UNIVERSITY OF SWAZILAND 65

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2011

TITLE OF PAPER	:	**THERMODYNAMICS**
COURSE NUMBER	:	**P242**
TIME ALLOWED	:	**THREE HOURS**
INSTRUCTIONS	:	**ANSWER ANY FOUR OUT OF FIVE QUESTIONS**
		EACH QUESTION CARRIES 25 MARKS
		MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN.

THIS PAPER HAS 7 PAGES, INCLUDING THIS PAGE.

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INFORMATION

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Universal gas constant	$= 8.31\ J\ mol^{-1}K^{-1}$
Specific heat of water	$= 4190\ J\ kg^{-1}K^{-1}$
Density of water	$= 10^3\ kgm^{-3}$
Specific heat of copper	$= 385\ J\ kg^{-1}K^{-1}$
Avogadro's number	$= 6.02 \times 10^{23}\ mol^{-1}$
Boltzmann constant	$= 1.38 \times 10^{-23}\ JK^{-1}$
Stefan-Boltzmann constant	$= 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$
1 atmosphere	$= 1.013 \times 10^5 Nm^{-2}$

QUESTION 1

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(a) What is meant by the term 'entropy'? (2 marks)

(b) State the second law of thermodynamics in terms of the concept of entropy . (2 marks)

(c) Suppose that a piece copper, 1kg in mass, and originally at 90°C is submerged in 0.1 m^3 of water. The initial temperature of the water is 5°C.

(i) the final temperature of the copper; (5 marks)

(ii) the change in entropy of the copper, water and the universe. (8 marks)

Assume that no heat is lost from the container.

(d) 1 kg of water at 50°C is mixed with 1 kg of water at 0°C. After equilibrium is reached, the mixture has a uniform temperature of 25°C.

What is the total change in entropy of the system? (8 marks)

QUESTION 2

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(a) Discuss the principle of operation of a commercial refrigerator with the aid of the p-V diagram shown in Fig. 2.1.

(10 marks)

(b) A refrigerator is kept in a room at 30°C. How much electrical energy would be required to remove 5×10^4 J of heat from the freezer of the refrigerator operating at its maximum coefficient of performance? Assume that the temperature of the freezer is -5°C.

(5 marks)

(c) Figure 2.2 shows the cycle of an ideal refrigerator. With reference to this diagram, derive an expression to show that the coefficient of performance of a Carnot refrigerator is:

$$\omega = \frac{T_C}{T_H - T_C}$$

(10 marks)

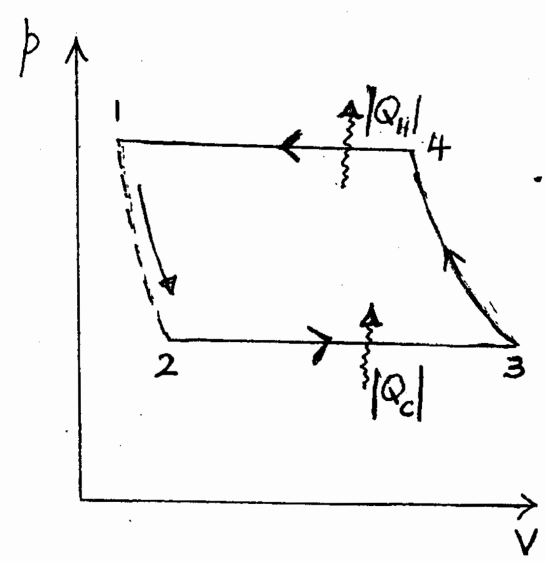

Figure 2.1

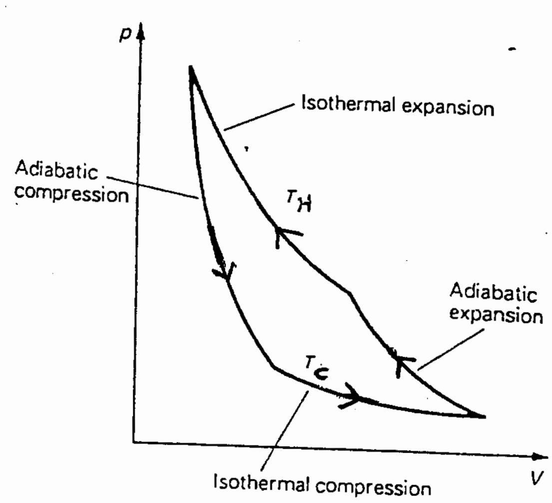

Figure 2.2

QUESTION 3

(a) Give the meaning of the term 'emissivity'. (2 marks)

(b) Consider the total surface area of the human body to be 2 m^2. How much heat would be radiated from the body in one hour if the surface temperature of the body is 40°C and that of the environment is 10°C? Take the emissivity of the skin to be 0.8.
(4 marks)

(c) Two rectangular bars of metals, Metal X and Metal Y, are in contact with each other, as shown in Figure 3.1. The metals are of the same length and the ends which are in contact have the same cross-sectional area. Assume that the thermal conductivity of Metal X is 200 $Wm^{-1}K^{-1}$ and that of Metal Y is 500 $Wm^{-1}K^{-1}$.

What would be the temperature at the interface or junction of the metals at steady state?
(5 marks)

(d) Show that the rate of heat flow through any number of slabs, n which are connected in series and have the same cross-sectional area A, but different thermal conductivities k_n and thicknesses L_n, is given by

$$\frac{dQ}{dt} = \frac{A(T_1 - T_n)}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots\ldots + \frac{L_n}{k_n}}$$

where T_1 and T_n are the temperatures at the extreme ends of the n slabs ($T_1 > T_n$).

