UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Chemical Eng E878: Physics for Chemical Engineers

COURSE CODE	:	**CENGE878**
UNIT VALUE	:	**0.50**
DATE	:	**04-MAY-05**
TIME	:	**14.30**
TIME ALLOWED	:	**3 Hours**

05-C0197-3-50

TURN OVER

*Answer **THREE** questions from* **Section A**, *__TWO__ questions from* **Section B** *and __TWO__ questions from* **Section C**.

The marks available for each question or part of each question are shown in square brackets in the right-hand margin thus... [ ]

A total of 30 marks are available from Section A, 50 from Section B and 20 from Section C.

Data

Constants:

Avogadro's constant $N_A = 6.022 \times 10^{26}$ kmol^{-1}
Boltzmann's constant, $k = 1.381 \times 10^{-23}$ J K^{-1}
Electrostatic constant, $1/4\pi\varepsilon_0 = 8.988 \times 10^{9}$ N m^2 C^{-2}
Gas constant, $R = 8314$ J kmol^{-1} K^{-1}
Gravitational acceleration, $g = 9.81$ m s^{-2}
Gravitational constant, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Planck's constant, $h = 6.63 \times 10^{-34}$ J s
Stefan's constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

Properties of materials:

property	*units*	*material*		
		Water	Air	Steel
Density	kg m^{-3}	1000	1.2	-
Viscosity	Pa s	1×10^{-3}	1.7×10^{-5}	-
Specific heat capacity	J kg^{-1} K^{-1}	4180	1000	460
Young's Modulus	N m^{-2}	-	-	20×10^{10}
Shear Modulus	N m^{-2}	-	-	7.5×10^{10}
Bulk Modulus	N m^{-2}	2×10^{9}	-	17×10^{10}
Yield Stress	N m^{-2}	-	-	3×10^{8}

Conversion factors:

1 eV = 1.602×10^{-19} J
1 mile = 1760 yard
1 yard = 36 inch
1 inch = 25.4 mm
1 ton = 2240 lb
1 lb = 0.4536 kg
1 bar = 10^5 Pa
1 atm = 1.01 bar

TURN OVER

Section A

*Answer **THREE** multiple choice questions from this section.*

A total of 30 marks are available for this section.

Select the correct option or options as required from the answers given. Justify your selection with appropriate calculations and/or explanations. Quoting a letter answer is not sufficient.

A.1 Power is consumed when a fluid flows through a pipe. On dimensional grounds which of the following expressions, if any, may represent the power required to pump a fluid? [10]

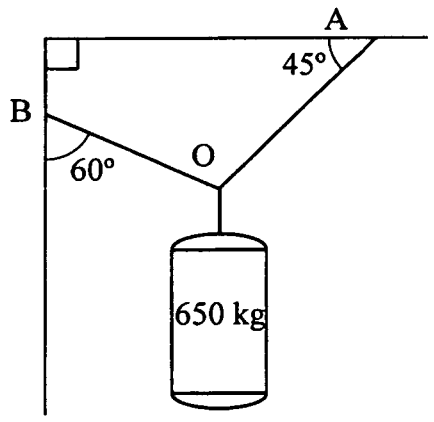
A: $\rho\mu Q$ ***B***: $\rho Q\Delta p$ ***C***: $G\Delta p$ ***D***: $Q\Delta p$ ***E***: $\Delta p\mu$

where G is the fluid mass flow rate, Q the fluid volumetric flow rate, ρ its density, μ its viscosity and Δp the pipe pressure drop.

A.2 During the construction of a chemical plant a piece of process equipment is suspended from two cables, OA and OB, that are attached to horizontal and vertical supports respectively, as shown in **Figure: A.2** below. If the mass of the equipment is 650 kg, what is the magnitude of the tension in cable OA? Select the option closest to your answer. [10]

A: 4500 N ***B***: 3300 N ***C***: 5700 N ***D***: 21300 N ***E***: 580 N

Figure: A.2



CONTINUED

A.3 Consider two samples of gas, with type A possessing three degrees of freedom and type B possessing seven degrees of freedom. According to the equipartition of energy theorem, which one of the following statements is true? [10]

A: At the same temperature, type A will have more energy per molecule than type B.

