Reg. No: 24BNT0014

BG/K/TY

Final Assessment Test – November 2025

VIT Vellore Institute of Technology

Course: BHST203L - Fundamental Principles of Biomechanics

Class NBR(s): 0966 Slot: E1+TE1

Time: Three Hours Max. Marks: 100

- KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE
- DON'T WRITE ANYTHING ON THE QUESTION PAPER

General Instruction : Make suitable assumptions wherever necessary

COs	CO Statements
CO1	To understand the application of mechanics to biological systems.
CO2	To apply concepts of rigid body mechanics to analyze skeletal systems.
CO3	Develop an understanding of various concepts of mechanics.
CO4	To apply concepts of deformable body mechanics to analyze various biological tissues / systems.
CO5	To understand the mechanics of blood flow and muscle functions.

L – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)

Answer ALL Questions

(10 X 10 = 100 Marks)

1. An athlete is doing shoulder muscle strengthening exercises by lowering and raising a bar-bell with straight arms. The position of the arms when they make an angle θ with the vertical is shown in figure 1. Point O represents the shoulder joint, A is the center of gravity of one arm, and B is a point of intersection of the centerline of the barbell and the extension of line OA. The distances OA = 24 cm and OB = 60 cm. Each arm weighs W1 = 50 N and the total weight of the barbell is W2 = 300 N. Determine the net moment due to W1 and W2 about the shoulder joint as a function of θ, which is the angle the arm makes with the vertical. Calculate the moments for θ = 0°, 15°, 30°, 45°, and 60°. Note that there are two arms holding the single barbell. CO1 BL3

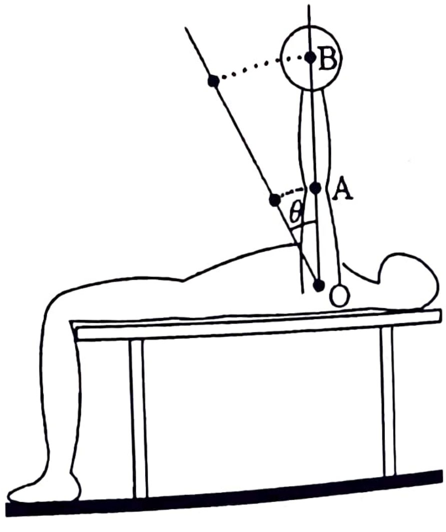

Figure 1

2. Consider a person strengthening the shoulder muscles by means of dumbbell exercises. Figure 2 illustrates the position of the left arm when the arm is fully abducted to horizontal. Assume that the Deltoid muscle connecting from humerus to the collar bone is the major contributor. Point O corresponds to the axis of rotation of the shoulder joint, point A is where the deltoid muscle is attached to the humerus, point B is the center of gravity of the entire arm, and point C is the center of gravity of the dumbbell. W is the weight of the arm, Wo is the weight of the dumbbell, F_M is the magnitude of the tension in the deltoid muscle, and F_J is the magnitude of the joint reaction force at the shoulder. The resultant of the deltoid muscle force makes an angle θ with the horizontal. Given, OA = 15 cm, OB = 30 cm, OC = 60 cm, $\theta = 15^\circ$, W = 40 N, and Wo = 60 N. Draw the free body diagram and determine the tension in the deltoid muscle, F_M and the joint reaction force at the shoulder. **CO2 BL3**

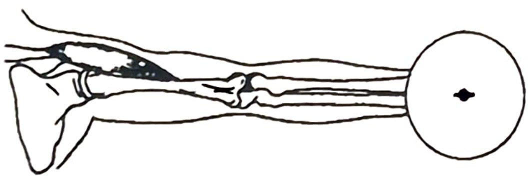

Figure 2

3. Why is it important to study the mechanics of the human body? Give a few examples where the study of biomechanics of human body is useful. **CO1 BL3**

4. Marker data is collected in a gait lab for a person walking at a self-selected speed. The (x,y) coordinates of the ankle and metatarsal markers for a randomly chosen instance during swing phase of the limb are: ankle (0.75, 0.15) m and metatarsal (0.83, 0.06) m. The velocity of the ankle is (3.9, −0.79) m/sec. The acceleration of the ankle is (1.3, 8.6) m/sec^2.The angular velocity of the foot at this instance is 6.85 rad/sec counter clockwise and the angular acceleration of the foot at this instance is 10 rad/sec^2 clockwise. Find the position (x,y), velocity and acceleration of the center of mass of the foot segment. Anthropometric data for the foot is as follows: foot segment length = distance between ankle marker and metatarsal marker; distance of center of mass = 0.5 x segment length (from proximal joint). **CO3 BL3**

5. A bone scaffold sample made of material (Young's modulus E = 200 GPa and v = 0.35) is tested for it's strength. An axial forces of Fx = 15 MN along x-axis, Fy = - 5 MN along y-axis and Fz = -10 MN along z-axis are applied on the sample of dimensions 20 cm x 5 cm x 2 cm (Figure 3). Determine the average normal stresses and strains induced in the scaffold. **CO4 BL3**

