CONFIDENTIAL

UNIVERSITI KUALA LUMPUR
Malaysian Institute of Marine Engineering Technology

FINAL EXAMINATION
JULY 2025 SEMESTER SESSION

SUBJECT CODE	:	**LMD14203**
SUBJECT TITLE	:	**APPLIED THERMODYNAMICS**
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	:	**DIPLOMA OF ENGINEERING TECHNOLOGY IN MARINE ENGINEERING**
TIME / DURATION	:	**09.00 AM - 12.00 PM (3 HOURS)**
DATE	:	**17 DECEMBER 2025**

INSTRUCTIONS TO CANDIDATES

1. Please read **CAREFULLY** the instructions given in the question paper.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of **TWO (2)** sections; Section A and Section B.
4. Answer **ALL** question in Section A, and **TWO (2)** questions ONLY in Section B.
5. Please write your answers on this answer booklet provided.
6. Answer **ALL** questions in English language **ONLY**.
7. Answer should be written in blue of black ink except for sketching, graphic and illustration.
8. Steam Table of Properties and Formula has been appended for your reference.

THERE ARE 6 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

SECTION A (Total: 60 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

With reference to energy transfer in the marine heat engine and ideal gases cycle:

(a) Define the following:

i. Internal combustion

(2 marks)

ii. Bore

(1 mark)

iii. Compression ratio

(2 marks)

(b) Describe the working principle of a simple heat engine using a temperature reservoir model.

(5 marks)

(c) Identify FOUR (4) main thermodynamics processes involved in the Diesel cycle.

(5 marks)

(d) Reciprocating engines are classified as spark ignition (SI) engines and compression ignition (CI) engines. Sketch and label the expansion stroke for SI engine.

(5 marks)

Question 2

With reference to energy transfer in the vapor power cycle of marine steam turbine engine:

(a) Illustrate the Temperature-entropy (T-s) diagram for simple ideal Rankine cycle.

(5 marks)

(b) A simple ideal Rankine cycle was modified by superheating the steam to a high temperature at a turbine. State the effect (*decrease, increase or remain constant*) after modification as shown in Table 1:

Table 1: Effect of modification on energy transfer

Energy transfer	Effects
Pump work input, $w_{pump,in}$	(i)
Heat transferred, q_{in}	(ii)
Work output, w_{out}	(iii)
Cycle efficiency, η_{th}	(iv)
Moisture content	(v)

(5 marks)

(c) Steam power plant operates on simple ideal Rankine cycle with water as the working fluid. Solve energy transfer in Table 2 below by showing all the calculations involved.

Table 2: Thermodynamic properties of simple ideal Rankine cycle

State	Pressure (kPa)	Energy transfer (kJ/kg)	Enthalpy, h (kJ/kg)
1	12.352	$w_{pump,in}$ (i)	209.34
2	3500	q_{in} (ii)	212.87
3	3500	$w_{turb,out}$ (iii)	3104.9
4	12.352	q_{out} (iv)	2131.61

(10 marks)

Question 3

With reference to energy transfer in the marine refrigeration cycle:

(a) List THREE (3) types of refrigerants commonly used in the marine refrigeration systems.

(3 marks)

(b) Name TWO (2) parameters to be considered when selecting the right refrigerant for the design of a vapor-compression refrigeration system.

(2 marks)

(c) Describe any TWO (2) components involved in the ideal vapor compression refrigeration cycle.

(5 marks)

(c) A refrigerator with refrigerant-134a (R-134a) as the working fluid operates on an ideal vapor-compression cycle. Complete Table 3 by showing all calculations involved.

Table 3: Properties of R-134a

State	Pressure, P (kPa)	Enthalpy, h (kJ/kg)	Entropy, s (kJ/kg. K)	Phase
1	60	**(i)**	**(ii)**	**(iii)**
2	1200	**290.66**	**(iv)**	**(v)**
3	1200	**(vi)**	-	**(vii)**
4	**(viii)**	**(ix)**	-	**(x)**

(10 marks)

SECTION B (Total: 40 marks)

INSTRUCTION: Answer only TWO (2) questions.
Please use the answer booklet provided.

Question 4

With reference to the problem solving of marine heat engine cycle and ideal gases cycle:

An internal combustion engine operates on an ideal Otto cycle using air as the working fluid. The air intake is at 150 kPa (P_1) and 300°K (T_1) with a compression ratio of 9.5 (r) and receives 1500 $\frac{kJ}{kg}$ (q_{in}) of heat during the constant volume heat addition process. The volume of the chamber is 280 cm³ (V_1) prior to the compression stroke. Utilizing the cold-air standard assumptions:

(a) Estimate the mass of air intake, (m) in kg unit.

