National Exams May 2015

04-Bio-A4, Biomechanics

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 an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.
3. FOUR (4) questions constitute a complete exam paper.
4. Each question is of equal value.
5. Clarity and organization of the answer are important.

1. A person is kicking the base of a door in order to open it (Figure 1). At the instant of contact with the door, the toe decelerates with a value of 50 m/s^2 (tangential relative to the hip center). The thigh segment has a length of 51 cm, mass of 7 kg, radius of gyration of 16 cm and its center of mass is 20 cm from the hip. The lower leg has a length of 49 cm. The mass of the lower leg plus the foot is 4.4 kg, has a radius of gyration of 16 cm, the center of mass is 22 cm from the knee joint.

   At the instant shown, the knee joint is flexed at 28 degrees and the ankle joint is in the neutral position. There is no relative rotation of these joints at the instant shown.

   a) Calculate the direction of the toe tangential acceleration as it contacts the door, **(4 marks)**

   b) Draw the free body diagram of the entire leg showing all the relevant forces and moments and derive the equations of motion that balance the forces vertically and horizontally and the moments of force about the hip joint **(4 marks)**

   c) Calculate the contact force between the door and the toe at the instant shown if the muscles of the hip produce a flexion moment of 2 Nm, but the hip is not moving or accelerating linearly in any direction (i.e. fixed in space), **(4 marks)**

   d) Speculate on which muscle(s) will be active to produce the observed moment. **(3 marks)**

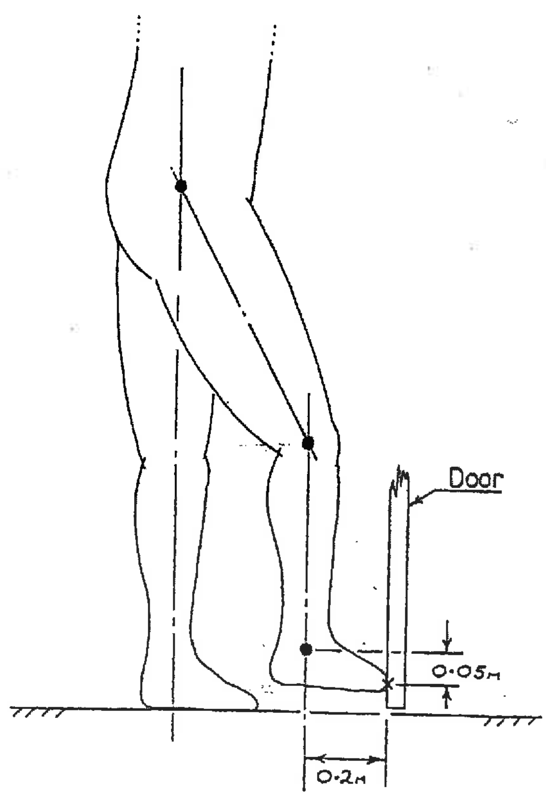
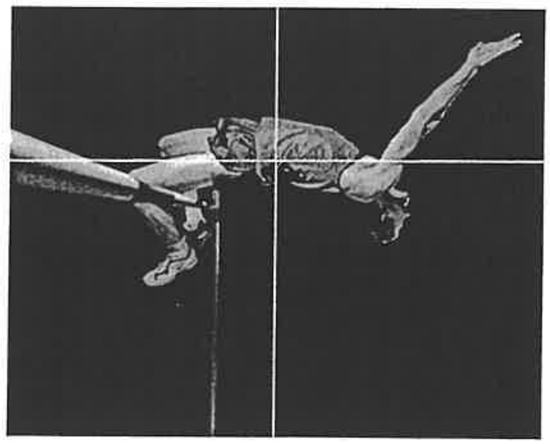


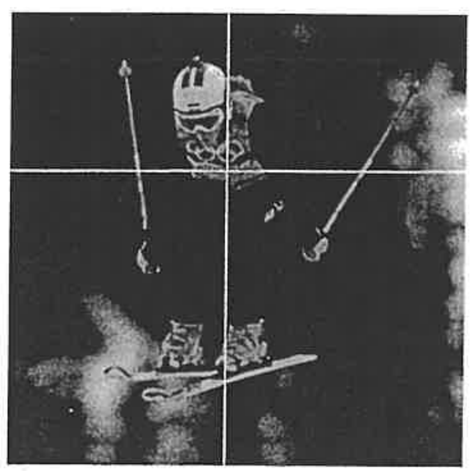
Figure 1

2. Consider the athletes in the three photographs below. In each case, i) sketch the orthogonal angular velocity components and resultant angular velocity vector using the right-hand rule rotation convention, ii) calculate the magnitude of the unknown components or resultant, and iii) calculate the angulation of the resultant relative to the orthogonal components.

