**SiMiODE Resource Guide or Table of Contents**

**Guide to Modeling Scenarios and Technique Narratives**

**Organized as Traditional Table of Contents for Differential Equations Text**

This is a growing list of resources and as developed, refereed, edited, and finalized, new materials will be published.

- **Technique Narratives** are focused on solution strategies for differential equations, but with a motivational connection to a real-world situation.
- **Modeling Scenarios** are modeling driven activities motivated by rich detail and engagement in real world opportunities, often with data and model validation activities.

This Guide or Table of Contents is organized to follow the topics found in a traditional differential equations course, hence, the numbering system approximately reflects chapter sequencing in a standard differential equations text.

These materials are hyper-linked to [SiMiODE Publications](#) and they are available to all as Open Education Resources (OER) for adaptation and use in coursework with a request to acknowledge the source.

The link for each Publication takes the reader to a resource page which may have more than just the document.

Please use the Comments tab at each Publication to make suggestions, point to corrections needed, relate experiences in your use of the resource, upload further resources we will add to the resource, discuss technical materials, and share your thoughts on the material. These comments will go to the author and the SiMiODE editorial leadership.
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List of All Technique Narratives and Modeling Scenarios by Chapter

Modeling One — First Order Differential Equations

**Technique Narratives** — [Back to Main Table of Contents]

1-001-SeparationOfVariable  
Technique narrative on solution method of separation of variables

1-002-Integrating Factor  
Technique narrative on solution method of integrating factor

1-003-IntroNumericalMethods  
Introduction to numerical methods for solving first order differential equations

1-005-NavigatingNumericalMethods  
Using a lost at sea situation to learn numerical methods

1-009-Bifurcation  
Early introduction to bifurcation with experimentation

1-010-AtmosphericCO2Bifurcation  
Study of bifurcation of atmospheric carbon dioxide

1-015-DimensionlessVariables  
Scaling for differential equations and dimensionless variables is discussed

1-030-RandomPerturbation  
Tutorial on random perturbations for a linear first order equation

Modeling Scenarios — [Back to Main Table of Contents]

1-001-MMDeathImmigration  
Modeling Death and Immigration with M&M 's and Simulation

1-001A-MMDeathImmigration-Variation  
Variation on modeling death and immigration with M&M’s

1-001B-MM-DeathImmigrationMystery  
Each student sets own immigration rate and others need to solve this mystery

1-001C-PopulationDecayThenSome  
Variation on death and immigration with hotel modeling and MatLab

1-001D-HotelPopulationDecay  
Modeling the comings and goings of hotel patrons using various models

1-001s- BirthDeathImmigration  
Probability generating function approach to simulation

1-002-Tossing  
Modeling a simulation of a large number of dice tossings

1-003-CollegeSavings  
Saving for Child's College Education

1-004-MicroorganismImmigration  
Modeling Immigration in a Petri Dish

1-005-OilSlick  
Modeling the Spread of Oil Slick with Incomplete Data

1-005A-ChemDataCollection  
Analysis of incomplete reaction data
1-005b-ChemDataCollection
Analysis of incomplete reaction data

1-005C-OilSlick
Modeling Spread of Oil Slick with Incomplete Data for Calculus I Class

1-006-FinancingSavingsAndLoan
Bank Investment Analysis and Bank Loan Analysis

1-007-AntTunnelBuilding
How long does it take an ant to build a tunnel of length x in soil?

1-009-ICUSpread
Modeling the spread of ICU’s in US Hospitals from 1958-1974

1-010-AtmosphericCO2Bifurcation
Modeling atmospheric carbon dioxide

1-011-Kinetics
Chemical Kinetics Models - Zeroth, First, and Second Order Reactions

1-011A-Kinetics
Same as 1-11-Kinetics but with more guidance and less narrative

1-012-SublimationCarbonDioxide
Sublimation of Carbon Dioxide

1-013-SleuthingWithDifferentialEquations
Situations associated with stopping cars, projectile steel ball, and time of death

1-014-DrainingContainers
For fixed volume column which radius of cylinder of water drains fastest

