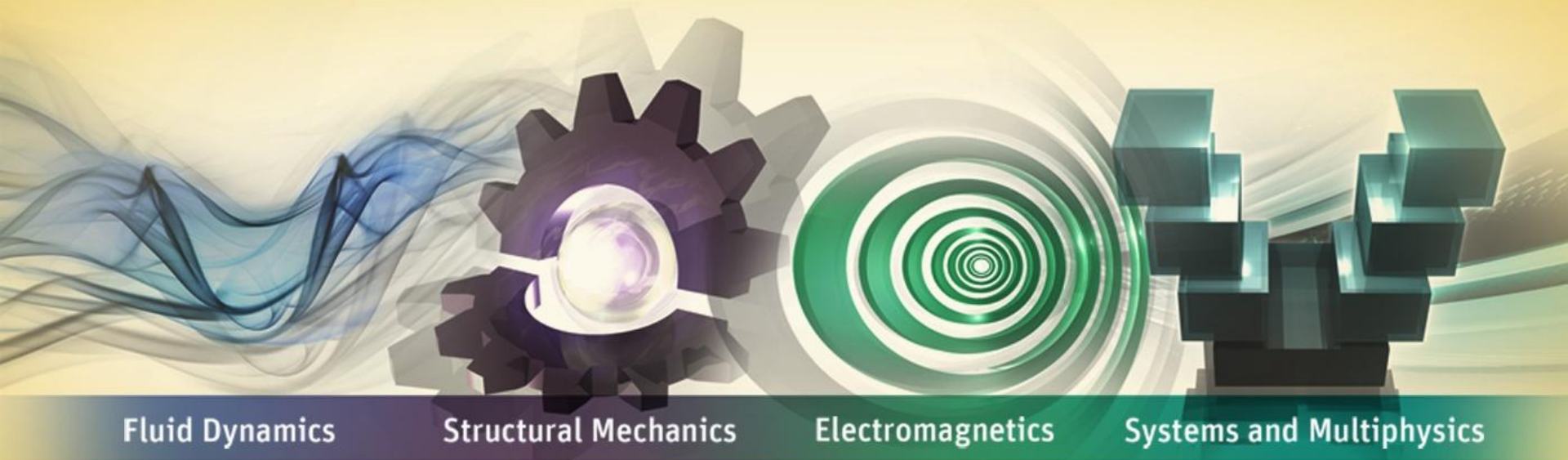


Lecture 1: Introduction to ANSYS Maxwell



ANSYS Maxwell V16 Training Manual

- A. About ANSYS Inc.**
- B. ANSYS EKM**
- C. ANSYS Customer Portal**
- D. ANSYS Maxwell Overview**
- E. Platforms and System Requirements**
- F. Getting Started with Maxwell**
- G. Maxwell GUI**
- H. Maxwell Designs**
- I. Maxwell Solvers**
- J. Maxwell File Structure**



A. About ANSYS, Inc.

More than 60 offices worldwide plus an extensive network of distributors

Over 2,200 direct employees of ANSYS and its subsidiaries worldwide

Listed on NASDAQ (ANSS)

Visit www.ansys.com for more information



Corporate Headquarters
Canonsburg, PA

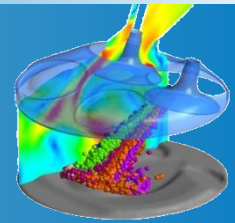
A. Breadth of Technologies



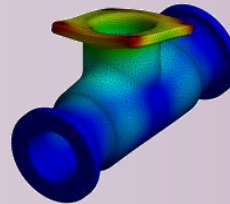
Fluid Mechanics:
From Single-Phase Flows



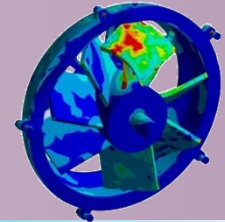
To Multiphase
Combustion



Structural Mechanics:
From Linear Statics



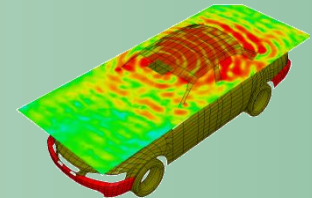
To High-Speed Impact



Electromagnetics:
From Low-Frequency
Windings



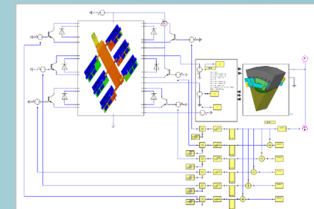
To High-Frequency
Field Analysis



Systems:
From Data Sharing



To Multi-Domain
System Analysis



B. Breadth of Technologies

ANSYS EKM - Engineering Knowledge Manager

ANSYS Engineering Knowledge Manager (EKM) is a multi-user collaborative solution that is aimed at meeting the Simulation Process and Data Management challenges

