NOTRE DAME UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

THERMODYNAMICS FINAL EXAMINATION
MEN 210

FALL SEMESTER 2003
DR. WALID C. ASSAF

NAME & ID NUMBER: ____

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- No questions please
- No borrowing
- Circle the correct answer.
- Do not explain an answer unless the question asks for explanation.
- Answer as many questions as you can.
- Read each question very carefully.
- Do not spend more than a few minutes on each question.
- No penalty for wrong answers.

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Air at 95 kPa and 20 degrees C enters an adiabatic compressor at low velocity and leaves the compressor discharge port at 1140 kPa and 380 degrees C with a velocity of 110 meters per second. The power input to the compressor is 5000 k Watts. Answer the following two questions.

One The first law of thermodynamics when applied to this problem reduces to:

(a) $W = Q + m_i h_i - m_e h_e$
(b) $-W = Q + m_i h_i - m_e h_e$
(c) $-w = (h_e - h_i) + V_e^2/2$
(d) $w = (c_{po})(T_i - T_e) + V_e^2/2$
(e) $-w = (u_e - u_i) + V_e^2/2$

Two The air mass flow rate in kilograms per second can be found by dividing:

(a) The work input by 5000 kW
(b) The heat input by the work output in kJ per kg
(c) The power input by the work input in kJ per kg
(d) The power input by the work output in kJ per kg
(e) The mass flow rate is impossible to find in this problem

Air flows in a pipeline at 500 kPa and 20 degrees C where enthalpy has a value of 300 kJ per kg. The line is connected to an evacuated vessel. The valve is now open and air flows into the vessel until the pressure inside reaches 500 kPa. Answer the following:

Three If the process occurs adiabatically, the first law reduces to the following form:

(a) $m_i = m_e$ (b) $m_1 = m_2$ (c) $m_e = m_1$
(d) $m_i = m_1$ (e) $m_i = m_2$

where the subscripts (i) and (e) refer to input and output mass flow and the subscripts (1) and (2) represent mass present in the control volume at initial and final states.

Four Assuming constant specific heats, the final temperature in the vessel in degrees Kelvin is:

(a) 300 (b) 400 (c) 412 (d) 500 (e) 290

Five Methane gas is contained in a cylinder fitted with a piston at a temperature of 10 degrees C and a pressure of 200 kPa and a volume of 200 liters. The gas is now compressed slowly in an isothermal process to 600 kPa. This process must follow a path given by:

(a) pv^n = constant (b) pv^k = constant (c) pv = constant
(d) none of these describes the path for the process correctly

Six What criteria is available that would give us an indication whether or not methane can be treated as an ideal gas?

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Seven Which of the following properties of an ideal gas is/are not a function of pressure?

- (a) constant pressure specific heat
- (b) internal energy
- (c) constant volume specific heat
- (d) all of the above
- (e) none of the above

Eight The constant pressure specific heat of air at 300 K is 29.071 kilo J per kmole per K degree and its molecular mass/weight is 28.97. A mass of 1.6 kg of air at 300 K is enclosed in a rigid vessel. Assuming ideal gas behavior and no heat loss, the heat necessary to raise air temperature to 250 degrees C in kJ is:

(a) 358 (b) 255.8 (c) 223.9 (d) 159.9 (e) none of the above

$Q = \Delta u + w^{\to 0}$
$= (1.6)(c_v)(523 - 300)$

$c_p - c_v = R$
$1.003 - c_v = \ldots$
$\Rightarrow c_v = 0.\ldots$

Nine In the equations that were given in question number (1) parts (c), (d) and (e) the SI unit for specific work (w) is:

- (a) square metes per square seconds
- (b) square meters per kg per square seconds
- (c) kilo joule per kilogram
- (d) both parts (a) and (b)
- (e) both parts (a) and (c)

Ten In a simple steam power plant low pressure steam leaves the turbine and enters the condenser where one of the following processes takes place:

- (a) heat is transferred to the steam causing it to condense
- (b) heat is transferred from the cooling water causing its temperature to drop
- (c) large quantities of cooling water are pumped
- (d) evaporation of water takes place
- (e) none of the above is true

Eleven In steam power plants pressurized water leaves the boiler in a state of:

- (a) *super heat* in order to increase the thermal efficiency of the plant
- (b) *saturation* because this is cheaper and uses less energy to heat
- (c) *super heat* in order to reduce wet steam at the exit of the turbine
- (d) both parts (a) and (c) are correct
- (e) none of the above is correct

Twelve A thermodynamic system can best be described by one of the following statements:

- (a) a quantity of matter having a moving boundary at constant speed
- (b) a quantity of matter which has surroundings
- (c) a quantity of matter having variable mass
- (d) a quantity of matter having fixed mass and identity
- (e) None of these

Thirteen In vapor compression refrigeration cycle the refrigerant leaves the condenser as:

(a) high pressure gas at high temperature
(b) saturated vapor at low pressure
(c) low pressure liquid at high temperature
(d) liquid at high pressure
(e) none of the above

Fourteen An isolated system is one which

(a) is not influenced by the surroundings
(b) has no boundary
(c) does not allow heat alone to cross its boundary
(d) does not allow work alone to cross its boundary
(e) none of these

Fifteen The thermodynamic approach to analysis which reduces the number of variables to a few that can be handled is:

(a) the microscopic approach
(b) the macroscopic approach
(c) the control volume approach
(d) only the statistical approach
(e) none of these

Sixteen Temperature, volume, density and pressure are thermodynamic properties or variables classified as:

(a) extensive properties
(b) intensive properties
(c) only temperature and volume are extensive properties
(d) only pressure and density are intensive properties
(e) volume is an intensive property

Seventeen The term phase in thermodynamics refers to:

(a) a quantity of matter which is partly homogeneous
(b) a quantity of matter having fixed mass
(c) a quantity of matter in the solid state region
(d) a quantity of matter that is homogenous throughout
(e) none of the above

Eighteen A thermodynamic property or variable such as pressure, temperature and specific volume can best be described as:

(a) any variable that depends on the state of the system
(b) any variable that does not depend on the state of the system but depends on the path by which the system arrived at a given state
(c) any variable that depends on the state of the system and is independent of the path referred to in part b above
(d) any quantity to which the first law of thermodynamics is applicable

Nineteen A quasi equilibrium process is one in which:

(a) there is a considerable deviation from thermodynamic equilibrium
(b) the deviation from thermodynamic equilibrium is infinitesimal
(c) the work level of a state is fixed
(d) the heat level of the state is fixed
(e) none of the above

Twenty A pure substance is one which has:

(a) a homogeneous chemical composition
(b) an invariable and homogeneous chemical composition
(c) one single phase
(d) not more than three phases
(e) none of the above

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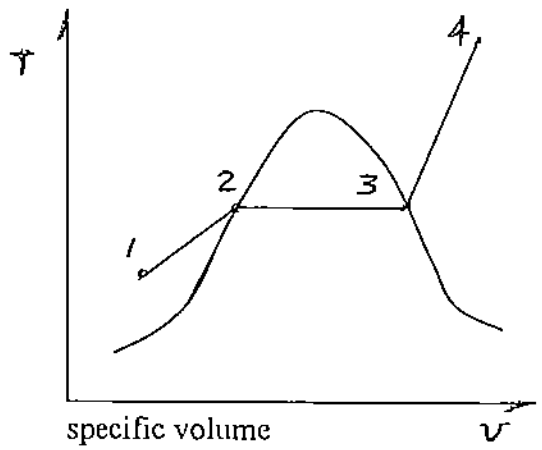
temperature properties of water