1-015-Torricelli
Modeling falling column of water

1-016-DogDrugs
Modeling drugs for anesthesiology

1-017-DiseaseSpread
Modeling spread of disease using logistic equation

1-018-LogisticPopModeling
Limited Growth Population Modeling

1-019-RocksInTheirHeads
Data Collection Experiment Comparing of Rock Masses

1-020-IceMelt
Which melts first a sphere or cube of ice of the same volume

1-021-FeralCatControl
Model for three feral cat control policies

1-022-SpreadOfTechnology
Model the spread of a number of technological advances

1-023-RumorSpread
Rate of Spread of False and True articles on the Internet

1-024-MalariaControl
Modeling and numerical methods for first order malaria growth

1-025-MixingItUp
Modeling more and more complex salt mixing situations

1-026-Evaporation
Modeling the evaporation of an alcohol and water mixture in various containers
1-027-StochasticProcesses
Modeling randomness with stochastic processes

1-028-SouthernSweetIcedTea
Data is offered to model making sweet iced team using luminescence

1-029-ConeToCubeFlow
Modeling water flowing from cone to cube and out

1-030-EyeModel
Modeling dissipation of intraocular gas bubbles used in eye surgery

1-031-CoolIt
Changing temperature of container of water in a changing environment

1-032-WordPropagation
Modeling the rate at which words propagate through English language text

1-033-SouthernBarbeque
Phases of barbecuing brisket are modeled using real data

1-034-FishMixing
Student designed fishing strategies for mix of fish in lake

1-036-NeutralBuoyancy
Finding depth in water at which an object settles to neutral buoyancy

1-037-CommonColdSpread
Students conduct simulation of spread of common cold and model

1-038-Ebola
Modeling Ebola epidemic with first order differential equation models

1-039-StochasticPopModels
Creating population models using simple probabilistic assumptions

1-040-OutcomeSavings
Determining monthly deposit rate for long term savings goal

1-041-AirToTop
Variable ascent rate and air management in SCUBA diving

1-042-Kool-Aid
Modeling the amount of drink powder in a second tank of flow system

1-043-CoolingUpAndDown
Air conditioning cooling modeling

1-044-CollegeBound
Planning for full college education costs for the daughter of a friend

1-045-TimeOfDeath
Determining time of death given observations and environmental conditions

1-046-GoingViral
Simulation of spread of disease with logistic modeling

1-047-Condensation
Simulate the random motion of 200 particles in a 50 by 50 square

1-047A-CondensationOptimization
Optimize a condensation process which is modeled by a simulation

1-050-BargingAhead
Optimizing a barge trip upriver

1-051-OneTankSaltModel
Build one compartment salt mixing model
1-052-SaltWaterTanks
Studying tank in which water inflow containing salt increases

1-053-SlimeSpread
Modeling the spread of a slime puddle from video collected data

1-054-GrowthInFarmland
Modeling the growth of farmland with incomplete data

1-055-WaterFallingInCone
Modeling the falling of water in a right circular cone

1-057-FiguringFluidFlow
Evaluating three models of fluid flow from a tank using data

1-058-WaterClocks
A container is designed so water will fall out at constant rate of change in height

1-059-ContainerShapeFallingWater
Modeling column of falling water in different shaped containers

1-060-SalesMarketing
Building a model of sales of consumer products from a classic marketing study

1-061-PotatoCooling
Modeling the cooling of a baked potato

1-062-BacterialGrowth
Several models offered for exponential growth in increased complexity

1-064-TorricelliBox
Modeling falling column of water with a box at the base of the column

1-061-PotatoCooling
Cooling of a baked potato and compare it to student-collected data

1-063-ThreeHoleColumnOfWater
A column of water with three holes or spigots water exits

1-064-ToprricelliBox
Emptying column of water with box on the bottom

1-065-AlgalBlooms
Investigation of massive algal blooms on Lake Chapala MEXICO

1-066-USCensus Modeling
Modeling the US Census data with several different models

1-067-ModelingWithSigmoidCurve
Modeling using logistic and Gompertz S-shape curves is offered

1-068-WaterBottleCooling
How fluid in a water bottle changes its temperature to approach ambient

1-070-FisheryHarvest
Modeling harvesting of Atlantic cod fishery

1-071-NewtonWatsonTimeOfDeath
Sherlock Holmes determines time of death

1-073-WaterExitBottle
Estimating a parameter in Torricelli’s model of water exiting a container