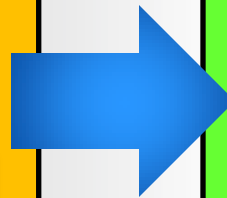
Use Case:
Knowledge Retention and Reuse



Index and store CAE files automatically

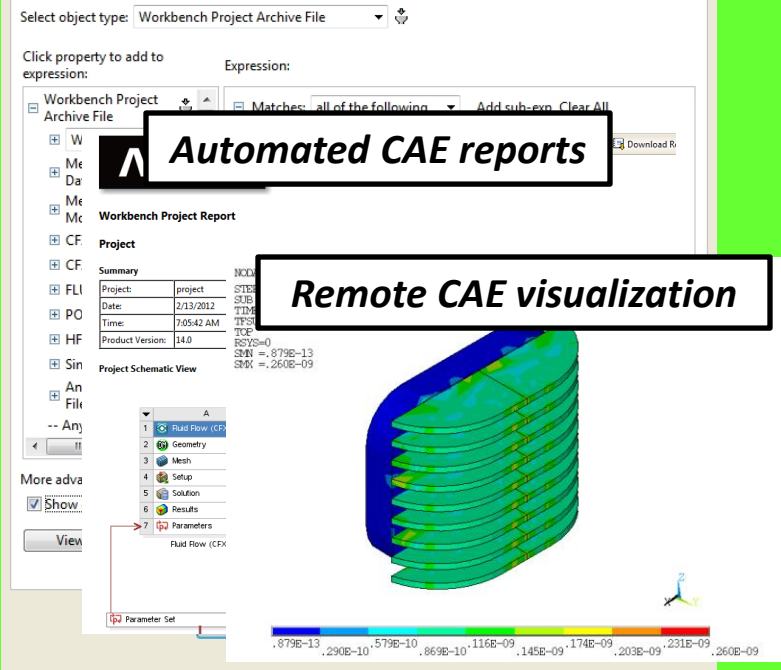
Find and reuse past CAE files efficiently

Trace and audit simulation decisions



EKM capabilities

Simulation focused search and retrieval



Automated CAE reports

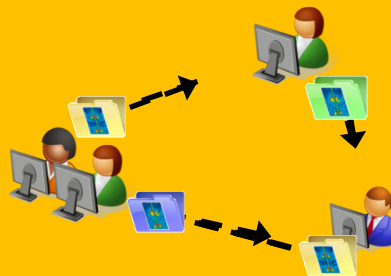
Remote CAE visualization

... Breadth of Technologies

ANSYS EKM - Engineering Knowledge Manager

ANSYS Engineering Knowledge Manager (EKM) is a multi-user collaborative solution that is aimed at meeting the Simulation Process and Data Management challenges

Use Case: Collaboration



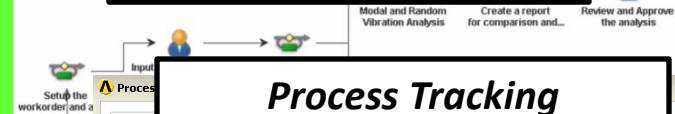
Build and run CAE workflows

Allow multi site, multi user access

Deploy templates for what if studies

EKM capabilities

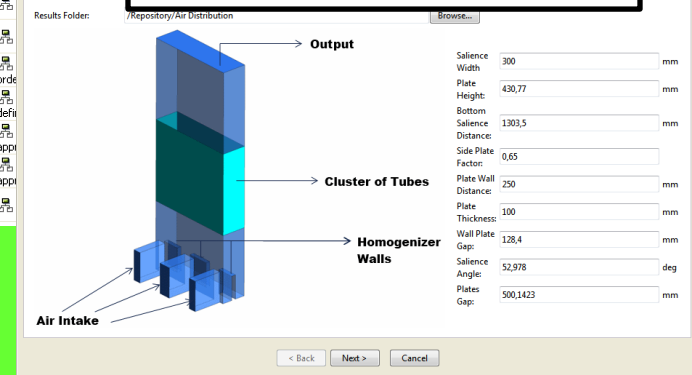
Workflow Modeling



Process Tracking

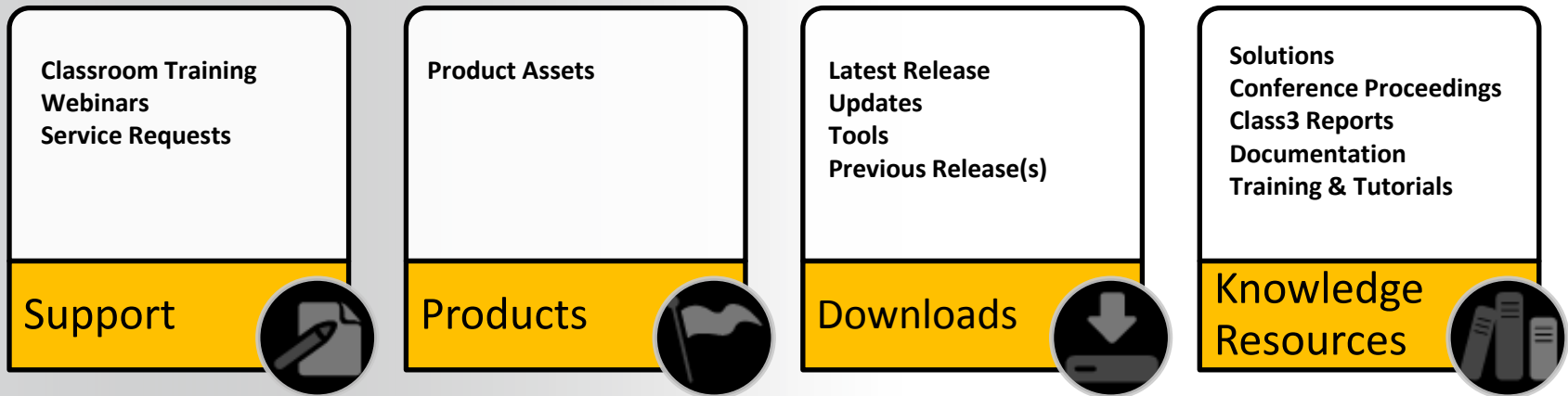
Name	Description	Assignee	Status	Start Time	End Time
Approve package	Approve package		Not Started		
Approve project scope	Approve project scope		Not Started		

Hosted Applications



support.ansys.com

Contains over 50,000 support assets powered by a modern web user interface and powerful search engine.



