

THP203 2026 Deferred Exam

Section 1 – Physics (70 points)

Question 1

A football of mass 0.45 kg is initially at rest. A player kicks the ball, applying a force of 300 N for 0.2 seconds.

- a) What is the impulse applied to the ball during the kick?

(2 points)

The football was kicked with an initial resultant velocity of 30 m.s^{-1} at an angle of 20° to the horizontal.

- b) How far (what distance) was the ball kicked, assuming there was no air resistance?

(10 points)

Question 2

Two handball players collide during a game. Player A has a mass of 75 kg and is running at 6 m.s^{-1} . Player B has a mass of 80 kg and is running at -4 m.s^{-1} , i.e. in the opposite direction to Player A.

- a) What is the kinetic energy of Player A prior to collision?

(3 points)

- b) What is the combined velocity of Players A and B immediately after the collision?

(6 points)

Question 3

An athlete holds their knee in a flexed position whilst resistance with a force of 165 N downwards is applied at a distance of 0.35 metres from the knee flexion axis (Figure 1). The knee is supported on a box. The lower leg is held in a horizontal position by contraction of the hamstrings muscles (H). The mass of the lower leg is 2.8 kg and its centre of mass is 0.21 metres from the knee flexion axis. The hamstrings muscular force (H) acts at an angle of 63 degrees relative to the horizontal and at a distance of 0.012 metres from the knee flexion axis.

- a) What is the force applied by the hamstrings muscles (H) to hold this position?
(12 points)
- b) What magnitude are the reaction forces acting at the knee joint, and in which directions are they acting?
(8 points)

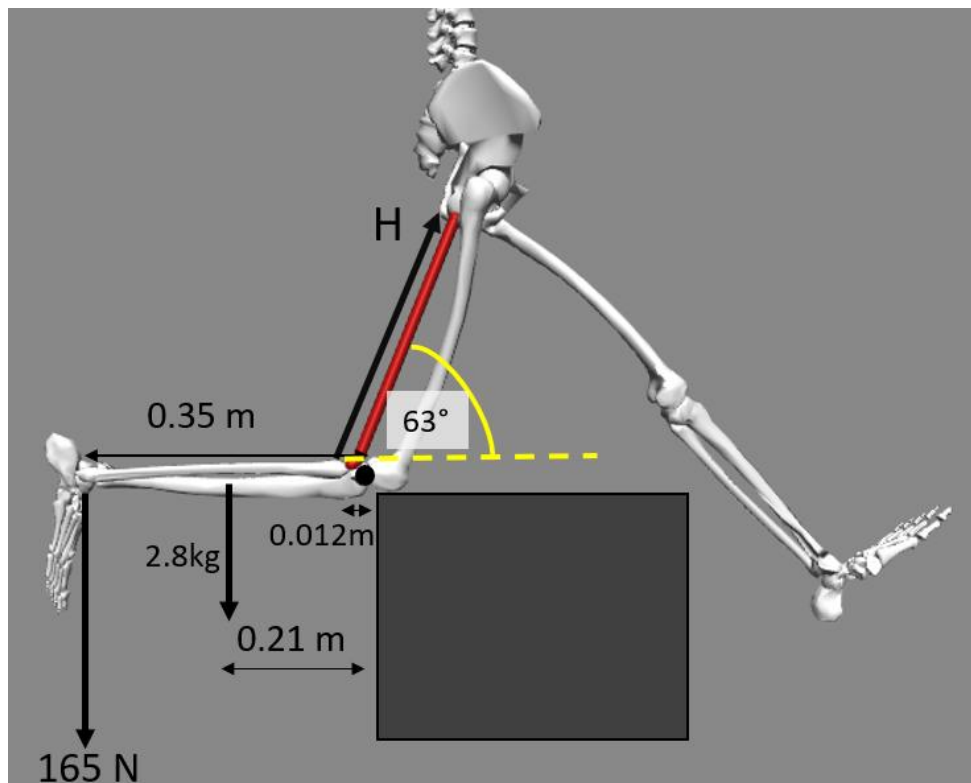


Figure 1. An athlete holds a static position with the knee positioned on a box and the lower leg parallel to the ground. Resistance is applied vertically downwards by a resistance band and contraction of the hamstrings muscles counters this. The hamstrings muscular force (H) is acting upwards to the right at an angle of 63 degrees to the horizontal. The mass of the lower leg (including the foot) is 2.8 kg and the centre of mass is 0.21 m from the knee joint centre. The knee joint centre is marked with a black circle. A resistance band provides 165N of force vertically downwards at a distance of 0.35 m from the knee joint centre. The hamstrings muscle inserts 0.012 m from the knee flexion axis.

