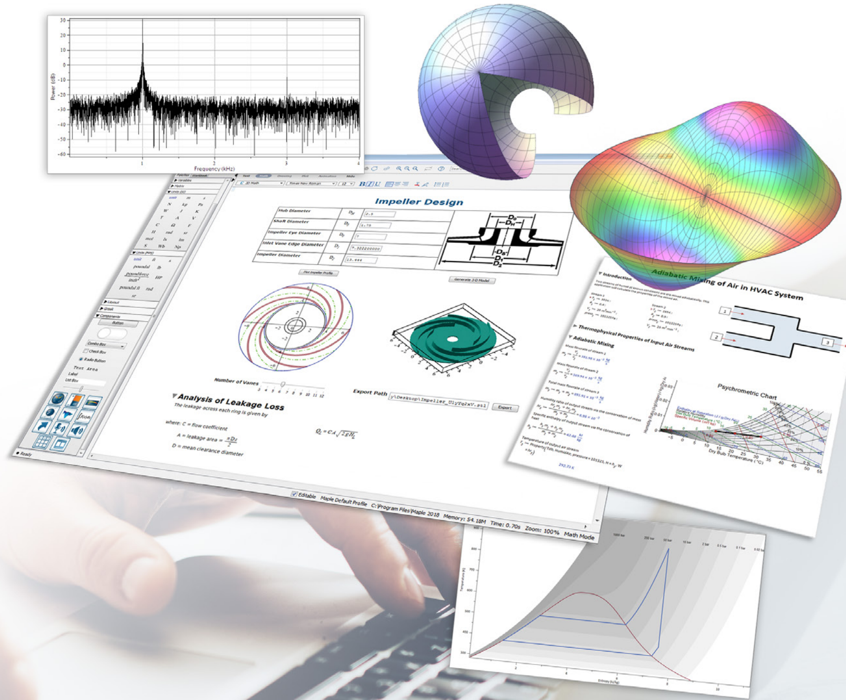
Maple™

Engineering Worksheets for Maple™



Discover the many ways engineers use Maple to solve problems, with over 70 engineering worksheets you can use in Maple straight away.

Download all the worksheets from www.maplesoft.com/engineeringapplications.zip

PDF versions are included so you can view the worksheets even if Maple is not installed.

Table of Contents

1 Introduction

Engineers and scientists across all sectors of industry and academia use Maple for mathematics, data analysis, programming, and visualization.

They use Maple to solve real-world problems, derive equations from first-principles physics, make technical concepts come alive in the classroom, and explore the design space.

This guide introduces over 70 worksheets that demonstrate how Maple can be used across many engineering disciplines. The worksheets can be downloaded from:

www.maplesoft.com/engineeringapplications.zip

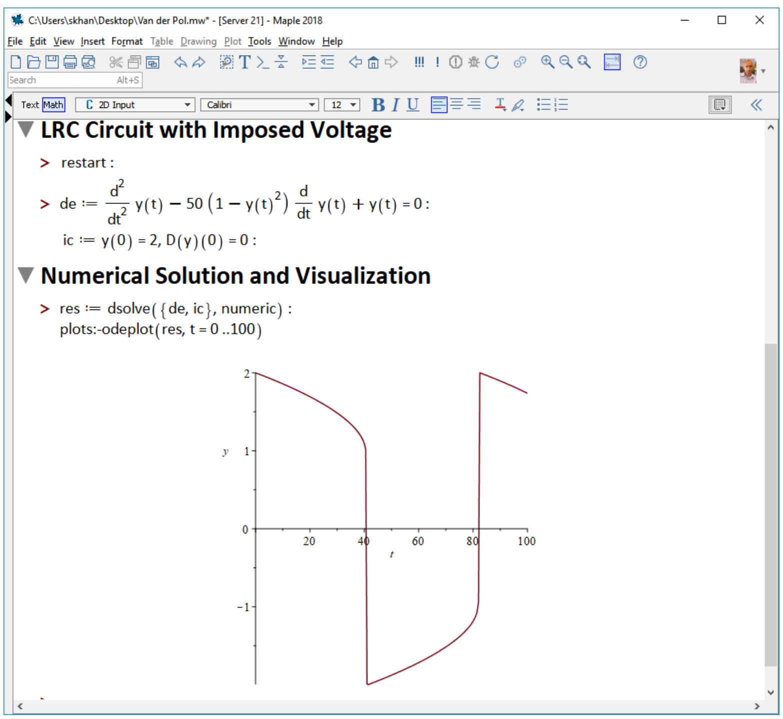
PDF versions of these worksheets are also included.

You can use worksheets for your own analyses, modify them to suit your own needs, and learn to apply the techniques shown in these examples to completely different problems.

Before we describe the worksheets, let's first explore why engineers use Maple for their calculations and analyses.

Symbolic and Numeric Mathematics Engine

Maple offers practical high-level tools for numeric and symbolic math, data analysis, and programming. These tools are designed for both simple and complex engineering problems.



Stiff differential equation from an LRC circuit with an imposed voltage

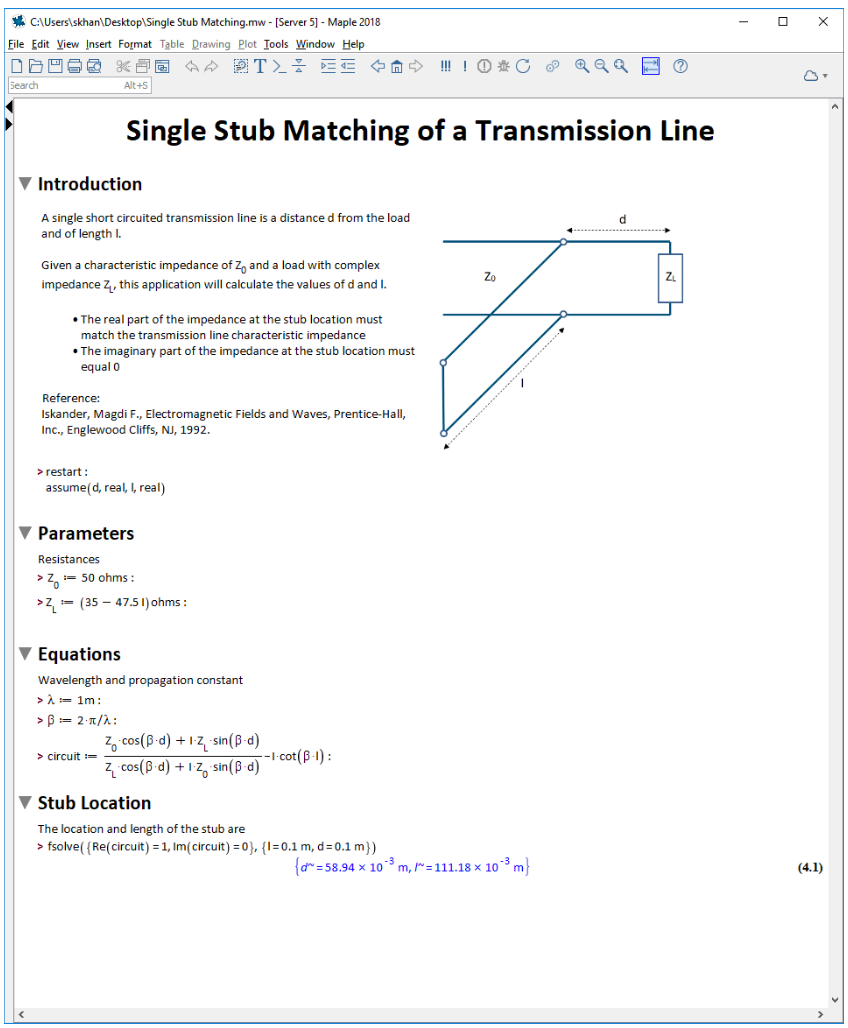
The symbolic and numeric mathematics engines are seamlessly connected; parameters, equations and calculations flow fluidly between the two. This means you can derive and numerically evaluate your equations in a single cohesive workflow.

Moreover, Maple's programming language benefits from an interactive development environment and can use any of Maple's high-level mathematical tools, making the code:

- Faster to develop, debug and verify
- Able to use Maple's high level mathematical functions
- Easier to read by humans

Technical Documentation Environment

A Maple worksheet combines live math, text, images, tables and plots. In effect, Maple captures the inherent assumptions and thought process behind an analysis, as well as the calculations. This turns calculations into reusable and easily understood documents.



Document Interface

Units

Units are fully integrated into the Maple environment, and can be used in simple calculations as well as numeric solving and optimization.

$$\text{volt} := 5.2\text{V} :$$
$$\text{curr} := 3.2\text{A} :$$
$$\text{power} := \text{curr} \cdot \text{volt} = 16.64\ \text{W}$$

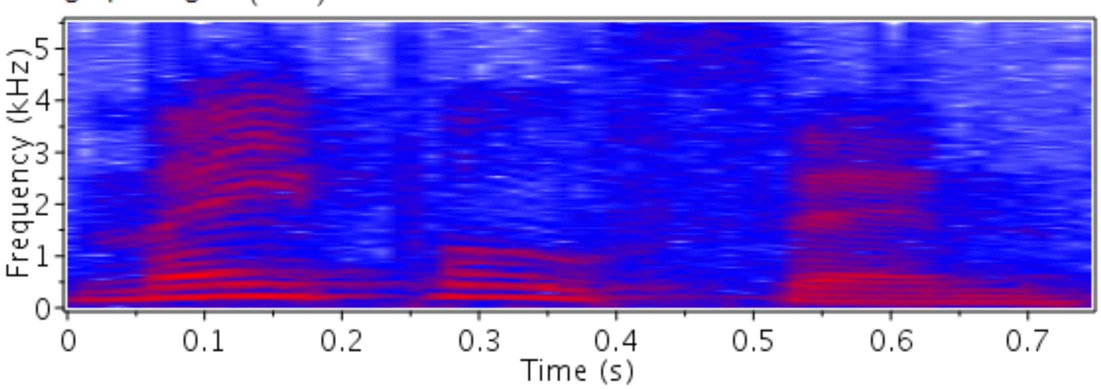
Calculations with Units

Using units in calculations removes the risk of manual unit conversion errors, and also acts as a check on the physical validity of the equation.

Import Data and Connect to Other Tools

You can import and export data to and from spreadsheets, text files, audio data and many other file formats.

```
data := AudioTools:-Read("C:\\Program Files\\Maple 2018\\data\\audio\\maplesim.wav") :
SignalProcessing:-Spectrogram(data)
```

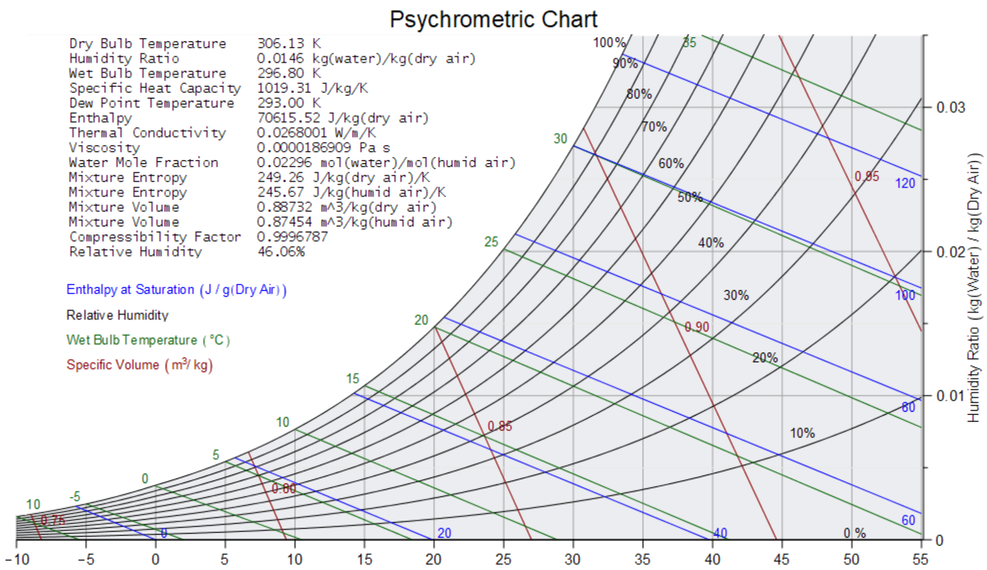


Importing audio and generating a spectrograms

Maple can also call externally defined code (for example external solvers or proprietary data sources defined in a DLL) and provides full two-way connectivity with MATLAB®.

Visualizations

Maple boasts a broad range of built in plots. These visualizations are fully customizable, and new plot types can be programmatically generated.



Psychrometric chart and humid air properties

Deployment

Work done in Maple can be deployed in many different ways, including:

- Documents can be exported as PDF, HTML, and more
- Mathematical expressions and user-developed programs can be exported to C, Python®, Java and several other languages.
- Plots can be exported to JPEG, GIF, SVG, and more
- Interactive applications can be shared with non-Maple users with the free Maple Player™ or over the web

Worksheets can be password protected. This means live applications can be distributed while the intellectual property is securely locked away.

The remainder of this document provides an overview of over 70 Maple applications that solve problems electrical engineering, signal processing, mechanical engineering, hydraulics, earth and building science, chemistry, chemical engineering, aerospace engineering, structural engineering, and thermal engineering and thermodynamics. To see the full problem and solution, download the worksheets described here from:

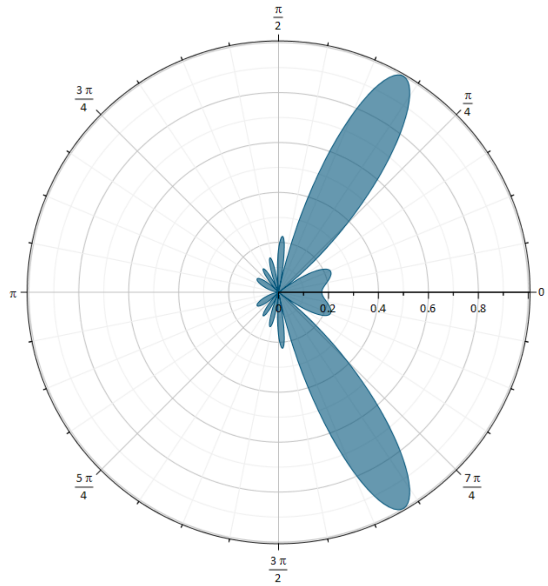
www.maplesoft.com/engineeringapplications.zip

PDF versions are included so you can view the work even if Maple is not installed.