The ANSYS Customer Portal's search is powered by dedicated Google® hardware.



Mesh = Meshed = Meshing
Export = Exported = Exporting
XXXXX = YYYYYY = ZZZZZ

Example:

You want a meshing tutorial for ANSYS Meshing and your search has results for other products that are not of interest to you; by selecting the product facet “ANSYS Meshing” you can narrow down your results further.

Product Family

Structural Mechanics (60)

Fluid Dynamics (57)

Workbench (20)

Application Specific (18)

General (6)

[+ View More](#)

Product

ANSYS Mechanical APDL (54)

ANSYS Fluent (29)

ANSYS CFX (18)

ANSYS Polyflow (11)

ANSYS TurboGrid (7)

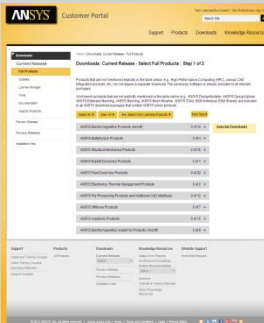
[+ View More](#)

... Support / downloads / training



Submit and review service requests

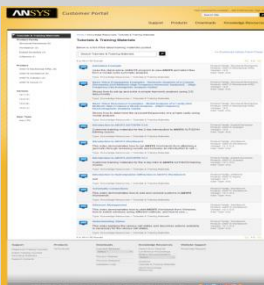
If you cannot find the answer to your question within the ANSYS Customer Portal then you can submit a service request. A member of ANSYS technical support will then get back to you with advice or a solution.



Download the latest software and updates

Download ISO images if you wish to create a DVD which is recommended for installations on multiple computers and allows you to keep an archive of the installation for later re-use.

Individual downloads can also be selected if you have a limited speed internet connection.



Download classroom and video training material

Training and tutorial material are available for both a broad range of ANSYS products and user's experience. Search the hundreds of courses available and improve your knowledge of ANSYS software.

- **About ANSYS Maxwell**

- ANSYS Maxwell is a high-performance interactive software package that uses finite element analysis (FEA) to solve electric or magnetic problems.
- Maxwell solves the electromagnetic field problems by solving Maxwell's equations in a finite region of space with appropriate boundary conditions and user-specified initial conditions in order to obtain a solution with guaranteed uniqueness.

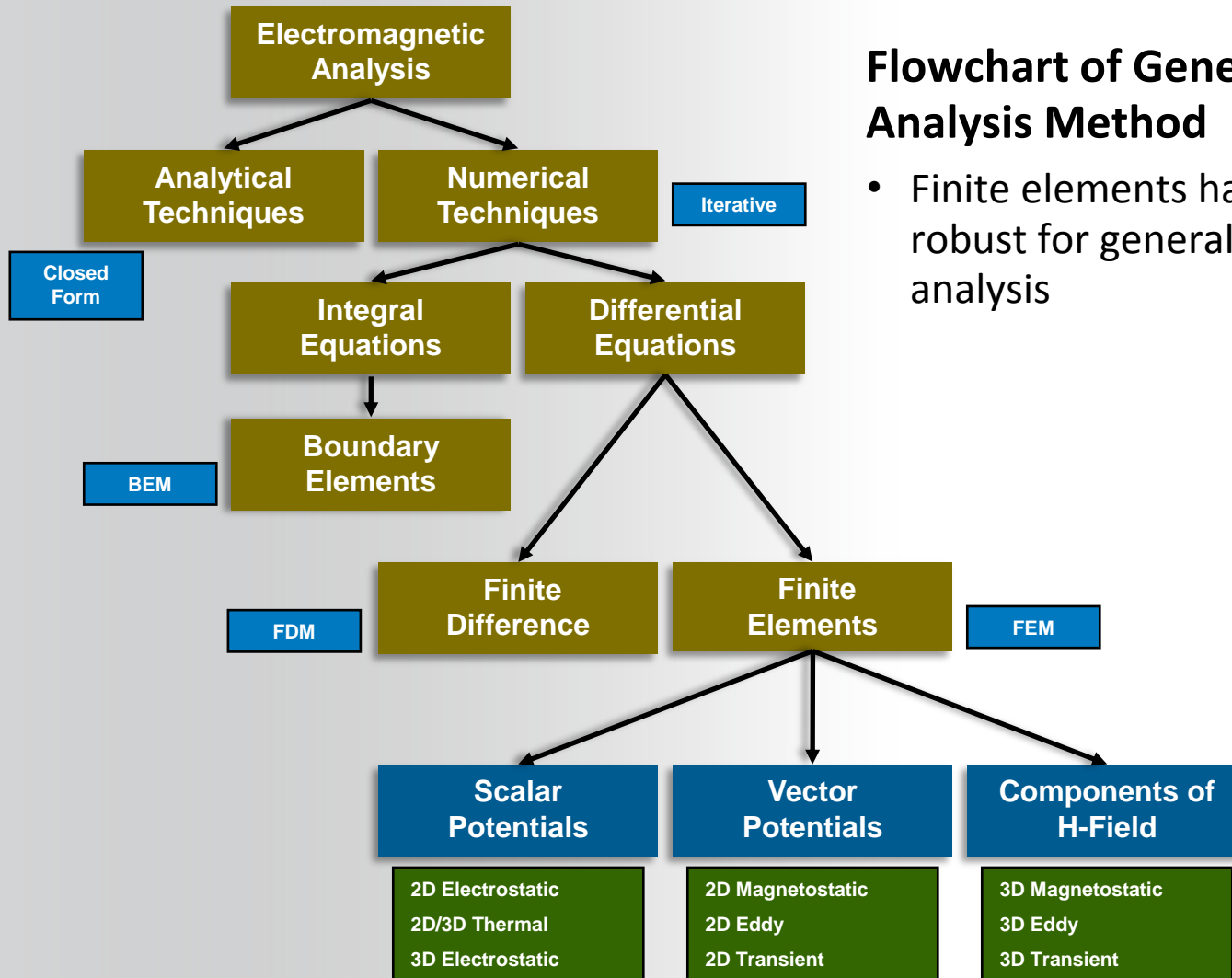
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \cdot \mathbf{B} = 0$$

