

SOLIDWORKS®

SOLIDWORKS Simulation Professional

Dassault Systèmes SolidWorks Corporation
175 Wyman Street
Waltham, MA 02451 U.S.A.

© 1995-2016, Dassault Systemes SolidWorks Corporation, a Dassault Systèmes SE company, 175 Wyman Street, Waltham, Mass. 02451 USA. All Rights Reserved.

The information and the software discussed in this document are subject to change without notice and are not commitments by Dassault Systemes SolidWorks Corporation (DS SolidWorks).

No material may be reproduced or transmitted in any form or by any means, electronically or manually, for any purpose without the express written permission of DS SolidWorks.

The software discussed in this document is furnished under a license and may be used or copied only in accordance with the terms of the license. All warranties given by DS SolidWorks as to the software and documentation are set forth in the license agreement, and nothing stated in, or implied by, this document or its contents shall be considered or deemed a modification or amendment of any terms, including warranties, in the license agreement.

Patent Notices

SOLIDWORKS® 3D mechanical CAD and/or Simulation software is protected by U.S. Patents 6,219,049; 6,219,055; 6,611,725; 6,844,877; 6,898,560; 6,906,712; 7,079,990; 7,477,262; 7,558,705; 7,571,079; 7,590,497; 7,643,027; 7,672,822; 7,688,318; 7,694,238; 7,853,940; 8,305,376; 8,581,902; 8,817,028; 8,910,078; 9,129,083; 9,153,072; 9,262,863; 9,465,894 and foreign patents, (e.g., EP 1,116,190 B1 and JP 3,517,643).

eDrawings® software is protected by U.S. Patent 7,184,044; U.S. Patent 7,502,027; and Canadian Patent 2,318,706.

U.S. and foreign patents pending.

Trademarks and Product Names for SOLIDWORKS Products and Services

SOLIDWORKS, 3D ContentCentral, 3D PartStream.NET, eDrawings, and the eDrawings logo are registered trademarks and FeatureManager is a jointly owned registered trademark of DS SolidWorks.

CircuitWorks, FloXpress, PhotoView 360, and TolAnalyst are trademarks of DS SolidWorks.

FeatureWorks is a registered trademark of Geometric Ltd.

SOLIDWORKS 2017, SOLIDWORKS Standard, SOLIDWORKS Professional, SOLIDWORKS Premium, SOLIDWORKS PDM Professional, SOLIDWORKS PDM Standard, SOLIDWORKS Workgroup PDM, SOLIDWORKS Simulation Standard, SOLIDWORKS Simulation Professional, SOLIDWORKS Simulation Premium SOLIDWORKS Flow Simulation, eDrawings Viewer, eDrawings Professional, SOLIDWORKS Sustainability, SOLIDWORKS Plastics, SOLIDWORKS Electrical Schematic Standard, SOLIDWORKS Electrical Schematic Professional, SOLIDWORKS Electrical 3D, SOLIDWORKS Electrical Professional, CircuitWorks, SOLIDWORKS Composer, SOLIDWORKS Inspection, SOLIDWORKS MBD, SOLIDWORKS PCB powered by Altium, SOLIDWORKS PCB Connector powered by Altium, and SOLIDWORKS Visualization are product names of DS SolidWorks.

Other brand or product names are trademarks or registered trademarks of their respective holders.

COMMERCIAL COMPUTER SOFTWARE - PROPRIETARY

The Software is a "commercial item" as that term is defined at 48 C.F.R. 2.101 (OCT 1995), consisting of "commercial computer software" and "commercial software documentation" as such terms are used in 48 C.F.R. 12.212 (SEPT 1995) and is provided to the U.S. Government (a) for acquisition by or on behalf of civilian agencies, consistent with the policy set forth in 48 C.F.R. 12.212; or (b) for acquisition by or on behalf of units of the Department of Defense, consistent with the policies set forth in 48 C.F.R. 227.7202-1 (JUN 1995) and 227.7202-4 (JUN 1995).

