INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

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IMA schedules, newsletters, updates and preprints are available at http://www.ima.umn.edu
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IMA NEWSLETTER # 335

1 September–1 October 2004

2004–2005 Program

MATHEMATICS OF MATERIALS AND MACROMOLECULES: MULTIPLE SCALES, DISORDER, AND SINGULARITIES

See http://www.ima.umn.edu/matter/ for a full description of the 2004–2005 program on Mathematics of Materials and Macromolecules: Multiple Scales, Disorder, and Singularities

IMA schedules are subject to revision, particularly during workshops. See http://www.ima.umn.edu/~seminar/sched and http://www.ima.umn.edu/newsltrs/ for the latest scheduling information.

PART I: News and Notes

New Participating Corporations in 2004: Corning and Johnson & Johnson

This year both Corning Inc. and Johnson & Johnson have joined the IMA as Participating Corporations. We welcome Dipak Chowdhury of Corning and Jim Merritt of Johnson & Johnson as IMA contacts and members of the IMA Industrial Advisory Board. Peter Philip, a new IMA Industrial Postdoc, will be working with Corning this year. Jing Wang, a departing IMA Postdoc, will be joining Johnson & Johnson as a research scientist.

Thematic Program Focus Areas

The goal of the 2004–2005 IMA Thematic Program "Mathematics of Materials and Macromolecules: Multiple Scales, Disorder, and Singularities" is the development of multi-disciplinary research efforts at the cutting edge of research in matter. In pursuit of this goal, three focused research groups have been formed: Multiscale Modeling and Computing, Singularities, and Soft Matter. Each group will investigate a physical or biological system, starting from elementary aspects and progressing to research projects. During the first weeks of the Fall semester, each IMA post-doc and long-term visitor will join one or more focus groups.

Multiscale Modeling and Computing

Organizers: Richard D. James (University of Minnesota)
Mitchell Luskin (University of Minnesota)

http://www.ima.umn.edu/matter/focus.html

PARTICIPATING INSTITUTIONS: Consiglio Nazionale delle Ricerche, Georgia Institute of Technology, Indiana University, Iowa State University, Kent State University, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), Michigan State University, Mississippi State University, Northern Illinois University, Ohio State University, Pennsylvania State University, Purdue University, Rice University, Sandia National Laboratories, Seoul National University (BK21 Math-SNU), Statistical Research Center for Complex Systems (SRCCS) at Seoul National University, Texas A&M University, University of Chicago, University of Cincinnati, University of Delaware, University of Houston, University of Illinois (Urbana), University of Iowa, University of Kentucky, University of Maryland, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, University of Wisconsin, University of Wyoming, Wayne State University.

PARTICIPATING CORPORATIONS: Boeing, Corning, ExxonMobil, Ford, GE, General Motors, Honeywell, IBM, Johnson & Johnson, Lockheed Martin, Lucent, Motorola, Schlumberger, Siemens, Telcordia Technologies, 3M.

Version of September 1, 2004

The Multiscale Modeling and Computing Focus Group will meet on Mondays to work on the development of methods to model and compute phenomena existing on different scales of length and time. Discussion on the selected topic will be lead by either a long-term visitor or a short-term visitor invited specifically for his/her research contributions to the topic. The group will continue to meet informally during the remainder of the week to investigate the current topic and to formulate research directions.

Singularities

Organizers: Fanghua Lin (Courant Institute)
Chun Liu (Penn State University)
Peter Sternberg (Indiana University)

http://www.ima.umn.edu/matter/focus3.html

The focus group on singularities in materials will meet weekly on Wednesdays. Topics will include (but are not restricted to) vortex structures in superconductors, domain walls in micromagnetics, phase transitions in co-polymers, singularities in liquid crystals and blistering patterns in thin films.

Speakers for the seminar will be drawn from the many IMA visitors, both long-term and short-term, who have expertise in these areas, along with post-docs and UMinn faculty from mathematics and the sciences. There will also be more informal meetings throughout the week to discuss possible research directions.

Soft Matter

Organizers: Maria-Carme Calderer (University of Minnesota)
Chun Liu (Penn State University)
Eugene Terentjev (University of Cambridge)

http://www.ima.umn.edu/matter/focus2.html

The focus group on soft matter will meet on Fridays to work on identifying problems and on developing models and analytic and numerical methods to solve them. Topics addressed by the group during the fall semester may include liquid crystals, ferroelectric materials, elastomers, polymers and gels.

During the months of January and February, in addition to the continuation of the topics initiated in the fall, the group will focus on polymer rheology. The focus of efforts during the months of March and April will be on complex fluids.

In addition to the above organizers, long-term visitors will help to set topics, organize activities, and coordinate participation with short-term visitors.

New IMA Postdocs

The new 2004–2006 IMA postdoctoral members are: Brian DiDonna (formerly of University of Pennsylvania), Sookyung Joo (Purdue University), Richard Kollar (University of Maryland), Matthias Kurzke (Max Planck Institute for Math in the Sciences), Frederic Legoll (CERMICS), and Xiantao Li (Princeton University).

The new 2004–2006 IMA postdoctoral members in industrial mathematics are: Qianyong Chen (formerly of Brown University), who will be working with ExxonMobil; Chiu Yen Kao (UCLA), working with the VA Medical Center; and Peter Philip (WIAS - Berlin), working with Corning.

