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	:	**21-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

TURN OVER

Answer ***THREE*** *questions from* ***Section A, TWO*** *questions from* ***Section B*** *and* ***TWO*** *questions from* ***Section C. Only the first seven answers will be marked.***

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

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}

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

PLEASE 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 answers with appropriate calculations and or explanations. Quoting a letter is not sufficient.

A.1 A catalyst consists of a monolayer of platinum on a honeycomb substrate with a surface area of 120 m^2. Platinum has an atomic weight of 195.08 and density of 21.5×10^3 kg m^{-3}. Estimate the mass of monolayer of platinum on the catalyst. Select the option closest to your answer. [10]

A: 21.4 kg *B*: 0.11 kg *C*: 21.4 g *D*: 3.2 g

E: 0.64 g

F: 0.11 g *G*: 3.2 mg *H*: 0.64 mg

A.2 Work is done on a fluid when it flows. On dimensional grounds which of the following expressions, if any, may represent the rate of energy dissipation per unit volume of fluid? [10]

A: ρu *B*: $\rho \dfrac{\mathrm{d}u}{\mathrm{d}y}$ *C*: $\rho\mu \dfrac{\mathrm{d}u}{\mathrm{d}y}$ *D*: $\mu \dfrac{\mathrm{d}u}{\mathrm{d}y}$

E: $\mu\left(\dfrac{\mathrm{d}u}{\mathrm{d}y}\right)^2$ *F*: $\dfrac{\rho}{\mu}\dfrac{\mathrm{d}u}{\mathrm{d}y}$

where u is the fluid velocity, ρ its density, μ its viscosity and $\dfrac{\mathrm{d}u}{\mathrm{d}y}$ the velocity gradient.

CONTINUED

A.3 During the construction of a chemical plant, a piece of equipment, mass 200 kg, is suspended from two cables, OA and OB, that are attached to horizontal and vertical supports, as shown in figure overleaf. What is the magnitude of the tension in cable OA? Select the option closest to your answer. [10]

A: 2000 N *B*: 3400 N *C*: 2310 N *D*: 3150 N
E: -3150 N *F*: -3400 N

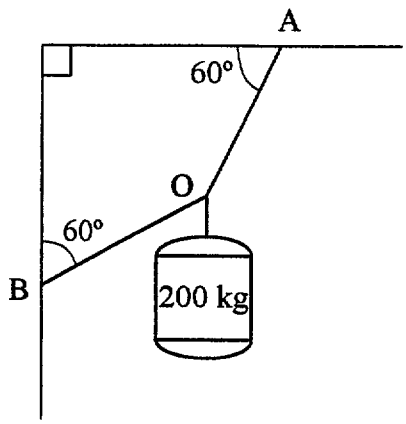

Figure: Question A.3

A.4 A hi-fi turntable is essentially a uniform disc, with mass 1.5 kg and radius 13 cm. A constant torque is applied to the turntable, which accelerates from rest to an angular speed of $33\frac{1}{3}$ rpm in 2 s. What is the value of the magnitude of the torque? (The moment of inertia of a homogeneous solid disk of mass, m, and radius, r, is $I = \frac{1}{2}mr^2$.) Select the option closest to your answer. [10]

A: 0.0035 N m *B*: 0.022 N m *C*: 0.044 N m *D*: 0.077 N m
E: 0.17 N m *F*: 0.72 N m *G*: 1.3 N m *H*: 5.1 N m

A.5 Taking the Clausius-Clapeyron equation, $\frac{dp}{dt} = \frac{nL}{T\Delta V}$ and assuming the volume of liquid is negligible compared with the volume of vapour, it may be shown that the variation of vapour pressure with temperature is given by $p = C\,e^{-L/RT}$ where the C is a constant, L the molar latent heat and the other symbols have their usual meaning. Starting from the vapour pressure at the normal boiling point of gold, use information selected from the data given below to estimate the temperature at which the vapour pressure of the liquid gold is 1 Pa. Select the option closest to the correct answer [10]

A: 1350 °C *B*: 1550 °C *C*: 1750 °C *D*: 1950 °C
E: 2150 °C *F*: 2350 °C

Data: Gold: Melting point: 1064.4 °C; Specific latent heat of fusion: 64.5 kJ kg^{-1}; Boiling point: 2966 °C; Specific latent heat of vaporization: 1.578 MJ kg^{-1}; Relative atomic mass: 197 kg $kmol^{-1}$.

PLEASE TURN OVER

Section B

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

A total of 50 marks are available for this section.

B.1 A concrete dam, illustrated below, is 40 m wide and holds back water 20 m deep.

