National Exams May 2017

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.

Marking Scheme

1. 15 marks total: a) 4, b) 4, c) 5, d) 2
2. 15 marks total: a) 5, b) 5, c) 5
3. 15 marks total: a) 3, b) 3, c) 3, d) 6
4. 15 marks total: a) 5, b) 3, c) 4, d) 3

1. A truck driver is attempting to pull a gear lever toward himself with his right arm and hand (Figure 1). At the instant shown the driver is applying a force of 120 N horizontally to the left and 80 N vertically upwards. The hand also applies a small clockwise moment of 5 Nm to the handle at point H on the diagram. All motion occurs within the plane of the page.

   For the limb position and dimensions shown in Figure 1, do the following:

   a) Draw a free body diagram of the forearm and upper arm showing all relevant forces and moments, **(4 marks)**

   b) Calculate the moment at the elbow joint, **(4 marks)**

   c) Calculate the moment at the shoulder joint, **(5 marks)**

   d) At each of the joints, which muscles are likely to be active? **(2 marks)**

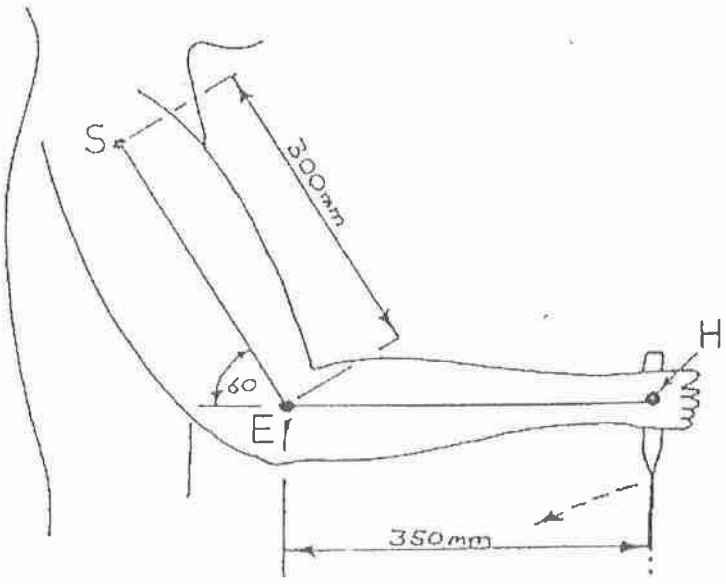
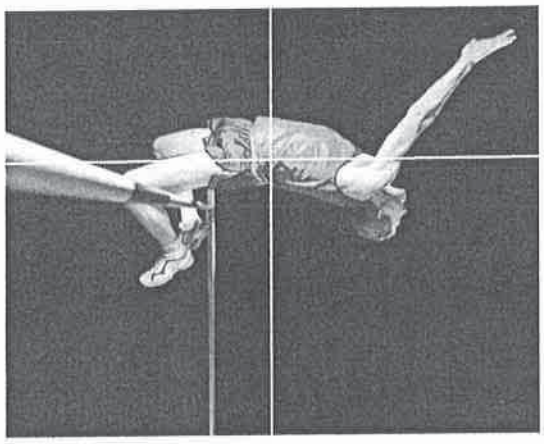


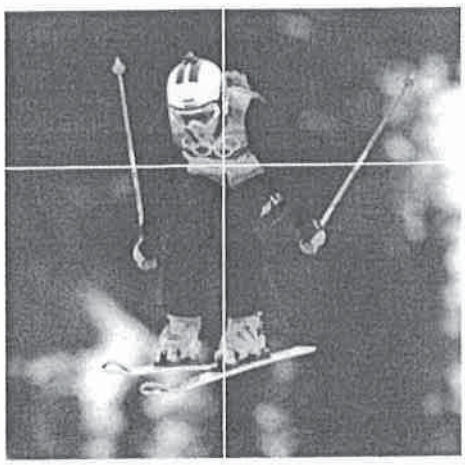
Figure 1: A truck driver pulling a stiff gear lever with his right arm and hand

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.