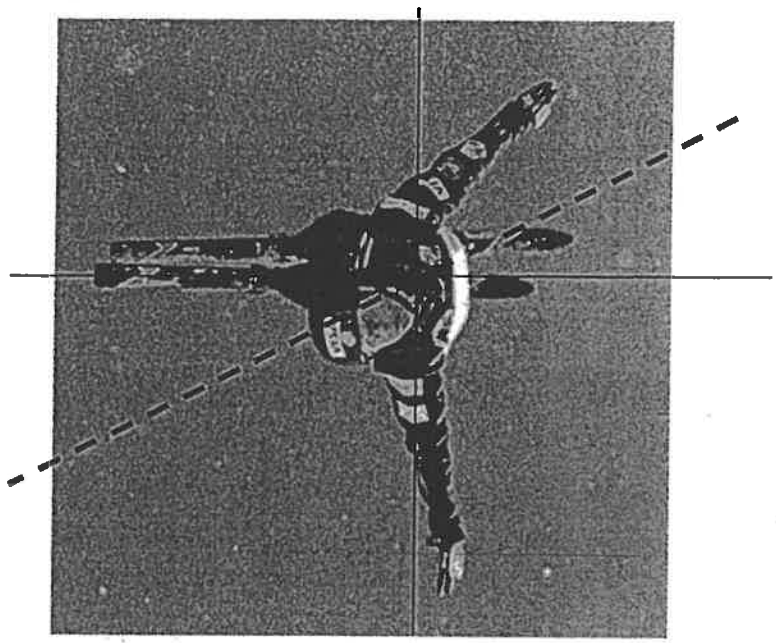
a) A high jumper rotating in the frontal plane at 180 deg/sec with their head moving to their left and spinning about their long axis at 120 deg/sec with their right shoulder moving upwards, **(5 marks)**



b) A ski racer somersaulting forward at 180 deg/s and twisting to their right about their long axis at 360 deg/s, **(5 marks)**

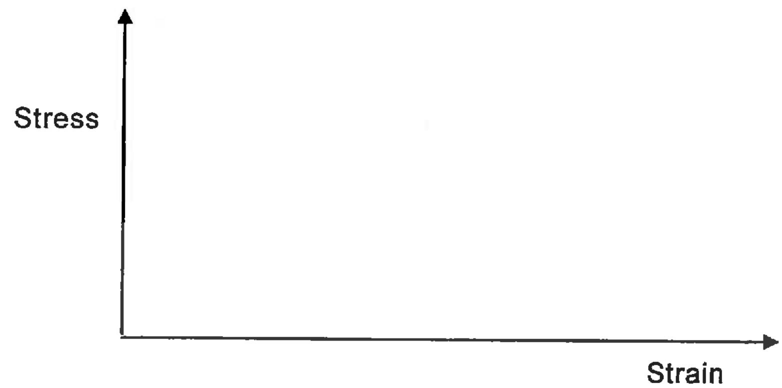


c) An aerial skier is rotating about the dotted resultant axis at 220 deg/s. They are rotating with the left shoulder moving to their left about their anterior-posterior axis and somersaulting backward about medio-lateral axis. **(5 marks)**



3. a) Sketch an example of a stress-strain curve for <u>tendon</u> using the axes below (please draw these axes in your answer booklet). Don't worry about the scale on the vertical or horizontal axes- just sketch the shape of the curve. Clearly show the following: **(5 marks)**

   i) Failure stress
   ii) Elastic region
   iii) Toe region
   iv) Yield stress
   v) Plastic region



   b) What <u>motion</u> is being forcefully applied to the left knee of the rugby player in the green jersey? **(3 marks)**

   c) What structures of the knee are most likely to be injured and in what way? **(4 marks)**

   d) What surgical procedure is the most common treatment for this musculoskeletal injury? **(3 marks)**

Figure 3

4. Consider a person walking through a motion capture laboratory during a testing session. Data from motion analysis system and force plate show that the forces and moments acting externally on the knee at a certain instant in time are:

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} 0 \\ 650 \\ 0 \end{bmatrix} N \quad \text{and} \quad \begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} +21 \\ 0 \\ -23 \end{bmatrix} Nm$$

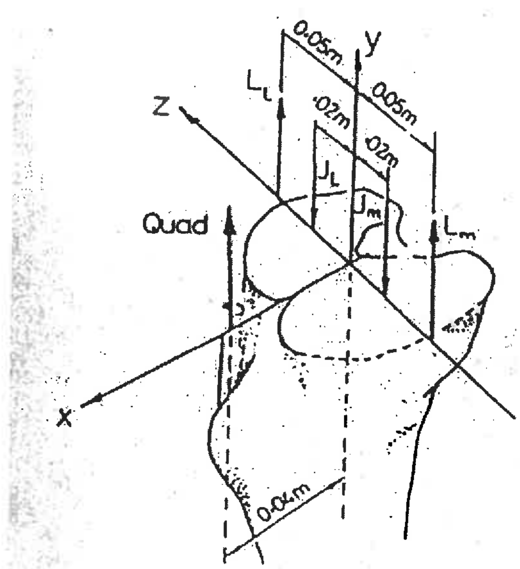
The internal structures of the knee are shown in Figure 4.

a) Calculate the tension in the quadriceps muscle by balancing the moments of force about the z-axis, **(3 marks)**

b) Write the two (2) equations for balancing the moments about the x-axis and the forces along the y-axis, showing all unknowns. **(4 marks)**

c) Choose two structures that might bear the loads in the equations from part b) and solve for the internal loading of the knee. Is this solution physiologically possible? **(5 marks)**

d) Choose two different structures that might bear the loads in the equations from part b) and solve for the internal loading of the knee. Is this solution physiologically possible? **(3 marks)**



Key

L_m = medial ligament
L_L = lateral ligament
J_m = medial joint force
J_L = lateral joint force

Figure 4

Marking Scheme

1. 15 marks total; a) 4, b) 4, c) 4, d) 3 marks
2. 15 marks total; a) 5, b) 5, c) 5 marks
3. 15 marks total; a) 5, b) 3, c) 4, d) 3 marks
4. 15 marks total; a) 3, b) 4, c) 5, d) 3 marks