Name:___________________________ Instructor:____________ Section:__________ ENGR 222 - Final Exam February 17, 2017

Allowed Materials: *pencils and/or pens.*

ExamForm := 41

Honor Statement: *On my honor, I promise that I have not received any unauthorized assistance on this exam (I didn't look at another student's paper, I didn't view any unauthorized written materials, I didn't talk or listen to another student, I didn't use an unauthorized calculator, I didn't use any electronic device, any visual or auditory signals, or any other techniques of exchanging information with others.) I have maintained the highest standards of academic integrity while completing this exam.*

*Signed:*____

Please put your final answers on the answer sheet that was given to you. You must show your work to receive full credit.

The words "steam" can be used to describe water in any of the following states: compressed liquid, saturated liquid, saturated mixture, saturated vapor, and superheated vapor. If you see the word "steam", DO NOT assume that it is in a vapor state. Use the state postulate to determine the state.

Unless the problem states otherwise, assume the density of water is 1000 kg/m^3 or 62.4 lbm/ft^3.

Unless the problem states otherwise, assume that the atmospheric pressure is 101.325 kPa or 14.7 psia.

Read the questions carefully and CHECK YOUR UNITS.

DO NOT treat water as an ideal gas (especially if it is in a liquid state).

Be sure to check problems for violations of the first and/or second law of thermodynamics. If the problem violates one of the laws select the appropriate answer. Also, be aware of problems where not enough information is given. If there is not enough information (use the State Postulate to check), select the appropriate answer choice.

You may write on the exam. There is additional space on the back if you need it.

You have two hours to complete the exam. If you finish early, it is recommended that you check your work. Please turn in your exam, answer sheet, and steam table packet when you are done.

If you made any marks in your table packet, please erase them before turning in your packet.

Good luck!

1. (3 points) A device that violates the first or second law of thermodynamics is called:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"refrigerator"} \\ \text{"B"} & \text{"heat engine"} \\ \text{"C"} & \text{"reversible machine"} \\ \text{"D"} & \text{"isentropic machine"} \\ \text{"E"} & \text{"heat pump"} \\ \text{"F"} & \text{"perpetual motion machine"} \\ \text{"G"} & \text{"irreversible compressor"} \\ \text{"H"} & \text{"adiabatic machine"} \end{pmatrix}$$

2. (3 points) An example of an extensive property is:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"specific volume"} \\ \text{"B"} & \text{"specific weight"} \\ \text{"C"} & \text{"temperature"} \\ \text{"D"} & \text{"specific gravity"} \\ \text{"E"} & \text{"pressure"} \\ \text{"F"} & \text{"volume"} \\ \text{"G"} & \text{"quality"} \\ \text{"H"} & \text{"density"} \end{pmatrix}$$

3. (3 points) Which of the following is an example of an irreversibility?

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"friction"} \\ \text{"B"} & \text{"electrical resistance"} \\ \text{"C"} & \text{"unrestrained expansion"} \\ \text{"D"} & \text{"mixing of two fluids"} \\ \text{"E"} & \text{"inelastic deformation of solids"} \\ \text{"F"} & \text{"all of the above"} \end{pmatrix}$$

4. (3 points) According to the state postulate, two of what kind of properties are needed to completely specify the state of a simple compressible system?

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  i. extensive
 ii. intensive
iii. specific
 iv. independent
  v. dependent
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$$Choices = \begin{pmatrix} \text{"A"} & \text{"ii, iii \& v"} \\ \text{"B"} & \text{"i \& v"} \\ \text{"C"} & \text{"ii"} \\ \text{"D"} & \text{"ii \& iv"} \\ \text{"E"} & \text{"iii \& iv"} \\ \text{"F"} & \text{"i \& ii"} \\ \text{"G"} & \text{"i"} \\ \text{"H"} & \text{"none of these"} \end{pmatrix}$$

5. (3 points) Enthalpy is a combination property of which properties?

