UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Biochemical Eng E124: Biotransport Processes II

COURSE CODE	:	**BENGE124**
UNIT VALUE	:	**0.25**
DATE	:	**09-MAY-05**
TIME	:	**14.30**
TIME ALLOWED	:	**2 Hours**

05-C0103-3-50

TURN OVER

*Answer **ONE** question from **Section A** and answer **TWO** questions from **Section B**.*
***ALL** questions carry a total of **25 MARKS** each, distributed as shown* [ ].
*Only the **FIRST THREE ANSWERS** will be marked.*

SECTION A

1.

At the end of a milk pasteurisation cycle, milk is to be cooled from 90°C to 15°C at a rate of at least 9,702 kg h^{-1}. A single-pass counter-current shell and tube heat exchanger with the following specification is available:

Number of tubes = 250

Tube length = 1.0 m

Internal tube diameter = 23.5 mm

External tube diameter = 25 mm

Thermal conductivity of tube wall = 15 W m^{-1} K^{-1}

Milk will pass through the tubes of the exchanger and chilled water will be supplied to shell-side at 4°C and is expected to discharge at 10°C. From experience it is assumed that the film heat transfer coefficients for the shell-side (water) and the tube-side will be 2,500 W m^{-2} K^{-1} and 3,000 W m^{-2} K^{-1}, respectively. The mean heat capacity of milk is 3.9 kJ kg^{-1} K^{-1}.

a) Is the heat exchanger adequate for the proposed heat load? [15]

b) After some time of operation the tubes become scaled and a fouling factor of 5000 W m^{-2} K^{-1} can be assumed. What fraction of the total resistance to heat transfer will be due to fouling? [3]

c) Assuming that the inlet and outlet temperatures remain unchanged, how will the fouling affect the amount of milk that can be cooled per hour? Comment on your answer. [7]

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2.

An existing $10m^3$ working volume fermenter is to be redesigned to take on board a new fermentation protocol which will be for the growth of the same *E.coli* cells but with a final broth viscosity of 200 rather than 10 cP. Using the data given below:

i) evaluate the overall resistance to heat transfer for the existing fermenter. [3]

ii) evaluate the "film heat transfer resistance" (fermenter-side) for the existing fermentation operation. [9]

iii) evaluate the likely increase in overall resistance to heat transfer for the new fermentation protocol. [4]

iv) give three methods on how you might redesign the fermenter or respecify its operation to make the new fermentation protocol feasible. Calculations are NOT NEEDED but commentary IS NEEDED on advantages and disadvantages for each method. [9]

Data for existing fermentation protocol:

Fermentation broth:

Density = 1g/mL;
Thermal conductivity = 0.5 $W\,m^{-1}K^{-1}$;
Specific heat = 4000 $J\,kg^{-1}\,K^{-1}$

Fermentation:

Maximum heat output = 40 kW
Optimum temperature = 30°C

Cooling water:

Observed maximum temperature for effective control =20°C

Fermenter:

Jacket-cooled; area available for heat transfer = $20m^2$
Vessel diameter = 2.1m
Impeller diameter = 0.7m
Stirrer speed = 200 rpm

The following correlation applies in the fermenter:

$$Nu = 0.6\,Re^{2/3}\,Pr^{1/3}$$

NB 1 cP = 0.001 Nsm^{-2}

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SECTION B

3.

At the end of a canning process, a can containing concentrated tomato puree is cooled from 80°C. The puree is assumed to cool by conduction. Cooling is achieved using a continuous flow of water with a convective heat transfer coefficient of 10 W m^{-2} K^{-1} on the can surface. The temperature of the cooling water is assumed to remain constant. The properties of the puree are thermal conductivity 0.4 W m^{-1} K^{-1}; specific heat 4 kJ kg^{-1} K^{-1}; and density 1000 kg m^{-3}. The can has a diameter of 80 mm and a height of 100 mm.

a) Determine the temperature of the cooling water required to reduce the temperature at the centre of the puree to 50°C in 2 hours. State any assumptions used. [20]

b) Sketch the temperature profile across the can at time t=0 and after 2 hours. Comment on the profiles. [5]

Centreline temperature charts for an infinite slab and an infinite cylinder are provided.

4.

You are required to review a proposal for the change in operation of a spray drier. The current drier is used to prepare a powder containing a therapeutic protein to be administered by inhalation. It appears that some degradation of the protein is occurring and this has to be avoided.