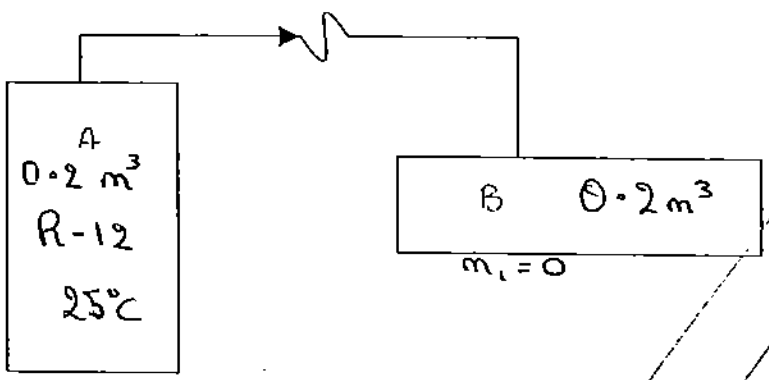
specific volume

Figure (1)
temperature vs. specific volume

Twenty One In Figure (1) above, the line 1,2,3,4 describes the path taken only by a:

(a) constant temperature process
(b) constant pressure process
(c) polytropic process only
(d) constant volume process only
(e) none of these

Figure (2) Valve



Tank (A)
200 liters

Tank (B)
200 liter

Consider tanks (A) and (B) connected by a valve as shown in Figure (2) above. Each tank has a volume of 200 liters. Tank (A) contains refrigerant F-12 at 25 degrees C, 10% liquid and 90% vapor by volume. Tank (B) is evacuated. The valve connecting the tanks is now opened and saturated vapor flows out of tank (A) until the pressure in (B) reaches that of (A) at which point the valve is closed. This process occurs slowly and is isothermal at 25 degrees C. Answer the following questions:

Twenty Two The specific volume in tank B after the expansion takes place is in cubic meters per kilogram equal to:

(a) 0.026854 (b) 0.000763 (c) 0.036555 (d) 0.00774

Twenty Three The quality in tank (B) after the expansion is:

(a) zero (b) one (c) 0.500 (d) 75%

Twenty Four The quality in tank (A) before the valve is opened is:

(a) 0.2056 (b) 0.2066 (c) 0.2086 (d) 0.203

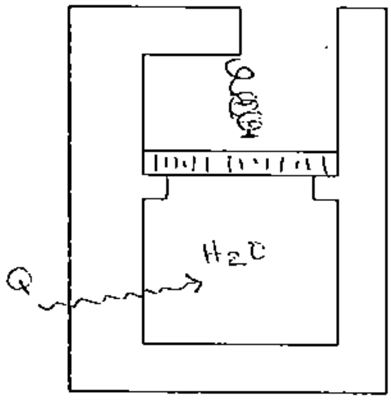
Twenty Five The total mass of refrigerant F-12 in tank (A) before the expansion takes place is (in kilograms) equal to:

(a) 30 (b) 32.915 (c) 7.447 (d) 6.703

Twenty Six The work done in a process of an ideal gas system undergoing a quasi-equilibrium polytropic compression process is given by:

(a) $\int v\,dp$ (b) $R(T_2 - T_1) \div (1 - n)$ (c) $(P_2V_2 - P_1V_1) \div (1 + n)$

