Name: ______________________________

Midterm Exam II

Chem Eng 170A: Biochemical Engineering

100 points

Constants

$$R = 8.314 J/K \cdot mol$$

Equations

$$k = k_0 e^{-\frac{E_A}{RT}}$$
$$k_2 = k_1 e^{\frac{E_A}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$
$$Power\ Number = \frac{P g_c}{\rho_L N^3 D_i^5}$$
$$Re = \frac{\rho_L N D_i^2}{\mu^{app}}$$

Question 1: Choosing an Agitator (20 pts)

You are put in charge of choosing an agitator to employ in your fermentation process. The process has the following parameters:

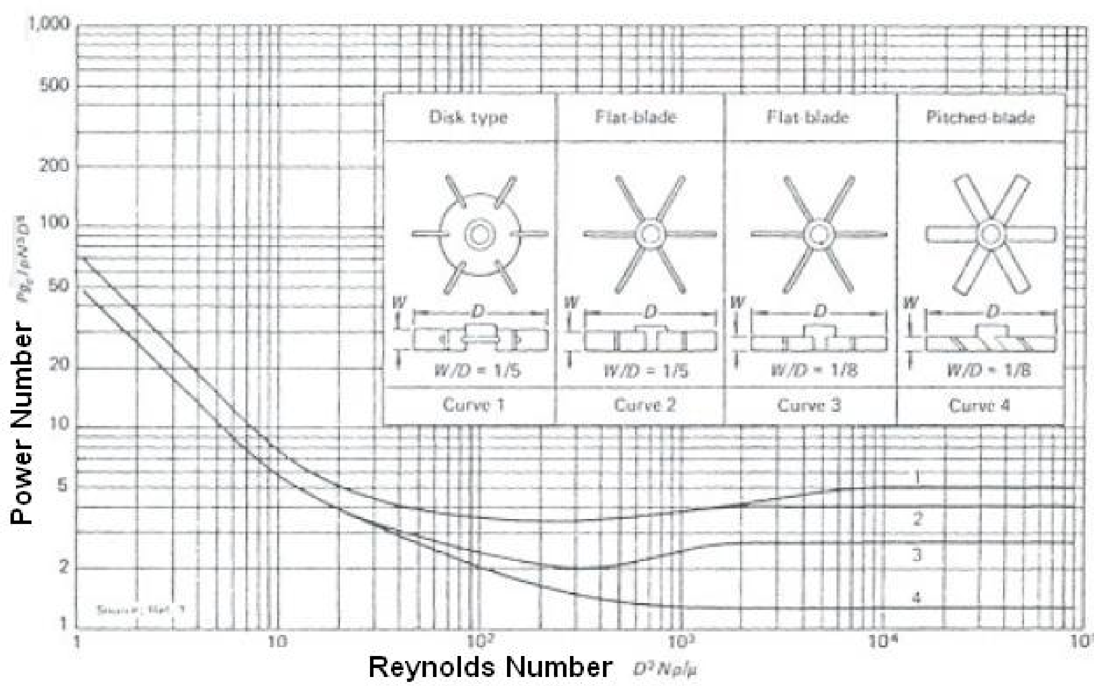
$$\rho_L = 1000\ kg/m^3$$
$$\mu^{app} = 0.002 N \cdot sec/m^2$$
$$N = 120\ rpm$$

Searching ebay, you narrow down your option to two choices:

	Cost	Imepeller Type	W/D	D_i
Option 1:	\$10,000	Disk type	1/5	0.75m
Option 2:	\$ 45,000	Flat-blade	1/5	0.75m

You plan to operate your process 24 hours a day, 340 days out of the year, for 3 years. Which type of impeller has less overall cost? How much money is saved?

Cost of electricity: \$0.058 per kW-hr[1]



[1]kW-hr is a unit of energy, the multiplication of power (in kWatts) and time (in hours).

(Extra space for work)

Question 2: Sterilization(20 pts)

You want to sterilize 2 L of liquid medium before using it in a fermentation process. The initial concentration of cells in the medium is 100 cells/L. From the literature, you find:

$$k_d = 2\ min^{-1}\ (measured\ at\ T = 120°C)$$
$$E_A = 300\ kJ/mol$$

For how long must you hold the temperature at $T = 115°C$ to reduce the probability of contamination to 2%? Ignore heating and cooling stages.