2 Electrical Engineering

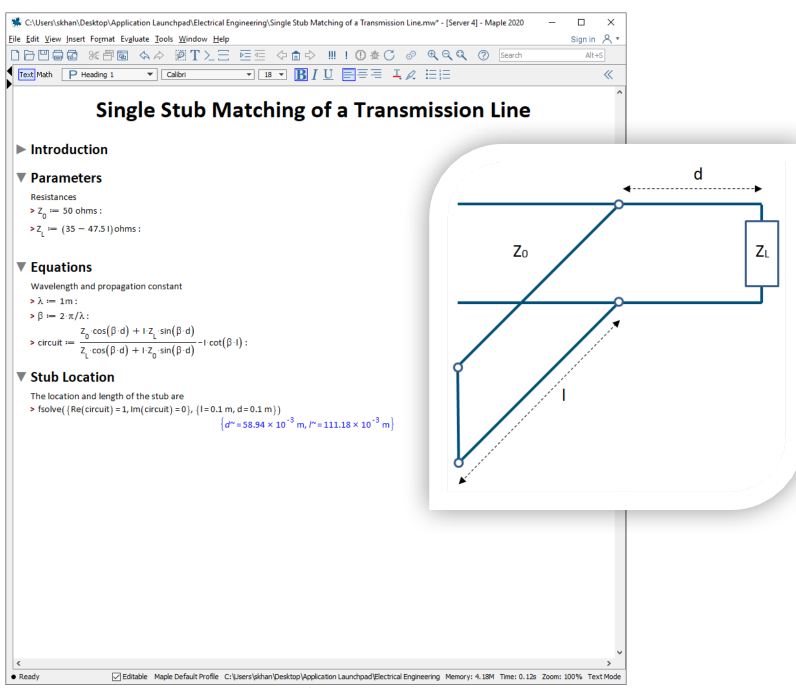
2.1 Radiation Pattern and Directivity of an Antenna Array

The application calculates the array factor and directivity for a uniform linear antenna array, and then plots the radiation pattern.



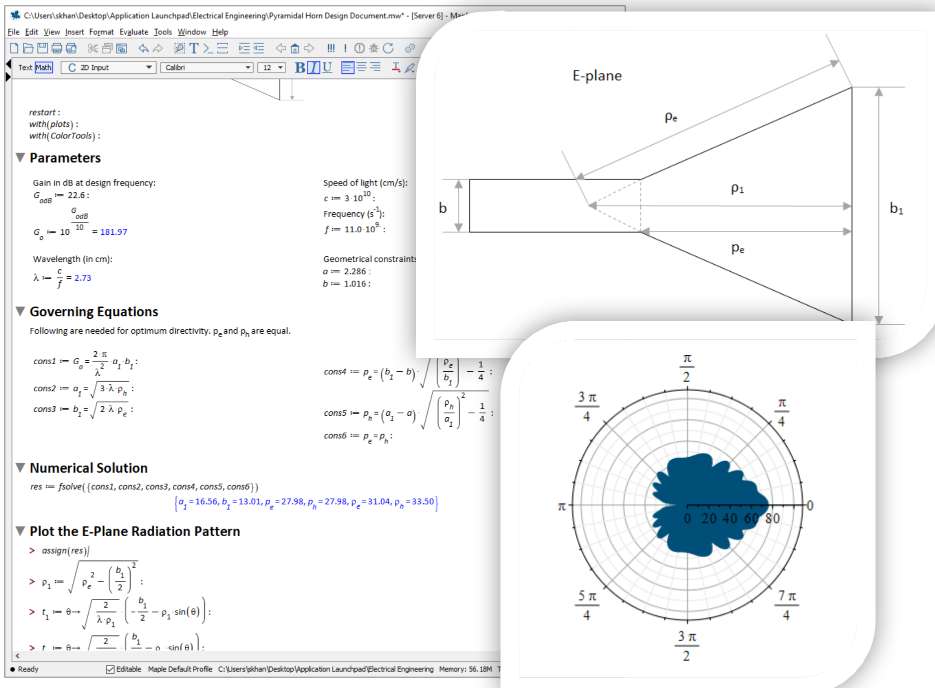
2.2 Single Stub Matching of a Transmission Line

Given required characteristic impedance, this application will calculate the position of a stub on a transmission line.



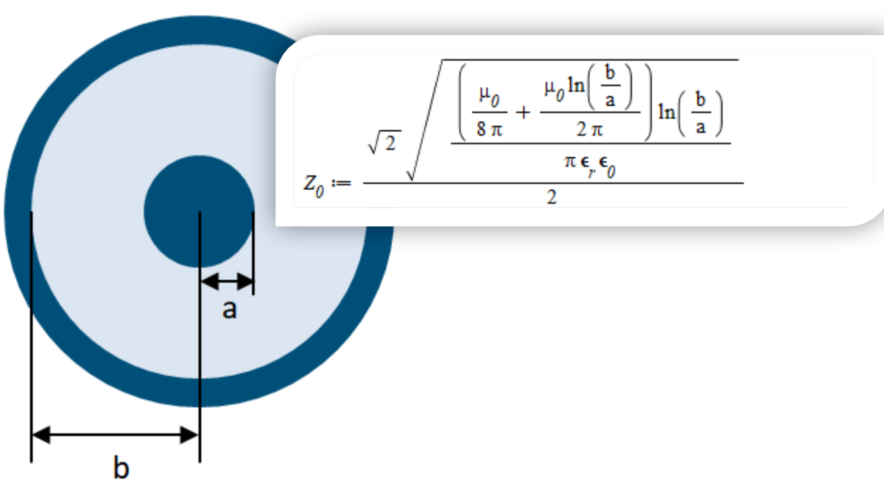
2.3 Pyramidal Horn Design

This application calculates the optimum design parameters for an X-band pyramidal horn. Additionally, the E-plane radiation pattern is visualized on a polar plot.



2.4 Coaxial Cable Transmission Line Design

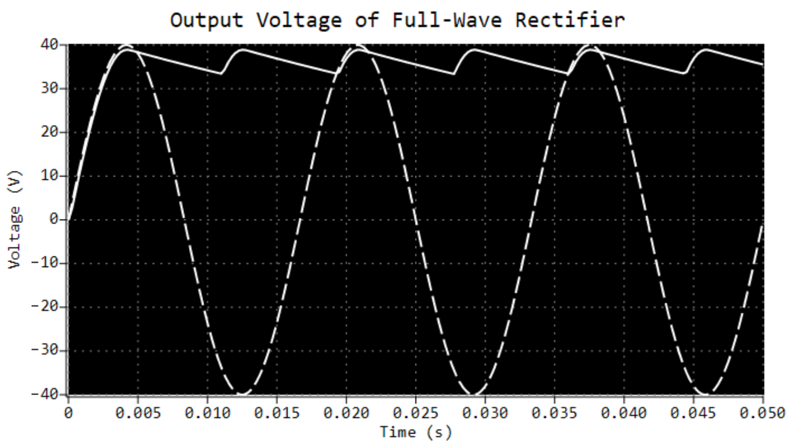
This application will calculate the outer radius of a coaxial transmission line, given a characteristic impedance and phase velocity.



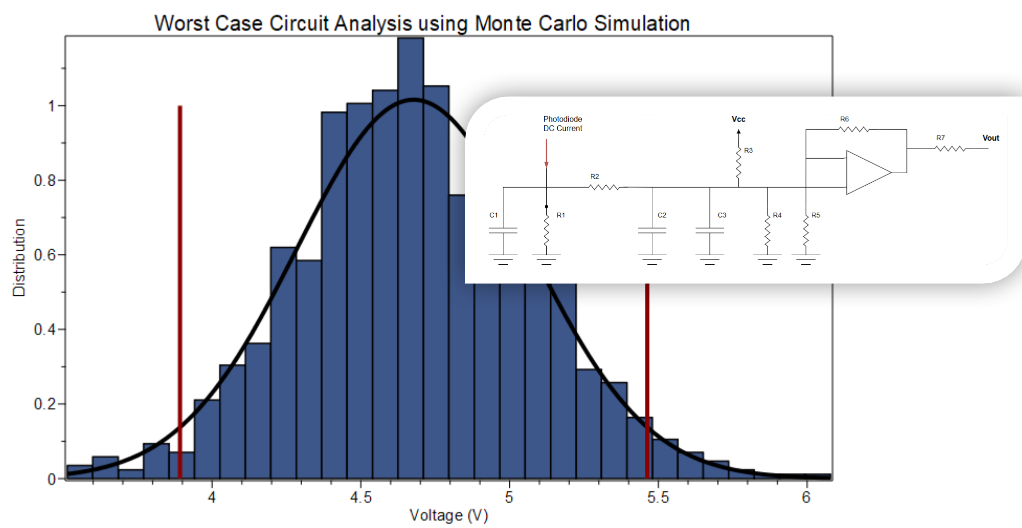
2.5 Half-Wave and Full-Wave Diode Rectifiers

Rectifiers convert alternating current to direct current. This worksheet calculates the response of both a half-and full-wave diode rectifier with a single capacitor filter, given a sinusoidal input.

Differential equations that describe the response of half- and full-wave rectifiers are derived symbolically, and then solved numerically.



2.6 Worst Case Circuit Analysis with Monte Carlo Simulation

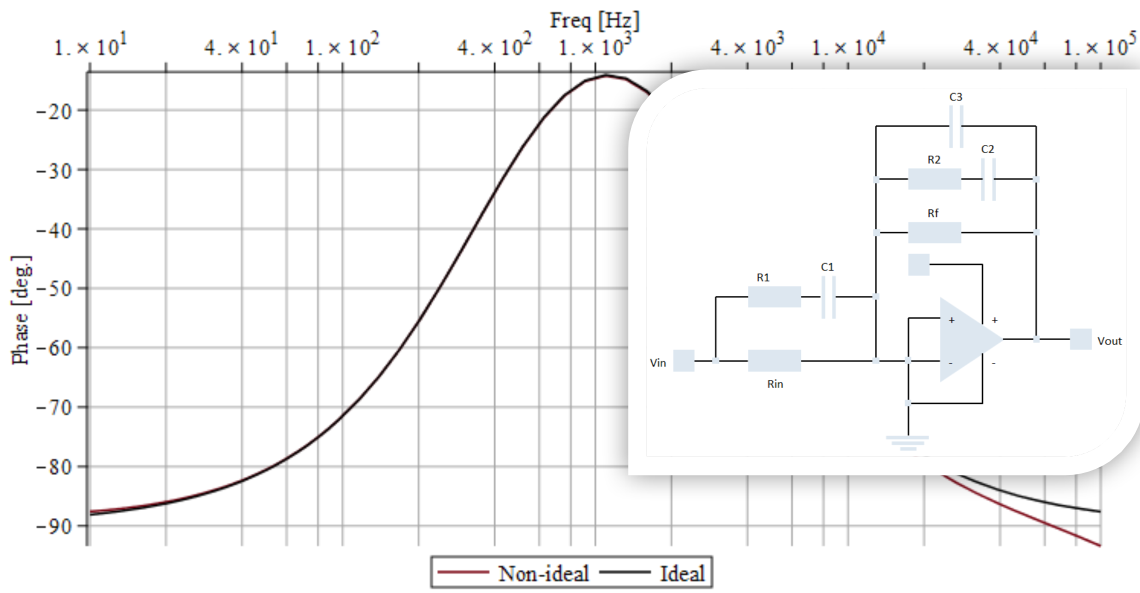


Worst Case Circuit Analysis is a set of techniques used to analyse how variations in parameters influence the performance of an electrical circuit.

This application analyses the performance of a photodiode circuit using a Monte Carlo approach.

2.7 Gain of an Amplifier Circuit

Here, we plot the gain of an amplifier circuit, for both the ideal and non-ideal response.



2.8 Parameter Estimation for a Photovoltaic Diode

The behaviour of a photovoltaic diode is described by this equation.

$$If = Ipv - I0\left(e^{\frac{If\,Rs + Vf}{n\,vt}} - 1\right) - \frac{If\,Rs + Vf}{Rp}$$

This application will:

- Rearrange this equation to give the current I in terms of the LambertW equation (this cannot be done with standard mathematical functions, but requires a symbolic solver that understands advanced mathematical functions)
- Find the best-fit parameters for a set of experimental data

2.9 Extreme Value Analysis of an Electrical Circuit

Extreme Value Analysis is a process in which the behaviour of a circuit is simulated for every permutation of extreme component parameters - that is, a resistor of 5 Ω ± 5% is simulated at 4.75 Ω and 5.25 Ω, in combination with every permutation of extreme values for all other components

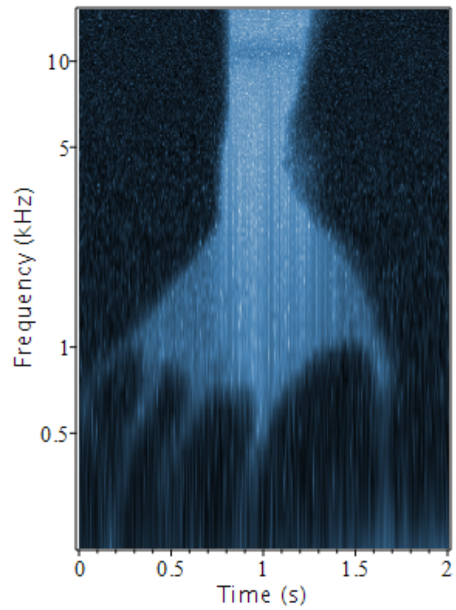
This application performs an extreme value analysis of a photodiode circuit (the principles, however, can be extended to any circuit). Light hits a photodiode and generates a current. A non-inverting op-amp then produces a linearly-proportional voltage from the photodiode current. Capacitors are ignored - hence this is a DC analysis.

3 Signal Processing

3.1 Spectrograms of Audio Files

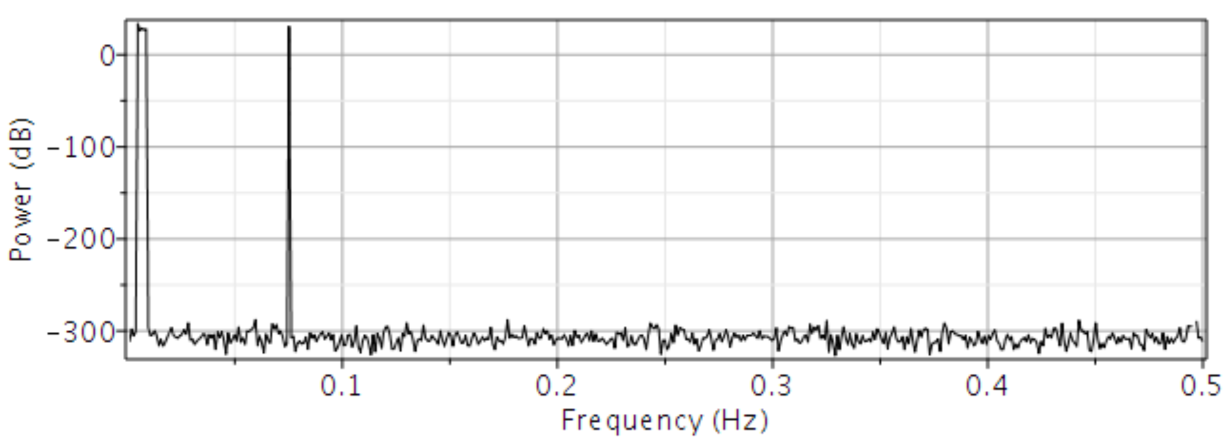
A spectrogram illustrates how the frequencies in a signal vary over time. This application generates the spectrogram of several audio files.

Some electronic musicians hide images in their music; you can only view these images with a spectrogram of the appropriate part of the audio. This includes the track "*My Violent Heart*" by the Nine Inch Nails.



