22CGB021
Food Engineering

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Attempt **FOUR** questions in total. Each question carries 25 marks.

Candidates should show full working for all calculations and derivations.

Graph paper is provided for question 5 and should be submitted with the answer booklet if used.

1. (a) What is the difference between intrinsic and extrinsic factors in food safety? Give examples of two intrinsic and two extrinsic factors that are important for food. Explain, in relation to one intrinsic and one extrinsic factor, how these factors work to control microbial growth in food. [6 marks]

(b) A prominent ground meat manufacturing company decides to produce their product at 7°C with an initial microbial load of 1×10^4 CFU g^{-1}. This arrangement is to ensure that the final microbial load on the product will not reach an unacceptable level of 1×10^8 CFU g^{-1}. The typical microbes grown on ground meat have a specific growth rate of 0.2 h^{-1} at 37°C. If the specific growth rate of the microbes is decreased by 8-fold at 7°C, estimate the time for the final microbial load in the meat product to reach an unacceptable level of 1×10^8 CFU g^{-1}. [5 marks]

Equation

$N = N_0 e^{kt}$, where the symbols have their usual meanings.

(c) Consider a 50 mL sample of milk that contains ~10 million anaerobes, ~100,000 aerobes, an unknown number of *Staphylococcus aureus*, ~30 *E. coli* cells, and ~10 *Salmonella* cells (all on a per-millilitre basis). An inexperienced food engineer conducted viable plate count experiments to enumerate different types of microbes present in the sample as shown in Figure Q1, overleaf:

(i) Enumerate the number of aerobic organisms in the sample in CFU mL^{-1}. [2 marks]

(ii) Enumerate the number of anaerobic organisms in the sample in CFU mL^{-1}. [2 marks]

(iii) Which organism(s) were detected in the Baird-Parker agar? Explain why only those specific organism(s) were seen in that medium. Enumerate their numbers in the sample in CFU mL^{-1}. [6 marks]

(iv) Explain if the viable plate count method is sufficient to enumerate all types of organisms present in the sample. If not, then suggest a suitable method and justify your answer. [4 marks]

Each dilution test tube contains 9 ml of medium and 1 ml of sample from the tube to its left; 0.1 ml is plated
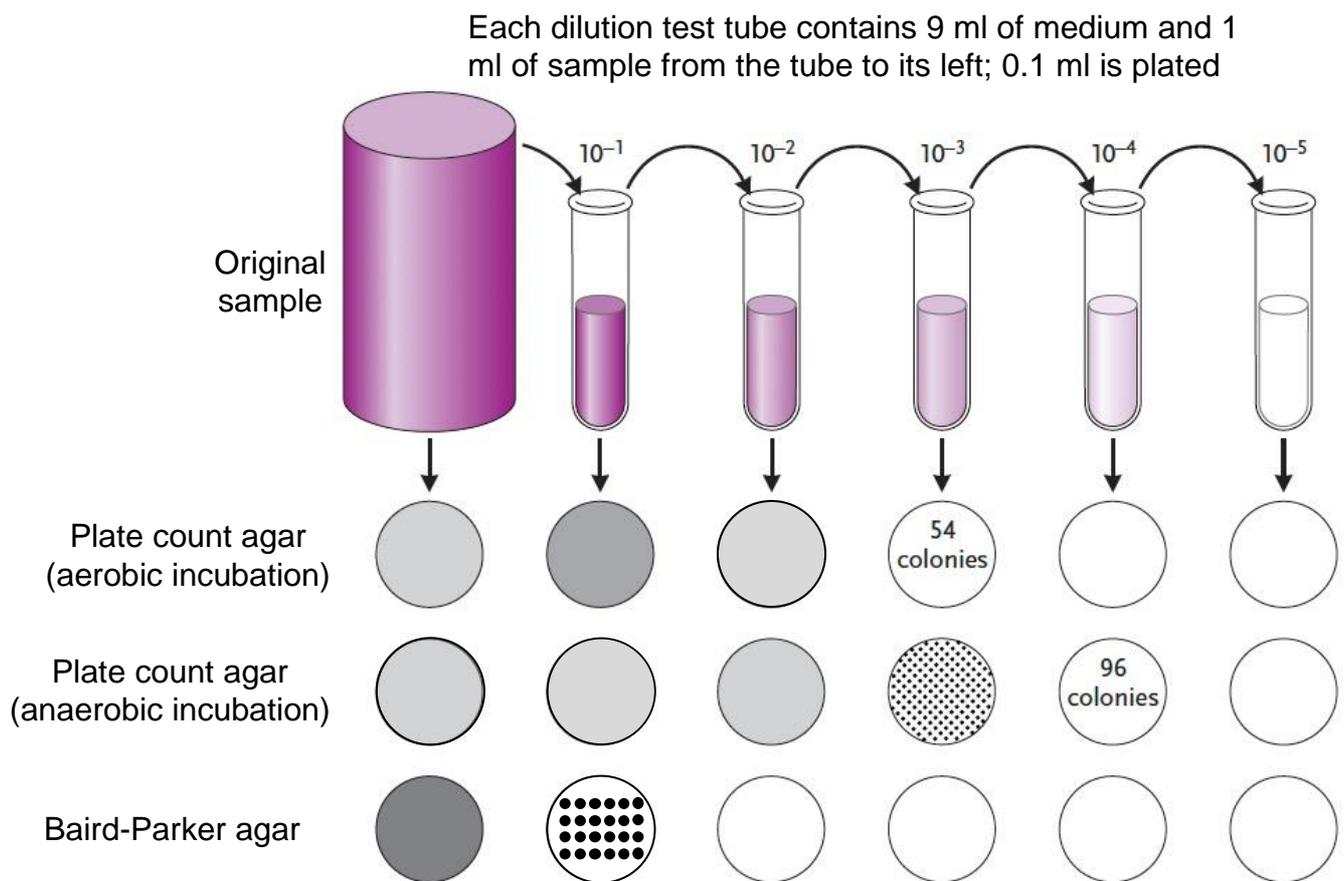

