



**UNIVERSITI KUALA LUMPUR**  
**Malaysian Institute of Marine Engineering Technology**

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**FINAL EXAMINATION**  
**MARCH 2025 SEMESTER SESSION**

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<b>SUBJECT CODE</b>	<b>: LGD21002</b>
<b>SUBJECT TITLE</b>	<b>: FUNDAMENTAL THERMODYNAMICS</b>
<b>PROGRAMME NAME</b> (FOR MPU: PROGRAMME LEVEL)	<b>: DIPLOMA OF ENGINEERING TECHNOLOGY IN SHIP CONSTRUCTION AND MAINTENANCE</b>
<b>TIME / DURATION</b>	<b>: 9.00 AM - 11.30 AM (2 HOURS 30 MINUTES)</b>
<b>DATE</b>	<b>: 26 JUNE 2025</b>

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**INSTRUCTIONS TO CANDIDATES**

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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.
  4. Answer **ALL** questions in Section A and **TWO (2)** questions in Section B.
  5. Please write your answer on the answer booklet provided.
  6. Answer **ALL** questions in English language **ONLY**.
  7. The formulae sheet has been appended for your reference. Steam Tables will be provided.
  8. The answer should be written in blue or black ink except for sketching, graphics, and illustration.
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**THERE ARE 7 PAGES OF QUESTIONS, INCLUDING THIS PAGE.**

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**SECTION A (Total: 60 marks)**

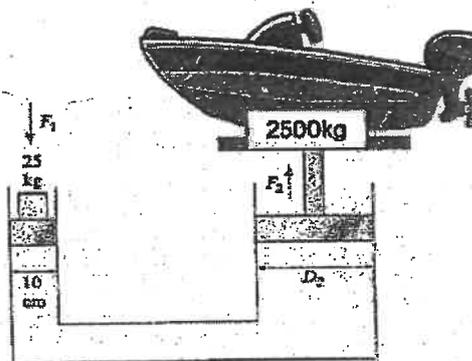
**INSTRUCTION: Answer ALL questions. Please use the answer booklet provided.**

**Question 1**

(a) The recommended tire pressure for a car is around 250 kPa. Use unity conversion ratio to convert the pressure unit into:

- (i) Psi (2 marks)
- (ii) Atm (2 marks)
- (iii) Bar (2 marks)

(b) A hydraulic lift is to be used to lift 2500 kg weight by putting a weight of 25 kg on a piston with diameter 10 cm as shown in figure.



**Figure 1: Hydraulic lift**

- (i) Briefly explain the principle involved. (2 marks)
  - (ii) Calculate pressure at  $P_1$  and  $P_2$ . (3 marks)
  - (iii) Determine the force  $F_2$  and diameter  $D_2$ . (5 marks)
- (c) A manometer is used to measure gas pressure in a tank. The manometer column height is 50 cm. Determine the absolute pressure of the gas if the fluid used has density of  $700\text{kg/m}^3$  and the local atmospheric pressure is 100kPa. (4 marks)

## Question 2

- (a) Define macroscopic and microscopic forms of energy  
(4 marks)
- (b) A person gets into an elevator at the lobby level of a hotel together with his 30-kg suitcase and gets out at the 10th floor 35 m above. Determine the amount of energy consumed by the motor of the elevator that is now stored in the suitcase. Show the necessary unity conversion ratio used in your solution.  
(4 marks)
- (c) A wind turbine is rotating at 15 rpm under steady winds flowing through the turbine at a rate of 42,000 kg/s. The tip velocity of the turbine blade is measured to be 250 km/h. If 180 kW power is produced by the turbine, determine the following.
- (i) The average velocity of the air.  
(7 marks)
- (ii) The conversion efficiency of the turbine if density of air to be  $1.31 \text{ kg/m}^3$ . Show the necessary unity conversion ratio used in your solution.  
(5 marks)

## Question 3

- a) Illustrate and completely label the T-v diagram for the heating process of water at constant pressure from 20°C to 100°C and from 100°C to 300°C. The axis and phase change needs to be clearly labelled.