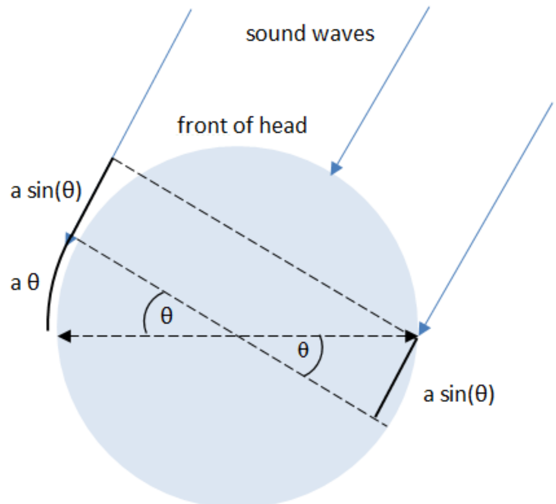
3.2 Signal Denoising

This application filters noise from a noisy signal using thresholding with discrete Fourier transforms and Haar wavelets.



3.3 Interaural Time Delay

This application modifies a single-channel audio file so that the sound appears to originate at an angle from the observer. It does this by introducing an extra channel of sound. The new channel is equivalent to the old channel, but is delayed.



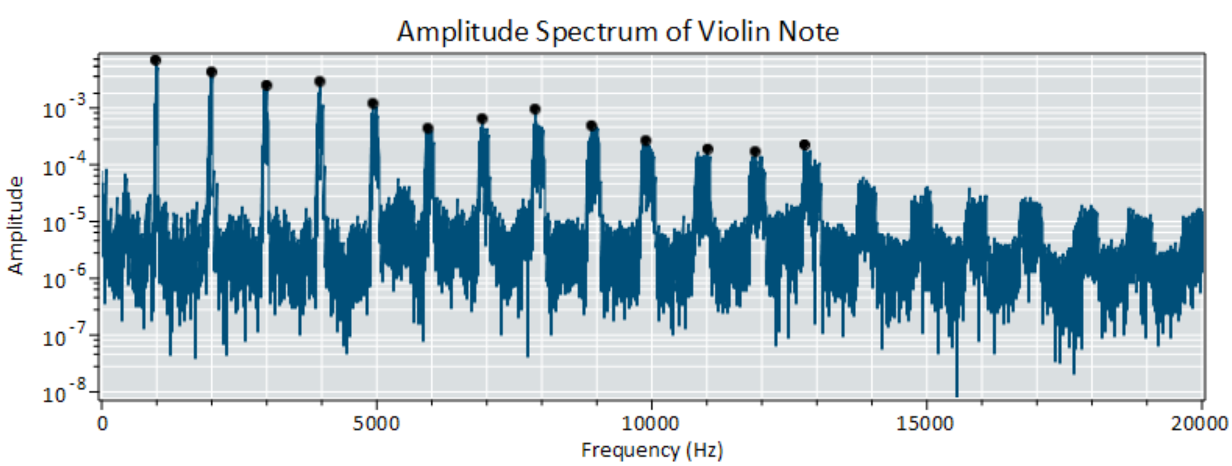
The delayed sound channel reflects the phenomenon that sound travels further to reach one ear than the other.

3.4 Fundamental Frequency of a Human Voice

Using cepstrum analysis, this application predicts the fundamental frequency of a human voice.

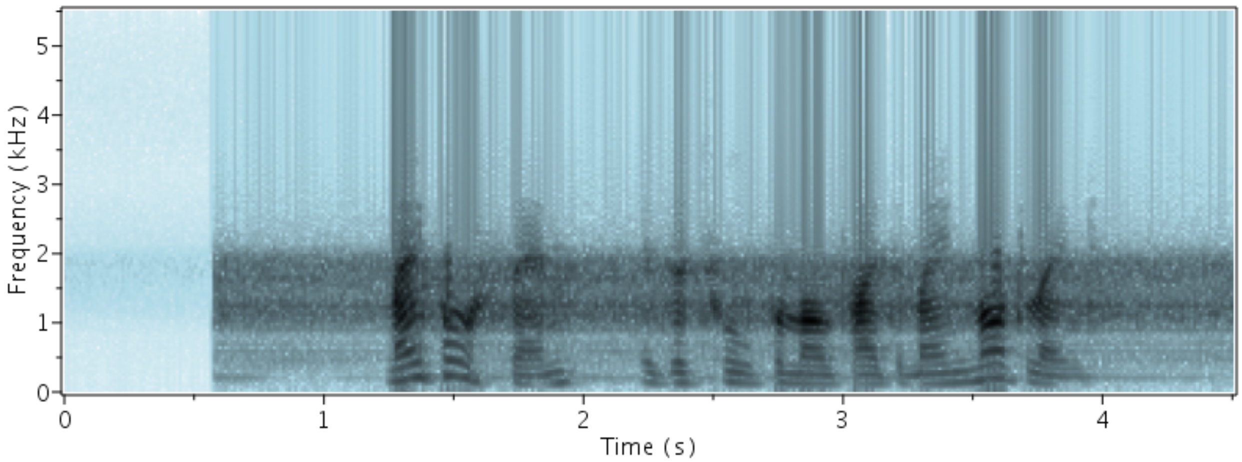
3.5 Fundamental Frequency and Harmonics of a Violin Note

In this application, we find the fundamental frequency and harmonics of a violin note by locating the peak points in its amplitude spectrum. Then, we generate a sinusoidal signal with the same frequency-amplitude characteristics of the violin note, and play the resulting sound.



3.6 FIR and IIR Filters

In this application, audio is filtered with a range of FIR and IIR filters. The pre- and post-filtered results are viewed with periodograms and spectrograms.

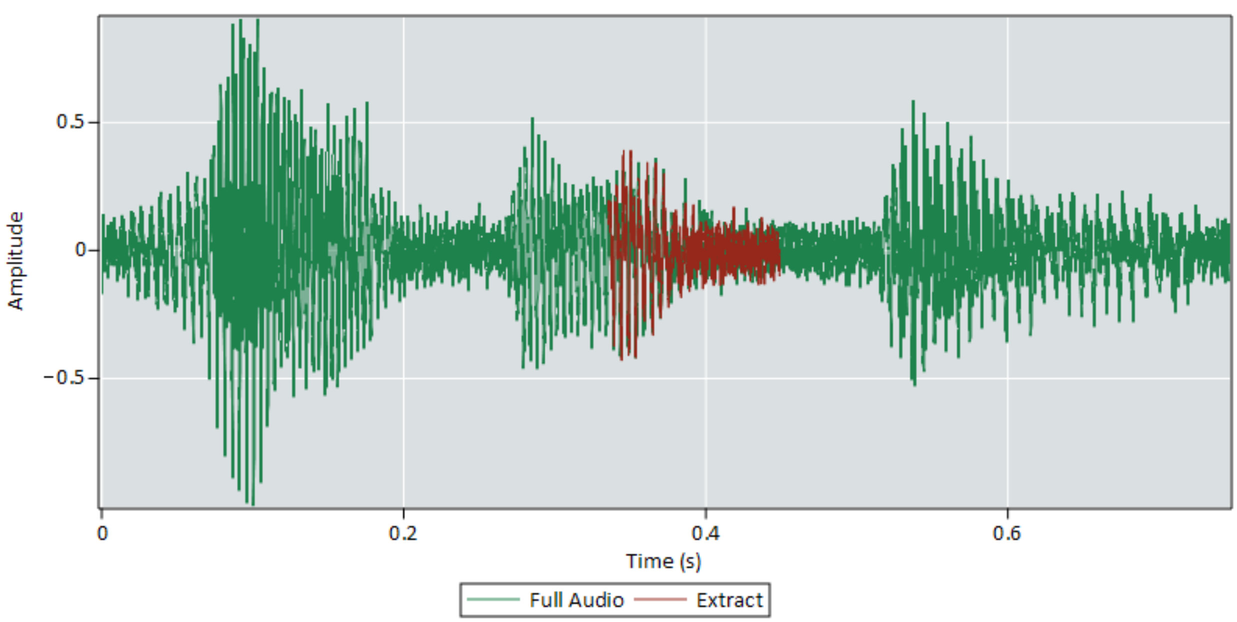


3.7 Locate a Signal in Audio in the Presence of Noise

This application demonstrates how you can estimate the location of a signal that might exist in a larger signal.

First, an audio file is loaded, a small segment is extracted, and random Gaussian noise is added to both.

Then, the cross-correlation of the full audio and the extract is computed. The maximum lag of the cross-correlation is the index at which the extract is predicted to be found in the full audio.



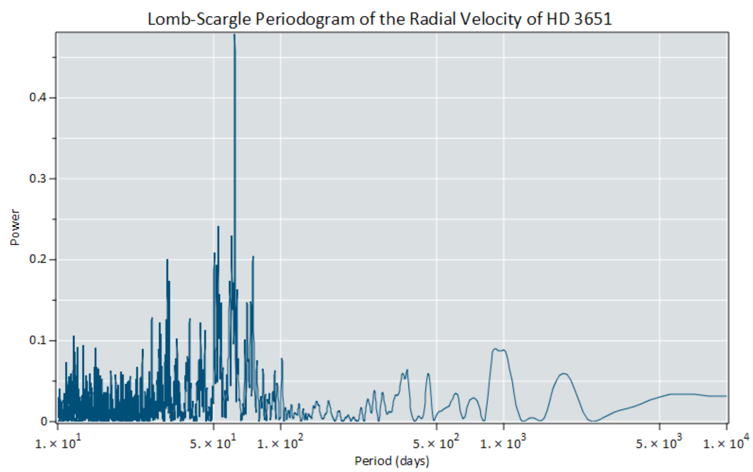
3.8 Pricing Options with FFTs

This application calculates the price of a European call option with FFTs, and compares the result to the analytical solution.

3.9 Detecting the Orbital Period of Exoplanets by Analysing the Wobble of Stars

Stars are pulled in a circle or ellipse in response to the gravity of orbiting plants. By analysing the "wobble" (or radial velocity) of a star, astronomers can predict the presence and orbital period of exoplanets.

Radial velocity is recorded, often over months or years, with a spectrograph connected to a telescope. This data is used to generate a periodogram, in which a strong peak is evidence of an exoplanet.



However data is generally not regularly sampled. This means that discrete Fourier transforms cannot be used to generate a periodogram, and other approaches are needed.

A common method for the frequency analysis of irregularly sampled data is the Lomb-Scargle approach.

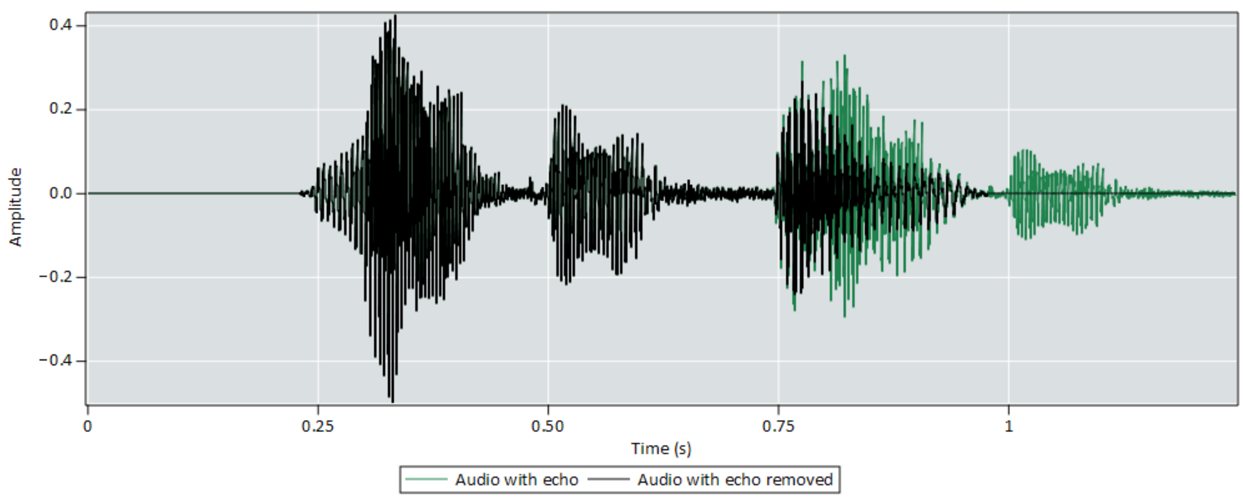
This application uses a Lomb-Scargle approach to analyse the radial velocity of the star HD 3651, and generate a periodogram. The periodogram predicts the presence of an exoplanet.

3.10 Removing Echo from Audio

This application will:

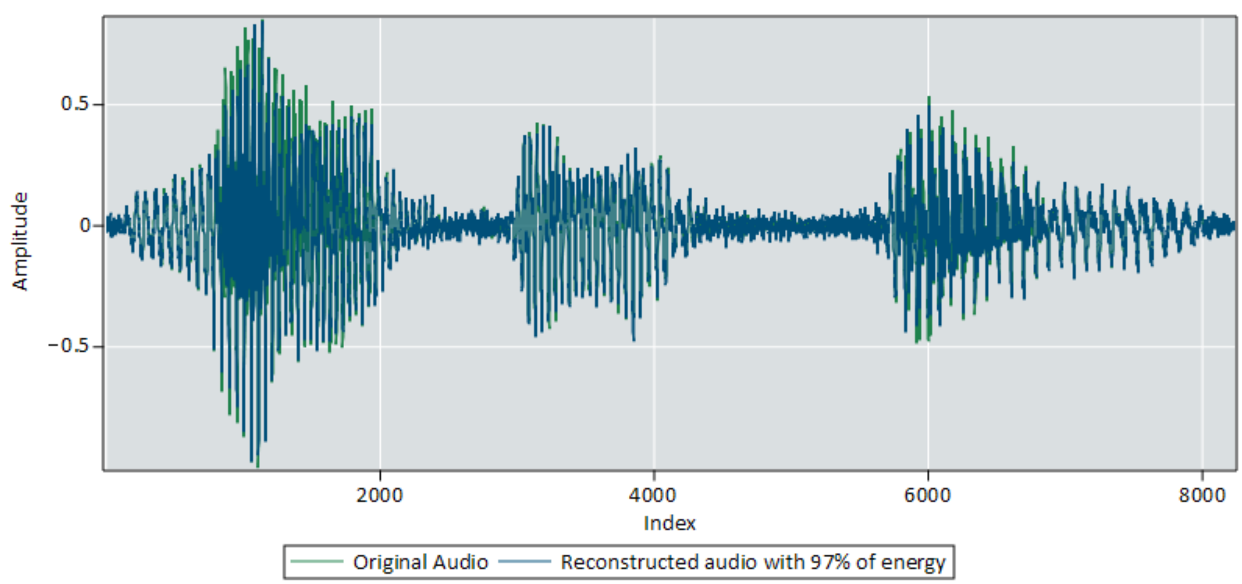
- Import an audio file that has an echo
- Identify the start of the echo with cepstrum analysis
- Use this information to generate and apply an IIR filter to remove the echo

It will then write the de-echoed audio back to a sound file.



