National Exams November 2012

04-Bio-A4-Biomechanics

3 hours duration

Notes

1. If doubt exists as to the interpretation of any question, the candidate is urged to include a clear statement of any assumptions made in the answer booklet.
2. This is an OPEN BOOK EXAM.
3. Five (5) questions constitute a complete exam paper.
4. Each question is of equal value.
5. Clarity and organization of the answers are important.
6. Any non-communicating calculator is permitted.

(15 marks) 1. Figure 1 below shows an athlete performing a wide grip pull-up. The left picture shows the starting position and the right picture shows a midway position after the athlete has started to pull himself up. It is this position that needs to be analyzed kinematically.

Assume that the athlete's body including his shoulder (point S) moves only along a vertical path with a constant upward velocity of 0.8 m/s. Also assume a forearm length of 30 cm and an upper arm length of 35 cm. At the instant shown in the right picture $\theta=55°$ and $\beta=45°$. Using general plane motion, do the following:

a) Draw the vector diagram for the motion of the forearm segment **(3 marks)**
b) Draw the vector diagram of the motion of the upper arm segment **(3 marks)**
c) Calculate the angular velocity of the forearm **(4 marks)**
d) Calculate the angular velocity of the upper arm **(5 marks)**

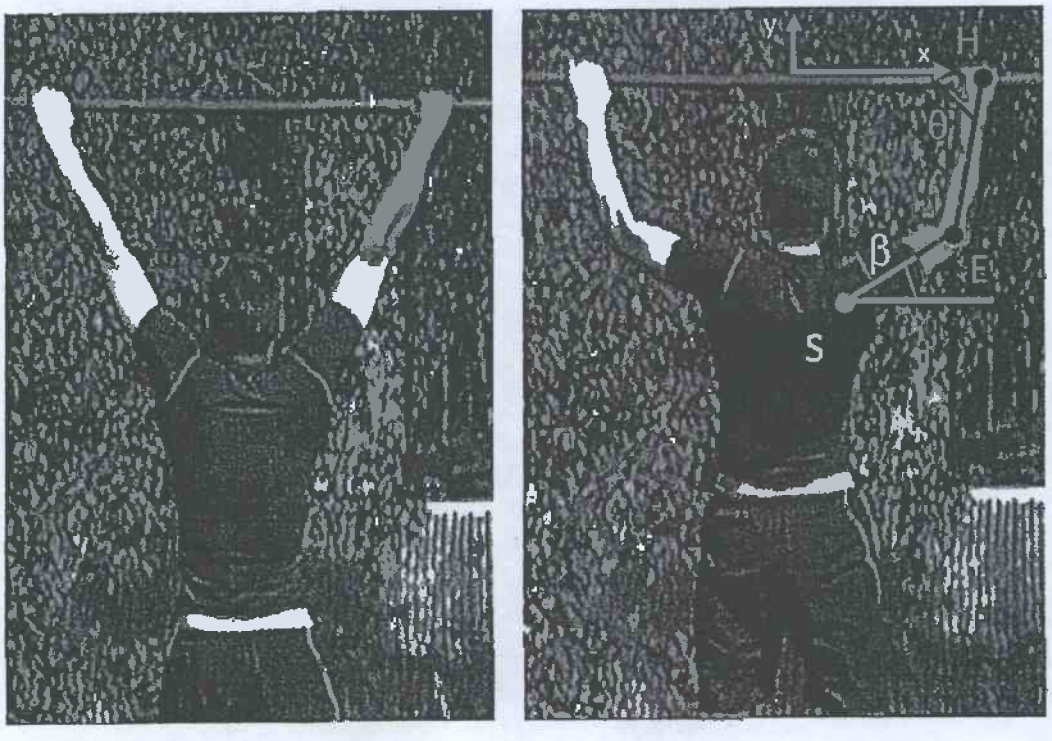


Figure 1: Wide grip pull-up start position (left) and midway position (right) showing angles and points of relevance.

