B

UNIVERSITY OF GHANA

BSC. BIOMEDICAL ENGINEERING FIRST SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF BIOMEDICAL ENGINEERING

BMEN 307: BIOMECHANICS (3 CREDITS)

INSTRUCTIONS:

Answer all questions

For all calculations use $g = 9.81$ **ms**$^{-2}$ and $\pi = 3.142$

TIME ALLOWED: TWO AND A QUARTER ($2^1/_4$) HOURS

1. In an effort to assess the effectiveness of treatment given to a female patient, you are required to perform gait analysis of the movement of her total leg, which is made up of the thigh, shank and the foot. Consider the greater trochanter as the effective centre of rotation for the hip joint. Use the following information: the mass of patient is 60 kg and she is 170 cm tall. The *kinematic data* gathered from the gait experiment is shown in Table 1.

Table 1: Kinematic Data. The frequency of measurement was 60 Hz.

Frame	Marker Locations (cm)			
	1	2	3	4
5	$-28.30i + 96.59j$	$-6.85i + 55.73j$	$-7.38i + 49.26j$	$7.28i + 11.68j$
6	$-25.14i + 96.21j$	$-3.22i + 56.04j$	$-3.81i + 49.21j$	$10.84i + 11.41j$
7	$-21.52i + 95.50j$	$-0.50i + 56.32j$	$-0.26i + 49.11j$	$13.73i + 11.12j$

Using frame 6 for your analysis,

(a) Compute the length of the total leg segment and centres of mass (with reference to the proximal end of the thigh) for each frame. Assume that markers 1 and 4 were placed on the greater trochanter (thigh) and the medial malleolus (ankle). **[8 marks]**

(b) Compute the linear accelerations of the centre of mass of the total leg segment in the x and y directions. **[6 marks]**

(c) Compute the reaction forces at the hip at the instant when the ground reaction force is given by $F_G = -30i + 420j$ N. **[6 marks]**

(d) Explain the implication of the forces calculated in (c) in terms of the bone-to-bone force. **[5 marks]**

2. During a rather rough basketball game a player falls and lands on his lower arm, creating a 0.1 cm defect in the radius bone 8 cm from the elbow. For his next workout session at the gym, the player decides to lift a 120 N weight to exercise his biceps. Use the following information for the radius bone: material constants C = 2.5×10^{-6}m $(\mathrm{MN/m^{3/2}})^{-2.5}$ and m = 2.5; Young's modulus, E = 16 GPa, Toughness, $G_c = 800$ Jm^{-2}

   (a) If the maximum axial force generated in his radius bone is 304.3 N, calculate the maximum stress. Assume that the radius is a hollow beam of circular cross-section with an outer diameter equal to 1.4 cm. Take the moment of inertia, I_z, to be equal to 0.177 cm^4. **[9 marks]**

   (b) Determine whether fast fracture will occur or not. Give a reason(s) for your answer. **[9 marks]**

   (c) Determine how many times the player can lift the weight before his bone fractures. Assume that the change in stress over one cycle is equal to 2.65 Pa. **[7 marks]**

3. Your classmate, who weighs 735 N, agrees to have his standing jump analysed for an on-going independent study to investigate the effect of diet on terrestrial locomotion. The position of his centre of gravity during the jump is given by

$$z(t) = 10t^2 + 8\sin t$$

   where $z(t)$ is in metres and t is time. The push-off duration is 180 ms.

   (a) What is the average push-off force exerted during the jump? **[10 marks]**

   (b) Assuming that the elevation of the centre of gravity at the beginning of the push-off phase is measured at $t = 0$, calculate the height attained by the centre of gravity. **[10 marks]**

   (c) Calculate his velocity at the end of the push-off phase. **[5 marks]**

4. (a) List 3 core ideas of functional adaptation that continue to intrigue researchers today. **[3 marks]**

   (b) With the aid of a diagram, outline the major components of the hierarchy of organisation in collagen tissue from molecular to whole tissue scales. **[10 marks]**

   (c) Describe the general structural organization of ligament and tendon. **[12 marks]**

Figure 1: Anthropometric Data

Segment	Definition	Segment Weight/ Body Weight	Center Mass/ Segment Length Proximal	Center Mass/ Segment Length Distal
Hand	Wrist axis/knuckle II middle finger	0.006	0.506	0.494
Forearm	Elbow axis/ulnar styloid	0.016	0.430	0.570
Upper arm	Glenohumeral axis/elbow axis	0.028	0.436	0.564
Forearm and hand	Elbow axis/ulnar styloid	0.022	0.682	0.318
Total arm	Glenohumeral joint/ulnar styloid	0.050	0.530	0.470
Foot	Lateral malleolus/head metatarsal II	0.0145	0.50	0.50
Leg	Femoral condyles/medial malleolus	0.0465	0.433	0.567
Thigh	Greater trochanter/femoral condyles	0.100	0.433	0.567
Foot and leg	Femoral condyles/medial malleolus	0.061	0.606	0.394
Total leg	Greater trochanter/medial malleolus	0.161	0.447	0.553
Head and neck	C7-T1 and 1st rib/ear canal	0.081	1.000	
Shoulder mass	Sternoclavicular joint/glenohumeral axis		0.712	0.288
Thorax	C7-T1/T12-L1 and diaphragm	0.216	0.82	0.18
Abdomen	T12-L1/L4-L5	0.139	0.44	0.56
Pelvis	L4-L5/greater trochanter	0.142	0.105	0.895
Thorax and abdomen	C7-T1/L4-L5	0.355	0.63	0.37
Abdomen and pelvis	T12-L1/greater trochanter	0.281	0.27	0.73
Trunk	Greater trochanter/glenohumeral joint	0.497	0.50	0.50
Trunk, head, neck	Greater trochanter/glenohumeral joint	0.578	0.66	0.34
Head, arm, trunk	Greater trochanter/glenohumeral joint	0.678	0.626	0.374

Adapted from Winter, 1990, Table 3.1, pp. 56–57.

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