

THP203 2025 Exam

Section 1 – Physics (70 points)

Question 1

An athlete completes a vertical jump on a force platform. The impulse during the jump is 211.1 Ns. The athlete jumps with a resultant take off velocity of $2.3 \text{ m}\cdot\text{s}^{-1}$.

- a) What is the mass of the athlete in kilograms?
(4 points)
- b) What is the weight of the athlete in Newtons?
(2 points)

Question 2

A gymnast with a mass of 62 kg is 1.8 metres above the ground during a competition.

- a) How much potential energy does the athlete have?
(4 points)
- b) Two handball players with mass and velocities as detailed in Table 1 below collide on the court. What is the total velocity after the collision?
(6 points)

Table 1: Mass and velocity of the two athletes before they collided

	Athlete 1	Athlete 2
Mass (kg)	68	81
Velocity ($\text{m}\cdot\text{s}^{-1}$)	- 4.1	3.9

Question 3

A ball is kicked with a vertical velocity of $5.1 \text{ m}\cdot\text{s}^{-1}$ and horizontal velocity of $8.8 \text{ m}\cdot\text{s}^{-1}$.

- a) What was the angle between the ball and the ground at the instant it was kicked?
(4 points)
- b) The ball lands back on the ground at the same height as it was kicked from. How far was the ball kicked?
(8 points)

Question 4

A diver is 12.1 metres over the water when they reach their maximum height.

- a) How long (how much time) did it take to reach the water from 12.1 metres?
(6 points)

On the way down, the diver rotates with an angular velocity of $4.01 \text{ rad}\cdot\text{s}^{-1}$ and an angular momentum of $15.0 \text{ kg}\cdot\text{m}^2\cdot\text{s}^{-1}$. Just before landing, the diver changes their body position so that the moment of inertia increases by $0.6 \text{ kg}\cdot\text{m}^2$.

- b) What is the angular velocity of the diver in this new body position?
(6 points)

Question 5

A slalom skier with a mass of 71 kg is skiing downhill on a slope with an incline of 18 degrees relative to the horizontal. What is the friction force acting on the skier if the coefficient of friction between the ground and the skis is 0.08?

(6 points)

Question 6

An athlete is holding a dumbbell (weight) with a mass of 13kg in a static position, as shown in Figure 1 below.

The muscular force (blue arrow, B) acts at an angle of 79 degrees relative to the horizontal, upwards and to the left, at a perpendicular distance of 0.03 m distal from the elbow flexion axis. The external force from the dumbbell acts downwards at a perpendicular distance of 0.33 metres from the elbow flexion axis. The mass of the forearm is 1.6 kg and the mass centre is 0.18 metres from the elbow flexion axis.

- a) What magnitude is the muscular force required to hold this position?
(10 points)
- b) What magnitude are the reaction forces acting at the elbow joint, and in which direction are they acting?
(8 points)