- Appropriate set of equations and its terms are used based on the solver selected such as Electrostatic, Magnetostatic, Eddy Current and Magnetic Transient.

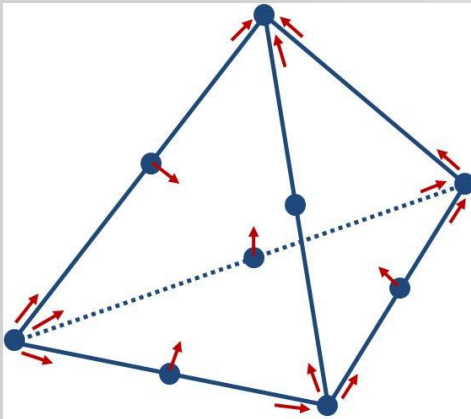


Flowchart of General Finite Element Analysis Method

- Finite elements have proven to be very robust for general electromagnetic analysis

- **Finite Element Method in Maxwell**

- Finite element refers to the method from which the solution is numerically obtained from an arbitrary geometry by breaking it down into simple pieces called finite elements
- In Maxwell3D, the fundamental unit of the finite element is a tetrahedron



The Components of a Field that are tangential to the edges of an element are explicitly stored at the vertices.

The Components of a field that is tangential to the face of an element and normal to an edge is explicitly stored at the midpoint of selected edges.

The Values of a vector field at an interior point is interpolated from the nodal values.

- The desired field in each element is approximated with a 2nd order quadratic polynomial (basis function):
 - $H_x(x,y,z) = a_0 + a_1x + a_2y + a_3z + a_4xy + a_5yz + a_6xz + a_7x^2 + a_8y^2 + a_9z^2$
- In order to obtain the basis functions, field quantities are calculated for 10 points in a 3D simulation (nodal values at vertices and on the edges).

- **Maxwell Solution Method**

- Once the tetrahedra are defined, the finite elements are placed in a large, sparse matrix equation.

$$[S][H] = [J]$$

- This can now be solved using standard matrix solution techniques such as:
 - **Sparse Gaussian Elimination (direct solver)**
 - **Incomplete Choleski Conjugate Gradient Method (ICCG iterative solver)**
 - It should be noted that the direct solver is the default solver, and is generally the best method. The ICCG solver is included for special cases and for reference.

- **Error Evaluation**

- For each solver, there is some fundamental defining equation that provides an error evaluation for the solved fields.
 - Energy produced by these error terms is computed in entire solution volume. This is compared with the total energy calculated to produce percent error energy number

$$\text{percent error energy} = \frac{\text{error energy}}{\text{total energy}} \times 100\%$$

- The value of percent error energy number is reported by Maxwell after each solution pass and used as a measure of solution convergence with respect to the adaptively refined mesh

E. Platforms and System Requirements

Supported Platforms for Maxwell V16

- **Microsoft Windows:**
 - Windows XP Service Pack 2 (32 and 64-bit)
 - Windows 7 Business Class (32 and 64-bit)
 - Windows Server 2003 Service Pack 1 (32 and 64-bit)
 - Windows HPC Server 2008
- **Linux**
 - Red Hat Enterprise Linux v4 and v5
 - SUSE Linux Enterprise Server v10 and v11.

Note: For future versions of Maxwell (Maxwell 17 and onwards), support for Windows XP platform and all 32 bit platforms will be discontinued

#Please also see Maxwell V16.0 Readme file

System Requirements for 32-Bit System

- **Minimum System Requirements**
 - Processor: All fully compatible 686 (or later) instruction set processors, 500 MHz
 - Hard Drive Space (for Maxwell software): 200 MB
 - RAM: 512 MB
- **Recommended Minimum Configuration for Optimal Performance**
 - Processor: All fully compatible 786 (or later) instruction set processors, 1 GHz
 - Hard Drive Space (for Maxwell software and temporary files): 500 MB
 - RAM: 2 GB

System Requirements for 64-Bit System

- **Minimum System Requirements**
 - Processor: AMD Athlon 64, AMD Opteron, Intel Xeon with Intel EM64T support, Intel Pentium 4 with Intel EM64T support
 - Hard Drive Space (for Maxwell software): 200 MB
 - RAM: 512 MB
- **Recommended Minimum Configuration for Optimal Performance**
 - Processor: AMD Athlon 64, AMD Opteron, Intel Xeon with Intel EM64T support, Intel Pentium 4 with Intel EM64T support
 - Video card: 128-bit SVGA or PCI Express video card
 - Hard Drive Space (for Maxwell software and temporary files): 500 MB
 - RAM: 2 GB

