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	:	**16-MAY-03**
TIME	:	**14.30**
TIME ALLOWED	:	**2 Hours**

03-C0103-3-50

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Answer 4 QUESTIONS. **Only the first 4 answers given will be marked.**
ALL questions carry a total of 20 MARKS each, distributed as shown [ ]

1.

i) For a surface losing heat by natural convection, the heat transfer coeeficient is given by $Nu = C(Gr.\Pr)^n$ where $n = ¼$ for $10^3 < Gr.\Pr < 10^8$ and $n = ⅓$ for $Gr.\Pr > 10^8$. Show by dimensional analysis how this form of equation arises. [5]

ii) For air the equations can be written for the two regimes as $h = 1.35(\frac{\Delta T}{H})^{1/4}$ and $h = 2.00(\Delta T)^{1/3}$ W/m^2K respectively for a particular geometry. Show how this arises. [10]

iii) A large cylindrical storage vessel 10 m high and 30 m diameter is filled with a hot liquid. Calculate the heat loss to surrounding air on a windless day when the surface is at uniform temperature 27 K above ambient. Assume that the equations above apply to the vertical surface with height as the characteristic dimension and that the same heat transfer coefficient applies to the top surface. Assume the following physical properties for air: [5]

$\rho = 1.3$ kg/m^3, $\mu = 1.7x10^{-5} N^s m^2$, $\beta = \frac{1}{273} K$,
$C_P = 1.0$ kJ/kg K, k = 24 x 10^{-6} kW/mK, g =9.81m/s^2

2.

The local Nusselt number for laminar flow on a vertical pipe is given by:

$$Nu_x = \frac{h_x x}{k_L} = \left[\frac{\rho_L g(\rho_L - \rho_v) h_{fg} x^3}{4\mu_L k_L (T_{sat} - T_s)} \right]^{1/4}$$

Saturated steam, at 80 °C, condenses on the outer surface of a vertical pipe, 0.31 m long and 0.16 m OD, maintained at 60 °C. Calculate:

a) the rate of heat transfer if the average heat transfer for coefficient is $\frac{4}{3}h_x$ [10]

b) the mass flow rate of the condensate, assuming laminar flow. [10]

The properties of steam and water are:
h_{fg} = 2.4 x 10^6 J/kg; ρ_v = 0.0456 kg/m^3;
ρ_L = 994 kg/m^3; μ_L = 7.6 x 10^{-4} kg/ms;
k_L = 0.618 W /m °C

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3.

A mercury still is heated with an electric immersion heater. Tests show that the evaporative rate varies with temperature difference between heater and liquid as follows:

Rate	75	188	300	375	420	g/s
ΔT	4	5	6	7	8	k

Comment on the proposal to increase the rate to 500 g/s by adding 30% length of heating element. [20]

4.

With the aid of diagrams, discuss and explain the significance of the main features of the flow regimes in;

i) pool boiling and
ii) two – phase flow in a vertical pipe. [20]

5.

A non-Newtonian liquid is to be cooled in an agitated vessel 2.0m in diameter. Two arrangements are to be considered.

a) coil heat transfer using a turbine of diameter 0.7m at a speed of 2 rps
b) jacket heat transfer using an anchor of diameter 1.9m at a speed of 0.7 rps. [20]

If the fluid obeys the power law relationship over a wide range of shear rates, giving n = 0.5, K = 1.0 kg s^{n-2}/m, calculate the process side heat transfer coefficients for the two arrangements. Comment on your results.

For the fluid $C_p = 700$ J/kg K
$k = 0.15$ W/mK
$\rho = 800$ kg/m^3

For anchors use $$\frac{h_o D_T}{k} = 0.35\, Re^{2/3}\, Pr^{1/3}$$

Turbines use $$\frac{h_c D_T}{k} = 1.4\, Re^{0.62}\, Pr^{0.33}$$

END OF PAPER