Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2020 Preliminary Examination

PHYSICS **9749/03**
Higher 2

23 September 2020
Paper 3 Longer Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only and **circle the question number** on the cover page.

You are advised to spend one and half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section B.**

For Examiner's Use		
Section B (circle 1 question)	7	/ 20
	8	/ 20
Deduction		

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Section B

Answer **one** question from this Section in the spaces provided.

7 A metal cylinder that contains a fixed amount of a monatomic ideal gas is shown in Fig. 7.1. The cylinder is fitted with a piston that moves freely.

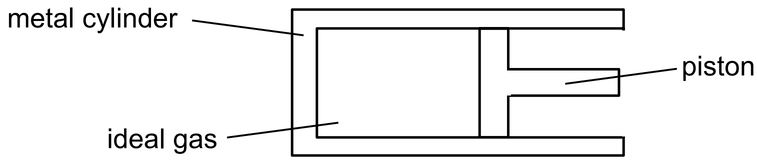

Fig. 7.1

Initially, the gas in the cylinder has a volume of 10.0 cm^3 and a temperature of 27.0 °C. Its initial pressure is the same as the atmospheric pressure of 1.00×10^5 Pa.

(a) **(i)** Explain what is meant by *an ideal gas*.

....

....

.... [1]

(ii) Calculate the number of moles n of gas in the cylinder.

n = ... mol [2]

(b) The gas in the cylinder undergoes a cycle of changes A→B→C→A, where

process A→B: the gas is expanded at a constant temperature until its pressure decreases to 0.10×10^5 Pa.
process B→C: the gas is heated at a constant volume until it reaches atmospheric pressure again.
process C→A: the gas is compressed at a constant pressure until it returns to its initial state.

Fig. 7.2 shows the *p*-*V* curves for two of the three processes.

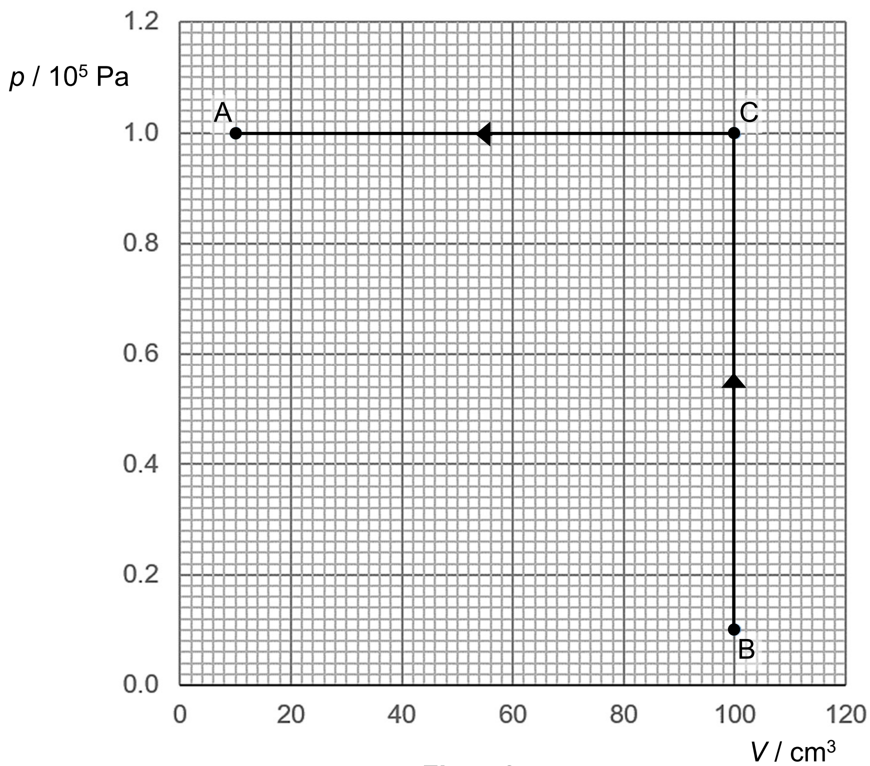

Fig. 7.2

(i) State *the first law of thermodynamics*, indicating the directions of all energy changes.

....

....

....

.... [1]

(ii) With reference to the process A→B,

1. state how this process can be achieved in practice,

....

.... [1]

2. complete Fig. 7.2 by drawing the *p*–*V* curve as accurately as possible. [2]

(iii) With reference to the process B→C, show that the heat supplied to the gas is 13.5 J.

[2]

(iv) With reference to the process C→A,

1. by considering the change in internal energy during one complete cycle, state and explain the change in internal energy of the gas during this process,

....

....

....

....

....

....

.... [3]

2. compare the rate at which heat is removed from the gas and the rate at which work is done on the gas.

....

....

.... [2]

(c) The product of the pressure p and the volume V of an ideal gas, as derived from the kinetic theory of gases, is given by the equation

$$pV = \frac{1}{3}Nm\left\langle c^2 \right\rangle .$$

(i) State the meaning of each of the symbols N, m and $\langle c^2 \rangle$.

N: ....

m: ....

$\langle c^2 \rangle$: .... [2]

(ii) State the assumption of the kinetic theory of gases that allows the potential energies associated with the gas particles to be neglected.

....

.... [1]

(iii) Using the given equation in **(c)**, derive an expression for the relationship between the average translational kinetic energy of a gas particle and the thermodynamic temperature T.

