

# Numerical analysis using R

Solutions to ODEs and PDEs

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## 1 Errata

- Page 324: Middle of third paragraph, change "Chapter 12" to read Chapter 10".
- Page 324: Middle of third paragraph, change "Chapter 12" to read Chapter 10".

## 2 Clarifications

### 2.1 Chapter 6, p322 and p346: Taylor–Sedov model

The Taylor–Sedov blast wave simulations are based on the Euler equations. The explosion is initialized by the injection of a gas having a total thermal energy of  $E_0 = 2.5$  [GJ], into the central two cells of the model. This simulated detonation is equivalent to an explosion of approximately 0.5 long tons<sup>1</sup> of TNT<sup>2</sup>.

*Post simulation* calculations performed in file `SedovTaylorPostSimCalcs.R`, are:

$\nu = 1,$	planar=1, cyl=2, sph=3, p148
$S_{\text{pl}} = 0.9756 = \alpha_{\text{pl}}^{-1/(\nu+2)} = 1.077^{-1/3},$	similarity constant
$R(t) = (S_{\text{pl}} E_0 / \rho_1)^{1/(\nu+2)} t^{2/(\nu+2)},$	position of shock wave at $t$
$r_2 = R(t_{\text{end}}),$	position of shock wave at $t_{\text{end}}$
$\rho_2 = \rho_1(\gamma + 1)/(\gamma - 1),$	density at $r_2$ , p212
$c_2 = (2/(\nu + 2))r_2/t_{\text{end}},$	shock velocity at $r_2$ , p214
$p_2 = (2/(\gamma + 1))\rho_1 c_2^2,$	pressure at $r_2$ , p212

where page numbers refer to Sedov's book:

**Sedov, L. I.** (1959), *Similarity and Dimensional Methods in Mechanics*, Academic Press.

The following provides conversions between *Sedov* and *Taylor* variable locations – see eqns. (10.72) of book:

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<sup>1</sup>One long ton is equal to 2240 lbs or 1016 kg.

<sup>2</sup>Taylor defines the amount of energy liberated by an explosion of one long ton of TNT to be 4.25 [GJ].

- $c_2 = u_s$ , the speed of the shockwave
- $v_2 = v_1$ ,  $p_2 = p_1$ ,  $\rho_2 = \rho_1$  are shock conditions immediately behind the shock wave -  
Key: 2=Sedov, 1=Taylor.

Analytical data is loaded from data file `SedovTaylorPlanar_39pts.data`. This data, which has been generated using the methods outlined in Appendix (10.C) – see Table (10.3) p553 of the book, is plotted in (Figs. (6.24), (6.25) and (6.32) along with simulated data for comparison purposes.

### 3 Directory structure for supporting files

NOTE:

- 1) Some files are duplicated, where appropriate, to minimize the requirement to access files in other directories.
- 2) Most programs are started by running a file in the example directory with *main* in the name.

CHAPTER 01 – ODE Integration Methods	Date modified	Size (kB)
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CHAPTER 02 - Stability Analysis of ODE Integrators	Date modified	Size (kB)
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R\Ryacas	07/03/2016 14:49	Directory
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R\wave_2D.polar\deriv2nd10pt.R	31/01/2014 15:01	3.32
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R\waveEqn_2D\wave2D_deriv.R	26/05/2015 12:13	1.53
R\waveEqn_2D\wave2D_main.R	26/05/2015 14:31	3.3
R\waveEqn_2D\wave2D_postSimCalcs.R	07/02/2016 16:51	3.37

