Prof. M Reza Kholghy
Energy and Particle Technology Laboratory
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Micro- and Nanoparticle Technology (MAAE4906) FS2022

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, nickel and high purity alumina[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.

Prerequisites: This is a demanding course, and you should dedicate at least 9 h/week (3 h lectures, 1.5 h PA sessions, 4.5 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. Tim Sipkens (Metrology Center, NRC)
Dr. Keun Su Kim (SDT Research Centre, NRC)

Lectures: Monday & Wednesdays, 16.05 – 17.25, Southam Hall 318
Problem Analysis Sessions, Wednesdays, 8.35-9.55, Canal Building 3101

Fundamentals

7, 12 & 14.9. 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.
Project presentations by mentors on 12.9

19 & 21.9. Continuum & Free Molecular Regimes, Particle Diffusion, *Ch#7 & 8*
Coaching on proposal writing on 21.9

26 & 28.9. Brownian Coagulation, *Ch#7,8 &12*
Exercise 1 on Particle Size Distribution due on 25.9
2-page mini-project proposals are due on 25.9

3 & 5.10. Shear Coagulation, Sintering, Agg(reg/lomer)ates, *Ch#7*
Exercise 2 on Diffusion due on 3.10
Marked proposals will be returned during the PA session on 5.10

12, 17 & 19.10. Critical Size - Condensation Surface Growth – Nucleation, *Ch#13*
Exercise 3 on Coagulation I due on 9.10

24 & 26.10. Fall Break, No Lectures or Assignments

31.10 & 02.11. Light Absorption & Scattering by Nanoparticles, *Ch#16*
Exercise 4 on Coagulation II due on 30.10
Midterm during the PA session on 2.11

Practical Applications

7 & 9.11. Characterization of Particles, Forces on a Single Particle, *Ch#10&15*
Exercise 5 on Critical Size and Nucleation due on 7.11

14 & 16.11. Fixed and Fluidized Beds
Exercise 6 on Optical Properties due on 14.11
Coaching on preparing presentations on 16.11

21 & 23.11. Separation, Solid-liquid & Solid-gas systems, *Ch#3, 5*
Exercise 7 on Forces on a Single due on 21.11

28 & 30.11. Nanoscale Heat Transfer & Laser-Induced Incandescence (Dr. Sipkens)
Exercise 8 on Particles Flow Through Particle Beds due on 28.11
Final project presentations by students on 28.11

05 & 07.12. Nanoparticle Synthesis by Thermal Plasma Jets, (Dr. Kim)
Exercise 9 on Separations due on 4.12, Coaching on report writing on 7.12
Exercise 10 on Particle Brownian Motion due on 11.12

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- **Grading:**

- Exercises, 4 points each (40 points+10 bonus points) expected work: 4.5 hours each
  Minimum of 8 Exercises are needed to pass the course

- Midterm and Final Exam (20+40 points)

OR

Mini- Project, (2-page proposal, final presentation, & report, 15+15+30 points)

- Exercises and 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 projects.

- Exercises and 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:** Mo Adib, MoAdib@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
4. Powder Technology Handbook, 4th Eddition, 2019, Higashitani, K., Makino, H. and Matsusaka, S. (E book is available on Carleton Library)