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	:	**29-APR-04**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

04-C0182-3-80

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

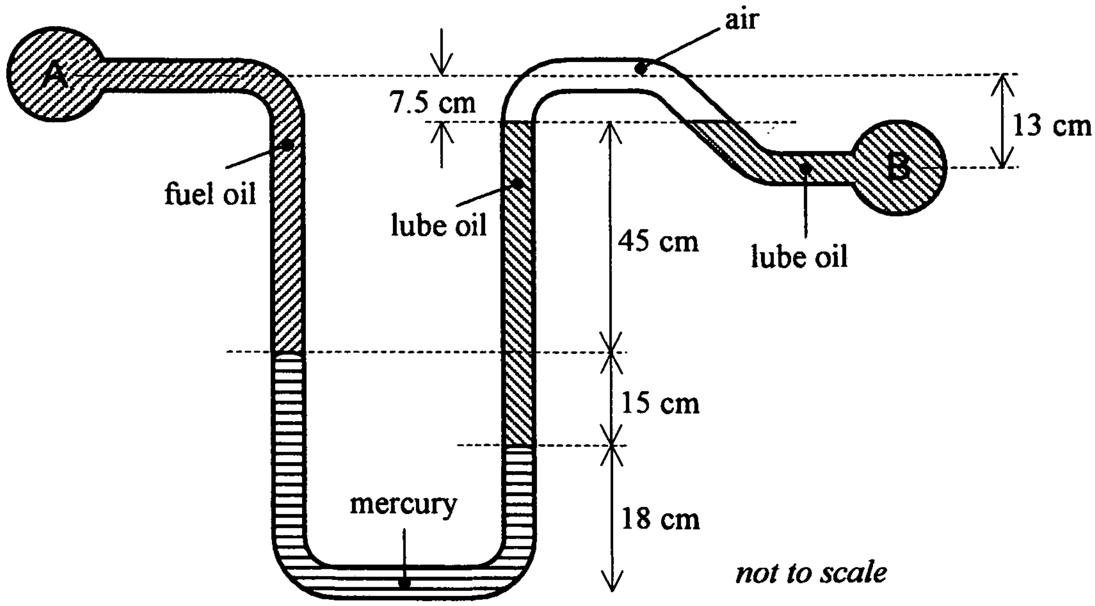
1. By drawing a control volume in the z direction show that the difference in static pressure between two points at different height in a static fluid is equal to:

$$\frac{dP}{dz} = -\rho g$$

where ρ is the fluid density, z is the vertical direction and g is the acceleration of gravity. [6]

How does pressure vary in a horizontal level in a continuous static fluid? [2]

A mercury manometer is used to measure the pressure difference in the two pipelines A and B shown in the figure. Fuel oil (density = 832 kg m^{-3}) is flowing in pipeline A and lube oil (density = 895 kg m^{-3}) is flowing in pipeline B. An air pocket has become entrapped in the lube oil as indicated. Determine the pressure in pipe B if the pressure in pipe A is 1.05 bar. [12]



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2. A sphere with diameter d, soaked with ethanol is kept still in a stream of air. Show by dimensional analysis that the expression which relates the mass transfer coefficient of the ethanol evaporation, k, to the sphere diameter d, the mean air velocity, u, the diffusion coefficient of the ethanol in the air, D, and the air properties, density ρ and viscosity μ, is of the form:

$$Sh = f(Re, Sc)$$

where $Sh = \frac{kd}{D}$ is the Sherwood number, $Re = \frac{du\rho}{\mu}$ is the Reynolds number

and $Sc = \frac{\mu}{\rho D}$ is the Schmidt number. [10]

What is the significance of each of the dimensionless groups? [3]

A sphere, 5 cm in diameter, soaked in ethanol, is within a stream of air. Experiments have given the following values of the mass transfer coefficient of the ethanol in the air:

air velocity (m s^{-1})	10	20	30	40
mass transfer coefficient (m s^{-1})	4.6	7.9	10.9	13.6

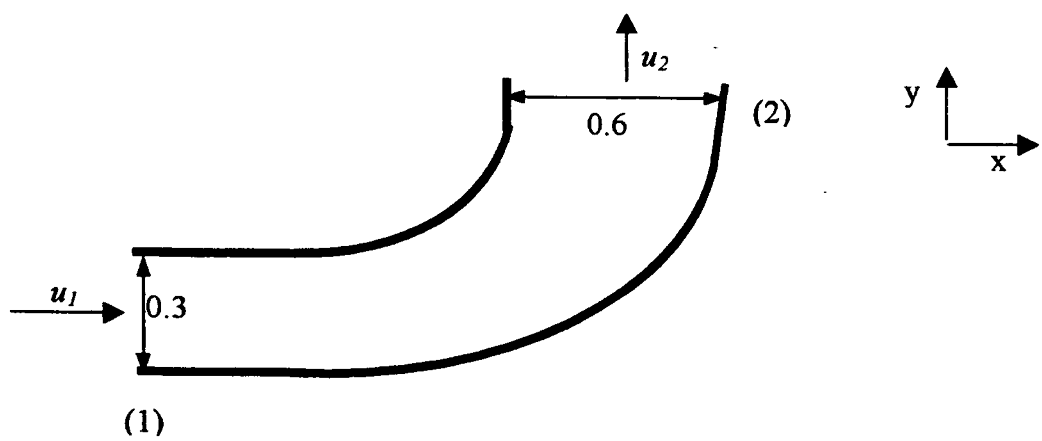
What is the mass transfer coefficient for a sphere of 2 cm in diameter that is within a stream of air with velocity 50 m s^{-1}? [7]

