Electrical Engineering 3BA3: Structure of Biological Materials

Day Class Instructor: Dr. I. C. BRUCE
Duration of Examination: 90 Minutes
McMaster University Midterm Quiz #1 October, 2008

This examination paper includes four (4) pages and twelve (12) questions. You are responsible for ensuring that your copy of the paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1–8 are multiple-choice questions, each worth 5 pts. Only one answer, *a*, *b*, *c* or *d*, is correct for each question. Please answer these questions in the answer booklet, NOT on this questions sheet.

Questions 9–12 are short answer and/or mathematical questions, each worth 15 pts.

1. Tendons and ligaments:
   a. have very rubbery stress-strain relationships,
   b. contain a greater proportion of elastin than collagen,
   c. have fairly crystalline stress-strain relationships, or
   d. are manufactured by chondrocytes. **(5 pts)**

2. Maintenance of healthy bone requires the normal functioning of:
   a. fibroblasts only,
   b. osteoclasts only,
   c. osteoblasts only, or
   d. both osteoblasts and osteoclasts. **(5 pts)**

3. The *first* stage of wound repair is :
   a. inflammation,
   b. remodelling,
   c. proliferation, or
   d. coagulation/haemostasis. **(5 pts)**

4. *Carbon materials* have not been successful utilized in orthopaedic implants because:
   a. they all have very poor biocompatibility,
   b. nobody has thought of it yet,
   c. it is not yet possible to obtain suitable mechanical properties, or
   d. they are much too heavy. **(5 pts)**

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5. To prevent infection, synthetic biomaterials:
   a. must be sterilized using steam under pressure,
   b. must be sterilized using radiation,
   c. must be sterilized using ethylene oxide gas, or
   d. can be sterilized using any of the above. **(5 pts)**

6. The chemical *acetylcholine* (ACh) is:
   a. the neurotransmitter used in neuromuscular junction (i.e., the synapse between a motor neuron and a muscle fiber),
   b. a constituent chemical of nylon,
   c. present in fast glycolytic muscle fibers but not in slow oxidative fibers, or
   d. the chemical that causes myosin filaments to move along actin filaments in myofibrils. **(5 pts)**

7. In a normal running motion, the *hip* joint:
   a. has a much higher maximum power than the maximum knee or ankle power,
   b. only produces power,
   c. only absorbs power, or
   d. is mainly involved in placing the leg in the correct position for each phase of the stance. **(5 pts)**

8. *Thin* split-thickness skin grafts:
   a. damage the donor site more than do *full-thickness* grafts,
   b. can be stretched to cover a greater recipient area than can *full-thickness* grafts,
   c. include only a portion of the epidermis and none of the dermis, or
   d. look like normal skin immediately after transplantation. **(5 pts)**

9. Discuss briefly:
   a. why *cost-benefit analysis* is important for the application of technology to healthcare, and
   b. how the cost-benefit analysis of technology to treat a non-life-threatening condition could be compared to that for a life-threatening condition. **(15 pts)**

10. Briefly explain the difficulties involved with anchoring of metal alloy prostheses in bone and compare the advantages and disadvantages of using cements versus direct osseointegration. **(15 pts)**