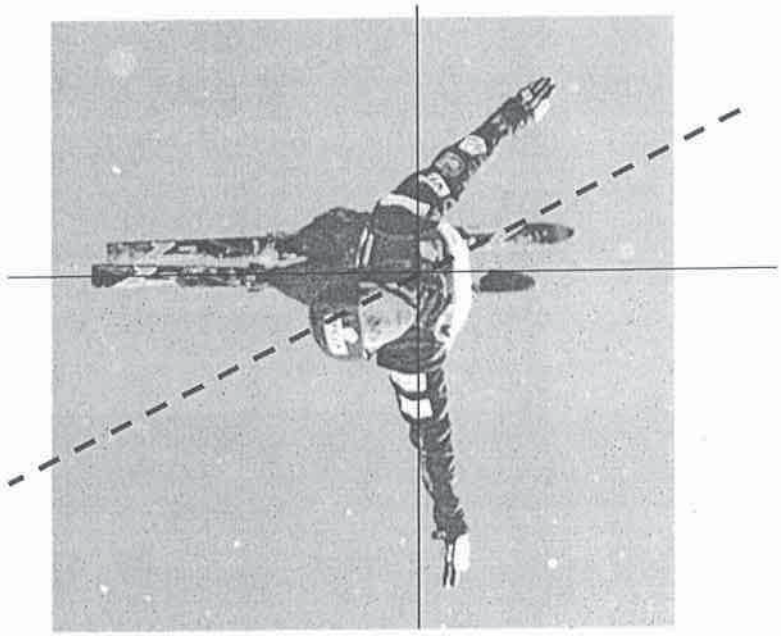
a) A high jumper rotating in the frontal plane at 90 deg/sec with their head moving to their right and spinning about their long axis at 27 deg/sec with their right shoulder moving upwards, **(5 marks)**



b) A ski racer somersaulting forward at 10 deg/s and twisting to their left about their long axis at 36 deg/s, **(5 marks)**



c) An aerial skier is rotating about the dotted resultant axis at 360 deg/s. They are rotating with the left shoulder moving to their right about their anterior-posterior axis and somersaulting backward about medio-lateral axis. **(5 marks)**

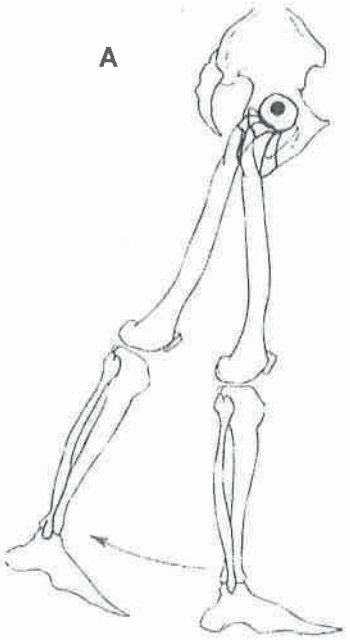


3. a) For the body part in A) describe the motion and the anatomical axis about which is occurs **(3 marks)**

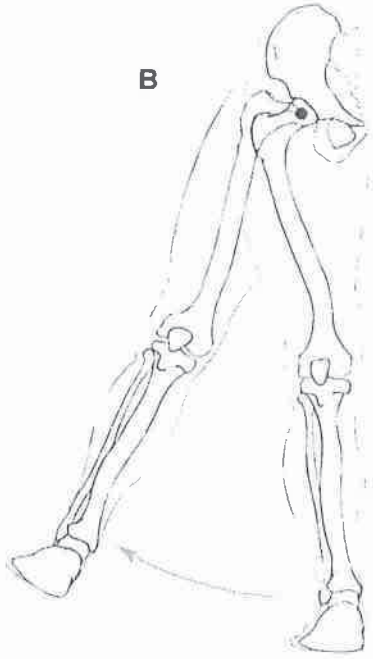
b) For the body part in B) describe the motion and the anatomical axis about which is occurs **(3 marks)**

c) For the body part in C) describe the motion and the anatomical axis about which is occurs **(3 marks)**

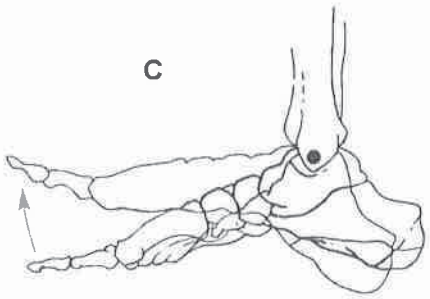
A



B



C



d) In the photo in D), what is the motion that is being forcefully applied to the left elbow and what structures in the elbow are likely to be injured as a result? **(6 marks)**

D

4. Motion analysis determines that the sum of the forces and moments acting externally on the femur are the following:

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} +120 \\ +760 \\ -200 \end{bmatrix} N \text{ and } \begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} +33 \\ +25 \\ +4 \end{bmatrix} Nm$$

