UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Chemical Eng E802: Transport Processes I

COURSE CODE	:	**CENGE802**
UNIT VALUE	:	**0.50**
DATE	:	**19-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

03-C0182-3-70

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

$g = 9.81$ m s^{-1}, $R = 8.314$ kJ kg^{-1} K^{-1}, 1 bar = 10^5 Pa.

1.

An object with characteristic length d and constant surface temperature T_o, is placed in a stream of air with velocity u, constant temperature T_a, density ρ, viscosity μ, specific heat c_p and thermal conductivity k. If q is the heat flux between the object and the air, using 4 fundamental dimensions show that the process can be described by the following dimensionless groups:

$Nu = f(Re, Pr)$

Where:

$$Nu = \frac{hd}{k},\ \mathrm{Re} = \frac{\rho u d}{\mu},\ \mathrm{Pr} = \frac{\mu c_p}{k}$$

and h is the heat transfer coefficient between the object and air, $h = \dfrac{q}{\Delta T}$

with $\Delta T = T_o - T_a$ [10]

When an object with characteristic length 1m and constant surface temperature of 200°C was placed in an air stream with velocity 100 m s^{-1} and temperature 20°C, it was found that the heat flux was 20000 W m^{-2}. Calculate the heat flux for a geometrically similar object with characteristic length 5 m, that is placed in an air stream with velocity 20 m s^{-1}, when the object and air temperatures are the same in both cases. [10]

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2.

What is the general form of macroscopic balance equations? [2]

Plug A is used to block the end of the round pipe shown in the figure below. When the plug is partially fitted water leaves radially from the end of the pipe with a velocity of 5 m s^{-1}. Assuming that gravitational and viscous forces are negligible, calculate:

a) the flowrate through the pipe [3]
b) the gauge pressure at point 1 [5]
c) the gauge pressure at the tip of the plug, point 2 [5]
d) the force F needed to hold the plug in place. [5]

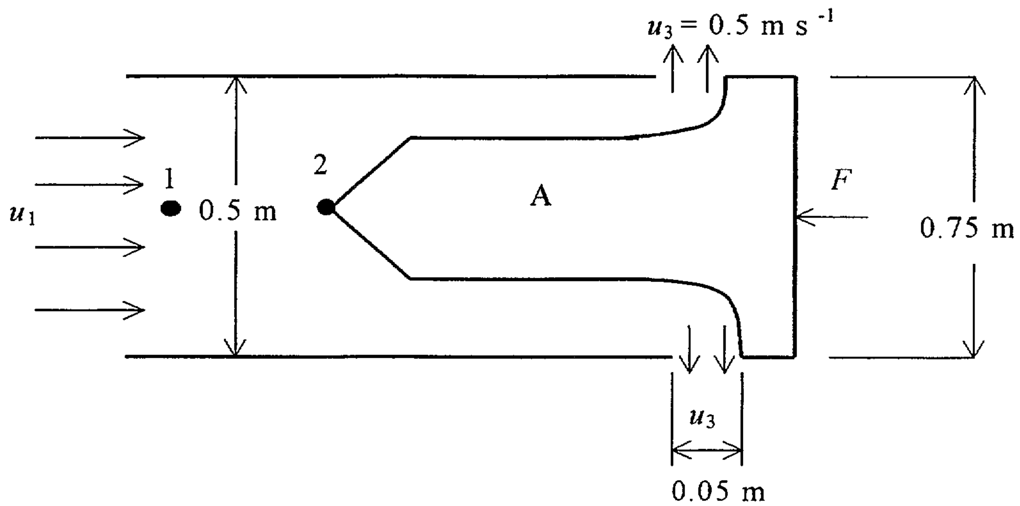

Figure: Question 2

3. A cylindrical tank with diameter 0.7 m is being filled with water that enters with a constant flowrate of 50×10^{-3} m^3 s^{-1}. When the water in the tank reaches a height H, a valve at the bottom of the tank is activated that allows water to leave with volumetric flowrate Q_2 (m^3 s^{-1}) given by:
$Q_2 = 110 \times 10^{-3} \times h$
where h (m) is the height of water in the tank at any moment.

