CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS

FIRST YEAR EXAMINATIONS FOR THE AWARD OF EDUCATION SCIENCE AND BACHELOR OF SCIENCE

PHYS 161: HEAT AND THERMODYNAMICS

STREAMS: BED (SCI) and BSC **TIME: 2 HOURS**

DAY/DATE: FRIDAY 14/12/2018 **8.30 A.M - 10.30 A.M.**

INSTRUCTIONS:

- Answer Question One in Section A and any other Two Questions in Section B
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely

Useful constants

i. **Universal gas constant** $R = 8.31\, J\, K^{-1} mol^{-1}$

ii. **Specific heat capacity of copper** ¿ $385\, J\, Kg^{-1} °C^{-1}$

iii. **Specific heat capacity of water** $C_w = 4.186\, J\, Kg^{-1} °C^{-1}$

iv. **Specific heat of Aluminum** ¿ $900\, J\, Kg^{-1} °C^{-1}$

SECTION A

QUESTION ONE: (30 MARKS)

a. Define the following terms as used in thermodynamics

i. Heat engine [1 Mark]

ii. Reservoir [1 Mark]

iii. An isothermal process [1 Mark]

iv. An adiabatic process [1 Mark]

b. The length of a mercury column in a glass tube of a uniform bore is 30 mm at freezing point of water and 280 mm at the boiling point of water. Calculate the temperature in degree Celsius recorded by the thermometer when the length of the column is 180 mm. [3 Marks]

c.

i. State the first law of thermodynamics [2 Marks]

ii. If all the heat Q absorbed by an thermodynamic system is converted into work, what can you say about the internal energy U of the system? [3 marks]

iii. If 300 kJ if work is done on the system and 450 kJ of heat extracted from the system , deduce the value of W(work), Q(quantity of heat) and change in internal energy ΔU

[3 Marks]

d. An 0.07 kg copper ball is taken from a furnace and quickly dropped into a 0.25 kg aluminum can containing 0.20 kg of water at $15\,℃$, the temperature of the water rises to $28\,℃$, what was the original temperature of the furnace? [4 Marks]

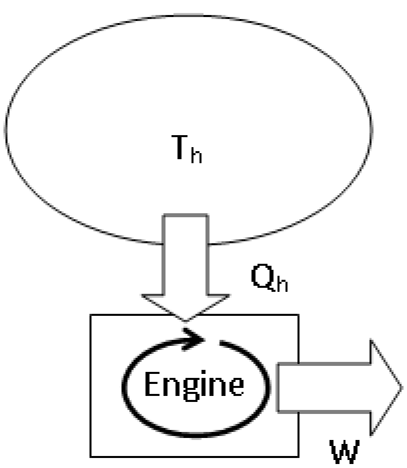
e. Convert the following temperature units into the units indicated in brackets

i. 100 ℃ ¿) [1 Mark]

ii. $50\,℉(K)$ [1 Mark]

iii. $5\,℉(℃)$ [1 Mark]

f. In one complete cycle, a heat engine extracts heat Q_h from a thermal reservoir, does work W and does **not** eject any heat into the environment. This heat engine is impossible. Which law of thermodynamics does it violate? Discuss your answer. [3 Marks]



g. An ideal Carnot engine is being used as refrigerator to cool a room where some students are working with computers. The students plus computers are generating 10, 000 watts of heat (10,000 joules/second). The Carnot refrigerator removes heat from the room, where the temperature is$20\,℃$, and delivers it outside the building, where the temperature is $30\,℃$. How much power must be put into the Carnot refrigerator to maintain the room at $20\,℃$.

[5 Marks]

QUESTION TWO:[20 MARKS]

a. Define the term '**heat of transformation**' [2 Marks]

b. 100g of ice is taken from a deep freezer at $-17\,℃$ and added to a cup holding 400g of water at $20\,℃$

i. How much heat is needed to raise the temperature of the ice from $-17\,℃$ to $0\,℃$ [2 Marks]

ii. How much heat is required to decrease the temperature of the water from $20\,℃$ to $0\,℃$. [2 Marks]

iii. How much heat is required to melt all the ice to water? [3 Marks]

iv. From your answers to (i), (ii) and (iii) do you think the heat lost by the water from $20\,℃$ and $0\,℃$ is enough to melt all the ice? [2 Marks]

v. Calculate the amount of ice which melts ad indicate the final contents of the cup and their masses. (assume the specific heat of the cup is negligible). [7 Marks]

c. What are three conditions necessary for heat to be transported in fluids by convection? [2 Marks]

QUESTION THREE: [20 MARKS]

The Carnot cycle comprises sequentially (i) a reversible isothermal expansion of a working substance in contact with a high-temperature reservoir at temperature, T_1,(ii) a reversible adiabatic expansion to a final state having a temperature T_2 equal to that of a low-temperature reservoir (iii) an isothermal reversible compression in thermal contact with the low-temperature reservoir, (iv) a reversible adiabatic compression returning the working substance to its initial state.

i. Sketch the above cycle on a PV indicator diagram, labelling each step (i)-(iv) [2 Marks]

ii. What is the direction of heat transfer for each step of the cycle? [2 Marks]

iii. Starting from the Kelvin-Planck or Clausius statement of the second law of thermodynamics, explain why no heat engine working in a closed cycle between two fixed temperature reservoirs can be more efficient than a Carnot engine (Carnot's theorem) [6 Marks]

