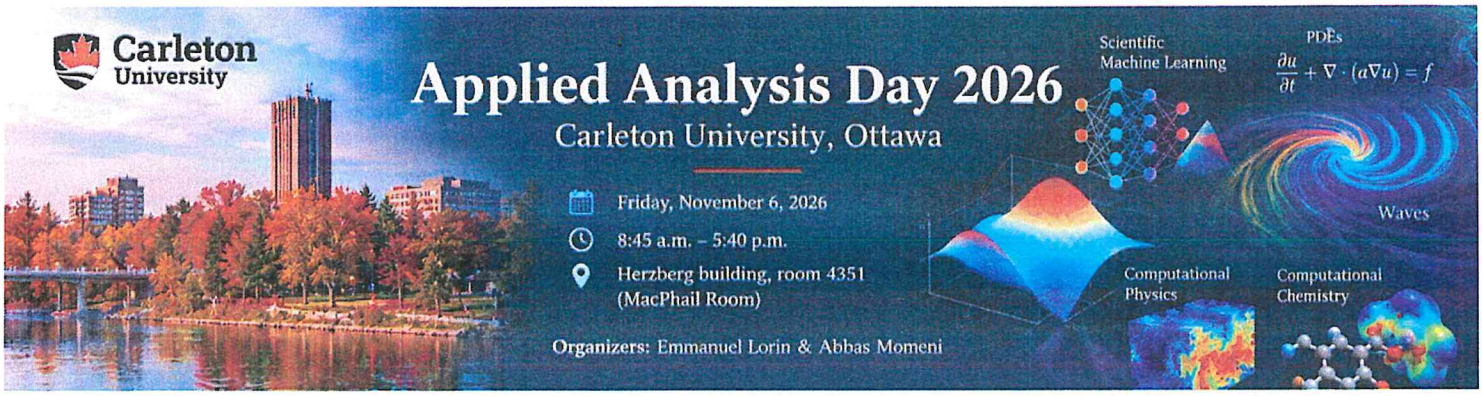


About the Event

Applied Analysis Day brings together researchers in the Ottawa region and beyond—including professors, graduate students, and postdoctoral fellows—to exchange recent results, inspire new ideas, and encourage collaborations. Hosted this year by Carleton University, the event will place particular emphasis on recent developments in mathematical and numerical modeling, PDE analysis, numerical analysis, and scientific machine learning.

Program

Time	Speaker / Activity	Affiliation
8:50 – 9:00	*Welcome*	
9:00 – 10:00	**Félix Kwok**	Université Laval
10:00 – 10:30	*Coffee break*	
10:30 – 11:00	**Arian Novruzi**	University of Ottawa
11:00 – 11:30	**Elham Rezazadeh**	Carleton University
11:30 – 12:00	**Mingyao Cai**	Carleton University
12:00 – 13:30	*Lunch break*	
13:30 – 14:00	**Tristan Montoya**	NSERC and University of Saskatchewan
14:00 – 14:30	**Tanya Schmah**	University of Ottawa
14:30 – 15:00	**Abdelkhalek Baroudi**	University of Ottawa and Carleton University
15:00 – 15:30	**Rémi Yvant Temgoua**	Fields Institute
15:30 – 16:00	*Coffee break*	
16:00 – 16:30	**Loïc Cappanera**	University of Ottawa

Time	Speaker / Activity	Affiliation
16:30 – 17:00	Abderrahmane Benfanich	University of Ottawa
17:00 – 17:10	*Closing remarks*	

Click a speaker's name to view the talk title and abstract.



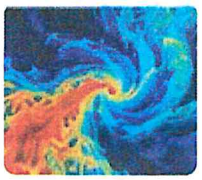
Date
Friday, November 6, 2026

Time
8:45 a.m. – 5:10 p.m.

