In Session Practice Problems – Thermodynamics (EGN 3343)

January 2024

Hello everyone,

These are some problems that, in my experience, provide students with a wider understanding of the topics covered in the first weeks of classes. I will go over these and other problems during my sessions. I highly recommend that you attend these sessions to solve any doubts.

Disclaimer: There is no guarantee that any of these problems will be included in any exam, so the best way to approach these problems is like practice problems that will help you familiarize yourself with important concepts learned during the semester. Finally, do not use this guide as your ONLY study resource for the exams.

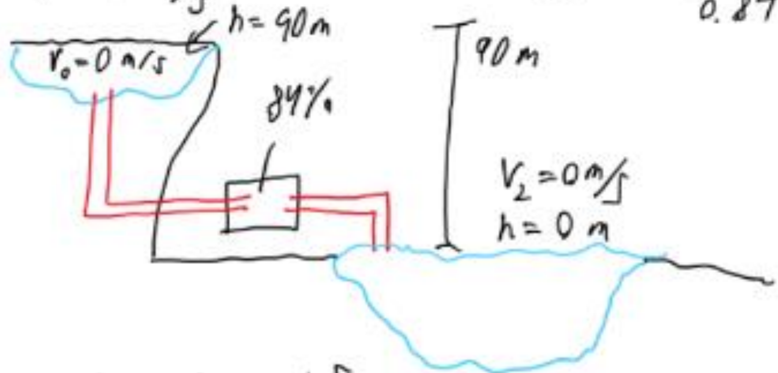
Important Note: All problems and diagrams presented here were extracted from Cengel, Yunus, et al. Thermodynamics: An Engineering Approach. Available from: Yuzu Reader, (9th Edition). McGraw-Hill Higher Education (US), 2018.

2.12 In a hydroelectric power plant, 65 m3/s of water flows from an elevation of 90 m to a turbine, where electric power is generated. The overall efficiency of the turbine–generator is 84 percent. Disregarding frictional losses in piping, estimate the electric power output of this plant.

2-121

$\dot{V} = 65\ m^3/s$ $h = 90\ m$ efficiency = 84%

0.84



$$E_2 - E_1 = \Delta E$$

$$(\underbrace{\cancel{KE_2}}_{\text{since } V=0} + \underbrace{\cancel{PE_2}}_{\text{since } h=0}) - (\underbrace{\cancel{KE_1}}_{\text{since } V=0} + PE_1) = \Delta E$$

$$-PE_1 = \Delta E$$

If water losses energy, the pump gains, so if we look at the change in energy of the pump, it must be positive

$$\Delta E_{(pump)} = mgh$$

we could find mass with volume and density, but we have rate of volume not volume, so we cannot find mass but mass per unit time. Therefore, we cannot find energy but power

$\rho = \frac{\dot{m}}{\dot{V}} \rightarrow \dot{m} = \rho \dot{V} \rightarrow \dot{m} = 1000 \frac{Kg}{m^3} \; 63 \frac{m^3}{s}$

$\dot{m} = 63000 \frac{Kg}{s}$

$\Delta \dot{E}_{pump} = \dot{m} g h = 63000 \frac{Kg}{s} (9.81 \frac{m}{s^2})(90m)$

$\Delta \dot{E}_{pump} = 55622700 \frac{N \cdot m}{s} \left(\frac{J}{J}\right) W$

But is not a 100% efficient, so we need to find how much energy are we actually getting

$\text{Efficiency} = \frac{\text{what we get out}}{\text{what we put in}}$

$\text{Eff} = \frac{\text{out}}{\text{in}} \rightarrow \text{out} = \text{Eff} \cdot \text{in}$

$\text{out} = 55622700 \, W \, (0.84)$

$= 46723068 \, W$

$\approx 46.7 \, MW$

3–29E One pound-mass of water fills a container whose volume is 2 ft3. The pressure in the container is 100 psia. Calculate the total internal energy and enthalpy in the container.

—//— $\boxed{\text{Water}}$

3 - 29E

$V = 2\,ft^3$ $m = 1\,lbm$ $P = 100\,psia$

$v = \frac{V}{m} = \frac{2\,ft^3}{1\,lbm} = 2\,ft^3/lbm$

$u = ?$ $h = ?$

Look at table A-5E at 100 psi:

v of sat. water $= 0.01774\,ft^3/lbm$

v of sat. gas $= 4.4327\,ft^3/lbm$

Our value ($2\,ft^3/lbm$) is between, so our water must be a sat. mixture.

