



UNIVERSITI KUALA LUMPUR
Malaysian Institute of Marine Engineering Technology

FINAL EXAMINATION
JULY 2025 SEMESTER SESSION

SUBJECT CODE : LMD25202

SUBJECT TITLE : APPLIED THERMODYNAMICS

PROGRAMME NAME : DIPLOMA OF ENGINEERING TECHNOLOGY IN
(FOR MPU: PROGRAMME LEVEL) MARINE ENGINEERING

TIME / DURATION : 09.00 AM - 11.30 AM
(2 HOURS 30 MINUTES)

DATE : 15 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 or black ink except for sketching, graphic and illustration.
8. Steam Table of Properties and Formula has been appended for your reference.

THERE ARE 5 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 cycle and ideal gases cycle:

(a) Define the following:

i. External combustion

(2 marks)

ii. Stroke

(1 mark)

iii. Ideal cycle

(2 marks)

(b) Figure 1 shows the basic component of the reciprocating engine. Label all the components completely.

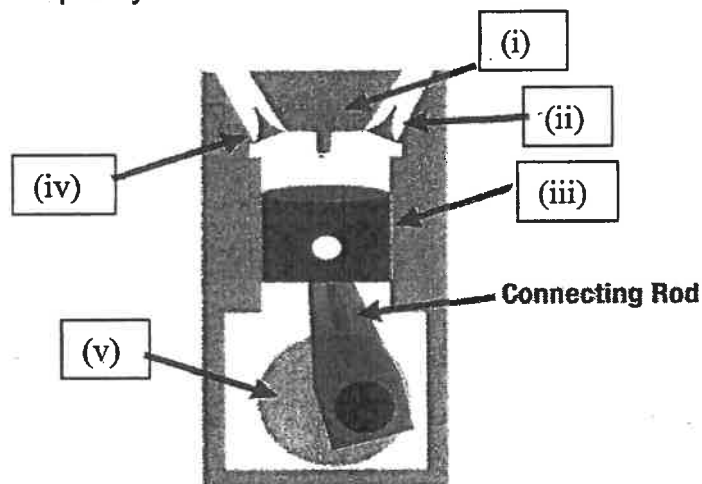


Figure 1: Reciprocating engine

(5 marks)

(c) Sketch and label the schematic diagram of each stroke for an actual four stroke spark ignition engine by showing the position of the valves, the piston, and the direction of the stroke.

(10 marks)

Question 2

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

- (a) Identify the steam phase change in ideal reheat Rankine cycle as shown in Table 1.

Table 1: Phases occur for each state in Reheat Rankine cycle

State	Component	Phase Occur
1	Pump	(i)
2	Boiler	(ii)
3	High Pressure Turbine (HPT)	(iii)
5	Low pressure turbine (LPT)	(iv)
6	Condenser	(v)

(5 marks)

- (b) A simple ideal Rankine cycle was modified by superheating the steam to a high temperature at a turbine. Indicate its effect (*decrease, increase or remains constant*) after modification on the following:

- i. Pump work input ($w_{pump,in}$) (1 mark)
- ii. Moisture content at turbine exit (1 mark)
- iii. Cycle efficiency (η_{th}) (1 mark)
- iv. Turbine work output ($w_{turb,out}$) (1 mark)
- v. Heat input (q_{in}) (1 mark)

- (c) Steam power plant operates on simple ideal Rankine cycle with water as the working fluid. Solve energy transfer as shown 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	100	$w_{pump,in}$ (i)	417.51
2	15000	q_{in} (ii)	433.05
3	15000	$w_{turb,out}$ (iii)	3310.8
4	100	q_{out} (iv)	2298.01

(10 marks)

Question 3

With reference to energy transfer in the marine refrigeration cycle:

- (a) State FOUR (4) thermodynamics processes for ideal vapor compression refrigeration cycle in refrigeration system. (5 marks)
- (b) Illustrate and label the Pressure - enthalpy (P-h) diagram for 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 the 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	140	(i)	(ii)	(iii)
2	800	275.389	(iv)	(v)
3	800	(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:

A gasoline engine operating on an ideal Otto cycle receives air at 12°C (T_1), 100 kPa (P_1), having a compression ratio (r) of 9. The heat addition at constant volume ($V_2 = V_3$) by combustion gives the highest temperature as 1500K (T_3) as shown in Table 4. Assume air standard assumptions are used for air and the internal energy is determined.

