Bioreactor:

Dissolve oxygen is essential for cell growth in a bioreactor. Due to the low solubility of oxygen in water, chemical engineers often need to design a bioreactor with maximized oxygen transport. In our lab is a bioreactor for aerobic fermentation. Your task is to determine the oxygen mass transfer characteristics of the bioreactor, mainly volumetric mass transfer coefficient $k_L a$ as a function of air flow rate and agitation speed for a constant temperature operation.

There are two dynamic methods for determining, $k_L a$, the volumetric mass transfer coefficient – the aeration method and the deaeration method. I would suggest that you use *at least* 4 different agitation speed and three air-flow rates for each of these methods so that you obtain $k_L a$ as a function of agitator speed and air flow rate for each. You should develop an empirical correlation for $k_L a$ [$k_L a = f$(agitation speed, air flow rate)] for each method, compare the results and indicate what conditions maximizes oxygen transfer. One of the considerations in these experiments is the response time of the oxygen electrode. Measure the response time of the existing probe and model the results with a first-order time constant. Discuss in your report the effects the probe response might have on your $k_L a$ measurements.

Please include this assignment in your report as an appendix but do not cite it in the body of your report.

Bubble-cap Distillation Column

Please operate the laboratory distillation column in two modes: 1) at total reflux and 2) when top and bottom products are being taken with a recycle ratio of approximately twice the minimum recycle ratio. Determine the overall and stage-by-stage efficiency of the laboratory distillation column under these two modes of operation. Please assure that the distillation column is operating at steady state before samples are taken for your analysis of the efficiency.

For your oral exam please predict the overall stage efficiency from a correlation available in the literature. For this calculation, assume that the column capacity is limited by flooding considerations and make your estimate of overall efficiency at 80% of flooding. Also be prepared to discuss errors in your experimentally measured quantities and error propagation of the overall stage efficiency determined. Which mode of analysis and operation will give the lowest errors?

An estimate is needed of the capacity (GPM of Feed) of the laboratory distillation column to process a 15% ethanol in water stream and to produce a 95% ethanol product. The approximate reflux ratio, the reboiler duty required, the optimum feed plate location and the expected percent ethanol recovery are to be specified.

You are to make this estimate based upon the results of operation of the same laboratory column on the water-isopropanol solution available. Necessary corrections to these laboratory data are to be made based upon standard correlations, to permit the evaluations needed for the ethanol-water system.

Be prepared in your oral quiz to address the following:
a) Safety issues with this experiment
b) Equipment operation
c) Data sheets
d) Other germane points with respect to this experiment

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Double Pipe Heat Exchanger

One technique for the determination of individual heat-transfer coefficients from heat exchanger data was originally suggested by E.E. Wilson many years ago. This method is described on page 345 of the book by W.H. McAdams, *Heat Transmission 3rd Ed.*, McGraw-Hill Book Co. New York, N.Y. (1954).

(a) By use of this technique, you are to determine the water side heat-transfer coefficient at water velocities of 1, 2, 4 and 6 ft/sec in the double-pipe heat exchanger.
(b) Compare your measured coefficients to published correlations and explain any discrepancies in your report.
(c) Calculate the "dirt" coefficient (fouling factor) for the heat-exchanger tube by assuming that the steam side coefficient can be calculated by use of the Nusselt equation for film-type condensation. Compare these measured "heat-transfer coefficients for deposits" to published data (see Perry's Chemical Engineers Handbook 5^{th} edition, p. 10-38-39 (Table 10-9 and 10-10) and comment on the relevance of your results in your report.