The proposed change is for a decrease in the outlet air temperature of the drier from 70°C to 60°C. To review this proposal you are required to complete the following stages.

i) Explain why a reduced outlet air temperature might reduce the extent of protein damage. In particular you should relate this explanation to heat and mass transfer processes occurring in the drier. [7]

ii) Evaluate the decrease in throughput which would have to occur to achieve a powder of the same final moisture content and water activity. [10]

iii) Suggest alternative solutions which would allow you to maintain the original drier throughput and also to achieve a final powder of the same water activity as the original. [8]

Moisture sorption isotherms solutions and air water enthalpy diagrams are provided. Current drier condition – inlet air humidity 0.008kg moisture/ kg dry air; inlet air temperature to drier 120°C.

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5.

You are required to review two proposals for doubling the dose size of a highly labile therapeutic protein product as prepared by freeze drying in vials (single vial per dose).

The first proposal is to double the volume of the liquid feed to be processed in the vial (sufficient space is available).

The second proposal is to keep the volume processed the same but to double the solids concentration from 10% to 20% of the liquid feed to the vial.

To complete the review you need to address the following stages:-

i) Show that for the primary drying phase the time of drying (t) is related to the depth of frozen material (x) and the volume fraction of ice (ø) by

$$t = (\rho \o x^2) / (2k_p \;\Delta P)$$

(You should provide a full explanation of all the terms given in this relationship and the assumptions behind its derivation.) [9]

ii) Estimate the change in time required for the primary drying phase for both proposals and comment on how realistic these estimates are likely to be. [5]

iii) Comment on the effect of both proposals on:-

a) the freezing time [3]

b the time for secondary drying [3]

c) the maintenance of a fully active protein in the final freeze dried material [5]

