UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: March 2026

Module Number: ME1202 **Module Name: Fundamentals of Thermodynamics (C-23)**

[Three Hours]

[Answer all questions; each question carries 12 marks]

Note: Provide neat sketches and state any reasonable assumptions made; Symbols have their usual meaning; the steam table is provided.

Q1 a) Using a creative approach, draw a poster that represents the role of thermodynamics in day-to-day life.

[3.0 Marks]

b) Draw pressure-specific volume (p-v) diagram for the isochoric, isobaric, isothermal, and adiabatic processes.

[4.0 Marks]

c) Distinguish between intensive and extensive properties, giving two examples of each.

[2.0 Marks]

d) Briefly explain three modes of heat transfer and provide two practical examples for each.

[3.0 Marks]

Q2 a) A gas contained in a piston–cylinder device expands following the relation $pV^n =$ constant. Given that the initial pressure is 3 bar, the initial volume is 0.1 m^3, and the final volume is 0.2 m^3. Calculate the work done during the process in kJ for: $n = 1.5$, $n = 1.0$, and $n = 0$.

[3.0 Marks]

b) Briefly describe the difference between compressible and incompressible fluids.

[1.0 Mark]

c) A closed system containing 0.4 kg of gas in a piston–cylinder arrangement expands following a polytropic relation with an exponent of 1.5. Initially, the gas is at a pressure of 4 bar and occupies a volume of 0.2 m^3, and it expands to a final volume of 0.3 m^3. During this process, the specific internal energy decreases by 55 kJ/kg. Assuming negligible kinetic and potential energy effects, determine the amount of heat exchanged during the process in kJ.

[3.0 Marks]

d) A 0.5 kg of air is enclosed within a frictionless vertical cylinder equipped with a freely moving piston. The piston having the surface area of 200 x 10^{-3} m^2 is subjected to atmospheric pressure of 1 x 10^5 Pa as well as its own weight of 100 kg. An electric heating element placed inside the cylinder supplies energy to the air, causing it to expand at constant pressure. During this process, the air volume increases by 0.1 m^3, and its specific internal energy rises by 100 kJ/kg accordingly. The system is well insulated, and both the piston and air remain stationary at the beginning and end of the process. Take the local acceleration of gravity as 9.81 m/s^2. Determine the heat transfer from the resistor to the air, in kJ for a system consisting of:

i) the air alone

[2.5 Marks]

ii) the air and the piston

[2.5 Marks]

Q3 a) A closed, rigid container is filled with water in a two-phase (liquid–vapor) equilibrium state. The system is then heated continuously until all the liquid completely evaporates and reaches saturation conditions. Throughout this transformation, how does the pressure inside the container behave?

[2.0 Marks]

b) Water flows into a top of an open barrel at a constant mass flow rate of 30 lb/s. Water exits through a pipe near the base with a mass flow rate proportional to the height of liquid inside: $\dot{m}_e = 9\ L$, where L is the instantaneous liquid height, in ft. The area of the base is 3 ft^2, and the density of water is 62.4 lb/ft^3. If the barrel is initially empty, plot the variation of liquid height with time.

[5.0 Marks]

c) During an experiment using a Marcet Boiler, it is observed that even a small rise in temperature leads to a sharp increase in the equilibrium pressure of water at saturation conditions. What fundamental physical phenomenon is responsible for this strong dependence of pressure on temperature?

[3.0 Marks]

d) On a temperature–specific volume (T–v) diagram of a pure substance, there exists a unique state where the distinction between liquid and vapor phases completely disappears. Identify this state and explain its physical significance. Support your explanation with a suitable sketch.

[2.0 Marks]

Q4 a) Draw the p-v diagram of the Carnot power cycle and briefly explain each process.

[3.0 Marks]

b) Consider a heat engine that functions between two thermal energy sources at significantly different temperatures. It absorbs heat from a high-temperature reservoir at 2000 K and discharges heat to a low-temperature reservoir maintained at 400 K. Based on different performance data provided below, assess whether its operation complies with the principles of thermodynamics. Specifically, identify whether each case represents an ideal process, a real process, or a physically impossible one.

i) 1000 kJ of heat energy is received and operates with an efficiency of 60%.

[1.0 Mark]

ii) 1000 kJ of heat energy is received and produces 850 kJ of net work output.

[1.0 Mark]

iii) 1000 kJ of heat energy is received and rejects 200 kJ of heat to the low-temperature reservoir.

[1.0 Mark]

c) A residential space is kept at a comfortable indoor temperature (20 °C) using a heat pump system. The device consumes a minimum input power of 3 kW while extracting heat from the outdoor environment (3 °C), where the temperature is significantly lower. Based on these conditions, determine the rate at which thermal energy must be supplied to offset heat loss from the house, and express the total heat loss over a one-minute interval.

[2.0 Marks]

d) A refrigeration system extracts heat from a low-temperature region and rejects it to a warmer environment. The system operates between temperature limits of −5 °C and 30 °C. Although the ideal performance is known, the actual system performs below this limit. Given that the real coefficient of performance is 3.0 and the theoretical maximum is 5.0, evaluate how efficiently the system utilizes the available thermodynamic potential.

[4.0 Marks]

Q5 a) Name **three** devices that operate based on the refrigeration cycle.

[1.5 Marks]

b) List **three** examples of systems that function using a power cycle.

[1.5 Marks]

c) State **two** reasons why the reversed Carnot cycle is considered impractical for use in refrigeration applications.

[1.0 Mark]

d) A Steam power plant operates on the Carnot cycle, working between the pressure limits of 7 MPa and 7 kPa.

i) Illustrate the system using a schematic representation.

[1.0 Mark]

ii) Draw the relevant *T-S* diagram.

[1.0 Mark]

iii) Determine the thermal efficiency, turbine work, and compressor work per kilogram of steam.

[6.0 Marks]