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  i. Heat
 ii. Shaft Work
iii. Flow Energy
 iv. Internal Energy
  v. Potential Energy
 vi. Kinetic Energy
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$$Choices = \begin{pmatrix} \text{"A"} & \text{"iii \& v"} \\ \text{"B"} & \text{"v \& vi"} \\ \text{"C"} & \text{"ii and iii"} \\ \text{"D"} & \text{"i \& ii"} \\ \text{"E"} & \text{"iv \& vi"} \\ \text{"F"} & \text{"i, ii, \& iii"} \\ \text{"G"} & \text{"iv \& v"} \\ \text{"H"} & \text{"iii \& iv"} \\ \text{"I"} & \text{"i, ii, iii, \& iv"} \end{pmatrix}$$

6. (3 points) A process in which entropy remains constant is called:

$$Choices = \begin{pmatrix} \text{"A"} & \text{"isometric"} \\ \text{"B"} & \text{"adiabatic"} \\ \text{"C"} & \text{"isentropic"} \\ \text{"D"} & \text{"isothermal"} \\ \text{"E"} & \text{"isobaric"} \end{pmatrix}$$

7. (3 points) A substance with a constant density is known as:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"gaseous"} \\ \text{"B"} & \text{"plasma"} \\ \text{"C"} & \text{"absolute"} \\ \text{"D"} & \text{"saturated"} \\ \text{"E"} & \text{"incompressible"} \\ \text{"F"} & \text{"adiabatic"} \\ \text{"G"} & \text{"superheated"} \\ \text{"H"} & \text{"isothermal"} \end{pmatrix}$$

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8. (3 points) An ideal cycle for vapor power plants that is internally reversible that has an isentropic pump and turbine is called the ...

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"Carnot cycle"} \\ \text{"B"} & \text{"Otto cycle"} \\ \text{"C"} & \text{"Rankine cycle"} \\ \text{"D"} & \text{"Vapor-compression cycle"} \\ \text{"E"} & \text{"Brayton cycle"} \end{pmatrix}$$

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9. (3 points) How can energy be transfered into a closed system?

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  i. heat transfer
 ii. work transfer
iii. mass transfer
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$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"iii"} \\ \text{"B"} & \text{"i \& ii"} \\ \text{"C"} & \text{"i \& iii"} \\ \text{"D"} & \text{"ii"} \\ \text{"E"} & \text{"ii \& iii"} \\ \text{"F"} & \text{"i, ii \& iii"} \\ \text{"G"} & \text{"i"} \end{pmatrix}$$

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10. (3 points) A formal definition of the specific heat c_v can be written as:
"the change in _________ with _____________ at constant ______________ "
(select the correct order of the words to fill in the blanks)

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"enthalpy, temperature, pressure"} \\ \text{"B"} & \text{"internal enregy, temperature, pressure"} \\ \text{"C"} & \text{"enthalpy, temperature, volume"} \\ \text{"D"} & \text{"internal energy, temperature, volume"} \\ \text{"E"} & \text{"pressure, temperature, enthalpy"} \\ \text{"F"} & \text{"temperature, internal energy, pressure"} \end{pmatrix}$$

11. (5 points) Helium is contained in a vertical, frictionless piston-cylinder device. The piston has a mass of $\text{mass} = 21 \cdot \text{kg}$ and a cross-sectional area of $\text{area} = 50 \cdot \text{cm}^2$. The absolute pressure of the gas in the device is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 90.4 \\ \text{"B"} & 99.1 \\ \text{"C"} & 108.0 \\ \text{"D"} & 116.6 \\ \text{"E"} & 125.1 \\ \text{"F"} & 133.9 \\ \text{"G"} & 142.5 \end{pmatrix} \cdot \text{kPa}$$

12. (5 points) The specific internal energy of steam at a $\text{temperature} = 150 \cdot {}^\circ\text{C}$ and with a density of $\rho = 12 \cdot \frac{\text{kg}}{\text{m}^3}$ is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 825.6 \\ \text{"B"} & 879.3 \\ \text{"C"} & 931.4 \\ \text{"D"} & 984.1 \\ \text{"E"} & 1036.7 \\ \text{"F"} & 1089.1 \\ \text{"G"} & 1141.7 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot \frac{\text{kJ}}{\text{kg}}$$