1-074-BottleWaterFlow
Comparing two models of water flowing out of a container through exit hole

1-076-ClimateBifurcation
Modeling the Earth's climate using known parameters
Modeling an RL series circuit with differential equations and Multisim software

Modeling bacteria growth in limited environment

Modeling how to heat your home while you are away

Building a simple model for drug administration

Two different models for growth of cancer tumor

Foucault Knife Edge Test, an optical test used in lens making is modeled

A falling meteorite is modeled with a number of factors considered

Randomized spread of viral disease and full model build and fit

Modeling intravenous bolus of drug in the body

Modeling administration of medicinal pills

Villain Thanos attempts to restore balance to the world

Analyzing room temperature in a temperature changing environment

Spread of disease and applications to Sleeping Beauty fairy tale

Comparing two ways to empty spherical tank of water

Building population models for various situations and using slope fields

World record sprinter's maximum effort race is modeled

Determining model for sucrose hydrolysis using lab data

Modeling temperature change and dissolution of sugar in brewing fruit tea

Using Elo's Method for rating chess players and difference equations

Modeling an Op Amp Differentiator circuit using Multisim

Dynamics of chlorine concentration during regular swimming pool maintenance cycles

Coincidence detection in the integrate-and-fire neuron modeling

Several models are offered for demographics of women in engineering
Generating data and using individual model to estimate parameters

Several models are offered along with data for cancer growth models

Using Calculus skills models are offered along with data for cancer growth

Comparing exponential and logistic models for solving epidemic issues

Comparing terminal velocity for variety of animal’s falling

Modeling the rate at which drying takes place in a cloth wet with water

Probability functions for Poisson process waiting time are built

Maintaining workforce of employees after attrition

Modeling temperatures of sand tide pool and snail shells

A simulation with coins and data on the spread of information

Investigate the Earth’s climate using an energy balance model

Several short illustrations and two exercises for modeling

Modeling the decay of tropical cyclone winds

Analysis of the Solow-Swan model of economic growth theory

Modeling population growth of a dairy farm

Modeling a circular roller coaster to determine velocity to stay on track

Using recent sales data model the spread of plug-in electric vehicles

Modeling world population with varying growth rates,“

Using dodecahedral dice population to model death and immigration

Modeling the process of entry into marriage by an individual

Modeling a fish harvesting operation over a 25 year time period

Modeling a rocket trajectory as it consumes fuel

Pharmacokinetic modeling of absorption of aspirin in body
1-131-CaffeineElimination
Pharmacokinetic modeling of elimination of caffeine from the body

1-132-DigoxinElimination
Pharmacokinetic modeling of elimination of digoxin from the body

1-134-LanguageDynamics
Modeling change in the fraction of a population speaking one language over another

1-135-FishHarvesting
Studying bifurcation through a fish harvesting model

1-136-MarriageAge
Model of fraction of people who are first time married by a certain age

1-137-SheepGraze
Developing a model for sheep grazing

1-138-InnerEarDrugDelivery
Developing a model for administering drugs to the inner ear

1-139-PlantsVsHerbivores
Developing a model for herbivores grazing

1-140-LeakyBucket
Modeling the height of water in a tank with a leak and water pouring in

1-141-M&MGameRevisit
We use a simulation and observe long term behavior to estimate a parameter

1-142-WaterBottles
Application of Newton's law of cooling to the study of insulated water bottles

1-143-PopulationModelVariations-MATLAB
Using populations and modeling while enhancing MATLAB skills

1-145-FastPitch
Modeling the velocity of Major League Baseball fastball

1-150-CancerTherapy
Uses population growth models to compare treatments for cancer

1-160-HeartDeathRate
Modeling Two — Simulation of the heart death rate

1-165-FlushToilet
Spread of flush toilet technology

1-170-CensusModeling
Exploring modeling assumptions with census data

1-190-IntroClass
Broad first day cover of many themes beginning with first order equations

Modeling Two — Numerical Methods

2-001-NumericalMethodsComparisons
Developing and caring for several numerical methods for first order equations

2-005-Linearize It All
Analytic solutions and linear approximation solutions compared to data
Modeling Three — Second Order Homogeneous Differential Equation Models

