

Deferred Exam THP203 2024-25

Section 1 – Physics (70 points)

Question 1

A golfer hits a ball with a golf club by rotating at the shoulder with an angular velocity of $6.4 \text{ rad}\cdot\text{s}^{-1}$. The linear velocity of the ball when it is hit is $10.9 \text{ m}\cdot\text{s}^{-1}$. What is the length of the radius between the point of rotation at the shoulder joint and the point of contact with the ball?

(5 points)

Question 2

An athlete with a mass of 68 kg completes a squat jump on a force platform. During the jump, the total measured impulse is 175 Ns.

a) What is the vertical take-off velocity of the athlete?

(4 points)

b) What is the weight of the athlete in Newtons?

(2 points)

Question 3

Two American football players run towards a ball. One player has a mass of 78kg and is running with a velocity of $-4.2 \text{ m}\cdot\text{s}^{-1}$. The other has a mass of 83 kg and is running with a velocity of $4.1 \text{ m}\cdot\text{s}^{-1}$.

a) The two players collide. What is their total velocity immediately after they collide?

(8 points)

b) What is the kinetic energy of each player before they collide?

(4 points)

Question 4

A ball is kicked with an initial horizontal velocity of $7.0 \text{ m}\cdot\text{s}^{-1}$ and an initial vertical velocity of $5.6 \text{ m}\cdot\text{s}^{-1}$.

- a) What was the angle between the ball and the ground at the point of take off?

(4 points)

- b) The ball lands back on the ground at the same height it was kicked from. How far was the ball kicked?

(8 points)

Question 5

A trampolinist is rotating in the air with an angular velocity of $3.84 \text{ rad}\cdot\text{s}^{-1}$ and an angular momentum of $13.00 \text{ kg}\cdot\text{m}^2\cdot\text{s}^{-1}$. Just before they land, they change their body position so that their body's moment of inertia increases by $1.00 \text{ kg}\cdot\text{m}^2$.

- a) What is the angular velocity of the trampolinist in the new body position?

(8 points)

The trampolinist's warm-up included lifting of barbells and dumbbells. During one warm-up exercise, the trampolinist lifted a 24 kg barbell vertically 1.8 m upwards by applying a constant muscular force of 1100 N .

- b) What was the total work done by the system (i.e. the sum of work done by trampolinist and by gravity) during this lift?

(5 points)

Question 6

A participant holds a 6kg dumbbell in a static position as shown in Figure 1 below.

The muscular force D acts at an angle of 20 degrees relative to the horizontal, in the upwards – left direction. This force, D , acts at a distance of 0.14 m from the shoulder rotation axis.

The external force from the dumbbell acts downwards at a distance of 0.58 m from the shoulder axis. The mass of the forearm is 0.6 kg and acts at a distance of 0.39 m from the shoulder axis. The mass of the upper arm is 0.9 kg and acts at a distance of 0.21 m from the shoulder axis.

- What is the magnitude of the muscular force required by the deltoid muscle group (D) to hold this position?
(12 points)
- What magnitude are the reaction forces acting at the shoulder joint, and in which direction are they acting?
(10 points)