(d) $(P_1V_1 - P_2V_2) \div (1 - n)$



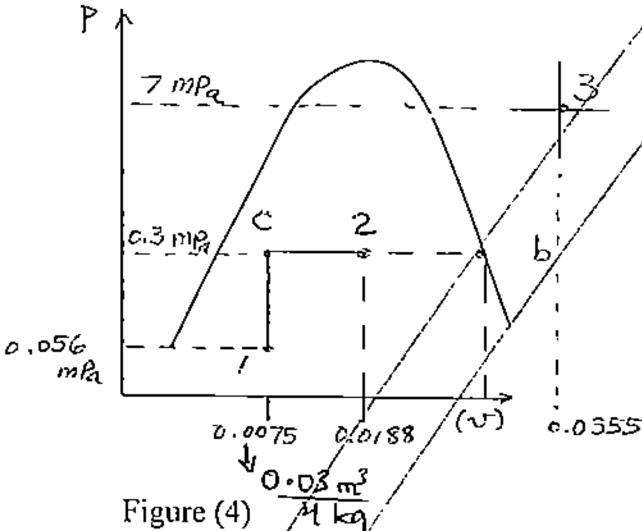


Figure (3)
system showing piston, spring and the stops

Figure (4)
vertical axis is pressure in MPa
horizontal axis is specific volume

A frictionless piston having an area of 0.06 square meters rests on the stops shown in Figure (3) above such that the contained volume in the cylinder equals (0.03) cubic meters. The piston's mass is such that the 300 KPa is required to raise the piston against ambient pressure outside. When the piston has moved to a point where the contained volume is 0.075 m^3, the piston encounters a spring with a linear constant of 360 kN/m. Initially the cylinder contains 4 kg of saturated water (liquid plus vapor at 35 °C. This system is heated until the final pressure inside is 7 MPa. Answer the following questions:

Twenty Seven The path for the process on the PV-diagram shown in Figure (4) is given by the sequence:

(a) 1-2-3 (b) 1-a-2-b-3 (c) 1-c-2-b-3 (d) 1-c-2-3

Twenty Eight The first law for the process is written as:

(a) ${}_1Q_2 + {}_2Q_3 = (E_3 - E_1) + {}_1W_2 + {}_2W_3$
(b) ${}_1Q_3 = m\,(u_3 - u_1)$
(c) ${}_1Q_3 = m\,(u_3 - u_1) + {}_1W_3$
(d) both part (a) and (c) are correct
(e) none of the above is correct

$300\,kPa(0.0188 - 0.0075) + \left(\frac{2000+300}{2}\right)(0.0355 - 0.0188) \cong 64.3$

Twenty Nine The work for the process in kilo J per kilogram is:

(a) 250 (b) 258 (c) 64 (d) 68 (e)none of these

A rigid container is filled with super heated steam at 700 kPa and 200 degrees C. Answer the following questions:

Thirty Steam begins to condense when the container is cooled to a temperature of in degrees C equal to:

(a) 165 (b) 161 (c) 170 (d) 174 (e) 200

$v_g = 0.2999$

Thirty One Fifty percent of the steam condenses at a temperature measured in degrees C equal to:

(a) 165 (b) 155 (c) 130 (d) 134 (e) 180 (Trial and error)

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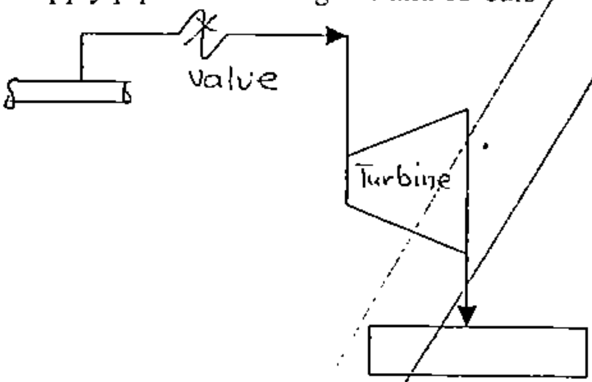
steam supply pipe 320 ° C degrees and 15 bars



small tank 0.60 m^3

initially evacuated

Figure (5)

Figure five above shows a pipe line with running steam at 593 K and a pressure of 15 bars. The pipe line is connected through a turbine to a small evacuated tank having a volume of 0.6 cubic meters. The valve is opened and 2.96 kilograms of steam fills the small tank until the pressure is 15 bars. The valve is then closed. The filling process takes place adiabatically. KE and PE terms are ignored. The work produced by the turbine in this process is 386.6 kJ. The control volume consisting of valve, turbine and small tank is insulated and the process is adiabatic.