CHAPTER 04 - PDE Stability Analysis	Date modified	Size (kB)
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R\vonNeumannSemiDiscrete	07/03/2016 14:51	Directory
R\matrixStability\matConvDiffEigenCheck.R	30/05/2015 20:23	1.07
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R\matrixStability\matStabAdvec_upwind.R	31/05/2015 11:01	2.3
R\matrixStability\matStabConvDiff_main.R	07/02/2016 18:17	2.84
R\matrixStability\RKcontours.R	29/05/2015 20:19	1.15
R\vonNeumannFullyDiscrete\Thumbs.db	28/06/2015 13:44	86
R\vonNeumannFullyDiscrete\vonNeumannFullyDiscrete.R	07/02/2016 18:04	2.73
R\vonNeumannSemiDiscrete\vonNeumannSemiDiscrete.R	07/02/2016 18:15	2.49
CHAPTER 05 - Dissipation and Dispersion	Date modified	Size (kB)
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R\dissipationDispersion.R	07/02/2016 19:26	5
R\dissipationDispersionDiagrams.R	23/06/2014 22:53	1.25
R\dissipationDispersionDynamics.R	07/02/2016 19:39	2.71
R\init.R	24/06/2014 10:01	2.17
CHAPTER 06 - High Resolution Schemes	Date modified	Size (kB)
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Maxima	07/03/2016 14:49	Directory
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R\EulerEqns	07/03/2016 14:51	Directory
R\frontogenesisWENO	07/03/2016 14:51	Directory
R\limiterPlots	07/03/2016 14:51	Directory
R\scalar1D	07/03/2016 14:51	Directory
Maple\Euler_A_matrix.mw	20/03/2015 19:46	45.13
Maple\Weno_3rdPolyApprox.mw	08/02/2016 09:26	60.1
Maple\Weno_3rdPolyApprox_2.mw	08/02/2016 09:24	36.77
Maple\Weno_3rdPolyApprox_3.mw	08/02/2016 09:27	43.89
Maple\Weno_3rdPolyApprox-NEW.mw	20/08/2013 08:09	64.99
Maple\Weno_5thSmoothingIndicators.mw	21/03/2015 12:24	54.97
Maple\WenoMirror.mw	08/02/2016 09:28	40.94
Maxima\Euler_A_matrix.wxm	20/03/2015 19:46	1.94
Maxima\Weno_5thSmoothingIndicators.wxm	21/03/2015 12:23	2.61
Maxima\Weno_polyApprox.wxm	08/02/2016 09:50	4.17
R\advection2D\advection2D_deriv_WENO.R	06/02/2014 13:46	1.19
R\advection2D\advection2D_KandT_calc.R	06/02/2014 14:09	0.99
R\advection2D\advection2D_main_WENO.R	08/02/2016 10:37	3.92
R\advection2D\advection2D_postSimCalcs.R	06/02/2014 20:36	3.28
R\advection2D\WENO3rdOrdRecon_2D.R	06/02/2014 13:52	2.79
R\advection2D\WENO5thOrdRecon_2D.R	26/03/2014 17:22	3.62
R\advection2D\WENOArrays5th.R	04/12/2012 14:52	1.54
R\EulerEqns\Euler_deriv.R	02/06/2015 13:23	3.42
R\EulerEqns\Euler_initial.R	08/02/2016 12:54	3
R\EulerEqns\Euler_main.R	08/02/2016 14:06	7.05
R\EulerEqns\Limiter.R	31/05/2015 14:28	1.74

