Prof. M Reza Kholghy
Energy and Particle Technology Laboratory
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Micro- and Nanoparticle Technology (MAAE4906) FS2021

Why taking this course is important? Particles are omnipresent. We inhale millions of particles with the air we breathe[1]. Dental fillings or medications we take have several types of particles mixed together. The tires on our cars rely on carbon black nanoparticles for their strength. Quality of the paint on the walls depends on the morphology of nanoparticles in it. Batteries in electronic devices use nano or micron-sized carbon and nickel[2] particles for energy storage. Metal particles such as iron, and aluminum are used for chemical energy storage and transport[3]. Particles are even used to purify human blood from dangerous pathogens[4] or make gas sensors for breath analysis[5]. Particles also play an important role in our environment. One example is soot (Black Carbon), arguably the oldest nanoparticle produced due to anthropogenic activity, which is a major air pollutant in Canada and around the world. Its emissions from combustion processes or fires (~8 M tons/y) are responsible for a wide range of health problems and it is the third strongest contributor to global warming[6]. Accurate assessment of the environmental and health impact of soot requires knowledge of its morphology, chemical composition, and optical properties which are traced to the particle formation process. The potential for an understanding of the behavior of particles at the nanoscale makes particle technology exciting and facilitates fabrication of new particles with unique properties and their integration into devices[7].

Course content: Introduction to fundamentals of particle dynamics including diffusion and coagulation. Micro- and nanoparticle synthesis and processing, their applications and environmental impact. Sampling of nanoparticle and measuring techniques to characterize their size distribution, morphology and optical properties. Modeling of nucleation, agglomeration, surface growth and optical properties of particles. Combustion made nanoparticles as functional materials and pollutants. Radiative transfer and remote sensing. Energetic Particles.

Prerequisites: This is an EXCEPTIONALLY demanding course, and you should dedicate at least 15 h/week (3 h lectures, 6 h reading and preparation, 6 h assignments) to it. You need to have a strong understanding of calculus and ordinary differential equations (MATH1004 & 1104) and chemistry (CHEM1101) and passed *Computation and Programming, (ECOR1041), Fluid Mechanics I (MAAE2300), Thermodynamics & Heat Transfer (MAAE2400)*, with high marks. Having knowledge of Heat Transfer (MECH 4406) and Fluid Mechanics II -Differential relations for fluid flow- (MAAE3300) is a plus.

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[1] Watch "Something In The Air" from The **Nature of Things** by David Suzuki
[2] https://nickelinstitute.org/about-nickel/nickel-in-batteries/
[3] Bergthorson, J.M., 2018. *Prog. Energy Combust. Sci.*, *68*, 169.
[4] Magnetic nanoparticles used in blood purification to cure sepsis
[5] Guntner, A.T., Abegg, S., Konigstein, K., Gerber, P.A., Schmidt-Trucksass, A. and Pratsinis, S.E., 2019. *ACS sensors*, *4* ,268.
[6] Quaas, J., 2011. The soot factor. *Nature*, *471*(7339), 456-457.
[7] How is nanotechnology affecting your wine, gut and climate?

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Course Organizer: Prof. M. Reza Kholghy

Guest Lecturers: Dr. Fengshan Liu (Senior Research Officer at NRC)
Dr. Prem Lobo (Team Leader at NRC)
Prof. Thomas Walker (Carleton University)
Dr. Florin Saceleanu (Carleton University)

Time, place: Monday & Wednesdays, 16.05 – 17.25, Live Lectures on Zoom

Fundamentals

08 to 15.09. Gas Properties, Particle Motion & Size Distributions, *Ch#2, 3, 4 & 20*
Suggested readings: G.D. Ulrich,1984. Flame Synthesis of Fine Particles, Chem. Eng. News 62 (34)
Strobel, R. and Pratsinis, S.E., 2007. Flame aerosol synthesis of smart nanostructured materials. J. Mater. Chem., 17, 4743.

20 & 22.09. Continuum & Free Molecular Regimes, Particle Diffusion, *Ch#7 & 8*
Exercise 1 on Particle Size Distribution due on 22nd

27 & 29.09. Brownian Coagulation, *Ch#7,8 &12*
Exercise 2 on Diffusion due on 29th

04 & 06.10. Shear Coagulation, Sintering, Agg(reg/lomer)ates, *Ch#7*
Exercise 3 on Coagulation I due on 6th

13 & 18.10. Critical Size - Condensation Surface Growth – Nucleation, *Ch#13*
Exercise 4 on Coagulation II due on 18th

25 & 29.10. Fall Break, No Lectures or Assignments

01 & 03.11. Light Absorption & Scattering by Nanoparticles (Dr. Fengshan Liu), *Ch#16*
Exercise 5 on Critical Size and Nucleation due on 1st
Mini Project 1 on Particle Brownian Motion due on 3rd

Practical Applications

08 & 10.11. Characterization of Particles, Fixed and Fluidized Beds, *Ch#10&15*
Exercise 6 on Optical Properties due on 10th

15 & 17.11. Separations: Solid Liquid & Solid Gas Systems
Exercise 7 on Flow Through Particle Beds due on 17th

22 & 24.11. Forces on Particles, Combustion Synthesis of Materials, *Ch#3, 5*
Exercise 8 on Separations due on 24th

29.11. Radiative Transfer and Remote Sensing (Prof. Thomas Walker)

01.12. Energetic Particles (Dr. Florin Saceleanu)
Exercise 9 on Forces on Particles due on 1st

06.12. Black Carbon Emissions from Aviation & Marine Engines (Dr. Prem Lobo)

08.12. Review
Exercise 10 on Remote Sensing and Black Carbon Emissions due on 8th

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- **Grading:**

- Exercises, 5 points each (40 points+10 bonus) expected work: 6 hours each
  Minimum of 8 Exercises are needed to pass the course
- Mini Project, (10 points) expected work: 15 hours

- Final Exam (50 points)

- Exercises and Mini projects are individual work and students must not collaborate or share solutions with each other. The final exam might include detailed questions about Exercises and Mini projects.

- Exercises and Mini project reports will be submitted electronically as a PDF file and must be typed or written with stylus using a tablet or in blank letter paper (8.5 * 11 inches) and scanned. 20% of their mark is dedicated to the style and organization of the writing.

- Students are not allowed to post exercises or projects online in any format.

- **Teaching Assistant:** Jason Scott, JASONSCOTT3@cmail.carleton.ca

- **Office Hours:** by appointment only

Required Reference:

1. Aerosol Technology: Properties, Behaviour, and Measurement of Airborne Particles, W. Hinds, Wiley, 2nd Ed, 1982 or 1999.

Recommended Additional Reference:

1. Smoke, Dust and Haze, S.K. Friedlander, Oxford, 2nd Ed, 2000.
2. Powder Technology: fundamentals of particles, powder beds, and particle generation. Masuda, H., Higashitani, K. and Yoshida, H. eds., 2006. CRC press. (E book is available on Carleton Library)
3. Atmospheric Chemistry and Physics, J. H Seinfeld, S. N. Pandis, Wiley, 3rd Ed. 2016