F. Getting Started with Maxwell

- **Downloading ANSYS Maxwell**

- ANSYS Maxwell can be downloaded along with rest of ANSYS portfolio products from ANSYS Customer Portal using a valid User Name and Password

https://support.ansys.com/AnsysCustomerPortal/en_us/Downloads/Current+Release/Full+Products

- Maxwell 16 installation can be found under **ANSYS Electromagnetics Products**

- **Installation and Licensing Help**

- Users can download Installation and Licensing Guide from ANSYS Customer Portal using below link


https://support.ansys.com/AnsysCustomerPortal/en_us/Downloads/Installation+and+Licensing+Help+and+Tutorials

- **Starting ANSYS Maxwell**

- Click the Microsoft **Start** button, select **Programs**, and select the **ANSYS Electromagnetics > Maxwell 16.0 > Windows 64-bit > Maxwell 16.0**
- Or Double click on the Maxwell 16 icon on the Windows Desktop



- **Adding a Design to Maxwell**

- A design can be added to a Maxwell project from the Project menu bar or selecting icon from 

- **Maxwell Design Types**

1. **RMxpert:**

- Rotating Machinery Expert is an interactive analytical tool used for designing and analyzing electrical machines.

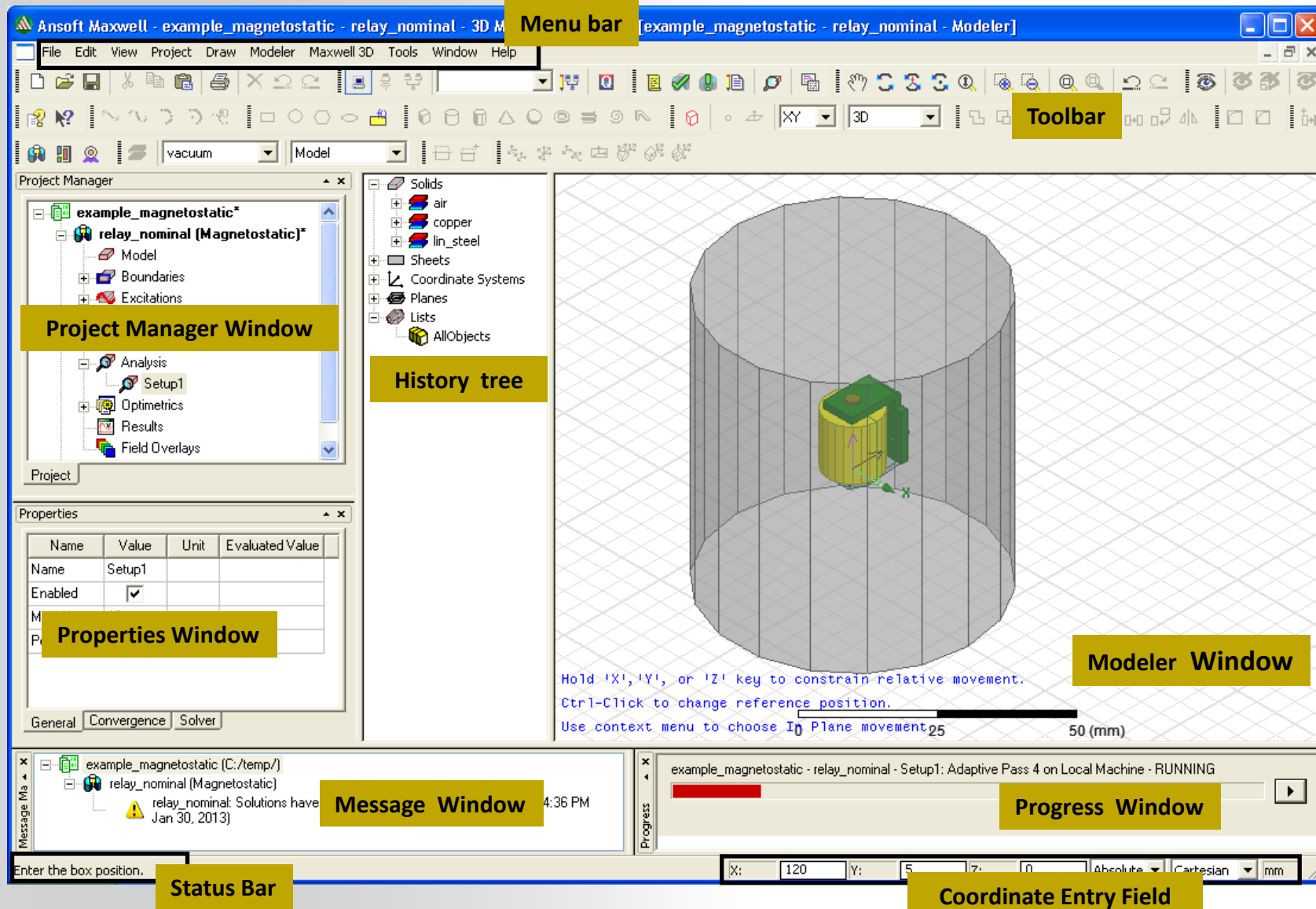
2. **Maxwell 2D:**

- Maxwell 2D uses Finite Element Analysis to simulate and solve 2D electromagnetic fields in XY or RZ planes

3. **Maxwell 3D:**

- Maxwell 3D uses Finite Element Analysis to simulate and solve three dimensional electromagnetic fields.