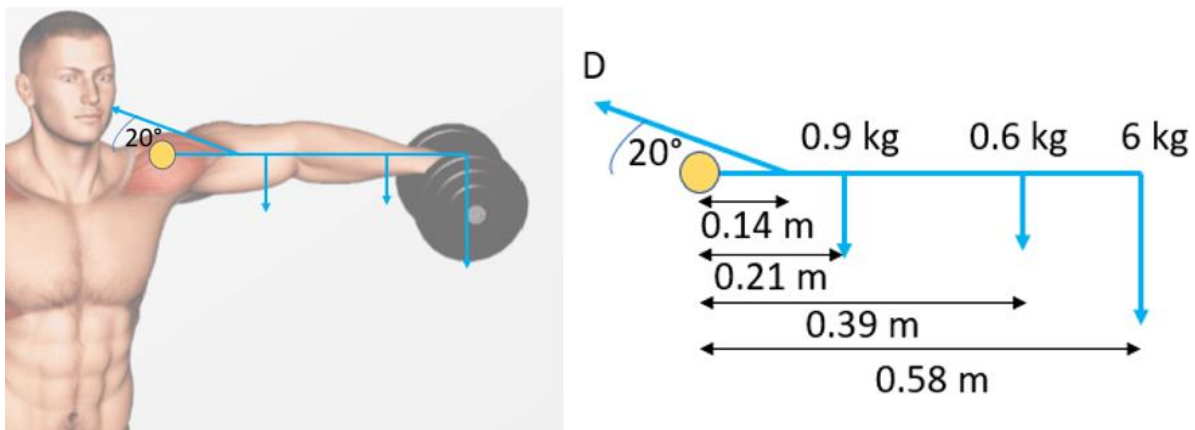


Figure 1: Forces acting on the arm, about the rotation axis at the shoulder joint. D is the force from the deltoid muscle group acting upwards to the left at an angle of 20 degrees to the horizontal. This force acts at a distance of 0.14 m from the shoulder axis. The mass for the upper arm, forearm and dumbbell are 0.9 kg, 0.6 kg and 6 kg respectively. These forces act vertically downwards at respective distances of 0.21 m, 0.39 m and 0.58 m from the shoulder joint.

Section 2 – Muscle and connective tissue mechanics (20 points)

General Questions

1. Define stress, strain, and Young's modulus. Explain why Young's modulus is necessary for comparing different tissues.
(3 points)
2. Describe the force–elongation curve of a viscoelastic material. How are stiffness and elastic energy calculated from the curve?
(3 points)
3. Define the safety factor of connective tissue. How is it related to tissue injury?
(2 points)

Bone Mechanics

4. List and briefly describe five types of mechanical loading that apply to bones. Which type is best tolerated by bone structure?
(3 points)
5. Name and explain five of the eight factors that influence the mechanical properties of bone tissue.
(3 points)
6. Explain how strong, active muscles can reduce the risk of bone fracture, using the example of gluteus medius attached to the greater trochanter.
(2 points)

Muscle and Tendon

7. Describe how to measure the stiffness of the patellar tendon using ultrasound and a dynamometer.

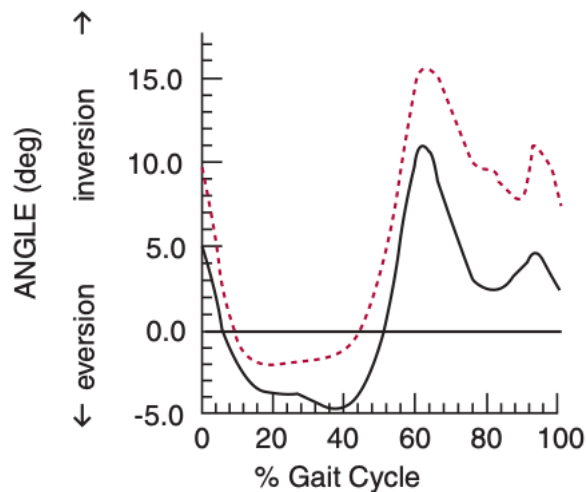
(2 points)

8. Explain how EMG and torque measurements from an isokinetic dynamometer can be used to estimate quadriceps force, accounting for co-activation of hamstrings.

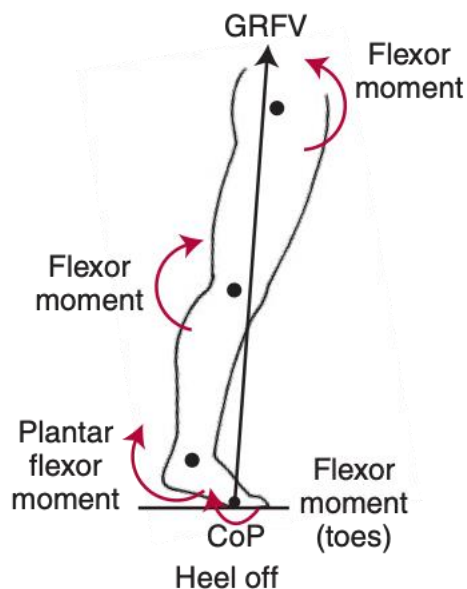
(2 points)

Section 3 – Applied biomechanics (10 points)