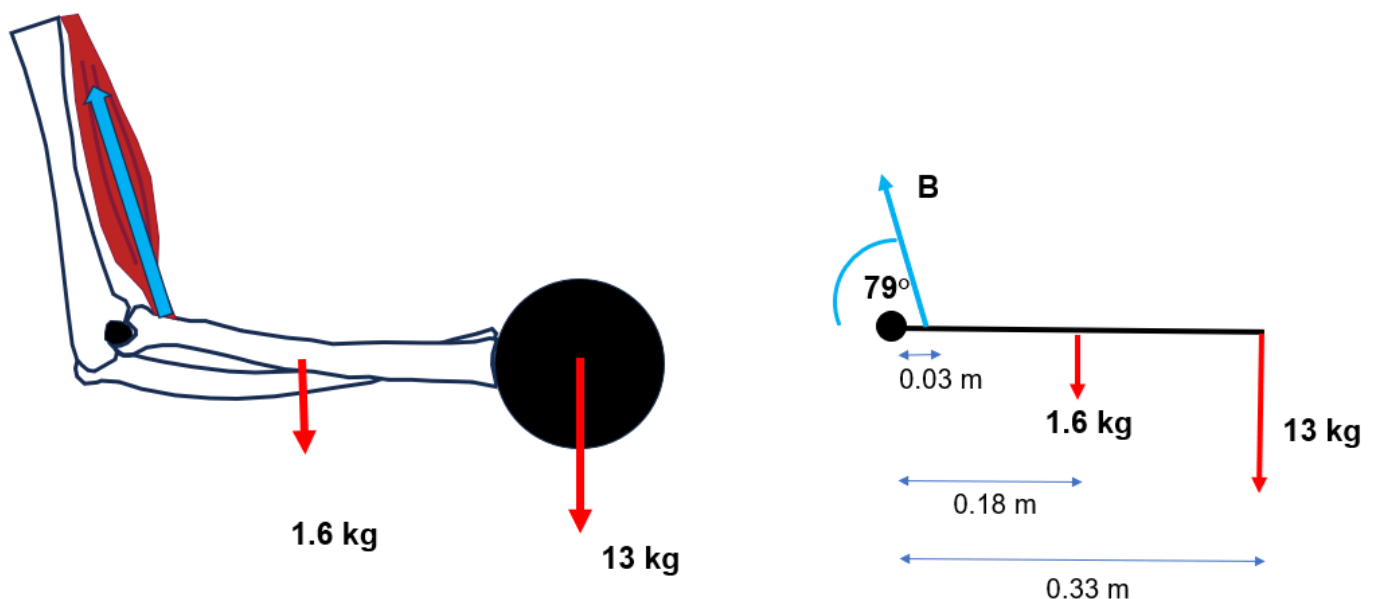


Figure 1. Muscular force (blue arrow going upwards to the left, at an angle of 79 degrees to the horizontal) and locations of the centre of masses (forearm and barbell) that are applied to the forearm whilst holding a dumbbell of mass 13kg in a static position. The perpendicular distance from the elbow flexion axis to the muscular force is 0.03m, to the forearm centre of mass is 0.18m and to the dumbbell centre of mass is 0.33 m.

Question 7

An athlete of mass 74 kg completes a long jump with a horizontal take-off velocity of $7.94 \text{ m}\cdot\text{s}^{-1}$ at an angle of 26 degrees to the horizontal.

a) What is the vertical take-off velocity?

(2 points)

b) What was the kinetic energy of the athlete in the vertical direction at take-off?

(4 points)

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

General Questions

1. Define stiffness and Young's modulus. Explain why Young's modulus is necessary for comparing different tissues.

(3 points)

2. Describe the stress-strain curve for a viscoelastic material. How are Young's modulus and elastic energy calculated from the curve?

(3 points)

Bone Mechanics

3. List and briefly describe five types of loading that apply to bones.

(3 points)

4. Briefly explain the factors that influence bone fractures.

(3 points)

Muscle and Tendon

5. Define skeletal muscle work, and power in relation to force.

(2 points)

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

(3 points)

7. Explain how electromyographic (EMG) activity can be used to measure force from antagonist muscles.

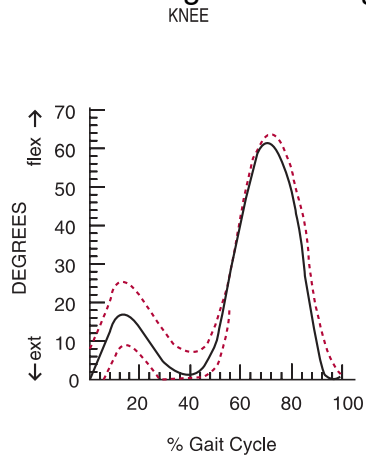
(3 points)

Section 3 – Applied biomechanics (10 points)

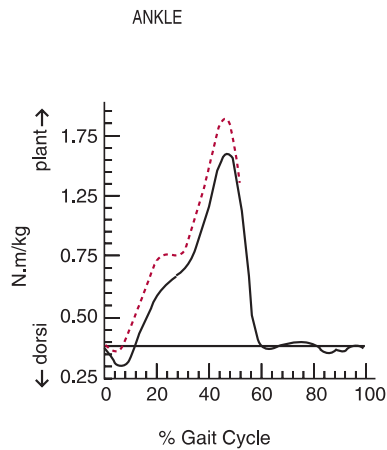
1. Technique analysis

- a) Why are different locomotive patterns or specific sport techniques divided into different phases?
(2 points)

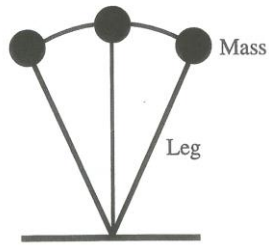
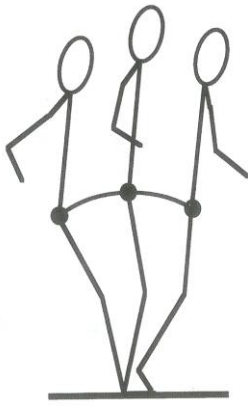
2. Walking and running



