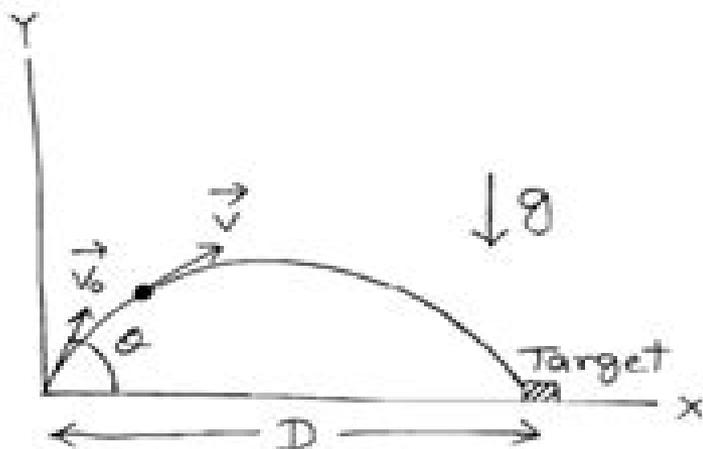Consider the motion of a projectile in earth's gravitational field. The projectile of mass m is launched from the origin in a direction making an angle θ with the horizontal so as to hit a target placed at a distance D. There is a frictional force due to the air resistance acting on the projectile, which is opposite to the velocity direction and proportional to the square velocity. The equation of motion from the Newton's Laws is:

$$M \left(\hat{\imath} \frac{d^2x}{dt^2} + \hat{\jmath} \frac{d^2y}{dt^2} \right) = -Mg\,\hat{\jmath} - \kappa v^2\,\hat{v}$$

The following parameters are given: $g = 10$ m/sec², $D = 1$ Km, and the air friction parameter $\alpha = \kappa / M = 0.001$ m⁻¹. If air friction is zero, then the analytical solution is known from elementary physics (formula given below), which you can use to check the results from your computer code. Draw appropriate graphs to discuss all key results.

(a) Write a computer code to solve the boundary value problem by using the shooting method.

(b) Determine the initial speed v_0 as a function of θ ($0 < θ < π/2$) so that it hits the target.

(c) What is the minimum value of v_0 needed for the projectile to hit the target and what is the corresponding θ?

(d) Repeat the above for $\alpha = 0.002$ m⁻¹ and $\alpha = 0.005$ m⁻¹.

Note: I suggested above some values for α. Determine appropriate values from your own numerical simulations so that you can see the effect of friction on motion. If friction is too high, the particle may not reach the target. If it is too low, you obtain results close to the analytical solution from elementary physics, viz., $v_0 = \sqrt{Dg / \sin 2θ}$.

Numerical Method: Choose one of the following methods to solve the differential equations. Use a constant step size, just small enough that you can reproduce the analytical result for the initial speed v_0 accurate to within 0.001 % for the case of zero air resistance and θ = 45°.

I. The fourth-order Runge Kutta Method to carry out the entire integration.

Projectile Motion Using Runge Kutta Methods

George Klimi

Projectile Motion Using Runge Kutta Methods:

Numerical Calculation for Physics Laboratory Projects Using Microsoft EXCEL® Shinil Cho,2019-10-31 This book covers essential Microsoft EXCEL s computational skills while analyzing introductory physics projects Topics of numerical analysis include multiple graphs on the same sheet calculation of descriptive statistical parameters a 3 point interpolation the Euler and the Runge Kutter methods to solve equations of motion the Fourier transform to calculate the normal modes of a double pendulum matrix calculations to solve coupled linear equations of a DC circuit animation of waves and Lissajous figures electric and magnetic field calculations from the Poisson equation and its 3D surface graphs variational calculus such as Fermat s least traveling time principle and the least action principle Nelson s stochastic quantum dynamics is also introduced to draw quantum particle trajectories **Exterior Ballistics with Applications** George Klimi,2008-07-30 Exterior Ballistics with Applications Skydiving Parachute Fall Flying Fragments presents a modern approach to introduce the basics of exterior ballistics and its methods from the simple ideal model of projectile motion to the automatic solution of the differential equations of projectile flight using PC programs The book uses different approaches to solve the differential equations of projectile motion among them the Siacci method and the numerical methods The results obtained through the integration of differential equations of projectile flight are mostly analytical formulas that describe the projectile trajectory and make the exterior ballistics a comprehensible science The Differential Equations of Projectile Flight are also integrated numerically using some original PC programs that can be easily modified to be used in similar scenarios or other new ones and give the reader the possibility to solve a great variety of Exterior Ballistics problem Exterior Ballistics with Applications can be considered as an interdisciplinary applied mathematics and physics manuscript for the vast mathematics and physics models and techniques employed It is a great source for applications in physics calculus differential equations numerical methods and PC programming as well The book is illustrated with about 140 solved examples related to different artillery and infantry firearms that demonstrate the use of formulas and the solution methods of ballistics to find the elements of projectile trajectories Exterior Ballistics with Applications includes as well two interesting topics that can be considered as applications of exterior ballistics 1 Skydiving and parachute falling related with the trajectory of a parachutist launched from a horizontally flying airplane with un deployed parachute in different meteorological conditions and in presence of air resistance and wind 2 The ballistics of projectile fragments that is an important element of Terminal Ballistics necessary to study the effectiveness of fragmentation ammunitions on the personnel and objects and other problems related with the construction of fragmentation ammunitions or with Forensic Sciences Exterior Ballistics with Applications is comprehensive and serves as reference material to provide answers to problems encountered in the practice of motion of unguided projectiles skydiving and flying fragments of antipersonnel ammunitions **Exterior Ballistics with Applications** Gjergj Klimi,2008-07-30 Exterior Ballistics with Applications Skydiving Parachute Fall Flying Fragments presents a modern

