear programming, optimality conditions for constrained problems. Additional topics from linear and nonlinear programming. P/NP or letter grading.The following schedule, with textbook sections and topics, is based on 27 lectures. The remaining classroom meetings are for leeway, reviews, and a midterm exam. These are scheduled by the individual instructor.E. K.P. Chong and S. Zak, An Introduction to Optimization, 4th Edition, Wiley.LectureSectionTopicsReview vector space, transforms geometry, calculusOptimization models, constraintsFeasible set, feasible directionsGradient methods, steepest descent methodAnalysis of gradient methodsNewton's methodModified Newton's methodGauss-Newton methodThe Conjugate Direction methodsQuasi-Newton MethodsMidtermSolving Linear equationsIntro. to linear programming, polyhedronLinear programming Simplex methodNonlinear optimization with equality constraintsNonlinear optimization with inequality constraintsAlgorithms for constrained optimizationCatch-up, Review Math 167: Mathematical Game Theory Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 115A. Quantitative modeling of strategic interaction. Topics include extensive and normal form games, background probability, lotteries, mixed strategies, pure and mixed Nash equilibria and refinements, bargaining; emphasis on economic examples. Optional topics include repeated games and evolutionary game theory. P/NP or letter grading.LectureSectionTopicsExample and graphical solutionMake eplicit definitios in 2×2 case and minmax. Minmax StatementNash equilibria (mutual best responses)Proof of minmax: assume separating hyperplane theorem and derive proof. Do planar n by 2 case first with pictures.Prove separating hyperplanesWork on good problems in classIntroduce non-cooperative (aka general sum) gameBasic 2 x 2 examples (PD, Dove-Hawk, etc.)Solve two- player NE's (2×2, 3×3 case)Beginning of proof of NE's: definition of a convex correspondence.Proof NE's exist based on Kakutani (convex correspondences have fixed points)Price of Anarchy, Chapter 8Stable matching, Chapter 10 Math 168: Introduction to Networks Course Description (4) Lecture, three hours; discussion, one hour. Requisites: courses 115A, 170A or Electrical and Computer Engineering 131A or Statistics 100A. Introduction to network science (including theory, computation, and applications), which can be used to study complex systems of interacting agents. Study of networks in technology, social, information, biological, and mathematics involving basic structural features of networks, generative models of networks, network summary statistics, centrality, random graphs, clustering, and dynamical processes on networks. Introduction to advance topics as time permits. P/NP or letter grading. Students will develop a sound knowledge and appreciation of some of the tools, concepts, and computations used in the study of networks. The study of networks is predominantly a modern subject, so the students will also be expected to develop the ability to read and understand current research papers in the field. They will also have a chance to explore a topic in depth in a final project. Topics include basic structural features of networks, generative models of networks, centrality, random graphs, clustering, and dynamical processes on networks. Mark E. J. Newman, Networks 2nd Edition, 2018 [primary text]Mason A. Porter and James Gleeson, Dynamical Systems on Networks: A Tutorial, 2016Supplementary material from survey, review, and tutorial articles. Lecture Section Topics Introduction and Basic Concepts Models of Network Formation Newman 7 + supplementary material Network Summary Statistics Newman 11 + supplementary articles Newman 16-18; Porter & Gleeson Dynamical Processes on Networks Introduction to Advanced Topics Math 170A: Probability Theory I Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 32B, 33A, 131A. Not open to students with credit in course 170E, Electrical Engineering 131A or Statistics 100A. Rigorous presentation of probability theory based on real analysis. Probability space, probability and conditional probability, independence, Bayes? rule, discrete and continuous random variables and their distributions, expectation, moments and variance, conditional distribution and expectation, weak law of large numbers. P/NP or letter grading.The course discusses the foundations of probability as a mathematical discipline