University of Ruhuna- Faculty of Technology

Bachelor of Biosystems Technology Honours Degree
Level 2 (Semester I) Examination, June/July 2026
Academic year 2024/2025

Course Unit: BST2152-Physics for Biosystems Technology (Written)
Duration: 1 and ½ hours

INSTRUCTIONS:

- Answer any **THREE (03)** out of the four questions provided.
- Use a separate answer booklet for your answers.
- Each question must begin on a new page.
- If more than three questions are answered, only the **first three** will be marked.

1. Biological order is maintained despite the universal tendency toward disorder, a concept central to the Second Law of Thermodynamics.

   a) List five (05) factors that affect the increase of entropy in a system. (20 Marks)

   b) Consider the metabolism of one mole of glucose in muscle tissue during intense exercise:

   $$C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O\ (l)$$

Substance	Formula	State	Standard Entropy S° (J/K·mol)
Glucose	$C_6H_{12}O_6$	Solid (s)	212.1
Oxygen	O_2	Gas (g)	205.0
Carbon dioxide	CO_2	Gas (g)	213.7
Water	H_2O	Liquid (l)	69.9

   Using the standard entropy values (S°) provided above Table, calculate the standard entropy change for the reaction ($\Delta S°rxn$). (30 Marks)

   c) The standard enthalpy change ($\Delta H°rxn$) for the same reaction is -2800 kJ/mol.

      i. Calculate the standard Gibbs free energy change ($\Delta G°rxn$) for the reaction at a body temperature of 37°C (310 K). (30 Marks)

      ii. Based on calculated $\Delta G°$ in c (i), is the reaction spontaneous under standard conditions? Explain your answer. (20 Marks)

(Total - 100 Marks)

2. A rural health clinic uses a vaccine refrigerator powered by a small petrol generator. The refrigerator maintains a cold compartment at 2 °C while operating in a 32 °C room. The energy efficiency of the refrigerator is indicated by Coefficient of Performance (COP). The COP is defined as the ratio of the amount of heat removed of a system to its electrical work (Power) used.

a) Why does a refrigerator require work input to move heat from a cold space to a hot space? (20 Marks)

b) The refrigerator removes Q_C = 180 kJ of heat from the cold compartment during each cycle. The compressor does W = 60 kJ of work on the refrigerant per cycle.

i. Using the First Law for a cycle, calculate the heat rejected (Q_H) to the warm room. (15 Marks)

ii. Calculate the Coefficient of Performance (COP) of this refrigerator. (10 Marks)

iii. If the refrigerator runs at 50 cycles per minute, calculate the mechanical power (in watts) of the compressor. (15 Marks)

c) The refrigerator's cold compartment contains 10 kg of vaccine vials (average specific heat capacity = 3.0 kJ/(kg·°C)) at 2°C. A power failure occurs, and the refrigerator stops. The clinic staff open the door briefly, allowing warm air to enter. As a result, the vaccines warm up to 8°C before the generator restarts.

i. Calculate the heat (Q) that entered the vaccines. (20 Marks)

ii. If the compressor can deliver 500 W of mechanical power continuously, how many minutes will it take to re-cool the vaccines? (20 Marks)

(Total - 100 Marks)

3. Rotational motion and energy storage are critical for both normal physiological function and the design of diagnostic tools.

a) Identify and list three (03) physiological or pathological impacts resulting from centripetal force acting on blood flowing through the aortic arch. (15 Marks)

b) A swing rotor in a laboratory centrifuge has a radius of 0.12 m. It spins at 4000 revolutions per minute (rpm) to separate plasma from whole blood.

i. Calculate the angular velocity (ω) of the rotor in radians per second. (20 Marks)

ii. Calculate the centripetal acceleration (m/s^2) experienced by a tube at the end of the rotor. (20 Marks)

c) The Achilles tendon acts as a biological spring, storing and returning elastic energy during running. It has an effective spring constant (k) of 200 kN/m.

i. During stance, the tendon stretches by 0.9 cm. Calculate the elastic potential energy (SE) stored in the tendon. (15 Marks)

ii. A 70 kg runner has a metabolic power output of 1000 W while running at 5 m/s. If this runner's stride length (a single long step) is 2.0 m, calculate the total metabolic energy (in Joules) used per stride? (15 Marks)

iii. If the stored energy from the tendon in one stride is 30 J, calulatethe percentage of the metabolic energy per stride is "free" energy returned by the tendon? (15 Marks)

(Total- 100 Marks)

4. In biomechanics, the efficiency of human movement is largely determined by how the body manages and transforms energy.

a) Explain how a walking human exchanges Kinetic energy and Potential energy to improve efficiency based on inverted walking pendulum model. (20 Marks)

b) A 70 kg runner accelerated from rest to a velocity of 8 m/s on a horizontal track.

i. Calculate the runner's final kinetic energy. (10 Marks)

ii. Calculate the total work done on the runner. (15 Marks)

iii. If this total work is provided by the runner's muscles over a distance of 20 m, calculate the average net horizontal force. (15 Marks)

c) The runner (70 kg) went up a flight of stairs of vertical height 12 m in 10 seconds.

i. Calculate the gain in gravitational potential energy. (10 Marks)

ii. Calculate the average mechanical power required to lift the body against gravity. (15 Marks)

iii. If the runner's metabolic power during stair climbing is 1500 W, calculate the mechanical efficiency. (15 Marks)

(Total - 100 Marks)

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