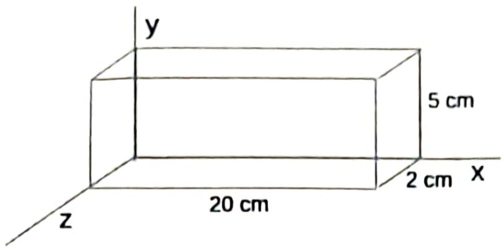

Figure 3

6. How are the (bio) mechanical characteristics of bone different from any regular metals? Explain in detail. **CO4** **BL3**

7. Describe the composition, structure and mechanical properties of blood vessels. **CO5** **BL2**

8. a) How are parallel and pinnate muscle types different? **CO5** **BL3**

   b) What equations / models are used to describe the biomechanics of the muscles?

9.(a) An implant material sample of solid circular cylinder is shown Figure 4. The cylinder has a length l = 10 cm and radius ro = 2 cm. The cylinder is made of a linearly elastic material with shear modulus G = 10 GPa. If the cylinder is subjected to a twisting torque with magnitude M = 3000 Nm, calculate: (i) The polar moment of inertia, J, of the cross-section of the cylinder (ii) The maximum angle of twist, θ, in degrees (iii) The maximum shear stress, τ, in the transverse plane (iv) The maximum shear strain, γ, in the transverse plane. **CO4** **BL3**

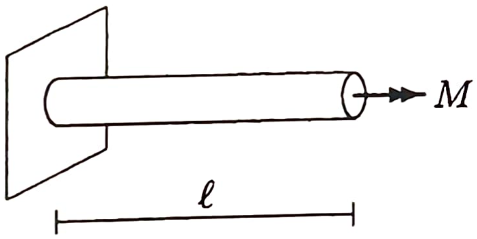

Figure 4

OR

9.(b) A human femur bone is subjected to bending during the bench test by a horizontal force F applied to the head of the femur at point P (Figure 5). The free body diagram is shown. Bending moment generated at section aa, located at a vertical distance h = 17.5 cm measured from point P of the bone was M = 91 Nm. Assuming circular geometry of the bone at section aa, with inner radius ri = 5.5 mm and outer radius ro = 12.5 mm, determine: **CO4** **BL3**

(i) The magnitude of shear force, V, at section aa

(ii) The maximum normal stress, σmax, at section aa

(iii) The maximum shear stress, τmax, at section aa

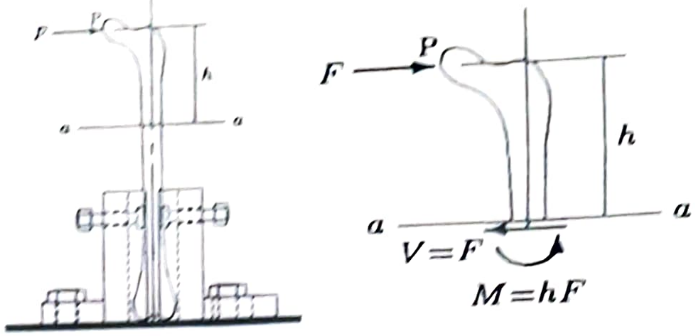

Figure 5

10.(a) Assuming that a subject is standing erect with the two feet together, calculate the moment of inertia of HAT (Head, Arms and Trunk) about the hip joint, the knee joint, and the ankle joint. What does the relative size of these moments of inertia tell us about the relative magnitude of the joint moments required to control the inertial load of HAT. Length of segments are: leg = 0.435 m, thigh = 0.410 m, HAT = 0.295 m. Total mass = 80 kg. Anthropometric data is as follows: (i) mass of HAT = 0.678 x Total mass (ii) Distance of CoM of HAT from hip joint = 1.142 x segment length (iii) Radius of gyration of HAT about CoM = 0.903 x segment length. CO2 BL3

OR

10.(b) The free body diagram of a weight lifter's leg is shown in Figure 6. Hip joint force F_J is acting at O and the net muscle force of the back muscles F_M is acting at A. Leg weight and reaction from the floor are shown in the FBD. Given $\theta = 45°$, a = 0.02 h, b = 0.08 h and c = 0.12 h, Wo = W and W1 = 0.4W, Determine the joint reaction force and the net muscle force in terms of W. CO2 BL3

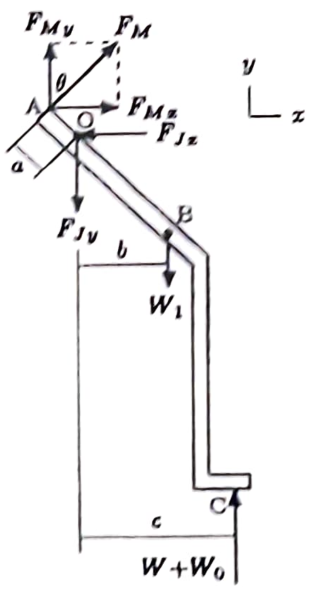

Figure 6