UNIVERSITY OF GHANA

BSC. ENGINEERING

SECOND SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF BIOMEDICAL ENGINEERING

BMEN 402: TISSUE ENGINEERING AND BIOTECHNOLOGY (3 CREDITS)

INSTRUCTIONS:
PLEASE READ THE PREAMBLE BELOW CAREFULLY AND ATTEMPT ALL QUESTIONS, MAKING SURE YOUR ANSWERS ARE DIRECTLY LINKED TO THE SCENARIO DESCRIBED. YOU MAY USE THE INFORMATION PROVIDED ON PAGE 3, WHERE NECESSARY.

TIME ALLOWED: TWO AND HALF (2½) HOURS

Osteomyelitis (OM) is infection and inflammation of the bone or bone marrow. In children, the long bones are usually affected and the most common causative agent is *Staphylococcus aureus* (a bacterium). Once the bone is infected, leukocytes enter the infected area and in their attempt to engulf the infectious organisms, release enzymes that lyse the bone. Pus is formed and spreads into the bone's blood vessels, impairing blood flow. When OM is chronic, it can lead to bone sclerosis and deformity. Chronic OM is difficult to eradicate and may result in significant costs and disability, potentially leading to amputation. In severe cases the pathology is treated by surgical debridement (removal of infected tissue to promote the healing potential of remaining healthy tissue) followed by prolonged antibiotic therapy for weeks or months.

A tissue engineer would like to design a product to address the interrelated problems described above for a 4 year old patient suffering from severe, chronic OM in the femur. The goal is to avoid amputation by replacing the infected bone with a tissue-engineered option that also reduces the pain associated with therapy by eliminating the need for antibiotic injections.

1. List 5 independent, but critical characteristics of a suitable scaffold material for this tissue engineering project and explain each one. [10 marks]

2. The compressive strength of the boy's healthy bone is measured to be 100 MPa. If a dense material with compressive strength of 550 MPa is to be used to fabricate an open pore foam as a scaffold, estimate the maximum porosity that can be achieved using this material. State and explain all relevant assumptions. [10 marks]

3. If a porosity of 90% is required, calculate the compressive strength of an ideal material for the project. Give one method by which the material in question (2) above can be modified to achieve this compressive strength. [10 marks]

4. When cells become more specialized do they lose the genes that are no longer required? Give **one** compelling piece of evidence to support your answer and explain what happens to the genes of differentiated cells. [10 marks]

5. Considering the ideal cell type for this bone engineering project,
   a. Identify three high potential candidate cell types. Please give specific answers. [3 marks]
   b. Critically assess the three options in (a) and use the analysis to choose one cell type. [7 marks]
   c. Give **five** strong reasons for your choice of cell type. [5 marks]

6. Assume 10 embryonic stem cells are harvested and expanded using dishes with circular culture areas of 120 cm^2.
   a. Estimate the number of cells that will eventually be harvested from a confluent dish. [5 marks]
   b. If the cell population doubles every 3 hours, how long will it take to obtain 5×10^6 cells? [10 marks]
   c. Knowing that cell viability is compromised at oxygen partial pressure of 100 Pa Calculate the minimum flow rate of culture medium necessary to prevent hypoxia-induced cell death if 5×10^6 cells are maintained in perfusion culture. [10 marks]

7. How would you get the undifferentiated cells produced in question (6) to express the osteoblastic phenotype **and** express antibiotics to treat the infection? Be as specific as possible and explain your answer. [10 marks]

8. Some tools of Tissue Engineering, specifically genetic engineering and use of embryonic stem cells are considered by some to be unethical.
   a. List five arguments to support this view. [5 marks]
   b. Provide one corresponding rebuttal to each of the arguments in (a). [5 marks]

Some Useful Information

Solubility of oxygen in culture medium (k):	8.93 nmol/ ml/ kPa
Diffusivity of oxygen through culture medium at 37°C (D):	2×10^{-5} cm^2/s
Maximum oxygen uptake by cells:	3×10^{-7} nmol/s/cell
Partial pressure of oxygen in cell culture incubator:	21 kPa

Diffusion rate in culture medium = $DkA(P_1-P_2)/d$

Where: d is the distance or thickness of the barrier to diffusion

A is the area for gas exchange

(P_1-P_2) is the difference in partial pressure on either side of the diffusion barrier