Room
Herzberg Building, room 4351
(MacPhail Room)

Organizers
Emmanuel Lorin & Abbas Momeni

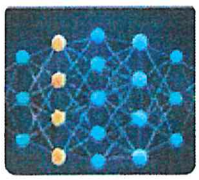
Research Themes



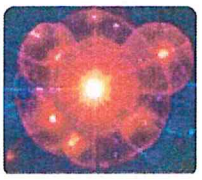
Partial Differential Equations



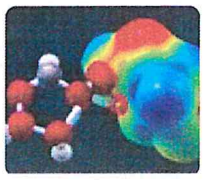
Waves and Wave Propagation



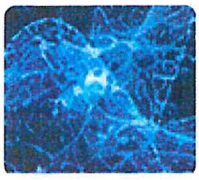
Scientific Machine Learning



Computational Physics



Computational Chemistry



Multiscale Methods and Applications

Talk Titles & Abstracts

Click on a speaker in the programme to jump to their presentation. Unavailable abstracts are marked "To be announced."

Félix Kwok

Université Laval · 9:00 – 10:00

Title: Schwarz waveform relaxation methods: theory and practice

The accurate numerical solution of partial differential equations (PDEs) often require solving huge linear or nonlinear systems, with millions or even billions of unknowns. Domain decomposition methods speed up the calculation by dividing the computational domain into

many subdomains, so that the smaller subproblems that can be solved in parallel on different processors; once solved, the subdomains exchange information and repeat the solution process until it converges to a self-consistent global solution. For time-dependent PDEs, subdomains must solve subproblems in space and time and exchange information over the whole time window; the resulting methods are known as Schwarz waveform relaxation (SWR) methods in the literature. The convergence properties of SWR are markedly different from their counterparts for elliptic equations: for instance, they almost always converge superlinearly, which is rarely the case for elliptic equations. In this talk, we will present a new superlinear convergence result when Robin interface conditions are used for the information exchange. We will also show how such methods can be implemented efficiently using pipelining techniques.

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Arian Novruzi

University of Ottawa · 10:30 – 11:00

Title: The structure of the solution to the generalized Stokes equations and a new method for solving them

We show that the velocity solution u to the generalized Stokes equations with Dirichlet boundary conditions in dimension two and three is the superposition of two divergence-free velocity fields $\boldsymbol{\omega}$ and ϑ, $u=\boldsymbol{\omega}+\vartheta$. Both $\boldsymbol{\omega}$ and ϑ solve screened Poisson vector equations with right hand side respectively the rotational component in the Helmholtz decomposition of the external force, and the gradient of a harmonic scalar function q called "solid pressure". Similarly, the fluid pressure p is the superposition of the potential π in the Helmholtz decomposition of the external force, and of q, $p=\pi+q$. It turns out that regardless the pressure q, $\boldsymbol{\omega}+\vartheta$ is divergence-free and satisfies the generalized Stokes equations, except the normal component of the Dirichlet boundary condition. The role of q, which solves a boundary linear equation with a self-adjoint definite positive operator, is to constrain $\boldsymbol{\omega}+\vartheta$ to satisfy even the normal component of the Dirichlet boundary condition.

The method is attractive for solving numerically the time dependent Navier-Stokes equations in two and three dimensions. It decouples the velocity from the pressure and solves the incompressibility constraint as a byproduct of unconstrained screened Poisson vector equations for $\boldsymbol{\omega}$ and ϑ, equipped with appropriate boundary conditions. In the two last sections we present two methods for solving numerically the generalized Stokes equations, and some results to demonstrate the efficiency of our approach.

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Elham Rezazadeh

Carleton University · 11:00 – 11:30

Title: Topographic Effects on Resonant Waves in a Shallow Rectangular Tank

Resonance is a fundamental phenomenon that manifests across both natural and engineered systems, from earthquakes amplifying structural vibrations in buildings to mechanical oscillations in engines. While previous research has examined resonant forcing in rectangular tanks and the evolution of periodic long surface waves over bottom topography in unbounded domains, the influence of bottom configurations on free surface evolution in bounded domains remains less well understood. In this talk, we investigate the interplay between periodic bottom topography and resonantly forced oscillations of fluid in a shallow rectangular tank of finite length. Starting from the governing equations for an inviscid fluid, we outline how perturbation methods and multiplescale techniques yield a forced evolution equation that captures the combined influence of the finite geometry, the oscillatory forcing, and the variable bottom topography. We then present numerical results obtained from this model and describe how the topography affects the resonant response.