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CHARTS for Q3

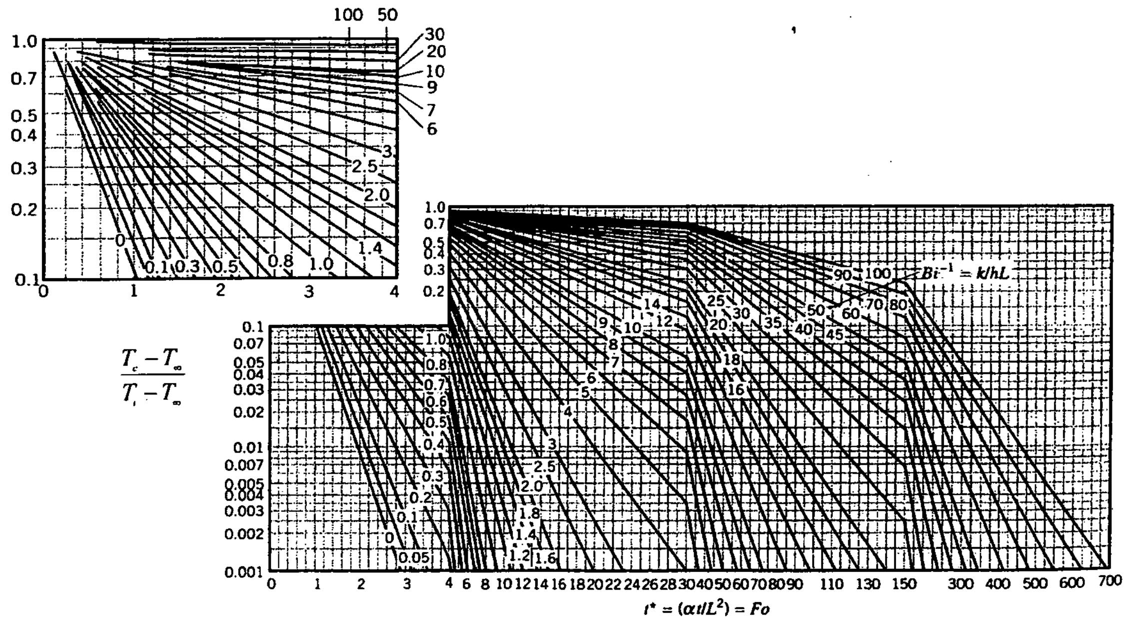

Figure 1. Midplane temperature for a plane wall of thickness 2L

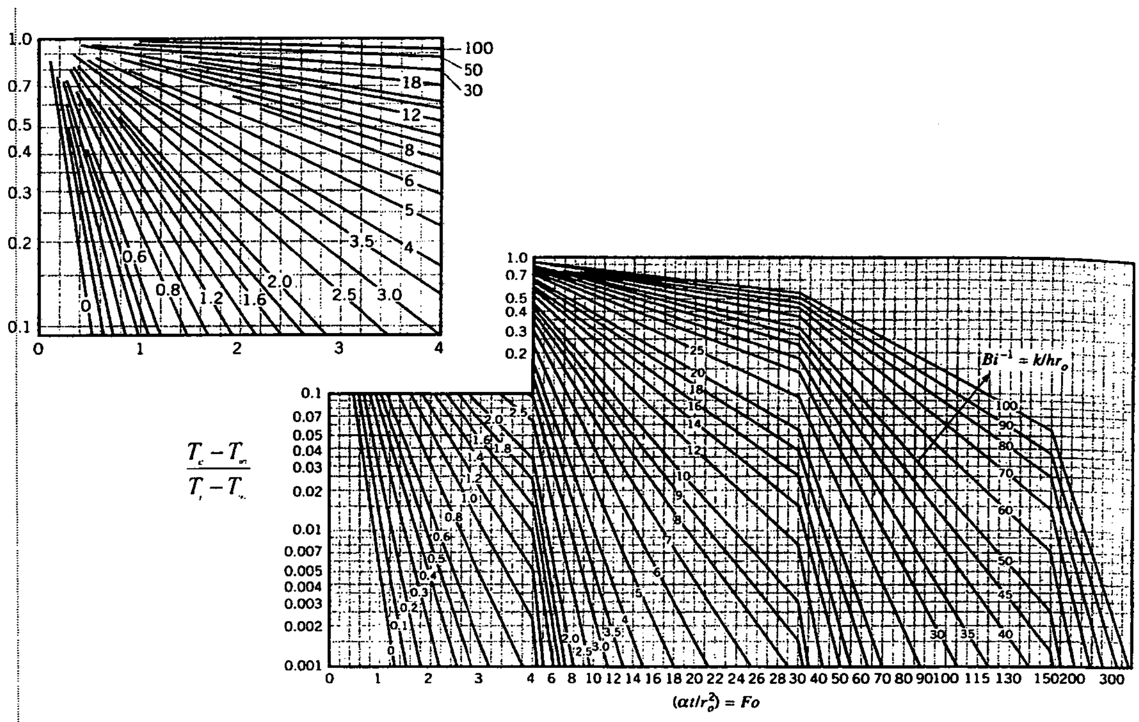

Figure 2. Centreline temperature for an infinite cylinder of radius r_o

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CHARTS for Q4