(5 marks)

(b) Calculate the maximum temperature, (T_3)

(6 marks)

(c) Determine the network output $(w_{net,out})$ in kJ/kg unit.

(9 marks)

Question 5

With reference to the problem solving of Rankine cycle for marine steam turbine engines:

A simple ideal Rankine cycle uses water as the working fluid. The boiler and condenser operate at 6 MPa and 50 kPa, respectively as shown in Figure 1.

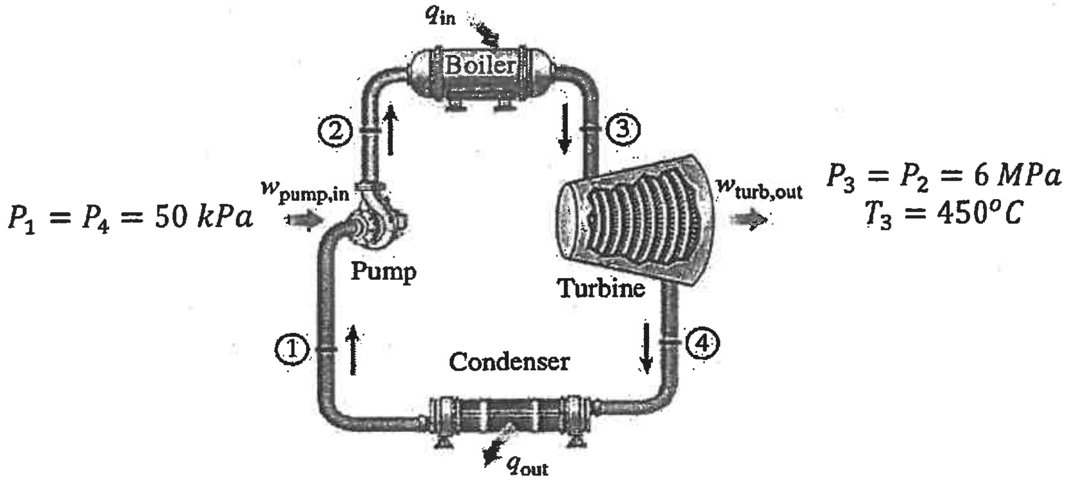

Figure 1: Simple ideal Rankine cycle

i. Determine the heat added (q_{in}), to the cycle in kJ/kg unit.

(10 marks)

ii. Determine the heat rejected (q_{out}) , from the cycle in kJ/kg unit.

(5 marks)

iii. Determine the thermal efficiency (η_{th}), of this cycle.

(5 marks)

Question 6

With reference to the problem solving of marine refrigeration cycle:

A heat pump used to heat a house operates on an ideal vapor-compression refrigeration cycle with refrigerant-134a (R-134a) as the working fluid as shown in Figure 2. The condenser and evaporator pressures are 900 kPa ($P_3 = P_2$), and 200 kPa ($P_4 = P_1$), respectively. If the mass flow rate of the refrigerant is 0.32 kg/s ($\dot{m}$):

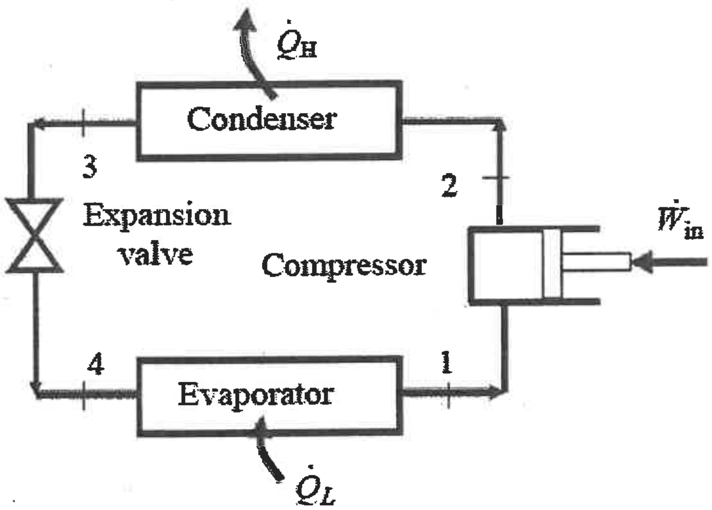

Figure 2: Schematic diagram for ideal vapor compression refrigeration cycle

(a) Calculate the rate of heat supply,($\dot{Q}_L$) to the evaporator in kW unit.