Figure Q1. Viable plate count experiments to enumerate bacteria in the milk sample. The original sample (which represents a 10^0 dilution) is diluted through a series of 10-fold dilutions before enumeration.

2. (a) Define the following parameters used in food sterilisation:

    (i)   *D*-value   [1 mark]

    (ii) *Z*-value   [1 mark]

    (iii) *F*-value   [1 mark]

    (iv) F_0-value   [1 mark]

(b) Using the chart shown in Figure Q2 overleaf, determine:

    (i)   The *Z*-value for the given strain (Hint: Find *D*-values at 116°C and 126°C using the graph in Figure Q2 and Eq. 2.1 and then apply Eq. 2.2).   [6 marks]

    (ii) The *D*-value at 121°C.   [4 marks]

    (iii) The required cooking time at 126°C to achieve F_{121} = 15 minutes.   [4 marks]

    (iv) The number of spores surviving heat treatment at 121°C for 15 minutes.   [4 marks]

    (v) How many spoiled containers can be expected per year for the sterilisation process in part (iv) if the plant capacity is 10 million containers per year?   [3 marks]

Equations

$$D_T = \frac{t}{log\frac{N_o}{N}} \tag{2.1}$$

$$D_T = D_\theta 10^{\frac{\theta - T}{z}} \tag{2.2}$$

where:

    D_T and D_θ are the *D*-values at temperatures T and θ respectively,

    t is the cooking time at temperature T,

    N_o is the initial number of spores per container,

    N is the number of surviving spores after cooking per container,

    Z is the *Z*-value.
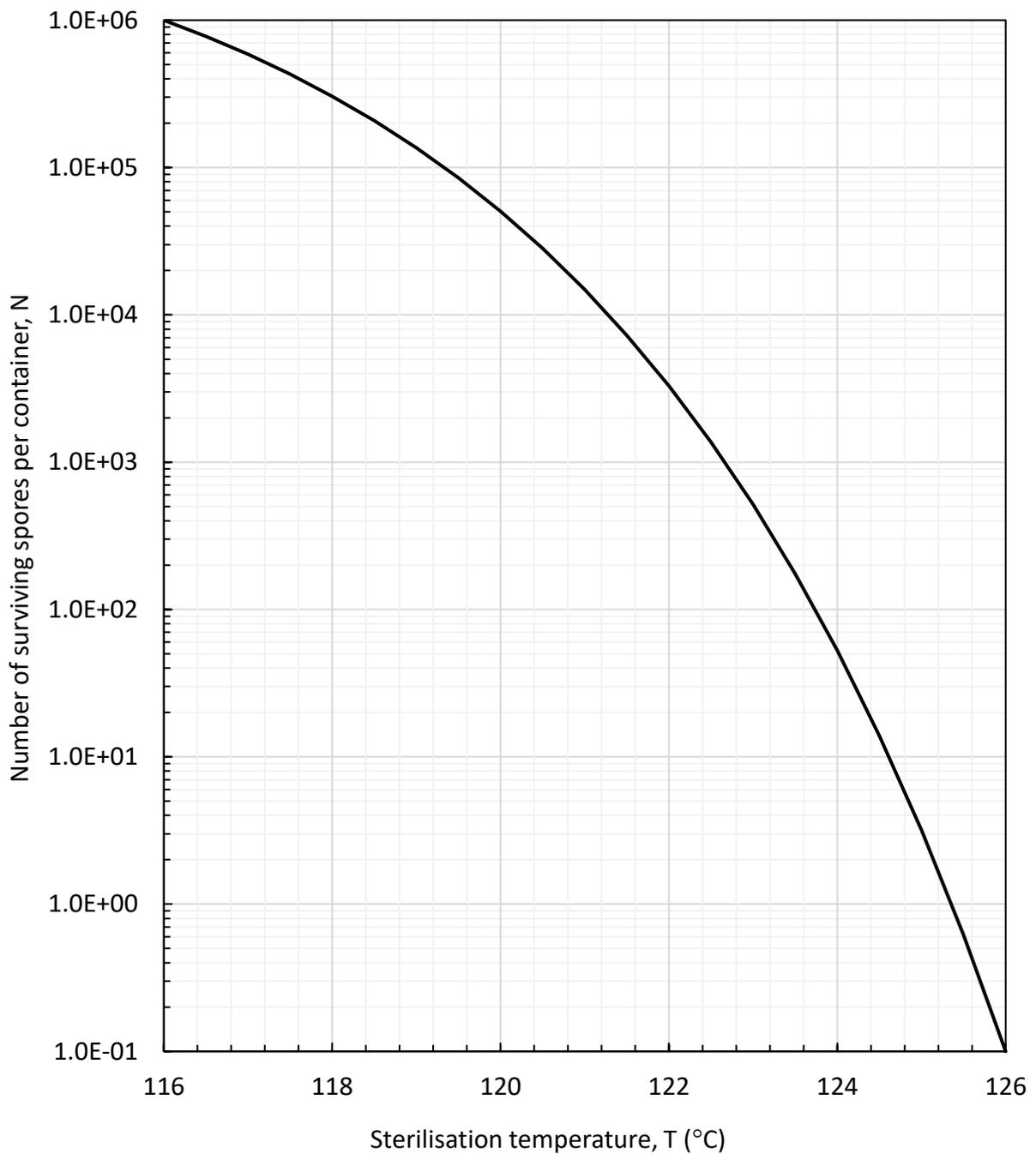
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Figure Q2. Number of spores of a given strain in a single container surviving a sterilisation for 3 minutes at a given temperature. The initial number of spores per container was 10^7.

3. 420 kg h^{-1} of potato granules (wet weight of feed) are to be dried in a counter-current perforated band dryer from an initial dry-basis moisture content of 40% to a final dry-basis moisture content of 5%. The dryer is 12 metres long x 80 cm wide x 340 cm high. The air is supplied with a dry bulb temperature of 132°C and a relative humidity of 0.5%. The flowrate of dry air (not including water) is 5000 kg h^{-1}.