For any value that is a sat. mixture, we know that:

$$y_{avg} = y_f + x\,\underbrace{y_{fg}}_{y_g - y_f}$$

- Where y is the specific volume (v), enthalpy (h), or interal energy (u)

- So we first need to find x, and we know all specific volumes

$$\underbrace{v_{av}}_{2\ ft^3/lbm\ \text{Given}} = \underbrace{v_f}_{0.01774\ \text{Table}} + x\, v_{fg}$$

$$v_{fg} = v_g - v_f = \underbrace{4.4327}_{\text{Table}} - 0.01774$$

$$v_{fg} = 4.41496$$

$$v_{av} = v_f + x\, v_{fg}$$

$$\frac{v_{av} - v_f}{v_{fg}} = x$$

$$\frac{2 - 0.01774}{4.41496} = x \rightarrow x = 0.448987$$

- Now that we have x, we can use a similar equation to find u (internal energy) and h (enthalpy)

- u

$$u = \underbrace{u_f}_{\text{Table}} + x\, \underbrace{u_{fg}}_{\text{Table}}$$

$$u = 298.19\ \frac{Btu}{lbm} + 0.448987\left(807.29\ \frac{Btu}{lbm}\right)$$

$$u = 660.652\ \frac{Btu}{lbm}$$

$$\underbrace{U}_{\text{Total internal energy}} = \underbrace{u}_{\text{internal energy per unit mass}} \cdot \underbrace{m}_{\text{mass}}$$

$$U = 660.652\ \frac{Btu}{\cancel{lbm}}(1\ \cancel{lbm}) = \boxed{661\ Btu}$$

- H

$$h = h_f + x\,h_{fg}$$

$$h = 298.51\ \frac{Btu}{lbm} + 0.448487\left(888.99\ \frac{Btu}{lbm}\right)$$

$$h = 697.655\ \frac{Btu}{lbm}$$

$$\underbrace{H}_{\text{Total Enthalpy}} = \underbrace{h}_{\text{Enthalpy per unit mass}} \cdot \underbrace{m}_{\text{mass}}$$

$$H = 697.655\ \frac{Btu}{\cancel{lbm}}(1\ \cancel{lbm})$$

$$\boxed{H = 698\ Btu}$$

3–78 A rigid tank whose volume is unknown is divided into two parts by a partition. One side of the tank contains an ideal gas at 927°C. The other side is evacuated and has a volume twice the size of the part containing the gas. The partition is now removed and the gas expands to fill the entire tank. Heat is now transferred to the gas until the pressure equals the initial pressure. Determine the final temperature of the gas.

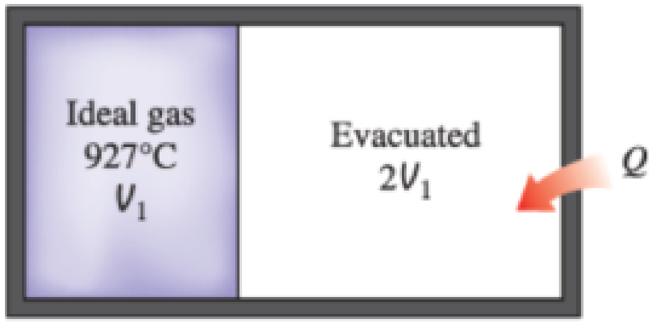


FIGURE P3–78

$PV = RTm$

Pressure, Volume, Gas constat, mars, Temperaturt, kelving

$R = 0.287 \frac{kJ}{kg \cdot K}$

$T_0 = 927°C + 273.15$

$T_0 = 1200.15$

$\boxed{P_0 = ?}$

$P_0 = \frac{RTm}{V}$

$\frac{m}{V} = \rho$

$v = \frac{V}{m}$

$v = \frac{1}{\rho}$

$\rho = \frac{1}{v}$

$P_0 = RT\rho$

$P_0 = 0.287 \frac{kJ}{kg \cdot \cancel{K}} (1200.15 \cancel{K}) \rho_0$

$P_0 = 344.44 \frac{kJ}{kg} \cdot \rho_0$

P_0	P_2	$P_0 = P_3$
T_1	T_2	$\boxed{T_3 = ?}$
v_1	$3v_1$	$3v_1$
m	m	m

$$\rho_0 = \frac{m}{v_1} \qquad \rho_2 = \frac{m}{3v_1} \qquad \rho_3 = \frac{m}{3v_1}$$

$$\rho = \rho_0 \qquad \rho_2 = \frac{\rho_0}{3} \qquad \rho_3 = \frac{\rho_0}{3}$$