(6 marks)

(b) Calculate the rate of heat supply, ($\dot{Q}_H$) to the house in kW unit.

(9 marks)

(c) Determine the coefficient of performance, (COP_{HP}) of the heat pump.

(5 marks)

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULAE

First Law of Thermodynamics
Quality, $x = \frac{m_g}{m_{total}} = \frac{v - v_f}{v_{fg}}$ $v = v_f + (x)v_{fg}$; $u = u_f + (x)u_{fg}$; $h = h_f + (x)h_{fg}$
Mass total, $m_{total} = m_f + m_g$
Ideal gas equation $PV = mRT$; $Pv = RT$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
General Energy Balance $E_{in} - E_{out} = \Delta E_{system}$
$\Delta E_{system} = \Delta U + \Delta KE + \Delta PE$
Energy Balance for a closed system, constant volume process $Q\text{-}W = \Delta U + \Delta KE + \Delta PE$ $Ideal\ gas:\ Q - W = mc_v(T_2 - T_1)$
Energy Balance for a constant pressure process $W_b + \Delta U = \Delta H$ $Q\text{-}W_{other} = \Delta H + \Delta KE + \Delta PE$ $Ideal\ gas:\ Q - W = mc_p(T_2 - T_1)$
Conservation of mass and energy equations for steady-flow process $\sum \dot{m}_{in} = \sum \dot{m}_{out}$ $\dot{Q}\text{-}\dot{W} = \sum_{out}\dot{m}[h + V^2/2 + gz] - \sum_{in}\dot{m}[h + V^2/2 + gz]$ $\dot{Q}_{in} + \dot{W}_{in} + \dot{m}\left(h_1 + \frac{V_1^2}{2} + gz_1\right) = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}\left(h_2 + \frac{V_2^2}{2} + gz_2\right)$
Boundary work (P = constant), $W_b = mP_0(v_2 - v_1)$
Boundary work (T = constant), $W_b = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$
Polytropic Process, $PV^n = C$ Boundary work (Polytropic), $W_b = \frac{P_1V_1 - P_2V_2}{1-n}$

Mass flow rate
$\dot{m} = \rho AV = \rho\dot{V} = \frac{\dot{V}}{v}$
Volume flow rate
$\dot{V} = VA = \frac{\dot{m}}{\rho}$
Thermal efficiency of a Heat Engine
$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$
Coefficient of Performance of a Refrigerator and Heat Pump
$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L}$ $COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L}$
Carnot Heat Engine
$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$
Carnot Refrigerators and Heat Pumps
$COP_{R,carnot} = \frac{1}{\frac{T_H}{T_L} - 1}$
$COP_{HP,carnot} = \frac{1}{1 - \frac{T_L}{T_H}}$
Isentropic Process (Cold-air standard)
$s_2 = s_1$
$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k-1}$
$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$
$\left(\frac{P_2}{P_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k}$

$\left(\frac{P_2}{P_1}\right)_{s=const.} = \frac{P_{r2}}{P_{r1}}$
$\left(\frac{v_2}{v_1}\right)_{s=const.} = \frac{v_{r2}}{v_{r1}}$
Power Cycles
Compression ratio, $r = \frac{V_{max}}{V_{min}} = \frac{V_{BDC}}{V_{TDC}} = \frac{V_1}{V_2} = \frac{v_1}{v_2} = \frac{v_{r1}}{v_{r2}}$
$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{w_{net}}{v_{max} - v_{min}} = \frac{w_{net}}{v\left(1 - \frac{1}{r}\right)}$
Otto Cycle
$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_{exit} - h_{inlet}$
$q_{in} = u_3 - u_2 = c_v(T_3 - T_2)$
$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$
Thermal efficiency, $\eta_{th,Otto} = \frac{W_{net}}{Q_{in}} = 1 - \frac{q_{out}}{q_{in}}$
$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}}$ = cold-air standard
Diesel Cycle
$q_{in} = w_{b,out} + (u_3 - u_2) = P_2(v_3 - v_2) + (u_3 - u_2) = h_3 - h_2 = c_p(T_3 - T_2)$
$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$
Cutoff ratio, $r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$
$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]$ = cold-air standard
Joule-Brayton Cycle
$q_{in} = w_{b,out} + (u_3 - u_2) = P_2(v_3 - v_2) + (u_3 - u_2) = h_3 - h_2 = c_p(T_3 - T_2)$
$q_{out} = h_4 - h_1 = c_p(T_4 - T_1)$
Pressure ratio, $r_p = \frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$