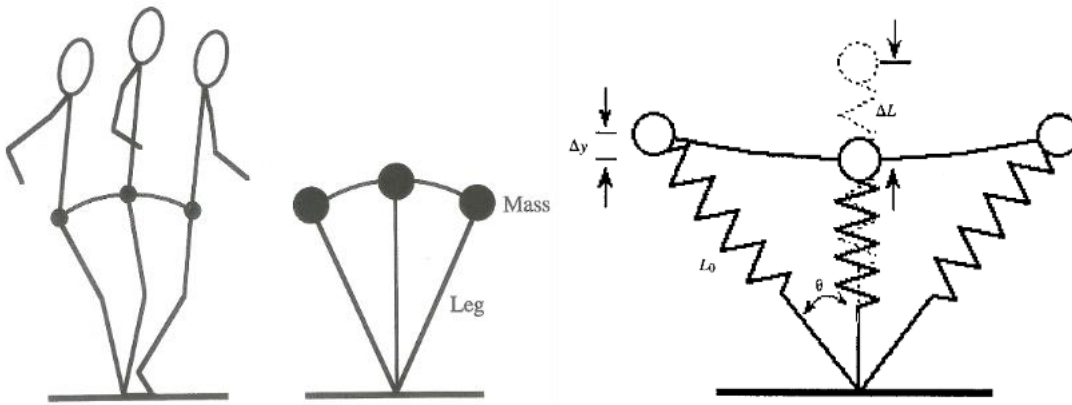
1. Why are different sport specific techniques and different movement patterns divided into different phases? (2 points)



2. The figure above shows movement of the ankle/foot in the frontal plane of one gait cycle. What movement and in what position is the ankle/foot from 5 to 40% of the gait cycle? (2 points)



3. The figure above shows a position between heel rise and toe off in walking. The black arrow shows the ground reaction force in the sagittal plane. The red arrows represent internal joint moments. Why do the internal joint moments have the direction that they have? (2 points)



4. The figure above shows both the inverted pendulum (left) and mass-spring model (right). Explain the differences between these models and how and why they are applied to walking and running. (4 points)

Assessment Guide

Section 1 – Physics (70 points)

In this section:

- subtract one point where rounding has been done too early in the calculation or is incorrect at the end. Final answers should be to 2 decimal places where relevant, and 3 in all the workings
- subtract one point when units are not presented in the final answer
- award “follow through” points when errors are made but steps are correct

Question 1

$$v_T = r \omega$$

$$10.9 = 6.4 r$$

$$r = 1.70 \text{ m} \quad (5 \text{ points})$$

Question 2

a) Impulse = $m (v_f - v_i)$

$$175 = 68 (v_f - 0)$$

$$v_f = 2.57 \text{ m.s}^{-1} \quad (4 \text{ points})$$

b) $F = ma$

$$F = 68 \times 9.81 = 667.08 \text{ N} \quad (2 \text{ points})$$

Question 3

a) $P = mv$

$$P_1 = 78 \times -4.2 = -327.6$$

$$P_2 = 83 \times 4.1 = 340.3$$

$$P_{\text{TOTAL}} = 12.7$$

$$P_{\text{TOTAL}}/m_{\text{TOTAL}} = v_{\text{TOTAL}} = 12.7/(78+83) = 0.079 \text{ m.s}^{-1}$$

(8 points)

b) $E_K = \frac{1}{2} mv^2$

$$E_{K1} = \frac{1}{2} 78 \times -4.2^2 = 687.96 \text{ J}$$

$$E_{K2} = \frac{1}{2} 83 \times 4.1^2 = 697.62 \text{ J} \quad (4 \text{ points})$$

Question 4



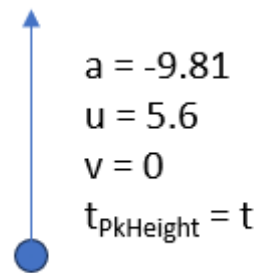
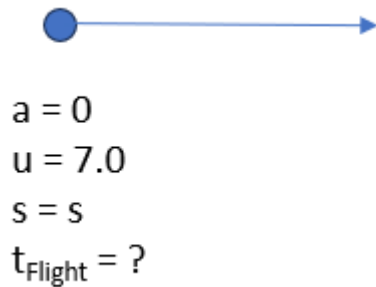
a) $\tan\theta = 5.6/7.0$

$$\theta = \tan^{-1}(5.6/7.0)$$

$$\theta = 38.66^\circ$$

(4 points)

b)



