UNIVERSITI KUALA LUMPUR
Malaysian Institute of Marine Engineering Technology

FINAL EXAMINATION

FEBRUARY 2025 SEMESTER SESSION

SUBJECT CODE	: **LMB22203**
SUBJECT TITLE	: **THERMODYNAMICS**
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	: **BACHELOR OF MARINE ENGINEERING TECHNOLOGY WITH HONOURS**
TIME / DURATION	: **9.00 AM – 11.30 AM** **(2 HOURS 30 MINUTES)**
DATE	: **1 JULY 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. Answer FOUR (4) questions ONLY.

4. Please write your answers on the answer booklet provided.

5. Answer all questions in English language ONLY.

6. Answer should be written in blue or black ink except for sketches, graphic and illustrations.

7. Steam Table of Properties and Formula has been appended for your reference.

THERE ARE 8 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

INSTRUCTION: Answer FOUR questions ONLY.

Question 1

With reference to the problem concerning property diagrams and tables.

(a) Complete the Table 1(a) below for refrigerant-134a (R-134a). Use the following abbreviations where needed:

- CL – Compressed (Subcooled) liquid
- SL – Saturated liquid
- SM – Saturated Mixture
- SV – Saturated Vapor
- SHV – Superheated Vapor
- NA – Not applicable
- INSUF – insufficient information given

Table 1(a): Properties of R-134a

State	Pressure, P [kPa]	Temperature, T [°C]	Specific volume, v [m³/kg]	Specific enthalpy, h [kJ/kg]	Phase	Quality, x
1	280	-12	**(i)**	**(ii)**	**(iii)**	**(iv)**
2	**(v)**	20	0.005	**(vi)**	**(vii)**	**(viii)**

(10 marks)

(b)   A closed tank contains water at **150 kPa** with a specific volume of **0.85 m³/kg.**

    i.   Using the saturation tables, **analyze** and **justify** the **phase** condition of the water.

                                                            (5 marks)

    ii.   Sketch T-v diagram with complete label to show the phase condition.

                                                            (4 marks)

    iii.   Calculate the quality, X

                                                            (3 marks)

    iv.   Volume of the tank, V (m³)

                                                            (3 marks)

Question 2

With reference to the problem solving and energy transfer analysis of closed system.

(a)　Complete the Table 2(a) below based on the conservation of energy principle.

Table 2(a): Conservation of energy principles

W_{in} (kJ)	Q_{out} (kJ)	E_{final} (kJ)	$E_{initial}$ (kJ)	m (kg)	e_2-e_1 (kJ/kg)
280	(i)	1500	720	9	(ii)
(iii)	200	88	(iv)	2.5	32
120	40	(v)	60	(vi)	50
-350	130	(vii)	550	5	(viii)

(10 marks)

(b)　A 1 kg sample of oxygen is heated from 20°C to 120°C. Calculate the amount of heat transfer required when this heating is done:

i.　at constant volume and

(5 marks)

ii.　at constant pressure

(5 marks)

iii.　Compare and analyze the results obtained in part (i) and (ii). Explain, based on thermodynamic principles, why the heat required at constant pressure is higher than at constant volume.

(5 marks)

Question 3

With reference to the problem solving and energy transfer analysis of an open system.

(a) Characterize between nozzle and diffuser. You may include diagram, functions, velocity, pressure and cross section area between inlet and exit.

(10 marks)

(b) Refrigerant-134a (R-134a) enters a 28 cm diameter pipe as shown in Figure 1 steadily at 200 kPa and 20°C with a velocity of 5 m/s. The refrigerant gains heat as it flows and leaves the pipe at 180 kPa and 40°C.
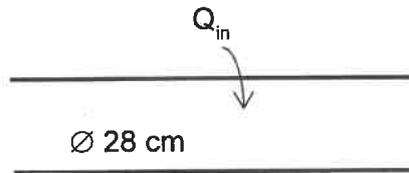
Q_{in}

Ø 28 cm

Figure 1: Pipe

i. Determine the volume flow rate, $\dot{V}_{in}$, of the refrigerant at the inlet.

(3 marks)

ii. Compute the mass flow rate, $\dot{m}$, of the refrigerant

(3 marks)

iii. Calculate velocity, V_e, at the exit

(4 marks)

iv. Discuss how the changes in temperature and pressure affect the velocity and volume flow rate of the refrigerant across the pipe. Use thermodynamic reasoning based on the principles of mass conservation and the specific volume change of R-134a.

(5 marks)

Question 4

With reference to solve problems concerning gas and vapor power cycles, refrigeration and heat pump as well as air conditioning:

An air-standard Diesel cycle has a compression ratio of 16 and a cutoff ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27°C. Assume constant properties for air at 300 K with C_v = 0.718 kJ/kg.K, C_p = 1.005 kJ/kg.K, R=0.287 kJ/kg.K, k = 1.4.

(a)   Determine the temperature after the heat-addition process;

(6 marks)

(b)   Compute the thermal efficiency.

(10 marks)

(c)   Calculate the mean effective pressure, MEP

(7 marks)

(d)   Analyze how the cutoff ratio affects the thermal efficiency of the Diesel cycle compared to the Otto cycle with the same compression ratio. Justify your answer briefly.

(2 marks)

Question 5

With reference to solve problems concerning gas and vapour power cycles, refrigeration and heat pump as well as air conditioning:

A simple Rankine cycle uses refrigerant R134a as the working fluid. The boiler operates at 2000 kPa and the condenser at 24°C. The mixture at the exit of the turbine has a quality of 93 percent.

(a)   turbine inlet temperature, T_3

(6 marks)

(b)   cycle's thermal efficiency, η_{th}

(10 marks)

(c)   back-work ratio of this cycle, r_{bw}

(4 marks)

(d)   Identify and label the key state points (1 to 4) on a T-s diagram.