$$\eta_{th,Brayton} = 1 - \frac{1}{r_p^{\frac{k-1}{k}}}$$ = cold-air standard

Rankine Cycle

$$w_{pump,in} = h_2 - h_1 = v_1(P_2 - P_1)$$

$$q_{in} = h_3 - h_2$$

$$w_{turb,out} = h_3 - h_4$$

$$q_{out} = h_4 - h_1$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

$$w_{net} = q_{in} - q_{out} = w_{turb,in} - w_{pump,in}$$

Reheat Rankine Cycle

Total heat input, $q_{in} = q_{primary} + q_{reheat} = (h_3 - h_2) + (h_5 - h_4)$

$$q_{out} = h_6 - h_1$$

$$w_{turb,out} = w_{turb,I} + w_{turb,II} = (h_3 - h_4) + (h_5 - h_6)$$

Refrigeration Cycle

$$W_{net,out} = Q_H - Q_L$$

$$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

$$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L} = \frac{h_2 - h_3}{h_2 - h_1}$$

$$COP_{HP} = COP_R + 1$$

Combustion

$$Air\ Fuel\ Ratio\ (AF) = \frac{m_{air}}{m_{fuel}} = \frac{(NM)_{air}}{(NM)_C + (NM)_{H_2}}$$

Conversion Factors

DIMENSION	METRIC	METRIC/ENGLISH
Acceleration	1 m/s^2 = 100 cm/s^2	1 m/s^2 = 3.2808 ft/s^2 1 ft/s^2 = 0.3048* m/s^2
Area	1 m^2 = 10^4 cm^2 = 10^6 mm^2 = 10^{-6} km^2	1 m^2 = 1550 in^2 = 10.764 ft^2 1 ft^2 = 144 in^2 = 0.09290304* m^2
Density	1 g/cm^3 = 1 kg/L = 1000 kg/m^3	1 g/cm^3 = 62.428 lbm/ft^3 = 0.036127 lbm/in^3 1 lbm/in^3 = 1728 lbm/ft^3 1 kg/m^3 = 0.062428 lbm/ft^3
Energy, heat, work, internal energy, enthalpy	1 kJ = 1000 J = 1000 N · m = 1 kPa · m^3 1 kJ/kg = 1000 m^2/s^2 1 kWh = 3600 kJ 1 cal[†] = 4.184 J 1 IT cal[†] = 4.1868 J 1 Cal[†] = 4.1868 kJ	1 kJ = 0.94782 Btu 1 Btu = 1.055056 kJ = 5.40395 psia · ft^3 = 778.169 lbf · ft 1 Btu/lbm = 25,037 ft^2/s^2 = 2.326* kJ/kg 1 kJ/kg = 0.430 Btu/lbm 1 kWh = 3412.14 Btu 1 therm = 10^5 Btu = 1.055 × 10^5 kJ (natural gas)
Force	1 N = 1 kg · m/s^2 = 10^5 dyne 1 kgf = 9.80665 N	1 N = 0.22481 lbf 1 lbf = 32.174 lbm · ft/s^2 = 4.44822 N
Heat flux	1 W/cm^2 = 10^4 W/m^2	1 W/m^2 = 0.3171 Btu/h · ft^2
Heat transfer coefficient	1 W/m^2 · °C = 1 W/m^2 · K	1 W/m^2 · °C = 0.17612 Btu/h · ft^2 · °F
Length	1 m = 100 cm = 1000 mm = 10^6 μm 1 km = 1000 m	1 m = 39.370 in = 3.2808 ft = 1.0926 yd 1 ft = 12 in = 0.3048* m 1 mile = 5280 ft = 1.6093 km 1 in = 2.54* cm
Mass	1 kg = 1000 g 1 metric ton = 1000 kg	1 kg = 2.2046226 lbm 1 lbm = 0.45359237* kg 1 ounce = 28.3495 g 1 slug = 32.174 lbm = 14.5939 kg 1 short ton = 2000 lbm = 907.1847 kg
Power, heat transfer rate	1 W = 1 J/s 1 kW = 1000 W = 1.341 hp 1 hp[‡] = 745.7 W	1 kW = 3412.14 Btu/h = 737.56 lbf · ft/s 1 hp = 550 lbf · ft/s = 0.7068 Btu/s = 42.41 Btu/min = 2544.5 Btu/h = 0.74570 kW 1 boiler hp = 33,475 Btu/h 1 Btu/h = 1.055056 kJ/h 1 ton of refrigeration = 200 Btu/min
Pressure	1 Pa = 1 N/m^2 1 kPa = 10^3 Pa = 10^{-3} MPa 1 atm = 101.325 kPa = 1.01325 bars = 760 mm Hg at 0°C = 1.03323 kgf/cm^2 1 mm Hg = 0.1333 kPa	1 Pa = 1.4504 × 10^{-4} psia = 0.020886 lbf/ft^2 1 psi = 144 lbf/ft^2 = 6.894757 kPa 1 atm = 14.696 psia = 29.92 in Hg at 30°F 1 in Hg = 3.387 kPa
Specific heat	1 kJ/kg · °C = 1 kJ/kg · K = 1 J/g · °C	1 Btu/lbm · °F = 4.1868 kJ/kg · °C 1 Btu/lbmol · R = 4.1868 kJ/kmol · K 1 kJ/kg · °C = 0.23885 Btu/lbm · °F = 0.23885 Btu/lbm · R

