

Major Examination: BEL 102 (Bioprocess Calculations)

Max Marks: 30

Time: 2 hours

Each step should be clearly indicated.

Calculations without steps, and without proper units will not be graded!

1. Saturated steam is produced in a boiler by heating liquid water (10 bar, 24 °C) at constant pressure. Assuming that the kinetic energy of input stream of liquid water is negligible, calculate the heat input required to produce 250 m³/min of steam from the boiler that is discharged through a pipe of 7.5 cm internal radius.
(5)
2. A compressor unit lowers the temperature of any input gas to 60 °F while increasing the pressure to 304 KPa. In a compression and condensation process, air containing 10 mole percent of water, maintained at an absolute pressure of 1 atm and a temperature of 90 °C is first passed through the compressor unit and then heated to 100 °C at constant pressure. What fraction of water is condensed from the air? What is the relative humidity of the air at 100 °C? What is the volumetric fraction of air that comes out of the process?
(2+2+3 = 7)
3. Assume that the examination hall (the one you are sitting in right now!) has air at 24 °C (wouldn't that be nice!). Also assume that composition of the air is: 2% moisture (water), 20.6% oxygen and 77.4% nitrogen. Now assume that you inhale 360 L of air in an hour. Of course you do not explode since you are breathing (i.e. a cycle of inhale and exhale) at the rate of 2 breaths every 10 seconds. Assume that the air you exhale is at 37 °C (unless you suddenly developed a high fever due to this exam!) and has an increased moisture content of 6.2% along with unconsumed oxygen of 15.1%. It also has 3.7% carbon dioxide and 75% nitrogen. If nitrogen is not consumed in the process of respiration (a biochemical process in your body, not to be confused with breathing) determine the amount (g) of each of the individual components of air exchanged per minute due to respiration. How much weight do you expect to gain or lose by simply breathing during the examination period? Is the volume of air exhaled the same as the volume inhaled per breath?
(3+2+2 = 7)
4. A set of solar panels in a solar power plant produces saturated steam at an absolute pressure of 10 bar at the rate of 200 kg/h. Another set of solar panels in the same plant produces superheated steam at 300 °C and 10 bar. If the power plant requires turbines to be run by steam at 10 bar and 250 °C at the rate of 300 kg/h, how should the output steam of the two solar panels be mixed (i.e. withdraw or add heat), without disturbing the output flow rate of saturated steam from the first panel? What will be the rate of steam generated at 10 bar and 250 °C if the saturated steam from the first solar panel and superheated steam from the second panel are mixed adiabatically?
(4+2 = 6)
5. The human heart behaves exactly as a pump with inlet gauge pressure of blood as 0 mm Hg and outlet gauge pressure as 100 mm Hg. Blood is pumped at an average rate of 5 L/min. Absorption of oxygen by the heart muscles releases 20.2 KJ of energy per mL of oxygen absorbed. Considering that some of this energy is utilized for pumping blood and the remaining is lost in form of heat transferred to surrounding tissues, what percentage of the energy absorbed by the heart muscles is converted to flow work if oxygen is absorbed at the rate of 5 mL (STP) per minute?
(3)
6. How can one quantify cell growth in a batch culture?
(2)