Second Yamabe Memorial Symposium: Geometry and Physics

University of Minnesota Mathematics Department

17–19 September 2004

Organizers: Bob Gulliver, Conan Leung, Tian-Jun Li, and Jiaping Wang

Speakers: Robert Bryant (Duke University)
Sheldon Katz (University of Illinois)
Kefeng Liu (UCLA)
Duong Phong (Columbia University)
Paul Seidel (University of Chicago)
Isadore M. Singer (MIT)
Karen Uhlenbeck (University of Texas)
Shing-Tung Yau (Harvard University)

See http://www.math.umn.edu/yamabe for further information.

IMA Tutorial:

Mathematics of Materials

20–24 September 2004
Speakers: Masao Doi (Tokyo University)
Chun Liu (Pennsylvania State University)
Ellad B. Tadmor (Technion - Israel Institute of Technology)
Qiang Du (Pennsylvania State University)
Kaushik Bhattacharya (California Institute of Technology)

See http://www.ima.umn.edu/matter/t1.html

The tutorial week will consist of lectures by five distinguished researchers on background topics in methods to analytically and numerically address emerging modeling problems for materials. Applications will include multiscale methods for gels, liquid crystals, superconductivity, micromagnetics, elastomers, and crystalline solids.

IMA Workshop:

Modeling of Soft Materials

27 September–1 October 2004
Organizers: Maria-Carme T. Calderer (University of Minnesota),
Eugene Terentjev (University of Cambridge)

See http://www.ima.umn.edu/matter/fall/softmatter.html

The physics of soft matter–materials such as gels, foams, liquid crystals, elastomers, and soft ferroelectrics–is an area of intense interest and contemporary study. Moreover, soft matter plays a role in a wide variety of important processes and application. For example, gel swelling is an essential part of many biological processes such as motility mechanisms in bacteria and the transport and absorption of drugs. Ferroelectrics, liquid crystals, and elastomers are being used to design ever faster switching devices. Electron microscopy and experimental activity have provided a great deal of detailed information on structures. But the integration of mathematical modeling and analysis with experimental approaches promises to greatly increase our understanding. This workshop will take such an integrated approach. The workshop will bring together researchers in applied and computational mathematical fields such as differential equations, dynamical systems, analysis, and fluid and solid mechanics, and scientists and engineers from a variety of disciplines relevant to soft matter physics. An important goal of the workshop is to identify beautiful and novel scientific problems arising in soft matter that are in need of mathematical modeling and appear amenable to it and so to set the stage for further research.

Ordway Lectures: P.L. Lions

University of Minnesota Mathematics Department

28–30 September 2004

Tuesday: From molecules to nonlinear elasticity : a mathematical journey

Wednesday: New problems in control and differential games arising in finance

Thursday: Convexity and parabolic equations

IMA Website

Comments or suggestions concerning the IMA website may be addressed to `webmaster@ima.umn.edu`.
In particular, we appreciate any information about World-Wide Web links relevant to current and upcoming IMA programs.

PART II: Schedule for 1 SEPTEMBER – 1 OCTOBER 2004

Friday, September 3

Special Lecture 409 Lind

11:15	**Yitzhak Rabin** Department of Physics, Bar-Ilan University	Modeling of bio-filaments: elasticity and fluctuations combined

New studies of DNA molecules and protein filaments indicate the need to go beyond standard polymer models and construct a theory of fluctuating elastic filaments that would account for both bending and twist rigidity of these objects, as well as for their intrinsic shape. We discuss the intrinsic geometry, theory of elasticity and statistical mechanics of such objects, present a new type of Monte Carlo simulation based on this theory, and consider the implications of the theory for single molecule experiments on stretching, twisting and cyclization of double stranded DNA molecules.

Monday, September 13

10:00	**Pre-orientation breakfast**	Lind Hall 400
11:00	**Orientation for IMA postdocs, long term visitors, and participating faculty.**	Lind Hall 409

Wednesday, September 15

10:00	**"Show and Tell": 10 minute presentations by the incoming postdocs**	EE/CS 3-180
12:30	**Lunch and Posters**	Lind Hall 400

Second Yamabe Memorial Symposium
Geometry and Physics

University of Minnesota Mathematics Department

Organizers: Bob Gulliver, Conan Leung, Tian-Jun Li, and Jiaping Wang

Speakers: Robert Bryant (Duke University)
Sheldon Katz (University of Illinois)
Kefeng Liu (UCLA)
Duong Phong (Columbia University)
Paul Seidel (University of Chicago)
Isadore M. Singer (MIT)
Karen Uhlenbeck (University of Texas)
Shing-Tung Yau (Harvard University)

See http://www.math.umn.edu/yamabe for further information.

Friday, September 17

All talks are in 16 Vincent Hall. All coffee breaks are in 120 Vincent Hall.

2:30	**Registration**	120 Vincent Hall
3:15	**Welcoming remarks by Bob Gulliver, Conan Leung, Tian-Jun Li, Jiaping Wang**	
3:30	**Robert Bryant** Duke University	Gradient Kahler-Ricci solitons

Abstract: Some observations about the local and global generality of gradient Kähler Ricci solitons are made, including the existence of a canonically associated holomorphic volume form and vector field, the local generality of solutions with a prescribed holomorphic volume form and vector field, and the existence of Poincaré coordinates in the case that the Ricci curvature is positive and the vector field has a fixed point.

