

SOLIDWORKS®

SOLIDWORKS Motion

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

© 1995-2023, 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.

For a full list of the patents, trademarks, and third-party software contained in this release, please go to the Legal Notices in the SOLIDWORKS documentation.

Restricted Rights

This clause applies to all acquisitions of Dassault Systèmes Offerings by or for the United States federal government, or by any prime contractor or subcontractor (at any tier) under any contract, grant, cooperative agreement or other activity with the federal government. The software, documentation and any other technical data provided hereunder is commercial in nature and developed solely at private expense. The Software is delivered as "Commercial Computer Software" as defined in DFARS 252.227-7014 (June 1995) or as a "Commercial Item" as defined in FAR 2.101(a) and as such is provided with only such rights as are provided in Dassault Systèmes standard commercial end user license agreement. Technical data is provided with limited rights only as provided in DFAR 252.227-7015 (Nov. 1995) or FAR 52.227-14 (June 1987), whichever is applicable. The terms and conditions of the Dassault Systèmes standard commercial end user license agreement shall pertain to the United States government's use and disclosure of this software, and shall supersede any conflicting contractual terms and conditions. If the DS standard commercial license fails to meet the United States government's needs or is inconsistent in any respect with United States Federal law, the United States government agrees to return this software, unused, to DS. The following additional statement applies only to acquisitions governed by DFARS Subpart 227.4 (October 1988): "Restricted Rights - use, duplication and disclosure by the Government is subject to restrictions as set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at DFARS 252-227-7013 (Oct. 1988)."

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.

Contents

Introduction

About This Course	2
Prerequisites	2
Course Design Philosophy	2
Using this Book	2
Laboratory Exercises	3
Training Files	3
Windows	3
Conventions Used in this Book	4
Use of Color	4
More SOLIDWORKS Training Resources	4
Local User Groups	4
What is SOLIDWORKS Motion?	5
What is Motion Simulation?	5
Understanding Basics	5
Mass and Inertia	5
Degrees-of- Freedom	5
Constraining Degrees-of- Freedom	6
Motion Analysis	6
How is Motion Analyzed on the Computer?	6

Basics of Mechanism Setup in SOLIDWORKS Motion	7
Rigid Body	7
Fixed Parts	7
Floating Parts	8
Mates.	8
Motors.	8
Gravity	8
Constraint Mapping Concept	8
Forces	8
Summary.	8

Lesson 1:

Introduction to Motion Simulation and Forces

Objectives	9
Basic Motion Analysis	10
Case Study: Car Jack Analysis	10
Problem Description	10
Stages in the Process.	11
Driving Motion	14
Gravity	16
Forces	17
Understanding Forces	17
Applied Forces	17
Force Definition	17
Force Direction	18
Case 1	18
Case 2	18
Case 3	19
Results.	21
Plot Categories	21
Sub-Categories	21
Resizing Plots	21
Exercise 1: 3D Fourbar Linkage.	28

Lesson 2:

Building a Motion Model and Post-processing

Objectives	31
Creating Local Mates	32
Case Study: Crank Slider Analysis.	32
Problem Description	32
Stages in the Process.	32

Mates	33
Concentric Mate	34
Hinge Mate	34
Point-to-Point Coincident Mate	34
Lock Mate	35
Two Face-to-Face Coincident Mates	35
Universal Mate	35
Screw Mate	36
Point-on-Axis Coincident Mate	36
Parallel Mate	37
Perpendicular Mate	37
Local Mates	38
Function Builder	43
Importing Data Points	46
Power	48
Alternative Units	48
Plotting Kinematic Results	51
Absolute vs. Relative Values	51
Output Coordinate System	51
Angular Displacement Plots	56
Angular Velocity and Acceleration Plots	59
Summary	60
Exercise 2: Piston	61
Exercise 3: Trace Path	67

Lesson 3:

Introduction to Contacts, Springs and Dampers

Objectives	71
Contact and Friction	72
Case Study: Catapult	72
Problem Description	73
Stages in the Process	73
Interference Detection	77
Contact	79
Contact groups	80
Contact Friction	81
Translational Spring	82
Magnitude of Spring Force	83
Translational Damper	84
Post-processing	86
Analysis with Friction (Optional)	88
Summary	89
Exercise 4: The Bug	90
Exercise 5: Door Closer	92

Lesson 4: Advanced Contact

Objectives	95
Latch Forces	96
Case Study: Trailer Hitch	96
Problem Description	96
Fixing Motion with Motors	97
Motor Input and Force Input Types	99
Functional Expressions	100
Force Functions	101
STEP Function	101
Contact: Solid Bodies	105
Poisson Model (Restitution Coefficient)	106
Impact Force Model	106
Closing Remarks	108
Geometrical Description of Contacts	113
Tessellated Geometry	113
Precise Geometry	113
Integrators	115
GSTIFF	115
WSTIFF	115
SI2_GSTIFF	115
Closing Force	118
Summary	119
Discussion: References	119
Exercise 6: Latching Assembly	120
Problem Description	120
Exercise 7: Hatchback	127
Exercise 8: Conveyor Belt (No Friction)	136
Path Mate Motor	141
Exercise 9: Conveyor Belt (With Friction)	144