Table 4: Properties of Ideal Otto cycle

Processes/ State	Pressure, P (kPa)	Temperature, T (K)	Relative specific volume, v_r	Internal energy, u (kJ/kg)
1	100	285	v_{r1}	u_1
2	P_2	T_2	v_{r2}	u_2
3	P_3	1500	v_{r3}	u_3

- (a) Sketch Pressure-volume (P-v) diagram for the said cycle. (5 marks)
- (b) Calculate the following:
- temperature at the beginning of heat addition process (T_2) (7 marks)
 - amount of heat added (q_{in}) to this cycle, in kJ/kg unit. (8 marks)

Question 5

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

A simple ideal Rankine cycle with water as the working fluid operated between the pressure limits of 10MPa ($P_3 = P_2$) in the boiler and 30kPa ($P_4 = P_1$) in the condenser. The temperature at the turbine inlet is 600°C (T_3).

- (a) Determine the pump work input, ($w_{pump,in}$) (5 marks)
- (b) Determine the turbine work output, ($w_{turb,out}$) (10 marks)
- (c) Calculate the cycle thermal efficiency, (η_{th}) (5 marks)

Question 6

With reference to the problem solving of marine refrigeration cycle:

An ideal vapor-compression refrigeration cycle which uses refrigerant-134a (R-134a) as its working fluid maintains a condenser at 800kPa ($P_2 = P_3$) and the evaporator at -20°C ($T_4 = T_1$).

- (a) Determine the enthalpy at the condenser, h_2 in kJ/kg unit. (5 marks)
- (b) Calculate the heat absorbed (q_L), from the cold space in kJ/kg unit. (6 marks)
- (c) Calculate the heat rejection (q_H), to the surrounding in kJ/kg unit. (3 marks)
- (d) Determine the coefficient of performance (COP_R) of this system. (6 marks)

END OF EXAMINATION PAPER

THERMODYNAMICS FORMULAE

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

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)

$$s_2 = s_1$$

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

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

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

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

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

Power Cycles

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

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

Otto Cycle

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

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

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

$$\text{Thermal efficiency, } \eta_{th,Otto} = \frac{W_{net}}{Q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

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

Diesel Cycle

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

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

$$\text{Cutoff ratio, } r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$$

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

Joule-Brayton Cycle

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

$$q_{out} = h_4 - h_1 = c_p(T_4 - T_1)$$

$$\text{Pressure ratio, } r_p = \frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

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

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

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

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

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

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

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

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 lbf/in ³ 1 lbf/in ³ = 1728 lbf/ft ³ 1 kg/m ³ = 0.062428 lbf/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 J = 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 lbf · 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 ⁵ 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 lbf 1 lbf = 0.45359237* kg 1 ounce = 28.3495 g 1 slug = 32.174 lbf = 14.5939 kg 1 short ton = 2000 lbf = 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/lbf · °F = 4.1868 kJ/kg · °C 1 Btu/lbfmol · R = 4.1868 kJ/kmol · K 1 kJ/kg · °C = 0.23885 Btu/lbf · °F = 0.23885 Btu/lbf · K

*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	$1 \text{ m}^3/\text{kg} = 1000 \text{ L}/\text{kg} = 1000 \text{ cm}^3/\text{g}$	$1 \text{ m}^3/\text{kg} = 16.02 \text{ ft}^3/\text{lbm}$ $1 \text{ ft}^3/\text{lbm} = 0.062428 \text{ m}^3/\text{kg}$
Temperature	$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$ $\Delta T(\text{K}) = \Delta T(^{\circ}\text{C})$	$T(\text{R}) = T(^{\circ}\text{F}) + 459.67 = 1.8T(\text{K})$ $T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32$ $\Delta T(^{\circ}\text{F}) = \Delta T(\text{R}) = 1.8\Delta T(\text{K})$
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	$1 \text{ m}^3/\text{s} = 60,000 \text{ L}/\text{min} = 10^6 \text{ cm}^3/\text{s}$	$1 \text{ m}^3/\text{s} = 15,850 \text{ gal}/\text{min (gpm)} = 35.315 \text{ ft}^3/\text{s}$ $= 2118.9 \text{ ft}^3/\text{min (cfm)}$

^aMechanical 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	$c_0 = 2.9979 \times 10^8 \text{ m}/\text{s}$ $= 9.836 \times 10^8 \text{ ft}/\text{s}$
Speed of sound in dry air at 0°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	$h_{fg} = 2256.5 \text{ kJ}/\text{kg}$ $= 970.12 \text{ Btu}/\text{lbm}$