National Exams December 2015

04-BS-13, Biology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM. One aid sheet written on both sides is permitted as well as an approved Casio or Sharp model calculator.

3. FIVE (5) questions constitute a complete exam paper. 3 questions from Part I and 2 questions from Part II must be attempted. Unless otherwise indicated on the exam booklet the first 3 questions from Part I and the first 2 questions from Part II will be marked.

4. Each question is of equal value.

5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

Part I: Solve any 3 questions out of the following 6 questions (20 marks for each)

Note: For questions 1 to 4, in order to calculate molecular weights of biomasses, products and substrates, elemental atomic masses will be needed. These are: for C = 12, for H = 1, for N = 14, and for O = 16.

1. *Klebsiella aerogenes* ($CH_{1.75}\ O_{0.43}\ N_{0.22}$) is produced from glycerol ($C_3H_8O_3$) in aerobic culture with ammonia (NH_3) as nitrogen source. The biomass contains 8% ash, 0.40 g biomass is produced for each g glycerol consumed, and no major metabolic product is formed. What is the oxygen requirement for this culture in mass terms? This process can be represented by:
   $C_3H_8O_3 + aO_2 + bNH_3 \rightarrow c\ CH_{1.75}O_{0.43}N_{0.22} + dCO_2 + eH_2O$
   (Molecular weight of glycerol = 92; Glycerol degree of reduction (γ_S) = 4.67; biomass degree of reduction (γ_B) = 4.23). (20 marks)

2. Yeast growing in continuous culture produce 0.37 g biomass per g glucose consumed; about 0.88 g O_2 is consumed per g cells formed. The biomass contains 5% ash. The nitrogen source is ammonia, and the biomass composition is $CH_{1.79}\ O_{0.56}\ N_{0.17}$. Are other products also synthesized? The process is represented by:
   $C_6H_{12}O_6 + aO_2 + bNH_3 \rightarrow c\ CH_{1.79}O_{0.56}N_{0.17} + dCO_2 + eH_2O + fC_jH_kO_LN_m$
   (Molecular weight of glucose = 180). (20 marks)

3. *Methylophilus methylotrophus* ($CH_{1.68}N_{0.22}\ O_{0.36}$) bacteria used as single-cell protein for human or animal consumption are produced from methanol (CH_4O) under aerobic conditions. The cells contain 6% ash. The growth of biomass on the substrate is described by:
   $CH_4O + aO_2 + bNH_3 \rightarrow cCH_{1.68}N_{0.22}\ O_{0.36} + dH_2O + eCO_2$
   (Molecular weight of methanol = 32; methanol degree of reduction (γ_S) = 6; biomass degree of reduction (γ_B) = 4.3).

   (a) Determine the maximum possible biomass yield in molar form. (15 marks)
   (b) If the actual yield of biomass from methanol is 42% of the thermodynamic maximum, what is the oxygen demand? (5 marks)

4. The most economic method of sewage wastewater treatment is bacterial digestion. As an intermediate step in the conversion of organic nitrogen to nitrates, it is reported that the *Nitrosomonas* bacteria cells metabolize ammonium compounds into cell tissue and expel nitrite as a by-product by the following relationship:
   $5CO_2 + 76O_2 + 55NH_4^+ \rightarrow C_5H_7NO_2 + 52H_2O + 54NO_2 + \log H+$

If 20000 kg of wastewater containing 5% ammonium ions by weight flows through a septic tank inoculated with the bacteria, how many kg of cells are produced provided that 95% of the NH_4^+ is consumed? The molecular weight of NH_4^+ = 18, calculate molecular weight of the biomass considering no ash. (20 marks)

5. How cell wall properties of a plant or animal product affect mechanical properties – elasticity, strength of rigidity? Discuss with a few examples after providing cell wall structures. (20 marks)

6. A continuous stirred-tank reactor is being operated. The volume of liquid in the tank is V. Food enters with volumetric flow rate F_i; product leaves with flow rate F_0. The concentration of reaction A in the feed is C_{Ai}; the concentration of A in the exit stream is C_{Ao}. The density of the feed stream is ρ_i; and the density of the product stream is ρ_o. The tank is well mixed. The concentration of A in the tank is C_A and the density of liquid in the tank is ρ. In the reactor, compound A undergoes reaction and is transformed into compound B. The volumetric rate of consumption of A by reaction is given by the first order $r_C = k_1 C_A$. Using unsteady-state balances, derive differential equations for (a) total mass, and (b) mass of compound A. (20 marks)

Part II. Answer any 2 questions out of the following 4 questions (20 marks for each question)

7. *Escherichia coli* is being used for the production of recombinant porcine growth hormone. The bacteria are grown aerobically in batch culture with glucose as growth limiting substrate. Cell and substrate concentrations are measured as a function of culture time, and tabulated below:

Time, h	Cell concentration (x), kg/m^3	Substrate concentration (s), kg/m^3
0.0	0.20	25.0
0.33	0.21	24.8
0.5	0.22	24.8
0.75	0.32	24.6
1.0	0.47	24.3
1.5	1.00	23.3
2.0	2.10	20.7
2.5	4.42	15.7
2.8	6.9	10.2
3.0	9.4	5.2
3.1	10.9	1.65
3.2	11.6	0.2
3.5	11.7	0.0
3.7	11.6	0.0

(a) Plot cell specific growth rate (μ) as a function of time. (10 marks)
(b) What is the value of maximum specific growth rate (μ_{max})? (3 marks)
(c) What is the observed biomass yield (Y_{XS}) i.e. kg of biomass per kg of substrate? Is it constant? (7 marks)

8. A new microorganism has been discovered which at each cell division yields three daughters. From the growth rate data given below calculate the mean time between successive cell divisions. (20 marks)

Time, h	0	0.5	1.0	1.5	2.0
Dry mass, g/L	0.10	0.15	0.23	0.34	0.51

9. (a) To calculate biological oxygen uptake rate (q_{O2}) under steady state, which parameters should be measured? (6 marks)

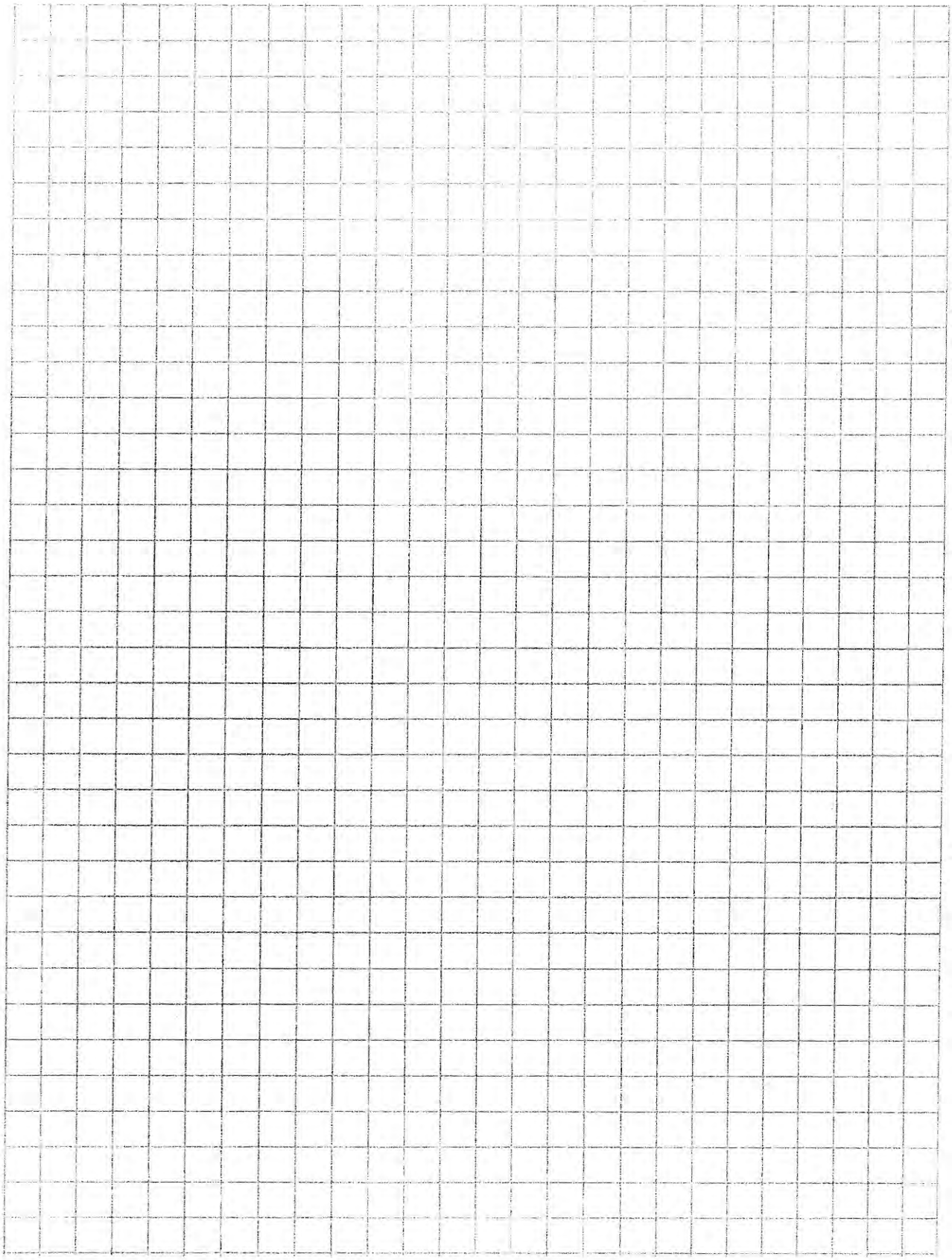
(b) Why in many cases gas balanced method is not accurate to measure O_2 uptake rate? (6 marks)