→ 1500000 N/m^2

$$2.96(3082) = (2.96)(u_2) - 0 + 0 + 386.6$$

$$m_i h_i = (m_2 u_2 - m_1 u_1) + 0 + W$$

Thirty Two The final internal energy (u_2) in the small tank is in kJ/kg:

(a) 3081.9 (b) 2826.1 (c) 2951.3 (d) 2817.1

Thirty Three The final temperature in the small tank is in degree C equal to:

(a) 320 (b) 400 (c) 198.32 (d) 311

Thirty four If the expansion of the steam into the small tank is to take place under the same conditions but without the turbine, then the final temperature in the small tank will be in degree C:

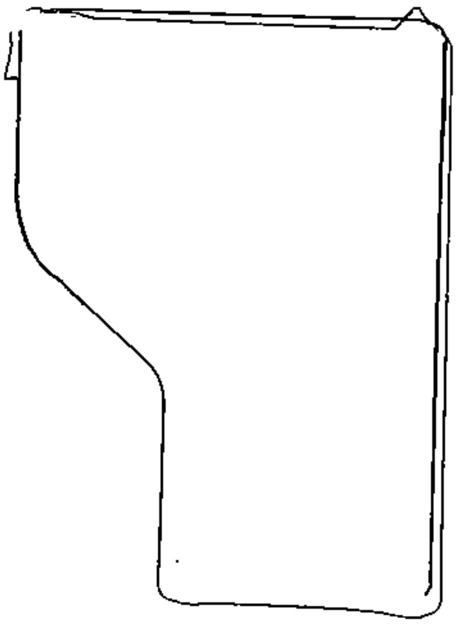
(a) 311 (b) 477 (c) 400 (d) 320

Thirty Five In filling of the small tank and for the control volume identified, the generated entropy is:

(a) more when the turbine is removed and no work is produced
(b) it is less when the turbine is removed and no work is produced
(c) the generated entropy is the same in both cases
(d) no entropy is generated in either case because the process is adiabatic

Thirty Six When the change in entropy between two thermodynamic states is given in the form $S°(T_2) - S°(T_1) - R\ Ln\ [P_2/P_1]$ the assumption made must have been that:

(a) the specific heats are variable
(b) the specific heats are constant
(c) only the constant volume specific heat is a variable
(d) ideal gas laws do not apply
(e) none of the above applies in this case



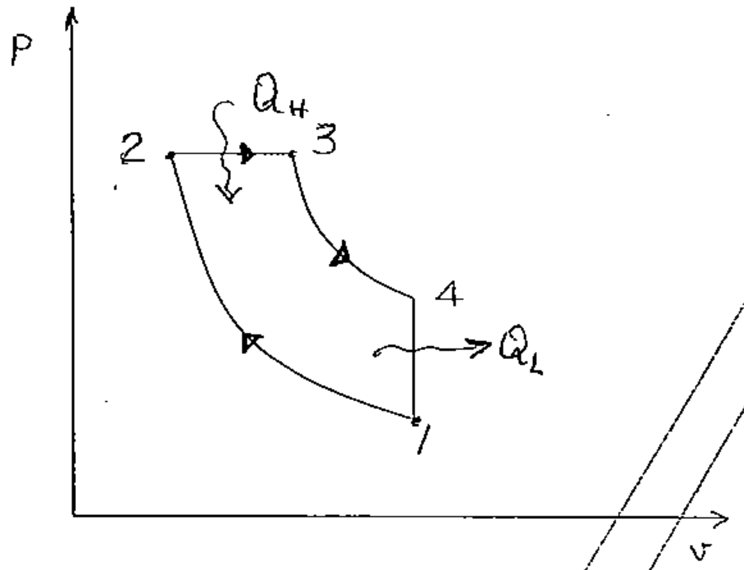


Figure (6)
Air Standard Diesel Cycle

The displacement of an internal combustion engine is 3 liters. The processes within each cylinder of the engine are modeled as an air-standard Diesel cycle with a cut off ratio of 2.5. The state of the air at the start of compression is fixed by:

$P_1 = 95$ kPa $T_1 = 22$ °C $V_1 = 3.17$ liters

Refer to the above Figure (6).

at 3, fuel injection stops, cut off ratio $= 2.5 = \frac{V_3}{V_2}$

Problem 37 The ratio of the volumes V_2/V_3 is:

(a) 3   (b) 0.4   (c) 3.1   (d) 2.5   (e) none of these

Problem 38 The difference between the volumes V_2 and V_1 measured in liters is:

(a) 3.1   (b) 2.5   (c) 3   (d) 0.4   (e) we don't know

Problem 39 When the value of υ_{r1} is 647.9 then the value of υ_{r2} must be on of the following:

(a) 647.9   (b) 45.223   (c) 34.740   (d) 2.5

Ignore

Problem 40 The net heat for this cycle can best be found by using one of the following relations:

(a) Sum of Q for the cycle is given by $[h_2 - h_1]$

(b) Sum of Q for the cycle can be found from $T\,\Delta S$

(c) The net heat for the cycle has to be equal to W cycle = (mass) $[(h_3 - h_2) - (u_1 - u_1)]$

(d) The net heat Q for the cycle is best found by calculating ΔU

The gear box problem done in class and shown in figure E6.5 on page 219 of the third edition shows that the input shaft is rated at 600 kilo Watts and the output shaft transmits 588 kilo Watts to the drive train. Answer the following questions:

Problem 41 The time rate of availability transfer accompanying heat measured in kilo Watts is:

(a) 1.41 (b) -1.41 (c) zero (d) not known

Problem 42 The time rate of availability transfer accompanying work is measured in kilo Watts is:

(a) zero (b) –12 (c) 12 (d) unknown

Problem 43 For the enclosed system boundary made up of the gear box the total irreversibility is measured in kilo Watts is:

(a) 59 (b) –59 (c) 10.59 (d) 15

Answer the following questions about the Ideal Rankin Cycle:

Problem 44 The working fluid passing through the boiler experiences no pressure drop because:

(a) There is no entropy change

(b) There is heat transfer

(c) There is no friction

(d) There is variation in specific volume

Problem 45 The working fluid passing through the boiler:

(a) remains at constant temperature

(b) remains at constant temperature only during phase change

(c) changes both temperature and pressure

(d) experiences too many unknown changes in thermodynamic states

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Answer the following questions regarding gasoline and diesel fired piston type reciprocating internal combustion engines.

Problem 46 The compression for the ideal air standard Otto cycle process is modeled as:

(a) a steady state steady flow process
(b) a system undergoing entropy change due to change in temperature
(c) a system experiencing heat transfer
(d) a flow process experiencing no heat transfer while entropy changes
(e) a system undergoing an adiabatic process

Problem 47 The efficiency of the ideal air standard cycle:

(a) is given by the expression $[1 - T_L/T_H]$
(b) is a function of pressure only
(c) is a function of compression ratio only
(d) is a function of to many unknown variables

Problem 48 In a real gasoline fired engine the compression stroke involves:

(a) compressing air only
(b) compressing a mixture of air and gasoline
(c) injecting gasoline at the end of compression
(d) non of the above

Problem 49 Auto ignition is a problem that:

(a) happens in diesel fueled engines
(b) occurs in gasoline engines
(c) does not occur in any engine
(d) in gas turbines only

Problem 50 Two stroke engine has an advantage over four strokes because:

(a) Its displacement is larger
(b) Its efficiency is higher
(c) It delivers one power stroke every revolution
(d) It delivers one power stroke in two revolutions
(e) None of the above is really true