13. (5 points) A container divided into two equal parts each with a volume of 5 ft^3 is separated by a partition. On one side of the partition, air is at 90 °F and the $\text{pressure} = 11 \cdot \text{psig}$; the other side is evacuated. The partition is removed and air fills the empty space. If the temperature of the gas is $\text{temperature} = 60 \cdot °\text{F}$, the measured pressure of the air is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & -2.55 \\ \text{"B"} & 0.25 \\ \text{"C"} & 3.06 \\ \text{"D"} & 5.86 \\ \text{"E"} & 8.67 \\ \text{"F"} & 11.47 \\ \text{"G"} & 14.28 \\ \text{"H"} & 17.08 \end{pmatrix} \cdot \text{psig}$$

14. (5 points) A 5-m by 8-m wall with a $\text{thickness} = 30 \cdot \text{cm}$ and a thermal conductivity of 0.69 W/m °C separates a warm room maintained at 25°C from the cold outside at a constant $\text{temperature} = 3 \cdot °\text{C}$. The rate of entropy that is generated due to heat transfer through the wall is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.133 \\ \text{"B"} & 0.215 \\ \text{"C"} & 0.297 \\ \text{"D"} & 0.378 \\ \text{"E"} & 0.459 \\ \text{"F"} & 0.541 \\ \text{"G"} & 0.622 \\ \text{"H"} & 0.704 \end{pmatrix} \cdot \frac{\text{W}}{\text{K}}$$

15. (5 points) A piston cylinder containing $\text{mass} = 5 \cdot \text{kg}$ of saturated liquid R-134a at 20°C has an electrical resistance heater in it. The heater uses 4 kW over a $\text{time} = 2.1 \cdot \text{min}$ period. While the heater is on, the tank of refrigerant loses 100 kJ of heat to the surroundings. The final volume of the refrigerant is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 49.0 \\ \text{"B"} & 57.3 \\ \text{"C"} & 65.4 \\ \text{"D"} & 73.7 \\ \text{"E"} & 82.0 \\ \text{"F"} & 90.3 \\ \text{"G"} & 98.5 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot \text{L}$$

16. (5 points) A piston cyclinder initially contains 0.5 kg of air at 27°C and $\text{pressure} = 150 \cdot \text{kPa}$. Initially, the piston rests on stops and requires 300 kPa to move. The air is heated until it has a final temperature of $\text{temperature} = 820 \cdot {}^\circ\text{C}$. The boundary work done by the air during this entire process is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 70.7 \\ \text{"B"} & 78.5 \\ \text{"C"} & 86.4 \\ \text{"D"} & 94.3 \\ \text{"E"} & 102.1 \\ \text{"F"} & 109.9 \\ \text{"G"} & 117.8 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot \text{kJ}$$

17. (5 points) Air enters a compressor at 200 kPa and 300 K and leaves at 800 kPa and 500 K. The mass flow rate of the air is $\mathrm{mass} = 0.05 \cdot \frac{\mathrm{kg}}{\mathrm{s}}$. During the process, the compressor loses heat at a rate of $\mathrm{heat} = 16 \cdot \frac{\mathrm{kJ}}{\mathrm{kg}}$. Assuming potential and kinetic energy differences can be ignored, the power input to operate the compressor is closest to:

$$\mathrm{Choices} = \begin{pmatrix} \text{"A"} & 4.32 \\ \text{"B"} & 5.44 \\ \text{"C"} & 6.53 \\ \text{"D"} & 7.64 \\ \text{"E"} & 8.74 \\ \text{"F"} & 9.84 \\ \text{"G"} & 10.94 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot \mathrm{kW}$$