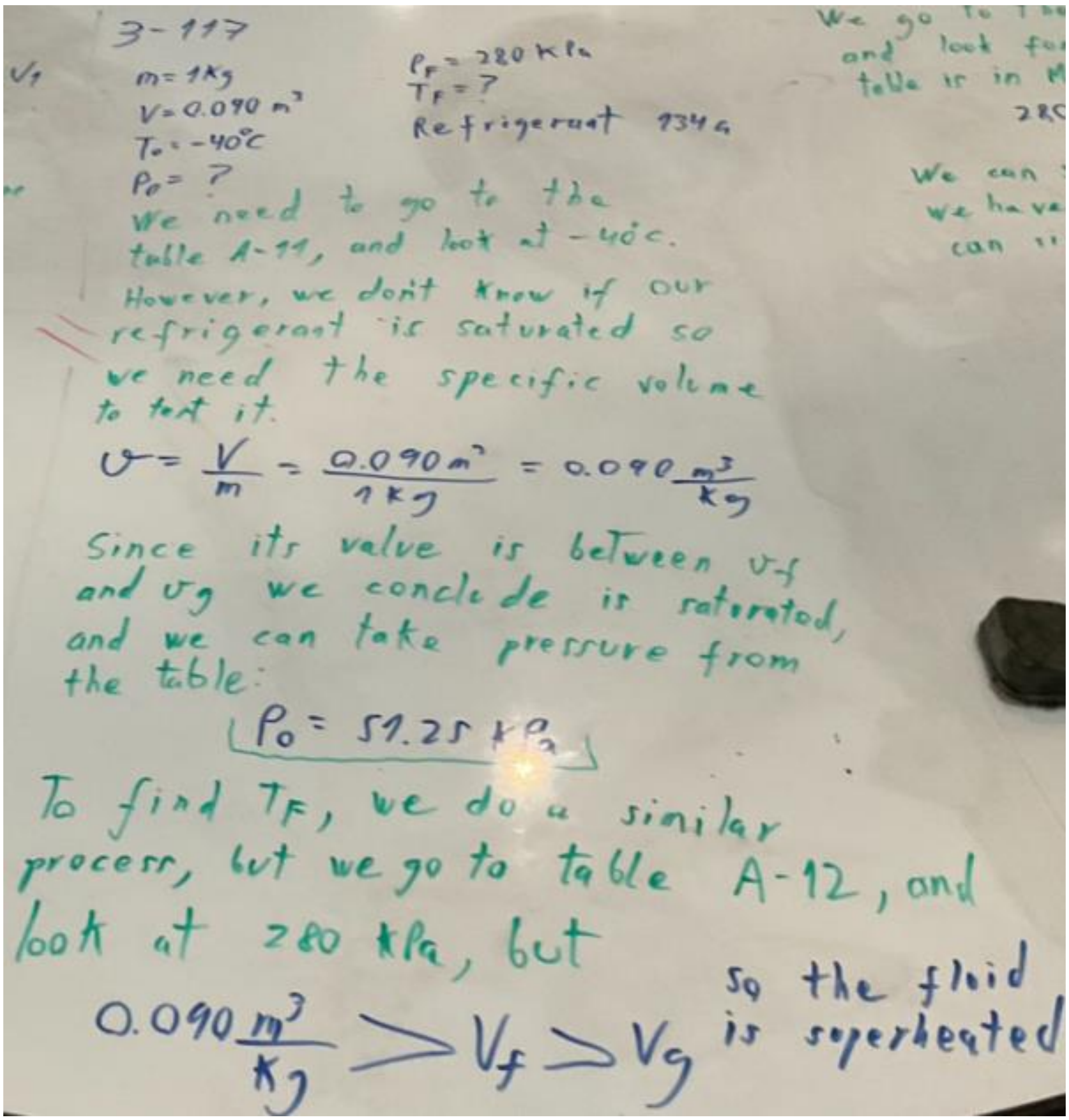
$$P_3 = R_3 T_3 \rho_3 \longrightarrow T_3 = \frac{P_3}{R_3\,\rho_3}$$

$$T_3 = \frac{344.44\,\cancel{\frac{kJ}{kg}} \cdot \rho_0}{0.287\,\cancel{\frac{kJ}{kg}}\cdot K \cdot \frac{\rho_0}{3}}$$

$$T_3 = 3600.41\ K$$

$$\boxed{T_3 = 3327.26\ ^{\circ}C}$$

3–117 One kilogram of R-134a fills a 0.090-m3 rigid container at an initial temperature of -40°C. The container is then heated until the pressure is 280 kPa. Determine the initial pressure and final temperature.



