UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Eng.

Chemical Eng E878: Physics for Chemical Engineers

COURSE CODE	:	**CENGE878**
UNIT VALUE	:	**0.50**
DATE	:	**13-MAY-02**
TIME	:	**14.30**
TIME ALLOWED	:	**3 hours**

02-C0196-3-30

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Duration 3 hours

*Answer **FOUR** questions from Section A, **THREE** 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 [].

A total of 20 marks is available from Section A, 60 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 inch = 25.4 mm	1 bar = 10^5 Pa
1 mile = 1760 yard	1 ton = 2240 lb	
1 yard = 36 inch	1 lb = 0.4536 kg	

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SECTION A

*Answer **FOUR** multiple-choice questions from this section.*

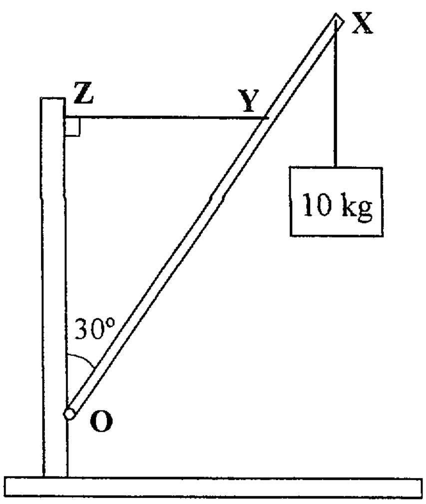
A total of 20 marks is available for this section.

Select the correct option or options as required from the answers given. Justify all your selections with appropriate calculations.

A.1 In a partially evacuated discharge tube, a sulphur atom (S) with speed 7×10^6 m s^{-1} collides with a stationary zinc atom (Zn), which is free to move in any direction. The sulphur atom moves backwards along its original path with a speed of 10^6 m s^{-1}. Assuming that no other particles are emitted in the collision and that the mass of the zinc atom is double that of the sulphur atom, select the *two* correct statements concerning the collision. [5]

- ***A***: If the momentum of the zinc atom after the collision is denoted by p_{Zn}, the momentum of the sulphur atom after the collision must be given by $\frac{1}{8}\, p_{Zn}$.
- ***B***: The collision is inelastic.
- ***C***: After the collision, the zinc atom and the sulphur atom have equal amounts of kinetic energy.
- ***D***: The speed of the zinc atom after the collision is 4×10^6 m s^{-1}.
- ***E***: The speed of the zinc atom after the collision is 3×10^6 m s^{-1}.

A.2 The figure below shows a uniform rod **OX** of length 3 m and negligible mass, pivoted at **O**. A load, of mass 10 kg, is suspended from **X** by a rope. The system is maintained in equilibrium by a horizontal cable attached to the rod at **Y**, which is 2.5 m from **O**. What is the torque exerted by the rope attached to the 10 kg load, on the rod about the pivot **O**? [5]



A: 15 N m	*B*: 26 N m	*C*: 150 N m
D: 17 N m	*E*: 170 N m	*F*: 260 N m

TURN OVER

A.3 A centrifuge is being designed and it is proposed that the diameter of the rotating bowl be 650 mm. What is the rate of rotation required such that the centripetal acceleration experienced at the bowl's periphery is 100*g*? [5]

A: 0.28 Hz *B*: 0.89 Hz *C*: 1.7 Hz *D*: 6.2 Hz
E: 8.78 Hz *F*: 55 Hz *G*: 480 Hz *H*: 525 Hz

A.4 Two equally charged particles are held stationary, 3.6×10^{-3} m apart, and then released. One particle has a mass of 5.6×10^{-8} kg and is observed to have an initial acceleration of magnitude 7.0 m s^{-2}. What is the magnitude of the charge on the particles? [5]

A: 4.0×10^{-10} C *B*: 2.4×10^{-11} C *C*: 4.6×10^{-2} C *D*: 2.1×10^{-1} C

A.5 A metal vessel with a heat capacity of 0.8 kJ K^{-1} contains a mixture of 0.6 kg of ice and 0.4 kg of water in equilibrium at 0.0°C. Into this vessel is bubbled 0.1 kg of steam at 100 °C. When thermal equilibrium is re-established, it is found that all the ice is melted and that the vessel contains only water at temperature θ. Assuming the container is so well lagged that it exchanges a negligible amount of energy with the surroundings, calculate the value of θ. [5]

A: Impossible to say without knowing the mass of the metal vessel.
B: 14.5 °C *C*: 12.4 °C *D*: 10.6 °C *E*: 7.5 °C
F: None of the above.

Data:
Specific heat of water = 4.2 kJ kg^{-1} K^{-1};
specific latent heat of fusion of ice at 0 °C = 336 kJ kg^{-1}; and
specific latent heat of vaporisation of water at 100 °C = 2.268 MJ kg^{-1}.

