



Mathematics  
Department

Temporarily at Preble Hall

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## Profile of the Month Prof. Reza Malek-Madani

Prof. Reza Malek-Madani earned his B. S. and M. S. in Mathematics from Southern Illinois University and a Ph. D. in applied mathematics from Brown University. His research interests are in the field of partial differential equations of continuum mechanics, and computation of

solutions of the governing equations of geophysical fluid dynamics. In a 1998 textbook he outlined his approach to modeling physical systems, especially geophysical systems, and how to use high level languages such as Mathematica and MATLAB to study them. Beginning in 1990 Prof.



Malek-Madani became the program manager for the Applied Analysis Program at the Office of Naval Research (ONR) where he supervised the development of Navy's dynamical system approach to ocean dynamics. In the past 4 years, in his capacity at ONR, he has directed a basic research program in the area of image analysis where the computational tools for solving partial differential equations are applied to image compression, segmentation, registration and restoration. Since his arrival at USNA in 1983, Prof.

Malek-Madani has collaborated closely with colleagues in the Oceanography Department. This collaboration has resulted in the development of several new joint courses. The most recent one, SM415, Mathematical Modeling of Oceanic and Atmospheric Processes, was inaugurated this Spring. For more information about Dr. Malek-Madani and his research and teaching visit his website <http://web.usna.navy.mil/~rmm>.



The symbol used on this current issue of Math News is one of the Platonic Solids. The Platonic solids, also called the regular solids or regular polyhedra, are convex polyhedra with equivalent faces composed of congruent convex regular polygons. There are exactly five such solids: the cube, dodecahedron, icosahedron, octahedron, and tetrahedron, as was proved by Euclid in the last proposition of the *Elements*. Ref. <http://mathworld.wolfram.com/PlatonicSolid.html> More on this in the next Math News Issue.

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# Math News

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Volume 4, Issue 4

March 4, 2005

## Dynamical Systems and the Chesapeake Bay

(by Prof. Reza Malek-Madani)

Dynamical systems is an area of mathematics that aims to understand how solutions of differential equations behave when physical parameters are allowed to vary. You may have already come across this topic in calculus and mechanics when studying the motion of a pendulum – the circumstances of a pendulum depend crucially on its initial state and on whether the pendulum swings in vacuum, air or molasses. Typically, a dynamical system consists of a set of ordinary differential equations (ODEs), a set of initial conditions, and a set of physical parameters. The ODEs often come about because Newton's laws of motion must be satisfied. In such settings the position of a particle, whether fluid or solid, is linked to its velocity, which in turn is linked to its acceleration, which ends up being balanced by a force through the familiar  $f = ma$  conservation law. What is remarkable in physics, and more recently in social science settings, is that the force  $f$  ends up being related BACK to the position, hence giving us a closed

system of ODEs, a system that we can study analytically and computationally. Consequently so many physical and social science problems can ultimately be reduced to solving a system having the form

$$dx/dt = v(x, t), \quad x(0) = x_0,$$

where  $v$ , the velocity field, is a known function of position  $x$  and time  $t$ . This approach attracted the attention of some of the greatest applied mathematicians beginning in the late 19<sup>th</sup> century. Poincare, Lyapunov, Lefschetz, Lasalle, Kolmogorov, Moser, Smale and Arnold are just a few mathematicians whose contributions to the field of dynamical systems eventually revolutionized our understanding of phenomena as diverse as ocean currents, blood flow in our veins, propagation of a virus in a computer network, and the behavior of an unruly crowd in a soccer game. To this day tools from dynamical systems continue to play a key role in the development of science and engineering.