In the event that you receive a request from any agency of the U.S. Government to provide Software with rights beyond those set forth above, you will notify DS SolidWorks of the scope of the request and DS SolidWorks will have five (5) business days to, in its sole discretion, accept or reject such request. Contractor/Manufacturer: Dassault Systemes SolidWorks Corporation, 175 Wyman Street, Waltham, Massachusetts 02451 USA.

Copyright Notices for SOLIDWORKS Standard, Premium, Professional, and Education Products

Portions of this software © 1986-2016 Siemens Product Lifecycle Management Software Inc. All rights reserved.

This work contains the following software owned by Siemens Industry Software Limited:

D-Cubed® 2D DCM © 2016, Siemens Industry Software Limited. All Rights Reserved.

D-Cubed® 3D DCM © 2016, Siemens Industry Software Limited. All Rights Reserved.

D-Cubed® PGM © 2016, Siemens Industry Software Limited. All Rights Reserved.

D-Cubed® CDM © 2016, Siemens Industry Software Limited. All Rights Reserved.

D-Cubed® AEM © 2016, Siemens Industry Software Limited. All Rights Reserved.

Portions of this software © 1998-2016 Geometric Ltd.

Portions of this software incorporate PhysX™ by NVIDIA 2006-2010.

Portions of this software © 2001-2016 Luxology, LLC. All rights reserved, patents pending.

Portions of this software © 2007-2016 DriveWorks Ltd.

© 2011, Microsoft Corporation. All rights reserved.

Includes Adobe® PDF Library technology

Copyright 1984-2016 Adobe Systems Inc. and its licensors. All rights reserved. Protected by U.S. Patents 5,929,866; 5,943,063; 6,289,364; 6,563,502; 6,639,593; 6,754,382; Patents Pending.

Adobe, the Adobe logo, Acrobat, the Adobe PDF logo, Distiller and Reader are registered trademarks or trademarks of Adobe Systems Inc. in the U.S. and other countries.

For more DS SolidWorks copyright information, see **Help > About SOLIDWORKS**.

Copyright Notices for SOLIDWORKS Simulation Products

Portions of this software © 2008 Solversoft Corporation.

PCGLSS © 1992-2016 Computational Applications and System Integration, Inc. All rights reserved.

Copyright Notices for SOLIDWORKS PDM Professional Product

Outside In® Viewer Technology, © 1992-2012 Oracle

© 2011, Microsoft Corporation. All rights reserved.

Copyright Notices for eDrawings Products

Portions of this software © 2000-2014 Tech Soft 3D.

Portions of this software © 1995-1998 Jean-Loup Gailly and Mark Adler.

Portions of this software © 1998-2001 3Dconnexion.

Portions of this software © 1998-2014 Open Design Alliance. All rights reserved.

Portions of this software © 1995-2012 Spatial Corporation.

The eDrawings® for Windows® software is based in part on the work of the Independent JPEG Group.

Portions of eDrawings® for iPad® copyright © 1996-1999 Silicon Graphics Systems, Inc.

Portions of eDrawings® for iPad® copyright © 2003 – 2005 Apple Computer Inc.

Copyright Notices for SOLIDWORKS PCB Products

Portions of this software © 2016 Altium Limited.

Contents

Introduction

About This Course	2
Prerequisites	2
Course Design Philosophy	2
Using this Book	2
Laboratory Exercises	2
About the Training Files	3
Windows® 7	3
User Interface Appearance	3
Conventions Used in this Book	3
Use of Color	4
More SOLIDWORKS Training Resources	4
Local User Groups	4
What is SOLIDWORKS Simulation?	5
Limitations of SOLIDWORKS Simulation Professional	6

Lesson 1:

Frequency Analysis of Parts

Objectives	7
Modal Analysis Basics	8
Required Material Properties	10
Frequencies and Mode Shapes	10
Fundamental Frequency	10
Case Study: The Tuning Fork	11

