CONFIDENTIAL

UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY

FINAL EXAMINATION
JANUARY 2016 SEMESTER

COURSE CODE	:	LGD 20303
COURSE NAME	:	FUNDAMENTAL OF THERMODYNAMICS
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	:	DIPLOMA IN SHIP DESIGN DIPLOMA IN SHIP CONSTRUCTION AND MAINTENANCE
DATE	:	24 MAY 2016
TIME	:	08.00 AM – 11.00 AM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please CAREFULLY read 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 questions in Section A. For Section B, answer TWO (2) questions ONLY.
5. Please write your answers on the answer booklet provided.
6. Answer all questions in English language ONLY.
7. Property Tables has been appended for your reference.

THERE ARE 6 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

SECTION A (Total: 60 M)

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

QUESTION 1

(a) A 3 kg rock is thrown upward with a force of 200 N at a location where the local gravitational acceleration is 9.79 m/s^2. Determine the:

i. weight of the rock

(3 Marks)

ii. net force that act on the rock

(2 Marks)

iii. acceleration of the rock

(3 Marks)

(b) Define the *intensive* and *extensive* properties. Give one example for each type of properties.

(4 Marks)

(c) The pressure in a compressed air storage tank is 1200 kPa. Determine the tank pressure in the chamber in the following units:

i. kN and m units

(2 Marks)

ii. kg, m and s units

(3 Marks)

iii. kg, km, and s units

(3 Marks)

QUESTION 2

(a) Define total energy. List the forms of energy that contribute to the internal energy.

(5 Marks)

(b) Determine the torque applied to the shaft of a car that transmits 335 kW and rotates at a rate of 3000 rpm.

(5 Marks)

(c) Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 35 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 500 N.m. If its final energy is 10 kJ:

i. write the energy balance for this system

(4 Marks)

ii. determine the final energy of the system.

(6 Marks)

QUESTION 3

(a) Define the quality. Explain if the quality have any meaning in the *compressed liquid* and *superheated vapor* regions.

(4 Marks)

(b) A rigid vessel contains 8 kg of R-134a at 500 kPa and 120 ^{0}C. Determine the volume of the vessel and total internal energy.

(6 Marks)

(c) Complete this table for H_2O: (*show all the calculations involved*)

(10 Marks)

Table 1: H_2O Properties

T (°C)	P (kPa)	h (kJ/kg)	X	Phase Description
(i)	200	(ii)	0.7	(iii)
140	(iv)	1800	(v)	(vi)
(vii)	950	(viii)	0.0	(ix)
80	500	(x)	(xi)	(xii)

SECTION B (Total: 40 M).

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

QUESTION 4

(a) Complete Table 2 below on the basis of the conservation of energy principle for a closed system. Show all the calculations involved.

(10 Marks)

Table 2: Conservation of energy principle

Q_{in}, (kJ)	W_{out}, (kJ)	E_1, (kJ)	E_2, kJ	m, kg	e_2-e_1, kJ/kg
280	(i)	1020	860	3	(ii)
-350	130	550	(iii)	5	(iv)
(v)	260	300	(vi)	2	-150
300	(vii)	(viii)	500	1	-250

(b) A rigid 10 liter vessel initially contains a mixture of liquid water and vapor at 100 ^{0}C with 12.3 percent quality. The mixture is then heated until its temperature is 150 ^{0}C.

i. Sketch the process on a T-v diagram.

(2 Marks)

ii. Determine its final internal energy per unit mass, u_2.

(5 Marks)

iii. Determine the heat transfer required for this process, in kJ.

(3 Marks)

QUESTION 5

(a) Explain *conservation of mass principle* for a control volume (open system). Sketch schematic illustrations for any engineering devices and write the *formula* for conservation of mass principle.

(8 Marks)

(b) Steam enters a long, horizontal pipe with an inlet diameter of D_1 = 16 cm at 2 MPa and 300 ^{0}C with a velocity of 2.5 m/s. Farther downstream, the conditions are 1.8 MPa and 250 ^{0}C, and the diameter D_2 = 14 cm as shown in Figure 2. Determine the :

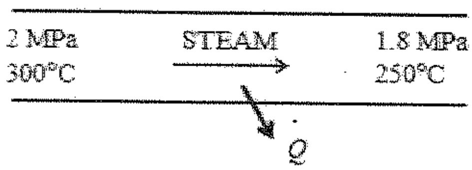

Figure 2: Horizontal pipe

i. mass flow rate of the steam, $\dot{m}(kg/s)$

(6 Marks)

ii. rate of heat transfer, $\dot{Q}(kJ/s)$

(6 Marks)

QUESTION 6

(a) State the Second Law of Thermodynamics. Briefly explain a thermal energy reservoir. Give TWO (2) examples.