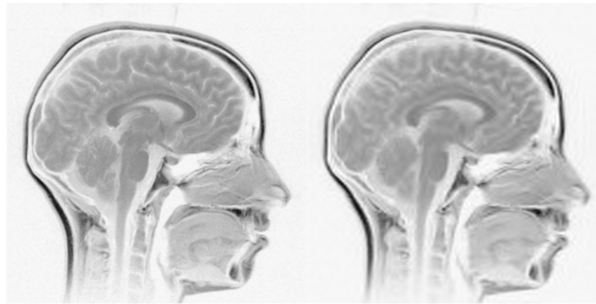
3.11 Compressing Audio

This application demonstrates how you can compress audio by discarding low-energy parts of its discrete cosine transform. The audio, before and after compression, is played to illustrate the loss of legibility at higher compression ratios.



3.12 Compression of a Brain MRI Image

This application reduces the size of a brain MRI image by removing low-level components by wavelet thresholding.

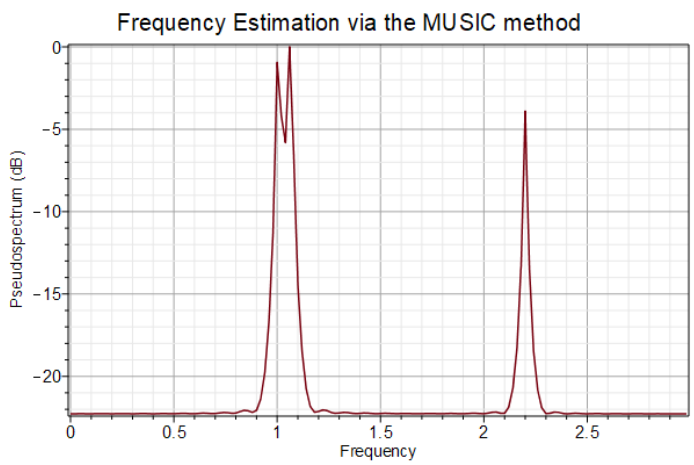


3.13 Blurring an Image in the Spatial Frequency Domain

This application applies a 2D Fourier transform to a black and white image. A low pass filter is applied to the image in the spatial frequency domain. Inverting the spatial frequencies back to the image domain demonstrates that the image is blurred.

3.14 MUSIC Method for Spectral Estimation

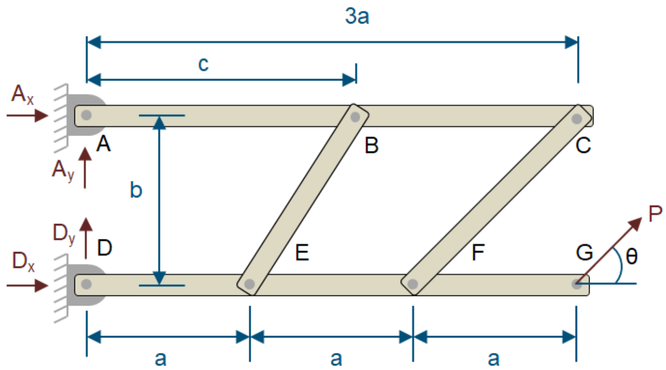
The Multiple Signal Classifier (MUSIC) method for spectral estimation offers higher frequency resolution than Fourier based approaches. This technique is particularly appropriate for signals that consist of multiple sinusoids polluted with white (i.e. Gaussian) noise.



This application generates a noisy sinusoidal data set, and then applies the MUSIC method to identify the frequencies used to generate the signal. Two closely spaced peaks are clearly identified; this would not be possible with a discrete Fourier transform because the distance between the peaks is smaller than the sampling time.

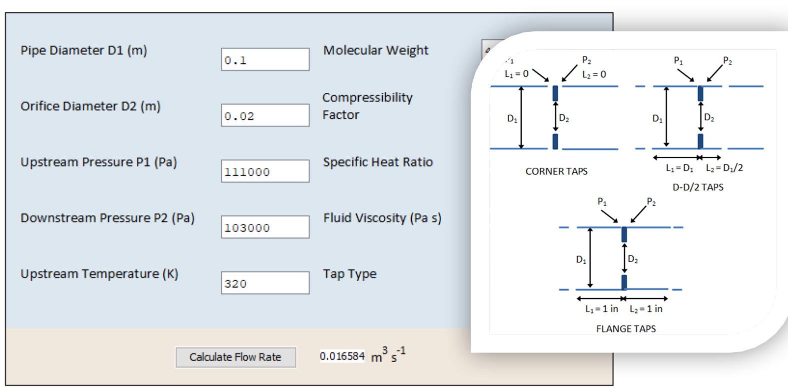
4.1 Forces in a 4 Member Frame

This application determines the forces in a frame. Since the frame is in equilibrium, the sum of horizontal forces, sum of vertical forces, and sum of momentum about a point is zero. This allows us to identify the unknown forces in a system.



4.2 Gas Orifice Flow Meter Calculator

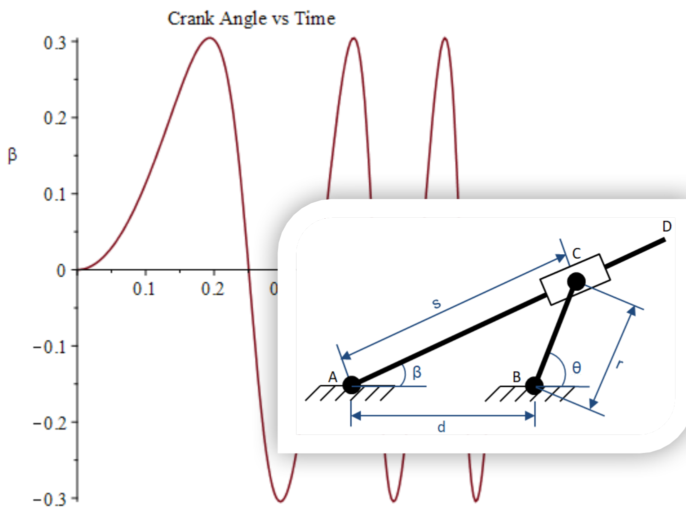
This application calculates the flow rate through a large-diameter orifice using the approach outlined in ISO 5167 2:2003.



4.3 Kinematic Analysis of a Quick Return Device

This application will:

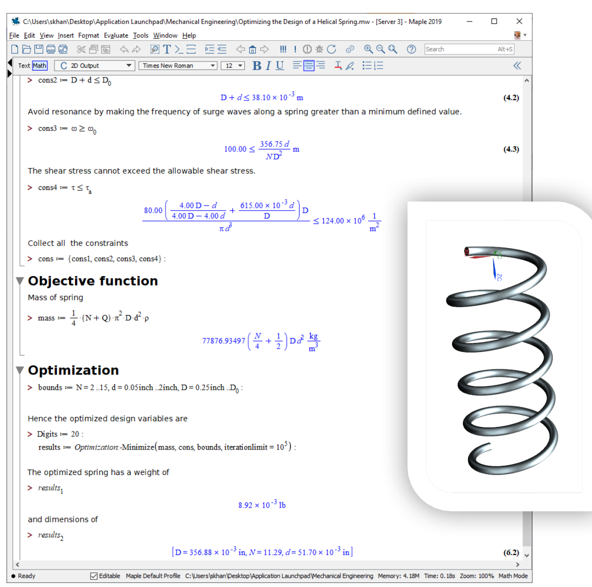
- Determine the range of motion of a quick return device
- Determine its behaviour if the crank driven at (i) a constant angular velocity, and (ii) a constant angular acceleration



The latter involves numerically solving differential equations. These are symbolically derived by differentiating the geometric relationships with respect to time.

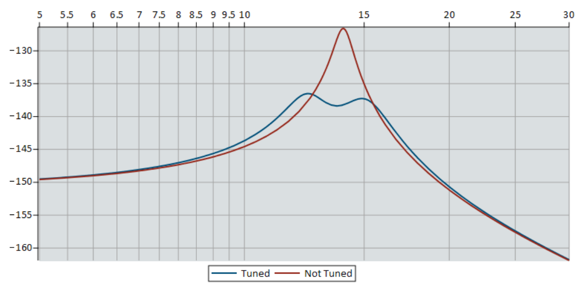
4.4 Optimizing the Design of a Helical Spring

This application minimizes the mass of a helical spring. The constraints include the minimum deflection, the minimum surge wave frequency, the maximum stress, and a loading condition.



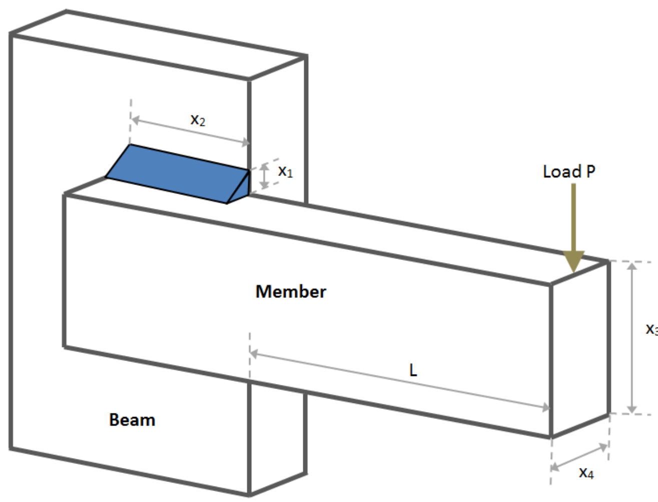
4.5 Tuned Mass Damper Design

A mass-spring-damper is disturbed by a force that resonates at the natural frequency of the system. This application calculates the optimum spring and damping constant of a parasitic tuned-mass damper that minimizes the vibration of the system.



4.6 Welded Beam Design Optimization

The diagram illustrates a rigid member welded onto a beam. A load is applied to the end of the member.

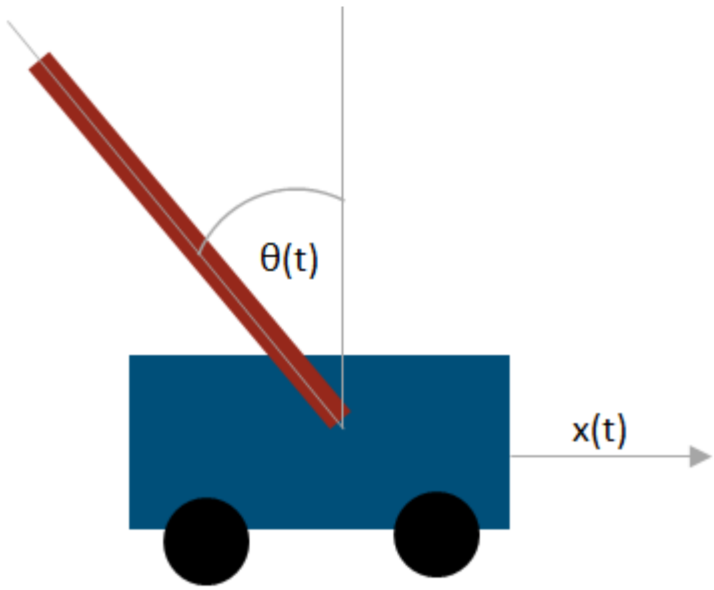


The total cost of production is equal to the labour costs for welding, plus the cost of the weld and beam material.

This application minimizes the total cost by varying the weld and member dimensions, subject to constraints on the shear stress, bending stress, buckling load, and end deflection.

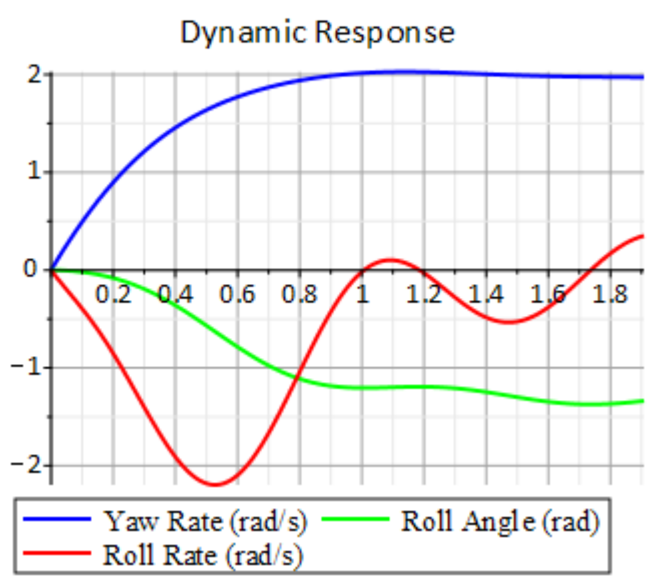
4.7 LQR Controller for an Inverted Pendulum on a Cart

This worksheet derives the equations that describe the dynamics of an inverted pendulum on a cart, creates a linear quadratic state (LQR) controller that stabilizes the position of the pendulum, and animates the motion of the controlled cart.



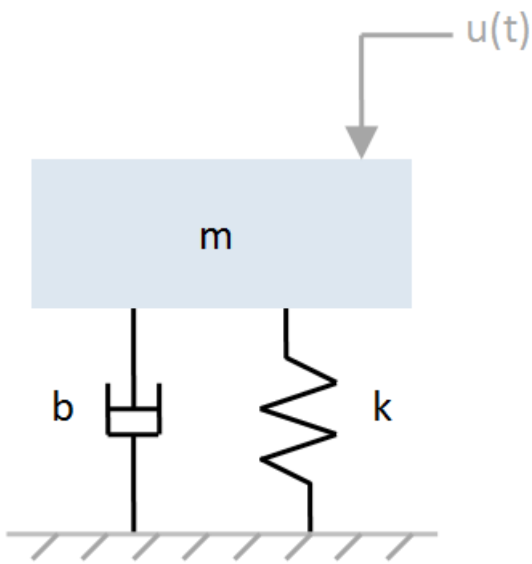
4.8 Vehicle Ride and Handling Analysis

This tool lets you experiment with the steer- and camber-by-roll coefficients of a 3-DOF vehicle model, and simulate the effect on the yaw gain curve and the understeer coefficient.



4.9 System Identification for a Mass Spring Damper

A mass spring damper is disturbed by an input force, with its response recorded in a spreadsheet.



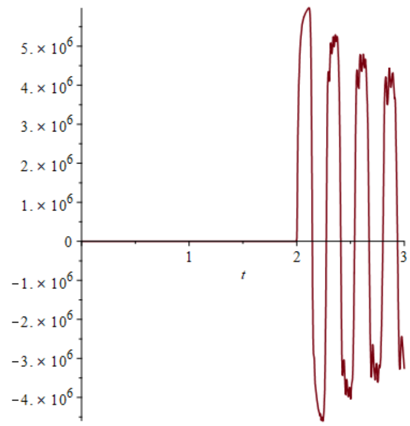
This application will:

- Import the time-based experimental data from the spreadsheet
- Translate the experimental data to the frequency domain
- Identify the mass, damping coefficient and spring constant via system identification of a model transfer function

5 Hydraulics

5.1 Water Hammer

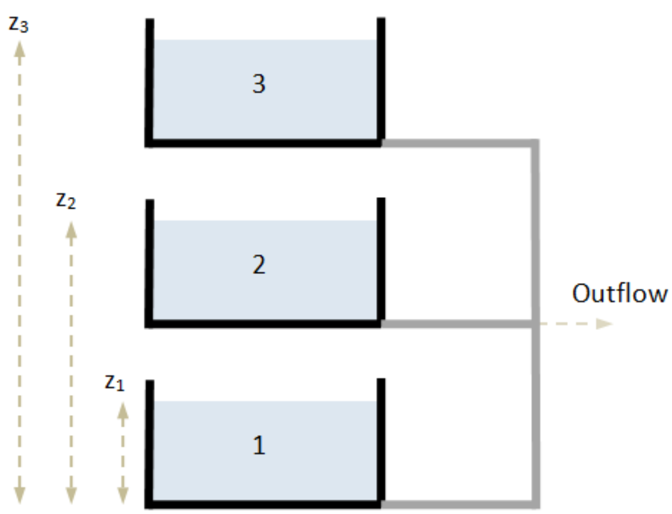
When a valve at the end of a pipeline suddenly closes, a pressure surge hits the valve and travels along the pipeline. This is known as water hammer. This process is modelled by two partial differential equations (PDEs).