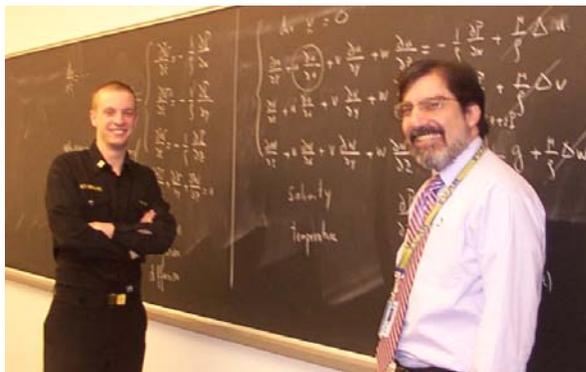
### Inside this issue:

Learn how mathematics can help you to save the Chesapeake Bay.



## Dynamical Systems and the Chesapeake Bay (cont)

Since 1990 the development of dynamical systems was singularly influenced by the U. S. Navy. The Navy's interest in the subject was piqued when velocity fields of interest to the Navy and the Marine Corps became available through the use of High Frequency (HF) Radar. A good example of such data is available at <http://www.oc.nps.navy.mil/~radlab/avhrr.html> where the vectors shown on this site represent surface velocities measured from a triangulation of three radar sites around the



Monterey Bay. Mathematicians at Brown University and at the California Institute of Technology worked feverishly during the last decade of the 20<sup>th</sup> century to generalize the ideas of Poincare and Kolmogorov to velocity fields like the one in the Monterey Bay for which we only had an observational knowledge. As is typical with many real-world data, the data collected at Monterey Bay was incomplete (often because it was difficult to keep all three radar sites operational for an extended period of time) and noisy. The article written by Chris Jones (see <http://web.usna.navy.mil/~rmm/>

Papers/JonesOceanSiam.pdf) gives an excellent overview of recent accomplishments by the Brown/CalTech groups. Among the remarkable achievements of these groups was devising a computational method that

identifies regions in any data-based vector field that act as barriers to transport and mixing in a fluid flow. These barriers end up holding the key to our understanding of the prevalent motions in as well as the biological health of bodies of water in which the Navy and the Marine Corps operate. Today we are fortunate that the state-of-the-art work of the past 15 years is becoming accessible to all of us. Two of the Trident Scholars of the Class of 05, MIDN 1/C Nathan Brasher and MIDN 1/C Grant Gillary have applied the recent developments in dynamical system to study our own Chesapeake Bay. By their efforts they have demonstrated the feasibility of implementing



a set of tools of enormous significance to the Navy and have thus paved the way for transitioning this methodology to the fleet. I invite you to stop MIDN Brasher and Gillary in the hallways of Bancroft Hall and ask them about their experience.

### Something about the Bay



“The Chesapeake Bay -- the largest estuary in the U.S. -- is an incredibly complex ecosystem that includes important habitats and food webs. The Bay itself, its rivers, wetlands, trees and land all provide homes, protection or food for complex groups of species. Fish of all types and sizes either live in the Bay and its tributaries or they use the waters as they migrate along the East Coast.

Young crabs hide from predators in underwater grasses, while oysters filter water as they feed on plankton. The intertwined combinations of relationships are countless.” (<http://www.chesapeakebay.net/info/about.cfm>)

### Something about Math

Mathematics is at the core of our attempts to understand the cosmos at every level: Riemannian geometry and topology furnish models of the universe, numerical simulations help us to understand large-scale dynamics, celestial mechanics provides a key to comprehending the solar system, and a wide variety of mathematical tools are needed for actual exploration of the space around us. ([www.mathaware.org](http://www.mathaware.org))

**Answers for last issue puzzles:** The answer for last issue's question is number 139. Last issue's winners were MIDN 4/C Jeffrey T Turner and MIDN 4/C Jesse A. Burdick.

### Question of the Month

Two jawbreaker-lovers stand at the vending machine with their pennies. The machine has 35 yellow jawbreakers and 35 blue jawbreakers. If they got a jawbreaker for each penny they put into the machine, how many pennies would they have to use to be sure of having two jawbreakers of the same color? E-mail your answer to Prof. Garcia [smg@usna.edu](mailto:smg@usna.edu). Among those with the right answer, a randomly chosen midshipman will get a fantastic math water bottle.