(6 marks)

- b) A mass of 10 g of oxygen fills a weighted piston-cylinder device at 20 kPa and 100°C. The device is now cooled until the temperature is 0°C. Determine the change of the volume of the device during this cooling. (Hint: Get the gas constant for oxygen from the table).

(6 marks)

- c) Given the enthalpy of water is 2828 kJ/kg at 0.8 MPa pressure. Determine:

(i) The correlation and phase change of the substance,

(2 marks)

(ii) The temperature, (*Hint: perform linear interpolation*), and

(3 marks)

(iii) Draw the process on a T-h diagram with respect to the saturation lines.

(3 marks)

**SECTION B (Total: 40 marks)**

**INSTRUCTION: Answer TWO (2) questions in Section B. Please use the answer booklet provided.**

**Question 4**

- (a) Complete Table 1 below based on the conservation of energy principle for a closed system. Show all the necessary calculations that are involved.

Table 1

$Q_{in}$ (J)	$W_{OUT}$ (J)	$E_1$ (J)	$E_2$ (J)	$m$ (kg)	$e_2 - e_1$ (J/kg)
(i)	274	623	(ii)	1.5	162
-542	(iii)	1422	880	5	(iv)
(v)	-67	1200	(vi)	4	-198

(12 marks)

- (b) A mass of 5 kg of saturated water vapor at 300 kPa is heated at constant pressure until the temperature reaches 200°C. Calculate the work done by the steam during this process and sketch the P-v diagram of the process.

(8 marks)

## Question 5

- (a) Complete Table 2 below based on the conservation of mass principle for air that flows steadily in a pipe. Show all the necessary calculations that are involved.

Table 2

Pressure	Temperature	Volume flow rate	Mass Flow rate	Specific volume	Area	Diameter
P (kPa)	T (°C)	V (m/s)	$\dot{m}$ (kg/s)	v (m <sup>3</sup> /kg)	A (m <sup>2</sup> )	D (m)
300	77	25	0.3	(i)	(ii)	(iii)
(iv)	90	21.21	(v)	0.2451	0.0052	(vi)

(12 marks)

- (b) Water enters the constant 0.13-m inside-diameter tubes of a boiler at 7 MPa and 60°C and leaves the tubes at 6 MPa and 450°C with a velocity of 80 m/s.

(i) Calculate the cross-sectional area of the tube.

(2 marks)

(ii) mass flow rate of the water.

(2 marks)

(iii) velocity of the water at the tube inlet.

(2 marks)

(iv) the inlet volume flow rate.

(2 marks)

## Question 6

- (a) State Kelvin Planck statement on the second law of thermodynamics. (3 marks)

- (b) Draw a heat pump complete with label. (5 marks)

- (c) A Carnot heat engine receives heat from a reservoir at  $1000^{\circ}\text{C}$  at a rate of  $840\text{ kJ/min}$  and rejects the waste heat to the ambient air at  $25^{\circ}\text{C}$ . The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at  $-5^{\circ}\text{C}$  and transfers it to the same ambient air at  $25^{\circ}\text{C}$ .

Calculate:

- (i) The thermal efficiency of the heat engine. (3 marks)
- (ii) The rate of work out for the heat engine. (3 marks)
- (iii) The coefficient of performance for the refrigerator. (3 marks)
- (iv) The rate of heat removal from the refrigerated space in  $\text{kJ/s}$ . (3 marks)