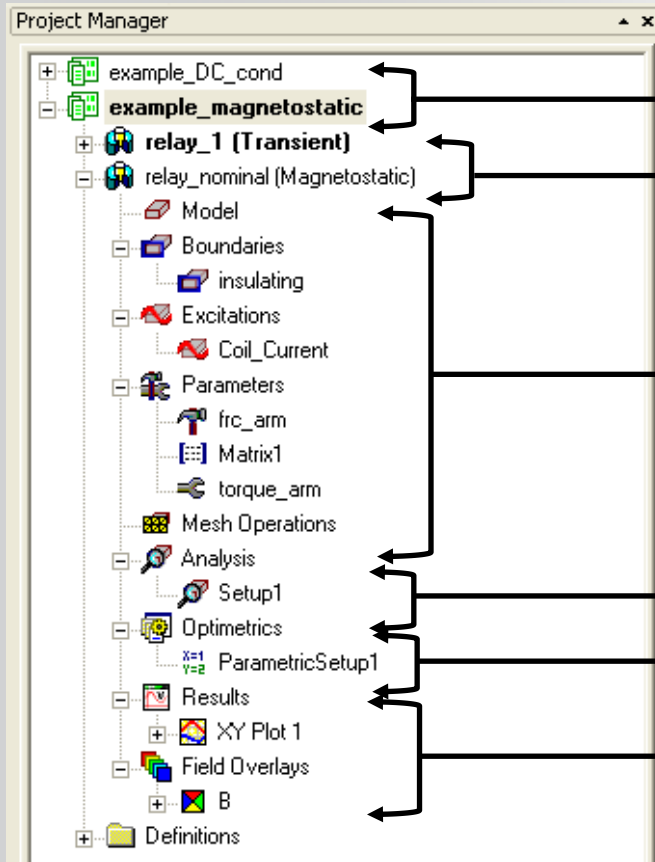
Note: Most of the lectures in this course are focused on Maxwell 2D and Maxwell 3D and does not cover RMxpert.



- **Menu Bar**
 - File Edit View Project Draw Modeler Maxwell 3D Tools Window Help
- **File Menu**
 - Opening, closing and saving a project
- **Edit Menu**
 - Geometry selection and geometry manipulation
- **View Menu**
 - Set display option or hide/unhide geometry object
- **Project Menu**
 - Insert designs, Project datasets, variables
- **Draw Menu**
 - Geometry objects from primitives
- **Modeler Menu**
 - Geometry operations and analysis commands
- **Maxwell 3D/2D Menu**
 - Maxwell analysis setup and post processing commands
- **Tools, Window and Help menu**
 - Record and Run scripts, window management, accessing help commands

- **Project Manager window**

- Project Manager window contains all the details of Problem Setup done for any project



Project Name (multiple projects per Desktop)
Design Name (multiple Designs per Project, Can be a combination of Maxwell 3D, 2D and RMXprt)

Design Setup

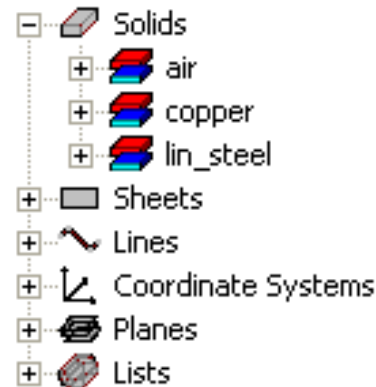
Analysis Setup(Can contain multiple setups)

Optimetrics Analysis Setups

Postprocessed Results

- **History Tree**

- History tree contains details of all geometrical operations performed in a Design
- Any line, surface or solid objects, coordinate systems or its planes can be accessed from History tree
- Solid objects are categorized based on assigned materials in 3D while in 2D sheet objects are categorized

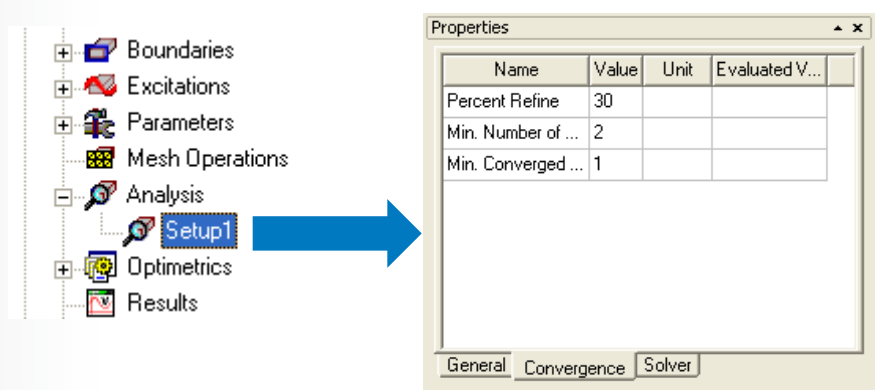
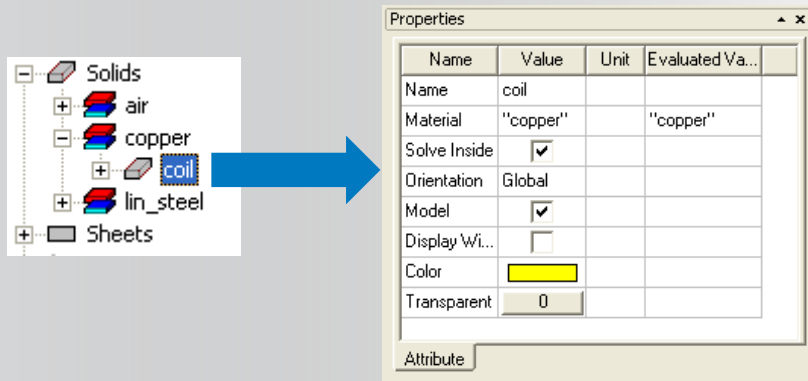


