
References

1. W. Gander, M. J. Gander, and F. Kwok, *Scientific Computing - An Introduction Using Maple and MATLAB*. Texts in Computational Science and Engineering. Springer, 2015
2. D. Griffiths, F. David, and D. J. Higham, *Numerical Methods for Ordinary Differential Equations: Initial Value Problems*. Springer, 2010
3. E. Hairer, S. P. Nørsett, and G. Wanner, *Solving Ordinary Differential Equations I. Nonstiff Problems*. Springer, 1993
4. G. Hairer and E. Wanner, *Solving Ordinary Differential Equations II*. Springer, 2010
5. J. D. Hunter, D. Dale, E. Firing, and M. Droettboom, Matplotlib documentation, 2012. <http://matplotlib.org/users/>
6. H. P. Langtangen, Quick intro to version control systems and project hosting sites. <http://hplgit.github.io/teamods/bitgit/html/>
7. H. P. Langtangen, SciTools documentation. <http://hplgit.github.io/scitools/doc/web/index.html>
8. H. P. Langtangen, *A Primer on Scientific Programming with Python*. Texts in Computational Science and Engineering. Springer, fourth edition, 2014
9. H. P. Langtangen and G. K. Pedersen, *Scaling of Differential Equations*. SimulaSpringerBrief. Springer, 2015. <http://tinyurl.com/qfjgxmfw>
10. H. P. Langtangen and L. Wang, Odespy software package. <https://github.com/hplgit/odespy>
11. D. B. Meade and A. A. Struthers, Differential equations in the new millenium: the parachute problem. *International Journal of Engineering Education*, 15(6):417–424, 1999
12. L. Petzold and U. M. Ascher, *Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations*, volume 61. SIAM, 1998
13. L. N. Trefethen, *Trefethen's index cards - Forty years of notes about People, Words and Mathematics*. World Scientific, 2011

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