(5 marks)

Question 6

With reference to solve problems concerning gas and vapour power cycles, refrigeration, and heat pump as well as air conditioning:

A heat pump that operates on the ideal vapor-compression cycle with refrigerant-134a is used to heat a house. The mass flow rate of the refrigerant is 0.25 kg/s. The condenser and evaporator pressure are 1400 kPa and 320 kPa, respectively.

(a)   Sketch a T-s diagram with respect to the saturation lines.

(6 marks)

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

(8 marks)

(c)   Determine the volume flow rate of refrigerant at the compressor inlet.

(3 marks)

(d)   Compute the coefficient of performance, COP of the heat pump.

(3 marks)

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULAE

First Law of Thermodynamics

Quality, $x = \dfrac{m_g}{m_{total}} = \dfrac{v - v_f}{v_{fg}}$

$v = v_f + (x)v_{fg}; \quad u = u_f + (x)u_{fg}; \quad h = h_f + (x)h_{fg}$

Mass total,

$m_{total} = m_f + m_g$

Ideal gas equation

$PV = mRT; \quad Pv = RT$

$\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$

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

$Q-W = \Delta U + \Delta KE + \Delta PE$

Ideal gas : $\quad Q - W = mc_v(T_2 - T_1)$

Energy Balance for a constant pressure process

$W_b + \Delta U = \Delta H$

$Q - W_{other} = \Delta H + \Delta KE + \Delta PE$

Ideal gas : $\quad Q - W = mc_p(T_2 - T_1)$

Conservation of mass and energy equations for steady-flow process

$\sum \dot{m}_{in} = \sum \dot{m}_{out}$

$\dot{Q} - \dot{W} = \sum_{out} \dot{m}[h + V^2/2 + gz] - \sum_{in} \dot{m}[h + V^2/2 + gz]$

$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}\left(h_1 + \dfrac{V_1^2}{2} + gz_1\right) = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}\left(h_2 + \dfrac{V_2^2}{2} + gz_2\right)$

Boundary work (P = constant), $W_b = mP_0(v_2 - v_1)$

Boundary work (T = constant), $W_b = P_1V_1 \ln\left(\dfrac{V_2}{V_1}\right)$

Polytropic Process, $PV^n = C$

Boundary work (Polytropic), $W_b = \dfrac{P_1V_1 - P_2V_2}{1-n}$

Mass flow rate
$$\dot{m} = \rho A V = \rho \dot{V} = \frac{\dot{V}}{v}$$
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
$$s_2 = s_1$$
$$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k-1}$$
$$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$
$$\left(\frac{P_2}{P_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k}$$

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

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

Power Cycles

Compression ratio, $r = \dfrac{V_{max}}{V_{min}} = \dfrac{V_{BDC}}{V_{TDC}} = \dfrac{V_1}{V_2} = \dfrac{v_1}{v_2} = \dfrac{v_{r1}}{v_{r2}}$

$$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{w_{net}}{v_{max} - v_{min}} = \frac{w_{net}}{v\left(1 - \dfrac{1}{r}\right)}$$

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, $\eta_{th,Otto} = \dfrac{W_{net}}{Q_{in}} = 1 - \dfrac{q_{out}}{q_{in}}$

$$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}} = \text{cold-air standard}$$

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, $r_c = \dfrac{V_3}{V_2} = \dfrac{v_3}{v_2}$

$$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] = \text{cold-air standard}$$

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, $r_p = \dfrac{P_2}{P_1}$

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

Rankine Cycle

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

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

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

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

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

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

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

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

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

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

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

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

Conversion Factors

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

*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	$1\ W/m \cdot °C = 1\ W/m \cdot K$	$1\ W/m \cdot °C = 0.57782\ Btu/h \cdot ft \cdot °F$
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	$1\ m^3 = 1000\ L = 10^6\ cm^3\ (cc)$	$1\ m^3 = 6.1024 \times 10^4\ in^3 = 35.315\ ft^3$ $= 264.17\ gal\ (U.S.)$ $1\ U.S.\ gallon = 231\ in^3 = 3.7854\ L$ $1\ fl\ ounce = 29.5735\ cm^3 = 0.0295735\ L$ $1\ U.S.\ gallon = 128\ fl\ ounces$
Volume flow rate	$1\ m^3/s = 60,000\ L/min = 10^6\ cm^3/s$	$1\ m^3/s = 15,850\ gal/min\ (gpm) = 35.315\ ft^3/s$ $= 2118.9\ ft^3/min\ (cfm)$

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

Some Physical Constants

Universal gas constant	$R_u = 8.31447\ kJ/kmol \cdot K$ $= 8.31447\ kPa \cdot m^3/kmol \cdot K$ $= 0.0831447\ bar \cdot m^3/kmol \cdot K$ $= 82.05\ L \cdot atm/kmol \cdot K$ $= 1.9858\ Btu/lbmol \cdot R$ $= 1545.37\ ft \cdot lbf/lbmol \cdot R$ $= 10.73\ psia \cdot ft^3/lbmol \cdot R$
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	$\sigma = 5.6704 \times 10^{-8}\ W/m^2 \cdot K^4$ $= 0.1714 \times 10^{-8}\ Btu/h \cdot ft^2 \cdot R^4$
Boltzmann's constant	$k = 1.380650 \times 10^{-23}\ J/K$
Speed of light in vacuum	$c_o = 2.9979 \times 10^8\ m/s$ $= 9.836 \times 10^8\ ft/s$
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	$h_{fg} = 2256.5\ kJ/kg$ $= 970.12\ Btu/lbm$