Project name: Using mathematical modeling, develop insight into polymer thin-film dynamics subject to surface-tension-gradient forces

Resources: (references given at the end of the document)

Appreciate the motivation behind this study (look up other references online with ref-4 as a starting point)

Module 1a: Developing fundamental understanding of fluid mechanics (4-5 weeks)

- Basics of transport phenomenon[1]
  - scalars, vectors, and tensors[1] (self-study)
  - shell balance for heat/mass/momentum transport (self-study)
  - application to 2 model problems: flow between parallel plates and pressure-driven flow (work out examples on your own and walk me through it)
  - surface tension and its effects[3] (self-study)
- Navier-Stokes equation[1]
- dimensionless groups and their importance
- lubrication theory[2] (Here, I will conduct a short session on the concept and direct them to some useful resources (ref-2 being one of them) to learn more)
  - understand assumptions and the simplified modeling approach
- boundary and initial conditions[1]
  - stress balance at deformable interfaces
- research further on Marangoni-driven patterning of polymer films (use google scholar, web of science)
  - appreciate the basic concepts learnt above to real-world applications
  - think critically about open problems in this field
    (I will eventually help narrow down on specific problem statement)

Module 1b: Familiarizing with the research toolkit (3-4 weeks)

- numerical methods to solve PDEs (read about various tools)
  - finite-difference, finite element, finite volume- which one to choose?
- MATLAB (or Python) programming for solving the governing equations
  - learn basics like for loops, defining arrays/variables, using built-in solvers, plotting tools
  - solving PDEs/ODEs, implementing periodic boundary conditions
- linear analysis/perturbations theory[2]
  - basic assumptions and conditions for validity (does it apply to the system under study?)
- validate code
  - use ideas from linear analysis (think critically, how?)

Module 2: Run numerical simulations (8 weeks)

- validate model predictions with experimental studies in literature
- identify drawbacks in the field so far- and propose research investigation to advance the scientific understanding in the domain
- independently compare your results with some recently published data
- propose some ideas for future research and design experiments to validate the findings

Module 3: Research presentations (8 weeks)

- write a scientific report detailing key findings- 10 pages.
- prepare and give an oral presentation- ~10 min
- write a cover letter to a faculty with an intention of applying for a summer internship in their research lab.

At the end, I'll provide guidance in the US/Europe graduate schools admission process (writing SOPs, preparing for GRE/TEOFL, selecting universities, writing emails to faculties to express interest)

References:

1. Transport Phenomena (2nd Edition) by Bird, Steward and Lightfoot.

(https://www.eng.uc.edu/~beaucag/Classes/AdvancedMaterialsThermodynamics/Books/R.%20Byron%20Bird,%20Warren%20E.%20Stewart,%20Edwin%20N.%20Lightfoot%20-%20Transport%20Phenomena,%202nd%20Edition-Wiley%20(2001).pdf)

2. Long scale evolution of thin liquid films, A. Oron et al., Rev. Mod. Phys. 67 (1997) 931
3. Intermolecular and Surface Forces by J. Israelachvili (https://www.eng.uc.edu/~beaucag/Classes/AdvancedMaterialsThermodynamics/Books/Jacob%20N.%20Israelachvili%20-%20Intermolecular%20and%20Surface%20Forces,%20Third%20Edition_%20Revised%20Third%20Edition-Academic%20Press%20(2011).pdf)
4. Patterning by Photochemically Directing the Marangoni Effect, ACS Macro Lett. 1 (2012) 1150