Modeling Scenarios — Back to Main Table of Contents

3-001-SpringMassDataAnalysis
Data on a spring mass system with resistance is given for modeling for analysis

3-002-ModelsMotivatingSecondOrder
From real data several ways to model spring mass system emerge

3-004-VanderPol
Study of van der Pol’s equation with applications and spreadsheet simulation

3-006-Buoyancy
Data on a bobbing container motivates model and parameter estimation

3-008-HangTime
Hang Time Modeling

3-009-BallDropInWater
Analysis of a falling ball in liquid to reach terminal velocity

3-010-EnergyInSpringSystems
Exploring damping and forcing terms to discover energy in system

3-011-EulerBallThrowing
Using Euler's Method in maximizing distance for throwing a ball

3-013-WhiffleBallFall
Using data on whiffle ball fall model resistance and predict the fall position

3-015-StyrofoamBallFall
Modeling a falling Styrofoam ball's motion

3-016-FallingCoffeeFilters
Using data on stack of coffee filters to build model

3-017-StackedCoffeeFilters
Using data on stacked coffee filter falling from the literature build models

3-019-ShuttleCock Fall
Modeling a falling shuttlecock

3-020-ChordPathTime
Time mass to slide along chord from high point to any point on a circle

3-026-SpringInverseProblem
Estimating an unknown parameter in an oscillating spring mass system

3-027-BobbingDropping
Modeling wood block bobbing in water and falling object

3-029-FerrisWheelCatch
We model the throw of an object to a person on a moving Ferris wheel

3-030-SecondOrderIntro
Intro to second order differential equations with applications

3-031-SpringCost
Producing a spring meeting industrial specifications at lowest cost

3-034-CarSuspensions
Study of spring-mass-dashpot which is part of car suspension system

3-035-StadiumDesign
Design a stadium which is fair to home run hitters in all directions

3-040-FirstPassageTime
We model and determine the first passage time for underdamped oscillator
3-041-UpDown
Relate times when projectile passes the same point – up and then down
3-042-CatapultLaunch
Maximizing the ranges of a projectile by backing up an incline
3-043-BallisticsModeling-SpongeDart
Building and comparing models for Sponge Dart ballistics
3-044-DeepWell
Given total time of pebble fall to sound coming back tell how deep a well
3-045-RampBounce
Bounce a ball on a tilted ramp for optimal horizontal distance traversed
3-054-Relay
Place infielder in optimal position for minimum time relay through form outfield
3-055-FloatingBox
Modeling floating bobbing box
3-060-DataToDifferentialEquation
Estimating damping coefficient and spring constant from data
3-061-ChemEng
Calculating concentration profile of cyclohexane
3-063-FallingBuildingIce
Modeling the fall of a piece of ice off a building
3-064-GearTrain
Modeling gear trains built with various gear combinations
3-065-UpDown
Modeling vertical projectile motion with resistance to address some issues
3-067-RLCSeriesCircuit
Comparing analytic solution and numerical simulation for RLC series AC circuit
3-069-HeatInBar
Modeling the temperature distribution along a uniform slender bar
3-070-FallingInWater
Drop a canister in column of water, collect data from video, model motion
3-071-WirelessTelegraphy
A study of LC circuits, beats, and wireless telegraphy
3-072-EarthQuake-Part I
Bad Vibrations: Modeling a Building During an Earthquake - Part I: No Damping
3-073-EarthQuake-Part II
Bad Vibrations: Modeling a Building During an Earthquake - Part II: With Damping
3-075-RLCcircuits
An introduction to RLC circuits is offered including definitions and modeling
3-076-CircuitBuilding
Building a circuit analytically in simulation, and physically
3-080-PendulumModeling
Several different pendulum configurations are modeled and compared
3-085-SimplePendulum
Modeling pendulum motion and verification of period with data
3-087-ThanosPopulationDynamicsInteractingSpecies
Thanos of "The Avengers" acts on world population modeled/strong>
3-090-OneMassSpring
Data on a single mass spring system permits modeling of oscillator

3-090-ChebyshevPolynomialSolution
Small study of Chebyshev Equation for which there are polynomial solutions