- **Toolbar**

- Most of the menu bar commands can be accessed from Toolbar as an icon
- Toolbar can be customized to add or remove any options by right clicking on Toolbar or selecting the menu item **Tools → Customize**

- **Properties Window**

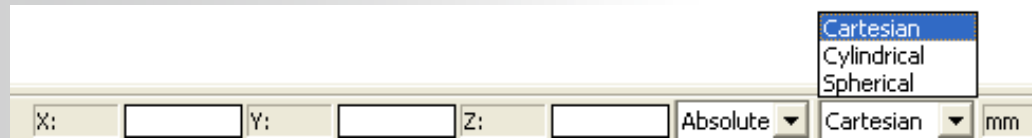
- Shows all the properties of selected entities
- Selected entity can be any geometrical object, performed geometrical operations from history tree or any added setup entities selected from Project Manager window
- Display of Properties window will change based on selected entity



Note: Double clicking on any selected entity will also initiate a dialog box for property display and editing.

- **Coordinate Entry Field**

- This window appears whenever an operation requires entry of coordinates
- Coordinate values can be entered in Cartesian, cylindrical or spherical form



- **Message Window**

- Displays Error, Warning or Information messages resulting from an operation
- Messages can be Copy-Pasted to text file if required

- **Status Bar**

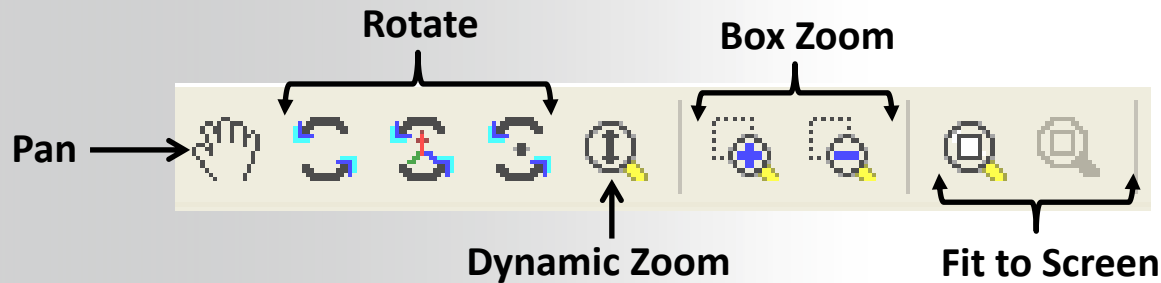
- Shows status of Maxwell window, prompts next course of action for any geometrical operation or information about any command on which mouse is placed

- **Progress Window**

- Shows progress of Analysis operation being carried out

- **Modeler Window**

- Modeler window enables users to view and interact with geometry dynamically.
- Geometry in Modeler window can be Manipulated either using Toolbar commands or Mouse-keyboard keys
- Right Mouse click in Modeler window also gives access to various menu bar commands through context window



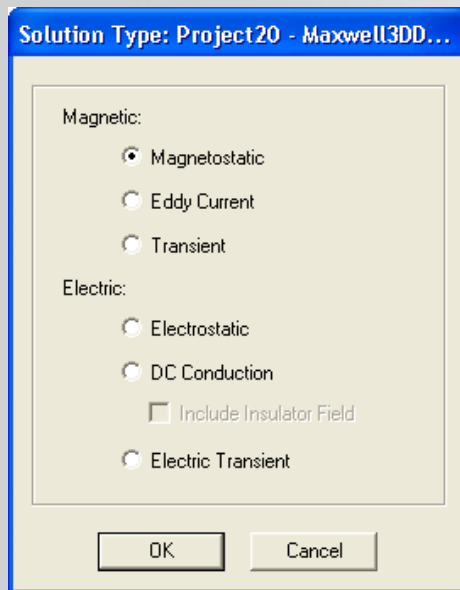
Mouse Commands for Geometry Manipulation

- Zoom: Right click and drag the mouse button with **SHIFT+ALT** pressed
- Pan: Right click and drag the mouse button with **SHIFT** pressed
- Rotate: Right click and drag the mouse button with **ALT** pressed

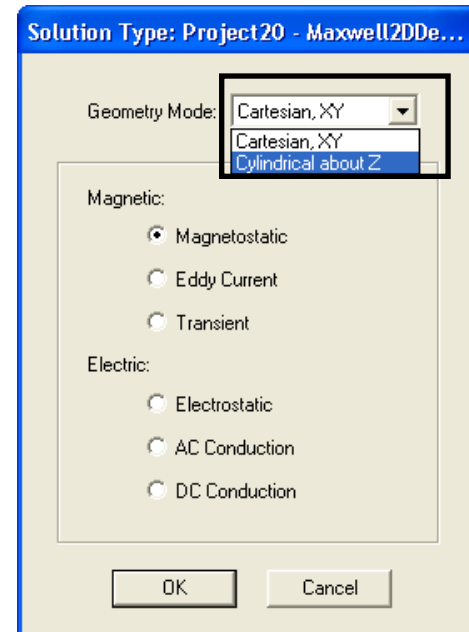
I. Solvers in Maxwell

- **Setting a Solver Type**

- Appropriate Maxwell solver can be selected based on the application being solved.
- Solver type can be set by selecting the menu item **Maxwell 3D/2D** → **Solution Type**
- For 2D, users can also specify if the problem will be solved in XY or RZ plane



