RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

BSc in Applied Sciences
Second Year - Semester I Examination – June/July 2022

PHY 2101 – Thermodynamics and Radiation

Time: One (01) and Half (1/2) hours

Answer ALL Questions

Provide detailed solutions to ensure total points.

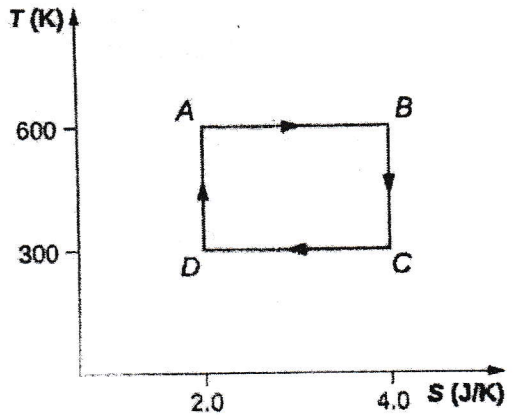
Common Constants: Specific Heat Capacity of Water = 4186 J/Kg K, Universal Gas Constant = 8.3 J/K mol, Avogadro's Constant = 6.02×10^{23} /mol, Boltzmann Constant = 1.38×10^{-23} J/K, Stephen-Boltzmann Constant = 5.67×10^{-8} W/m^2 K^4, Wein's Law Constant = 2.898×10^{-3} m K.

1.
   a) State the assumptions that allow to apply Newton's laws to a system of gas particles **(3 marks)**
   b) State the standard rule that establishes a relationship between the particle properties of a gas system and the temperature. Interpret all the terms involved in this relationship. **(2 marks)**
   c) Demonstrate how the application of Newton's laws lead to the derivation of the ideal gas equation **(7 marks)**
   d) State Boyle's law. Use the model established with the assumptions you mentioned in part a) to interpret the phenomenon given by the Boyle's law for a monoatomic gas system **(3 marks)**

2. A steel rod and an aluminum rod, each of diameter 1 cm and length 25 cm, are welded to form a composite rod. The free end of the steel rod is placed in a tank of boiling water while the free end of the aluminum rod is placed in a tank of water at 20 ^{0}C. The rods are insulated
   a) What is θ_{joint}, the temperature of the composite rod at the welded joint? **(7 marks)**
   b) What is Q, the rate of heat flow across the rod? **(3 marks)**

   Thermal conductivity of aluminum and steel respectively are 237 W/m ^{0}C and 45 W/m ^{0}C. Show the process of your solution in terms of the variables you define for the situation.

3. The image below shows the TS diagram of a thermodynamic cyclic process followed by 1 mol of an ideal monoatomic gas. The system started with an initial volume of 3 liters. Assume all the processes are quasistatic and reversible. The universal gas constant R is 8.31 J/mol K.



a) What is the adiabatic constant γ for this system of gas? **(2 marks)**
b) For each node (A, B, C, D) of the cycle, evaluate the pressure, volume, and the temperature coordinates of the system. **(8 marks)**
c) Produce the p-V diagram for this thermodynamic cycle. Mark appropriate values on the axes. **(4 marks)**
d) For each step of the cycle, evaluate ΔU, the change in the internal energy, Q, the amount of heat transfer, and W, the work done by the system. **(12 marks)**
e) If this cycle is an idealization of a heat engine, produce a schematic diagram of the heat-engine in the standard notation. List the appropriate values of the variables indicated in the diagram. **(5 marks)**
f) What is the thermodynamic efficiency of the heat engine? **(1 mark)**
g) What is the Carnot efficiency of the cycle? **(1 mark)**
h) Compare the two figures obtained in e) and f) and comment about the reason for their similarity or dissimilarity **(2 marks)**

4. A refrigerator designed to maintain its interior at -30 ^{0}C temperature, transfers 4186 kJ of energy from its interior per each cycle of the heat engine. The refrigerator is placed in a hall that maintains a 45 ^{0}C exterior temperature. This refrigerator has been perfected to achieve the maximum possible efficiency.
a) Provide a schematic diagram for this refrigerator in the standard notation. List the appropriate values of the variables indicated in the diagram. **(4 marks)**
b) What is the value of the coefficient of performance of this refrigerator? **(1 mark)**

5. A certain warm object indicates maximum spectral radiance at 1 μm wavelength. The radiant intensity doubled when the temperature of the object is increased.
a) What is the new temperature of the object? **(3 marks)**
b) At what wavelength will the object have the maximum spectral radiance at the new temperature? **(2 marks)**

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