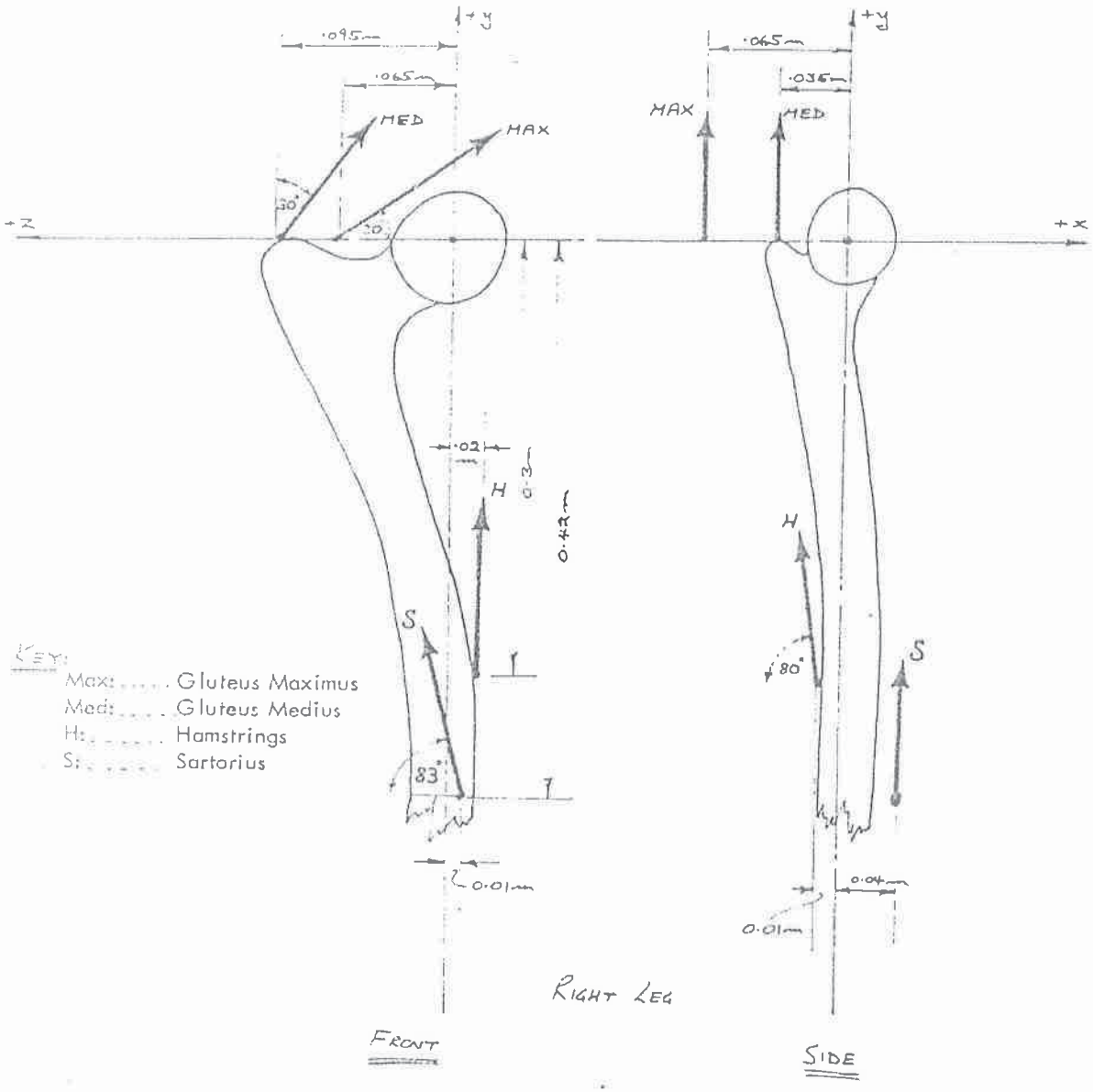
a) Using the diagrams on page 7 (Figure 4), draw the diagram of the femur segment and muscles in the transverse view with the axis origin at the centre. Clearly draw all positive axis and rotation directions. Show all dimensions **(5 marks)**

b) Including all the muscles shown, derive the three equations that balance the moments about each of the three axes **(3 marks)**

c) Considering your understanding of the hip joint and the external moments that are being applied, choose three of the four muscles that you consider appropriate and determine the muscle forces required for equilibrium **(4 marks)**

d) Using the muscle forces found in part c), balance the forces along the three axes and calculate the three components of the joint contact force (i.e. J_x, J_y, J_z) **(3 marks)**

Figure 4


+y
.095m
.065m
MED
MAX
30°
30°
+z
+x
.02
H
0.3
0.42m
S
KEY:
Max: . . . . . Gluteus Maximus
Med: . . . . Gluteus Medius
H: . . . . . Hamstrings
S: . . . . . Sartorius
83°
0.01m
FRONT
RIGHT LEG
.065m
.036m
MAX
MED
H
80°
S
0.04m
0.01m
SIDE