approach to introduce the basics of exterior ballistics and its methods from the simple ideal model of projectile motion to the automatic solution of the differential equations of projectile flight using PC programs The book uses different approaches to solve the differential equations of projectile motion among them the Siacci method and the numerical methods The results obtained through the integration of differential equations of projectile flight are mostly analytical formulas that describe the projectile trajectory and make the exterior ballistics a comprehensible science The Differential Equations of Projectile Flight are also integrated numerically using some original PC programs that can be easily modified to be used in similar scenarios or other new ones and give the reader the possibility to solve a great variety of Exterior Ballistics problem Exterior Ballistics with Applications can be considered as an interdisciplinary applied mathematics and physics manuscript for the vast mathematics and physics models and techniques employed It is a great source for applications in physics calculus differential equations numerical methods and PC programming as well The book is illustrated with about 140 solved examples related to different artillery and infantry firearms that demonstrate the use of formulas and the solution methods of ballistics to find the elements of projectile trajectories Exterior Ballistics with Applications includes as well two interesting topics that can be considered as applications of exterior ballistics 1 Skydiving and parachute falling related with the trajectory of a parachutist launched from a horizontally flying airplane with un deployed parachute in different meteorological conditions and in presence of air resistance and wind 2 The ballistics of projectile fragments that is an important element of Terminal Ballistics necessary to study the effectiveness of fragmentation ammunitions on the personnel and objects and other problems related with the construction of fragmentation ammunitions or with Forensic Sciences Exterior Ballistics with Applications is comprehensive and serves as reference material to provide answers to problems encountered in the practice of motion of unguided projectiles skydiving and flying fragments of antipersonnel ammunitions   **Computational Physics - A Practical Introduction to Computational Physics and Scientific Computing (using C++), Vol. I** Konstantinos Anagnostopoulos,2016-12-06 This book is an introduction to the computational methods used in physics and other related scientific fields It is addressed to an audience that has already been exposed to the introductory level of college physics usually taught during the first two years of an undergraduate program in science and engineering It assumes no prior knowledge of numerical analysis programming or computers and teaches whatever is necessary for the solution of the problems addressed in the text C is used for programming the core programs and data analysis is performed using the powerful tools of the GNU Linux environment All the necessary software is open source and freely available The book starts with very simple problems in particle motion and ends with an in depth discussion of advanced techniques used in Monte Carlo simulations in statistical mechanics The level of instruction rises slowly while discussing problems like the diffusion equation electrostatics on the plane quantum mechanics and random walks   Floating Point Numerics for Games and Simulations Nima Badizadegan,2025-05-30 Floating point is ubiquitous in computers where it is the default way to represent

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Elementary Differential Equations Werner E. Kohler,Lee W. Johnson,2003 Elementary Differential Equations with Boundary Value Problems integrates the underlying theory the solution procedures and the numerical computational aspects of differential equations in a seamless way that provides students with the necessary framework to understand and solve differential equations Theory is presented as simply as possible with an emphasis on how to use it With an emphasis on linear equations linear and nonlinear equations first order and higher order are treated in separate chapters In developing mathematical models this text guides the student carefully through the underlying physical principles leading to the relevant mathematics Asking students to use common sense intuition and back of the envelope checks as well as challenging them to anticipate and interpret the physical content of the solution encourage critical thinking MARKET Intended for use in introductory course in differential equations   Modelling with Projectiles Derek Hart,Tony Croft,1988   Solving ODEs with Maple V David Barrow,1996 This resource manual laboratory book shows students how to use the Maple computer algebra system to solve problems in ordinary differential equations Projects exercises and explanations show readers how to get the most out of the Maple computer algebra   **Applied Numerical Methods for Digital Computation with FORTRAN and CSMP** Merlin L. James,Gerald M. Smith,J. C. Wolford,1977   **Journal of Hydrodynamics** ,1999

Computer Simulation Studies in Condensed-Matter Physics XIV D.P. Landau,S.P. Lewis,H.-B. Schüttler,2002-05-28 Over the last 30 years Professor David P Landau s trailblazing research achievements and influential leadership have helped

establish computer sim ulation as a powerful and incisive mode of scientific investigation now on a par in the physical sciences with experimental and theoretical research This year we were very pleased to organize a special one day symposium honor ing the 60th birthday of our distinguished colleague and friend This event was held in conjunction with and immediately following the annual computer simulations workshop that Professor Landau founded 14 years ago Many of the papers presented at this honorary symposium are integrated into this pro ceedings volume and the accompanying photograph of participants serves to commemorate this very special event This volume contains both invited papers and contributed presentations on problems in both classical and quantum condensed matter physics We hope that each reader will benefit from specialized results as well as profit from exposure to new algorithms methods of analysis and conceptual devel opments   17th Werner Brandt Workshop on the Penetration of Charged Particles in Matter Raul Baragiola,1997   Applied Numerical Methods for Digital Computation with Fortran Merlin L. James,Gerald M. Smith,J. C. Wolford,1967   Ballistics of the Future Johannes Marie Joseph Kooy,Johannes Wilhelmus Huybert Uytenbogaart,1947   Introduction to Algorithms and Numerical Methods Brice Carnahan,James O. Wilkes,1971   **Computer Methods for Engineering** Yogesh Jaluria,1988 This text is aimed at helping engineering students develop expertise in numerical methods and use them to solve problems of practical interest It provides students with a treatment of numerical methods for important operations such as integration differentiation and root solving   American Journal of Physics ,1995   *Mathematical Reviews* ,2005-06   **Nuclear Instruments & Methods in Physics Research** ,2002   Digital Computing and Numerical Methods Brice Carnahan,James O. Wilkes,1973

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