R\EulerEqns\linearExtrapolation.R	31/05/2015 14:39	1.12
R\EulerEqns\MUSCL_KTEuler.R	02/06/2015 13:41	1.88
R\EulerEqns\parabolicReconstruction2.R	01/06/2015 17:13	1.05
R\EulerEqns\plotFireBall.R	08/02/2016 13:04	0.56
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R\EulerEqns\WENO3rdOrdReconstructionKL.R	12/10/2013 16:29	2.13
R\EulerEqns\WENO5thOrdReconstruction.R	13/10/2013 11:50	2.92
R\EulerEqns\WoodwardColella4k_x.data	16/10/2013 20:45	473.41
R\EulerEqns\Woodward-ColellaPostSimCalcs.R	08/02/2016 13:24	1.53
R\frontogenesisWENO\frontogenesisAnalytical.R	08/01/2014 12:35	1.18
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R\frontogenesisWENO\WENO5thOrdRecon_2D.R	06/02/2014 13:53	4.12
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CHAPTER 07 - Meshless Methods	Date modified	Size (kB)
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R\FisherEqn2D_local	07/03/2016 14:51	Directory
R\HaltonSequence	07/03/2016 14:51	Directory
R\heatEqn2D	07/03/2016 14:54	Directory
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R\interpolation2D_Ex1	07/03/2016 14:51	Directory
R\interpolation2D_Ex2	07/03/2016 14:51	Directory
R\interpolation3D_Ex1	07/03/2016 14:51	Directory
R\KdVEqn1D	07/03/2016 14:51	Directory
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R\LaplaceEx2_2D	07/03/2016 14:51	Directory
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R\PoissonEqn2D_Ex2_Electrostatic\rbfCalc_CS4.R	08/02/2016 19:21	6.57
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<b>CHAPTER 08 - Conservation Laws</b>	<b>Date modified</b>	<b>Size (kB)</b>
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Maple\KdV_consLaw_inf.mw	16/03/2015 15:02	87.03
Maple\NLS_consLaw_123.mw	16/03/2015 19:21	69.2
Maple\vcKdV_consLaw.mw	16/03/2015 19:19	39.08
Maxima\Drazin_Q5.2.wxm	16/03/2015 15:17	1.24
Maxima\KdV_consLaw_1.3.wxm	13/03/2015 16:14	3.03
Maxima\KdV_consLaw_inf.wxm	16/03/2015 15:04	2.25
Maxima\NLS_consLaw_123.wxm	16/03/2015 17:45	4.4
Maxima\vcKdV_consLaw.wxm	16/03/2015 19:21	1.73
<b>CHAPTER 09 - Case Study: Analysis of Golf Ball Flight</b>	<b>Date modified</b>	<b>Size (kB)</b>
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Maple\golfBallClubVelocities.mw	06/03/2013 12:37	31.81
R\airDensity.R	09/02/2016 12:36	1.98
R\CDandCLcomparisons.R	15/06/2015 16:01	3.2
R\golfballFlight_deriv.R	08/06/2015 18:47	2.9
R\golfballFlight_main.R	09/02/2016 11:32	5.7
R\golfballFlight_postSimCalcs.R	09/02/2016 11:29	4.4
R\init_ambientTest.R	08/06/2015 18:53	0.9
R\init_angleTest.R	08/06/2015 18:53	1.15
R\init_dragCarryTest.R	08/06/2015 18:54	0.96
R\init_drawsAndSlices.R	08/06/2015 18:54	1.22
R\init_drivers.R	08/06/2015 18:52	0.83
R\init_irons.R	08/06/2015 18:54	1.07
R\init_Test.R	08/06/2015 18:56	0.76
R\init_windTest.R	08/06/2015 18:55	1.03
R\init_woods.R	08/06/2015 18:55	1.02
R\windTestPlots.R	09/02/2016 10:57	1.22
R\WindToBlowGolfballOffTee.R	09/02/2016 13:59	1.39
<b>CHAPTER 10 - Case Study: Taylor-Sedov Blast Wave</b>	<b>Date modified</b>	<b>Size (kB)</b>
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Maple\BlastWave_TaylorPart_I.mw	14/04/2015 11:02	113.57
Maple\BlastWave_TaylorPart_I_cyl.mw	09/02/2016 20:33	115.83
Maple\BlastWave_TaylorPart_I_int.mw	13/02/2013 16:58	95.7
Maple\BlastWave_TaylorPart_I_int_cyl.mw	23/09/2013 20:31	97.15
Maple\BlastWaveGasLaws_1.mw	11/03/2015 15:04	47.38
Maple\BlastWaveGasLaws_2.mw	11/03/2015 16:42	75.73
Maple\intChk.mw	10/06/2015 14:07	56.8
Maple\sedovCalc.mw	12/03/2015 10:26	104.78
Maple\sedovCalc2.mw	08/03/2015 21:54	51.6
Maple\symmetryCalc.mw	13/02/2013 11:40	35.8
Maxima\BlastWave_TaylorPart_1.wxm	14/04/2015 11:03	7.85
Maxima\BlastWave_TaylorPart_I_int.wxm	14/04/2015 12:52	2.87
Maxima\BlastWaveGasLaws_1.wxm	11/03/2015 15:05	1.89
Maxima\BlastWaveGasLaws_2.wxm	11/03/2015 16:53	3.01
Maxima\sedovCalc1.wxm	17/03/2015 14:06	4.07
Maxima\sedovCalc2.wxm	17/03/2015 13:44	1.47
Maxima\symmetryCalc.wxm	12/03/2015 17:17	0.94
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R\TaylorSedov_main.R	10/06/2015 10:38	1.48
R\TaylorSedov_postSimCalcs.R	08/11/2015 19:58	5.27
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CHAPTER 11 - Case Study: The Carbon Cycle	Date modified	Size (kB)
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R\radiantEnergy	07/03/2016 14:51	Directory
Maple\BK_EquilibriumSolutionEqns.mw	09/12/2014 18:40	42.91
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R\carbonCycle\carbonCycle_fossilFuel.R	11/06/2015 10:59	0.95
R\carbonCycle\carbonCycle_init.R	11/06/2015 10:48	3.71
R\carbonCycle\carbonCycle_main.R	11/06/2015 12:35	2.96
R\carbonCycle\carbonCycle_pistonCalc.R	11/06/2015 12:51	1
R\carbonCycle\carbonCycle_postSimCalcs.R	12/06/2015 23:03	3.28
R\carbonCycle\carbonCycle_ratesOfChange.R	11/06/2015 11:22	2.32
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R\carbonCycle\global.1751_2010.csv	27/09/2014 13:31	24.53
R\carbonCycle\tempChange.R	09/02/2016 21:57	1.81
R\emissions\emissionData.R	09/02/2016 21:50	2.87
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R\emissions\global.1751_2010.csv	27/09/2014 13:31	24.53
R\radiantEnergy\e-490_solarData.txt	07/01/2008 23:20	21.22
R\radiantEnergy\EarthRadiationData1.txt	13/01/2008 22:32	2.5
R\radiantEnergy\radiationSpectra.R	09/02/2016 21:30	4.44
R\radiantEnergy\SolarSpectrumEarthSurf.txt	15/01/2008 16:54	6.64