4:30	**Coffee Break**	
5:00	**Karen Uhlenbeck** University of Texas	Virasoro actions on harmonic maps

Abstract: The Virasoro algebra is the formal algebra which arises as the infinitesimal algebra of the diffeomorphism of the line. It has been known for a long time that a half Virasoro algebra acts as an infinitesimal symmetry on the KdV equations and the higher order general Gelfand-Dickey equations (KdV-r). This action occurs in many integrable systems, and is viewed as an important ingredient in quantum cohomology. Since harmonic maps from a two-dimensional domain into a Lie group target have many of the properties of integrable systems, it is not surprising that these half-Virasoro actions occur in the context of harmonic maps. In this paper, we elaborate on a construction of John Schwarz for Virasoro actions on harmonic maps from $R^{(1,1)}$ into a Lie group. We give a general explanation of how such actions arise, and construct the Euclidean analogues.

6:15	**Reception**	120 Vincent Hall

Saturday, September 18

All talks are in 16 Vincent Hall. All coffee breaks are in 120 Vincent Hall.

9:30	**S.-T. Yau** Harvard University	Positive quasi-local mass in general relativity

Abstract: I will describe how to define quasilocal mass for surfaces in spacetime and their positivity.

10:30	**Coffee Break**	
11:00	**Kefeng Liu** UCLA	String Duality and Localization

Abstract: String duality has produced many interesting mathematical conjectures. I will discuss the proofs of some conjectures by using localization techniques. This includes the proof of the Marino-Vafa conjecture which gives a closed finite expression in terms of the Chern-Simons invariants for the generating series of triple Hodge integrals of all genera and all marked points, and a mathematical foundation for the theory of topological vertex developed by the Vafa group in string theory, which gives the most effective computational methods for the generating series of the Gromov-Witten invariants of all genera and all degrees on toric Calabi-Yau manifolds. Other results related to the equivariant index theory will also be discussed.

2:00	**Isadore Singer** MIT	The projective Dirac operator and its fractional analytic index

Abstract: For a finite-rank projective bundle over a compact manifold, so associated to a torsion Dixmier-Douady class w on the manifold, we define the ring of differential operators "acting on sections of the principal bundle" in a formal sense. In particular, any oriented even-dimensional manifold carries a projective spin Dirac operator in this sense. More generally, the corresponding space of psuedodifferential operatos is defined, with supports sufficiently close to the identity relation. For such elliptic operators we define the numerical index in an essentially analytic way, as the trace of the commutator of the operator and a parametrix and show that this is homotopy invariant. Using the heat kernel method for the twisted, projective spin Dirac operator, we show that this index is given by the usual formula, now in terms of the twisted Chern character of the symbol, which in this case defines an element of K-theory twisted by w; hence the index is a rational number but in general it is not an integer.

4:30	**Coffee Break**	
3:30	**Paul Seidel** University of Chicago	Khovanov homology and the symplectic geometry of nilpotent slices

Abstract: I will explain how one can use the symplectic geometry of certain manifolds which appear in Lie theory to define an invariant of oriented links. The relevant manifolds are transverse slices to certain nilpotent orbits inside sl_{2m}, and intersections of those with regular semisimple orbits. Conjecturally, this is a version of Khovanov's combinatorially defined homology theory.

6:30	**Banquet**	Third floor Coffman Union

Sunday, September 19

All talks are in 16 Vincent Hall. The coffee break is in 120 Vincent Hall.

9:30	**Sheldon Katz** University of Illinois at Champaign-Urbana	Donaldson-Thomas and topological string invariants

Abstract: I will discuss recent progress in Donaldson-Thomas theory as relates to Gromov-Witten theory, Gopakumar-Vafa invariants, and their incarnations in topological string theory.

10:30	**Coffee Break**	
11:00	**Duong Phong** Columbia University	TBA

IMA Tutorial:

Mathematics of Materials

20–24 September 2004
Speakers: Masao Doi (Tokyo University)
Chun Liu (Pennsylvania State University)
Ellad B. Tadmor (Technion - Israel Institute of Technology)
Qiang Du (Pennsylvania State University)
Kaushik Bhattacharya (California Institute of Technology)

See http://www.ima.umn.edu/matter/t1.html

The tutorial week will consist of lectures by five distinguished researchers on background topics in methods to analytically and numerically address emerging modeling problems for materials. Applications will include multiscale methods for gels, liquid crystals, superconductivity, micromagnetics, elastomers, and crystalline solids.

Monday, September 20

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:30	**Coffee and Registration**	Reception Room EE/CS 3-176
8:50	**Douglas N. Arnold and Organizers**	Welcome and Introduction
9:30	**Masao Doi** Tokyo University	Modeling of Gels (The Coupling Between Stress and Diffusion) *Lecture 1.* What is a Gel

Abstract: A gel is an elastic object swollen by solvent, so the force acting on the gel is coupled with the diffusion of the solvent. The stress-diffusion coupling is seen commonly in everyday life (water coming out of a squeezed gel) and is also important in many chemical engineering processes, soaking, drying and sedimentation. The stress diffusion coupling is also important in the study of artificial muscles, where the deformation of the gel is controlled by an electric field. Professor Doi will present equations for the stress diffusion coupling for an ionic gel and discuss electro-chemical effects.