B: At the same temperature, type A will have the same amount of energy per molecule as type B.

C: At the same temperature, the relative amounts of energy per molecule in the two gases will depend on the number of molecules in each sample.

D: At the same temperature, type A will have the same amount of energy per degree of freedom as type B.

E: At the same temperature, both gases will have the same total energy.

A.4 There are three different processes which can contribute to the transfer of heat through a medium. These are conduction, convection, and radiation. Which one of the responses offered in the key gives an accurate statement about all three? [10]

A: All three processes take place in all materials.

B: All three processes take place in all fluids.

C: Conduction and radiation take place in all materials, but convection is only possible in fluids.

D: Conduction and convection can take place in all fluids, but radiative transfer can only take place if the fluid is transparent to visible light.

E: Conduction and convection can take place in all fluids, but radiative transfer is only effective in wavelength ranges in which the fluid is transparent to electromagnetic radiation.

A.5 The kinetic theory of an ideal gas relates the temperature of the gas to the microscopic motion of the molecules. Which one of the following statements is true? [10]

A: The temperature of the gas is proportional to the mean–squared speed of a molecule in the gas.

B: The temperature of the gas is proportional to the average speed of a molecule in the gas.

C: The temperature of the gas is proportional to the root–mean–squared speed of a molecule in the gas.

D: The temperature of the gas is proportional to the sum of the speeds of all the molecules in the gas.

E: The temperature of the gas is proportional to the maximum squared speed of a molecule in the gas.

TURN OVER

Section B

*Answer **TWO** questions from this section.*

A total of 50 marks are available for this section.

B.1 (i) What is the effect of temperature upon the black body radiation spectrum? [5]

(ii) How is this effect used by a pyrometer to measure temperature? [3]

(iii) Calculate the power emitted via an 8 cm diameter "peep-hole" in the flat wall of a reformer furnace operating at a temperature of 1200 °C. [7]

(iv) An operator is standing with his head 200 mm from the hole described in (iii) above. Estimate the rate of radiatitive heat transfer to the worker's face which has a projected area in the direction of the hole of 0.035 m^2 and an emissivity 0.97. Assume that the heat from the hole is radiated outwards equally in all directions from the hole [7]

(v) How might the assumption used in (iv) be improved? [3]

B.2 (i) What happens to the energy added to an ideal gas when it is heated (a) at constant volume, and (b) at constant pressure? Explain how a gas can have a number of values of specific heat. [10]

(ii) Given that the difference in molar specific heats for an ideal gas is given by $C_P - C_V = R$, show that the difference in the mass specific heats for an ideal gas is given by $c_P - c_V = \frac{p}{\rho T}$. [7]

(iii) If the ratio $\gamma \equiv c_P / c_V$ of a certain gas is 1.4 and its density ρ at 1 atm and 0 °C is $0.090\,kg\,m^{-3}$, calculate the values of the specific heat capacity at constant pressure and at constant volume. [8]

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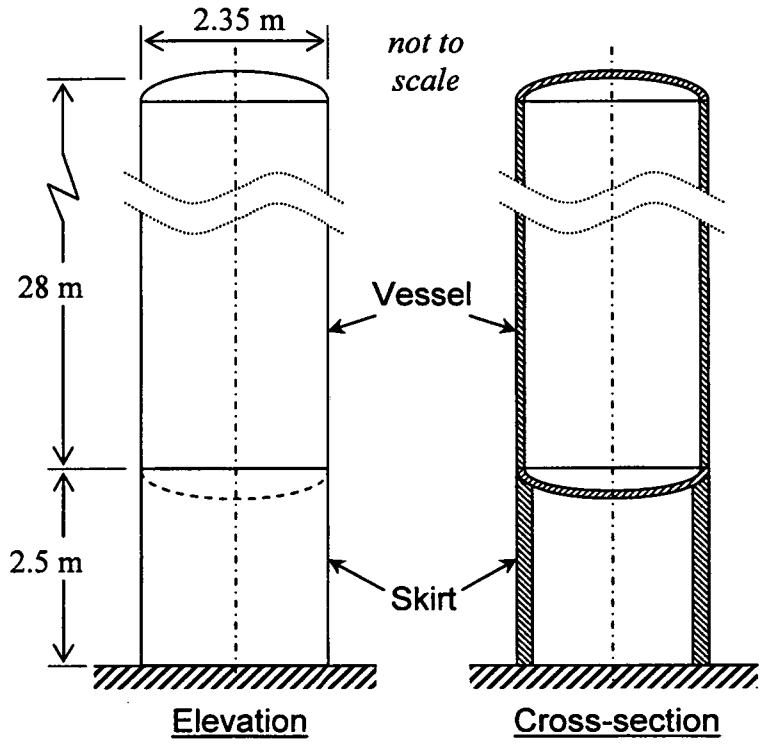
B.3 A process vessel or column in the form of a circular cylinder 28 m high and 2.35 m in diameter is illustrated in **Figure B.3**. The column is supported on a thin-walled cylindrical "skirt", of similar diameter to the column and 2.5 m in height. The column and skirt are all made of steel. During a hydraulic test, the column is filled with water and weighs a total, vessel and contents, of 140 tonnes.