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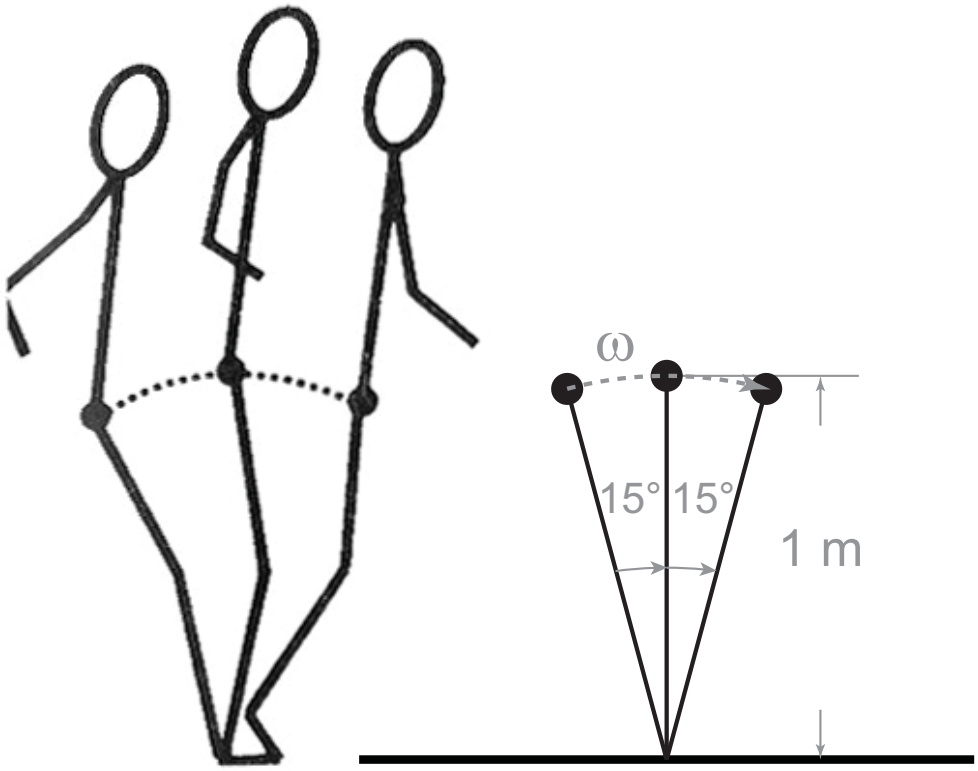
11. Consider the inverted-pendulum model of walking illustrated below.



Assume the following:

i. The person has a mass of 70 kg, and the acceleration due to gravity is $g = 9.8\ \mathrm{m/s^2}$.

ii. The person's leg joints move such that their centre of mass (COM) moves in an arc with a constant radius of 1 m around the pivot point in their ankle throughout the single-stance phase of walking, as depicted above.

iii. A single-foot stance phase begins at time $t = 0$ with the COM at 15° from vertical (relative to the pivot point in the ankle) and ends with the COM at 15° past vertical at time $t = 0.5\ \mathrm{s}$.

iv. The person is walking in such a way that their COM has a constant angular velocity $\omega = 60\ ^\circ/\mathrm{s}$ for $0 \le t \le 0.5\ \mathrm{s}$.

Determine the following:

a. The change in gravitational potential energy ΔE_{grav} from the lowest point in the single-stance phase (i.e., at $t = 0$) to the highest point (i.e., when the COM is directly above the pivot point in the ankle).

b. Expressions for the vertical ground reaction force $F_{gz}(t)$ and horizontal ground reaction force $F_{gy}(t)$ that would be measured during the period $0 \le t \le 0.5\ \mathrm{s}$ according to this model and the given assumptions. **(15 pts)**

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12. The total force F_T produced by a muscle as a function of muscle length is the sum of two components, the activate force F_A produced by myofibril contraction and the passive force F_P produced by the stress-strain characteristics of the muscle.

    Consider contraction of a particular muscle for which the activate force F_A depends on the muscle length according to the relationship:

$$F_A = \begin{cases} 0, & \text{for } L < 0.5, \\ 20 - 80\left(L - 1\right)^2, & \text{for } 0.5 \le L \le 1.5, \\ 0, & \text{for } L > 1.5, \end{cases}$$

    where F_A has units of N and L is the muscle length relative to (i.e., divided by) its resting length.

    The muscle's passive force F_P depends on the muscle's relative length according to the relationship:

$$F_P = \begin{cases} 0, & \text{for } L < 0.75, \\ 40\left(L - 0.75\right)^3, & \text{for } L \ge 0.75. \end{cases}$$

    where F_P has units of N.

    a. At what relative length L *within the muscle's normal operating range of* $0.5 \le L \le 1.2$ is the total force $F_T = F_A + F_P$ maximal?

    b. What is the maximal total force (i.e., the total force at the relative length L found in part a. above)? **(15 pts)**

THE END