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: BST2123-Engineering Properties of Bio-based materials (Written)
Duration: 2 hours

INSTRUCTIONS:

- Answer any **FOUR (04)** out of the five questions provided.
- Use a separate answer booklet for your answers.
- Each question must begin on a new page.
- If more than four questions are answered, only the **first four** will be marked.

1. A grain collection and processing center stores and handles paddy rice, maize, and Finger millet (Kurakkan). As the quality controlling officer of the facility, you are responsible for designing safe and efficient handling systems.

   a) Explain the difference between static friction and kinetic friction in the context of grain on a steel chute. How does moisture affect these coefficients?

   (20 Marks)

   b) The following laboratory data for three grain samples are provided.

Grain	Bulk density (kg/m^3)	Tapped density (kg/m^3)	Angle of repose (°)	Coefficient of static friction (steel)
Paddy Rice	560	640	31	0.42
Maize	720	760	23	0.35
Finger Millet	680	740	38	0.51

   i. Calculate the Carr Index and Hausner Ratio for each grain. Classify their flowability.

   (20 Marks)

   ii. A steel chute is fixed at an angle of 27° from horizontal. Which grain(s) will flow by gravity? Justify your answer. (20 Marks)

c) The manager of this facility wants to double the throughput of the paddy rice handling line by using a steeper chute (40°) and a higher air velocity in the pneumatic conveyor.

i. Discuss the possible negative consequences of increasing the chute angle and air velocity beyond the recommended values. (15 marks)

ii. Suggest three (03) alternative modifications (not involving chute angle or air velocity) that could increase throughput without causing significant grain breakage. Justify each modification using concepts from powder flow and aerodynamics.

(25 Marks)

(Total - 100 Marks)

2. A food packaging company developed a microwaveable frozen meal tray from a PLA-based biopolymer blend.

a) What is dielectric constant (ε_r)? Why is water's dielectric constant important for microwave heating? (20 Marks)

b) Following parameters are given for the PLA-based biopolymer blend.

Property	Value
Density, ρ (kg/m^3)	1250
Specific heat, c_p (kJ/(kg·K))	1.8
Thermal conductivity, k (W/(m·K))	0.16
Dielectric constant (dry)	3.2
Dielectric loss factor (dry)	0.06

i. Calculate the thermal diffusivity (α) of the blend.

(20 Marks)

ii. The tray contains a frozen meal with 70% water content (ice). The dielectric constant of ice is approximately 3.2. Explain why this can cause uneven microwave heating and edge overheating.

(20 Marks)

c) The tray warps severely near the edges during microwave testing.

i. Explain the thermal and electrical reasons for edge warping.

(20 Marks)

ii. If the nanocellulose-modified tray has a dielectric constant of 3.8 instead of 3.2, how would this affect microwave heating? Would it heat faster or slower? Explain.

(20 Marks)

(Total - 100 Marks)

3. A supermarket chain introduces smart packaging for fresh fish fillets that changes colour when the fish spoils.

a) What is a colorimetric indicator? How do anthocyanins indicate spoilage? (20 marks)

b) The following table presents the color values of a prototype anthocyanin-based indicator film.

Condition	L*	a*	b*
Fresh fish (pH 6.5)	68	25	15
Spoiled fish (pH 8.0)	74	8	22

i. Calculate the total colour difference (ΔE^*) between fresh and spoiled fish states. (15 Marks)

ii. The human eye can detect a ΔE^* greater than 3. Is the colour change visible? Justify your answer. (10 Marks)

iii. The packaging must have a ΔE^* of at least 12 for consumer confidence. If the a* value changes from 25 to 10, the b* from 15 to 20, and L* from 68 to 72, calculate ΔE^* and determine if it meets the requirement. (15 Marks)

c) The supermarket wants to replace the anthocyanin label with a modification of physical properties of the film.

i. The supplier offers a bio-based aerogel label that absorbs volatile amines from spoiled fish and changes colour. Compare this with a simple anthocyanin film. Which is likely more sensitive? Which is more expensive to produce? (20 Marks)

ii. To improve anthocyanin stability, the team adds lignin to the film and UV absorbance measured before and after adding lignin, using the absorbance equation $A=1-T-R$ (where A is absorbance, T is transmittance, and R is reflectance). The initial transmittance of UV light is 15%, and its initial UV reflectance is 10%. After adding 2% lignin, transmittance drops to 5% and reflectance increases to 15%. Recalculate absorbance and discuss the benefits between stability and visibility of colour change. (20 Marks)

(Total - 100 Marks)

4. A food company developed a plant-based cheese analogue and used TPA to compare it with dairy cheese.

a) TPA data are given (force–time curve parameters) in the following table.

Parameter	Dairy cheese	Plant-based analogue
Hardness (N)	12	9
Area under first compression (N·s)	8.5	6.2
Area under second compression (N·s)	6.0	3.1
Height recovery ratio	0.85	0.70

i. Calculate the cohesiveness and springiness for both cheeses.

(12 Marks)

ii. Calculate the gumminess for both samples. (8 Marks)

iii. Calculate the chewiness for both samples. (8 Marks)

iv. Based on your calculations, which cheese is more "chewy"? Justify your answer.

(12 Marks)

v. "The plant-based analogue has a higher loss modulus G″ than storage modulus G′ at 37°C". Describe its viscoelastic behavior based on the statement given. (10 Marks)

b) After one week of storage, the plant-based analogue becomes rubbery and less cohesive.

i. Explain the two (02) molecular changes that cause to increased stiffness and reduced cohesiveness. (Hint: bread staling) (20 Marks)

ii. Propose two (02) ingredient modifications that could improve the stability of the plant-based cheese analogue. For each modification, justify how it would affect viscoelastic properties. (15 Marks)

iii. After ageing, the analogue's tan δ (loss tangent = G″/G′) changes from 0.8 to 0.3. What does this change imply about the material's damping ability and brittleness?

(15 Marks)

(Total - 100 Marks)

5. A researcher is evaluating the surface area of a novel biochar made from rice husks for use as a catalyst support.

a) The researcher performs a nitrogen adsorption experiment at 77 K. The BET plot ($1/v[(P0/P)-1]$ vs. $P/P0$) yields a slope = 0.045 g/cm³ and an intercept = 0.002 g/cm³. Calculate:

i. The monolayer volume v_m (in cm³/g).

(15 Marks)

ii. The BET constant c.

(15 Marks)

b) Given that the cross-sectional area of a nitrogen molecule is s = 0.162 nm², Avogadro's number N = 6.02×10^{23} molecules/mol, and the molar volume of gas V=22400 cm³/mol,

i. Calculate the total surface area (St) (in m²) for a sample mass of 0.5 g.

(25 Marks)

ii. Calculate the specific surface area (S_{BET}) in m²/g.

(15 Marks)

c) A student produced a polylactic acid (PLA)/lignin biocomposite and analyzed it using differential scanning calorimetry (DSC). The DSC scan (heating rate 10°C/min) gives the following data for a 8.0 mg sample:

Parameter	Value
Melting enthalpy (ΔHm)	32.5 J/g
Cold crystallization enthalpy (ΔHcc)	8.2 J/g
Melting enthalpy for 100% crystalline PLA (ΔHm°)	93.0 J/g

i. Calculate the percentage crystallinity (% Xc) of the PLA in the composite.

(15 Marks)

ii. The student also recorded the DSC of a PLA/PBAT blend. Two distinct glass transitions were observed at −25°C and +58°C. Explain about the miscibility of the two polymers?

(15 Marks)

(Total - 100 Marks)

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