

Midterm #1

(100)1. In 2004, Crucell and Sanofi Pasteur announced a joint development of a new influenza vaccine based on a proprietary process using PER.C6TM cells to propagate the influenza viruses. To investigate the metabolic rate of the PER.C6TM cells, two scientists from Merck Research Laboratories, Luis Maranga and Charles F. Goochee (*Biotechnology and Bioengineering* 94(1) : 139-150, May 5 2006), performed a PER.C6TM cell culture in an automated fed-batch process. In the fed batch experiment, a well-mixed 10 L fermentor was initially filled with 500 mL of fermentation broth containing 10 weight % of glucose and trace amount of dissolved oxygen at 30% saturation. In addition, a known concentration of PER.C6TM cells was added into the fermentor maintained isothermally at 310 K. During the experiments, additional fermentation broth containing 10% weight glucose was prepared, preheated to 310K then continuously fed to the fermentor a rate of 100 mL/hour. Throughout the experiment, dissolved oxygen was present in excess and so that the metabolic rate is independent of oxygen concentration. The fermentation broth density is assumed to be constant at 1 g/mL, independent of the glucose concentration.

(10) i. Is this a steady state or a non-steady state process? Is this a batch, semi-batch or continuous process. Define the control volume and identify if the control volume chosen is an open or a closed system.

(25) ii. Find an expression for the liquid volume inside the fermentor as a function of t. What is the liquid volume at time = 5h. Identify the conditions when this equation becomes invalid.

(35) iii. Derive an expression for the glucose concentration (g/L) in the fermentor Assume that PER.C6TM cells metabolize the glucose at a constant rate of 5 g/h.

(10) iv. Classified the expression derived from part (iii) above, with a) the order of the differential equation, b) homogeneous or nonhomogeneous, c) state the method to solve for the expression in part(iii).

(15) v. Solve the expression above for the glucose concentration (in g/L) inside the fermentor with time.

(5) vi. Sketch the history of glucose concentration with time. Be sure to indicate the

initial concentration.

(100) 2. On Wednesday, September 13, 2006 (two weeks ago!) the National Transportation Safety Board (NTSB) announced in a national press conference that all new automobiles sold in the United States by 2012 must have VSA (vehicle stability assist). The spokesperson for the NTSB noted that over 50 % of sedan vehicle rollovers could be prevented if VSA were installed. This number is over 60 % for SUVs.

During questioning from the press, the NTSB representative was asked how long it would take after year 2012 for all automobiles in the US to have VSA. The spokesperson noted that on average a person in the US keeps an automobile for 8 years. Thus, it would take “quite a while” to replace all automobiles with VSA. You are to provide a quantitative answer to this question.

Additional Information

The current population of the US is 300 million. The estimated population growth rate is 1 % per year (including births, deaths, and net immigration). Populations grow in proportion to the number of people. Over 75 % of the US population owns an automobile! Barring a major decline in fuel supplies, this fraction is anticipated to remain constant into the future.

(20) i. Derive an expression for the US population, $P(t)$, as a function of time starting in year

2012. What will be the population in 2012?

(25) ii. Find an expression for the rate of sales of automobiles into the US market after 2012, EMBED Equation.DSMT4 .

(40) iii. Let f be the fraction of cars with VSA in the market starting after year 2012.

Make the

reasonable assumption that the scrap rate of VSA cars is f times the total rate of cars

scrapped, EMBED Equation.DSMT4 . Neglect those cars that already have VSA installed before year 2012.

Find an expression for how f increases in time beyond year 2012.

(15) iv. How long will it take for all US cars to have VSA installed? What will be the US population at that time?

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