Lesson 5: Curve to Curve Contact

Objectives	151
Contact Forces	152
Case Study: Geneva Mechanism	152
Problem Description	152
Curve to Curve Contact	153
Solid Bodies vs. Curve to Curve Contact	158
Solid Bodies Contact Solution	159
Summary	159
Exercise 10: Conveyor Belt (Curve to curve contact with friction)	160

Lesson 6: Cam Synthesis

Objectives	163
Cams	164
Case Study: Cam Synthesis	164
Problem Description	164
Stages in the Process	164
Generating a Cam Profile	165
Trace Path	167
Exporting Trace Path Curves	168
Cycle Based Motion	171
Exercise 11: Desmodromic Cam	175
Exercise 12: Rocker Cam Profile	181

Lesson 7: Motion Optimization

Objectives	189
Motion Optimization	190
Case Study: Medical Examination Chair	190
Problem Description	190
Stages in the Process	190
Sensors	193
Design Studies	196
Parameters	197
Optimization Analysis	197
Global Variables	198

Lesson 8: Flexible Joints

Objectives	203
Flexible Joints	204
Case Study: System with Rigid Joints	204
Problem Description	205
Stages in the Process	205
Calculation of Wheel Input Motion	207
Understanding Toe Angles	210
System with Flexible Joints	211
Summary	213
References	213

Lesson 9: Redundancies

Objectives	215
Redundancies	216
What are Redundancies?.....	219
Effects of Redundancies	220
How are Redundancies Removed in the Solver?	221
Case Study: Door Hinges	221
Problem Description	221
Degrees of Freedom Calculation	224
Total Actual and Estimated DOF	224
Using Flexible Joints Option to Remove Redundancies	227
Limitations of Flexible Mates.....	228
Bushing Properties	229
How to Check For Redundancies	231
Typical Redundant Mechanisms.....	231
Dual Actuators Driving a Part	231
Parallel Linkages.....	232
Summary.....	232
Exercise 13: Dynamic Systems.....	233
Exercise 14: Dynamic Systems 2	234
Exercise 15: Kinematic Mechanism	236
Exercise 16: Zero Redundancy Model-Part 1.....	241
Exercise 17: Zero Redundancy Model-Part 2 (Optional).....	245
Exercise 18: Removing Redundancies with Bushings	246
Exercise 19: Catapult	253

Lesson 10: Export to FEA

Objectives	259
Exporting Results	260
Case Study: Drive Shaft	260
Project Description	260
Stages in the Process.....	261
FEA Export.....	264
Load Bearing Faces	265
Mate Location.....	265
Export of Loads	265
SOLIDWORKS Simulation Users Only.....	269
Direct Solution in SOLIDWORKS Motion	276
Summary.....	280
Exercise 20: Export to FEA	281

Lesson 11: Event Based Simulation

Objectives	287
Event Based Simulation	288
Case Study: Sorting Device	288
Problem Description	288
Servo Motors	288
Sensors	290
Task	292
Summary	296
Exercise 21: Packaging Assembly	297

Lesson 12: Design Project (Optional)

Objectives	303
Design Project	304
Case Study: Surgical Shear - Part 1	304
Problem Description	304
Force to Cut the Catheter	305
Self Guided Problem - Part 1	307
Stages in the Process	307
Self Guided Problem - Part 2	308
Stages in the Process	308
Problem Solution - Part 1	309
Creating the Force Function	312
Force to Cut the Catheter	313
Creating the Force Expression	315
Force Expression	317
IF Statement	317
Developing the Expression	317
Case Study: Surgical Shear - Part 2	324
Stages in the Process	324
Summary	335

Appendix A: Motion Study Convergence Solutions and Advanced Options

Convergence	338
Accuracy	339
Integrator Type	340
GSTIFF	340
WSTIFF	340
SI2_GSTIFF	340
Integrator Settings	341
Maximum Iterations	341
Initial Integrator Step Size	341
Minimum Integrator Step Size	341
Maximum Integrator Step Size	341
Jacobian Re-evaluation	342
Conclusion	342

Appendix B: Mate Friction

Mate Friction	344
Concentric (Spherical) Mate Friction Model	345
Coincident Translational Mate Friction Model	345
Concentric Mate Friction Model	346
Coincident Mate (Planar) Friction Model	346
Universal Joint Friction Model	346
Friction Results Reported	347