Chapter 1

1. *How many molecules are in 10nm diameter water droplet? What about 1-mm rain drop? Ans. $1.8x10^4$,$1..8x10^{19}$*
2. *A person inhales approximately 20mg of tobacco smoke particles from one cigarette. If smoke particles are standard–density (ρ_p=1g/cm^3) spheres of 0.4um in diameter, what is the surface area of this amount of smoke? Ans. 0.3m^2*
3. *Determine the ratio of the surface area of a sphere to that of a fiber with the same volume. Assume that the fiber is a cylinder with a diameter equal to 20% of the diameter of the sphere. Assume the sphere and the fiber have standard density.*
4. *(Open problems)Read Feynman's article named "There are plenty of rooms at the bottom". What did he mean by "the bottom"? What mentioned by him came true nowadays? When?*
5. *(Open problems) Investigate recent 1-year achievement in nanoparticle technology. What made difference in our life?*
6. *(Open problems) What are in Lycurgus cup? What makes the cup colorful?*

Chapter 2

1. *A particle sampling instrument classifies an aersol into seven channels. A stream of particles is measured and gives the following numbers of particles in each channel of the device.*

(a) *Plot the size distribution function as a histogram where the number of particles measured in each channel is assumed to be concentrated at the arithmetic midpoint of the size range.*

(b) *(b) assuming that all the particles have the same density, plot the mass distribution function as a histogram.*

(c) *Estimate the number and mass median diameters of this aerosol.*

Channel	*Size range(nm)*	*Numbers*
1	0-15	80
2	15-23	140
3	23-32	180
4	32-45	220
5	45-60	190
6	60-80	60
7	>80	0

2. *For lognormal count and mass distribution of the same particle sample prove their standard deviations are equal.*
3. *An asbestos fiber is 10um in length with a circular cross-section of 0.5-um diameter. Find the diameter of a sphere that has the same volume as the fiber.*

4. *Prove the Hatch-Choate conversion equation when q=3.*
5. *For the log-probability diagram shown in the lecture note find the geometric standard deviation of the sample.*
6. *Express count distribution function in terms of mass distribution function.*
7. *An aerosol has a lognormal particle size distribution with a mass median diameter of 100nm and a geometric standard deviation of 2.5 What is the count median diameter? Assume* ρ_p*=2500kg/*m^3*.*
8. *An aerosol with a lognormal size distribution has a count median diameter of 2.0um and a geometric standard deviation of 2.2. If the mass concentration is 1.0mg/m3, what is the number concentration? Assume spherical particles with* ρ_p*=2500kg/*m^3*. Ans.* $5.8x10^6/m^3$
9. *Aerosol with a lognormal size distribution has a count median diameter of 0.3um and a GSD of 1.5. If the number concentration is* 10^6 *particles/*cm^3*, what is the mass concentration? The particles are spheres with a density of 4500kg/m3. Ans. 130mg/*m^3

10. Calculate the effective electron wavelength for electrons having 100KeV and 400keV energy. Ans.0.37nm What will be the resolution with 100KV TEM instrument if 0.2nm resolution is obtained by 400KV?

Chapter 3

1. *Assuming a Fermi energy of 5eV, calculate the spacing between energy levels for 10-, 100- and 100,000-atom metal particles.*
2. *Calculate the energy required to add a single electron to palladium particles with d=17nm. At what temperature can the electron transfer to the particle by single electron tunneling.*
3. *From a XRD pattern of silver particles, the half width of the primary peak at* $2\theta=38.16^o$ *is* 0.18^o*. Calculate the diameter of the silver crystallite. Assume the wavelength of X-ray used is 0.154nm. Ans. 46.7nm*
4. *Estimate the surface area per gram of the silica gel when from BET plot of nitrogen adsorption the slope of the curve is* $12X10^{-3}$ cm^3*/g and its intercept on the ordinate is* $0.1X10^{-3}$ cm^{-3}*. Ans. 550*m^2*/g*
5. *Calculate the smallest diameter of the pore which mercury can penetrate at a pressure of 3500psi? Ans.25nm*

4. (Open problem) What are candidates for deformation and fracture candidates? Explain.