rooted in undergraduate real analysis. At the end of the course, the students will have the tools and ability to formulate, analyze an answer questions in probability and prove the validity of their reasoning in full mathematical rigor.Probability: An Introduction (2nd ed.). by Grimmett, G. R., & Welsh, D. J. (2014).Oxford: Oxford University Press.Outline update: T. Austin, 01/20LectureSectionTopicsSample space, events, probabilityConditional probability and independencePartition theorem and Bayes rule, examplesDiscrete random variables, their functions, expectation and varianceConditional expectation, multivariate discrete distributionsIndependent discrete random variables, indicatorsCumulative distribution function, continuous random variablesMultivariate distributions and their marginalsChange of variables, conditional expectationSections 6.8, 7.3, 8.1-8.2Mutlivariate normal distribution, weak law of large numbers Math 170B: Probability Theory Course Description(4) Lecture, three hours; discussion, one hour. Enforced requisite: courses 170A, 131A. Continuation of rigorous presentation of probability theory based on real analysis. Moments and generating functions; laws of large numbers, the central limit theorem, and convergence in distribution; branching processes; random walks; Poisson and other random processes in continuous time. Advance topics in probability theory. P/NP or letter grading.Probability: An Introduction (2nd ed.). Oxford: Oxford University Press. by Grimmett, G. R., & Welsh, D. J. (2014).LectureSectionTopicsReview from 170A: probability spaces, random variables, and distributions; multi-variate distributions and independence; discrete and continuous conditional probabilityMoments, probability and moment generating functions, characteristic functionsInequalities. Laws of large numbers. The central limit theorem. Convergence in distribution.Branching processes and the method of generating functions, probability of extinctionRandom walks on the integers: recurrence vs transience, gambler's ruinPoisson processes and their inter-arrival times. Population growth, birth processesBirth-and-death processes, queueing models Math 170E: Introduction to Probability and Statistics: Part 1 Probability Course DescriptionLecture, three hours; discussion, one hour. Requisites: courses 31A, 31B. Not open to students with credit for course 170A, Electrical and Computer Engineering 131A, or Statistics 100A. Introduction to probability theory with emphasis on topics relevant to applications. Topics include discrete (binomial, Poisson, etc.) and continuous (exponential, gamma, chi-square, normal) distributions, bivariate distributions, distributions of functions of random variables (including moment generating functions and central limit theorem). P/NP or letter grading.Hogg, Tanis, Zimmerman Probability and Statistical Inference (10th Edition)LectureSectionTopicsBasic Properties of ProbabilityDiscrete Random VariablesNegative Binomial DistributionContinuous Random VariablesExamples: exponential, Gamma, Chi-squareMidterm on Chapters 1 and 2Add'l models: failure rate, mortality, insuranceDiscrete bivariate distributionsConditional DistributionsContinuous Bivariate DistributionsBivariate Normal DistributionFunctions of a random variableTransformations of 2 random variablesMoment generating functionsRandom functions associated to normal distributionsApproximations for Discrete distributionsChebyshev's inequality and convergence in probability Math 170S: Introduction to Probability and Statistics: Part 2 Statistics Course DescriptionLecture, four hours. Requisites: courses 31A, 31B, and 170E. The Math 170E and 170S two quarter probability and statistics sequence is aimed to equip Math-Econ and Financial Actuarial majors with essential skills in these areas. Math 170S is an introduction to statistics. Topics include sampling; estimation and the properties of estimators; construction of confidence intervals and hypotheses testing. It is designed to meet the Society of Actuaries' VEE Requirements for Mathematical Statistics. Letter grading.Hogg, Tanis, Zimmerman Probability and Statistical Inference (10th Edition)LectureSectionTopicsExploratory Data AnalysisMaximum Likelihood EstimationA Simple Regression ProblemConfidence Interval for MeansConfidence Intervals for the Difference of Two MeansConfidence Interval for ProportionsDistribution-Free Confidence