UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY

FINAL EXAMINATION
JANUARY 2016 SESSION

COURSE CODE	:	LGB31503
COURSE NAME	:	THERMODYNAMICS
PROGRAMME NAME	:	BET IN NAVAL ARCHITECTURE AND SHIPBUILDING
DATE	:	19 MAY 2016
TIME	:	2.00 PM – 4.30 PM
DURATION	:	2½ 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 ONE (1) section.
4. Answer FOUR (4) questions ONLY.
5. Please write your answers on the answer booklet provided.
6. Answer all questions in English language ONLY.
7. Thermodynamics Table of Properties and Formula have been appended for your reference.

THERE ARE 5 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

SECTION A (Total: 100 marks)

INSTRUCTION: Answer only FOUR questions.
Please use the answer booklet provided.

Question 1

A 0.7 m^3 rigid tank contains refrigerant-134a initially at 180 kPa and 40 percent quality. Heat is now transferred to the refrigerant until the pressure reaches 700 kPa. Determine

(a) The mass of the refrigerant in the tank,

(14 marks)

(b) The amount of heat transferred, and

(8 marks)

(c) Sketch the process on a P-v diagram with respect to saturation lines.

(3 marks)

Question 2

Refrigerant-134a enters an adiabatic compressor as saturated vapor at -26 °C and leaves at 0.8 MPa and 62 °C. If the mass flow rate of the refrigerant is 1.5 kg/s, calculate

(a) The initial pressure

(2 marks)

(b) The power input to the compressor

(16 marks)

(c) The volume flow rate of the refrigerant at the compressor inlet and exit. Will the volume flow rates be the same or not? Explain.

(7 marks)

Question 3

A Carnot heat engine operates between two reservoirs at 850 °C and 27 °C. The rate of heat supplied to the heat engine is 785 kJ/min as shown in Figure 1. One-half of the work output of the heat engine is used to drive a refrigerator that rejects heat from the cold refrigerated space at -5 °C and also transfers heat to the same warm environment at 27 °C. Determine

(a) The maximum rate of heat absorption from the refrigerated space by the refrigerant, and

(16 marks)

(b) The total rate of heat rejection to the warm environment.

(9 marks)

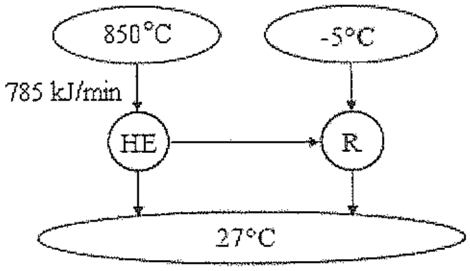

Figure 1: A refrigerator powered by a heat engine

Question 4

(a) Explain the meaning of entropy by considering the microscopic nature of matter.

(3 marks)

(b) 2 kg of R-134a initially at 700 kPa and 28 °C undergoes a process during which the entropy is kept constant until the pressure drops to 100 kPa. Determine

i. The internal energy change of the R-134 during this process.

(18 marks)

ii. The final temperature of the R-134a

(1 mark)

iii. Sketch the T-v diagram for this process

(3 marks)

Question 5

An ideal Otto cycle has a compression ratio of 10. At the beginning of the compression process, air is at and uses air as the working fluid as shown in Figure 2. At the beginning of the compression process, air is at 98 kPa and 300 K. The pressure is doubled during the constant-volume heat-addition process. Accounting for the variation of specific heats with temperature, determine

(a) The temperature and pressure at the end of the isentropic process, and

(15 marks)

(b) The amount of heat transferred to the air in kJ/kg.

(10 marks)

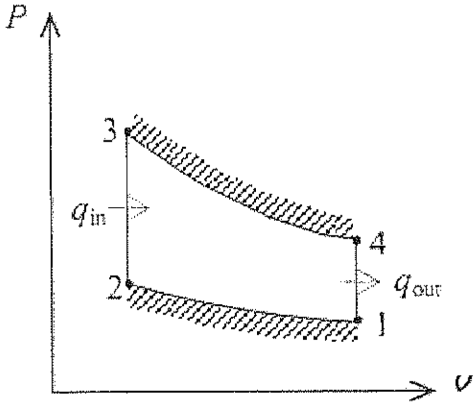

Figure 2: Otto cycle

Question 6

A heat pump used to heat a house operates on an ideal vapor-compression refrigeration cycle with refrigerant-134a as the working fluid as shown in Figure 3. The condenser and evaporator pressures are 900 kPa and 200 kPa, respectively. If the mass flow rate of the refrigerant is 19.2 kg/min, determine

(a) The rate of heat supply, $\dot{Q}_H$ to the house

(13 marks)

(b) The volume flow rate of the refrigerant at the compressor inlet, $\dot{V}_1$

(4 marks)

(c) The coefficient of performance, COP_{HP} of the heat pump, and

(4 marks)

(d) Sketch the cycle on a *T-s* diagram with respect to saturation lines.