Question 3: Chemostats in Series (20 pts)

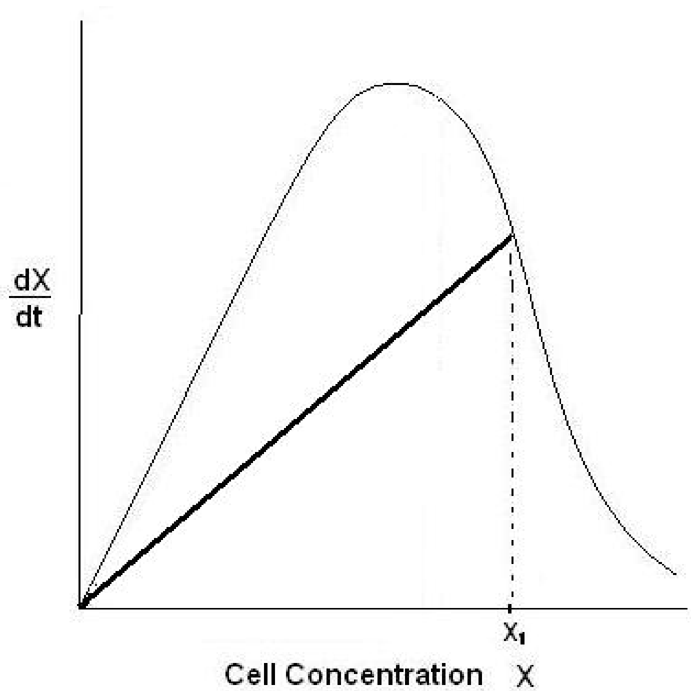
Consider a fermentation in a two-stage chemostat operating at steady-state.

(a) Derive an expression for the specific growth rate of cells (μ_2) in the second reactor in terms of the biomass concentrations entering and leaving the second reactor.

(b) Now assume that the biomass concentrations entering and exiting the second reactor are very similar to each other. What effect will this have on the specific growth rate of cells in the second reactor?

(c) Why might this be a desirable or advantageous outcome?

(d) Assume that $D_2 > D_1$. For your assumed value of D_2, determine and show the corresponding value of X_2 on the graph below. What does this tell you about what you need to do to achieve $X_2 \approx X_1$?



Question 4: Bioreactors and Media Development (20 pts)

In Dr. Maiorella's bioreactor lecture, we considered the effects of many parameters in designing bioreactors. Please answer the following questions regarding bubbles in airlift fermenters, in 1-2 sentences. Bulleted lists are okay.

(a) Why was it undesirable to use a very large bubble size ($D > 7mm$)?

(b) Why was it undesirable to use a very small bubble size ($D < 7mm$)?

(c) Other than varying bubble size, what can be done to further decrease cell death due to entrainment?

In Dr. Maiorella's media design lecture, we concluded that a two-stage control strategy was optimal for antibody production. In the first stage, conditions were optimized for cell growth. In the second stage, conditions were changed to halt cell growth. Please answer the following questions in 1-2 sentences. Bulleted lists are okay.

(c) Why did we choose this two-stage approach?

(d) How did we cause the cells to shift from a growth phase to a quiescent (non-growth) phase?

Question 5: Gas-Liquid Mass Transfer (20 pts)

In a recent homework problem we considered the situation where gas flow through a well-stirred fermentor can be described by plug flow. The unsteady state mass balance for the gas phase in this case is given below, where the terms have their usual definitions:

$$\frac{\partial\left(\frac{PV_g}{RT}y\right)}{\partial t} = -u_s\frac{\partial(\frac{PV_g}{RT}y)}{\partial z} - K_g a V_L P(y - \frac{H}{P}C_{O_2})$$

We wish to use this relationship in the experimental determination of $k_L a$, provided that the liquid and gas phase behavior is known.

Starting with the above equation and assuming steady state (and neglecting any pressure variation with the height of the reactor), derive an expression for $k_L a$ in terms of the inlet and outlet gas-phase mole fractions and the height of the reactor, Z (your expression will include other parameters as well, which you can assume are all known).