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Mingyao Cai

Carleton University · 11:30 – 12:00

Title: An investigation of the interaction between atmospheric internal gravity waves and surface water waves

We examine a coupled model that describes atmospheric internal gravity waves and surface water waves. The model is based on an anelastic approximation for internal gravity waves in an upper layer and shallow water equations for surface water waves which give a lower boundary condition for the internal waves. This configuration is relevant for situations such as the generation of atmospheric waves by tsunami or other ocean surface waves and for situations where there are coupled atmosphere-ocean interactions. We consider different configurations including cases where multiple surface waves collide, interact and generate gravity wave modes, which in turn interact with each other and with the background atmospheric flow. We present a weakly-nonlinear analysis which gives asymptotic approximations that are compared with our numerical solutions. Our results include the effects of the nonlinear wave interactions on the background atmospheric wind and temperature. Joint work with L. J. Campbell.

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Tristan Montoya

NSERC and University of Saskatchewan · 13:30 – 14:00

Title: Fully discrete mass conservation for an implicit high-order discretization of the Richards equation with spatial and temporal adaptivity

The Richards equation is a nonlinear, degenerate parabolic partial differential equation describing the transport of water in variably saturated soil. Accurately resolving the sharp wetting fronts that arise in realistic hydrologic scenarios can be computationally expensive, motivating the use of numerical methods that combine high-order accuracy with spatial and temporal adaptivity. However, maintaining an exact mass balance through implicit time integration and mesh adaptivity remains a challenge, even for spatial discretizations that are conservative at the semi-discrete level. This talk presents a provably mass-conservative adaptive numerical method for the one-dimensional Richards equation that combines a local discontinuous Galerkin spectral-element method with a linearly implicit Rosenbrock-Wanner time integration scheme. The method is based on a mixed formulation of the Richards equation that couples a conservation law for the water content with an algebraic constitutive relation between the water content and the pressure head, resulting in a stiff system of differential-algebraic equations after spatial discretization. Augmenting this system with auxiliary variables tracking the cumulative boundary fluxes yields a linear invariant representing the mass balance, which is preserved in exact arithmetic by the time integration scheme. A conservative solution transfer approach then ensures that the resulting mass balance is maintained under mesh adaptivity. Numerical experiments using the open-source package HydroTrixi.jl demonstrate high-order accuracy for a manufactured solution as well as mass conservation up to roundoff for adaptive simulations of canonical infiltration benchmarks. This talk is based on joint work with Raymond J. Spiteri.

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Tanya Schmah

University of Ottawa · 14:00 – 14:30

Title: Alternatives to Navier--Stokes: energy-conserving irreversible fluid models

For modelling dissipative phenomena such as friction, diffusion and viscosity, the Hamiltonian framework has a key limitation: since Hamiltonian flows preserve phase-space volume, they admit no asymptotically stable equilibria, so typical solutions never relax to a steady state. The metriplectic framework modifies the Hamiltonian structure so that the flow still conserves energy but drives a chosen ``generalised entropy'' monotonically, allowing solutions to relax. We apply

this construction to ideal fluids. In 2D, dissipating the enstrophy (mean-square vorticity) yields the Navier--Stokes equations with an extra nonlocal term restoring energy balance, which on the flat torus coincide with the constrained Navier--Stokes equations of Brzeniak et al. In 3D this fails, because vortex stretching can increase enstrophy even in ideal flow. Instead, for a fluid carrying an advected scalar such as temperature, we dissipate the ``potential enstrophy'', built from a combination of vorticity and the temperature gradient. The result is a new energy-conserving alternative to the 3D Navier--Stokes equations, in which dissipation is nonlinear and anisotropic: it vanishes where the temperature is uniform, and its direction is determined by the temperature gradient.

This is joint work with Erwin Luesink (Utrecht University), Archishman Saha (University of Michigan) and Cristina Stoica (Wilfrid Laurier University).

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Loïc Cappanera

University of Ottawa · 14:30 – 15:00

Title: Momentum-based methods for variable-density incompressible Navier-Stokes equations.