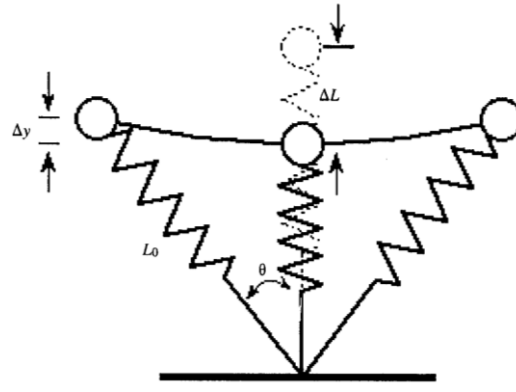
- a) The figure above shows the position of the knee joint during a full gait cycle (100%). What joint movements and in what position is the knee joint from 0 to about 40% of the gait cycle?
(2 points)



- b) The figure above shows the internal joint moment over the ankle joint during a full gait cycle (100%). What is the internal joint moment from 0 to about 10% and from 10 to about 60% of the gait cycle?
(2 points)



Inverted pendulum



Mass-spring model

- c) The figure above shows both the inverted pendulum and mass-spring model. 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

1a) $\text{Impulse} = m (v_f - v_i)$

$$211.1 = m(2.3)$$

$$m = 91.78 \text{ kg (91.783 for use in part b)}$$

1b) $F = ma$

$$\text{Weight} = 9.81 \text{ m}$$

$$\text{Weight} = 900.39 \text{ N}$$

2a) $E_P = mgh$

$$E_P = 62 \times 9.81 \times 1.8 = 1094.80 \text{ J}$$

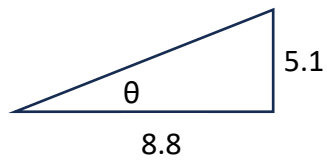
2b) $P = mv$

$$P_1 = 68 \times -4.1 = -278.8; \quad P_2 = 81 \times 3.9 = 315.9$$

$$P_{\text{TOTAL}} = P_1 + P_2 = 37.1 \text{ kg.m.s}^{-1}$$

$$V_{\text{TOTAL}} = P_{\text{TOTAL}} / \text{Mass}_{\text{TOTAL}} = 37.1 / (68+81) = 0.25 \text{ m.s}^{-1}$$

3a)



$$\tan \theta = 5.1/8.8$$

$$\theta = \tan^{-1}(5.1/8.8) = 30.09^\circ$$

3b)



$$u = 8.8; a = 0; t = ?; s = s$$



$$u = 5.1; a = -9.81; v = 0; t = t$$

$$v = u + at$$

$$0 = 5.1 - 9.81t$$

$$t = 0.520 \text{ to peak height; total time} = 1.040 \text{ s}$$

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

$$s = 8.8 \times 1.040 = 9.15 \text{ m}$$

4a)



$$u = 0; a = 0.81; s = 12.1, t = t$$

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

$$12.1 = \frac{1}{2} 9.81t^2$$

$$t = 1.57 \text{ s}$$

4b) $H = I\omega$

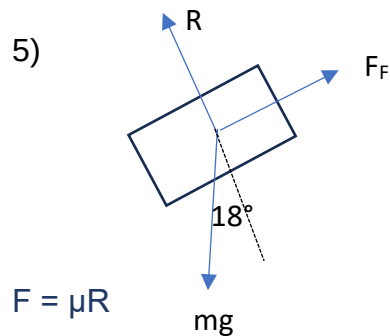
$$15 = 4.01I$$

$$I = 3.741 \text{ in initial position}$$

$$I \text{ in new position} = 3.741 + 0.6 = 4.341$$

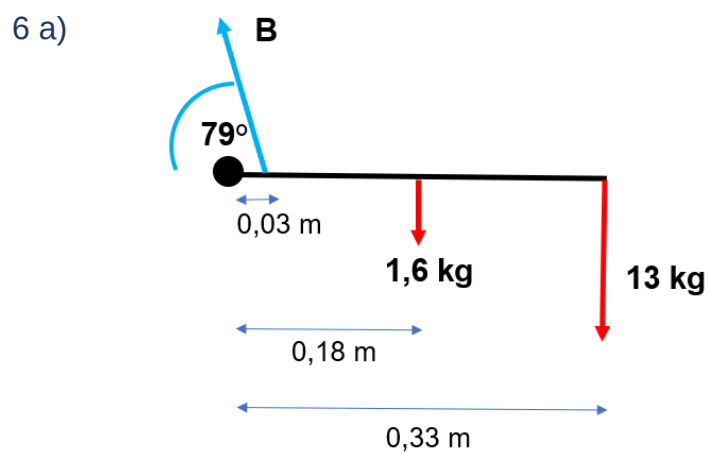
$$15 = 4.341\omega$$

$$\omega = 3.46 \text{ rad.s}^{-1}$$



$$F = -0.08 \times 71 \times 9.81 \times \cos(18)$$

$F = -52.99 \text{ N}$ (can receive full points if did not include the minus direction if they included a diagram that shows the correct direction)