(a) Calculate the humidity of the inlet and outlet air.   [6 marks]

(b) Using the drying rate equations below, and stating any assumptions made, calculate the required drying time.   [14 marks]

(c) Hence calculate the required conveyor speed to achieve this (in m s^{-1}).   [2 marks]

(d) If the dry-basis bulk density (*i.e.*, mass of dry potato per m^3) is 160 kg m^{-3}, calculate the required depth of granules on the conveyor to achieve the required throughput. [3 marks]

<u>Equations</u>

Constant rate period $\left(-\dfrac{dm}{dt} \right) = 30\left(H^{sat} - H \right)$ Eq 3.1

Falling rate period $\left(-\dfrac{dm}{dt} \right) = 2\,m$ Eq 3.2

where: m – **dry-basis** moisture content,

t – time (hours)

H – absolute humidity of air (kg kg^{-1})

H^{sat} – equilibrium humidity at wet bulb conditions (kg kg^{-1})

<u>Note</u>

Standard integral: $\int \dfrac{1}{a+bx}\,dx = \dfrac{1}{b}\ln(a+bx)$

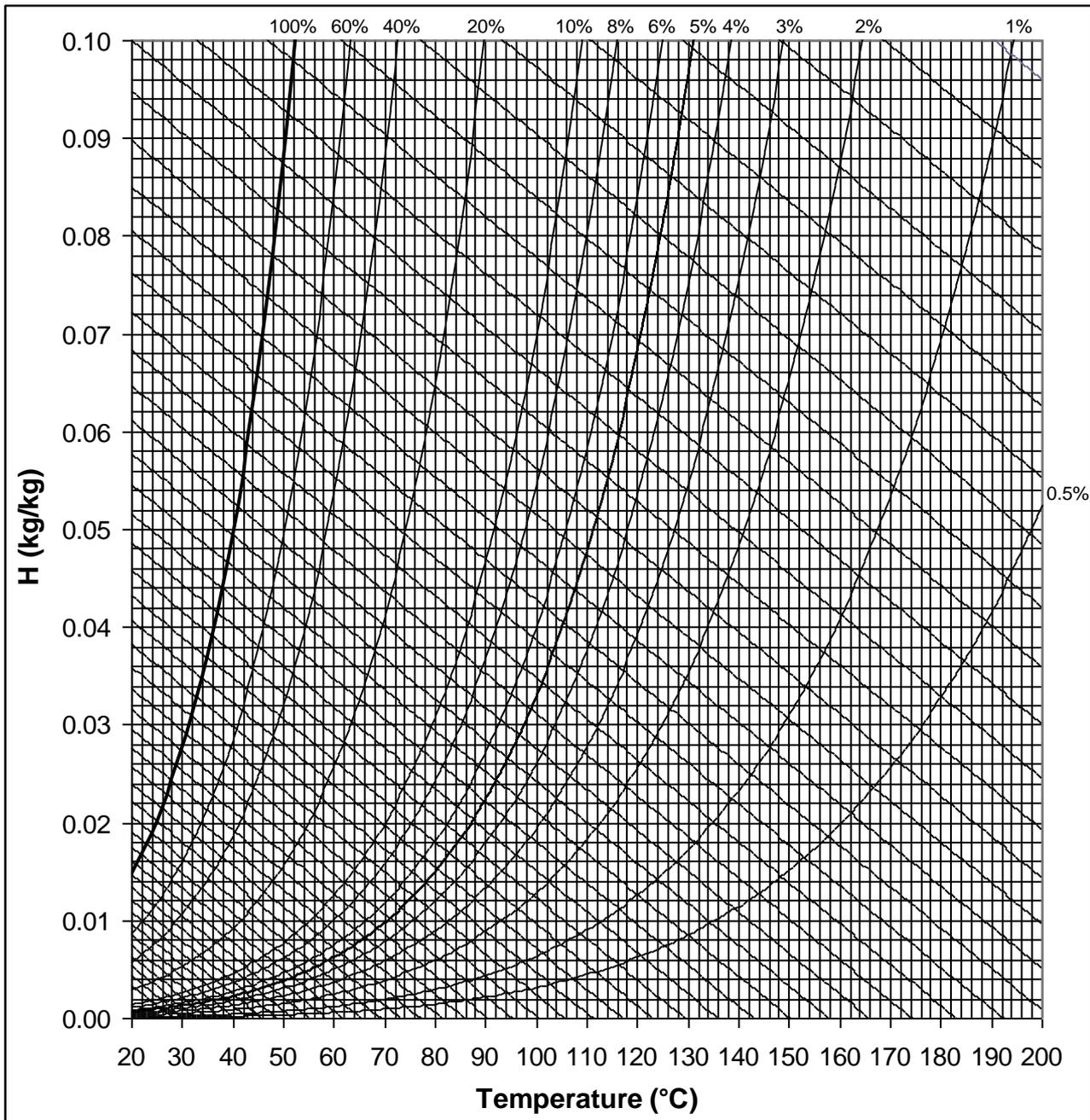Psychrometric chart attached overleaf (Figure Q3).