The PDEs can be discretized along the spatial dimension to give a set of ordinary differential equations, ODEs. For a given set of parameters, this application solves the resulting ODEs numerically and plots the pressure dynamics at the valve.

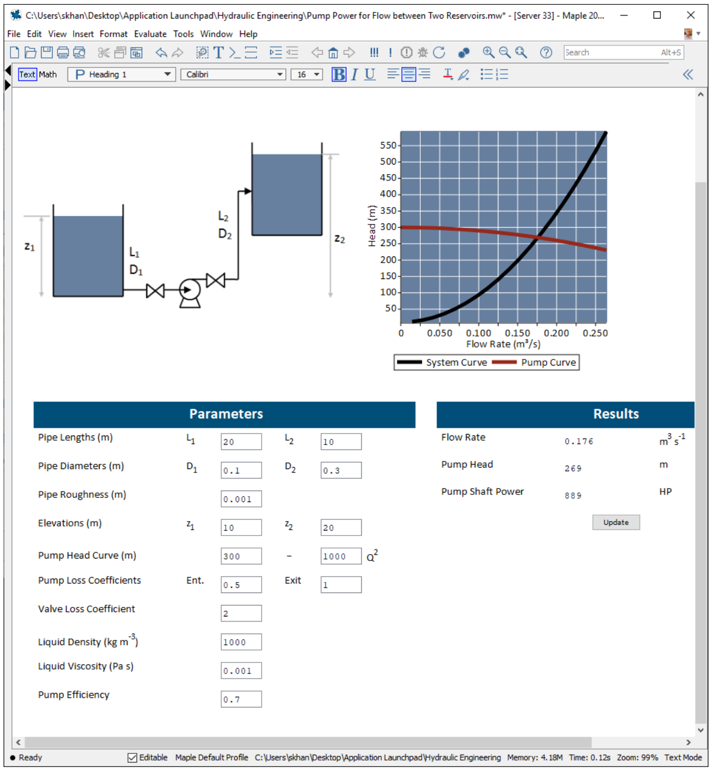
5.2 Three Reservoir Problem

Three reservoirs at different elevations are connected through a piping network at a single point, with an outflow from the common junction. This application will calculate the flow rates, flow directions, and head at the common junction.



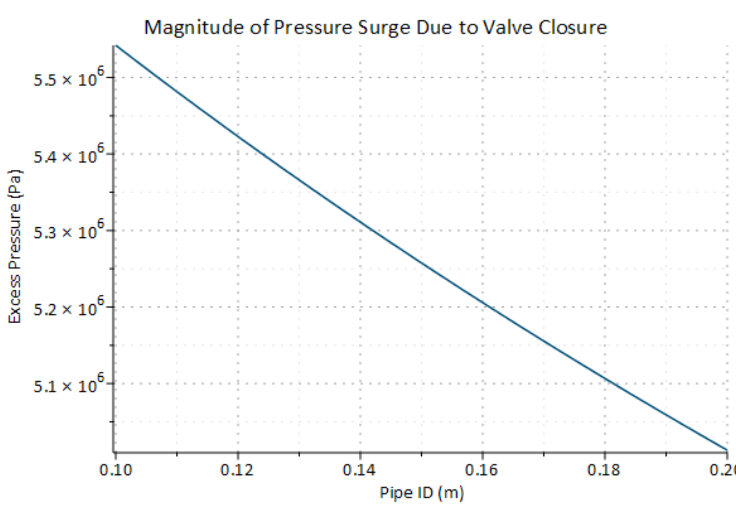
5.3 Pump Power for Flow between Two Reservoirs

A pump transfers liquid from one tank to another, with check valves placed on either side of the pump. Each tank is open to the atmosphere. This worksheet calculates the flow rate in the pipe by solving the Bernoulli equation for the system, taking into account the head added by the pump, and the head loss due to friction and pipe fittings.

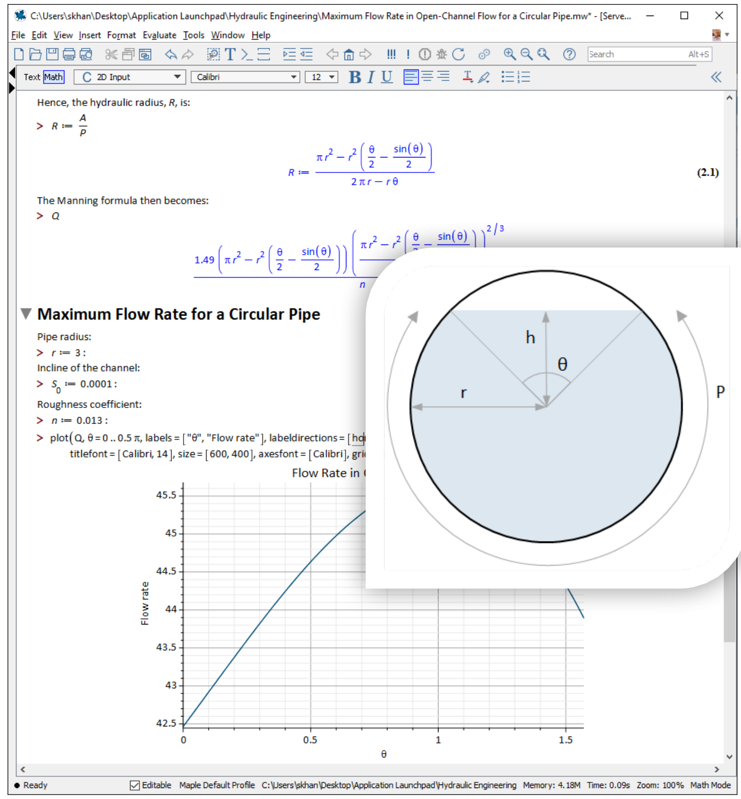


5.4 Maximum Pressure Surge Generated by Valve Shutoff

This application calculates the excess pressure generated by water hammer when a valve at the end of a pipeline instantaneously closes.



5.5 Maximum Flow Rate in Open-Channel Flow for a Circular Pipe



This application determines the greatest attainable water flow rate in a partially filled circular pipe. It uses the Manning formula to determine the flow rate in the open-channel flow of water.

An equation that represents the hydraulic radius of a partially filled circular pipe is derived and substituted into the Manning formula. The resulting equation is then optimized to find the maximum flow rate.

5.6 Interacting Tanks

This worksheet models liquid flow between three tanks connected in series.

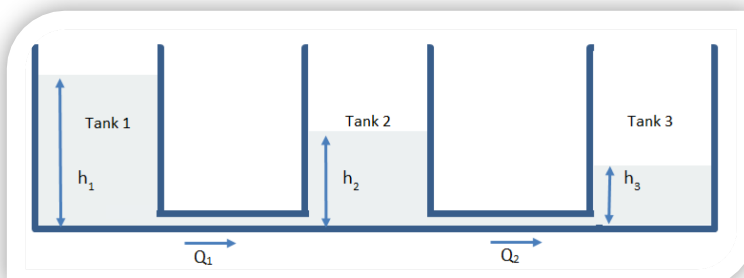
Rate of change of liquid height in Tank 1 and Tank 2

$$> \ \mathrm{height}_1 := \frac{d}{dt} H_1(t) = -\frac{Q_1(t)}{A_1} :$$

$$> \ \mathrm{height}_2 := \frac{d}{dt} H_2(t) = \frac{Q_1(t) - Q_2(t)}{A_2}$$

Rate of change of liquid height in Tank 3

$$> \ \mathrm{height}_3 := \frac{d}{dt} H_3(t) = \frac{Q_2(t)}{A_3}$$



Momentum balance

$$> \ \mathrm{momentumBalance}_1 := \frac{d}{dt} Q_1(t) = \frac{\pi\, \mathrm{Dia}^2\, g\, H_1(t)}{4\, L} - \frac{\pi\, \mathrm{Dia}^2\, g\, H_2(t)}{4\, L} - \frac{2 \cdot \mathrm{friction}(\mathrm{abs}(Q_1(t)))\, \mathrm{abs}(Q_1(t)) \cdot Q_1(t)}{\pi\, \mathrm{Dia}^3} :$$

$$> \ \mathrm{momentumBalance}_2 := \frac{d}{dt} Q_2(t) = \frac{\pi\, \mathrm{Dia}^2\, g\, H_2(t)}{4\, L} - \frac{\pi\, \mathrm{Dia}^2\, g\, H_3(t)}{4\, L} - \frac{2 \cdot \mathrm{friction}(\mathrm{abs}(Q_2(t)))\, \mathrm{abs}(Q_2(t)) \cdot Q_2(t)}{\pi\, \mathrm{Dia}^3} :$$

Initial conditions

$$> \ \mathrm{initialConditions} := Q_1(0) = 0,\ Q_2(0) = 0,\ H_1(0) = 1.5,\ H_2(0) = 1.2,\ H_3(0) = 2 :$$

This involves solving the differential equations that describe the momentum balance between each pair of connected tanks.

5.7 Calculating the Bulk Modulus of a Fluid

Maple has the thermodynamic and transport properties of many fluids built-in. Derived quantities, such as the bulk modulus can be computed from this data.

Hence to compute the bulk modulus we need (i) the fluid density, and (ii) the numeric derivative of pressure with respect to density (at constant temperature). These properties can be extracted from Maple's fluid properties database.

```
BulkModulus := proc(temp, press, fluid)

   local rho:
   uses ThermophysicalData:

   rho := Property(density, temperature = temp, pressure = press, fluid);
   return rho*fdiff(Property(P, density = D, temperature = temp, fluid), D = rho);

end proc:
```

5.8 Measurement Error in a Venturi Flowmeter

Venturi flowmeters use the height of a liquid column to measure the pressure drop (and hence the flowrate) of fluid in a pipe. However, errors in reading the column height will affect the calculated value of the flowrate.

Methane (at 1 bar and 40°C) enters a venturi meter with a water manometer (with a measurement error of ±1 mm). The upstream pipe area is 0.05 m^2 and the venturi throat diameter is 0.025 m^2.

The water displacement across the manometer is 3 cm. Given the measurement error, this application calculates the potential range of flowrates.

6 Earth and Building Science

6.1 DOE-2 Parameter Estimation

This application finds the parameters for a DOE-2 model of a chiller from its data sheet.

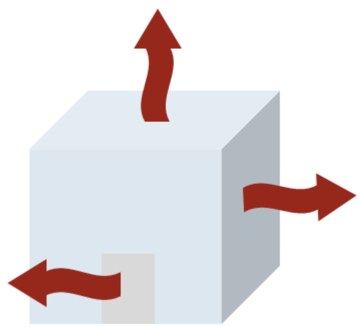
The DOE-2 model is then used to find the compressor power, COP and condenser heat flow rate for a specific heat load.

6.2 Cost of Heating a Home with Natural Gas

This application calculates the cost of heating a house with natural gas, assuming:

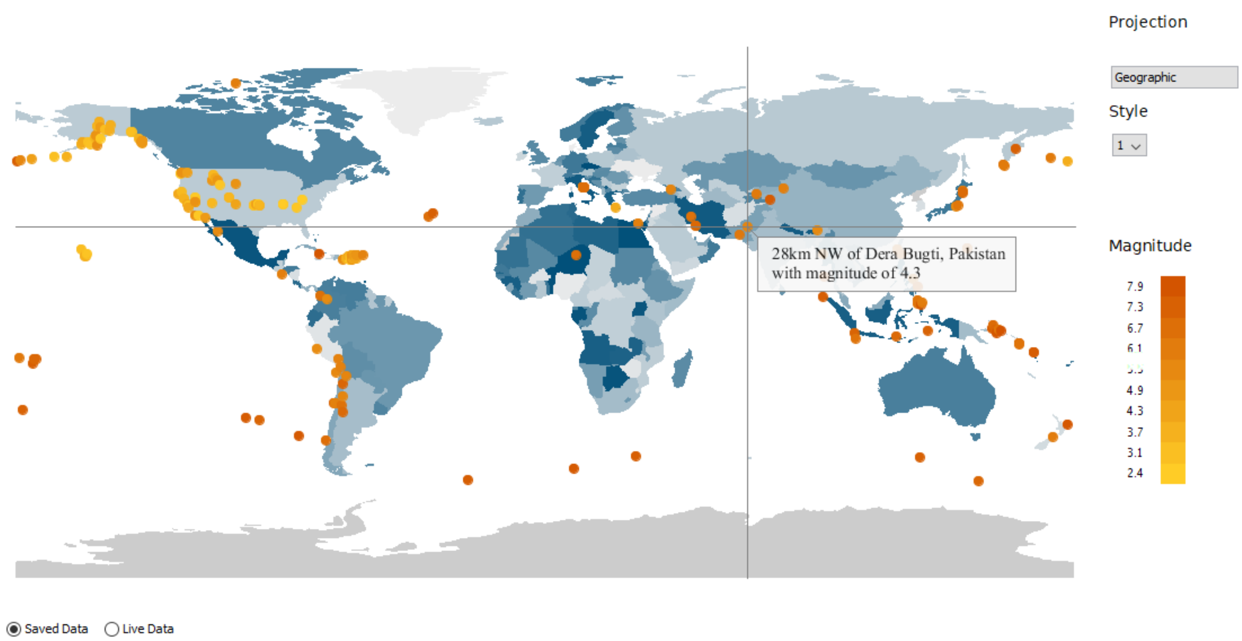
- Heat losses through four side walls (each with windows), a roof, and air exchanges with the environment
- Heat gains through a furnace

Historical heating degree day data for Kitchener, Ontario, will be used.