5. (open problem) Kelvar, a form of poly(p-phenylene terephthalamide) was invented by DuPont chemist Stephanie Kwolek; she was inducted into the National Inventor's Hall of Fame in1995 for this important invention. Kelvar has an ultrahigh Young's Modulus(1.8x105 MPa), as well as high tensile strength and high thermal stability, and low extension at the break point. Investigate where the strength of Kelvar come and explain the strength in terms of its structure. Also itemize its *application.*

6. (Open problem) Early measurement of the elastic constants on nanocrystalline materials gave the value of E, Young's modulus that were significantly lower than the values for conventional grain size materials. Now it is believed that for most nanostructured materials (grain size>10nm), E are not unique peoperties and not a "negative". What makes this conclusion? Explain.

7. (Open problem) What kinds of dislocation exist? Investigate how the dislocations move. Explain differences between the two dislocations min movement and its result.

8. (Open problem) Nanoparticles often exist in higher- temperature phase or higher-pressure phase. Why? Show some example for each.

9. (Open problem) What is dielectrics, ferroelectris, pyroelectrics, piezoelectricity, respectively?

10. Explain the principle of single electron transistor.

Chapter 4

1. What is Kelvin ratio is necessary to maintain the size of 0.05-um pure water droplets at 293K? What is the vapor pressure of the droplet for this situation? Vapor pressure of the water at 293K is given 2.34kPa. Ans. 1.044, 2.44kPa

2. What are the diameters of the critical nuclei of water droplet at 273K and saturation ratio of 3 and 4, respectively? Calculate nucleation rate of water droplets at this condition. What is the critical supersaturation ratio for water droplet formation at 300K? for water at 273K, σ*=76.1 dyn/cm and* p_0*=4.58mmHg.*

Ans.

3. What is the minimum relative humidity necessary to keep a 0.2-um-diameter water droplet from evaporating? Ans. 101.2%

3. What change in number concentration and particle size will occur during a 10-min period for a 0.8-um monodisperse aerosol having an initial number concentration of $10^8/cm^3$*? Assume simple monodisperse coagulation under standard conditions.*

6. *By what factor does the average particle size of tobacco smoke increase due to coagulation during the 2s it takes for the smoke to travel from the cigarette to your lung? Assume that the concentration leaving the cigarette is* $3\times10^9/cm^3$ *and K=7.0×10-10* cm^3/s *and is constant. Ans. 1.7*
7. *(Open problem) Discuss how do the crystalline particles grow by condensation and their crystallinity affect the growth mechanism.*

Chapter 6

1. What is the surface area of 1g of a monodisperse particles with standard density if the particle diameter is 10nm and 1um? An.s $6m^2/g$*, 60,000*cm^2/g

2. The specific area of Si nanoparticles is defined as the ratio of the total area of the particles divided by the total mass of the particles. For a particular synthetic technique this property was found, using inert gas adsorption/desorption, to be 20 m2/g. Assume that the particles are uniform spheres. What would be the radius of these particles if they are assumed to be uniform spheres of density 2.0 g/cm^3? Ans. 75nm

3. Calculate the van der Waals force between 10nm nanoparticles. Hamaker constant is 1x10^{-19}J, and separation distance is 0.4nm. What is the gravitational force of the single particle with density of 1000kg/m^3? What is the liquid-bridge force in this case assuming the two particles contact? The surface tension of water is 0.072N/m. Ans. 4.18x10^{-11}N, 5.1x10^{-21}N, 2.26x10^{-9}N

4. (Open problem) Low surface tension is important in our lungs to keep them from collapse. Explain how our alveoli achieve this.

5. (Open problem) A new coating made by copolymerization of esters of fluoroalkyl alcohols with functionalized vinyl monomers gives a nonstick material that cannot be wetted by solvents. Although the nonstick surface has some similarities to Teflon (also a fluorinated polymer), there is a major differences in that Teflon must be heated to get a good coating, and this material is heat sensitive. However, the surface of this material is so nonstick that magic markers, which will wet Teflon, cannot wet this surface. Investigate the detailed structure of this coating. Explain what makes it very durable and so nonstick. Discuss its application.