*Exact conversion factor between metric and English units.

[†]Calorie is originally defined as the amount of heat needed to raise the temperature of 1 g of water by 1°C, but it varies with temperature. The international steam table (IT) calorie (generally preferred by engineers) is exactly 4.1868 J by definition and corresponds to the specific heat of water at 15°C. The thermochemical calorie (generally preferred by physicists) is exactly 4.184 J by definition and corresponds to the specific heat of water at room temperature. The difference between the two is about 0.06 percent, which is negligible. The capitalized Calorie used by nutritionists is actually a kilocalorie (1000 IT calories).

DIMENSION	METRIC	METRIC/ENGLISH
Specific volume	1 m^3/kg = 1000 L/kg = 1000 cm^3/g	1 m^3/kg = 16.02 ft^3/lbm 1 ft^3/lbm = 0.062428 m^3/kg
Temperature	T(K) = T(°C) + 273.15 ΔT(K) = ΔT(°C)	T(R) = T(°F) + 459.67 = 1.8T(K) T(°F) = 1.8 T(°C) + 32 ΔT(°F) = ΔT(R) = 1.8 ΔT(K)
Thermal conductivity	1 W/m · °C = 1 W/m · K	1 W/m · °C = 0.57782 Btu/h · ft · °F
Velocity	1 m/s = 3.60 km/h	1 m/s = 3.2808 ft/s = 2.237 mi/h 1 mi/h = 1.46667 ft/s 1 mi/h = 1.6093 km/h
Volume	1 m^3 = 1000 L = 10^6 cm^3 (cc)	1 m^3 = 6.1024 × 10^4 in^3 = 35.315 ft^3 = 264.17 gal (U.S.) 1 U.S. gallon = 231 in^3 = 3.7854 L 1 fl ounce = 29.5735 cm^3 = 0.0295735 L 1 U.S. gallon = 128 fl ounces
Volume flow rate	1 m^3/s = 60,000 L/min = 10^6 cm^3/s	1 m^3/s = 15,850 gal/min (gpm) = 35.315 ft^3/s = 2118.9 ft^3/min (cfm)

[a]Mechanical horsepower. The electrical horsepower is taken to be exactly 746 W.

Some Physical Constants

Universal gas constant	R_u = 8.31447 kJ/kmol · K = 8.31447 kPa · m^3/kmol · K = 0.0831447 bar · m^3/kmol · K = 82.05 L · atm/kmol · K = 1.9858 Btu/lbmol · R = 1545.37 ft · lbf/lbmol · R = 10.73 psia · ft^3/lbmol · R
Standard acceleration of gravity	g = 9.80665 m/s^2 = 32.174 ft/s^2
Standard atmospheric pressure	1 atm = 101.325 kPa = 1.01325 bar = 14.696 psia = 760 mm Hg (0°C) = 29.9213 in Hg (32°F) = 10.3323 m H_2O (4°C)
Stefan–Boltzmann constant	σ = 5.6704 × 10^{-8} W/m^2 · K^4 = 0.1714 × 10^{-8} Btu/h · ft^2 · R^4
Boltzmann's constant	k = 1.380650 × 10^{-23} J/K
Speed of light in vacuum	c_o = 2.9979 × 10^8 m/s = 9.836 × 10^8 ft/s
Speed of sound in dry air at 0°C and 1 atm	c = 331.36 m/s = 1089 ft/s
Heat of fusion of water at 1 atm	h_{if} = 333.7 kJ/kg = 143.5 Btu/lbm
Enthalpy of vaporization of water at 1 atm	h_{fg} = 2256.5 kJ/kg = 970.12 Btu/lbm