END OF EXAMINATION PAPER

## THERMODYNAMICS FORMULA

<b>First Law of Thermodynamics</b>
<i>Density, <math>\rho = \frac{m}{V}</math></i>
<i>Specific Gravity, <math>SG = \frac{\rho}{\rho_{H_2O}}</math></i>
<i>Specific Weight, <math>\gamma_s = \rho g</math></i>
<i>Gage Pressure, <math>P_{gage} = P_{abs} - P_{atm}</math></i>
<i>Vacuum Pressure, <math>P_{vac} = P_{atm} - P_{abs}</math></i>
<i>Kinetic Energy, <math>KE = \frac{mV^2}{2}</math></i>
<i>Potential Energy, <math>PE = mgz</math></i>
<i>Total energy, <math>E = U + KE + PE</math></i>
<i>Heat transfer, <math>Q = \dot{Q}\Delta t</math></i>
<i>Work, <math>W = Fs</math></i>
<i>Force, <math>F = PA</math></i>
<i>Spring Force, <math>F = kx</math></i>
<i>Electrical work, <math>W_e = VI\Delta t</math></i>
<i>Shaft work, <math>W_{sh} = 2\pi nT</math></i>
<i>Shaft power, <math>\dot{W}_{sh} = 2\pi \dot{n}T</math></i>
<i>Spring Work, <math>W_{spring} = \frac{1}{2}k(x_2^2 - x_1^2)</math></i>
<i>Enthalpy, <math>H = U + PV</math></i>
<i>Quality, <math>x = \frac{m_g}{m_{total}}</math></i>
<i><math>x = \frac{y - y_f}{y_{fg}}</math> where <math>y = v, u</math> or <math>h</math></i>
<b>Mass total</b>
<i><math>m_{total} = m_f + m_g</math></i>
<b>Ideal gas equation</b>
<i><math>PV = mRT</math></i>
<i><math>\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}</math></i>

<b>General Energy Balance</b>
$E_{in} - E_{out} = \Delta E_{system}$
$\Delta E_{system} = \Delta U + \Delta KE + \Delta PE$
<b>Energy Balance for a closed system</b>
$\Delta Q - \Delta W = \Delta U + \Delta KE + \Delta PE$
<b>Energy Balance for a constant pressure process</b>
$W_b + \Delta U = \Delta H$
$Q - W_{other} = \Delta H + \Delta KE + \Delta PE$
<b>Conservation of mass and energy equations for steady-flow process</b>
$\sum \dot{m}_{in} = \sum \dot{m}_{out}$
$\dot{Q} - \dot{W} = \sum_{out} \dot{m} [h + V^2/2 + gz] - \sum_{in} \dot{m} [h + V^2/2 + gz]$
<b>Boundary work (<math>P = \text{constant}</math>), <math>W_b = mP_0(v_2 - v_1)</math></b>
<b>Boundary work (<math>T = \text{constant}</math>), <math>W_b = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)</math></b>
<b>Energy balance for a steady-flow process</b>
$\dot{E}_{in} - \dot{E}_{out} = \frac{dE_{system}}{dt} = 0$
$\dot{E}_{in} = \dot{E}_{out}$
<b>Mass flow rate, <math>\dot{m} = \rho AV = \rho \dot{V} = \frac{\dot{V}}{v}</math></b>
<b>Volume flow rate, <math>\dot{V} = VA = \frac{\dot{m}}{\rho}</math></b>
<b>Thermal efficiency of a Heat Engine</b>
$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$
<b>Coefficient of performance</b>
$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L}$
$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L}$
<b>Carnot Heat Engine</b>
$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$

