Math 534: Projects

1. Discrete sine-Gordon equation and sine-Gordon PDE
   Starting point: Physica D 14, 88-102 (1984). Possible Topics: collision of kinks, \(4\pi\), \(6\pi\) etc. kinks, stability, and dynamics.

2. Nonlinear Waves and their Interactions in Continuum and Discrete \(\phi^4\) models

3. Population Dynamics in Heterogeneous Environments

4. Continuum and/or Discrete Models of Neurons

5. Nonlinear Fiber Optics
   Starting Point: Review of Modern Physics 61, 763-915 [see particularly about the nonlinear Schrödinger equation]. Possible Topics: Study of the cubic NLS with a (quintic and/or impurity) perturbation.

6. Chemical Kinetics
   Starting Point: SIAM Review 42, 161-230 (2000) [see particularly about the KPP equation]. Possible Topics: Fronts, their dynamics, stability and potential dragging.

7. Discrete Nonlinear Optics

8. Catalytic Reactions and Chemical Turbulence

9. Calcium Waves in Cardiac Cells

10. Focusing/Blowup and Wave Collapse

11. Combustion and Flames

12. Water Waves
    Starting Point: Strauss, Chapter 14 (and references therein). Possible Topics: Korteweg-deVries equation, perturbations, discrete versions, dynamics and stability of solitons.

13. Photonic Crystals and Photorefractive Lattices
    Starting Point: New Journal of Physics 6, 47 (2004). Possible Topics: 1d propagation in double well, triple well or multi-well potentials; 2d propagation of discrete solitons, discrete vortices, higher charge vortices and multipoles.

14. **Special Emphasis Topic**: Bose-Einstein Condensates

15. Your own choice (in coordination with PK).
In the project, you are expected to study deeply with analytical and/or numerical methods that you should find in the existing literature, a topic of your own choice relating to the application of a (preferably nonlinear) partial differential equation to a specific physical, chemical, biological, engineering or other setting.

You should spend a considerable amount of time familiarizing yourself with the relevant model and examining in detail the methods developed mathematically or computationally to study it. You should be able to reproduce relevant calculations and computations and be familiar enough with them to present them in detail.

You are expected to compose a writeup of 10-20 pages which is to be sent to PK in .pdf form by the day of the class workshop. You are also expected on the day of the class workshop to make a 15-minute (per person involved in the project) presentation of the work you carried out in your project over the semester.

A rough guideline for your writeup is the following.

- You should have an introduction presenting the physical problem and the model PDE that is relevant for it.
- You should have a results section that presents the analysis and mathematical and/or numerical results that you have obtained from it.
- Finally, you should also have a conclusions and future plans sections, detailing the outcome and impact of your results to the physical problem of interest and what possibly could be done in the future.

A rough timeline for the work of your project is as follows:

- In February, you should formulate the project in consultation with PK.
- In March you should read the relevant literature and finalize your plans about what to do (by March 17, you should send to PK a title and abstract of what you plan to study and accomplish in your project).
- In April and beginning of May you should spend a fair amount of time performing the relevant tasks (a rough guide is that you should spend, on a weekly basis, twice the time spent in your homework, for your project).
- In May, you should also collect your results in the relevant writeup and presentation for the class workshop (that will take place right before the finals).