Vertically:

$$v = u + at$$

$$0 = 5.6 - 9.81 t$$

$$t_{\text{pkHeight}} = 0.571 \text{ s}$$

$$t_{\text{Flight}} = 0.571 \times 2 = 1.142 \text{ s}$$

Horizontally:

$$s = ut + \frac{1}{2} at^2$$

$$s = 7.0 \times 1.142 = 7.99 \text{ m}$$

(8 points)

Question 5

a) $H = I\omega$

$$H = I_{\text{POS1}} \times \omega_{\text{POS1}}$$

$$13.00 = 3.84 I_{\text{POS1}}$$

$$I_{\text{POS1}} = 3.385$$

$$I_{\text{POS2}} = 3.385 + 1.00 = 4.385$$

$$H = I_{\text{POS2}} \times \omega_{\text{POS2}}$$

$$13.00 = 4.385 \omega_{\text{POS2}}$$

$$\omega_{\text{POS2}} = 2.96 \text{ rad.s}^{-1} \quad \textbf{(8 points)}$$

b) $W = Fd$

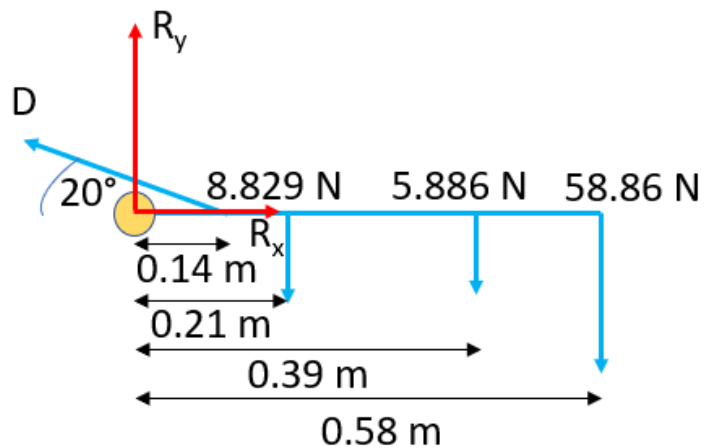
$$\text{Work done by trampolinist} = 1100 \times 1.8 = 1980 \text{ J}$$

$$\text{Work done by gravity} = 24 \times -9.81 \times 1.8 = -423.792 \text{ J}$$

$$\text{Total work done} = 1980 + -423.792 = 1556.21 \text{ J}$$

(5 points)

Question 6



a) $\Sigma \tau = 0$

$$(D \sin(20) \times 0.14) + (-8.829 \times 0.21) + (-5.886 \times 0.39) + (-58.86 \times 0.58) = 0$$

$$D \sin(20) \times 0.14 = 38.288$$

$$D = 799.628 \text{ N}$$

(12 points)

b) $\Sigma F = 0$

$$\Sigma F_x = 0$$

$$\Sigma F_x = R_x - D \cos(20) = 0$$

$$R_x = D \cos(20) = 751.40 \text{ N to the right}$$

$$\Sigma F_y = 0$$

$$\Sigma F_y = R_y + D \sin(20) - 8.829 - 5.886 - 58.86 = 0$$

$$R_y = 73.575 - D \sin(20)$$

$$R_y = -199.91 \text{ N i.e. downwards} \quad \textbf{(10 points)}$$

Section 2 – Muscle and connective tissue mechanics (20 points)

General Questions

1. **Stress:** Force per unit area.
Strain: Deformation relative to original length.
Young's modulus: Slope of stress–strain curve in elastic region; accounts for tissue dimensions.
2. **Curve:** Toe region, elastic region, plastic region.
Stiffness: Slope in elastic region.
Elastic energy: Area under the curve in elastic region.
3. **Safety factor:** Ratio of ultimate strength to daily average load.
Relation to injury: Low safety factor increases risk of tissue damage.

Bone Mechanics

4. **Loading types:** Compression, tension, shear, bending, torsion.
Best tolerated: Compression.
5. **Factors:** Material composition, load type, bone location, load orientation, loading rate, sex, age, structural properties.
Each should be briefly explained.
6. **Explanation:** Muscle contraction alters stress distribution—reduces tensile stress and increases compressive stress, which bone handles better.