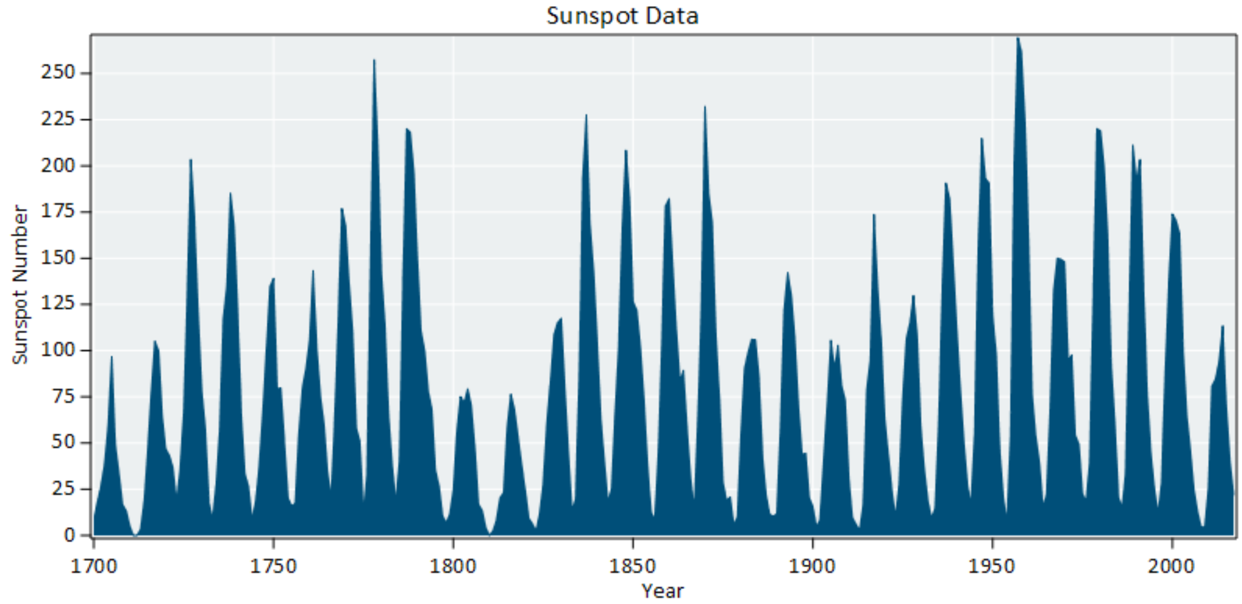
6.3 Live Earthquake Data

This application downloads live earthquake data from the USGS website, and plots the location and magnitude on a world map.



6.4 Sunspot Periodicity

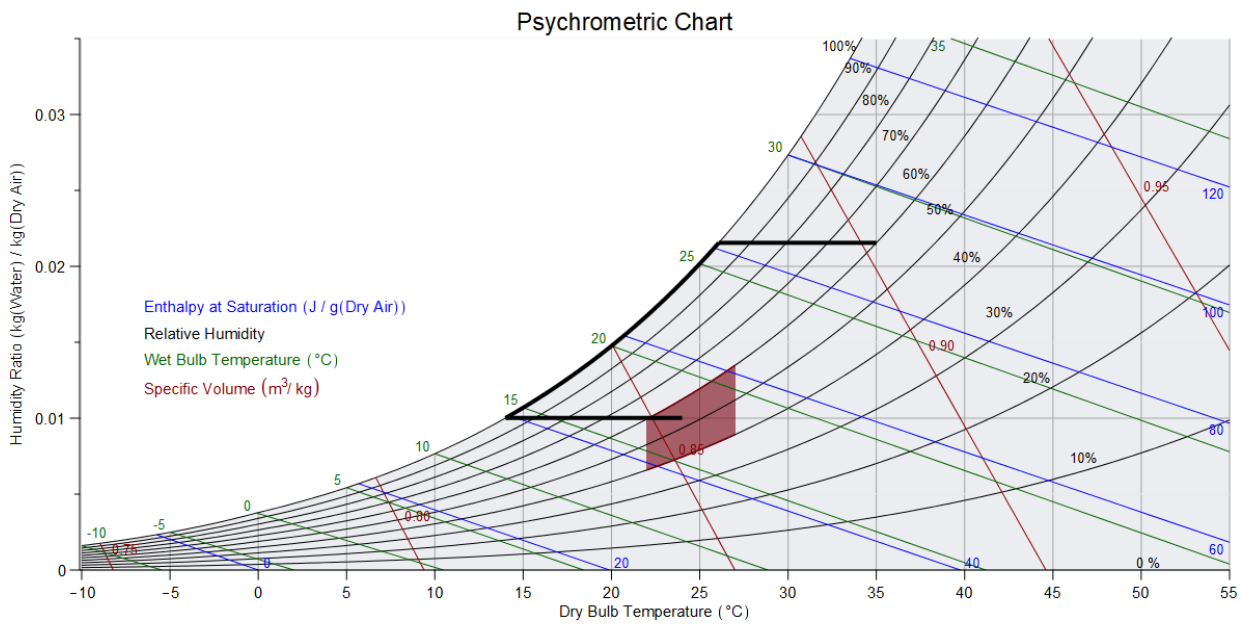
This application finds the periodicity of sunspots with two approaches – discrete Fourier transforms and autocorrelation.



6.5 Human Comfort Zone

Humans generally feel comfortable between temperatures of 22°C to 27°C and a relative humidity of 40% to 60%.

In this application, air at 35°C and 60% relative humidity will be conditioned into the human comfort zone, with the thermodynamic process plotted on a psychrometric chart.



7 Chemistry

7.1 Enthalpy Change of Combustion of Methane

This application calculates the enthalpy change of combustion of methane at standard conditions, given the reaction:

$$CH_4\ (g) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$$

The enthalpy of methane, oxygen, carbon dioxide and water are computed using the empirical correlations in Maple's built-in thermophysical properties database.

7.2 Gibbs Energy of Formation of Ethanol

This chemical reaction describes how ethanol is formed from carbon, hydrogen and oxygen in their stable states.

$$2\ C\ (gr) + 3\ H_2\ (g) + 0.5\ O_2\ (g) \rightarrow C_2H_5OH\ (g)$$

This application will calculate the Gibbs energy of formation of ethanol at any temperature, employing Maple's built-in thermodynamic data. The results are compared with values from the literature.

Values of the Gibbs energy of formation found in the literature are normally only given at standard temperature, or for tabulated at a few temperatures. However, Maple contains built-in thermodynamic data, correlated against temperature. This means you can calculate the Gibbs energy of formation at any temperature.

7.3 Parameter Estimation for a Chemical Reaction

This application estimates the rate parameters for a reversible reaction with dimerization of an intermediate.

$$A + B \underset{k_2}{\overset{k_1}{\leftrightarrows}} C$$

$$C + C \underset{k_4}{\overset{k_3}{\rightleftarrows}} D$$

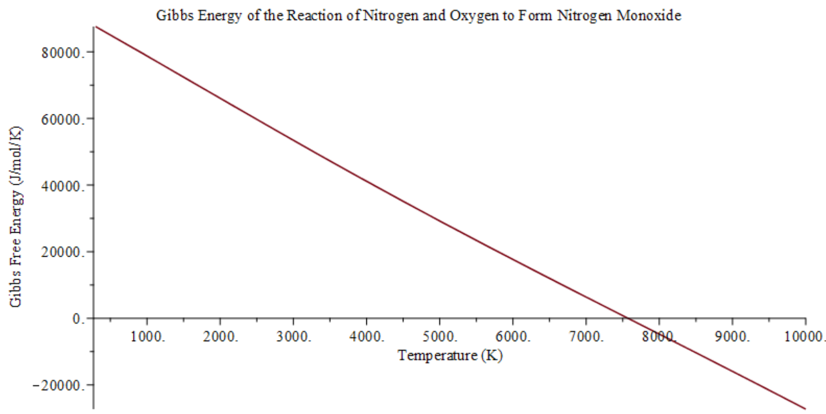
It does this by:

- Parameterizing (with respect to the rate constant) the numerical solution of the different equations that describe the reaction kinetics
- Calculating the sum of the square of the errors between the model predictions and experimental data
- Minimizing the sum of the square of the errors to find the best fit values of the rate constants

7.4 Spontaneity of the Reaction of Nitrogen and Oxygen to form Nitrogen Monoxide

This application will calculate the temperature at which nitrogen reacts spontaneously with oxygen.

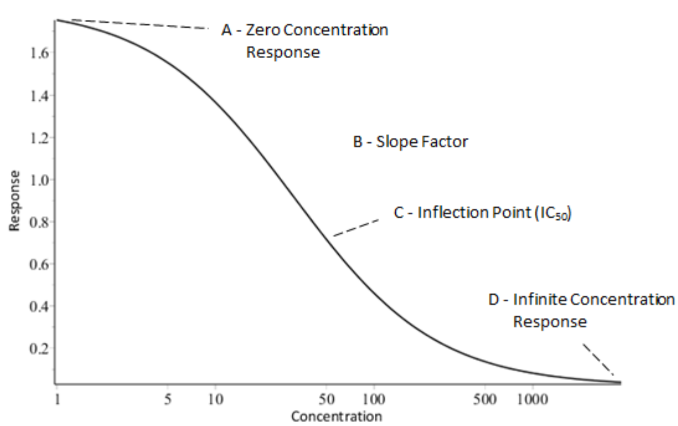
The application first defines a temperature-dependent function that describes the Gibbs Energy of the reaction.



This function is then numerically solved for the temperature at which the Gibbs Energy is zero. The reaction is spontaneous at or above this temperature.

7.5 Calibrating Response Curves for the Concentration of Melatonin Sulfate in Human Urine

This application calibrates response curves using data from an immunoassay. Both a four parameter logistic and five parameter logistic equation are fit to the data.



8 Chemical Engineering

8.1 Catalytic Cracking of Ethane

Ethylene and hydrogen are generated by a steam cracker using ethane as a feedstock.

$$C_2H_6\ (g) \rightleftharpoons C_2H_4\ (g) + H_2\ (g)$$

The products contain CH_4, C_2H_4, C_2H_2, CO_2, CO, O_2, H_2, H_2O, and C_2H_6.

This application calculates the composition of the reaction products by:

- Calculating the Gibbs energy of formation of the individual species in the products
- Constructing a function that describes Gibbs Energy of the products as a function of composition
- Minimizing the Gibbs Energy of the products, subject to constraints

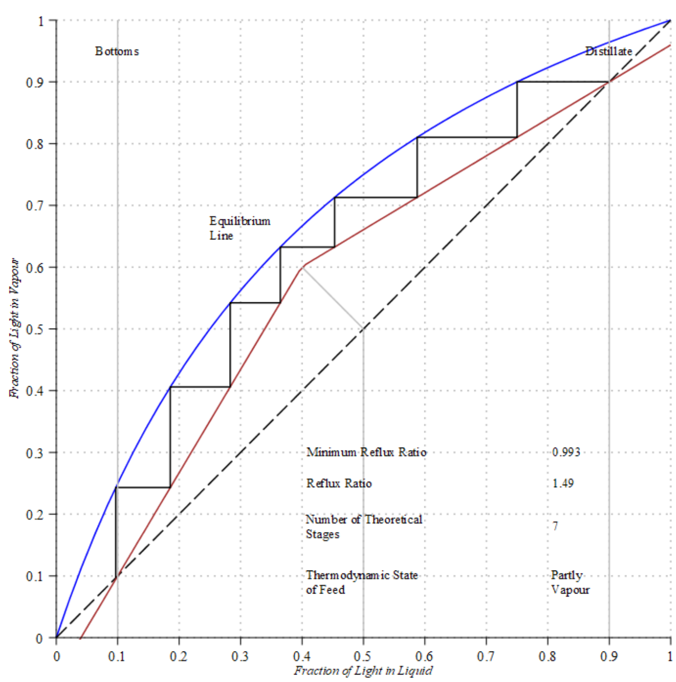
8.2 Terminal Settling Velocity of a Solid Particle in Fluid

This application calculates the terminal velocity of a solid particle settling in a fluid.

First, the settling velocity equation is derived symbolically. Then, the governing equations are solved numerically for a given set of parameters.

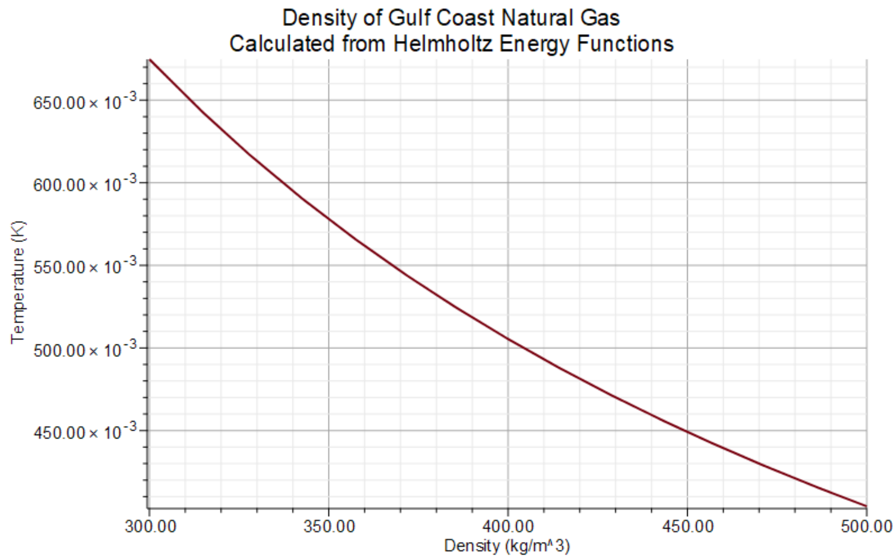
8.3 Binary Distillation with the McCabe-Thiele Method

This application calculates the required number of theoretical stages for a distillation column via the McCabe-Thiele method. It also plots the classic McCabe-Thiele diagram and evaluates the minimum and actual reflux ratio, and the thermodynamic state of the feed.



8.4 Physical Properties of Natural Gas

Here, we compute the transport properties of several standard natural gas mixes (Gulf Coast, Amarillo, Ekofisk, High N_2 and High N_2/O_2), and demonstrate how you can calculate the properties of your own custom blend.



8.5 Economic Pipe Sizing

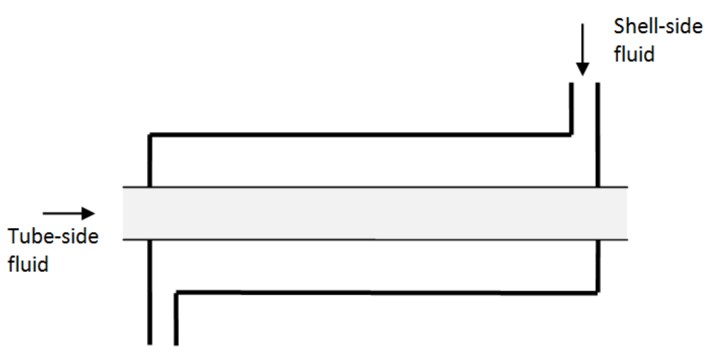
Pipework is a large part of the cost of a process plant. Plant designers need to minimize the total cost of this pipework across the lifetime of the plant. The total overall cost is a combination of costs for the pipe material, installation costs, energy costs for pumping, flowrates, and more.

This application finds the pipe diameter that minimizes the total overall cost (given a method outlined in a literature reference). The method involves the iterative solution of an empirical equation.

Bear in mind that the empirical parameters vary as economic conditions change. Those used in this application are correct for 1998 and 2008.