Note: A is the cross-sectional area perpendicular to the direction of flow of the heat.
(14 marks)

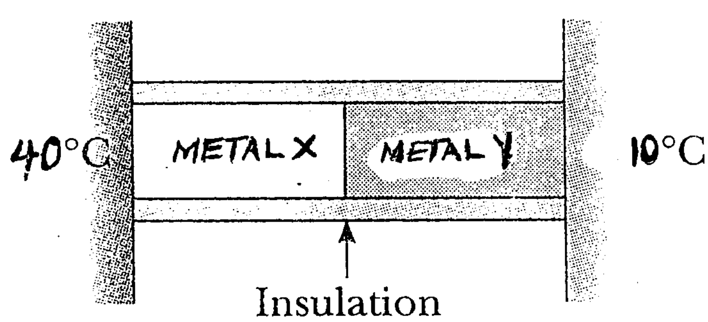

Fig. 3.1

QUESTION 4

(a) Find the mean free path of a nitrogen molecule at 30°C and at normal atmospheric pressure. The diameter of a nitrogen molecule is 3.15×10^{-10} m.

(4 marks)

(a) With the aid of a suitable diagram, derive an expression which shows the relationship between the density of molecules, n, the molecular diameter, d, and the average distance, l a molecule travels between collisions with other molecules of a gas. Use appropriate diagram(s) for illustration. (12 marks)

(c) Fig. 4.1 represents n mol of an ideal monatomic gas being taken through a reversible cycle consisting of two isothermal processes at temperatures $4T_o$ and T_o and two isovolumetric processes.

(i) Find an expression for the work done during each step in terms of the Universal gas constant, R, n, and T_o;

(6 marks)

(ii) Find the net work done by the gas. (3 marks)

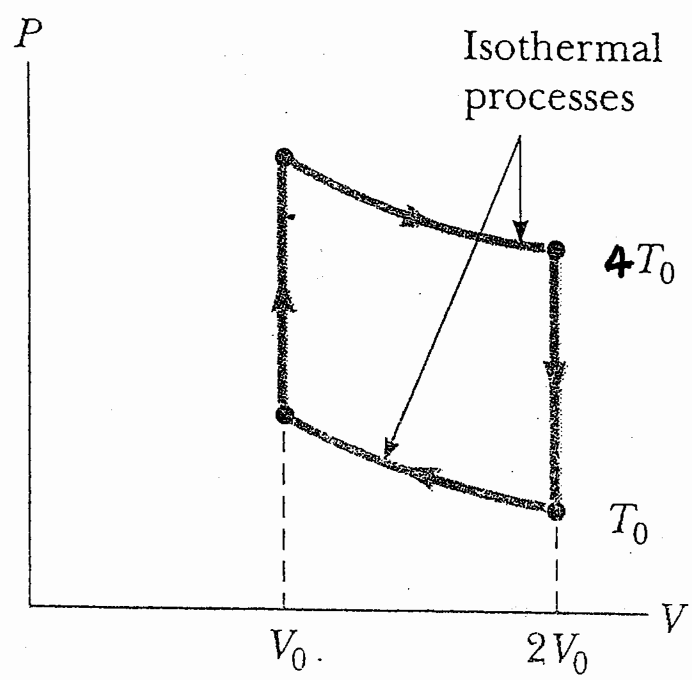

Fig. 4.1

QUESTION 5

(a) With reference to the Otto cycle shown in Fig. 5.1, explain the principle of operation of an internal combustion engine. Use a schematic diagram of this type of engine to illustrate your point. (12 marks)

(b) Show that the efficiency of an engine operating in the idealised Diesel cycle illustrated in Figure 5.2 is

$$e = 1 - \frac{1}{\gamma}\left(\frac{T_D - T_A}{T_C - T_B}\right)$$

(13 marks)

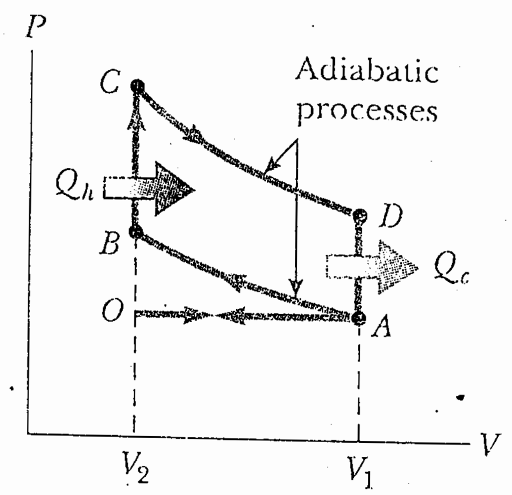

Fig. 5.1

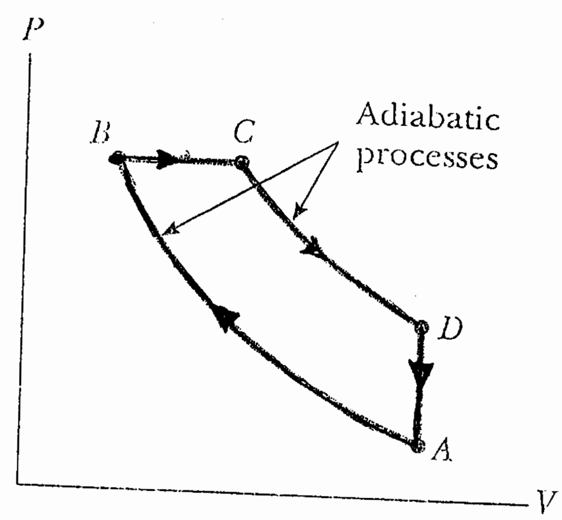

Fig. 5.2