Chapter 7

1. *What is Re in the wake of a micron-sized particle moving at a velocity of 1 micron/sec? Ans. Re = $10^{-6}\times10^{-6}\ \times10^{3}\ /10^{-3} = 10^{-6}$*
2. *Derive an expression for the aerodynamic diameter of a cylindrically shaped particle of diameter D and length L in terms of D, L, ρ_p, χ.*
3. *For a 0.15-um diameter spherical particle (ρ_p=2500kg/m^3), determine the Cunningham correction factor and the terminal settling velocity at a standard conditions. Ans. 2.11, 3.6x10^{-6}m/s*
4. *In 1883, the volcano Krakatoa exploded, injecting dust 32km up into the atmosphere. Fallout from this explosion continued for 15months. If one assumes the the settling velocity of the particles was constant and neglects slip correction, what was the minimum particle size present? Assume that the particles are rock spheres with a density of 2700kg/m^3. Ans. 3.2um*
5. *What is the drag force on a doublet composed of 2-um-diameter spheres traveling at its terminal settling velocity? The particle density is 3000kg/m3. Neglect slip correction. (Hint: There is an easy way to do this; review the derivation of the equation for terminal velocity of Stokesian particles. Ans. 2.5x10^{-13}N*
6. *how many elementary charges are acquired by a 100-nm water droplet in 1s by (a) diffusion charging in an ion concentration of 1013 /m3 and (b) field charging in an concentration of*

1013/m3 and an electric field of 600kV/m Ans. (a) 0.013, (b) 0.13

7. *What is the maximum charge for a negatively charged 100-nm sphere? Ans. 156*
8. *Determine the diffusion coefficient of a cigarette smoke particles(sphericaql shape, d p=250nm, ρp=900kg/m3. Assume T=20oC. Ans.* $1.62x10^{-6}cm^2/s$
9. *A hundred particles of equal size and density are released simultaneously and allowed to settle instill air for 5min. Because of Brownian motion along the vertical axis, some particles will progress farther than others. If the particles are 60-nm spheres of standard density, what are the mean and standard deviation of their displacements from origin after 5min?*
10. *What is the diffusion constant of a 1 micron-radius particle and a 1 nm-radius particle, both in water at room temperature?*

    Ans. D = 0.2 $\times 10^{-12}$ m^2*/sec, or equivalently D = 0.2 microns*^{2}*/sec, D = 200 microns*^{2}*/sec.*
11. *Estimate the diffusion constant of a sucrose molecule in water, modeling it as a sphere of some suitable radius. Compare your result with the known diffusion constant obtained from, e.g. the CRC Chemistry and Physics Handbook*
12. *A neurotransmitter molecule which is roughly spherical and of radius 0.5 nm is synthesized in the cell body of a neuron in your lower back. How long will it take to diffuse down the long, skinny axon to the synapse in your toe where it will be used to transmit a signal to one of your toe muscle? (this axon is a few microns wide, and about 1 m in length). Hint: this is one-dimensional diffusion*
13. *A sodium-chloride particle 3.0um in diameter flows between two vertical parallel plates 1mm apart maintained at* 40^oC *and* 0^oC*. What is the thermophoretic velocity toward the cooler plate? Ans.* $2.3x10^{-4}m/s$
14. *What are the velocity, acceleration and distance traveled of a 6-um water droplet 100us after release in stationary air?*

Chapter 8

1. *Determine the diameter and number of Stairmand HE gas cyclones to be operated in parallel to treat 1m3/s of gas of density 1.2kg/m3 and viscosity 18.5x10-6Pa s carrying a dust of density 1000kg/m3. An dp50 of at most 5um is to be achieved at a pressure drop of 1200kPa. Ans. One cyclone, 0.714m in diameter, dp50=3.6um*
2. *Air at 298K and 1atm flows at the rate of 5.0m3/s and carries with it particulate matter with a density of 1500kg/m3. The body diameter of the cyclone is 2.0m and a value of K, the geometric configuration parameter, of 551.3. Estimate the collection efficiency of the cyclone for 10-um particles. Ans. 0.742*
3. *What is the cut diameter d50 of round jet impactor operating at 1.0L/min if the jet diameter is 1mm. Assume that the impactor meets recommended design criteria. Ans. 1.28um*

