UNIVERSITY OF GHANA

BSC. ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2018/2019

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

INSTRUCTIONS:
ANSWER ALL QUESTIONS
FOR ALL CALCULATIONS USE g = 10 ms^{-2} and $\pi = 3.142$

TIME ALLOWED: TWO (2) HOURS

1. Consider that an 80 year old woman is subjected to a One-Legged Stance Test to screen for balance impairment. During the test, she stands on her right leg while carrying a load of 6 kg in each hand as shown in Figure (1a). The forces acting on the pelvis are shown in Figure (1b).

(a) (b)

Figure 1 (a)The man carrying a load of W_0 = 6kg in each hand and (b) Forces acting on the pelvis. Source: Özkaya *et al.* 2017

Point A is the point of attachment of the hip abductor muscle to the pelvis and where the magnitude of its resultant force, F_M, is applied. Point B is where the magnitude of the joint reaction force, F_J, is applied by the head of the femur. W_1 denotes the weight of the upper body and the left leg acting as a concentrated force at point C. The ratio of the perpendicular distance between point B and the line of action of W_1 to the perpendicular distance between F_M and point B is 2.6 cm. The right and left hands are 25 cm and 30 cm away from points B and C, respectively. The angle F_M makes with the horizontal, θ, is measured as 70°.

(a) Draw a free body diagram to represent the scenario described. **[5 marks]**

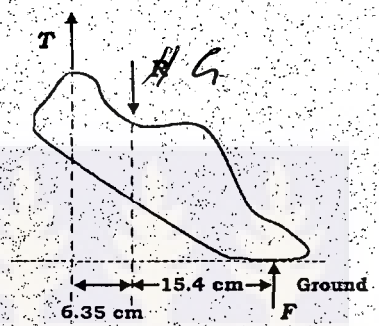
(b) Determine the magnitude of F_M acting at the point A if the distance between point B and the line of action of W_1 is 30 cm and W_1 = 40 N. **[8 marks]**

(c) Determine the magnitude of F_J and the angle it makes with the horizontal, φ. [12 marks]

2. During a routine biomechanical test, the strength of an athlete's leg musculature is assessed through an analysis of her standing jump. Starting from the anatomical position, she crouches, which lowers her centre of gravity by 8.4 cm, and then pushes against the ground with her legs until her feet leave the ground. The duration of the *pushoff* phase is 180 ms. The velocity of the jump is defined by:

$$v(t) = \frac{t^2}{2} + 4t - 3.61$$

where t is time. Fig. 2 shows the forces acting on the foot during the rest. G is the force exerted on the foot by the lower leg. Let F be the equivalent force exerted by the ground on the foot. T is the average tension present in her Achilles tendon.



m = 68kg

Figure 2 Forces exerted on the foot during the jump.

(a) Compute the maximum elevation, h, of the centre of gravity, measured with respect to its position when the athlete is standing in the anatomical position. [12 marks]

(b) Determine the equivalent ground reaction force, F, exerted by the ground on the foot. [7 marks]

(c) What is the average tension, T, present in the Achilles tendons. [6 marks]

3. Every year kinetic gait analysis of newly recruited infantry soldiers is performed to determine whether parameters such as joint and ground reaction forces can be used to predict lower-limb overuse injuries. During the experiment, the recruits march with straight legs on a force plate with reflective markers placed on their greater trochanter (hip) and lateral malleolus (ankle). Data for the motion of the *total leg* of a recruit are summarized in Table 1. The frequency of measurement was 50 Hz. The recruit's mass and height are 60 kg and 1.7 m respectively.

Table 1 : Data for one of the recruits. F_x and F_y are the horizontal and vertical ground reaction force on the foot measured by the force plate. L is the distance between the two markers. CoG is the location of the centres of gravity of the leg. θ is the angle the swing leg makes with the horizontal

Frame	F_x (N)	F_y (N)	L (mm)	CoG (mm)	θ(rad)
1	-0.7	-0.8	(366.4,-859.1)	(-457.9,1359.9)	-0.35
2	-0.7	6.0	(369.8,-855.7)	(-426.7,1352.6)	-0.07
3	-1.7	92.0	(364.5,-853.8)	(-390.1,1346.7)	0.12

CoG

The total leg is made up of the thigh, shank and foot. Take the greater trochanter to be the effective centre of rotation of the hip joint.

(a) Compute the reaction force at the hip joint for frame 2 **[10 marks]**

(b) What is the reaction moment exterted at the hip for frame 2. **[15 marks]**

4. (a) Explain how the following parameters affect the tension that a muscle fibre can generate: **[15 marks]**

   i. *Velocity* of contraction.

   ii. *Length* of muscle fibre.

   iii. *Time*.

   (b) In your own words, describe the main events occurring between the attachment of Ca^{2+} to *troponin* and detachment of *actin filaments* from *myosin filaments* after muscle contraction. **[10 marks]**

USEFUL EQUATIONS

$$a^n = \frac{CoG^{n-1} - 2CoG^n + CoG^{n+1}}{\Delta t^2}$$

$$I = mk^2$$

$$\alpha^n = \frac{\theta^{n-1} - 2\theta^n + \theta^{n+1}}{\Delta t^2}$$

TABLE 4.1 Anthropomorphic Data

Segment	Definition	Segment Weight/ Body Weight	Center Mass/ Segment Length		Radius Gyration/ Segment Length	
			Proximal	Distal	Proximal	Distal
Hand	Wrist axis/knuckle II middle finger	0.006	0.506	0.494	0.587	0.577
Forearm	Elbow axis/ulnar styloid	0.016	0.430	0.570	0.526	0.647
Upper arm	Glenohumeral axis/elbow axis	0.028	0.436	0.564	0.542	0.645
Forearm and hand	Elbow axis/ulnar styloid	0.022	0.682	0.318	0.827	0.565
Total arm	Glenohumeral joint/ulnar styloid	0.050	0.530	0.470	0.645	0.596
Foot	Lateral malleolus/head metatarsal II	0.0145	0.50	0.50	0.690	0.690
Leg	Femoral condyles/medial malleolus	0.0465	0.433	0.567	0.528	0.643
Thigh	Greater trochanter/femoral condyles	0.100	0.433	0.567	0.540	0.653
Foot and leg	Femoral condyles/medial malleolus	0.061	0.606	0.394	0.735	0.572
Total leg	Greater trochanter/medial malleolus	0.161	0.447	0.553	0.560	0.650
Head and neck	C7-T1 and 1st rib/ear canal	0.081	1.000		1.116	
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	0.830	0.607
Head, arm, trunk	Greater trochanter/glenohumeral joint	0.678	0.626	0.374	0.798	0.621

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

Figure 3 Anthropometric Data