Be prepared in your oral quiz to address the following:
a) Safety issues with this experiment
b) Equipment operation
c) Data sheets
d) Other germane points with respect to this experiment

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Fluidized Bed

Using the two types of diatomaceous earth samples we have in the lab (swimming pool grade and food grade), determine

1) the minimum fluidization velocity, u_{mf}, and the pressure drop and compare them with the various correlations published for minimum fluidization velocity. For the correlations you will need to characterize the particle size distribution and the particle shape factor.
2) the bed expansion and pressure drop above minimum fluidization from 1.0 u_{mf} to 2.0 u_{mf}, and
3) the rate of elutriation of material from the bed (gms/min in a bed of 1 kg, for example at $1.2u_{mf}$ and 1.4 u_{mf})

Above the minimum fluidization velocity the bed will become a bubbling fluidized bed which will give difficulty in measuring the bed height such that determining the min and max height is a more realistic way of measuring the bed height than trying to determine the average bed height. In addition to the bed height, please determine the pressure drop over the bed. Be sure to remove the pressure drop associated with the distributor plate so that only the pressure drop in the bed is given in your data. In your report please develop graphs of the min/max bed height and min/max pressure drop over the bed. Compare these graphs to those developed using theory associated with fluidized bed operation for this distribution of particle sizes. A microscope is available in the lab to measure the particle sizes and shapes which can be automated with the software ImageJ.

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Ebulliometer

You are to develop a comparison of the various methods available in the senior laboratory to measure the amount of ethyl alcohol in water. The various analytical methods that are available are reviewed in the website:

http://www.winegrowers.info/wine_making/Alcohol.htm

One of these methods is the ebulliometer, others are potentially the gas chromatograph, densitometer, refractometer, infra-red spectroscopy and liquid chromatography. For each of these techniques that you can make work used develop a calibration curve for the instrument. Determine which of the calibration curves is indicative of the most accurate alcohol-water analysis. Explain how you are going to do this in the preliminary lab conference.

The laboratory instructor will provide an unknown alcohol-water sample which is to be analyzed using the calibration curves developed for each of the analytical methods. Your final report is to report the results of the analysis of the unknown alcohol-water sample.

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Heat Conduction

A long cylindrical antenna on an airplane's exterior cools it's cylindrical aluminum electronics compartment to which it is attached. If the electronics are cooled to less than 0C then they will not work properly due to a surface acoustic wave transducer. The flight conditions are up to 8 hrs at 10,000 m altitude where the ambient temperature is –60C and with airspeed of 1,000 km/hr. You are to develop a model for the temperature distribution in the antenna and the cooling of the electronics compartment. The dimensions and materials of construction for the antenna and the electronics compartment are to be taken from the Heat Conduction experimental apparatus with its cylindrical steam chamber and its cylindrical metal rods in aluminum and stainless steel of various diameters. As part of your oral exam you will be required to predict the temperature transient profile for an aluminum rod as a function of time and location from one end where the temperature is held constant. You are to compare this model with measurements done on the Heat Conduction experimental apparatus in which you will monitor the transient heat conduction in the rods given an inlet of hot fluid at one end of the rods. In your final report compare the experimental transient temperature profile to the predicted transient temperature profile for all rods on the apparatus. Explain any differences you see between experiment and prediction in the discussion part of your report. Finally using this data and other materials and models, make suggestions for the materials of construction of the antenna for the airplane, its diameter (assuming it has to be of a given length to work as an antenna) and the heating requirements for a heater to be placed in the electronics compartment to provide the needed heat to keep the compartment at or above 0°C during the flight.

Please include this assignment in your report as an appendix but do not cite it in the body of your report.

Liquid Flow Bench

Use the liquid flow bench to determine the friction factor for water flow in pipes. Of particular interest is the turbulent regime where the pipe roughness plays a role. Carefully plan your experiments to obtain the most accurate measurements of the friction factor and the Reynolds number. For your preliminary laboratory conference please give the range of flow rates, pipe sizes, pressure drops and other parameters you intend to use. In addition please predict the range of Reynolds number to be investigated as well as the accuracy of the friction factor to be measured. Compare your results with those in the literature and discuss any differences.

With these experimental correlations, please design a pipeline to pump oil with a viscosity of 1,000 cp at pipeline temperatures from the Vernal, UT to North Salt Lake City. Please consider the major elevations gains and friction losses to place the various pumping stations along the route. Consider the pipeline to take a line of sight route.

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