4. *The fifth stage of the Andersen impactor has 400 holes, each 0.0135 inches in diameter. What is the theoretical d_{p50} of this stage for standard-density spheres at an impactor flow rate of 2ft3/min?*
5. *A filter has a fiber diameter of 10um and a solidity of 1%. What face velocity will give a particle size of minimum efficiency of 0.5um? Ans.0.12m/s*
6. *What minimum efficiency is predicted for a filter with t=1mm, solidity of 0.5, d_f=2um and U_0=0.1m/s? Ans. 56%*
7. *A fabric filter has 1000m^2 of filtering area and treats 10m3/s of air carrying a dust concentration of 0.005kg/m^3. Assume R_m=20kPa s/m and K=1.0x105s-1. If the filter must be cleaned when the pressure drop reaches 2.0kPa, after what period must be cleaning occur? Ans. 10h*

Chapter 9

1. *(Open problem) What are the important properties required for the particles to be used for dispersion? What properties are important for consolidation for porous materials? What about dense phase materials?*
2. *(Open problems) In supercritical fluid drying for aerogel, discuss its advantages and disadvantages. What is the role of solvent exchange? Why is solvent exchange required?*
3. *An interesting and very important laboratory growth process is the replication of DNA outside of living organism through a process called the polymerase chain reaction. This method is used in criminal cases to determine whether a particular sample of DNA matches a specific person. One starts with a small sample of human tissue such as blood or hair found at a crime scene. This is usually a very small quantity, perhaps a single drop of blood or a single hair. Explain the procedure of the polymerase chain reaction.*

7. *Search for an example for preparation of a nanowire in irradiation tracked-etched polycarbonate memebranes as a template by electrophoresis. How was it made and what were the important variables in the preparation process?*
8. *Wang et al.(Y.C. Wang, I.C. Leu and M.N. Hon, J. Mater. Chem., 12, 2439(2002)) used electrophoretic deposition to form nanorods of ZnO from colloidal sols. ZnO colloidal sol was prepared by hydrolyzing an alcoholic solution of zinc acetate with NaOH, with a small amount of zinc nitrate added to act as a binder. This solution was then deposited into the pores of anodic alumina membranes at voltages in the range of 10-400V. It was found that lower voltages led to dense, solid nanorods, while higher voltages caused the formation of hollow tubings. Discuss what makes such difference.*

Chapter 10

1. *Discuss on 1947-Texas disaster. What caused the explosion and how did the explosion proceed.*

Compare Ryongchon disaster in 2003 with it.

2. *A combustible dust has a lower flammability limit in air at 20^oC of 0.9% by volume. A dust extraction system operating at 2m3/s is found to have a dust concentration of 2% by volume. What minimum flow rate of additional air must be introduced to ensure safe operation? Ans.2.44m3/s*
3. *It is proposed to protect a section of dust used for pneumatically transporting a plastic powder in air by adding a stream of nitrogen. The air flow rate in the present system is 1.6m3/s and the air carries 3% powder by volume. If the minimum oxygen for combustion (by replacement of oxygen with nitrogen)of the powder is 11% by volume, what is the minimum flow rate of nitrogen which must be added to ensure safe operation? Ans. 1.36m3/s*
4. *According to Table 1, what section of the respiratory system has the highest Reynolds number, and what is the Reynolds number at an inhalation flow rate of 3.6m3/hr. Ans: Trachea, 4200*
5. *What fraction of inhaled 5-um particles will deposit in the head airway region?*

Assume standard density and an adult engaged in light work. Ans. 0.89

Estimate the fraction of 3.0-um particles (ρ_p=4000kg/m^3) that deposits in the alveolar region for an average adult. Ans. 0.045

6. *An aerosol is composed of equal numbers of 0.02- and 2.0-um particles. Estimate the fraction that will deposit in the alveolar region based on number and based on mass. Ans. 0.31, 0.14*
7. *Calculate the inhalable and thoracic fractions for 7-um spheres of standard density. Assume that the external air velocity is less than 4m/s. Ans. 0.83, 0.74*