3-117

$m = 1\,kg$
$V = 0.090\,m^3$
$T_o = -40°C$
$P_o = ?$

$P_F = 280\,kPa$
$T_F = ?$
Refrigerant 134a

We need to go to the table A-11, and look at -40°C.
However, we don't know if our refrigerant is saturated so we need the specific volume to test it.

$$v = \frac{V}{m} = \frac{0.090\,m^3}{1\,kg} = 0.090\,\frac{m^3}{kg}$$

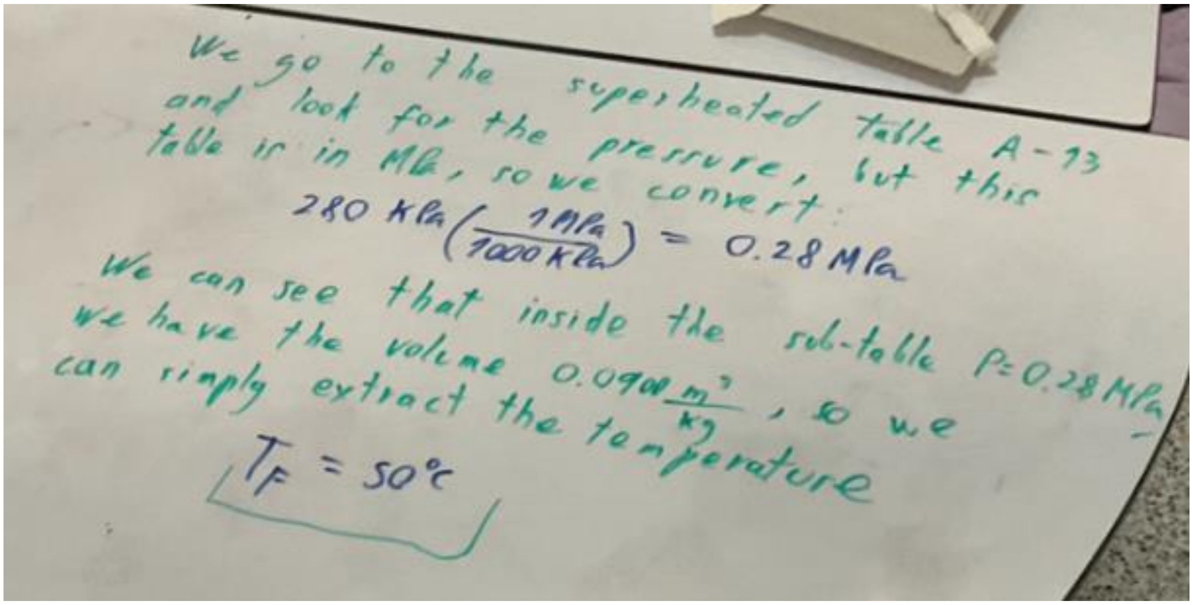
Since its value is between v_f and v_g we conclude is saturated, and we can take pressure from the table:

$$P_o = 51.25\,kPa$$

To find T_F, we do a similar process, but we go to table A-12, and look at 280 kPa, but

$$0.090\,\frac{m^3}{kg} > V_f > V_g$$

so the fluid is superheated



We go to the superheated table A-13 and look for the pressure, but this table is in MPa, so we convert:

$$280\ kPa\left(\frac{1\ MPa}{1000\ kPa}\right) = 0.28\ MPa$$

We can see that inside the sub-table $P = 0.28\ MPa$ we have the volume $0.0900\ \frac{m^3}{kg}$, so we can simply extract the temperature

$$\boxed{T_F = 50°C}$$

3–121 A 10-kg mass of superheated refrigerant-134a at 1.2 MPa and 70°C is cooled at constant pressure until it exists as a compressed liquid at 20°C. Determine the change in volume and find the change in total internal energy.

3 - 121BC

$m = 10\,kg$ $P_o = 1.2\,MPa$ | $T_f = 20°C$

$T_o = 70°C$ Superheated Refrigerant | compressed liquid

$\Delta V = ?$ $\Delta U = ?$

We first look at the ΔV and ΔU equations

$\Delta V = m(v_f - v_o)$ $\Delta U = m(u_f - u_o)$

First, lets find v_o and u_o by looking at Table A-13, subtable 1.2 MPa, $T = 70°C$

$v_o = 0.019502\ \frac{m^3}{kg}$ $u_o = 277.23\ \frac{kJ}{kg}$

There isn't a compressed liquid table, but if we use sat. liquid values, it will provide an adequate approx, so we go at table A-11 and look at $T = 20°C$. again we use sat. liquid values, so v_f and u_f

$v_f = 0.0008160\ \frac{m^3}{kg}$ $u_f = 78.85\ \frac{kJ}{kg}$

Now, we just have to replace in the equations

$$\Delta V = 10\,\cancel{kg}\left(0.0008110\,\frac{m^3}{\cancel{kg}} - 0.019502\,\frac{m^3}{\cancel{kg}}\right)$$

$$\Delta V = -0.18686\,m^3 \approx -0.187\,m^3$$

the volume reduced by $= 0.187\,m^3$

$$\Delta u = 10\,\cancel{kg}\left(78.85\,\frac{kJ}{\cancel{kg}} - 277.23\,\frac{kJ}{\cancel{kg}}\right)$$

$$\Delta u = -1983.8\,kJ \approx -1984\,kJ$$

The internal energy reduced by $= 1984\,kJ$