Air properties: density = 1.21 kg m^{-3}, viscosity = 1.78×10^{-5} kg m^{-1} s^{-1}.
Diffusion coefficient of ethanol in air = 1.26×10^{-5} m^2 s^{-1}.

3. What is the general form of the macroscopic balance equations? [3]

Air is flowing through the 90° bend shown in the figure below. The cross section of the bend is rectangular with 0.075 m depth. The width of the bend at the inlet, point (1), is 0.3 m and at the outlet, point (2), is 0.6 m. In the inlet the air velocity is u_1 = 55 m s^{-1} and the pressure is $P_1 = 2 \times 10^5$ Pa. The loss in the available energy during the flow in the bend is $(0.2u_1^2/2)$. What is the force exerted from the air to the bend? [17]

The height difference along the bend can be ignored. It can also be assumed that the air density does not vary significantly along the bend



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4. Discuss briefly **TWO** of the following:

(i) Mechanism of viscosity in gases and liquids. [10]

(ii) Advantages and disadvantages of Venturi and orifice meters and Pitot tubes. [10]

(iii) Stefaan's method for the measurement of the diffusivity of a volatile liquid in a gas. [10]

5. The velocity profile for well-developed laminar flow in a circular pipe is given by

$$u = \frac{1}{4\mu}\left(-\frac{dp}{dx}\right)\left(r_o^2 - r^2\right)$$

where the symbols have their usual meaning. Describe *briefly* with the aid of a sketch the shape of this profile. [5]

Why is there a negative sign associated with the $\frac{dp}{dx}$ term? [2]

Starting from the velocity profile above, show that the volumetric flowrate through the pipe is given by

$$Q = \frac{\pi r_o^4 \Delta p_f}{8\mu l}$$

where Δp_f is the frictional pressure drop over a length of pipe l. [7]

A tube viscometer consists of a long straight capillary tube of circular cross-section, 300 mm in length and of 2 mm internal diameter. Given that when a pressure difference of 3 bar is applied over the length of the pipe, it is found that 30 g min^{-1} of a fluid, density 920 kg m^{-3}, is passed through the pipe, calculate the viscosity of the fluid. [6]

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6. Heat is transferred by conduction through the cylindrical wall of a thick walled plastic pipe. A heat balance on a representative control volume yields

$$\frac{d}{dr}(r\,q_r)=0$$

where r is the radial co-ordinate and q_r the radial heat flux. Starting form this expression, show that q_r is given by

$$q_r=\frac{k(T_i-T_o)}{r\,ln\left(r_o/r_i\right)}$$

where T_i and T_o are the inner and outer cylinder surface temperatures and r_i and r_o their respective radii. [10]

Glacial acetic acid at 50 °C (melting point 16.6 °C) is being pumped through a long plastic pipe, internal diameter 15 cm, wall thickness 1 cm. The pump fails and the flow stops. Assuming that the resistance to heat transfer of the pipe wall dominates the overall heat transfer process, estimate the time that elapses before the acetic acid starts to freeze if the outside surface of the pipe wall is at 0 °C. [10]

Data:
Acetic acid, density = 1030 kg m^{-3}, specific heat capacity = 2.1 kJ kg^{-1} K^{-1},
Plastic pipe: thermal conductivity = 0.45 W m^{-1} K^{-1}.

7. Starting from the two-film theory of mass transfer show that the overall mass transfer coefficient, K_{OG}, is related to the film coefficients k_G and k_L by

$$\frac{1}{K_{OG}}=\frac{1}{k_G}+\frac{H}{k_L}$$

where H is the Henry's law constant. [7]

A wetted wall column is operated to investigate the overall mass transfer coefficients for the absorption of a gas into water. The data below show how the measured overall mass transfer coefficients varied with the Reynolds number for the gas flow through the column under constant liquid flow conditions.

Re	1.0×10^4	4.0×10^4	1.0×10^5	
K_{OG}	8.7×10^{-9}	15.5×10^{-9}	19.5×10^{-9}	kmol m^{-2} s^{-1} Pa^{-1}

Previous work has indicated that $k_G \propto Re^{0.83}$. Evaluate

a) the liquid film coefficient, and [7]

b) the gas film coefficient at a Reynolds number of 2.5×10^4. [6]

The Henry's law constant for the gas in water is 1.5×10^4 Pa m^3 $kmol^{-1}$.

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