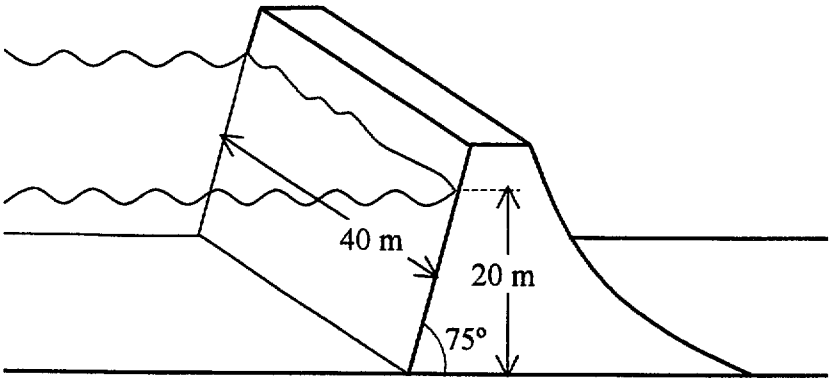

Figure: Question B.1

The pressure, p, in a fluid of density, ρ, varies with height, h, in the following manner

$$p = \rho g h$$

where g is gravitational acceleration.

(i) Assuming a density of water of 1000 kg m^{-3}, calculate the horizontal force exerted by the water on the dam. [15]

(ii) Assuming that the coefficient of friction between the dam and the underlying ground is 0.75, estimate the minimum mass that the dam must possess so that it does not slip. [10]

B.2 A concentric pipe heat exchanger consists of two concentric tubes. The inner tube has an outside diameter of 50 mm, a wall thickness of 4 mm, and is exactly 3 m in length at 20 °C.

(i) Assuming that it is free to expand, what would be the length of the inner tube at the operating temperature of 80 °C? [9]

(ii) However, if the inner tube is not free to expand and is held rigidly at each end, calculate (a) the compressive stress and (b) the compressive force at the operating temperature of 80 °C? [16]

Data:

Material	*coefficient of thermal expansion* ($°C^{-1}$)	*Moduli* ($N\ m^{-2}$)		
		Young's	*Shear*	*Bulk*
Steel	11×10^{-6}	20×10^{10}	7.5×10^{10}	17×10^{10}

PLEASE TURN OVER

B.3 An intrepid snow-boarder, illustrated below, is about to snow-board down a 30 m high snowy slope, which is at an angle of 60° to the horizontal. At the bottom of the slope there is a small section where the slope changes to the horizontal, the "jump". There is a horizontal landing area 10 m below this level.

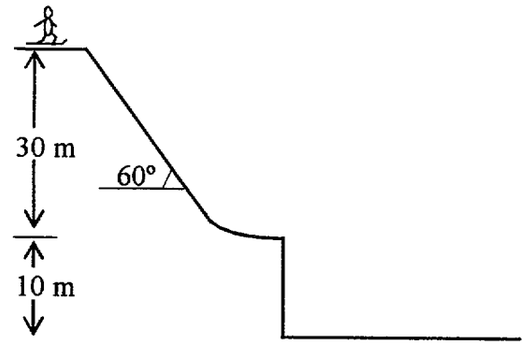

Figure: Question B.3

Assuming no wind resistance, no loss of momentum at the bottom of the slope and that a coefficient of sliding friction between the snow-board and the snowy slope is 0.05, estimate:

(i) the snow-boarder's speed at the bottom of the slope, before the "jump"; [12]

(ii) the horizontal distance travelled through the air by the snow-boarder during the "jump"; and [7]

(iii) the vertical speed of the snow-boarder at the moment he touches down in the landing area. [6]

B.4 A hot-air balloon has a total mass, including the balloon, its basket and contents, but excluding the mass of the air inside the balloon, of 250 kg.

(i) If the diameter of the balloon envelope is 50 m (assume spherical), estimate the temperature to which the air inside the balloon must be raised above ambient, 20°C, so that the hot-air balloon hovers just above the ground? Assume the air acts as an ideal gas. [18]

(ii) If the heat transfer coefficient from the balloon to the surroundings is 0.5 W m^{-2} K^{-1}, estimate the rate at which heat must be supplied to the air in the balloon. [7]

Data:

Molecular weight of air = 29 kg $kmol^{-1}$.

PLEASE TURN OVER

Section C

Write short notes upon ***TWO*** of the following.

A total of 20 marks are available for this section.

C.1 Friction and its atomic basis. [10]

C.2 The significance of parameters a and b in 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.4 Heat transfer by radiation. [10]

C.4 The Maxwell-Boltzmann speed distribution. [10]

END OF PAPER