Intervals for PercentilesMidterm 1 on Chapters 6 and 7Tests of the Equality of Two meansPower of a Statistical TestChi-Square Goodness-of-Fit TestsOne-Factor Analysis of VarianceTwo-Way Analysis of Variance Math 171: Stochastic Processes Course Description(Formerly numbered 151.)Lecture, three hours; discussion, one hour. Requisites: courses 33A, 170A (or Statistics 100A). Discrete Markov chains, continuous-time Markov chains, renewal theory. P/NP or letter grading. Math 174E: Mathematics of Finance for Mathematics/Economics Students Course Description(Formerly numbered 174.) Lecture, three hours; discussion, one hour. Enforced requisites: courses 33A, and 170E (or Math 170A or Statistics 100A). Not open for credit to students with credit for course 174A, Economics 141, or Statistics C183/C283. Mathematical modeling of financial securities in discrete and continuous time. Forwards, futures, hedging, swaps, uses and pricing (tree models and Black-Scholes) of European and American options, Greeks and numerical methods. P/NP or letter grading.Hull, John C., Options, Futures and Other Derivatives, 10th Edition. Pearson 2018.LectureSectionTopicsForwards, Futures, Options; Types of Traders; Examples of positions.Hedging Using Futures, Interest Rates (zero, forward, term structure) Bonds (duration, convexity)Swaps, Mechanics of Option Markets, Basic Properties of Stock Options (Put-Call Parity, Upper and Lower Bounds for Prices, Effect of Dividends)Binomial Tree Model of Option Pricing (include Proof in Appendix of Black Scholes model)Wiener Process (Brownian Motion) and Ito?s Lemma (include proof as per Appendix)Black-Scholes model (include risk neutral derivation in appendix)Instructor Choice: Do topics from Chapter 17 (Options on Stock Indices and Currencies) and Chapter 20 Volatility Smiles (Concerns deviation of real-world pricing from Black-Scholes model).Basic Numerical Procedures Math 177: Theory of Interest and Applications Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 32B. Types of interest, time value of money, annuities and similar contracts, loans, bonds, portfolios and general cash flows, rate of return, term structure of interest rates, duration, convexity and immunization, interest rate swaps, financial derivatives, forwards, futures, and options. Letter grading.An introductory course on financial mathematics, Math 177 lays the foundation and prepares students for the series of courses required for the Financial Actuarial Mathematics major. By the end of this course, students should be familiar with numerous foundational concepts of financial mathematics, especially those from the theory of interest rates. Since one goal of the course is to help students prepare for the challenging Financial Mathematics (FM) exam for the Society of Actuaries (SOA), two lectures before the midterms will be devoted to analysis of complex FM exam problems. While the basic ideas are mathematically elementary, their applications can be complex. The class is suitable for students who seek a career in financial engineering, the actuarial field, banking, etc., or are seeking to improve their financial literacy in a highly quantitative way.Broverman, Samuel A. Mathematics of Investment and Credit. 7th ed., Actex Publications, 2017.Bean, Michael A. (FSA, CERA FCIA, FCAS, PHD). Determinants of Interest Rates. Society of Actuaries, 2017. Education and Examination Committee of the Society of Actuaries – Financial Mathematics Study Note. Robert (ASA, MAAA). Using Duration and Convexity to Approximate Change in Present Value. Society of Actuaries, 2017. Education and Examination Committee of the Society of Actuaries – Financial Mathematics Study Note. ��Beckley, Jeffrey (FSA, MAAA). Interest Rate Swaps. Society of Actuaries, 2017. Education and Examination Committee of the Society of Actuaries – Financial Mathematics Study Note.Https://www.soa.org/Files/Edu/2017/fm-interest-rate-swaps.pdfLectureSectionTopicsSimple, compound, nominal and effective interest rates. Accumulation. Equation of value, actuarial notation.Effective and nominal discount rates, force of interest.Determinants of interest rates.Non-constant payments and other generalizations.Yield and reinvestment rates, depreciation.Determination of bond prices and amortization of a bond.Examples of bonds and applications.Internal rate of return defined and net present value.Other methods (dollar-weighted and time weighted) and examples of rate of return.Advanced problem analysis from Weeks 1-4.Advanced problem analysis from Weeks 1-4.Basic definitions, spot rates.Applications and examples of arbitrage, forward rate agreements and at-par yield.Macaulay duration and modified duration.Application to valuation of cash flows, dependence on term structure.Convexity and immunization.Definitions, determining swap rate.Case of constant notional amount, net payments.Advanced problem analysis from Weeks 6-8.Advanced problem analysis from Weeks 6-8.Derivatives, dividend discount model, short sale of equity investments, financial derivatives. Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 32B, 175 or 177, 170A or 170E or Statistics 100A. An introductory course on to the mathematics associated with long term insurance coverages. Single and multiple life survival models, annuities, premium calculations and policy values, reserves, pension plans and retirement benefits. Letter grading.A core sequence course for the Financial Actuarial Mathematics major, Mathematics 178A and the first half of Mathematics 178B cover the syllabus of the Society of Actuaries (SOA) Long-Term Actuarial Mathematics (LTAM) exam. By the end of this course, students will be able to value and set premiums for insurance instruments of various types using traditional actuarial models. They will also understand the typical models of life contingencies which are used in the calculations.Dickson, David C.M., Hardy, Mary R. and Waters, Howard R, Actuarial Mathematics for Life Contingent Risks. 2nd ed., Cambridge University Press, 2013.LectureSectionTopicsLife insurance and annuity contracts, pension benefits, mutual and proprietary insurers.Future lifetime random variable.First actuarial notation and basic properties of TX.Curtate future lifetime, further discussion and exercises.Life tables, fractional age assumptions.National life tables, survival models for life insurance holders, survival models for life insurance underwriting.Select and ultimate survival models, select life tables.Heterogeneity in mortality, mortality trends and sample problems.Whole life insurance (continuous, annual, 1/m-thly case).Recursions, term insurance, pure endowment and endowment insurance.Deferred insurance benefits, uniform distribution of deaths assumption, claims acceleration approach.Pure endowment, endowment insurance, deferred insurance benefits.Advanced problem analysis.Whole life annuity due and term life annuity.Whole life immediate, term life immediate, whole life continuous, term continuous, payable 1/m-thly cases, comparison by payment frequency.Deferred, guaranteed, increasing cases.Evaluating annuity functions, recursions, applying UDD assumption, Woolhouse?s formula.Present value of future loss random variable.Portfolio percentile maximum principle, extra risks.Policies with annual cash flows, future loss random variable.Case of policies with annual cash flows.Recursive formulas for policy values.Annual profit by source, case of policies with cash flows at 1/m-thly.Case of continuous cash flows.Negative policy values, deferred acquisition expenses and modified premium reserves, net premium approach. Course Description(4) Lecture, three hours; discussion, one hour. Requisite: 170S (or 170B or Statistics 100B), 178A. The second of the three quarter sequence 178ABC. Multiple state models, pensions, health insurance, profit testing. Topics in statistics used in actuarial work: methods of estimation and probability distributions. Letter grading.Mathematics 178A and the first half of Mathematics 178B will almost completely cover the syllabus of the Long-Term Actuarial Mathematics exam by the Society of Actuaries. At the end of Mathematics 178A, students learned to value and set premiums for different types of insurances using traditional actuarial models. They were also exposed to typical models and calculations used in life contingencies. Mathematics 178B first extends this work to multistate models and then covers pensions, health insurances, and profit-testing. The last three weeks of the course will cover the probability distributions employed in most common actuarial theory and begins the study of the Short Term Actuarial Mathematics syllabus by the Society of Actuaries.(DHW)Dickson, David C.M., Hardy, Mary R. and Waters, Howard R., Actuarial Mathematics for Life Contingent Risks. 