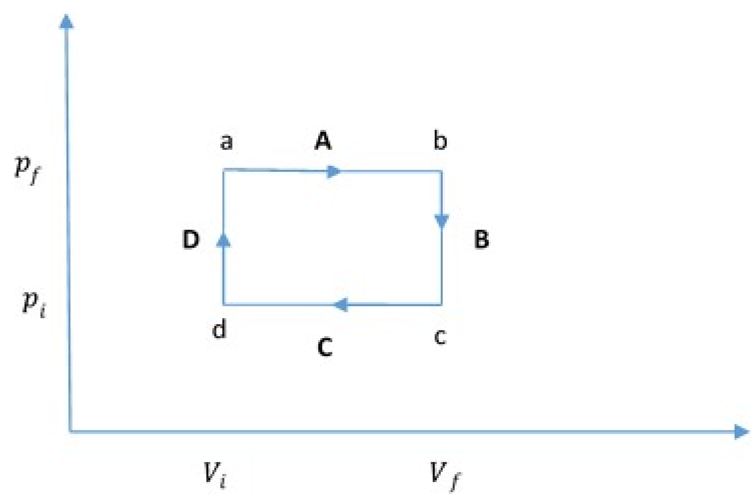
iv. By considering the working substance in a Carnot cycle to be an ideal gas show that the heat removed from the hot reservoir per cycle Q_1 and heat transferred to the cold reservoir per cycle Q_2 are related by

$$\frac{Q_1}{Q_2}=\frac{T_1}{T_2}$$

You may use without proof that $T V^{(\gamma-1)}=constant$ for reversible adiabatic changes of state of an ideal gas. [10 Marks]

QUESTION FOUR: [20 MARKS]

a. A gas undergoes a series of pressure and volume changes as shown below,



Where P_f and P_i is $2\,x\,10^5$ and 10^5 Pa respectively while V_i and V_f is $1\,m^3$ and $4\,m^3$ respectively.

i. Identify the thermodynamic processes labeled A,B,C and D [4 Marks]

ii. How much work is done by the gas along the path abc [3 Marks]

iii. How much work is done along the path cda? [3 Marks]

iv. How much heat enters the gas during the full cycle? [2 Marks]

b. Paraffin and water are both liquids. Its requires different amount of heat to rise the temperature of 1 kg of paraffin from $10\,℃$ to $20\,℃$ as required by 1 kg of water to raise the same temperature change. Explain? [2 Marks]

c. At what temperature is the Fahrenheit scale reading equal to

i. The reading on the Celsius scale [3 Marks]

ii. Half that of the Celsius scale [2 Marks]

QUESTION FIVE: (20 MARKS]

a. One mole of monoatomic ideal gas is brought through a cycle A to B to C to D to A as shown in the diagram. All processes are performed slowly. Respond to the following in terms of p_0, V_0, and R.

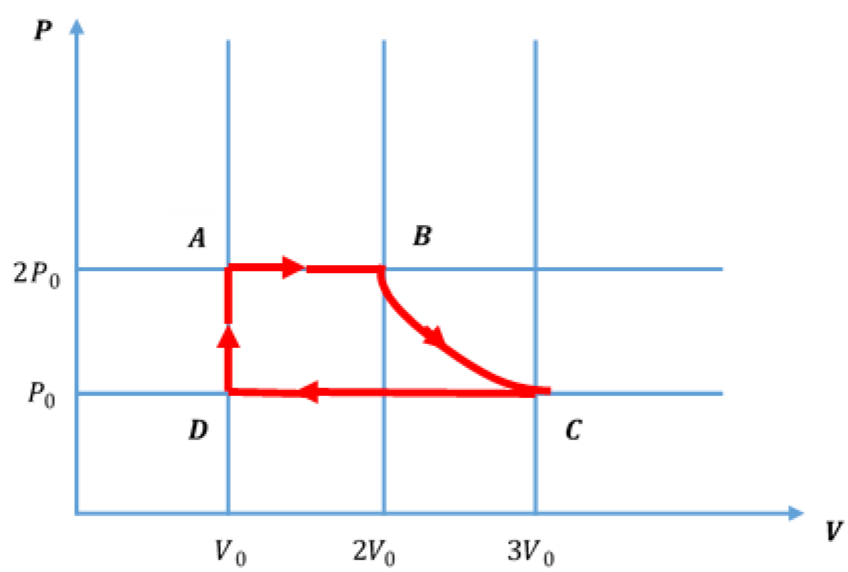
i. Find the temperature at each vertex [2 Marks]

ii. Find the heat added to the gas for the process A to B [2 Marks]

iii. Find the work done on the gas for the process C to D [2 Marks]

iv. Find the heat added to the gas for the process D to A [2 Marks]

v. Find the change in internal energy for the process B to C [2 Marks]



b. 25 g of $-10\,℃$ ice is to be converted into 150 $℃$ steam (use: heat of fusion of water = 334 J/g, latent heat of vaporization of water = 2257 J/g, specific heat capacity of ice = 2.09 J/g/$℃$, specific heat capacity of water = 4.2 J/g/$℃$, specific heat capacity of steam =2.09 J/g/$℃$). Determine the heat required to convert the 25 g of $-10\,℃$ ice into 150$℃$ steam in joules

[5 Marks]

c. 4.0 moles of argon gas is contained in a cylinder at 300K. How much heat must be added to the gas to raise its temperature to 600 K at:

i. Constant volume [3 Marks]

ii. Constant pressure [2 Marks]

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