UNIVERSITY OF GHANA

BSC. ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF BIOMEDICAL ENGINEERING
BMEN 307: BIOMECHANICS (3 CREDITS)

INSTRUCTIONS:

Attempt all questions
All questions should be answered in the booklet provided
Calculations should be detailed and systematic. Marks allocated to steps
Relevant formulae are provided at the end of the question sets
All symbols used have their usual meanings

TIME ALLOWED: ***TWO AND A HALF (2½) HOURS***

1. As part of rehabilitation, a patient with knowledge of biomechanics is asked to perform lunges to work the quadriceps and gluteus muscles. She has no knowledge of how this exercise is performed and you are asked to describe the movement to her. Using the appropriate terminology and the figure below, describe the lower limb movement involved in performing lunges to the patient.

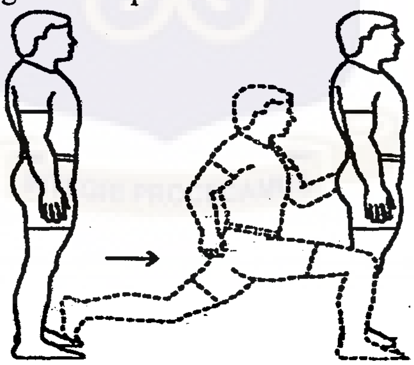

Figure 1. Illustration of a person performing lunges. Image from https://hifitnessclub.files.wordpress.com/2013/05/dynamic_forward_lunge_step.jpg

(10 marks)

2. A piece of muscle is identified as a viscoelastic material that can be modelled by the Maxwell Model of viscoelasticity. Given that it has a diameter of 2 cm;
   a. What is creep?

(5 marks)

   b. What is stress relaxation?

(5 marks)

c. Illustrate the phenomenon of stress relaxation with a sketch.

(5 marks)

d. Calculate the relaxation constant for the muscle if it takes 2 hours for the stress imposed by a 200 N load to decay by 10%.

(10 marks)

3. A 60 kg student is involved in an accident that leaves him injured. He has developed an incomplete fracture of the distal tibia. As a remedy, doctors prescribe a cast to stabilise the bone while it heals. He is advised not to place any load on the affected leg and is subsequently discharged. The student's upper body contributes 70% of the total weight with each leg contributing 15% to the weight. Using the figures below and the information provided answer the following questions. [Mass of cast = 2.5 kg, W_{LC}=Weight of leg and cast, W_U= Weight of upper body]

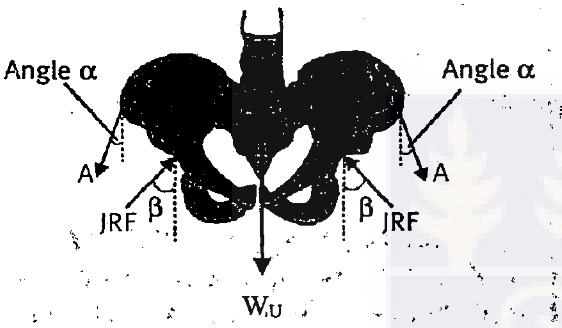

Figure 2. FBD of pelvis whilst standing on two legs. Adapted from Simpson et al., (2010)

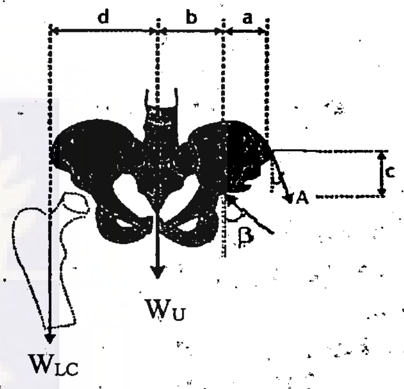

Figure 3. FBD of pelvis while standing on one leg with other leg hanging. Adapted from Simpson et al., (2010)

a. At home, the individual tries to walk and ends up standing on the uninjured leg with the other leg (with cast) hanging in mid-air (FBD indicated in Figure 3).

i. Calculate the magnitude of the Joint Reaction Force (JRF) and the force generated by the adductor muscle (A) to keep the student balanced. [a = 150 mm, b = 250 mm, c = 100 mm, d = 320 mm, α = 5° and β = 3°].

