INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Date: 28-04-2016 (AN) **Spring End-Semester 2016** **Time:** 3 hours **Full Marks:** 100

Department: **Mechanical Engg** Subject: **Mechanics of Human Body** Subject No: **ME 60407**

Marks distribution for each question is indicated within brackets.
Assume any suitable data that may be required for solution, stating clear justifications

Answer all questions.

(1) (a) What is meant by 'apparent density' of bone? How is bone mechanical properties related to apparent density and its structure?

(b) What is Hounsfield Unit? How is pixel grey value related to bone apparent density?

(c) State the criteria for selection of implant material for joint replacement. Name the commonly used biomaterials for load bearing implants.

(8 + 5 + 7= 20)

(2) (a) State the reasons for joint replacement? What are the problems associated with 'cemented' fixation?

(b) What are essential differences between hip resurfacing arthroplasty and total hip arthroplasty?

(c) What are the steps for developing a finite element model of bone from CT-scan data?

(d) A force vector in a Cartesian coordinate system **(A)** is given as 20i + 15j + 10k. Another new coordinate system **(B)** is obtained by applying the following sequential rotation and translation with respect to the original Cartesian coordinate system **(A)**:

(i) Rotations: +30° about y-axis, then –60° about z-axis, and then +30° about x-axis degrees.
(ii) Translations: 10 units along x, y and z-axes.

Calculate the transformation matrix and transformed force vector in the new coordinate system **(B)**.

(5 + 3 + 4 + 8 = 20)

(3) (a) What is meant by 'bone remodelling'?

(b) State the mathematical formulation of the 'external' and 'internal' bone remodelling process.

(c) Design a computational scheme, using flow diagram, for the iterative simulation of the bone remodelling process.

(4 + 8 + 8 = 20)

(4) (a) How is implant-bone interfacial failure evaluated? State and explain each term of the failure criterion.

(b) The state of stress at a point on the implant-bone interface is, σ_x = 30 MPa, σ_y = 15 MPa, σ_z = –10 MPa, $\tau_{xy} = \tau_{yz} = \tau_{zx}$ = 20 MPa. Determine the normal and shearing stresses at the implant-bone interface on a plane, which is inclined at **60° with x-axis**, **60° with y-axis** and **45° with z-axis**.

(c) Using data of Problem 4(b), evaluate Hoffman failure value at implant-bone interface, assuming adjacent bone density ρ =0.5 gm.cm^{-3}. Interfacial strengths (MPa): $S_t = 15\rho^{1.71}$, $S_c = 32\rho^{1.85}$, $S_s = 22\rho^{1.65}$

(4 + 10 + 6 = 20)

(5) (a) What are the techniques for fixation of implant with bone? Discuss briefly the major failure mechanisms of orthopaedic implants.

(c) Briefly describe the different pathways of tissue differentiation from Mesenchymal Cells.

(d) What are the salient differences between phenomenological and cell-phenotype specific tissue differentiation algorithm. Explain with the help of governing equations.

(8 + 6 + 6 = 20)