18. (5 points) A heat exchanger contains two liquids exchanging heat inside. Liquid A enters the heat exchanger at 90°C at a rate of 5 kg/s and leaves at a temperature of 40 °C and has a constant specific heat of $c_A = 2.4 \cdot \frac{\mathrm{kJ}}{\mathrm{kg \cdot K}}$. Liquid B enters at 5 °C at a rate of 8 kg/s and has a constant specific heat of $c_B = 4.9 \cdot \frac{\mathrm{kJ}}{\mathrm{kg \cdot K}}$. The heat exchanger is not insulated and loses heat to the surroundings at a rate of 70 kW. The temperature of liquid B as it leaves the heat exchanger is closest to:

$$\mathrm{Choices} = \begin{pmatrix} \text{"A"} & 14.60 \\ \text{"B"} & 15.90 \\ \text{"C"} & 17.21 \\ \text{"D"} & 18.52 \\ \text{"E"} & 19.83 \\ \text{"F"} & 21.14 \\ \text{"G"} & 22.44 \\ \text{"H"} & 23.76 \end{pmatrix} \cdot {}^\circ\mathrm{C}$$

19. (5 points) An insulated rigid tank filled with $volume = 3\cdot ft^3$ of air at $pressure = 20\cdot psia$ and 760 R. Half of the mass is let out of the tank. The temperature of the air inside the tank is held constant by means of an electrical resistance heater. The amount of electrical energy that the heater uses during the process is closest to:

$$1Btu = 1.055\cdot kJ$$

$$Choices = \begin{pmatrix} "A" & 3.21 \\ "B" & 4.09 \\ "C" & 4.97 \\ "D" & 5.86 \\ "E" & 6.74 \\ "F" & 7.62 \\ "G" & "not\ enough\ information" \end{pmatrix} \cdot kJ$$

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20. (5 points) A heat pump with R-134a as the working fluid uses a compressor that runs off $power = 80\cdot kW$. The refrigerant enters the condenser at a rate of $mass = 2.2\cdot \frac{kg}{s}$ at 70°C and 600 kPa and leaves as a saturated liquid at the same pressure. The COP of the heat pump is closest to:

$$Choices = \begin{pmatrix} "A" & 5.96 \\ "B" & 6.28 \\ "C" & 6.59 \\ "D" & 6.92 \\ "E" & 7.23 \\ "F" & 7.55 \\ "G" & 7.87 \end{pmatrix}$$

21. (5 points) Argon is compressed from $\text{pressure} = 110 \cdot \text{kPa}$ and $\text{temperature} = 23 \cdot {}^\circ\text{C}$ to a pressure of 750 kPa in an adiabatic compressor. The temperature of the argon after the reversible compression process is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 254.8 \\ \text{"B"} & 291.8 \\ \text{"C"} & 328.5 \\ \text{"D"} & 365.2 \\ \text{"E"} & 402.0 \\ \text{"F"} & 438.8 \\ \text{"G"} & 475.8 \end{pmatrix} \cdot {}^\circ\text{C}$$

22. (5 points) A heat engine has a furnace maintained at $\text{temperature} = 800 \cdot {}^\circ\text{F}$ and rejects heat into a nearby lake with a temperature of 55$^{\text{o}}$F. The working fluid rejects heat at a rate of $\text{heat} = 210 \cdot \frac{\text{Btu}}{\text{min}}$ into the lake. The maximum rate of work output for this heat engine is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 119.9 \\ \text{"B"} & 151.1 \\ \text{"C"} & 181.5 \\ \text{"D"} & 212.1 \\ \text{"E"} & 242.6 \\ \text{"F"} & 273.4 \\ \text{"G"} & 304.0 \end{pmatrix} \cdot \frac{\text{Btu}}{\text{min}}$$

23. (5 points) A hot block of silver with a $\text{mass} = 20 \cdot \text{kg}$ and an initial temperature of 400°C is dropped into a large lake with a $\text{temperature} = 19 \cdot {}^\circ\text{C}$. After a short period of time, the silver block reaches a state of thermal equilibrium with the large lake. The total entropy generated from this process is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 1.89 \\ \text{"B"} & 2.05 \\ \text{"C"} & 2.21 \\ \text{"D"} & 2.36 \\ \text{"E"} & 2.52 \\ \text{"F"} & 2.67 \\ \text{"G"} & 2.83 \end{pmatrix} \cdot \frac{\text{kJ}}{\text{K}}$$

