[ENG27]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (Hons) BIOMEDICAL ENGINEERING

SEMESTER 2 EXAMINATIONS 2023/24

INTERMEDIATE BIOMECHANICS

MODULE NO. BME5004

Date: Thursday 16th May 2024 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions on this paper: TWO questions in section A and FOUR questions in section B.

Section A: Answer ONE question

Section B: Answer TWO questions

Write your answers in the answer book provided, NOT on the question paper. You must clearly label each answer with the corresponding section letter, question number and part letter.

Electronic calculators may be used provided that data and programme storage memory is clear prior to the examination.

School of Engineering
BEng (Hons) Biomedical Engineering
Semester 2 Examination 2023/24
Intermediate Biomechanics
Module No. BME5004

Section A: Experimental

Answer ONE question from this section.

1. a) You are working with a client who has recently suffered neurological trauma who has some neuromuscular inefficiencies in performing basic tasks like standing and walking they will be completing a rehabilitation programme, and your objective is to document their progress. **Outline** a case study style investigation utilising 2-dimensional video analysis in assessment of linear and angular kinematics (e.g., joint displacement, velocities, accelerations) which will provide biomechanical evidence to support your report and recommendations. **(20 marks)**

b) Discuss the anticipated results and potential implications of the findings from the case study outlined above and provide a balanced overview of how the results would influence your recommendations, i.e., offering both primary and alternative recommendations, which will depend on the actual direction of the data should this case study investigation be completed. **(14 marks)**

c) Identify two key limitations - with a brief description of each - of 2-dimensional video analysis in the context outlined in 1.a) as a mode of biomechanical observation of human motion. **(6 marks)**

2. a) You are working with a client who is a single-leg amputee and wants to find the most appropriate dynamic prosthesis limb length to mitigate frontal plane motion in their healthy intact limb and muscular fatigue around the pelvis during prolonged bouts of physical exertion. **Outline** a case study style investigation utilising 2-dimensional video analysis in assessment of linear and angular kinematics (e.g., joint displacement, velocities, accelerations) which will provide biomechanical evidence to support your report and recommendations. **(20 marks)**

b) Discuss the anticipated results and potential implications of the findings from the case study outlined above and provide a balanced overview of how the results would influence your recommendations, i.e., offering both primary and alternative recommendations, which will depend on the actual direction of the data should this case study investigation be completed. **(14 marks)**

c) Identify two key limitations - with a brief description of each - of 2-dimensional video analysis in the context outlined in 2.a) as a mode of biomechanical observation of human motion. **(6 marks)**

PLEASE TURN THE PAGE…

School of Engineering
BEng (Hons) Biomedical Engineering
Semester 2 Examination 2023/24
Intermediate Biomechanics
Module No. BME5004

Section B: **Theoretical**

Answer TWO questions from this section.

3. a) Calculate the **linear tangential velocity** of a robotic arm the instant before releasing a projectile, which reaches peak angular velocity of 9.3 rad·s^{-1} and a radius of rotation of 1.34 m. The projectile is released from the very end of the robotic arm.

(3 marks)

b) Following a reduction in the mass of the robotic arm - after changing the material used in design - the angular velocity of the arm can now reach 13.3 rad·s^{-1} whilst the radius of rotation has remained the same.

i) Calculate the **linear tangential velocity** of the re-designed robotic arm the instant before releasing the projectile at the new angular velocity.

ii) What is the **change** in linear tangential velocity from the original robotic arm to the newer design?

iii) Explain an alternative way that the robotic arm could have been designed to specifically increase the linear tangential velocity.

(12 marks)

c) A human participant is aiming to compete against the newer robotic arm from part b

i) If the length of their radius of rotation (fingers to centre of the chest) is limited to 1.19 m, what **angular velocity** would they need to match the linear tangential velocity higher of the newer robotic arm?

ii) at the angular velocity from part c) i) what would be the **tangential acceleration** and **radial acceleration** the instant before releasing the projectile of that phase of the movement took 0.21 s?

(15 marks)

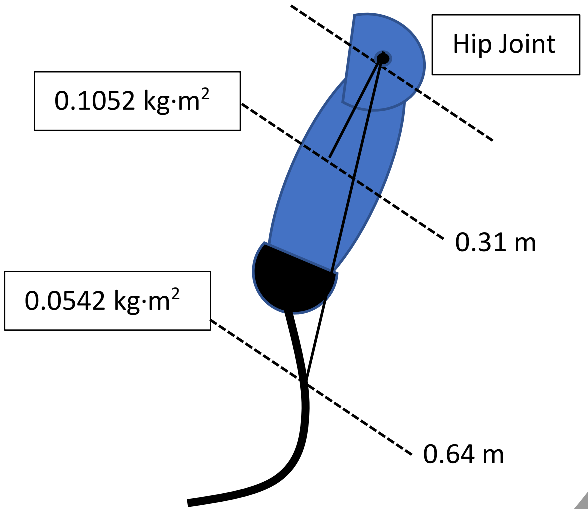
Formulae: $V_t = r\,\omega$

$a_t = r\,\alpha$

$a_r = V_t^2 / r$

School of Engineering
BEng (Hons) Biomedical Engineering
Semester 2 Examination 2023/24
Intermediate Biomechanics
Module No. BME5004

4. a) Using the Parallel Axis Theorem calculate the instantaneous **moment of inertia** of the leg in the recovery (swing phase) about the hip joint axis of a sprinter who has a prosthesis (see figure 1).