3-091-SpringModeling
Data analysis from videos for modeling spring mass motion

3-092-WirelessPower
Analyzing an efficient wireless power transmission system

3-095-ShotInWater
The resistance experienced by a bullet moving through water

3-099-PullBack
Modelling the velocity of a Pull-Back Toy

3-101-SpringMassFirstTry-NoResistance
Modeling a simple spring mass with no damping conjecturing solutions

3-102-SpringMassDamped
Modeling a simple spring mass with damping conjecturing solutions

3-105-FrequencyResponse
Understanding maximum frequency response to second order model

3-110-MilitarySpringMassApplication
Modeling the shock absorber system for an Army vehicle

3-130-MatterOfSomeGravity
Estimating acceleration due to gravity from pendulum modeling

3-140-TwoSpringOneMassFixedEnds
Modeling two spring, single mass with fixed ends

3-150-ItsABlastFurnace
Steady-state heat equation to model temperature distribution in industrial furnace

Modeling Four — Second Order NonHomogeneous Differential Equation Models

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4-020-AnIEDBlast
Modeling the effects of an Improvised Explosive Device

4-023-MysteryCircuit
Students assigned various input voltages to a circuit to see what the circuit is

4-035-ParEstSteadyState
Input Output Analysis analyzing steady state to estimate parameters

4-036-AltitudeDependentGravity
Studying projectile motion with altitude dependent gravity

4-039-FallingDarts
Analyzing data on darts going up and going down

4-050-ResonanceBeats
We study the notions of resonance and beats for undamped system

4-055-ShatterWineGlass
Shattering wine glasses and other resonance phenomena are studied

4-060-CircuitTuner
Building the differential equation for a radio tuner
4-065-GasInjection
Numerical methods for solving singular (ordinary or partial) differential equations with small coefficients for the highest derivative terms

### Modeling Five — Linear Systems of Differential Equation Models

#### Technique Narratives – Back to Main Table of Contents

**5-005-StiffDifferentialEquations**
- An introduction to stiff differential equations and attendant numerical solutions

**5-010-MatrixExponential**
- Using the matrix exponential to solve linear systems of ODEs

**5-012-LinearSystemConjecture**
- Consequences of conjecturing solutions to linear systems of ODEs

**5-030-LinNonHomoSystemSol**
- Strategies for solving system of nonhomogeneous differential equations

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**5-001-LSDAndProblemSolving**
- Modeling LSD in the body and correlating amounts with test performance

**5-002-RelationshipDynamics**
- Using phase plane portraits to analyze Romeo and Juliet's relationship

**5-005-Dialysis**
- Modeling Dialysis Machine

**5-007-ChemOpt**
- Optimization for a Chemical Reaction

**5-010-DNA Degradation**
- Modeling plasmid DNA degradation in rat plasma

**5-012-LipoproteinModeling**
- Medical study data to build and affirm model for low-density-lipoprotein

**5-014-TwoSpringMass**
- Build Free Body Diagram and model for two spring configuration

**5-015-RunnerSynchronize**
- Developing phase model to study oscillatory phenomena

**5-022-ColdPill**
- Modeling flow of drug from gastrointestinal tract to bloodstream for peak

**5-023-FakingGause**
- Seeking parameters in toy data set protozoan population model

**5-025-SaltCompartment**
- Amount of salt in two water tanks is modeled in several ways

**5-026-Eviction**
- A model for eviction in the United States is built

**5-030-AirshedSulphur**
- Analyzing a model of the production of sulphur compounds in a Montana airshed

**5-036-HalfCarVibration**
- Analyzing half-car approach to a vehicle’s response when subject to a speed bump

**5-040-TunedMassDampers-Part I**
- Applying a second mass to keep structure from experiencing resonance

**5-040-TunedMassDampers-Part II**
Applying second mass to keep structure from large displacement

**5-076-LanchesterLaws**
Using Lanchester's Laws to model strength of two armies' strengths

**5-077-MandMAttritionWarfare**
Using candies in simulations of attrition warfare

**5-080-SpaceFlightRecolonize**
Modeling the recolonization of the human race on a distant planet

**5-090-SolidParticleErosion**
Tutorial and modeling problems associated with pitting of ductile surface

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**Modeling Six — NonLinear Systems of Differential Equation Models**

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**6-001-Epidemic**
English Boarding School NonLethal Influenza