10:30	**Chun Liu** Pennsylvania State University	Variational Approaches in Complex Fluids *Lecture 1.* Background and Liquid Crystals

Abstract: Complex fluids such as polymeric solutions, liquid crystal solutions, pulmonary surfactant solutions, electro-kinetic fluids, magneto-rheological fluids and blood suspensions exhibit many intricate rheological and hydrodynamic features that are very important to biological and industrial processes.

The most common origin and manifestation of anomalous phenomena in complex fluids are different ”elastic” effects. They can be the elasticity of deformable cells, elasticity of the molecule alignment in liquid crystals, polarized colloids or

multi-component phases, elasticity due to microstructures, or bulk elasticity endowed by polymer molecules in viscoelastic complex fluids. The physical properties are purely determined by the interplay of entropic and structural intermolecular elastic forces and interfacial interactions. These elastic effects can be represented in terms of certain internal variables, for example, the orientational order parameter in liquid crystals (related to their microstructures), the distribution density function in the dumb-bell model for polymeric materials, the magnetic field in magneto-hydrodynamic fluids, the volume fraction in mixture of different materials etc. The different rheological and hydrodynamic properties can be attributed to the special coupling between the transport of the internal variable and the induced elastic stress. From the point of the view of the energetic variational formulation, this represents a competition between the kinetic energy and the elastic energy.

In these lectures, I will study three different but related types of problems to illustrate this unified energetic variational approach. All the systems are related and have common structures. However, each one posses its own distinct features (difficulties). I will present some modeling and analytical results, as well as those problems that remain to be solved.

1:30	**Ellad B. Tadmor** Technion - Israel Institute of Technology	Multiple-Scale Modeling of Materials Using the Quasi-continuum Method *Lecture 1.* Materials and Multiple Scales

Abstract: Atomistic and continuum methods alike are often confounded when faced with mesoscopic problems in which multiple scales operate simultaneously. In many cases, both the finite dimensions of the system as well as the microscopic atomic-scale interactions contribute equally to the overall response. This makes modeling difficult since continuum tools appropriate to the larger scales are unaware of atomic detail and atomistic models are too computationally intensive to treat the system as a whole.

We present an alternative methodology referred to as the ”quasicontiuum method” which draws upon the strengths of both approaches. The key idea is that of selective representation of atomic degrees of freedom. Instead of treating all atoms making up the system, a small relevant subset of atoms is selected to represent, by appropriate weighting, the energetics of the system as a whole. Based on their kinematic environment, the energies of individual ”representative atoms” are computed either in nonlocal fashion in correspondence with straightforward atomistic methodology or within a local approximation as befitting a continuum model. The representation is of varying density with more atoms sampled in highly deformed regions (such as near defect cores) and correspondingly fewer in the less deformed regions further away and is adaptively updated as the deformation evolves.

The method has been successfully applied to a number of atomic-scale mechanics problems including nanoindentation into thin aluminum films, microcracking of nickel bicrystals, interactions of dislocations with grain boundaries in nickel, junction formation of dislocations in aluminum, cross-slip and jog-drag of screw dislocations in copper, stress-induced phase transformations in silicon due to nanoindentation, polarization switching in ferroelectric lead-titanate and deformation twinning at aluminum crack tips. An overview of the methodology and selected examples from these applications will be presented.

Tuesday, September 21

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:45	**Coffee**	Reception Room EE/CS 3-176
9:30	**Masao Doi** Tokyo University	Modeling of Gels *Lecture 2.* Stress Diffusion Coupling: The Phenomena and Modeling

Abstract: See Monday’s abstract.

10:30	**Chun Liu** Pennsylvania State University	Variational Approaches in Complex Fluids *Lecture 2.* Viscoelastic Fluids

Abstract: See Monday’s abstract.

1:30	**Ellad B. Tadmor** Technion - Israel Institute of Technology	Multiple-Scale Modeling of Materials Using the Quasicontinuum Method *Lecture 2.* The Theoretical Foundations of the Quasicontinuum Method

Abstract: See Monday's abstract.

Wednesday, September 22

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:45	**Coffee**	Reception Room EE/CS 3-176
9:00	**Chun Liu** Pennsylvania State University	Variational Approaches in Complex Fluids *Lecture 3.* Free Interface Motions in Mixtures

Abstract: See Monday's abstract.

10:30	**Qiang Du** Pennsylvania State University	Mathematical Models of Superconductivity, an Introduction *Lecture 1.*

Abstract: Complex fluids such as polymeric solutions, liquid crystal solutions, pulmonary surfactant solutions, electrokinetic fluids, magneto-rheological fluids and blood suspensions exhibit many intricate rheological and hydrodynamic features that are very important to biological and industrial processes.