Sprinter's mass = 76 kg

Segmental Mass ratios:

Thigh = 0.103 (10.3%)

Prosthesis = 0.058 (5.8%)

Formula: $I = I_{CG} + md^2$

Figure 1. Sprinter's leg in the recovery (swing phase), scenario 1

(12 marks)

b) Following a redesign of the prosthesis socket you have been able to add a joint that allows simulated flexion without a change in prosthesis mass. Calculate the instantaneous **moment of inertia** in this new position.

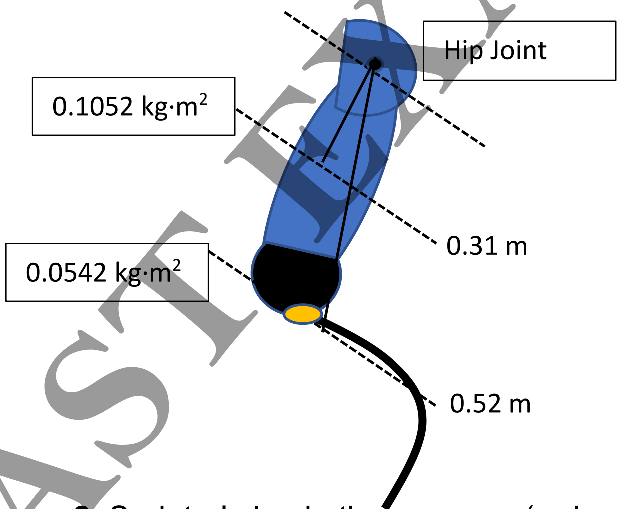


Figure 2. Sprinter's leg in the recovery (swing phase), scenario 2 – new socket joint

(12 marks)

c) Quantify the proportional change with the new socket design and explain the benefit for the sprinter. **(6 marks)**

PLEASE TURN THE PAGE…

5. a) What is the **angular momentum** of a 54 kg gymnast in an almost straight position rotating about her medio-lateral axis in a backflip at an angular velocity of 4.1 rad·s^{-1} given her radius of gyration is 0.78 m?

Formulae:

$I = mk^2$ $H = I\,\omega$

(6 marks)

b) A diver changes from a tuck position to an almost straight body position to enter the water during a dive. Considering the conservation of angular momentum, calculate the **angular velocity** of the diver just before entering the water given the information below.

Mass 71 kg

k (tuck) = 0.39 m

k (straight) = 0.81 m

ω (tuck) = 4.8 rad·s^{-1}

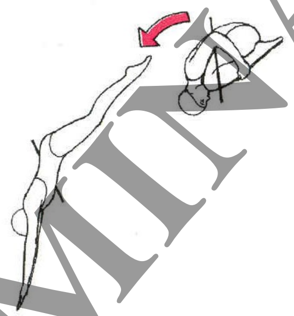


Figure 3. Diver changing from tuck to straight position to enter the water.

(12 marks)

c) Explain the principle of conservation of angular momentum and outline another applied example of this principle in some form of human movement.

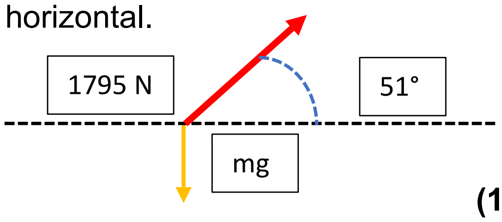
(12 marks)

6. a) Calculate the **resultant acceleration** of a propulsive step for a person of 87 kg applying a thrust of 1795 N at 51° to the horizontal.

Formulae:

$FV = F \cdot \sin\theta - mg$

$FH = F \cdot \cos\theta$ $F = m \cdot a$



(12 marks)

b) If the same person applies at thrust of 1823 N at 57° to the horizontal on the next step, what is the difference between the two steps in **resultant acceleration**?

(12 marks)

c) Sketch a force-time graph and plot the theoretical force-time curves that you would expect to see for one foot contact in i) walking; ii) rear-foot strike running; iii) forefoot sprinting trials.
(6 marks)

END OF QUESTIONS