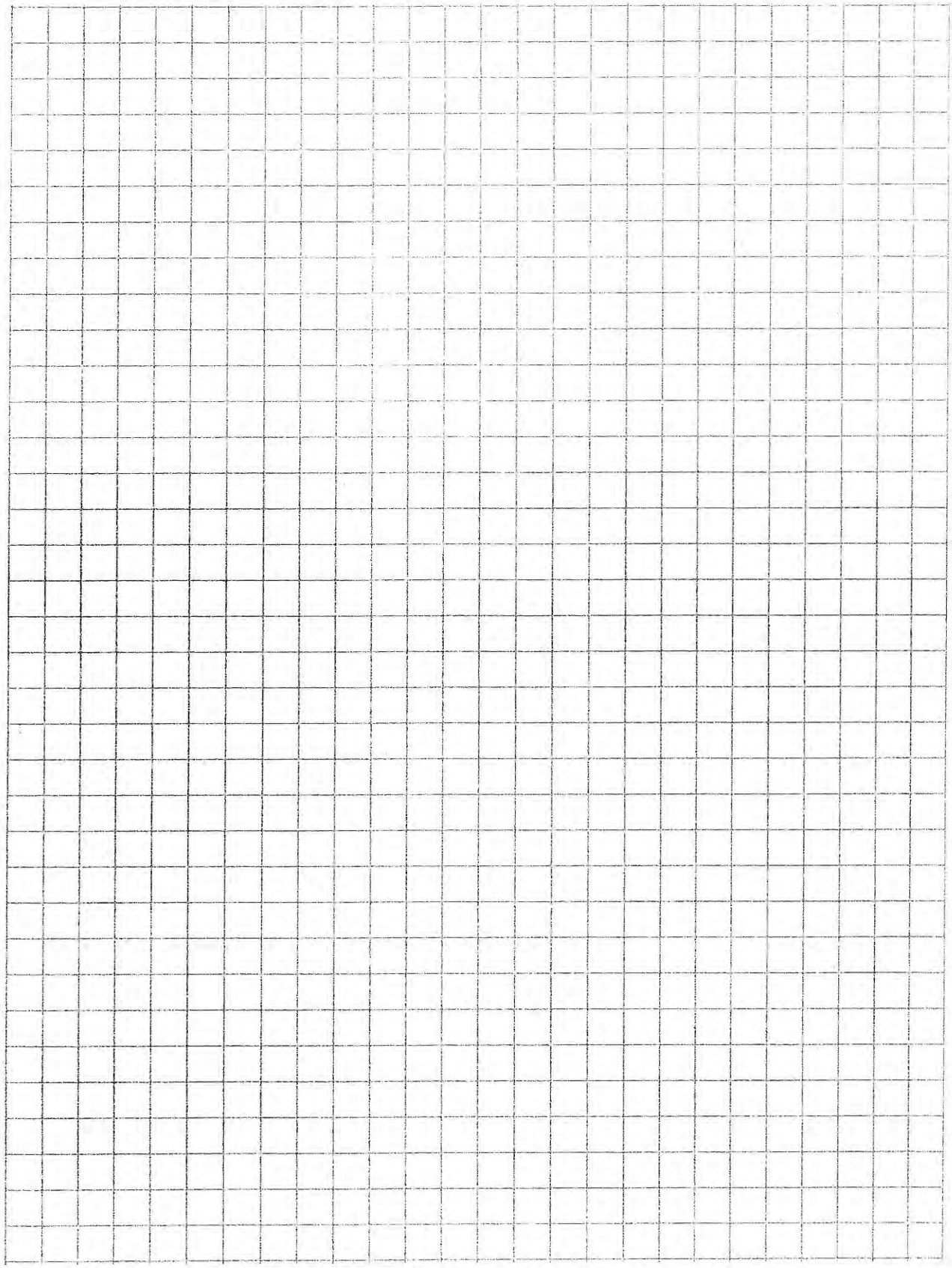
(c) Under what conditions, you will prefer to use dynamic and steady state methods to measure k_{La} for a bioreactor system. (8 marks)

10. (a) List five major characteristics currently used in the classification of bacteria. (6 marks)

(b) What is fungal spore? List and describe five types of asexual fungal spores. (8 marks)

(c) Why do some bacteria have multiple plasmids and others none? (6 marks)





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Marking Scheme

1. 20 marks total,
2. 20 marks total
3. 20 marks total; (a) 15 marks, (b) 5 marks
4. 20 marks total
5. 20 marks total
6. 20 marks total
7. 20 marks total (10, 3 and 7 for 3 sections)
8. 20 marks total
9. 20 marks total (6, 6 and 8 for 3 sections)
10. 20 marks total (6, 8 and 6 for 3 sections)