The most common origin and manifestation of anomalous phenomena in complex fluids are different "elastic" effects. They can be the elasticity of deformable cells, elasticity of the molecule alignment in liquid crystals, polarized colloids or multi-component phases, elasticity due to microstructures, or bulk elasticity endowed by polymer molecules in viscoelastic complex fluids. The physical properties are purely determined by the interplay of entropic and structural intermolecular elastic forces and interfacial interactions. These elastic effects can be represented in terms of certain internal variables, for example, the orientational order parameter in liquid crystals (related to their microstructures), the distribution density function in the dumb-bell model for polymeric materials, the magnetic field in magneto-hydrodynamic fluids, the volume fraction in mixture of different materials etc. The different rheological and hydrodynamic properties can be attributed to the special coupling between the transport of the internal variable and the induced elastic stress. From the point of the view of the energetic variational formulation, this represents a competition between the kinetic energy and the elastic energy.

In these lectures, I will study three different but related types of problems to illustrate this unified energetic variational approach. All the systems are related and have common structures. However, each one posses its own distinct features (difficulties). I will present some modeling and analytical results, as well as those problems that remain to be solved.

1:30	**Ellad B. Tadmor** Technion - Israel Institute of Technology	Multiple-Scale Modeling of Materials Using the Quasicontinuum Method *Lecture 3.* Quasicontinuum Applications

Abstract: See Monday's abstract.

3:00	**Kaushik Bhattacharya** California Institute of Technology	Energy Minimization and Microstructure *Lecture 1.*

Abstract: There are numerous phenomena in materials science where fine-scale microstructure is the result of the material seeking to optimize multiple incongruent objectives. Examples include alloy phase segregation, martensitic phase transformation, nematic elastomers, ferroelectrics and faceting of crystalline surfaces. Further the ability of a material to form microstructure and to change its microstructure depending on the macroscopic boundary conditions endow the materials with unusual macroscopic behavior like the shape-memory effect, electrostriction and the liquid-like behavior of solids.

These series of lectures will describe selected examples of such phenomena and how such a phenomenon can naturally be modeled as a variational problem, specifically a minimization problem with non-convex energy density. It will show that microstructure arises as an inevitable consequence of such a variational problem and that nontrivial aspects of the microstructure can be predicted from such a formulation. Finally, it will introduce the notion of effective behavior, i.e., the overall behavior of the material after it has formed microstructure, how microstructure gives rise to very unusual effective behavior and how one can describe it without having to resolve every fine detail of the microstructure. These lectures are intended to be accessible to a broad audience with a balance between phenomena, modeling and mathematical analysis.

Thursday, September 23

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:45	**Coffee**	Reception Room EE/CS 3-176
9:30	**Masao Doi** Tokyo University	Modeling of Gels *Lecture 2.* Stress Diffusion Coupling: The Phenomena and Modeling

Abstract: See Monday's abstract.

10:30	**Qiang Du** Pennsylvania State University	Mathematical Models of Superconductivity, an Introduction *Lecture 3.*

Abstract: See Wednesday's abstract.

1:30	**Kaushik Bhattacharya** California Institute of Technology	Energy Minimization and Microstructure *Lecture 2.*

Abstract: See Wednesday's abstract.

Friday, September 24

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:45	**Coffee**	Reception Room EE/CS 3-176
9:30	**Masao Doi** Tokyo University	Modeling of Gels *Lecture 4.* Electro-Responsive Gels

Abstract: See Monday's abstract.

10:30	**Qiang Du** Pennsylvania State University	Mathematical Models of Superconductivity, an Introduction *Lecture 3.*

Abstract: See Wednesday's abstract.

1:30	**Kaushik Bhattacharya** California Institute of Technology	Energy Minimization and Microstructure *Lecture 3.*

Abstract: See Wednesday's abstract.

IMA Workshop:

IMA Workshop: Modeling of Soft Materials

27 September–1 October 2004
Organizers: Maria-Carme T. Calderer (University of Minnesota),
Eugene Terentjev (University of Cambridge)

See http://www.ima.umn.edu/matter/fall/softmatter.html

The physics of soft matter–materials such as gels, foams, liquid crystals, elastomers, and soft ferroelectrics–is an area of intense interest and contemporary study. Moreover, soft matter plays a role in a wide variety of important processes and application. For example, gel swelling is an essential part of many biological processes such as motility mechanisms in bacteria and the transport and absorption of drugs. Ferroelectrics, liquid crystals, and elastomers are being used to design ever faster switching devices. Electron microscopy and experimental activity have provided a great deal of detailed information on structures. But the integration of mathematical modeling and analysis with experimental approaches promises to greatly increase our understanding. This workshop will take such an integrated approach. The workshop will bring together researchers in applied and computational mathematical fields such as differential equations, dynamical systems, analysis, and fluid and solid mechanics, and scientists and engineers from a variety of disciplines relevant to soft matter physics. An important goal of the workshop is to identify beautiful and novel scientific problems arising in soft matter that are in need of mathematical modeling and appear amenable to it and so to set the stage for further research.

Monday, September 27

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

8:30	**Coffee and Registration**	Reception Room EE/CS 3-176
9:15	**Douglas N. Arnold, Debra Lewis, and Organizers**	Welcome and Introduction
9:30	**David Morse** University of Minnesota	TBA
10:20	**Discussion and Coffee**	
11:00	**Masao Doi** Tokyo University	The Coupling Between Stress and Diffusion in the Dynamics of Soft Solids

Abstract: When small molecules diffuse into an elastic material, they create stress field within the material and deform the material. Conversely, when an external force is applied to an elastic material which contains small molecules, it squeezes out the small molecules. These are the examples of the stress-diffusion coupling. Here I disucss the mathematical formulation for the phenomena, and show some consequence arizeing from the couling between the elastic stress and diffusion.