Incompressible flows with variable density (and viscosity) have applications in many industries, such as energy (liquid metal batteries) and metallurgy (aluminum electrolysis), and geosciences (thermohaline ocean circulation). The numerical approximation of such problems can face many challenges such as dealing with differential operator with space-time dependent coefficients, enforcing the incompressibility of the flow or tracking the evolution of the density. After discussing the above challenges and motivations, we will introduce two methods that enforce the incompressibility constraints using either projection methods or artificial compressibility techniques. Both methods use the momentum, equal to the product of density and velocity, as a primary unknown. With an adequate treatment of the diffusion and nonlinear terms, it leads to time-independent stiffness matrices that can be assembled and preconditioned at initialization. After establishing the theoretical properties of both methods, we will present numerical illustrations using manufactured solutions and more challenging setups related to liquid metal batteries and aluminum electrolysis.

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Rémi Yvant Temgoua

Fields Institute · 15:00 – 15:30

Title: Fractional Hardy inequalities on C^{1,1} open sets

In a joint work with Abdelrazek Dieb, we study a family of fractional Hardy-type inequalities on bounded open sets where the Hardy weight is singular along the boundary. For all s \in (1,2), 1) we establish necessary and sufficient conditions to answer the attainability of the sharp constant. Our results are optimal in the setting of C^{1,1} open sets. Furthermore, for a given convex open set, we prove a new geometric improvement of the Fractional Hardy inequality, where the remainder term is given explicitly. Finally, for general bounded C^{1,1} open sets, we prove that for s close to 1/2 the Hardy constant is the same as the one for the half-space and then never achieved. This behavior is in sharp contrast with the local case, where the topology/geometry of the domain strongly influences the value of the optimal constant, and reveals a new rigidity phenomenon in the nonlocal setting.

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Abdelkhalek Baroudi

University of Ottawa and Carleton University · 16:00 – 16:30

Title: Separable Neural Networks for the Time-Dependent Schroedinger Equations

The numerical solution of the many-electron time-dependent Schroedinger equation (TDSE) remains a major computational challenge due to the curse of dimensionality. In this work, we investigate Tensor Neural Networks (TNNs) as a low-rank approach for approximating high-dimensional quantum wavefunctions. A central difficulty is in treating Coulomb interaction potentials, which are not naturally separable. We address this issue by constructing low-rank separable approximations using Gaussian expansions, allowing efficient evaluation of high-dimensional integrals through products of one-dimensional integrals. To describe the evolution of the wavefunction, we employ the Dirac–Frenkel time-dependent variational principle, which projects the Schroedinger dynamics onto the tangent space of the TNN manifold, leading to a system of ordinary differential equations for the network parameters. We present numerical experiments for the three-dimensional hydrogen atom and the six-dimensional hydrogen molecule, H_2. The results demonstrate accurate ground-state approximations and promising agreement of the time-dependent dipole response with established numerical methods. These findings highlight the potential of Tensor Neural Networks for the numerical simulation of high-dimensional quantum dynamical systems.

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Abderrahmane Benfanich

17:00 – 17:30

Title: Discrete positivity and maximum principles for the Richards equation

Joint work with: Yves Bourgault (University of Ottawa) and Abdelaziz Beljadid (University of Ottawa and UM6P, Morocco)

The Richards equation models water infiltration in unsaturated porous media. Its degeneracy and nonlinear constitutive laws make it challenging to construct numerical approximations that preserve physically meaningful saturation bounds. In this talk, we study a finite element discretization based on a bounded auxiliary variable, with mass lumping and a linearly implicit treatment of the gravity-driven flux. We first explain how an explicit treatment of gravity introduces a solution-dependent sufficient time-step restriction for positivity, which can become severe near dry regions. We then establish nonnegativity of the proposed scheme under a weakly acute mesh assumption and a local spatial Péclet condition, without a time-step restriction for this property. An additional nonnegative row-sum condition yields a discrete maximum principle. The analysis reveals that preserving the lower and upper bounds involves distinct algebraic mechanisms. Numerical experiments illustrate the advantage of the proposed gravity treatment, bound preservation in a diffusion-dominated regime, and the different effects of spatial refinement on lower and upper saturation bounds. We also discuss why these sufficient conditions need not be necessary for an individual computation.

Keywords: Richards equation; finite element methods; positivity; discrete maximum principle; degenerate parabolic equations.

Joint work with: Yves Bourgault (University of Ottawa) and Abdelaziz Beljadid (University of Ottawa and UM6P, Morocco)

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Location

Herzberg Building, Room 4351 (MacPhail Room), Carleton University, Ottawa, Canada.

Funding





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