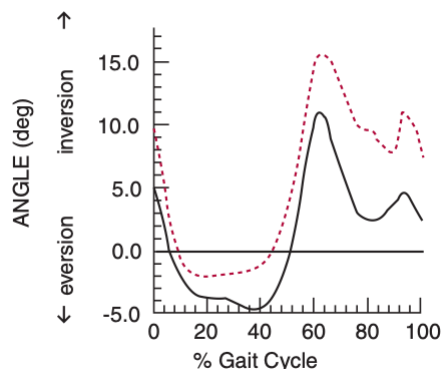
Muscle and Tendon

7. **Procedure:** Isometric contraction on dynamometer to estimate force; ultrasound to measure deformation.
Calculation: Stiffness = force / deformation.
8. **Steps:**
 - Estimate hamstring contribution using EMG and flexion torque.
 - Correct torque for co-activation by assuming a linear relationship between EMG and torque.
 - Calculate quadriceps force using corrected torque and internal moment arm.

Section 3 – Applied biomechanics (10 points)

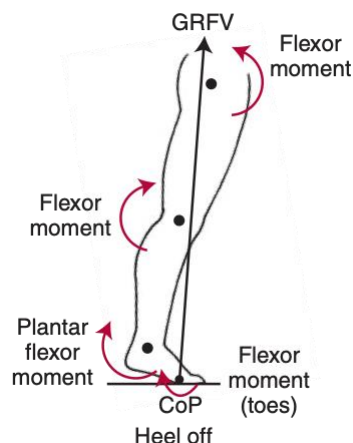
1. Why are different sport specific techniques and different movement patterns divided into different phases? (2 points)

In order to describe, analyze, understand and communicate complex movement patterns/techniques. How movements are divided into phases are divided into phases depends on their nature. For instance a jump or a throw could be based on body or joint positions, while other movements (i.e. 100 m sprint) could be based on speed.



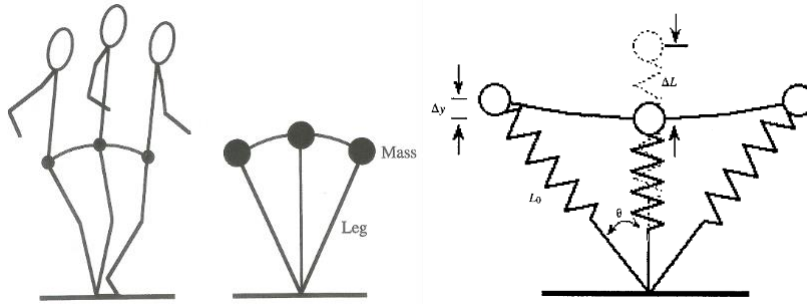
2. The figure above shows movement of the ankle/foot in the frontal plane of one gait cycle. What movement and in what position is the ankle/foot from 5 to 40% of the gait cycle? (2 points)

Position is everted and movement is eversion



3. The figure above shows a position between heel rise and toe off in walking. The black arrow shows the ground reaction force in the sagittal plane. The red arrows represent internal joint moments. Why do the internal joint moments have the direction that they have? (2 points)

The internal joint moments oppose the external joint moments, thus have the opposite direction. Example: at the ankle the external force acts in front of the ankle joint and creates an external dorsiflexion moment. Thus, the internal moment is plantarflexion.



4. The figure above shows both the inverted pendulum (left) and mass-spring model (right). Explain the differences between these models and how and why they are applied to walking and running. (4 points)

In walking there is an exchange of potential and kinetic energy. At heel strike the centre of mass is at its' lowest position, while at the highest in midstance. At heel strike the kinetic energy has its' maximum value and potential energy has its' lowest value. The opposite is observed at midstance. Thus, potential and kinetic energy is out of phase and there is an exchange of potential and kinetic energy, and there is a conservation of 70% of mechanical energy from step to step. In running this is not the case since potential and kinetic energy is more in synch with greater potential and kinetic energy at heel strike. Thus, a different model than the inverted pendulum is needed. The mass spring model is based on storage and release of elastic energy and is better suited to explain what happens in running.