11:50	**Discussion**	
12:00	**Lunch Break**	
1:30	**Alexander Grosberg** University of Minnesota	Knots in polymer physics

Abstract: We report a series of computer simulations and related analytical studies of the role of topological constraints in the equilibroium properties of polymeric loops. We show that no-knots loops exhibit swelling similar to that of self-avoiding chains even when polymer has negligible excluded volume. We further show that global topology of the loop has a profound effect on the local fractal geometry of the polymer. For compact polymers, this leads to locally shrunken conformations. We discuss implications of these findings for a number of polymer systems.

2:20	**Discussion and Coffee**	
3:30	**Group Photo**	
3:40	**IMA Tea and more (with POSTER SESSION)**	400 Lind Hall

Tuesday, September 28

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:30	**Robert Pelcovits** Brown University	Visualization of Topological Defects in Liquid Crystals

Abstract: I will discuss our ongoing work on the visualization of topological defects in numerical simulations of liquid crystals. We are collaborating with a computer scientist who has developed techniques which allow easy visualization of the features of tensor fields, originally in the context of MRI scans of the brain. In our case we wish to visualize the nematic order parameter tensor in order to locate and characterize defects in our data set. Our data set is produced by quenching a Gay-Berne nematic fluid of 65K particles. I will discuss the challenges faced in the study of defects in fluid (as opposed to lattice) models of liquid crystals and the significant progress we have made to date.

10:20	**Discussion and Coffee**	
11:00	**Randall D. Kamien** University of Pennsylvania	Bending The Rules

Abstract: We discuss the ordering of liquid crystalline phases which possess both cubic symmetry and smectic-like, lamellar ordering. We will show that there is a fundamental frustration in this system. We propose an ansatz based on triply-periodic minimal surfaces. We discuss more general constructions based on topological field configurations and tesselation of the hyperbolic plane.

11:50	**Discussion**	
12:00	**Lunch Break**	
1:30	**Eugene Terentjev** University of Cambridge	Kinetic Theory of Rotational Diffusion and Anisotropic Viscosity of Liquid Crystals

Abstract: We shall discuss the molecular-statistical approach to describing the rotational diffusion of anisotropic molecules (rods or disks) in a mean field of liquid crystalline order (nematic or smectic-C). The issues of microscopic stress tensor and its averaging, of the spectrum of relaxation times, of the role of more delicate ordering (e.g. smectic layering or biaxiality), and of the route to the full pair-correlation theory will be considered.

2:20	**Discussion and Coffee**	

3:00	**SECOND CHANCES**	A discussion period to revisit workshop topics and issues and look towards future directions
4:30	**P.L. Lions** Université de Paris IX – Dauphine	Ordway Lecture 1: From molecules to nonlinear elasticity: a mathematical journey

All three Ordway lectures will be held in 16 Vincent Hall.

Wednesday, September 29

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:30	**Antonio DeSimone** International School of Advanced Studies (SISSA)	TBA
10:20	**Discussion and Coffee**	
11:00	**Eliot Fried** Washington University	TBA
11:50	**Discussion**	
12:00	**Lunch Break**	
1:30	**Helmut R. Brand** Universitat Bayreuth	TBA
2:20	**Discussion and Coffee**	
2:45	**Raphael Blumenfeld** Cavendish Laboratory	Stress Field Equations in Granular Solids - A Shift of Paradigm

Abstract: A key concept to the understanding of stress transmission in granular materials is the Marginally Rigid State and an experiment is described which establishes the relevance of this state. The MRS can be regarded as a critical point wherein a particular lengthscale diverges. Granular matter at the MRS is statically determinate (isostatic), obviating elasticity theory. A new ”isostaticity theory” is formulated for stress transmission at the MRS. It explains the force chains, frequently observed in experiments, and makes it possible to predict their individual trajectories.

The insight from the static theory makes it possible to formulate a theory for the yield and failuer of granular solids and a new set of equations is presented for the flow of granular matter in this regime.

3:25	**SECOND CHANCES**	A discussion period to revisit workshop topics and issues and look towards future directions
4:30	**P.L. Lions** Université de Paris IX – Dauphine	Ordway Lecture 2: New problems in Control and Differential Games arising in Finance

All three Ordway lectures will be held in 16 Vincent Hall.

Thursday, September 30

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:30	**Andrei A. Gusev** ETH Zentrum	Finite Element Mapping for Spring Network Representations of the Mechanics of Solids

Abstract: We present a general finite element mapping procedure for defining spring network representations of solid mechanics. The procedure is rigorous and equally suitable for setting regular and unstructured spring network models of generally anisotropic solids. We use the procedure to define close-packed triangular and simple cubic lattice spring models of isotropic 2D and 3D elastic media, respectively. We extend the study to heterogeneous solids and show that the mapped spring network approach constitutes an appealing route for incorporating subelement level constitutive equations.

10:20	**Discussion and Coffee**	

11:00	**Francois Graner** Université Joseph Fourier	Models for Elastic, Plastic, Fluid Materials

Abstract: It is difficult to predict the constitutive relations of foams, emulsions, granular materials or gels from first principles. Experimentally, the mechanical behaviors of such viscoplastic materials do not appear to change discountinuously. However, mathematical singularities appear as soon as a solid exhibits plastic deformation, or a liquid a non-zero restoring force. The continuum elasticity theory and the Navier-Stokes equations break down.