(6 Marks)

(b) A food department is kept at -12 °C by a refrigerator in an environment at 30 °C. The total heat gain to the food department is estimated to be 3300 kJ/h and the heat rejection in the condenser is 4800 kJ/h as shown in Figure 3. Determine the :

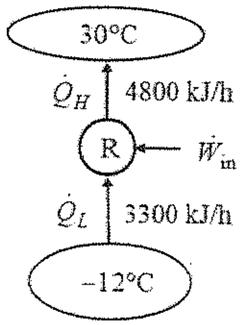

Figure 3: Refrigerator

i. power input to the compressor in kW.

(4 Marks)

ii. Coefficient of Performance (COP) of the refrigerator.

(3 Marks)

(c) During the isothermal heat addition process of a Carnot cycle, 900 kJ of heat is added to the working fluid from a source at 400 °C. Determine:

i. the entropy change of the working fluid, (ΔS_{fluid}).

(3 Marks)

ii. the entropy change of the source, (ΔS_{source}).

(3 Marks)

iii. the total entropy change for the process (ΔS_{total}).

(1 Marks)

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULA

First Law of Thermodynamics
Kinetic Energy, $KE = \frac{mV^2}{2}$
Potential Energy, $PE = mgz$
Total energy, $E = U + KE + PE$
Heat transfer, $Q = \dot{Q}\Delta t$
$W = Fs$
Force, $F = PA$
Spring Force, $F = kx$
Electrical work, $W_e = VI\Delta t$
Shaft work $W_{sh} = 2\pi nt$
Spring Work, $W_{spring} = \frac{1}{2}k(x_2{}^2 - x_1{}^2)$
Enthalpy, $H = U + PV$
Quality, $x = \frac{m_g}{m_{total}}$
Mass total $m_{total} = m_f + m_g$
Ideal gas equation $PV = mRT$
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
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 $Q - W = \Delta U + \Delta KE + \Delta PE$
Energy Balance for a constant pressure process $W_b + \Delta U = \Delta H$ $Q - W_{other} = \Delta H + \Delta KE + \Delta PE$
Conservation of mass and energy equations for steady-flow process $\sum \dot{m}_{in} = \sum \dot{m}_{out}$ $\dot{Q} - \dot{W} = \sum_{out} \dot{m}[h + V^2/2 + gz] - \sum_{in} \dot{m}[h + V^2/2 + gz]$
Boundary work (P = constant), $W_b = mP_0(v_2 - v_1)$
Boundary work (T = constant), $W_b = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$
Mass flow rate $\dot{m} = \rho AV = \rho\dot{V} = \dot{V}/v$
Volume flow rate $\dot{V} = VA = \dot{m}/\rho$

Thermal efficiency of a Heat Engine

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

Coefficient of performance

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

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

Carnot Heat Engine

$$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$$

Carnot Refrigerators and Heat Pumps

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

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

Isentropic Process

$$s_2 = s_1$$

$$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k-1}$$

$$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

$$\left(\frac{P_2}{P_1}\right)_{s=const.} = \left(\frac{v_2}{v_1}\right)^{k}$$

$$\left(\frac{P_2}{P_1}\right)_{s=const.} = \frac{P_{r2}}{P_{r1}}$$

$$\left(\frac{v_2}{v_1}\right)_{s=const.} = \frac{v_{r2}}{v_{r1}}$$

Power Cycles

Compression ratio, $r = \frac{V_{max}}{V_{min}} = \frac{V_{BDC}}{V_{TDC}} = \frac{V_1}{V_2} = \frac{v_1}{v_2}$

$$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{w_{net}}{v_{max} - v_{min}}$$

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, $\eta_{th,Otto} = \frac{W_{net}}{Q_{in}} = 1 - \frac{q_{out}}{q_{in}}$
$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}}$
Diesel Cycle
$q_{in} = u_3 - u_2 = P_2(v_3 - v_2) + (u_3 - u_2) = h_3 - h_2 = c_p(T_3 - T_2)$
$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$
Cutoff ratio, $r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$
$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]$
Rankine Cycle
$w_{pump,in} = h_2 - h_1 = v(P_2 - P_1)$
$q_{in} = h_3 - h_2$
$w_{turb,out} = h_3 - h_4$
$q_{out} = h_4 - h_1$
$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$
$w_{net} = q_{in} - q_{out} = w_{turb,in} - w_{pump,in}$
$x_4 = \frac{s_4 - s_f}{s_{fg}}$
$h_4 = h_f + x_4 h_{fg}$
Refrigeration Cycle
$W_{net,out} = Q_H - Q_L$
$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$
$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L} = \frac{h_1 - h_4}{h_2 - h_1}$
$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L} = \frac{h_2 - h_3}{h_2 - h_1}$
$COP_{HP} = COP_R + 1$

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	$T(K) = T(°C) + 273.15$ $\Delta T(K) = \Delta T(°C)$	$T(R) = T(°F) + 459.67 = 1.8T(K)$ $T(°F) = 1.8\,T(°C) + 32$ $\Delta T(°F) = \Delta T(R) = 1.8\,\Delta T(K)$
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)

[1]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