Project Description	11
Stages in the Process.	11
Frequency Analysis With Supports.	12
Procedure	12
Results.	13
Note.	14
Postprocessing Frequency Results	15
Frequency Analysis Without Supports	17
Rigid Body Modes	18
Fundamental Frequency	18
Effect of Restraints	18
Frequency Analysis with Load	18
Effects of Prestress	19
Summary.	20
Questions	20
Exercise 1: Frequency Analysis of a Car Suspension Bulkhead	21
Exercise 2: Frequency Analysis of a Blower Fan.	24
Part 1: Analysis Without Load	24
Part 2: Analysis With Load.	25
Design Study (optional)	27
Summary.	28
Exercise 3: Frequency Analysis of an Impeller	29
Summary.	31

Lesson 2:

Frequency Analysis of Assemblies

Objectives	33
Case Study: The Engine Mount	34
Project Description	34
Stages in the Process.	34
All Bonded Contact Conditions	34
Procedure	35
Remote Mass.	35
Mass Properties.	36
Connecting the Assembly Parts	37
Bonded and Allow Penetration Contacts	39
Discussion.	42
Summary.	42
Questions	43
Exercise 4: Frequency Analysis of a Particle Separator	44

Lesson 3: Buckling Analysis

Objectives	47
Buckling Analysis	48
Linear vs. Nonlinear Buckling Analysis	48
Buckling Factor of Safety (BFS)	49
Buckling Analysis Considerations	49
Case Study: Particle Separator	50
Project Description	50
Stages in the Process	50
Conclusion	52
Calculating Buckling Loads	52
Results Discussion	53
Will the structure Buckle or Yield First?	54
Summary	54
Questions	54
Exercise 5: Buckling Analysis of a Stool	55
Exercise 6: Cabinet	61

Lesson 4: Load Cases

Objectives	67
Load Cases	68
Case Study: Scaffolding	68
Project Description	68
Stages in the Process	69
Initial Load Case	76
Summary	79

Lesson 5: Submodeling

Objectives	81
Submodeling	82
Parent Study	82
Case Study: Scaffolding	83
Project Description	83
Stages in the Process	84
Part 1: Parent Study	84
Parent Load Cases in Submodeling Study	85
Part 2: Child Study	86
Selecting Components for Submodeling	87
Submodel Fixtures	88
Summary	91
Questions	91

Lesson 6: Thermal Analysis

Objectives	93
Thermal Analysis Basics	94
Mechanisms of Heat Transfer	95
Conduction	95
Convection	96
Radiation	97
Material Properties for Thermal Analysis	99
Case Study: Microchip Assembly	100
Project Description	100
Stages in the Process	100
Steady-State Thermal Analysis	101
Procedure	101
Interfacial Conductance	102
Insulation	105
Initial Temperature	105
Thermal Results	105
Heat Flux	106
Heat Flux Results	107
Heat Power	108
Transient Thermal Analysis	108
Importing Convective Effect from SOLIDWORKS Flow Simulation	110
Transient Data Sensors	111
Results Comparison	112
Transient Analysis with Time Varying Load	113
Time Curves	114
Temperature Curves	114
Transient Thermal Analysis using a Thermostat	115
Symmetry Boundary Condition in Thermal Analysis	118
Summary	118
Questions	118
Exercise 7: Thermal Analysis of a Cup	119
Summary	121

Lesson 7: Thermal Analysis with Radiation

Objectives	123
Case Study: Spot Light Assembly	124
Project Description	124
Stages in the Process	125
Steady State Analysis	125
Review of Analysis Parameters	130
Heat Flux Singularities	132
Summary	133