Question 4

A diver of mass 50 kg jumps off a 3-meter platform rotating with an initial angular velocity of $2 \text{ rad}\cdot\text{s}^{-1}$ and initial moment of inertia of $4.2 \text{ kg}\cdot\text{m}^2$. The diver tucks into a ball, reducing their moment of inertia by half to $2.1 \text{ kg}\cdot\text{m}^2$.

a) What is the diver's angular momentum throughout the motion?
(3 points)

b) What is the diver's angular velocity when in the tucked ball position?
(3 points)

Question 5

A weightlifter lifts a 120 kg barbell vertically to a height of 165 cm in 0.4 seconds, by applying a constant force of 1105 N.

a) How much work was done by the athlete during the lift?
(2 points)

b) What was the average power applied by the athlete during the lift?
(3 points)

Question 6

A skier of mass 65 kg is skiing down a slope inclined at 15° to the horizontal. The coefficient of kinetic friction between the skier and the slope is 0.1.

a) What is the friction force acting on the skier?
(6 points)

Question 7

A pole-vaulter with a mass of 61 kg reaches a maximum height of 6.0 metres (after releasing the pole). They take off with a velocity of $6.3 \text{ m}\cdot\text{s}^{-1}$. What is the strain energy of the pole vaulter at take-off?

(12 points)

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

General

Define stiffness and Young's modulus (modulus of elasticity). Explain why Young's modulus is necessary for comparing different tissues.

(3 points)

Bone

Name and explain 5 of the 8 factors that affect the mechanical properties of bone.

(5 points)

Bone Fracture

Name and explain the 2 types of bone fractures.

(2 points)

Muscle

A study aims to measure the effect of a training intervention on maximum quadriceps force. Maximum knee extension torque, maximum knee flexion torque, knee internal moment arm, and electromyographic activity of the hamstring muscles are collected. Explain how these data are used to estimate quadriceps force.

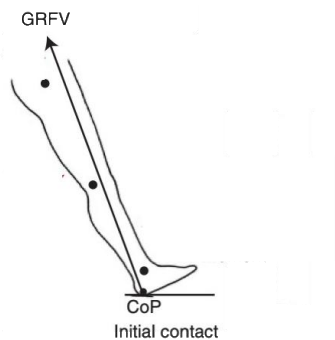
(8 points)

In addition, MRI and ultrasound scans were collected to calculate the physiological cross-sectional area ("PCSA") of each muscle in the quadriceps. How should this information be used to estimate the force of the vastus lateralis alone?

(2 points)

Section 3 – Applied Biomechanics (10 points)

1. Why are different movements and techniques commonly divided into phases?
Give examples. (2 points)
2. Explain the difference between walking and running using biomechanical principles. (2 points)
3. Why is the inverted pendulum model considered appropriate for walking but not running? (2 points)
4. What structures in the human body contribute to spring-like behavior during running? (2 points)
5. What are the external joint moments at the hip, knee and ankle joint based on GRFV (Ground Reaction Force Vector) at heel strike during walking as shown in the figure below? (2 points)



THP203 2026 Deferred Exam – Assessment Guide

Section 1 – Physics (70 points)

In this section:

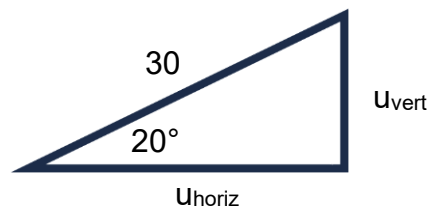
- subtract one point where rounding has been done too early in the calculation or is incorrect at the end. Final answers should be to 2 decimal places where relevant, and 3 in all the workings
- subtract one point when units are not presented in the final answer
- award “follow through” points when errors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

Question 1

a) Impulse = $F \cdot t = 300 \cdot 0.2 = 60 \text{ Ns}$

(2 points)

b)



$$u_{\text{vert}} = 30 \sin(20)$$

$$u_{\text{horiz}} = 30 \cos(20)$$

↑

$$\begin{aligned} u &= 30 \sin(20) \\ v &= 0 \\ a &= -9.81 \\ t &= t \end{aligned}$$