2nd ed., Cambridge University Press, 2013.(Hardy)Hardy, Mary R., Long-Term Actuarial Mathematics Study Note. Society of Actuaries, 2017. Education and Examination Committee of the Society of Actuaries – Long Term Actuarial Mathematics Supplementary Note. KPW)Klugman, Stuart A., Panjer, Harry H. and Willmot, Gordon E., Loss Models: From Data to Decisions. 3rd Edition, Wiley, 2012.LectureSectionTopicsExamples, assumptions and notations of multiple state models.Probability formulae and computations, Kolmogorov equations, premiums.Policy values, Thiele?s Differential EquationMultiple decrement modelsMultiple decrement tablesDisability income, long term care, critical illness insurance, continuing care communitiesMortality improvement modellingJoint life and last survivors benefits, independent future lifetimesIndependent future lifetimes (cont.), multiple state model for independent future lifetimesModel with dependent future lifetimes, common shock modelSalary scale function, DC contributionIntroduction to profit testing and principlesProfit measures. Using profit test to calculate premium and reserves, case of multiple state modelsBasic distributions (moments, percentiles, generating functions and sums of random variables)Tails and their classificationsMeasures of risk (value at risk, tail value at risk)Continuous models, background probabilityExamples of continuous models, creating new distributionsRelations between distributions. Linear exponential familyPoisson and negative binomial distributionsBinomial distributions and (a, b,0) classTruncation and modification at 0 Math 178C: Foundations of Actuarial Mathematics: Loss mode Course Description(4) Lecture, three hours; discussion, one hour. Requisite: 178B. This course is the third of the three quarter sequence 178ABC. 178C studies loss models associated with actuarial problems. It covers severity, frequency, and aggregate loss models, parameter estimation (frequentist, Bayesian), model selection and credibility. Letter grading.The three quarter sequence 178ABC is the actuarial core of the FAM major. 178C covers topics associated with short term actuarial risk. With 178B, most of the topics 1-7 on the SOA STAM exam are covered.S. Klugman, H. Panjer, G. Willmot, Loss Models: From Data to Decisions. 3rd Edition, Wiley, 2012.Hardy, Mary R., Long-Term Actuarial Mathematics Study Note. Society of Actuaries, 2017.Education and Examination Committee of the Society of Actuaries - Long Term Actuarial Mathematics Supplementary Note. Estimation ratio, policy limitsCoinsurance, deductibles, limits, impact of deductibles on claim frequencyIntroduction to aggregate loss models and model choiceOther closed form resultsKPW 9.5, 9.6-9.6.5 (exclude 9.6.1)Recursive method, arithmetic discretizationIndividual risk modelEffect of modifications and exposureEmpirical distributions, grouped dataApproximations for large data setsMaximum likelihood estimation of decrement probabilitiesEstimation of transition intensitiesMaximum likelihood estimationNon-normal confidence intervals and exercisesFrequentist estimation: Poisson and negative binomial casesBinomial and (a, b,1) cases and effect of exposureBayesian inference and predictionModel selection: introductory conceptsConditional Distributions Math 179: Advanced Topics in Financial Mathematics Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 174E. Continuation of Mathematics of Finance. In depth study of risk measures and the instruments of risk management in investment portfolios and corporate financial structure. Exotic and real options, value at risk, mean-variance analysis, portfolio optimization, capital asset pricing model, market efficiency and the Modigliani-Miller theory. P/NP or letter grading.Hull, J. Options., Futures and Other Derivatives, 10th edition. Pearson, 2018.Berk, J. and P. DeMarz., Corporate Finance, 4th edition. Pearson, 2017.White, Toby AMeasures of Investment Risk, Monte Carlo Simulation, and Empirical Evidence on the Efficient Markets Hypothesi Society of Actuaries, 2018. Education and Examination Committee of the Society of Actuaries ? Investment and Financial Markets Study Note. p.221-2, p.237-8, p.249, p.343-5, p.460-3Effect of Dividends on stock prices and option valuationHull 26.1-26.3, p.598-600Hull 26.4-26.7, p.601-603Hull 26.8-26.11, p.603-609Hull 26.12-26.14, p.609-612Hull 22.1-22.3, p. 494-504Hull 22.4-22.6, p. 504-512Hull 22.7-22.9, p. 