18.S996 HYDRODYNAMIC QUANTUM ANALOGS

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Office hours: after class, available upon request

Spring 2024
MW 2:30-4
Room 2-143

GRADING SCHEME

- 50%: 2 problem sets (group discussion encouraged)
- 50%: course project on subject of your choosing
    - 30% based on final paper, 20% final presentation

There is **no required text** for the course, which will be based on the lecture notes; however, supporting material will be suggested throughout the course.

COURSE OUTLINE

Lecture 1. Feb. 5 Introduction

- course survey, motivation and philosophy

Lecture 2. Feb 7. Analogical thinking

- degrees of similitude and modes of comparison
- metaphor, physical analogy, dynamic similarity, statistical similarity, philosophical similarity

Lecture 3. Feb 12. Quantum history and foundations

- quantum interpretations, impossibility proofs and paradoxes
- quantum pilot-wave theories: from de Broglie to Bohm to stochastic electrodynamics

Lecture 4. Feb 14. The early HQAs of Yves Couder

- the discovery of walking droplets
- single-droplet diffraction and interference
- orbital dynamics, tunneling, bound states

Lecture 5. Feb 20. (Monday schedule) Hydrodynamic preliminaries I

- continuum mechanics and Navier-Stokes equations
- surface tension and interfacial phenomena

Lecture 6: Feb. 21 Hydrodynamic preliminaries II

- water waves: gravity and capillary waves
- Faraday waves on a vibrating bath

Lecture 7: Feb. 26. Hydrodynamic preliminaries III

- droplet impact and non-coalescence events
- drops on a vibrating soap film

Lecture 8. Feb. 28. Bouncing droplets

- drops on a vibrating liquid bath
- the theoretical modeling of the drop dynamics and wave field

Lecture 9: March 4. Walking droplets (APS March?)

- the transition from bouncing to walking
- discrete and continuous models

Lecture 10: March 6. The stroboscopic model

- stability of the walking state
- stability of orbiting and promenading pairs
- energetics of pilot-wave hydrodynamics

Lecture 11: Mar. 11. Orbital pilot-wave dynamics

- walkers in a rotating frame: analog Landau levels
- walkers in a central spring force: analog particle in a SHO
- origins of quantization, chaos and emergent statistics

Lecture 12: Mar. 13. More recent theoretical models

- modeling boundaries (Luiz Faria)
- Faraday pilot-wave model
- discrete time model
- Rayleigh oscillator and Boost models

Lecture 13: March 18. Single-particle diffraction and interference

- historical context
- experimental and theoretical modeling
- comparison with Bohmian mechanics

Lecture 14: March 20. More boundary interactions

- scattering off a submerged pillar: the logarithmic spiral
- interaction with a submerged well: Friedel oscillations
- motion over sloping topography

SPRING BREAK March 25-29. NO CLASS

Lecture 15: Apr. 1. Non-resonant effects

- ratcheting pairs, orbital instability, tunneling
- stability of droplet pairs and rings
- erratic motion in the hydrodynamic corrals

Lecture 16: April 3. Crossing the threshold

- the Faraday-Talbot effect
- droplets walking above the Faraday threshold
- superradiant droplet emission
- ponderomotive effects in the corral and Kapitza-Dirac diffraction

Lecture 17: April 8. Corrals

- circular corrals: periodic and chaotic motion
- statistical projection effects in elliptical corrals
- the mean pilot-wave potential and its relation to the quantum potential
- modeling attempts

Lecture 18: Apr. 10. Motion in 1D cavities

- conformal maps in HQA
- single-particle tunneling; superradiant tunneling pairs
- droplet correlations at a distance

Patriot's Day: April. 15. No class.

Lecture 19: April 17. Droplet lattices

- spin lattices: long-range correlations and phase transitions
- Anderson localization

Lecture 20: April 22. Hydrodynamic interferometry

- real surreal trajectories
- the misinference of interaction-free measurement
- the Elitzur-Vaidman bomb tester

Lecture 21: April 24. Generalized pilot-wave framework

- spin states, in-line oscillations and chaotic motion
- orbital dynamics in a Bessel potential
- 3D classical pilot-wave theory

Lecture 22: April 29. Hydrodynamically-inspired pilot-wave theory for the microscopic scale

- extending de Broglie's double-solution pilot-wave theory
- towards a relativistic pilot-wave theory

Lecture 23: May. 1. Bell's Theorem

- the implications of Bell violations in quantum mechanics
- towards hydrodynamic Bell tests

Lecture 24: May. 6. Analog gravity

- hydrodynamic analogs of GR
- walkers as a vehicle for single-particle GR analogs

Lecture 25: May. 8. STUDENT PRESENTATIONS

Lecture 26: May. 13. STUDENT PRESENTATIONS. **Course Projects Due**