*Carnot Refrigerators and Heat Pumps*

$$COP_{R,carnot} = \frac{1}{T_H/T_L - 1}$$

$$COP_{R,carnot} = \frac{1}{1 - T_L/T_H}$$

## Conversion Factors

DIMENSION	METRIC	METRIC/ENGLISH
Acceleration	1 m/s <sup>2</sup> = 100 cm/s <sup>2</sup>	1 m/s <sup>2</sup> = 3.2808 ft/s <sup>2</sup> 1 ft/s <sup>2</sup> = 0.3048* m/s <sup>2</sup>
Area	1 m <sup>2</sup> = 10 <sup>4</sup> cm <sup>2</sup> = 10 <sup>6</sup> mm <sup>2</sup> = 10 <sup>-6</sup> km <sup>2</sup>	1 m <sup>2</sup> = 1550 in <sup>2</sup> = 10.764 ft <sup>2</sup> 1 ft <sup>2</sup> = 144 in <sup>2</sup> = 0.09290304* m <sup>2</sup>
Density	1 g/cm <sup>3</sup> = 1 kg/L = 1000 kg/m <sup>3</sup>	1 g/cm <sup>3</sup> = 62.428 lbm/ft <sup>3</sup> = 0.036127 lbm/in <sup>3</sup> 1 lbm/in <sup>3</sup> = 1728 lbm/ft <sup>3</sup> 1 kg/m <sup>3</sup> = 0.062428 lbm/ft <sup>3</sup>
Energy, heat, work, internal energy, enthalpy	1 kJ = 1000 J = 1000 N · m = 1 kPa · m <sup>3</sup> 1 kJ/kg = 1000 m <sup>2</sup> /s <sup>2</sup> 1 kWh = 3600 kJ 1 cal <sup>†</sup> = 4.184 J 1 IT cal <sup>†</sup> = 4.1868 J 1 Cal <sup>†</sup> = 4.1868 kJ	1 kJ = 0.94782 Btu 1 Btu = 1.055056 kJ = 5.40395 psia · ft <sup>3</sup> = 778.169 lbf · ft 1 Btu/lbm = 25,037 ft <sup>2</sup> /s <sup>2</sup> = 2.326* kJ/kg 1 kJ/kg = 0.430 Btu/lbm 1 kWh = 3412.14 Btu 1 therm = 10 <sup>6</sup> Btu = 1.055 × 10 <sup>6</sup> kJ (natural gas)
Force	1 N = 1 kg · m/s <sup>2</sup> = 10 <sup>5</sup> dyne 1 kgf = 9.80665 N	1 N = 0.22481 lbf 1 lbf = 32.174 lbm · ft/s <sup>2</sup> = 4.44822 N
Heat flux	1 W/cm <sup>2</sup> = 10 <sup>4</sup> W/m <sup>2</sup>	1 W/m <sup>2</sup> = 0.3171 Btu/h · ft <sup>2</sup>
Heat transfer coefficient	1 W/m <sup>2</sup> · °C = 1 W/m <sup>2</sup> · K	1 W/m <sup>2</sup> · °C = 0.17612 Btu/h · ft <sup>2</sup> · °F
Length	1 m = 100 cm = 1000 mm = 10 <sup>6</sup> 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 <sup>†</sup> = 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 <sup>2</sup> 1 kPa = 10 <sup>3</sup> Pa = 10 <sup>-3</sup> MPa 1 atm = 101.325 kPa = 1.01325 bars = 760 mm Hg at 0°C = 1.03323 kgf/cm <sup>2</sup> 1 mm Hg = 0.1333 kPa	1 Pa = 1.4504 × 10 <sup>-4</sup> psia = 0.020886 lbf/ft <sup>2</sup> 1 psi = 144 lbf/ft <sup>2</sup> = 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.