Use vertical component to find flight time:

$$v = u + at$$

$$0 = 30 \sin(20) - 9.81t$$

$$t = 1.046 \text{ s to reach peak height}$$

$$\text{Flight time} = 2t = 2.092 \text{ s}$$

Use horizontal component to find distance of the kick:



$$u = 30\cos(20)$$

$$a = 0$$

$$t = 2.092$$

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

$$s = 30 \cos(20) \cdot 2.092$$

$$s = 58.98 \text{ m (or } 58.971 \text{ m if use full unrounded time value)}$$

(10 points)

Question 2

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

$$E_K = \frac{1}{2} \cdot 75 \cdot 6^2$$

$$E_K = 1350 \text{ J}$$

(3 points)

b) $P_A + P_B = P_{TOT}$

$$(75 \cdot 6) + (80 \cdot -4) = P_{TOT}$$

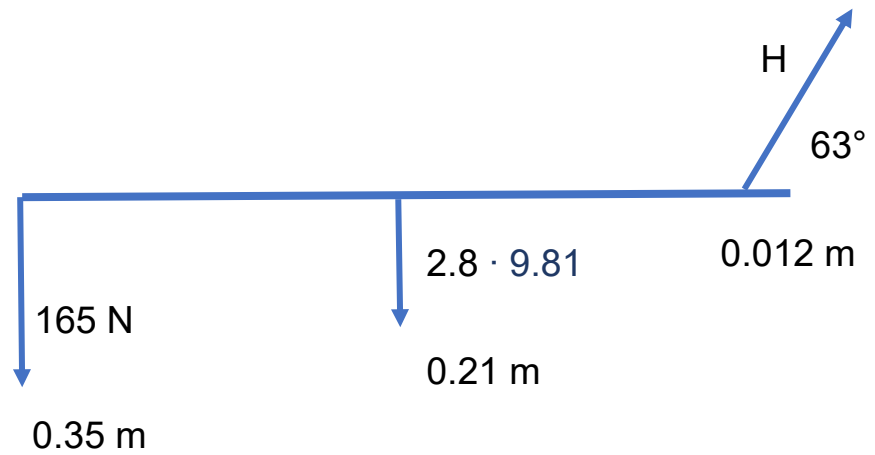
$$130 = P_{TOT}$$

$$130/(75 + 80) = \text{Combined Velocity}$$

$$0.84 \text{ m.s}^{-1} = \text{Combined Velocity}$$

(6 points)

Question 3



$$\sum T = 0$$

$$(H \sin(63) \cdot -0.012) + (-2.8 \cdot 9.81 \cdot -0.21) + (-165 \cdot -0.35) = 0$$

$$63.5183 = 0.012 \cdot H \sin(63)$$

$$H = 5940.676\text{ N (or } 5940.69 \text{ if using rounding to 3 dp above)}$$

(12 points)

b)

$$\sum F = 0$$

Vertically:

$$R_y + H \sin(63) - (2.8 \cdot 9.81) - 165 = 0$$

$$R_y + 5940.676 \sin(63) - 27.468 - 165 = 0$$

$$R_y = -5100.71\text{ N downwards}$$

(4 points)

Horizontally:

$$R_x + H \cos(63) = 0$$

$$R_x = -2697.01\text{ N to the left}$$

(4 points)

Question 4

a) $H = I \omega$

$$H = 4.2 \cdot 2 = 8.4 \text{ kgm}^2.\text{s}^{-1}$$

(2 points)

b) $H = I \omega$

$$8.4 = 2.1 \omega$$

$$\omega = 4.0 \text{ rad.s}^{-1}$$

Or can simply explain that since moment of inertia was halved, angular velocity was doubled due to the principles of conservation of angular momentum.

(3 points)

Question 5

a) $W = Fd$

$$W = 1105 \cdot 1.65$$

$$W = 1823.25 \text{ J}$$

(2 points)

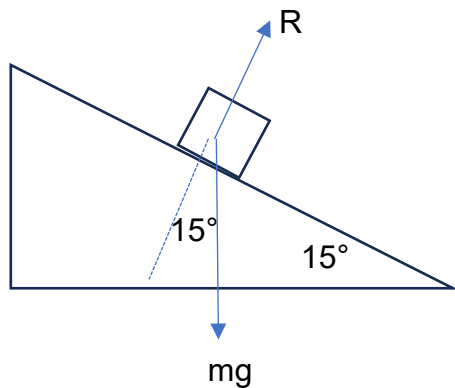
b) $\text{Power} = \text{Work done} / \text{time}$

$$\text{Power} = 1823.25 / 0.4$$

$$\text{Power} = 4558.13 \text{ W}$$

(3 points)

Question 6



a) $F_F = \mu R$
 $F_F = 0.1 \cdot mg \cos(15)$
 $F_F = 0.1 \cdot 65 \cdot 9.81 \cdot \cos(15)$
 $F_F = 61.59 \text{ N up the slope, or can present as } -61.59.$

No need to penalize if don't present as negative, as the question explicitly asks about the friction force so direction is implied.