8.6 Countercurrent Double-Pipe Heat Exchanger

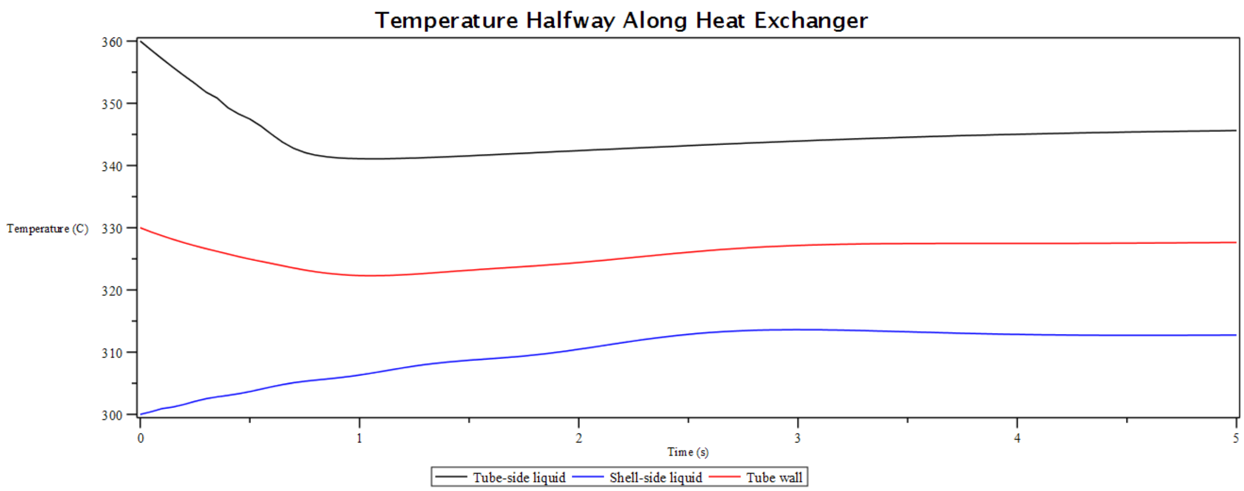
This application models the temperature dynamics of a countercurrent double pipe heat exchanger.



Three partial differential equations describe:

- Heat balances across the tube- and shell-side liquids,
- Heat balance across the tube-wall (taking into account the heat flow from the shell- and tube-side liquids, and conduction along the length of the tube)

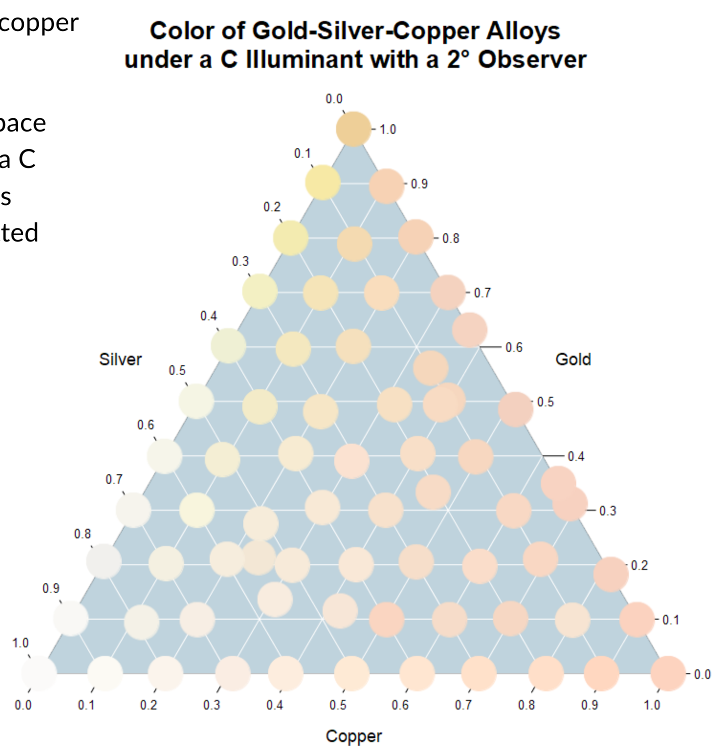
The equations are solved numerically, and the temperature profiles plotted.



8.7 Colour of Gold-Silver-Copper Alloys

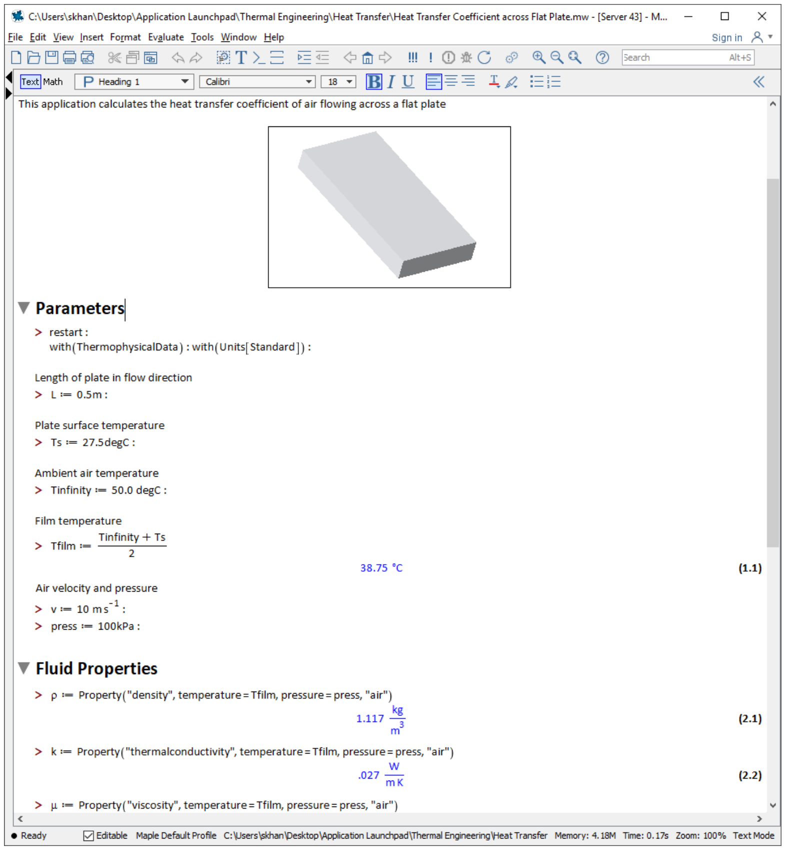
This application plots the colour of gold-silver-copper alloys on a ternary diagram.

Experimental data contains the CIE xyY colorspace coordinates of gold-silver-copper alloys under a C illuminant with a 2° observer. The colour data is translated into the CIE Lab colorspace and plotted on a ternary diagram.



8.8 Heat Transfer Coefficient of Air Flowing across a Flat Plate

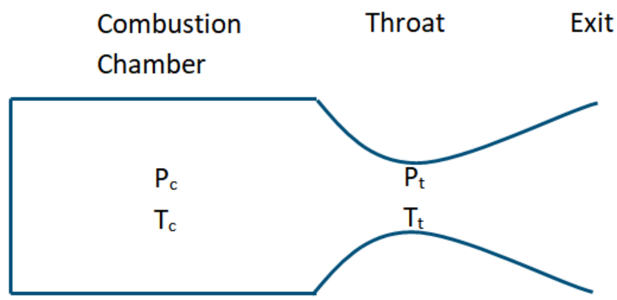
This application calculates the heat transfer coefficient of air flowing across a flat plate.



9 Aerospace Engineering

9.1 Performance of a Monomethylhydrazine-Dinitrogen Tetroxide Rocket Engine

Liquid Monomethylhydrazine (CH_6N_2) and Dinitrogen Tetroxide (N_2O_4) are burned in the combustion chamber of a rocket engine.



This application will calculate:

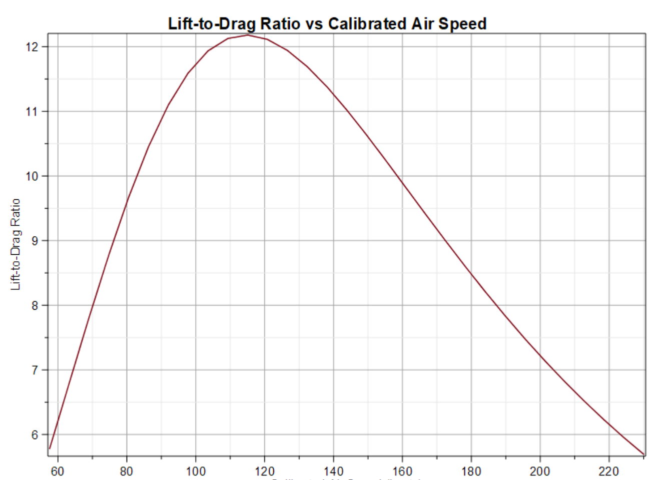
- The adiabatic flame temperature and composition of the combustion products (i.e. in the combustion chamber)
- The pressures and temperatures in the throat and exit
- The theoretical rocket performance, including the ideal specific impulse, characteristic velocity, and sonic velocity

Monomethylhydrazine and Dinitrogen Tetroxide are commonly used in spacecraft rocket engines as a fuel and oxidizer (for example, in SpaceX's Dragon spacecraft).

9.2 Unpowered Glide Analysis of a Baron 58 Light Aircraft

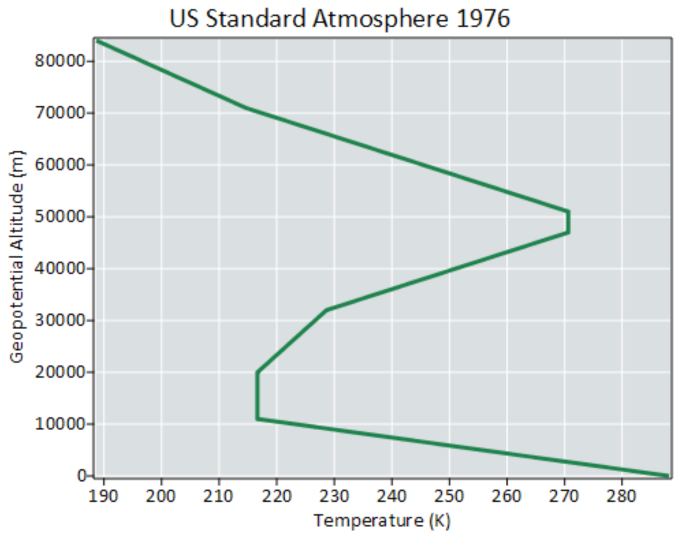
This application presents an unpowered glide analysis of a Baron 58 aircraft.

An aircraft with no engine power will glide to the ground. The best glide angle is the flight angle at which the airplane will travel the greatest distance, and occurs at the maximum lift-to-drag ratio.



9.3 US Standard Atmosphere 1976

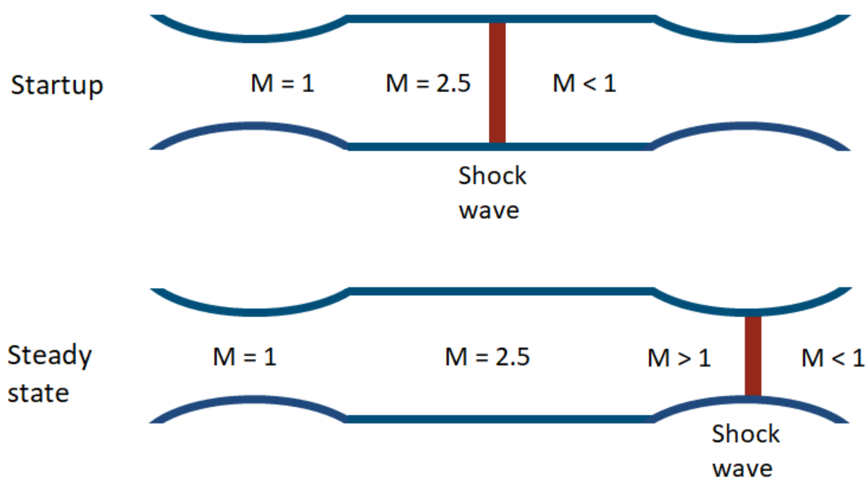
This application implements the 1976 US Standard Atmosphere model for the lower atmosphere.



The model gives the pressure, temperature, density and viscosity of air as a function of geopotential altitude, and is valid from a geopotential altitude of 0 m to 84852 m.

9.4 Compressor Power for Supersonic Wind Tunnel

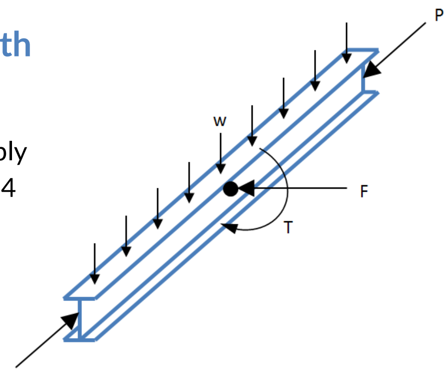
Given a supersonic wind tunnel, this application will calculate the compressor power at start-up and at steady-state



10 Structural Engineering

10.1 Simply Supported Beam Design with Torsional Loading

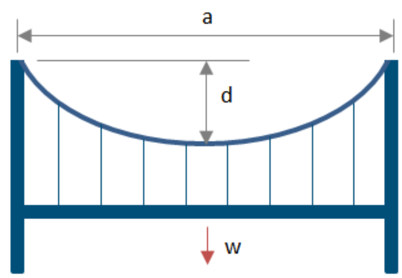
This application performs a design analysis on a simply supported beam with torsional loading for a W10X54 steel beam (as defined by the AISC Steel Shapes Database).



10.2 Parabolic Suspension Cable

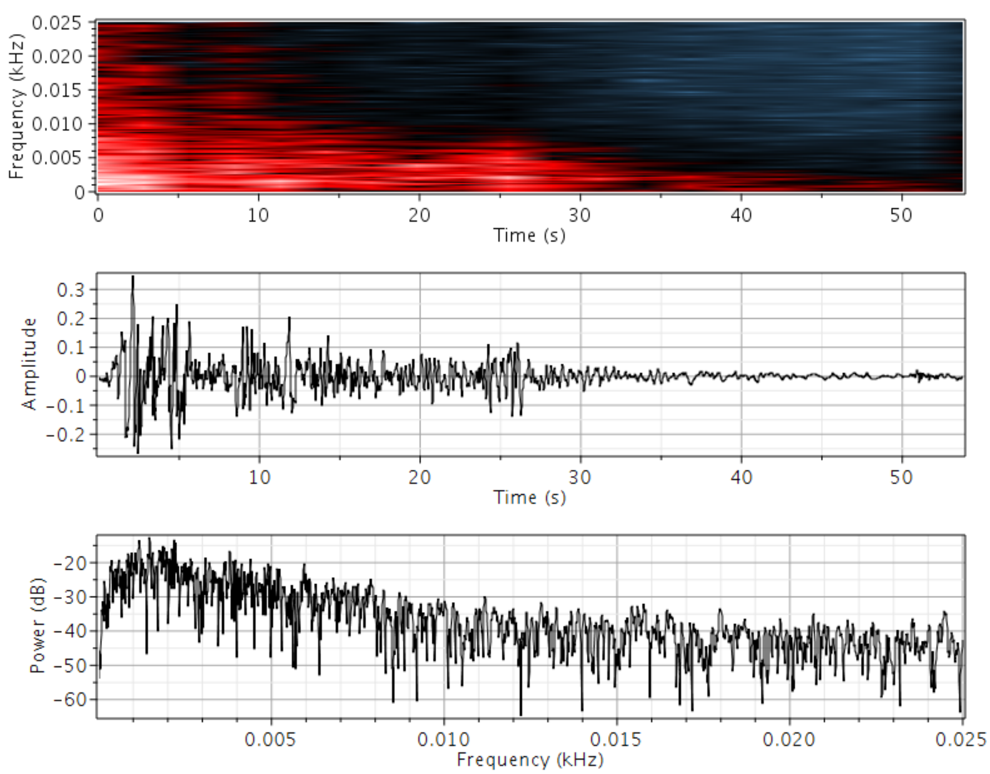
A cable is suspended between two supports.