Visco-elasto-plastic theories require an interpolation between these apparently orthogonal descriptions. We use physical quantities which exist and are measurable in all regimes. We define generalized stress and strain tensors as statistical averages over microscopical details (avoiding the use of a microscopic reference state). They recover each correct limiting behaviors when either classical theory applies.

We perform local and averaged measurements on foam flowing past an obstacle or through a constriction, or under Couette shear. Applications include discrete mechanics, where the sample size (upper cut-off) is not significantly larger than the individual size (lower cut-off): granular materials, nano-fluidics.

11:50	**Discussion**	

12:00	**Lunch Break**	

1:30	**Cheng-Cher Huang** University of Minnesota	Experimental and Theoretical Studies of Liquid Crystal SmC* Variant Phases

Abstract: In 1989, the discovery of antiferroelectric response in a liquid crystal mesophase (SmCA*) is an important landmark in soft condensed matter physics. Soon after, at least, three new mesophases (i.e. SmC.*, SmCFI2*, and SmCFI1*) were identified. Collectively, all these four new mesophases and SmC* are called SmC* variant phases. Since then, enormous experimental and theoretical effort has been aimed at addressing the following two important questions. Experimentally, our research group has accomplished remarkable tasks to identify the molecular arrangements in the SmC* variant phases [1]. Theoretically, one would like to figure out the origin or mechanism of such a rich phase sequence within a temperature window less than 50K. As a starting point, a phenomenological model based on mean-filed approaches will be presented [2].

1. A. Cady, et al., Phys. Rev. E 64, 050702 (2001) and Ref found therein.

2. D. A. Olson, et al., Phys. Rev. E 66, 021702 (2002).

2:20	**Discussion and Coffee**	

3:00	**SECOND CHANCES**	A discussion period to revisit workshop topics and issues and look towards future directions

3:30	**P.L. Lions** Université de Paris IX – Dauphine	Ordway Lecture 3: Convexity and parabolic equations

All three Ordway lectures will be held in 16 Vincent Hall.

TBA	**Banquet** **(Joint IMA-School of Mathematics)**	

Friday, October 1

All talks are in Lecture Hall EE/CS 3-180 unless otherwise noted.

9:30	**Robert Meyer** Brandeis University	TBA
10:20	**Discussion and Coffee**	
11:00	**Didier Long** Université Paris-Sud/CNRS	TBA
11:50	**Discussion**	
12:00	**Lunch Break**	
1:30	**David Kinderlehrer** Carnegie Mellon University	Cooperative Effects in a Dye/Liquid Crystal System

Abstract: We discuss the dichroic dye/liquid crystal interaction known as the Janossy effect and studied by Palffy-Muhoray, Kosa and E. A consistent variational principle is offered that takes advantage of Monge-Kantorovich mass transport ideas and some consequences, like whether or not such a formulation can actually predict the observed Janossy effect, are discussed. As time permits, we shall discuss the general issue of diffusion mediated transport, the interaction of transport mechanisms and diffusion at extremely small scale with hints to other systems. This is joint work with Stuart Hastings and Michael Kowalczyk.

2:20	**Discussion and Coffee**	
3:00	**SECOND CHANCES**	A discussion period to revisit workshop topics and issues and look towards future directions
3:30	**Concluding Remarks by Organizers**	
3:40	**End of Workshop**	

PART III: Current IMA Participants

FIRST YEAR POSTDOCTORAL MEMBERS

Brian DiDonna, Sookyung Joo, Richard Kollar, Matthias Kurzke, Frederic Legoll, Xiantao Li.

SECOND YEAR POSTDOCTORAL MEMBERS

Gerard Awanou, Tim Garoni, Lea Popovic.

POSTDOCTORAL MEMBERS IN INDUSTRIAL MATHEMATICS

Qianyong Chen (ExxonMobil), Chuan-Hsiang Han (Ford), Chiu Yen Kao (VA Medical Center), Peter Philip (Corning).