(4 marks)

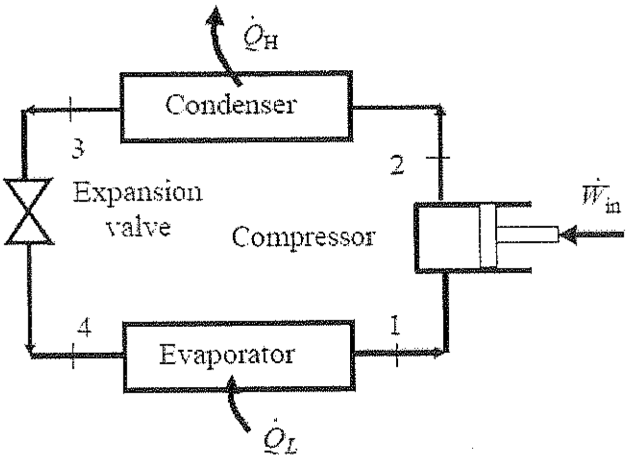

Figure 3: Ideal Vapor-Compression Refrigeration Cycle

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULA

First Law of Thermodynamics
$KE = \frac{mV^2}{2}$
$PE = mgz$
$E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out})$
$\Delta E_{system} = \Delta U + \Delta KE + \Delta PE$
$Q = \dot{Q}\Delta t$
Electrical power, $\dot{W}_e = VI$ (kW)
Electrical work, $W_e = VI\Delta t$ (kJ)
$W = Fs$
Shaft work, $W_{sh} = 2\pi nt$
$F = kx$
$F = PA$
Spring work, $W_{spring} = \frac{1}{2}k({x_2}^2 - {x_1}^2)$
$H = U + PV$
Quality, $x = \frac{m_g}{m_{total}}$
$m_{total} = m_f + m_g$
$v_{fg} = v_g - v_f$
$v_1 = v_f + x_1 v_{fg}$
$u_1 = u_f + x_1 u_{fg}$
$Pv = RT$
$PV = mRT$
$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
$Pv = ZRT$

$$W = W_b = \int_1^2 P dV$$

$$w = Pv$$

Entropy

$$dS = \left(\frac{dQ}{T}\right)_{\text{int}\,rev}$$

$$\Delta S = \frac{Q}{T_o}$$

$$S_{gen} \geq 0$$

$$s_2 - s_1 = c_{avg} \ln \frac{T_2}{T_1}$$

$$s_2 - s_1 = c_{v,avg} \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}$$

$$s_2 - s_1 = c_{p,avg} \ln \frac{T_2}{T_1} - R \ln \frac{v_2}{v_1}$$

$$s_2 - s_1 = s^o{}_2 - s^o{}_1 - R \ln \frac{P_2}{P_1}$$

$$w_{rev} = -\int_1^2 v dP - \Delta ke - \Delta pe$$

$$w_{rev} = -v(P_2 - P_1) - \Delta ke - \Delta pe$$

$$\text{(isentropic)}\ w_{comp,in} = \frac{kR(T_2 - T_1)}{k-1} = \frac{kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k} - 1\right]$$

$$\text{(polytropic)}\ w_{comp,in} = \frac{nR(T_2 - T_1)}{n-1} = \frac{nRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right]$$

$$\text{(isothermal)}\ w_{comp,in} = RT \ln \frac{P_2}{P_1}$$

$$\eta_T = \frac{w_a}{w_s} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$

$$\eta_C = \frac{w_s}{w_a} \cong \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$\eta_P = \frac{w_s}{w_a} = \frac{v(P_2 - P_1)}{h_{2a} - h_1}$$

Carnot Heat Engine

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

Isentropic Process

$$s_2 = s_1$$

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

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

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

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

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

Power Cycles

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

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

Otto Cycle

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_{exit} - h_{inlet}$$

$$q_{in} = u_3 - u_2 = c_v(T_3 - T_2)$$

$$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$$

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3}$$

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

$$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}}$$

Diesel Cycle

$$q_{in} = u_3 - u_2 = P_2(v_3 - v_2) + (u_3 - u_2) = h_3 - h_2 = c_p(T_3 - T_2)$$

$$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$$

$$r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$$

$$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_C^k - 1}{k(r_C - 1)}\right]$$

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

$$\dot{Q}_L = \dot{m}(h_1 - h_4)$$

$$\dot{Q}_H = \dot{m}(h_2 - h_3)$$

$$\dot{W}_{in} = \dot{m}(h_2 - h_1)$$

$$W_{in} = Q_H - Q_L$$

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

Heat Pump

$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L} = \frac{h_2 - h_3}{h_2 - h_1}$
$COP_{HP} = COP_R + 1$
Total Pressure
$P = P_a + P_v$ (kPa)
Partial Pressure of Water Vapor
$P_v = \phi P_g = \phi P_{sat@T}$
Specific Humidity of Air
$\omega = \frac{m_v}{m_a} = \frac{P_v V / R_v T}{P_a V / R_a T} = \frac{P_v / R_v}{P_a / R_a} = 0.622 \frac{P_v}{P_a}$
$\omega_2 = \frac{0.622 P_{g_2}}{P - P_{g_2}}$ (kg water vapor/kg dry air)
$\omega_1 = \frac{c_p (T_2 - T_1) + \omega_2 h_{fg_2}}{h_{g_1 - h_{f_2}}}$
Relative Humidity of Air
$\phi_1 = \frac{m_v}{m_a} = \frac{P_v V / R_v T}{P_g V / R_v T} = \frac{P_v}{P_g}$ where $P_g = P_{sat@T}$
$\phi_1 = \frac{\omega_1 P_1}{(0.622 + \omega_1) P_{g_1}}$
Enthalpy of Air
$H = H_a + H_v = m_a h_a + m_v h_v$
$h = h_a + \omega h_g \cong c_p T + \omega h_g$ (kJ/kg dry air)