$$\Sigma T = 0$$

$$(B \sin(79) \times 0.03) + (-1.6 \times 9.81 \times 0.18) + (-13 \times 9.81 \times 0.33) = 0$$

$$B \sin(79) \times 0.03 = 44.910$$

$$B = 1525.025 \text{ N}$$

b) $\Sigma F_y = 0$

$$R_Y + B\sin(79) - (1.6 \times 9.81) - (13 \times 9.81) = 0$$

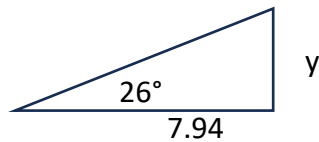
$$R_Y = -1353.78 \text{ N, downwards}$$

$$\Sigma F_X = 0$$

$$R_X - B\cos(79) = 0$$

$$R_X = 290.99 \text{ N, to the right}$$

7 a)



$$\tan(26) = y/7.94$$

$$y = \tan(26) \times 7.94$$

$$y = 3.873 \text{ m.s}^{-1}$$

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

$$E_K = \frac{1}{2} 74 \times 3.873^2$$

$$E_K = 555.00 \text{ J (or 554.89J if using the unrounded answer from above)}$$

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

General Questions

1. Define stiffness and Young's modulus. Explain why Young's modulus is necessary for comparing different tissues.

(3 points)

- Stiffness: Resistance to deformation when a force is applied. (1 point)
- Young's modulus: Ratio of stress to strain in the linear elastic region of the material. (1 point)
- Importance: Young's modulus accounts for tissue dimensions, making it essential for comparing different tissues. (1 point)

2. Describe the stress-strain curve for a visco-elastic material. How are Young's modulus and elastic energy calculated from the curve?

(3 points)

- Curve Description: Toe region, linear elastic region, plastic region. (1 point)
- Young's modulus Calculation: Slope of the linear elastic region. (1 point)
- Elastic Energy Calculation: Area under the curve in the elastic region. (1 point)

Bone Mechanics

3. List and briefly describe five types of loading that apply to bones.

(3 points)

- Types of Loading: Compression, tension, shear, bending, torsion. (1.5 points)
- Description: Brief explanation of each type. (1.5 points)

4. Briefly explain the factors that influence bone fractures.

(3 points)

- Factors: Frequency, rate, and direction of loading. (1.5 points)
- Explanation: How each factor affects bone fractures. (1.5 points)

Muscle and Tendon

5. Define skeletal muscle work, and power in relation to force.

(2 points)

- Work: Force x shortening or lengthening distance. (1 points)
- Power: Force x shortening or lengthening velocity. (1 points)

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

(3 points)

- Procedure: Isometric contraction on a dynamometer to estimate force, ultrasound to measure tendon deformation. (1.5 points)
- Calculation: Combining force and deformation to calculate stiffness. (1.5 points)

7. Explain how electromyographic (EMG) activity can be used to measure force from antagonist muscles.

(3 points)

- EMG Use: Measure muscle activity during maximal voluntary contraction. (1.5 points)
- Force Estimation: Relate EMG activity to force production. (1.5 points)

Section 3 – Applied biomechanics (10 points)

Section 3 – Applied biomechanics (10 points)

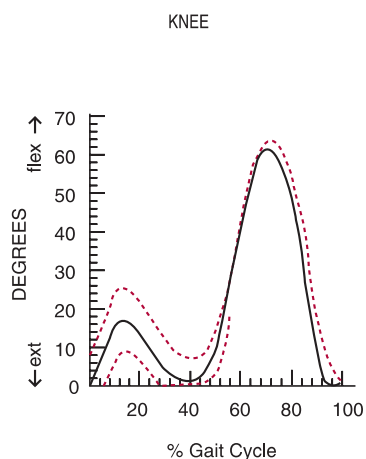
3. Technique analysis

- b) Why are different locomotive patterns or specific sport techniques divided into different phases?

(2 points)

To describe, analyze, communicate and understand movement and sport specific techniques. Criteria used to divide such movements into phases differ as they may be based on kinematics (i.e. position segment, maximum joint angle) and kinetics (i.e. relative or absolute force value). Example in walking in heel striking the ground. A 100 m sprint may be divided into different acceleration and top speed phase. A jump could be divided into deceleration and acceleration phases. Similarly, a horizontal change of direction may be divided into an initial acceleration, deceleration and re-acceleration phase. Throwing movements can be divided into cocking, acceleration and deceleration phases.