This application first derives an expression (using symbolic integration) that describes the relationship between the cable length, span and sag. Then, given values for the length and sag, this application will calculate the span.



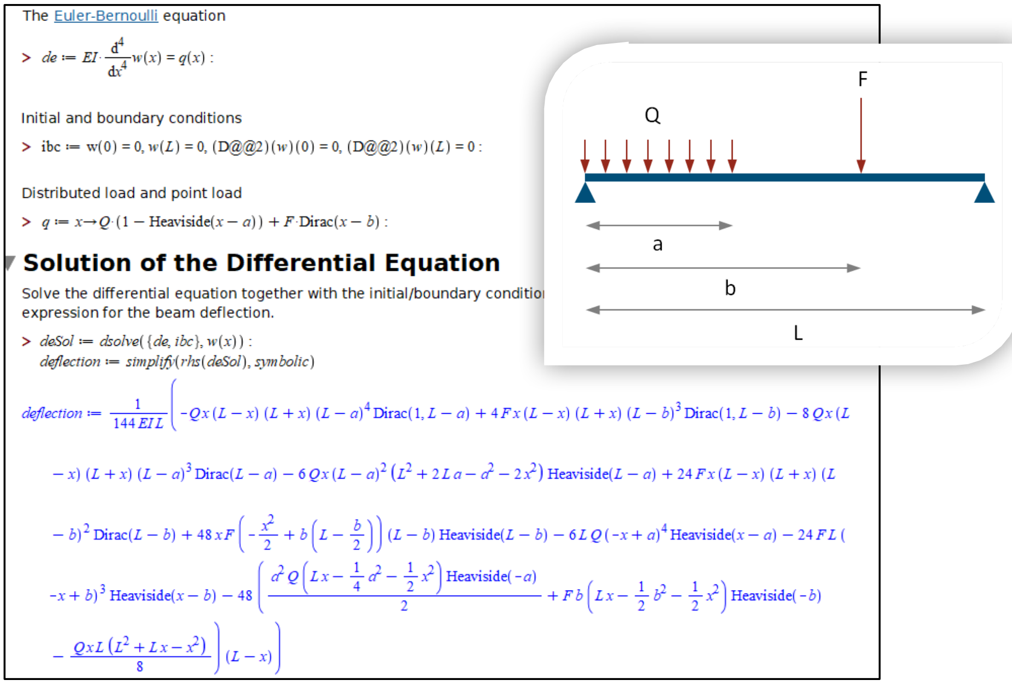
10.3 El Centro Earthquake Data Analysis

This application analyses the response of a SDOF to the 1940 El Centro earthquake using acceleration data recorded from a seismograph located near the fault line.



10.4 Deflection of a Beam with Distributed and Point Load

This application will derive an explicit expression for the deflection of a beam with a distributed load and a point load by solving the Euler-Bernoulli equation.



The Euler-Bernoulli equation

$$> \; de := EI \cdot \frac{d^4}{dx^4} w(x) = q(x):$$

Initial and boundary conditions

$$> \; ibc := w(0) = 0, w(L) = 0, (D@@2)(w)(0) = 0, (D@@2)(w)(L) = 0:$$

Distributed load and point load

$$> \; q := x \rightarrow Q \cdot (1 - \mathrm{Heaviside}(x - a)) + F \cdot \mathrm{Dirac}(x - b):$$

Solution of the Differential Equation

Solve the differential equation together with the initial/boundary conditio[ns …]
expression for the beam deflection.

$$> \; deSol := dsolve(\{de, ibc\}, w(x)): \quad deflection := simplify(rhs(deSol), symbolic)$$

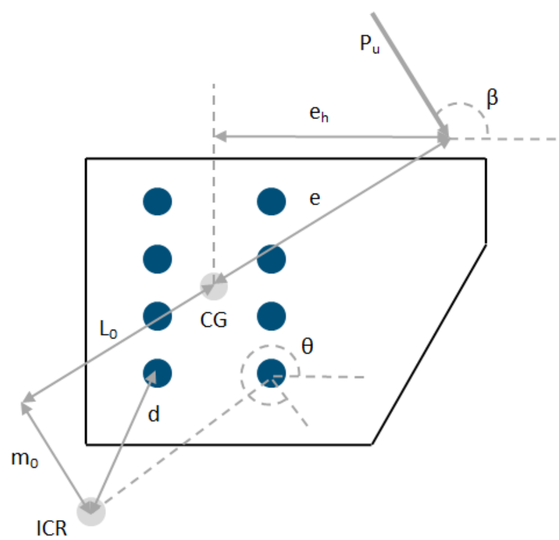
$$deflection := \frac{1}{144\,E I L}\Big(-Q x (L-x)(L+x)(L-a)^4 \mathrm{Dirac}(1, L-a) + 4 F x (L-x)(L+x)(L-b)^3 \mathrm{Dirac}(1, L-b) - 8 Q x (L-x)(L+x)(L-a)^3 \mathrm{Dirac}(L-a) - 6 Q x (L-a)^2 (L^2 + 2 L a - a^2 - 2 x^2) \mathrm{Heaviside}(L-a) + 24 F x (L-x)(L+x)(L-b)^2 \mathrm{Dirac}(L-b) + 48 x F \left(-\frac{x^2}{2} + b\left(L - \frac{b}{2}\right)\right)(L-b) \mathrm{Heaviside}(L-b) - 6 L Q (-x+a)^4 \mathrm{Heaviside}(x-a) - 24 F L (-x+b)^3 \mathrm{Heaviside}(x-b) - 48 \left(\frac{a^2 Q \left(L x - \frac{1}{4} a^2 - \frac{1}{2} x^2\right) \mathrm{Heaviside}(-a)}{2} + F b \left(L x - \frac{1}{2} b^2 - \frac{1}{2} x^2\right) \mathrm{Heaviside}(-b) - \frac{Q x L (L^2 + L x - x^2)}{8}\right)(L-x)\Big)$$

10.5 Bolt Group Coefficient

This application calculates the bolt coefficient for eccentrically loaded bolt groups using the Instantaneous Center of Rotation method (also known as the Ultimate Strength method).

Traditionally, bolt group coefficients are extracted by using tabulated values in the AISC Steel Construction Manual. However, these tables are limited to common bolt patterns, and specific load eccentricities and angles. Non-tabulated values must be extracted by using linear interpolation.

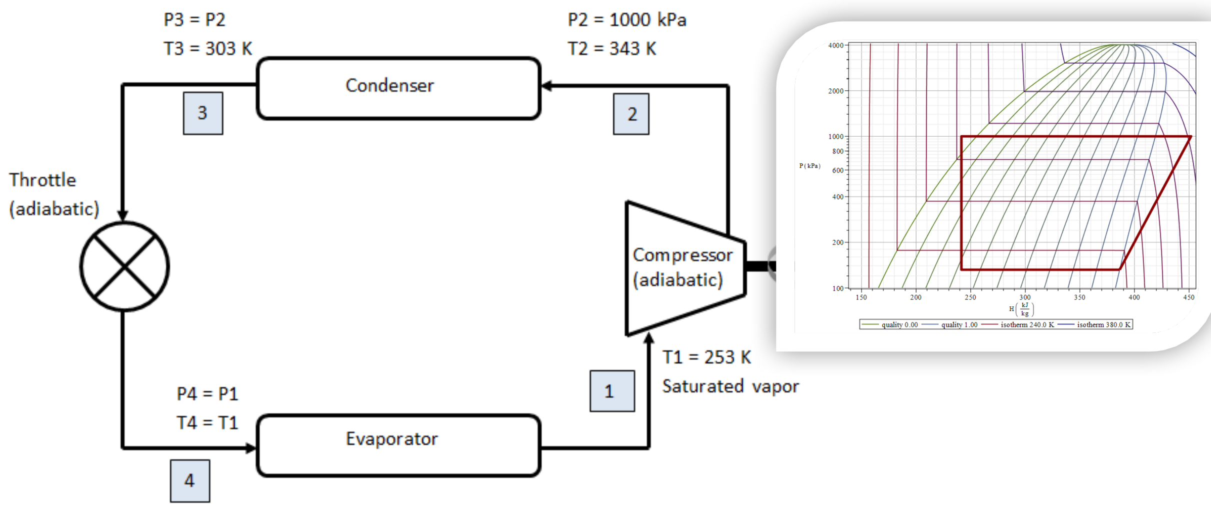
This Maple worksheet, however, calculates the bolt group coefficient for any bolt and load configuration by implementing the theory used to generate the tables.



11 Thermal Engineering and Thermodynamics

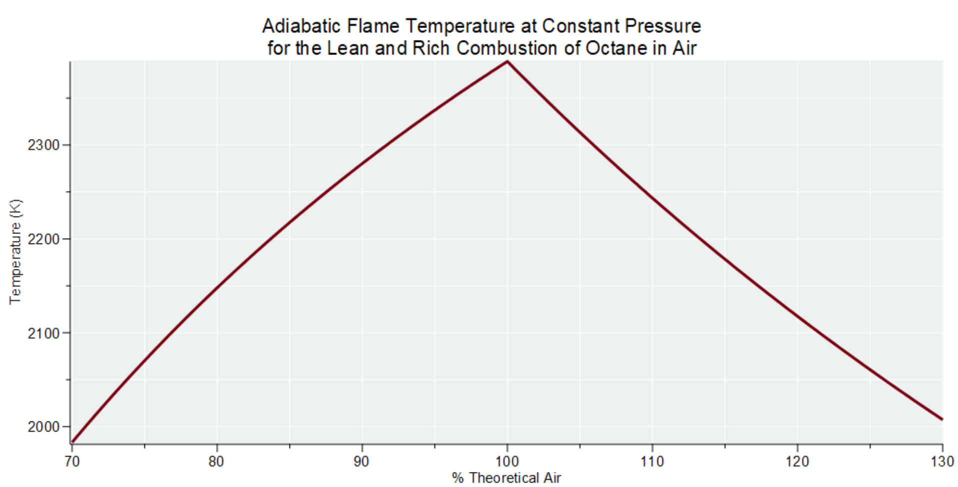
11.1 Vapour-Compression Refrigeration Cycle

This application calculates the coefficient of performance of a vapour-compression refrigeration cycle. Additionally, the thermodynamic cycle is plotted on a pressure-enthalpy-temperature chart.



11.2 Adiabatic Flame Temperature of Octane as a Function of Fraction of Air

This application will calculate the flame temperature of octane for a varying amount of air. Temperature-dependent thermodynamic properties are computed using Maple’s thermophysical properties engine.



11.3 Constant Volume Flame Temperature of the Combustion of Methane in Air

This application calculates the constant volume adiabatic flame temperature of the combustion of methane in air.

11.4 Isothermal Compression of Methane

Methane is compressed in a piston. This application calculates the work done and heat transferred by:

- Defining an equation that gives the pressure of methane at a specific volume V and a fixed temperature; then
- Numerically integrating this equation to calculate the work done

Pressure at specific volume V

$$> p := \text{Property}\left(\text{"pressure"}, \text{fluid}, \text{"temperature"} = T_1, \text{"D"} = \frac{1}{V}\right):$$

Work done

$$> w := \int_{V_1}^{V_2} p \, dV$$

$$-189.61 \frac{\text{kJ}}{\text{kg}}$$

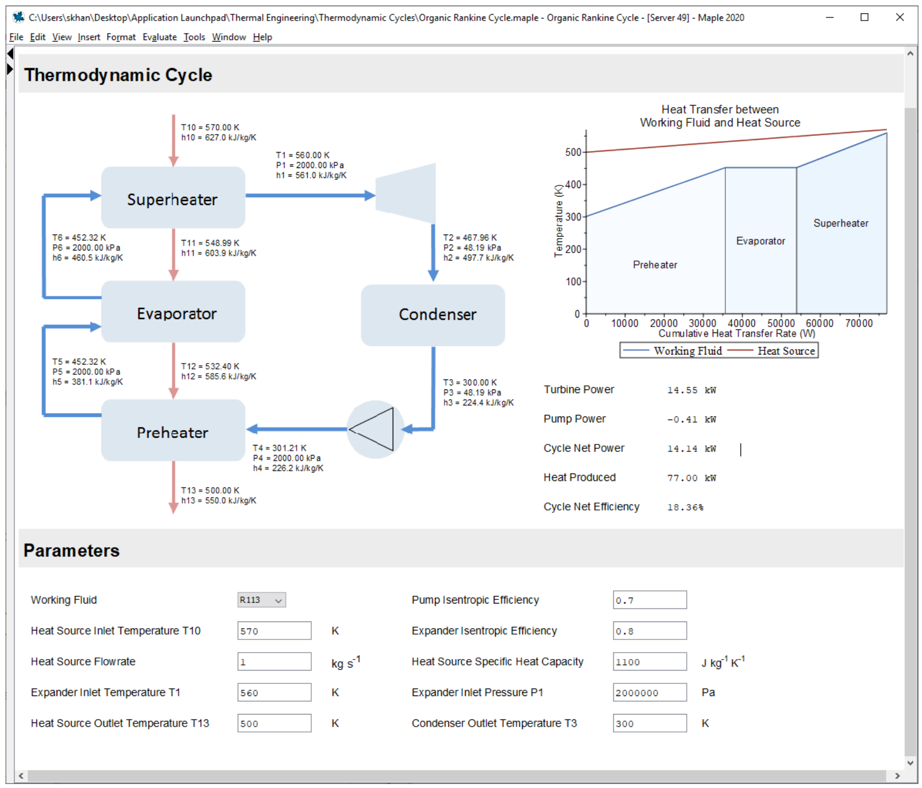
Heat transferred per unit mass of methane

$$> q := u_2 - u_1 + w$$

$$-203.82 \frac{\text{kJ}}{\text{kg}}$$

11.5 Organic Rankine Cycle

This application lets you experiment with the parameters that affect the performance of an organic Rankine cycle.



11.6 Adiabatic Flame Temperature and Equilibrium Composition of the Combustion of Carbon Monoxide

Carbon monoxide and oxygen are ignited, with the combustion products undergoing dissociation. Two groups of equations are defined:

- Equations that give the total Gibbs energy of the combustion products
- Equations that equate the enthalpy of the reactants and the enthalpy of the products

These equations are solved numerically.

12 Conclusion

This guide has described many engineering use cases for Maple. The worksheets demonstrate many Maple features, from symbolic and numeric mathematics to programming, visualization and more.

Many software tools will help with your calculations and analyses. Few, if any, support calculations in the same way Maple does with its document interface, units support, computation engine and connectivity.

Maple also gives you many worksheets you can use as a resource you can explore, experiment, and have fun with.

Get the worksheets from www.maplesoft.com/engineeringapplications.zip

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