LONG TERM VISITORS

Martin Z. Bazant	Massachusetts Institute of Technology	9/7/04 – 10/2/04
Josef Bemelmans	Rheinisch-Westfälische Technische Hochschule	9/16/04–10/1/04
Daniel E. Bentil	University of Vermont	9/18/04–10/2/04
Jorge Berger	Technion - Israel Institute of Technology	9/29/04–10/29/04
Fulvio Bisi	Universit di Pavia	9/25/04–10/9/04
Helmut Brand	Universitt Bayreuth	9/1/04 – 10/15/04
Maria-Carme Calderer	University of Minnesota	9/1/04 – 6/30/05
L. Pamela Cook	University of Delaware	9/1/04 – 12/31/04
Masao Doi	University of Tokyo	9/18/04–1/9/05
Georg Dolzmann	University of Maryland	9/12/04–10/3/04
Weinan E	Princeton University	9/20/04–10/8/04
Xiaobing Feng	University of Tennessee	9/25/04–10/30/04
Eliot Fried	University of Illinois - Urbana-Champaign	9/6/04 – 10/2/04
Matthias Gobbert	University of Maryland - Baltimore County	8/25/04–12/24/04
Robert Gulliver	University of Minnesota	9/1/04 – 6/30/05
Richard D. James	University of Minnesota	9/1/04 – 6/30/05
Richard Lavery	CNRS	9/1/04– 6/30/05
Benedict Leimkuhler	University of Leicester	9/15/04–10/1/04
Fanghua Lin	New York University	9/1/04 – 12/31/04
Chun Liu	Pennsylvania State University	9/1/04 – 6/30/05
Zuhan Liu	Xuzhou Normal University	9/1/04 – 1/31/05
Mitchell Luskin	University of Minnesota	9/1/04 – 6/30/05
Govind Menon	University of Wisconsin	9/1/04 – 12/15/04
Petr Plechac	University of Warwick	9/1/04 – 12/31/04
Harald Pleiner	Max Planck Institute for Polymer Research	9/1/04 – 10/17/04
Yitzhak Rabin	Bar-Ilan University	8/26/04–10/01/04
Rolf Ryham	Pennsylvania State University	9/1/04 – 6/30/05
George R Sell	University of Minnesota	9/1/04 – 6/30/05
Tien-Tsan Shieh	Indiana University	9/1/04 – 6/30/05
Peter J. Sternberg	Indiana University	8/15/04–6/30/05
Vladimir Sverak	University of Minnesota	9/1/04 – 6/30/05
Ellad Tadmor	Technion - Israel Institute of Technology	9/19/04–10/10/04
Eugene Terentjev	Cambridge University	9/1/04 – 10/10/04
Epifanio G. Virga	Universita di Pavia	9/12/04–10/2/04
Zhi-Qiang Wang	Utah State University	9/1/04 – 12/31/04
Stephen J. Watson	Northwestern University	9/1/04 – 6/30/05
Baisheng Yan	Michigan State University	9/1/04 – 6/30/05
Toshio Yoshikawa	City University of Hong Kong	9/13/04–10/2/04

VISITORS IN RESIDENCE (as of September 1, 2004)

Amandine Aftalion	Universite Pierre et Maris Curie (Paris VI)	9/6– 9/17
Timothy J. Barth	NASA Ames Research Center	9/19–9/28
Peter W. Bates	Michigan State University	9/26–9/30
Patricia Bauman	Purdue University	9/26–10/9
Yuxing Ben	University of Notre Dame	9/26–10/1
Ali Berker	3M	9/19–9/24
Kaushik Bhattacharya	California Institute of Technology	9/21–9/24
Raphael Blumenfeld	Cambridge University	9/26–10/1
Christine Carracino	University of Wisconsin	9/17–9/19
Hsueh-Chia Chang	University of Notre Dame	9/26–10/5
Athonu Chatterjee	Corning Inc.	9/19–9/24
Zhenlu Cui	Florida State University	9/26–10/01
Antonio DeSimone	SISSA-Italy	9/26–10/2
Qiang Du	Pennsylvania State University	9/19–9/22
James J. Feng	University of British Columbia	9/25–10/2
M. Gregory Forest	University of North Carolina	9/27–10/1
Francois Graner	Universit Joseph Fourier	9/25–10/2
Alexander Grosberg	University of Minnesota	9/27–10/1
Colette Guillope	University of Paris XII	9/26–10/2
Andrei Gusev	ETH Zentrum	9/26–10/1
Cheng-Cher Huang	University of Minnesota	9/27–10/1
Antal Jakli	Kent State University	9/26–10/1
Randall D. Kamien	University of Pennsylvania	9/26–10/1
Yun-Hui Kim	Indiana University	9/19–9/24
David Kinderlehrer	Carnegie Mellon	9/26–10/1
Bernhard Klampfl	Klaiss Inc.	9/19–9/24
Isaac Klapper	Montana State University	9/26–10/1
Huan Li	University of Maryland	9/19–9/24
Didier Long	Universite Paris Sud	9/26–10/1
Qingfeng Ma	Indiana University	9/19–9/24
L. Mahadevan	Harvard University	9/26–10/1
Michael Mlejnek	Corning Inc.	9/19–9/24
David Morse	University of Minnesota	9/27–10/1
Miao-Jung Yvonne Ou	University of Central Florida	9/19–9/24
Jinhae Park	University of Minnesota	9/20–9/24
Robert Pelcovits	Brown University	9/26–10/1
Daniel Phillips	Purdue University	9/5– 9/18
Riccardo Rosso	Universita di Pavia	9/25–10/2
Jonathan V. Selinger	Naval Research Laboratory	9/26–10/1
Andre M. Sonnet	University of Strathclyde	9/25–10/8
Eugene Starostin	Max Planck Institute (Physics of Complex Systems)	9/26–10/1
Iain W. Stewart	University of Strathclyde	9/26–10/1
Robert T. Tranquillo	University of Minnesota	9/27–10/1
Karl Voss	Bucknell University	9/26–10/1
Qi Wang	Florida State University	9/26–10/1
Olaf Weckner	Massachusetts Institute of Technology	9/19–9/24
Jon Wilkening	New York University	9/26–10/2
Xiaofeng Yang	Purdue University	9/19–9/24
Arghir Dani Zarnescu	University of Chicago	9/19–9/26

See also `http://www.ima.umn.edu/people/`