4. Walking and running

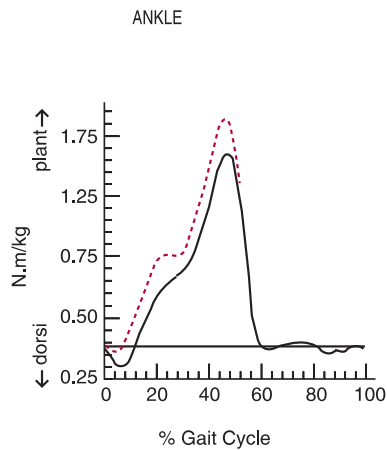


- d) The figure above shows the position of the knee joint during a full gait cycle (100%). What joint movements and in what position is the knee joint from 0 to about 40% of the gait cycle?

(2 points)

Since the graph is above zero, the position is flexed. From 0 to about 15% there is an increase in the magnitude of the flexed positioning, meaning that a flexion is

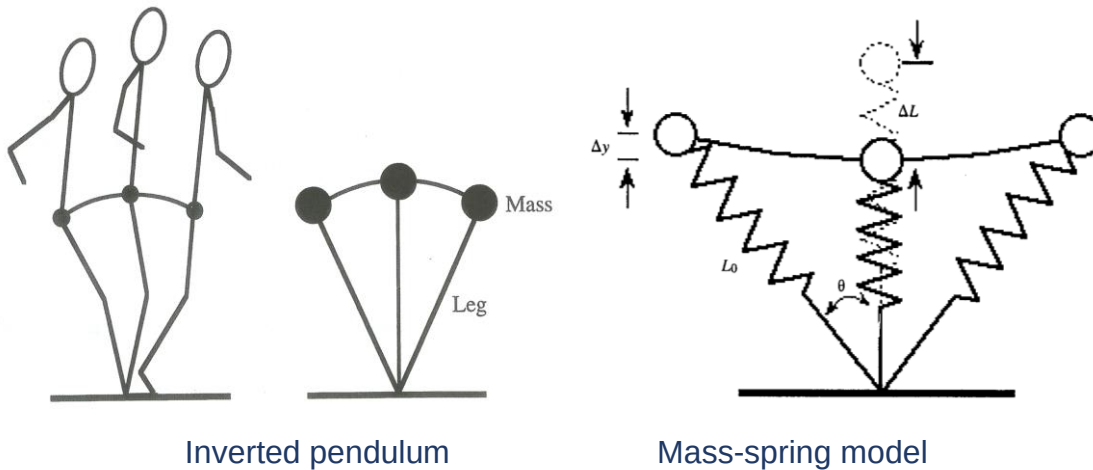
occurring. Also, the slope of the curve is positive, which is “pointing” toward a flexed positioning. From about 15 to 40% there is a decrease of the magnitude of the flexed positioning with a negative slope, meaning that there is an extension taking place.



- e) The figure above shows the internal joint moment over the ankle joint during a full gait cycle (100%). What is the internal joint moment from 0 to about 10% and from 10 to about 60% of the gait cycle?

(2 points)

From 0 to about 10% the value is negative (below the black line). According to the graph this is defined as an internal dorsiflexion moment. From about 10 to 60% there the moment is above to black line, meaning that it has another direction which plantarflexion. There is a steady increase until about 50% before it drops to around zero (having a little to no directionality and magnitude). This is associated with the toe off and the foot leaving the ground.



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

(4 points)

In walking the potential and kinetic energy is out of phase, meaning that there is a conservation of mechanical energy through an exchange from potential to kinetic energy and back. Specifically, the COM is at its lowest and has the greatest kinetic energy at heel strike, which is also when the potential energy is at its greatest. Conversely, the potential energy is at its greatest midstance when the kinetic energy is at its lowest. An inverted pendulum, where the mass represents the COM, serve as good model to explain the conservation of about 70% of the mechanical energy in walking. Please keep in mind that this is a vertical consideration/model.

The COM is at its lowest midstance and highest during swing (flight phase), which is opposite of what is observed in walking. Also, the kinetic and potential energy is not out of phase in running, but more in phase. Thus, the inverted pendulum model is not good to describe conservation of mechanical energy in running. Consequently, a different model, the mass-spring model, is used for running. In this model the lower extremity is modelled as mass (COM) with the lower extremity as spring. Thus, with the COM at its lowest point in midstance the lower extremity spring is compressed with storage of elastic energy that is subsequently released later in stance phase.