24. (5 points) Steam enters an adiabatic turbine at 3 MPa and $\text{temperature} = 400 \cdot {}^\circ\text{C}$ and leaves at $\text{pressure} = 50 \cdot \text{kPa}$ and 100°C. The isentropic efficiency of the turbine is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 53.1 \\ \text{"B"} & 56.5 \\ \text{"C"} & 59.9 \\ \text{"D"} & 63.3 \\ \text{"E"} & 66.7 \\ \text{"F"} & 70.0 \\ \text{"G"} & 73.4 \end{pmatrix} \cdot \%$$

25. (5 points) An ideal Brayton cycle has air entering the compressor at $\text{temperature} = 27\cdot°\text{C}$ and $\text{pressure} = 110\cdot\text{kPa}$. The air enters the turbine at $\text{temperature} = 600\cdot°\text{C}$ and $\text{pressure} = 1200\cdot\text{kPa}$. Assuming that the system can be analyzed by using constant specific heats of air at the temperature of the air at the compressor inlet, the thermal efficiency of the cycle is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 40.44 \\ \text{"B"} & 43.46 \\ \text{"C"} & 46.47 \\ \text{"D"} & 49.48 \\ \text{"E"} & 52.48 \\ \text{"F"} & 55.47 \\ \text{"G"} & 58.51 \end{pmatrix}\cdot\%$$

26. (5 points) Mr. Reis is tired of making up questions. How many points do you want for this question?

$$\text{Choices} = \begin{pmatrix} \text{"A"} & -1 \\ \text{"B"} & 0 \\ \text{"C"} & 1 \\ \text{"D"} & 2 \\ \text{"E"} & 3 \\ \text{"F"} & 4 \\ \text{"G"} & 5 \end{pmatrix}$$

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$$Key_{1\_9} := \begin{pmatrix} 1 & Key_1 \\ 2 & Key_2 \\ 3 & Key_3 \\ 4 & Key_4 \\ 5 & Key_5 \\ 6 & Key_6 \\ 7 & Key_7 \\ 8 & Key_8 \\ 9 & Key_9 \end{pmatrix} \qquad Key_{10\_18} := \begin{pmatrix} 10 & Key_{10} \\ 11 & Key_{11} \\ 12 & Key_{12} \\ 13 & Key_{13} \\ 14 & Key_{14} \\ 15 & Key_{15} \\ 16 & Key_{16} \\ 17 & Key_{17} \\ 18 & Key_{18} \end{pmatrix}$$

$$Key_{19\_26} := \begin{pmatrix} 19 & Key_{19} \\ 20 & Key_{20} \\ 21 & Key_{21} \\ 22 & Key_{22} \\ 23 & Key_{23} \\ 24 & Key_{24} \\ 25 & Key_{25} \\ 26 & Key_{26} \end{pmatrix}$$

$$Key_{1\_9} = \begin{pmatrix} 1 & \text{"F"} \\ 2 & \text{"F"} \\ 3 & \text{"F"} \\ 4 & \text{"D"} \\ 5 & \text{"H"} \\ 6 & \text{"C"} \\ 7 & \text{"E"} \\ 8 & \text{"C"} \\ 9 & \text{"B"} \end{pmatrix}$$

$$Key_{10\_18} = \begin{pmatrix} 10 & \text{"D"} \\ 11 & \text{"G"} \\ 12 & \text{"E"} \\ 13 & \text{"A"} \\ 14 & \text{"F"} \\ 15 & \text{"E"} \\ 16 & \text{"A"} \\ 17 & \text{"G"} \\ 18 & \text{"D"} \end{pmatrix}$$

$$Key_{19\_26} = \begin{pmatrix} 19 & \text{"D"} \\ 20 & \text{"B"} \\ 21 & \text{"D"} \\ 22 & \text{"G"} \\ 23 & \text{"C"} \\ 24 & \text{"E"} \\ 25 & \text{"D"} \\ 26 & \text{"G"} \end{pmatrix}$$