512-517Value at RiskSecond Reading: White, SOA Study Note IFM 21-18, Sections 1 and 2Hull 28.1-28.3, p. 655-660Hull 35.1-35.3, p. 792-796Hull 35.4-35.5, p. 796-803Berk & DeMarzo 10.1-10.4, p. 318-335Risk, Return, DiversificationBerk & DeMarzo 10.5-10.8, p. 335-350Risk, Return, DiversificationBerk & DeMarzo 11.1-11.3, p. 357-369Portfolio Optimization: Variance and CovarianceBerk & DeMarzo 11.4-11.5, p. 369-381Portfolio Optimization: Risk versus ReturnBerk & DeMarzo 11.6-11.8, p. 381-395Efficient Portfolio, Capital Asset Pricing Model and Risk PremiumBerk & DeMarzo 12.1-12.2, p. 404-413Cost of Capital: Equity Cost and Market PortfolioBerk & DeMarzo 12.3-12.4, p. 407-420Beta Estimation and Debt Cost of CapitalBerk & DeMarzo 12.5-12.7, p. 420-433Project Cost and Project RiskSecond Reading: White, SOA Study Note IFM 21-18, p. 1-7Berk & DeMarzo 13.1-13.4, p. 445-455Role of Investor BehaviorBerk & DeMarzo 13.5-13.6, p. 456-469Market Portfolio and EfficiencyBerk & DeMarzo 13.7-13.8, p. 469-479Multifactor Models of RiskSecond Reading: White, SOA Study Note IFM 21-18, p. 1-7Berk & DeMarzo 14.1-14.2, p. 487-498Modigliani-Miller: Equity vs. Debt FinancingBerk & DeMarzo 14.3-14.5, p. 498-511Leverage, Risk, Cost of CapitalBerk & DeMarzo 8.5, p. 258-265Project Analysis: Sensitivity, Break-Even, ScenarioSecond Reading: White, SOA Study Note IFM 21-18, p. 7-18Berk & DeMarzo 16.1-16.3, p. 551-561Default, Bankruptcy, and DistressBerk & DeMarzo 16.4-16.6, p. 562-575Optimal Capital Structure and LeverageBerk & DeMarzo 16.7-16.9, p. 575-588Agency Costs and Asymmetric Information Course Description(4) Lecture, three hours; discussion, one hour. Requisites: courses 31A, 31B, and 61. Strongly recommended preparation: 115A. Graphs and trees. Planarity, graph colorings. Set systems. Ramsey theory. Random graphs. Linear Algebra methods. Ideal for students in computer science and engineering. P/NP or letter grading.The following schedule, with textbook sections and topics, is based on 25 lectures. The remaining classroom meetings are for leeway, reviews, and midterm exams. These are scheduled by the individual instructor. Often there are reviews and midterm exams about the beginning of the fourth and eighth weeks of instruction, plus reviews for the final exam.J. Matousek and J. Nesetril, Invitation to Discrete Mathematics, 2nd Ed., OxfordLectureSectionTopicsBasic counting methods (induction, pigeonhole principle).Graphs, subgraphs, graph isomorphism. Connectivity. Score.Eulerian graphs, diagraphs. Hamiltonian cycles. 2-connected graphs.Trees, their characterizations, isomorphism. Minimal spanning tree problem.Planar graphs. Euler's formula. Examples of non-planar graphs. Five color theorem.Sperner's Lemma. Set systems. Sperner's theorem via LYM inequality.Probabilistic method (expectation, independence). 2-Colorings. Random sorting. Turan's theorem.Ramsey's theorem (upper bound, lower bound).Linear algebra methods. Cycle space of a graph. Graham-Pollak theorem. Matrix tree theorem.Probabilistic checking. Finite projective planes. Applications to graphs with no 4-cycles. Course Description(4) Lecture, three hours; discussion, one hour. Requisite: course 3C or 32A and 61. Lecture, three hours; discussion, one hour. Requisite: course 3C or 32A, and 61. Not open for credit to students with credit for Computer Science 180. Graphs, greedy algorithms, divide and conquer algorithms, dynamic programming, network flow. Emphasis on designing efficient algorithms useful in diverse areas such as bioinformatics and allocation of resources. P/NP or letter grading.Kleinberg, Tardos: Algorithm Design, Addison WesleyLectureSectionTopicsIntroduction, Stable Marriage Problem, Gale-Shapley algorithm.Orders of magnitude (Big O notation). Estimating the running time for simple algorithms looking up an entry in a sorted list, mergesort.Basic graph definitions. Directed graphs, trees, paths. Data structures as graphs: stacks, heaps. Breadth first search, Depth First search, test of bipartitness, DAG's.Introduction to the four main classes of algorithms: Greedy, Divide and Conquer, Dynamic programming, Network flow. Application of greedy algorithms to interval scheduling and shortest path problems, minimum spanning trees.Divide and conquer algorithms. Mergesort, counting inversions, closest pairs of points. Recurrences.Dynamic programming, weighted interval scheduling, Knapsack problems.Dynamic programming