Maxwell 3D







Maxwell 2D

- **Magnetic Solvers**
 - **Magnetostatic Solver**
 - Solves Static magnetic fields caused by DC currents and permanent magnets. Can solve both Linear and nonlinear materials.
 - **Eddy Current Solver**
 - Solves sinusoidally-varying magnetic fields in frequency domain. Solves only for linear materials in 3D. It is a full wave solver thus considers displacement currents. Induced fields such as skin and proximity effects are also considered.
 - **Transient Magnetic**
 - Solves Transient magnetic fields caused by time-varying or moving electrical sources and permanent magnets in Linear or Non-linear materials. Induced fields such as skin and proximity effects are considered.

- **Electric Solvers**
 - **Electrostatic Solver**
 - Solves Static Electric Fields in linear materials.
 - **DC Conduction**
 - Solves for voltage, electric field, and the current density from the potential. Can solve electric fields in insulators as well.
 - **AC Conduction (2D only)**
 - Solves sinusoidally-varying electric fields in Frequency domain. Available only with 2D solver.
 - **Transient Electric**
 - Transient electric fields caused by time-varying voltages, charge distributions, or current excitations in inhomogeneous materials. Electric potential is the solution quantity.

J. Maxwell File Structure

- **File Structure in Maxwell**
 - **FileName.mxwl**
 - This file contains all the information related to Maxwell project apart from results. The file is written in ASCII format.
 - **FileName.mxwresults**
 - This folder contains the mesh and solution related files. Users need to copy both .mxwl file and this folder in order to transfer the project with results
 - **FileName.mxwl.lock**
 - This is a lock file created when file is open to avoid overwriting of file from multiple sessions
 - **FileName.mxwl.auto**
 - Autosave file in order to recover lost data in case of unusual file closure. Created only when Autosave is turned ON

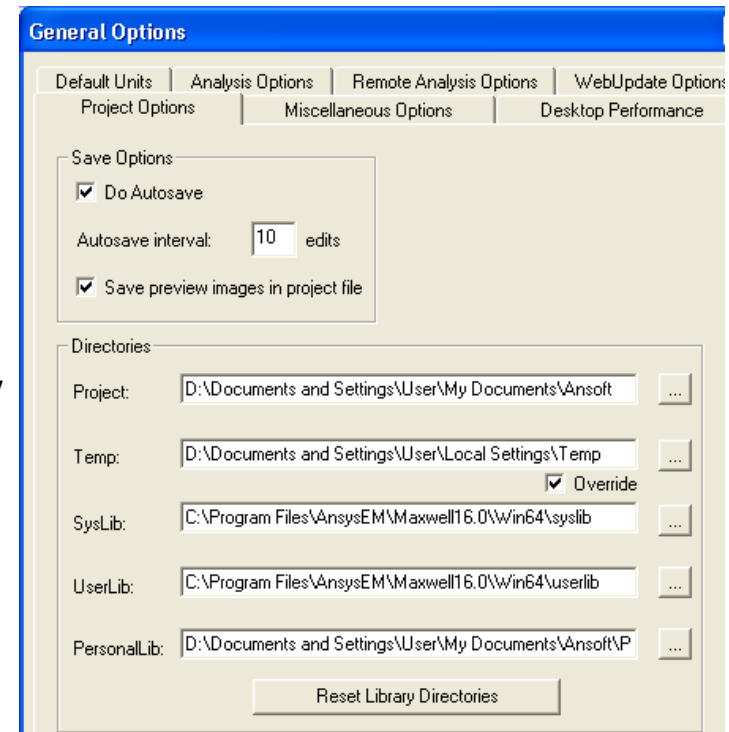
Name ▲	Size	Type
 example_magnetostatic.mxwresults		File Folder
 example_magnetostatic.mxwl	469 KB	Maxwell
 example_magnetostatic.mxwl.lock	1 KB	LOCK File
 example_magnetostatic.mxwl.auto	453 KB	AUTO File

...Maxwell Directories

- **Maxwell Directories**

- Maxwell Folder locations can be set from the menu item **Tools → Option → General Options → Project Options**

- **Project:** The default location where Maxwell project file is saved
 - **Temp:** Location for saving Temporary results files. Files will be deleted once project is saved
 - **SysLib:** Global level directory predefined by ANSYS and ships with new upgrades .
 - **UserLib:** Can host user created material libraries or script files. Can be shared among all users at a company
 - **PersonLib:** Can host user created material libraries or script files. Accessible only the user who creates it.



• Maxwell Material Libraries

- Maxwell default material library is loaded with Maxwell installation and is available under Syslib directory. This material database can not be modified by users
- Users can add their own material database to Personal or User library directories.
- Once the file is added, users can configure the material libraries from **Tool → Configure Libraries**.
 - Users can select and add their material database file to Configured Libraries which will make the selected database available for material assignment.