<sup>†</sup>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	$1 \text{ m}^3/\text{kg} = 1000 \text{ L}/\text{kg} = 1000 \text{ cm}^3/\text{g}$	$1 \text{ m}^3/\text{kg} = 16.02 \text{ ft}^3/\text{lbm}$ $1 \text{ ft}^3/\text{lbm} = 0.062428 \text{ m}^3/\text{kg}$
Temperature	$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$ $\Delta T(\text{K}) = \Delta T(^{\circ}\text{C})$	$T(\text{R}) = T(^{\circ}\text{F}) + 459.67 = 1.8 T(\text{K})$ $T(^{\circ}\text{F}) = 1.8 T(^{\circ}\text{C}) + 32$ $\Delta T(^{\circ}\text{F}) = \Delta T(\text{R}) = 1.8 \Delta T(\text{K})$
Thermal conductivity	$1 \text{ W}/\text{m} \cdot ^{\circ}\text{C} = 1 \text{ W}/\text{m} \cdot \text{K}$	$1 \text{ W}/\text{m} \cdot ^{\circ}\text{C} = 0.57782 \text{ Btu}/\text{h} \cdot \text{ft} \cdot ^{\circ}\text{F}$
Velocity	$1 \text{ m}/\text{s} = 3.60 \text{ km}/\text{h}$	$1 \text{ m}/\text{s} = 3.2808 \text{ ft}/\text{s} = 2.237 \text{ mi}/\text{h}$ $1 \text{ mi}/\text{h} = 1.46667 \text{ ft}/\text{s}$ $1 \text{ mi}/\text{h} = 1.6093 \text{ km}/\text{h}$
Volume	$1 \text{ m}^3 = 1000 \text{ L} = 10^6 \text{ cm}^3 (\text{cc})$	$1 \text{ m}^3 = 6.1024 \times 10^4 \text{ in}^3 = 35.315 \text{ ft}^3$ $= 264.17 \text{ gal (U.S.)}$ $1 \text{ U.S. gallon} = 231 \text{ in}^3 = 3.7854 \text{ L}$ $1 \text{ fl ounce} = 29.5735 \text{ cm}^3 = 0.0295735 \text{ L}$ $1 \text{ U.S. gallon} = 128 \text{ fl ounces}$
Volume flow rate	$1 \text{ m}^3/\text{s} = 60,000 \text{ L}/\text{min} = 10^6 \text{ cm}^3/\text{s}$	$1 \text{ m}^3/\text{s} = 15,850 \text{ gal}/\text{min (gpm)} = 35.315 \text{ ft}^3/\text{s}$ $= 2118.9 \text{ ft}^3/\text{min (cfm)}$

\*Mechanical horsepower. The electrical horsepower is taken to be exactly 746 W.

### Some Physical Constants

Universal gas constant	$R_u = 8.31447 \text{ kJ}/\text{kmol} \cdot \text{K}$ $= 8.31447 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K}$ $= 0.0831447 \text{ bar} \cdot \text{m}^3/\text{kmol} \cdot \text{K}$ $= 82.05 \text{ L} \cdot \text{atm}/\text{kmol} \cdot \text{K}$ $= 1.9858 \text{ Btu}/\text{lbmol} \cdot \text{R}$ $= 1545.37 \text{ ft} \cdot \text{lb}/\text{lbmol} \cdot \text{R}$ $= 10.73 \text{ psia} \cdot \text{ft}^3/\text{lbmol} \cdot \text{R}$
Standard acceleration of gravity	$g = 9.80665 \text{ m}/\text{s}^2$ $= 32.174 \text{ ft}/\text{s}^2$
Standard atmospheric pressure	$1 \text{ atm} = 101.325 \text{ kPa}$ $= 1.01325 \text{ bar}$ $= 14.696 \text{ psia}$ $= 760 \text{ mm Hg (} 0^{\circ}\text{C)}$ $= 29.9213 \text{ in Hg (} 32^{\circ}\text{F)}$ $= 10.3323 \text{ m H}_2\text{O (} 4^{\circ}\text{C)}$
Stefan-Boltzmann constant	$\sigma = 5.6704 \times 10^{-8} \text{ W}/\text{m}^2 \cdot \text{K}^4$ $= 0.1714 \times 10^{-8} \text{ Btu}/\text{h} \cdot \text{ft}^2 \cdot \text{R}^4$
Boltzmann's constant	$k = 1.380650 \times 10^{-23} \text{ J}/\text{K}$
Speed of light in vacuum	$c_o = 2.9979 \times 10^8 \text{ m}/\text{s}$ $= 9.836 \times 10^8 \text{ ft}/\text{s}$
Speed of sound in dry air at $0^{\circ}\text{C}$ and 1 atm	$c = 331.36 \text{ m}/\text{s}$ $= 1089 \text{ ft}/\text{s}$
Heat of fusion of water at 1 atm	$h_{if} = 333.7 \text{ kJ}/\text{kg}$ $= 143.5 \text{ Btu}/\text{lbm}$
Enthalpy of vaporization of water at 1 atm	$h_{fg} = 2256.5 \text{ kJ}/\text{kg}$ $= 970.12 \text{ Btu}/\text{lbm}$