continued, RNA secondary structures, sequence alignment.Network flow: Maximum flow problem. Min cuts. Circulations.Network flow: Airline scheduling, Image segmentation, Project selection.Introduction to P and NP. Math 184: Enumerative Combinatorics Course Description(Formerly numbered 180.) Lecture, three hours; discussion, one hour. Requisites: courses 31A, 31B, 61 and 115A. Permutations and combinations, counting principles, recurrence relations and generating functions. Application to asymptotic and probabilistic enumeration. Ideal for students in mathematics and physics. P/NP or letter grading.M. Bona, Introduction to Enumerative Combinatorics , 2nd Ed., Chapman and Hall/CRCLectureSectionTopicsBasic counting methods (induction, pigeonhole principle).Binomial coefficients, multinomial coefficients, set partitions, Stirling numbers.Integer partitions, partitions into odd and distinct numbers. Euler's Pentagonal theorem.Ordinary and exponential generating functions.Permutations, Number of cycles and descents. Derangements via Inclusion-Exclusion Principle.Inversions. Counting permutation by a cycle type.Counting labeled trees. Different proofs of Cayley's formula.Catalan numbers. Plane and binary trees.Chromatic polynomial. Enumerations of connected graphs and Eulerian graphs.Sequences. Unimodality. Log-concavity. Math 189HC: Honors Contracts Course Description(1) Tutorial, three hours. Limited to students in College Honors Program. Designed as adjunct to upper-division lecture course. Individual study with lecture course instructor to explore topics in greater depth through supplemental readings, papers, or other activities. May be repeated for maximum of 4 units. Individual honors contract required. Honors content noted on transcript. Letter grading. Math 191: Variable Topics Research Seminars: Mathematics Course Description(Formerly Math 197). Seminar, three hours. Math 191 is a variable topics research course in mathematics. Courses will cover material not covered in the regular mathematics upper division curriculum. Reading, discussion, and development of culminating project. May be repeated for credit with topic and/or instructor change. P/NP or letter grading. Math 191H: Honors Research Seminars: Mathematics Course Description(Formerly Math 190). Math Seminar, three hours. Participating seminar on advanced topics in mathematics. Content varies from year to year. May be repeated for credit by petition. P/NP or letter grading. Math 195: Community Internships in Mathematics Education Course DescriptionTutorial, to be arranged. Limited to juniors/seniors. Internship to be supervised by Center for Community Learning and Mathematics Department. Students meet on a regular basis with instructor, provide periodic reports of their experience, have assigned readings on mathematics education, and complete final paper. The final paper is a substantial part of course, and will require a significant investment of time during the quarter. May not be repeated and may not be applied toward major requirements. Individual contract with supervising faculty member required. P/NP grading. Math 197: Individual Studies in Mathematics Course Description(2 to 4 units). Tutorial, three hours per week per unit. Limited to juniors/seniors. At discretion of chair and subject to availability of staff, individual intensive study of topics suitable for undergraduate course credit but not specifically offered as separate courses. Scheduled meetings to be arranged between faculty member and student. Assigned reading and tangible evidence of mastery of subject matter required. May be repeated for maximum of 12 units, but no more than one 197 or 199 course may be applied toward upper division courses required for majors offered by Mathematics Department. Individual contract required. P/NP or letter grading. Math 199: Directed Research or Senior Project in Mathematics Course Description(2 or 4 units). Tutorial, three hours per week per unit. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Scheduled meetings to be arranged between faculty member and student. Culminating report required. May be repeated for maximum of 12 units, but no more than one 197 or 199 course may be applied toward upper division courses required for majors offered by Mathematics Department. Individual contract required. P/NP or letter grading.

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