Figure Q3. Psychrometric chart for the air-water system. The diagonal lines correspond to constant wet bulb temperature.

4. (a) Stating any assumptions you make, derive the Plank solution for the time to freeze a thin slab of material suspended in an air stream. [13 marks]

(b) Given the information below, use the generalised Plank equation to calculate the freezing time for a brick-shaped foodstuff of dimensions 5 cm x 10 cm x 20 cm in a high velocity air freezer at -40°C. You may assume that the product is initially at -5°C and that the foodstuff is in contact with the air-flow over all surfaces. [8 marks]

(c) Calculate the thawing time if the foodstuff is subsequently exposed to ambient air (over all surfaces) at 20°C. [4 marks]

Data

Thermal conductivity of the unfrozen material:	0.5 W m^{-1}K^{-1}
Thermal conductivity of the frozen material:	1.5 W m^{-1}K^{-1}
Surface heat transfer coefficient during freezing:	200 W m^{-2}K^{-1}
Surface heat transfer coefficient during thawing:	10 W m^{-2}K^{-1}
Mass of freezable water per unit volume:	850 kg m^{-3}
Latent heat of fusion:	0.3 MJ kg^{-1}
Freezing point of material:	-5°C

For a brick of dimensions 2ℓ x $2E_1\ell$ x $2E_2\ell$ the generalised Plank solution can be used with the factor G given by the following table:

		E_1			
		2	3	4	5
	2	-	0.570	0.565	0.563
E_2	3	0.570	0.567	0.562	0.559
	4	0.565	0.562	0.558	0.554
	5	0.563	0.559	0.554	0.549

Equation

The generalised Plank solution is
$$t = \frac{V\rho\lambda}{A\ell\Delta T}\left(\frac{\ell}{h} + \frac{G\ell^2}{k}\right)$$

where the symbols have their usual meanings.

5. (a) You are working at a food manufacturing company with a wide portfolio of products. One of the projects you are working on relates to a product which has shear dependent, time independent flow behaviour. The other has shear dependent, time dependent flow behaviour.

    (i) Explain briefly what shear dependent flow behaviour is and state an example type.

            [2 marks]

    (ii) Explain briefly what time dependent flow behaviour is and state an example type.

            [2 marks]

    (iii) For each of the two products mentioned above, what would you pay attention to during rheological characterisation to get accurate information on the flow behaviour that will be relevant to a process? Provide a brief explanation on why you think these are important. [2 marks]

(b) The rheology of a cake batter was characterised using a Couette type viscometer, which has a cup radius of 20 mm, bob radius of 18 mm and a bob height of 40 mm. The data obtained are presented in Table Q5 below.

    (i) Calculate the shear stress and shear rate values. [8 marks]

    (ii) Plot the flow curve for this cake batter on the graph paper provided. [2 marks]

    (iii) State the flow behaviour of the cake batter and propose a constitutive equation which best describes the flow behaviour of this cake mix. Show your calculations and provide the values obtained for the constants/parameters for the equation. [9 marks]

Data

Table Q5. Results from rheological measurement for a cake batter (Couette viscometer).

Rotational speed (rpm)	Measured Torque (mNm)
30	6
90	31
120	49
250	147
500	417
700	690

END OF PAPER

Dr A Islam, Dr G Vladisavljevic, Dr AGF Stapley, Dr NG Özcan-Taşkın