INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Date: 23-04-2015 (AN) **Spring End-Semester 2015** **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) Briefly describe the method of 'Inverse Dynamics'? State the difference between the methods 'Inverse Dynamics' and 'Forward Dynamics'?

(b) State clearly the steps and governing equations required to find out joint forces and moments in a limb segment using 'Inverse Dynamics Method'?

(c) A force vector in a Cartesian coordinate system **(A)** is given as 10i + 20j + 15k. 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 –20° about z-axis, and then +20° about x-axis degrees.
(ii) Translations: 20 units along x, y and z-axes.

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

(6 + 6 + 8 = 20)

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

(b) What are the techniques for fixation of implant with bone? Draw a labeled sketch of implanted femur.

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

(8 + 6 + 6= 20)

(3) (a) How is implant-bone interfacial failure evaluated? Discuss about Hoffman's failure criterion.

(b) The state of stress at a point on the implant-bone interface is, σ_x = 40 MPa, σ_y = 20 MPa, σ_z = –10 MPa, $\tau_{xy} = \tau_{yz} = \tau_{zx}$ = 30 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 3(b), evaluate Hoffman failure value at implant-bone interface, assuming adjacent bone density ρ =0.4 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)

(4) (a) What is meant by 'stress shielding' and 'bone remodelling'?

(b) State the mathematical formulation of the 'internal' bone remodelling process, considering bone remodelling caused by joint replacement.

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

(4 + 8 + 8 = 20)

(5) (a) 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.

(5 + 7 + 8 = 20)