Lesson 8:**Advanced Thermal Stress 2D Simplification**

Objectives	135
Thermal Stress Analysis	136
Case Study: Metal Expansion Joint	136
Project Description	136
Stages in the Process	137
Thermal Analysis	137
2D Simplification	137
Prescribed Temperature Condition	142
Meshing Considerations in Thermal Analysis	142
Thermal Stress Analysis	145
Importing Temperatures and Pressures from SOLIDWORKS Flow Simulation	146
Reference Temperature at Zero Strains	146
3D model	151
Summary	153
Questions	154
Exercise 8: Thermal Stress Analysis of a Microchip Testing Assembly	155
Thermal Stress Study	158
Change in Thermal Boundary Conditions	159
Summary	161
Exercise 9: Thermal Stress Analysis of a Gas Tank	162
Exercise 10: Thermal Stress Analysis of a Thermoelectric Cooler	167
Problem Description	167
Materials	168
Loading Conditions	169
Goal	169

**Lesson 9:
Fatigue Analysis**

Objective.....	171
Fatigue	172
Stages of Failure due to Fatigue	172
High vs. Low Cycle Fatigue	173
Stress-life (S-N) Based Fatigue	173
Fatigue Loading	173
Case Study: Pressure Vessel	175
Project Description	175
Stages in the Process.....	175
Thermal Study.....	177
Thermal Stress Study	177
Static Pressure Study	179
Fatigue Terminology.....	181
S-N Curve	181
Fatigue Study	184
Derive from Material Elastic Modulus.....	187
Constant Amplitude Events Interaction	187
Alternating Stress Computation	187
Mean Stress Correction.....	188
Fatigue Strength Reduction Factor.....	190
Damage Factor Plot	190
Damage Result Discussion	192
Fatigue Study with Dead Load	193
Dead Loads in Fatigue Analysis.....	193
Bolts in Fatigue Analysis	194
Find Cycle Peaks	195
Summary.....	197
Questions	197
Exercise 11: Fatigue Analysis of a Basketball Rim	198
Exercise 12: Fatigue of Trailer Hitch	204

Lesson 10:**Variable Amplitude Fatigue**

Objectives	207
Case Study: Suspension	208
Project Description	208
Stages in the Process.	209
Discussion.	210
Fatigue Study	211
Variable Amplitude Fatigue Event	211
Rainflow Cycle Counting Method	211
Variable Loading Curve	212
Bins for Rainflow Counting	217
Noise in Random Loading History	217
Fatigue Strength Reduction Factor	217
Rainflow Matrix Chart	220
Results.	220
Fatigue Literature	221
Summary	222
Questions	222

Lesson 11:**Drop Test Analysis**

Objectives	223
Drop Test Analysis	224
Case Study: Camera	224
Project Description	224
Stages in the Process.	224
Rigid Floor Drop Test.	225
Drop Test Parameters	226
Dynamic Analysis.	227
Damping	228
Solution Time	229
Graphing Results.	230
Linear vs. Nonlinear Solution.	232
Elastic Floor, Elasto-Plastic Material	234
Elasto-Plastic Material Model	236
Elasto-Plastic Model Parameters	237
Processing Elasto-Plastic Results	238
Discussion.	239
Drop Test with Contact (optional)	239
Summary	241
Exercise 13: Drop Test of a Clip	242

Lesson 12: Optimization Analysis

Objectives	245
Optimization Analysis	246
Case Study: Press Frame.	246
Project Description	246
Design Requirements	247
Stages in the Process.	247
Static and Frequency Analyses	247
Optimization Analysis	249
Design Study.	249
Optimization Goal.	250
Design Variable Summary	252
Define Constraints	252
Constraint Tolerance.	255
Constraint Definition Procedure	255
Postprocessing Optimization Results	256
Local Trend Graphs	260
Summary.	260
Exercise 14: Optimization Analysis of a Cantilever Bracket	261
Exercise 15: Optimization of Heat Sink	264

Lesson 13: Pressure Vessel Analysis

Objectives	265
Case Study: Pressure Vessel	266
Project Description	266
Stages in the Process.	266
Stress Intensity	268
Membrane and Bending Stresses (stress linearization)	268
Basic Stress Intensity Limits.	268
Pressure Vessel Analysis.	268
Load Case Combinations	270
General Primary Membrane Stress Intensity	271
Manhole Nozzle Flange and Cover	272
Stress Linearization.	273
Summary.	276