(15 marks) 2. Data collected from a motion capture laboratory shows that the position of a bone marker (in cm) varies with time (in seconds) according to the following equation:

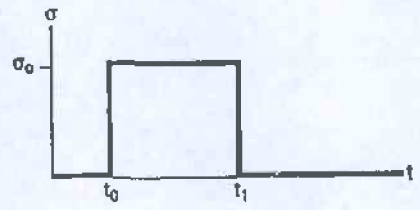
$$x(t) = 25 - 10\sin(30t) + 15\cos(45t) + 20\sin(45t) + 5\cos(60t)$$

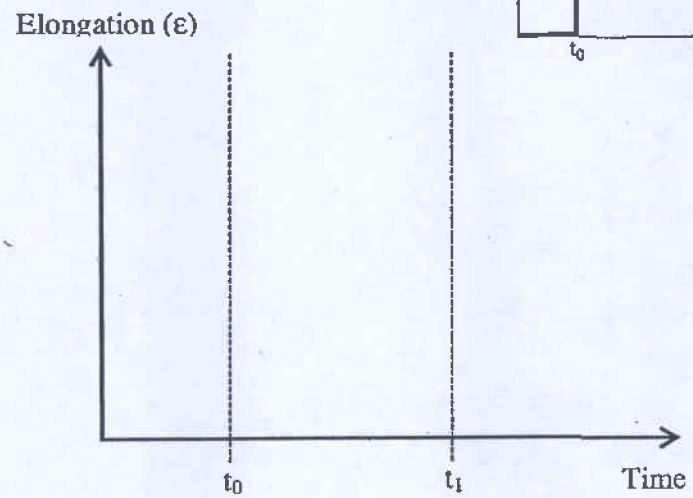
a) Rewrite the equation in terms of sine functions only **(5 marks)**
b) What minimum sampling rate (in Hz) should be used to measure this signal, and why? **(3 marks)**
c) What is the fundamental frequency in Hertz, and what harmonic orders are present? **(3 marks)**
d) If a sampling rate of 100 Hz is chosen, how many data points should be sampled to obtain an accurate representation of this input waveform? **(4 marks)**

3. a) Sketch an example of the elongation of a tendon that results from a creep-relaxation test using the axes below (please draw these axes in your answer booklet). The input stress is shown in the Figure 3a. At a t_0 constant stress σ_0 is applied. At t_1 the stress is removed. Clearly show the following: **(5 marks)**

   i) Creep
   ii) Relaxation
   iii) Residual elongation
   iv) Peak elongation

Figure 3a: Stress input



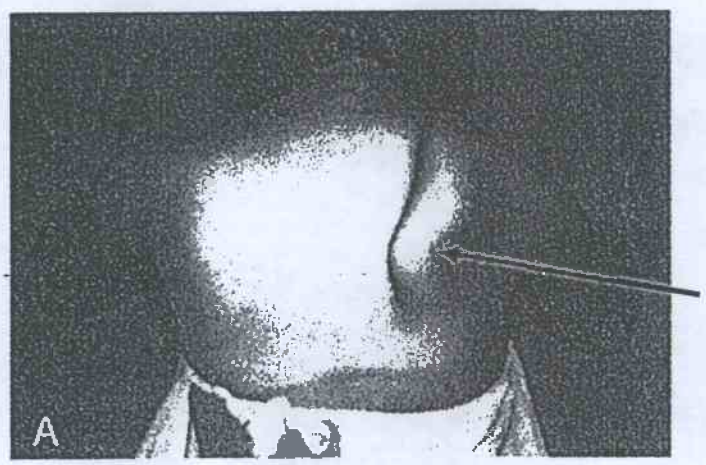


b) What condition does the girl have in the photo below (indicated by black arrow)? **(3 marks)**

c) What muscles might be strengthened to correct this condition? **(3 marks)**

d) What musculoskeletal disorders is this girl now at risk for? **(4 marks)**

Figure 3b:



4. An 85 kg athlete (1.85 m tall) does sit-ups at the gym on a level surface (Figure 4). The center of rotation is the between the spinal vertebrae at L4-L5, which is 80 mm horizontally proximal to the hip joints, as shown in the figure. The athlete holds both his arms behind his neck. At the instant shown, there is a moment of 256 Nm applied at L4-L5 tending to raise the trunk, etc. off the ground but the angular velocity (ω) is zero. The mass of the head plus arms plus hands plus trunk and abdomen is 49.5 kg and can be considered to act at 476 mm proximal to the L4-L5 joint. The radius of gyration is 255 mm.

   a) Draw the free body diagram of the relevant segment and show all the accelerations, forces and moments acting on the body. **(3 marks)**
   b) What is the angular acceleration of the trunk at the instant shown? **(5 marks)**
   c) What are the reaction forces at the L4-L5 joint arising from this motion? **(5 marks)**
   d) Calculate the vertical and horizontal components of acceleration at the shoulder joint. **(2 marks)**

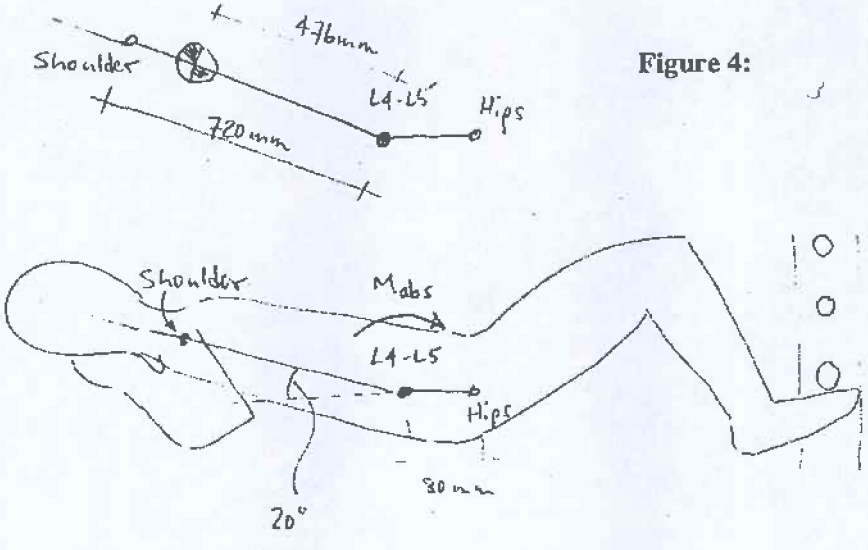
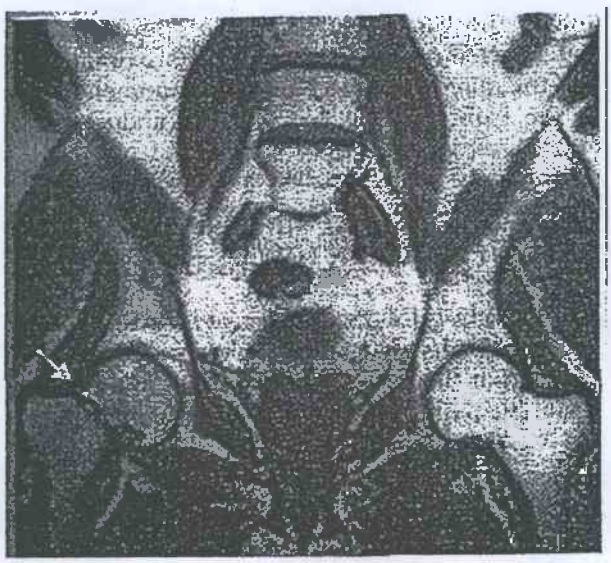


Figure 4:

5. Consider the MRI in Figure 5 below. This is a frontal pelvic view of a 64 year old male complaining of severe pain and loss of weight-bearing in the right hip.

   a) What injury has this person sustained (indicated by white arrow)? **(4 marks)**
   b) Suggest a biomechanical mechanism by which this injury occurred **(5 marks)**
   c) What surgical procedure should be used to correct this injury? How long do you expect the healing process to take before return to full function? **(4 marks)**
   d) Give two possible complications during the healing process. **(2 marks)**

Figure 5: MRI frontal view of the pelvic region.



Marking scheme

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