**6-002-EulerCromerPendulum**
Using the study of nonlinear pendulum to implement numerical methods

**6-003-SchoolFluEpidemic**
Using SIR model peak flu and total recovery times are determined

**6-004-VillageEpidemic**
Build a model of a mid seventeenth century English village epidemic

**6-005-InsectColonyCurvivalOpt**
Insect Colony Optimal Control

**6-006-ZombieGameHvZ**
Modeling this campus Zombie Game HvZ

**6-007- FunctionsAndDerivativesInSIRModels**
Relating functions and derivatives in SIR Models

**6-008-PursuitModels**
Linearization and Support from Homogeneous System Analysis

**6-009-FakeNews**
Model spread of fake news and ways to deter distributing misinformation

**6-010-SocialCampaigns**
Creating a model to capture the essence of social media campaigns

**6-011-HumansVsZombies**
Modeling variations of Humans vs Zombies battles

**6-012-RiverCrossing**
Building a model to help cross a river with current to land at specific spot

**6-015- CombatingEbolaEpidemic**
Making policy recommendations from models of spread of Ebola

**6-016-PandemicModeling**
Modeling COVID-19 Pandemic with SIR Model and Geogebra

**6-017-OncolyticViruses**
Explore oncolytic virotherapy using systems of differential equations

**6-018-ExploringSIRModel**
Modeling rumor and disease spread

**6-019-EnablingEpidemicExploration**
Several strategies for estimating parameters in models of epidemics
Investigate the massive algal blooms that struck Lake Chapala, Mexico
Building a three trophic level model of acorns, rodents, and snakes
Moving against a headwind create model of drone flight to fixed delivery point
Describe the flight path of a drone delivering a package using numerical methods
Use Excel to observe qualitative behavior a predator-prey model
Population ecology to connect vector calculus and differential equations
Amount of salt in two water tanks is modeled when tank volumes are changing
An introduction to systems and tumor growth modeling
Modeling complex salt levels in a falling column of water
Modeling the amount of shampoo in a bottle during a shower
Using historical data to model multiple species growth
Modeling of the Haitian cholera epidemic
Modeling the dynamics of Internet platform user's volume
Studying Lotka Volterra equations in integrated environment for R
Modeling the rise and size of beer bubbles in a sitting glass of beer
Modeling the chaos of the Lorenz System with a physical simulation

Modeling Seven — Changing the Venue for Solution Success - Laplace Transforms
Laplace Transform as the continuous analogue of a power series
Using a baby warmer coupled system Laplace transforms are presented

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Laplace Transforms - Convolution Applications - Replacement Theory
Modeling several multiple dose approaches for drugs is considered
7-020-ThermometerInVaryingTempStream
Study thermometer while sitting in a stream whose temperature oscillates

7-040-TankInterruptMixing
Several approaches model flow of consecutive streams of salt into a container

Modeling Eight — Representing Natural Phenomena with Sines and Cosines
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8-002-TrigSumRepresentation
Representing functions as sums of trigonometric functions

Modeling Nine — Modeling with Differential Equations in Higher Dimensions
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9-001-SkinBurnModelNumericalMethods
Numerical methods for Heat Equation are introduced in context of skin burn issues

9-002-GroundWaterFlow
Modeling groundwater flow and developing effective PDE models with data collection

9-005-InvasiveSpeciesModel
Gentle progression from ODE to PDE modeling through invasive species model

9-010-TravelingWaves
Modeling a traveling wave in porous medium

9-012-PDEGuitarTuning
Tuning a Stringed Instrument with the Wave Equation

9-014-TurkeyCook
Investigate several models for the cooking time for a turkey

9-015-UnearthingTruth
Using electrical resistivity tomography to unearth tunnels

9-020-HeatDiffusion
Build equipment, conduct experiment, model data - has it all

9-030-WaterHammer
Modeling an initial-boundary value problem describing the time evolution of a water hammer

9-125-BeamModeling
Modeling the deflection of a cantilever beam under two different distributed loads

9-152-HorizontalBeam
Modeling a suspended beam and collecting data to justify the model

Modeling Ten — Modeling with Difference Equations
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10-001-TilingHallway
Using tiling of hallways to motivate difference equation modeling

10-100-InsectOutbreaks
Modeling climate change effects on insect outbreaks