[1]

(iv) Calculate the root-mean-square speed of the gas particles at point B in Fig. 7.2. The mass of one mole of the gas is 14 g.

root-mean-square-speed = ... m s^{-1} [2]

8 **(a)** A rectangular block of length L and cross-sectional area S has an average density ρ. The block is immersed into a mixture of two liquids A and B of densities ρ_A and ρ_B respectively. The block floats vertically such that the midpoint C of the block is at the interface of the two liquids as shown in Fig. 8.1.

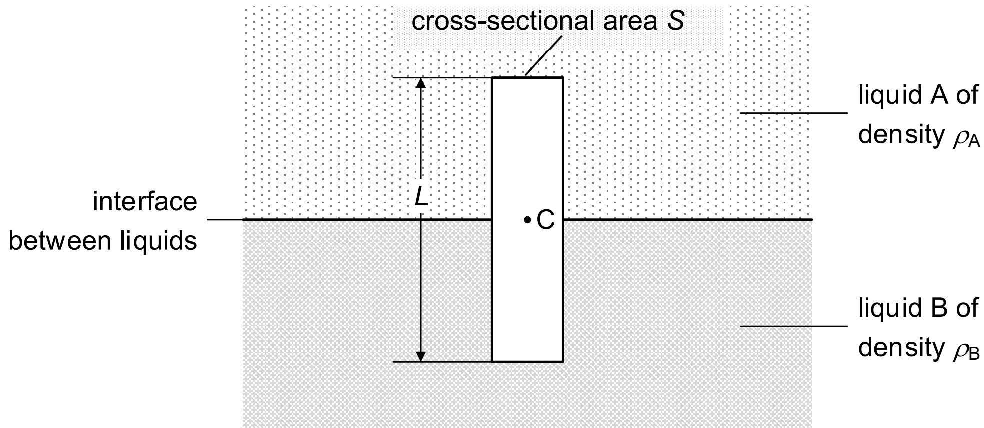

Fig. 8.1

(i) Show that the average density ρ of the block is

$$\rho = \tfrac{1}{2}\rho_A + \tfrac{1}{2}\rho_B .$$

[1]

(ii) The upthrust due to liquids A and B are U_A and U_B, respectively. State and explain whether U_A or U_B is larger.

....

....

.... [2]

(b) Due to some disturbance in the liquids, the block is now rotated slightly about its midpoint C as shown in Fig. 8.2. The block will return to its original vertical orientation.

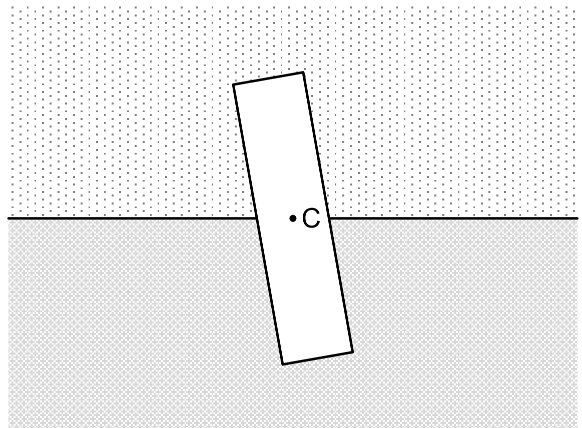

Fig. 8.2

(i) Indicate in Fig. 8.2, the upthrust U_A due to liquid A and U_B due to liquid B.

[2]

(ii) Hence by considering the moment of force about C, deduce whether the centre of gravity of the block is above or below C. Explain your reasoning.

....

....

....

....

.... [2]

(c) The block is now given a small displacement x upwards as shown in Fig. 8.2. The block will undergo simple harmonic motion when it is released.

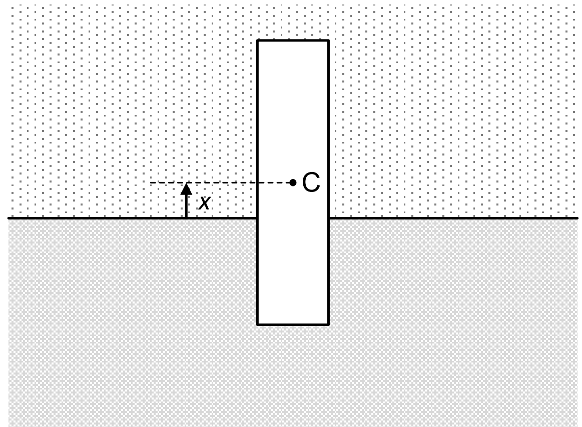

Fig. 8.2

(i) Deduce an expression, in terms of S, L, x, ρ_A, ρ_B and g, for

1. the upthrust in liquid A,

[1]

2. the upthrust in liquid B.

[1]

(ii) Starting with Newton's second law, show that the acceleration *a* of the block when it is released is given by

$$a = -\frac{2\left(\rho_{B} - \rho_{A}\right)g}{\left(\rho_{B} + \rho_{A}\right)L} \cdot x$$

Assume that all viscous forces are negligible and take upwards as positive.

[3]

(iii) Hence determine the period of oscillation, in terms of *g*, *L*, ρ_{A} and ρ_{B} .

[2]

(d) While the block is oscillating, it was found that the speed of the block when the midpoint C crosses the interface between the liquids is $0.40\ \text{m s}^{-1}$.
The length of the block is 0.25 m and the densities of liquids A and B are $860\ \text{kg m}^{-3}$ and $1300\ \text{kg m}^{-3}$, respectively.

(i) Determine the amplitude x_0 of the oscillations.

x_0 = ... m [2]

(ii) Calculate the period T of oscillations.

T = ... s [1]

(iii) Determine the time taken for the midpoint C to travel from $x = x_0$ to $x = \frac{1}{2}x_0$.

time taken = ... s [3]

End of Paper 3 Section B