(6 points)

Question 7

$$E_T = E_K + E_P + E_S$$

At highest point of jump, $E_K = 0$, $E_S = 0$
Therefore:
 $E_T = E_P$
 $E_P \text{ (at highest point)} = mgh = 61 \cdot 9.81 \cdot 6.0 = 3590.46 \text{ J}$
 $E_T = 3590.46 \text{ J}$

At take-off, total energy is conserved:

$$E_T = E_K + E_P + E_S$$
$$3590.46 = E_K + E_P + E_S$$
$$3590.46 = E_K + 0 + E_S$$
$$3590.46 = \frac{1}{2}mv^2 + 0 + E_S$$
$$3590.46 = (\frac{1}{2}61 \cdot 6.3^2) + 0 + E_S$$
$$E_S = 2379.92 \text{ J}$$

(12 points)

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

General

Define stiffness and Young's modulus (modulus of elasticity). Explain why Young's modulus is necessary for comparing different tissues.

Definitions of stiffness and Young's modulus, plus the importance of tissue dimensions being taken into account with Young's modulus, whereas they are not with stiffness.

Bone

Name and explain 5 of the 8 factors that affect the mechanical properties of bone.

Material composition, load type, bone location, load orientation, loading rate, sex, age, structural properties. Five of these factors should be mentioned, with one or two sentences explaining why they are important.

Bone Fracture

Name and explain the 2 types of bone fractures.

Traumatic and stress (or fatigue) fracture. One or two sentences should specify the frequency and intensity of stress that cause them, and optionally in which situations they can occur.

Muscle

A study aims to measure the effect of a training intervention on maximum quadriceps force. Maximum knee extension torque, maximum knee flexion torque, knee internal moment arm, and electromyographic activity of the hamstring muscles are collected. Explain how these data are used to estimate quadriceps force.

The different steps to estimate muscle force from torque should be explained. Briefly, the candidate should explain that the agonist torque can be estimated from EMG data and torque data from the antagonist muscles, and that force is obtained from the ratio of torque to the internal moment arm.

In addition, MRI and ultrasound scans were collected to calculate the physiological cross-sectional area ("PCSA") of each muscle in the quadriceps. How should this information be used to estimate the force of the vastus lateralis alone?

The candidate should explain that the fractional contribution to PCSA is close to the potential force contribution.

Section 3 – Applied Biomechanics (10 points)

1. Why are different movements and techniques commonly divided into phases? Give examples. (2 points)

Recommended answer: Movements are divided into phases to simplify biomechanical analysis and communication. Examples include acceleration and maximal velocity phases in sprinting.

2. Explain the difference between walking and running using biomechanical principles. (2 points)

Recommended answer: Walking involves continuous ground contact and is described by the inverted pendulum model. Running includes a flight phase and is described by the mass-spring model.

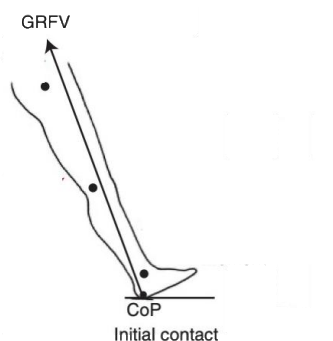
3. Why is the inverted pendulum model considered appropriate for walking but not running? (2 points)

Recommended answer: Walking involves out-of-phase fluctuations of kinetic and potential energy and continuous ground contact. Running includes a flight phase and greater elastic energy storage, making the mass-spring model more appropriate.

4. What structures in the human body contribute to spring-like behavior during running? (2 points)

Recommended answer: Structures include the Achilles tendon, plantar fascia, quadriceps tendon and other muscle-tendon units.

5. What are the external joint moments at the hip, knee and ankle joint based on GRFV (Ground Reaction Force Vector) at heel strike during walking as shown in the figure below? (2 points)



Recommended answer: Hip: flexion, knee: extension and ankle: plantarflexion.