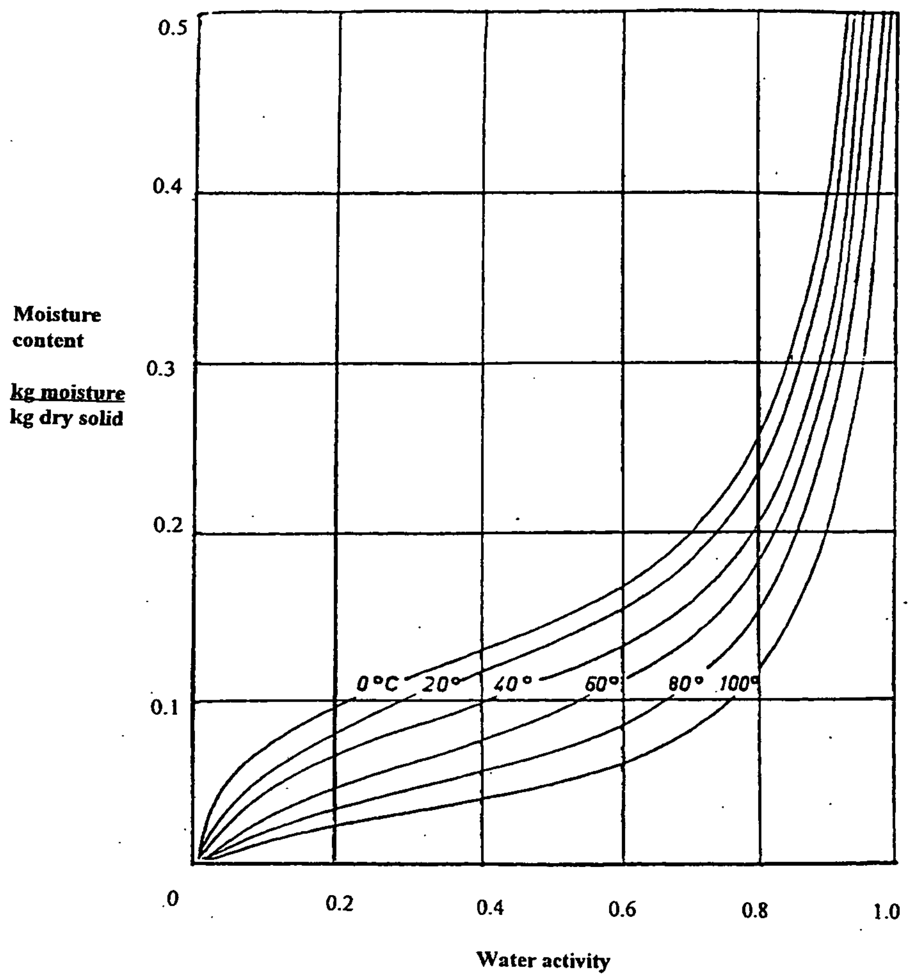

Figure 3. Moisture sorption isotherms

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CHARTS for Q4

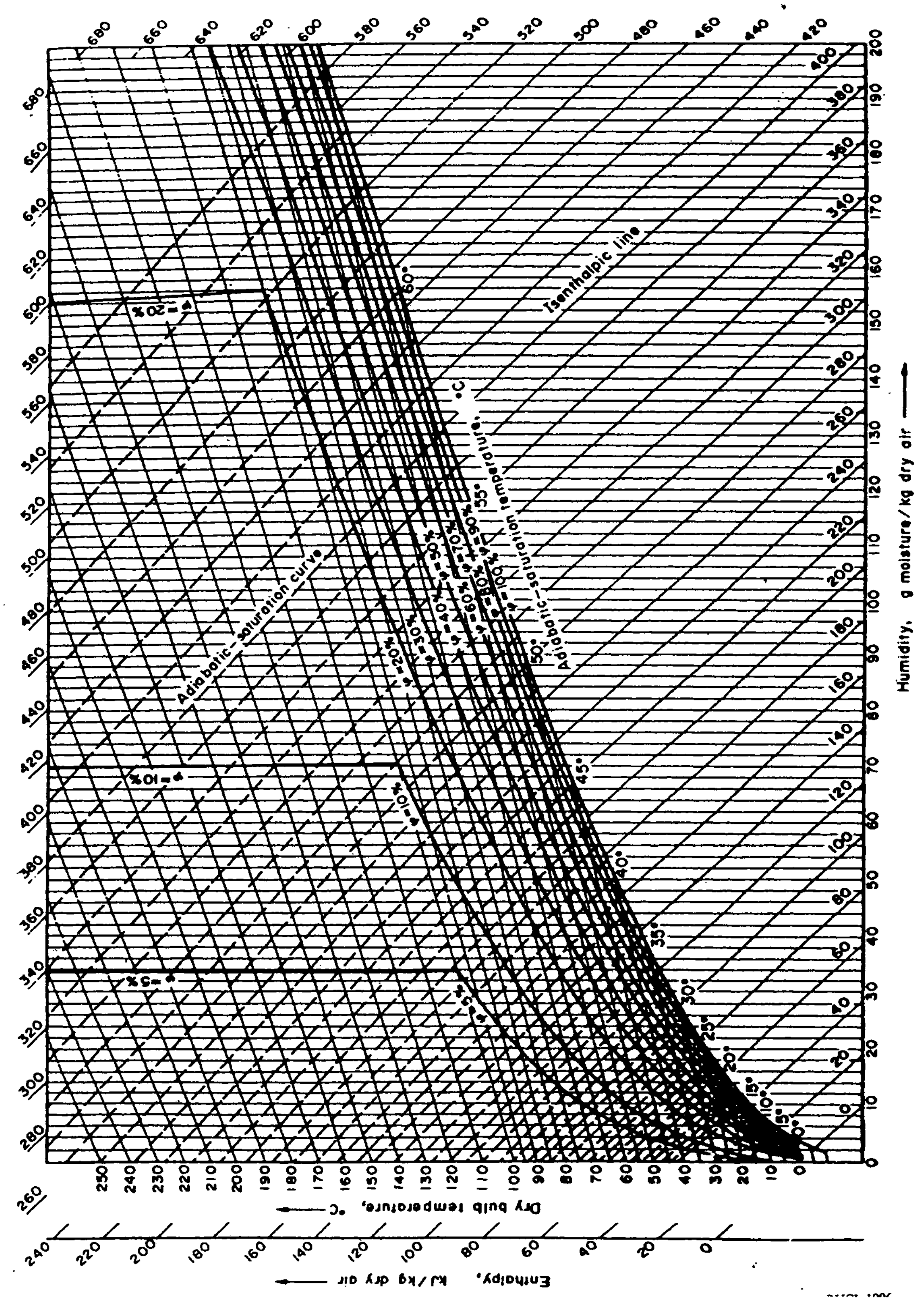

Figure 4. Enthalpy-humidity diagram for water vapour in air

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