A.6 A distillation column, including contents, has a mass of 37 tonnes. It is supported by a vertical, thin-walled cylindrical "skirt", circular in cross-section. The skirt has a diameter of 1.8 m and a wall thickness of 6 mm. Calculate the compressive stress in the skirt. [5]

A: 2.4×10^{3} N m^{-2} *B*: 1.1×10^{4} N m^{-2} *C*: 2.1×10^{4} N m^{-2} *D*: 3.4×10^{4} N m^{-2}
E: 1.1×10^{6} N m^{-2} *F*: 2.4×10^{6} N m^{-2} *G*: 1.1×10^{7} N m^{-2} *H*: 2.1×10^{7} N m^{-2}
I: 2.4×10^{7} N m^{-2} *J*: 3.4×10^{7} N m^{-2}

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SECTION B

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

A total of 60 marks is available for this section.

B.1 A roller-coaster ride consists of carriages running on a track of two parallel rails. Each carriage with occupants has a total mass of 800 kg. The ride starts with the carriages being pulled up a slope, at 60° to the horizontal, 20 m high. At the top, the coaches are released essentially from rest and travel down a 15 m long slope at 45° to the horizontal. At the bottom of this slope the track immediately turns into a horizontal 180° bend of 15 m radius. Neglecting friction, calculate:

(i) the power required to haul one carriage up the initial slope at 2 m s^{-1}; [4]

(ii) the speed of the carriage at the entry of the bend; [5]

(iii) at what angle to the horizontal must the track in the bend be inclined so that the resultant force exerted by a carriage on the track is normal to the track; [6]

(iv) the resultant force exerted by one carriage on the track in the bend. [5]

B.2 When either a molecule or atom of a substance vaporises it takes an amount of energy, called latent heat, to change the phase. If we assume all of this energy is used to break a bond, we can use this to estimate the bond strengths in substances.

Using data selected from the table below, estimate the strengths, in eV, of the bonds broken on vaporisation and hence the predominant type of broken bond in the following substances. In each case, describe *briefly* the bonding mechanism.

(i) liquid water [7]

(ii) solid CO_2 [7]

(iii) liquid lead [6]

Data:

substance	*Latent heats* (kJ kg^{-1})			*relative atomic / molecular mass*
	fusion	*vaporisation*	*sublimation*	
water	340	2260	-	18
CO_2	-	-	390	44
lead		858	-	207

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B.3 (i) Why does a *cavity radiator* approximate to a *black body*? [3]

(ii) What is the effect of temperature upon the black body radiation spectrum? [4]

(iii) How is this effect used by the *pyrometer* to measure temperature? [2]

(iv) Calculate the power emitted from a circular hole of diameter 10 cm in a flat wall of a large furnace at a temperature of 3000 °C. [3]

(v) A worker, wearing protective clothing of emissivity 0.1, is standing 10 m from the hole and presents a surface area of 0.55 m^2 facing the hole. Estimate the radiatitive heat transfer to the worker assuming that the heat from the hole is radiated outwards equally in all directions from the hole. [5]

(vi) How might the assumption used in (v) be improved? [2]

B.4 (i) Explain the phenomenon of *surface tension* in terms of intermolecular forces. [4]

(ii) Show that the excess pressure, Δp, inside a gas bubble, radius r, immersed in a liquid due to surface tension, γ, is given by $\Delta p = 2\gamma / r$. [4]

(iii) A bubble 0.8 mm in diameter is at a depth of 0.35 m below the surface of a liquid, density 850 kg m^{-3}. The pressure above the surface of the liquid is 0.1 bar. Using a value of 55×10^{-3} N m^{-1} for surface tension, calculate the total pressure inside the bubble. [6]

(iv) The bubble rises to the surface. Estimate its diameter as it reaches the surface. [6]

B.5 (i) Define *Young's modulus*, the *shear modulus* and the *bulk modulus*. [3]

(ii) Using data selected from the table below, answer the following questions.

(a) A structural support element is made of steel and is designed so that the maximum shear displacement under the expected shear stress will be 10 mm. If the support element were replaced by an identical one made of aluminium, what would be the maximum shear displacement? [5]

(b) Estimate the percentage change in density of water due to pressure between the sea surface and the bottom of the Marianas Trench (Pacific Ocean) at a depth of 11,000 m. The nominal density of sea water may be taken as 1030 kg m^{-3}. [6]

(c) A lift is supported by a steel cable with a radius of 15 mm. Assume that the original unstrained length of the cable was exactly 45 m. If the load is 2000 kg, calculate the stress, strain, and the amount the cable stretches under load. [6]

Data:

Material	*Moduli* (N m^{-2}) *Young's*	*Shear*	*Bulk*
Aluminium	7×10^{10}	2.5×10^{10}	7.5×10^{10}
Steel	20×10^{10}	7.5×10^{10}	17×10^{10}
Nylon	0.36×10^{10}	0.12×10^{10}	0.59×10^{10}
Water	-	-	0.28×10^{10}

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SECTION C

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

C.1 Compare and contrast *gravitational* and *electrostatic* fields. [10]

C.2 Evidence for the atomic basis of matter. [10]

C.3 *Avogadro's hypothesis* and the significance of *Avogadro's constant*. [10]

C.4 The *gas thermometer* and its operation. [10]

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