(20 marks)

ii. The tension generating capacity of muscle is known to be 90 Ncm^{-2}. How thick must the adductor muscle be to generate the force calculated above? Assume it has a circular cross-section.

(5 marks)

iii. If the adductor muscle were unipennate with the muscle fibres oriented at 15° to the line of the tendon, calculate the force generated by the muscle fibres.

(5 marks)

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b. The student receives a walking stick to aid in his movement. What is the ground reaction force (S) on the walking stick required to cause a 20% reduction in both the adductor muscle force (A) and the Joint Reaction Force (JRF) calculated in (a)? [e = 650 mm] ***(20 marks)***

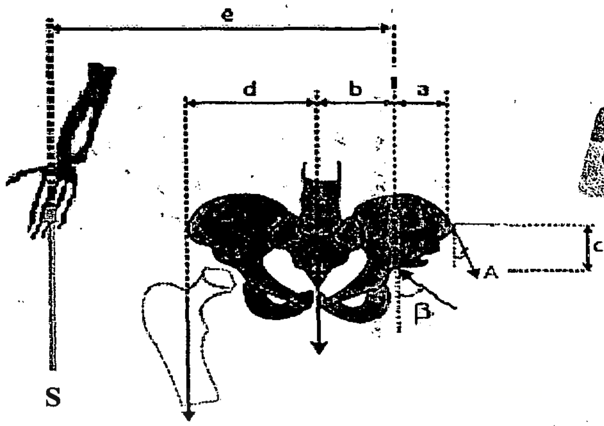

Figure 4. FBD of pelvis showing loading with the assistance of a walking stick. Adapted from Simpson et al., (2010).

4. With reference to the information in question 3, the student begins to walk on the incompletely healed leg after a week. Unfortunately the loading causes a complete fracture of the tibia and he is recommended for traction. Due to an influx of accident victims, the orthopaedic unit is short of weights and has only a 200 N weight available.
   a. List the three (3) principles/components of fracture fixation.

   (6 marks)

   b. Given the three pulley system below,
      i. How much tensile load can be generated by the 200 N weight for traction?

      (6 marks)

      ii. Calculate the mechanical advantage of this system.

      (2 marks)

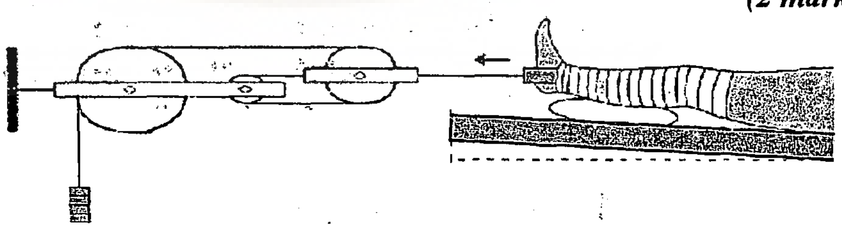

Figure 5: Lower limb traction using a 3-pulley system

   c. The student is immobilised for a long time and after the fracture has healed, he realizes the healed leg seems smaller than it was previously. Explain what could possibly account for this change.

   (6 marks)

Formula Bank:

$$F = ma$$

$$F = \sigma A$$

$$F_m = \sigma_m A_m$$

$$F_{tendon} = F_{fibre} \cos\theta$$

$$\sum \bar{F} = 0$$

$$\sum \bar{M} = 0$$

$$\sum \bar{F} - m\bar{a} = 0$$

$$\sum \bar{T} - \bar{I}\alpha = 0$$

$$M = force \times moment\ arm$$

$$I = \sum mr^2$$

$$U = \frac{1}{2}\frac{\sigma^2}{E}V$$

$$F_f = \mu F_n$$

$$\sigma_t = \sigma_0 e^{-\frac{E}{\mu}t}$$

$$MA = \frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load}$$

$$Work\ done\ by\ effort = Work\ done\ by\ load$$

Reference:

Simpson, D.J., *et al.* Biomechanics in orthopaedics: considerations of the hip and knee. *Surgery (Oxford)* 2010;28(10):478-482.