The valve is deactivated when the water level in the tank drops to $H/2$.
If H = 1m find out:

a) What are the units of the constant in the above equation? [3]
b) How does the outlet flowrate change with time when the exit valve is open? [12]
c) How long does it take for the water level to drop from H to $H/2$? [5]

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4. Answer *TWO* of the following

a) What is the pressure difference between two points at different heights in an ideal gas at constant temperature? [10]

b) Discuss briefly the experimental methods for determining liquid viscosity. [10]

c) Discuss briefly the similarity of the heat, mass and momentum transfer processes. [10]

5. The figure below shows how the drag coefficient for spheres, c_D, varies with Reynolds number, *Re*.

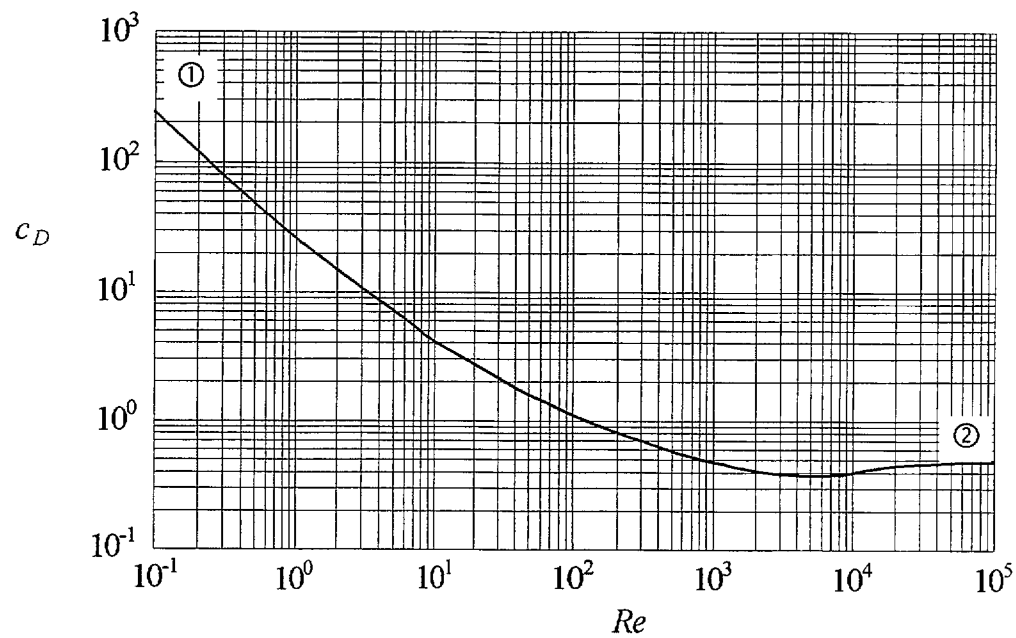

Figure: Question 5

Briefly, with the aid of diagrams, compare and contrast the flow around the sphere at the Reynolds numbers indicated by points ① and ② on the chart. [6]

Starting from a force balance on a sphere, show that its terminal velocity, u_t, falling through a fluid of density ρ, is given by

$$u_t = \sqrt{\frac{4dg(\rho_S - \rho)}{3c_D\rho}}$$

where g is the gravitational acceleration, d is the sphere diameter and ρ_s its density. [7]

Estimate the terminal settling velocity of a sphere of diameter 2.7 mm and density 5800 kg m^{-3} in a fluid with the following properties, density 1250 kg m^{-3} and viscosity 6 mPa s. [7]

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6. A section of pipe, 900 mm outside diameter, is insulated by a surrounding layer of rock-wool 80 mm thick. The thermal conductivity of the rock-wool, k, varies with temperature, T, according to

$$k\,[\mathrm{W\,m^{-1}\,K^{-1}}] = 0.009 + 0.00024 \times T\,[^\circ\mathrm{C}]$$

If the temperature of the pipe is 270 °C and the outside surface of the insulation is 40 °C, calculate the rate of loss of heat per metre length of insulated pipe. [20]

7. *Briefly* outline the main features of the "two film theory" of mass transfer. [5]

Ammonia is absorbed into water in a wetted wall column where the mass transfer coefficient in the gas phase is 0.3×10^{-3} kmol s^{-1} m^{-2} bar^{-1} and that for the liquid phase is 9.0×10^{-3} kmol s^{-1} m^{-2} mole fraction^{-1}. Analysis of samples taken from one level in the column indicated ammonia concentrations of 0.15 mole fraction in the gas phase and 0.075 mole fraction in the liquid phase. The column was operating at 15 °C and 2 bar. Under these conditions, the Henry's law constant for ammonia over water is 0.97 bar ammonia in the vapour phase per mole fraction of ammonia in the liquid phase.

Calculate

(i) the overall mass transfer coefficient based upon the gas phase; [4]

(ii) the molar flux of ammonia at the level in the column where the samples were taken; and [5]

(iii) the concentrations of ammonia in the liquid and gas phases at the interface, at the location where samples were taken expressing your answers in terms of mole fractions of ammonia. [6]

END OF PAPER