Figure B.3: Process vessel with skirt



(i) Estimate the skirt wall thickness required such that the compressive stress in the skirt does not exceed 20% of the yield stress of steel whilst the column undergoes the hydraulic test. [10]

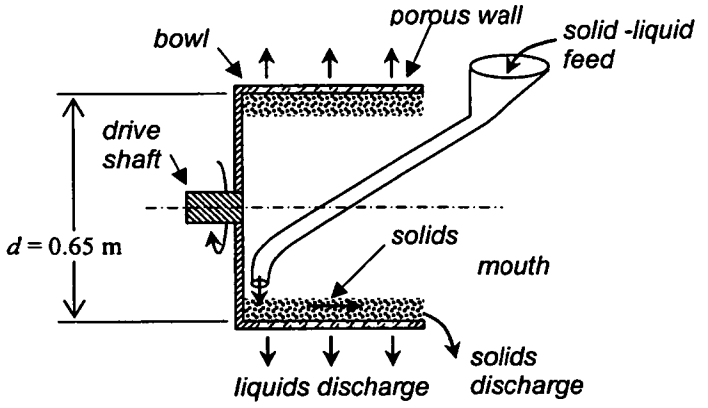
(ii) During operation the vessel may be exposed to gale-force winds. Calculate the force exerted by a 70 mph wind on the column and skirt together. You may assume the column and skirt experience the same wind speed and the drag coefficient for a cylinder has a value of 0.4 and is given by $c_{D_c} = \frac{2F/L}{d\rho u_\infty{}^2}$, where the symbols have their usual meaning. [8]

(iii) Estimate the torque exerted by the wind force, calculated in (ii) above, about the base of the skirt. [7]

TURN OVER

B.4 A horizontal basket centrifuge is illustrated in **Figure B.4** below. A solid - liquid mixture is fed into the centrifuge where the liquid is separated from the solids, with the liquid being discharged through the porous wall of the bowl and the solids via the mouth of the bowl.

Figure B.4: Centrifuge - sectional view



(i) If the bowl of the centrifuge has an internal diameter of 650 mm, calculate the rate of rotation of the centrifuge, in Hz, such that material in the bowl at its periphery experiences a centripetal acceleration of $900g$. [8]

(ii) Calculate the maximum thickness of the solid layer in the bowl such that the inner surface experiences a minimum centripetal acceleration of $800g$. [5]

(iii) 3 kg s^{-1} of solid - liquid mixture is fed into the bowl of the centrifuge rotating at the rate calculated in (i) above. Calculate the power required to accelerate this mixture from rest to the speed of the periphery of the bowl. [12]

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Section C

*Write short notes upon **TWO** of the following.*
A total of 20 marks are available for this section.

C.1 The significance of parameters a and b in the van der Waals equation of state, $\left(p + \frac{a}{V_m{}^2}\right)(V_m - b) = RT$ where the symbols have their usual meaning. [10]

C.2 *Avogadro's hypothesis* and the significance of *Avogadro's constant.* [10]

C.3 Evidence for the atomic basis of matter. [10]

C.4 Friction and its atomic basis. [10]

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