# 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 Chapter 4 of the book. 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.

4–18E During an expansion process, the pressure of a gas changes from 15 to 100 psia according to the relation P = a + b, where a = 5 $\frac{psia}{ft^3}$ and b is a constant. If the initial volume of the gas is 7 $ft^3$, calculate the work done during the process. Answer: 181 Btu

4.18E

$P_0 = 15\ psi \quad P_p = 100\ psi$

$a = 5\ psi/ft^3 \quad b = constant$

$P = aV + b$

We go back to the work formula

$W = \int P\,dV$ ?

$W = \int_{V_0}^{V_f} aV + b\,dV$

$V_0 \rightarrow 7 ft^3$

We need the final volume, so we go back to the equation of pressure given

$P = aV + b \rightarrow$ ?

Besides $V_f$ we have a second unknown b, but since we have our initial conditions, we could solve for b

$b = P - aV = 15\,psi - 5\frac{psi}{\cancel{ft^3}}(7\cancel{ft^3})$

$b = -20\,psi$

Now that we have b we can solve for our final volume

$$P = aV + b \rightarrow \frac{P-b}{a} = V$$

$$V = \frac{100\,\cancel{psi} - (-20\,\cancel{psi})}{5\,\frac{\cancel{psi}}{ft^3}} = \boxed{24\,ft^3} \; V_f$$

We can go back and solve our integral

$$W = \int_7^{24} 5V - 20\,dV$$

$$W = \frac{5}{2}V^2 - 20V \Big|_7^{24}$$

$$W = \frac{5}{2}(24^2 - 7^2) - 20(24 - 7)$$

$$W = 977.5\ psi \cdot ft^3$$

But the problem require Btu not $psi \cdot ft^3$, so

$$W = 977.5\,\cancel{psi \cdot ft^3}\left(\frac{1\,Btu}{5.404\,\cancel{psi \cdot ft^3}}\right)$$

$$W = 180.884\ Btu$$

$$\approx \underbrace{181\,Btu}$$

4–19 A piston–cylinder device initially contains 0.4 kg of nitrogen gas at 160 kPa and 140°C. The nitrogen is now expanded isothermally to a pressure of 100 kPa. Determine the boundary work done during this process. Answer: 23.0 kJ

4-19. $P_0 = 160$ KPa $T = 140°C$

$m = 0.4$ Kg $P_F = 100$ kPa

$\int P\,dV$

$PV = RTm$

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

$V = RTmP^{-1}$

$\frac{dV}{dP} = -\frac{RTm}{P^2}$

$W = -\int \frac{RTm}{P}\,dP$

$W = -RTm \int_{160}^{100} \frac{1}{P}\,dP$

$W = -RTm \ln(P)$

$W = -RTm\left(\ln(100) - \ln(160)\right)$

$W = RTm(\ln(160) - \ln(100))$

$W = 0.287 \frac{J}{Kg \cdot K}(140 + 273.15\ K)(0.4\ Kg)$

$(\ln(160) - \ln(100))$

$W = 22.29\,kJ$

4-19 (Second approach)

$m = 0.4\ kg$ $\quad P_0 = 160\ kPa$ $\quad T = 140°C$

$P_F = 100\ kPa$

$$W = P_1 \overset{?}{V_1} \ln \frac{\overset{?}{V_2}}{V_1} \quad \text{equation 4.7}$$

We need to find $V_1$ and $V_2$, so we will use the ideal gas equation

$$PV = RTm \rightarrow V = \frac{RTm}{P}$$

$$V_1 = \frac{0.287 \frac{kJ}{kg \cdot k} (140 + 273.15\ k)(0.4\ kg)}{160\ kPa}$$

$$V_1 = 0.296435\ m^3$$

$$V_2 = \frac{0.287 \frac{kJ}{kg \cdot k} (140 + 273.15\ k)(0.4\ kg)}{100\ kPa}$$

$$V_2 = 0.474296\ m^3$$

Now we can plug in in our work equation

$$W = 160(0.296435) \ln\left(\frac{0.474296}{0.296435}\right)$$

$$\boxed{W = 22.29\ kJ}$$

4–34E A rigid 1 $ft^3$ vessel contains R-134a originally at –20°F and 27.7 percent quality. The refrigerant is then heated until its temperature is 100°F. Calculate the heat transfer required to do this. Answer: 84.7 Btu

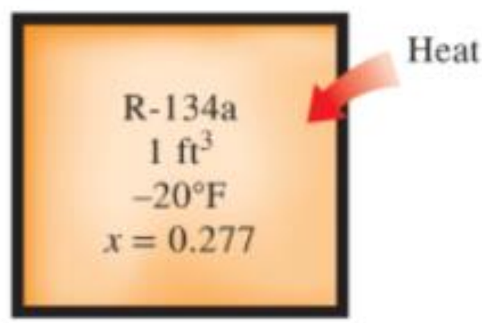



FIGURE P4–34E

4-34E R-134A

$V = 1\ ft^3$ $T_o = -20°F$ $x = 27.7$ $T_F = 100\ F$

$\Delta E = E_{in} - E_{out}$

$[U_2 + \cancel{\frac{1}{2}mV_2^2} + \cancel{mgh_2} + \cancel{P_2V_2}] - [U_1 + \cancel{\frac{1}{2}mV_1^2} + \cancel{mgh_1} + \cancel{P_1V_1}] = [Q_{in} + \cancel{W_{in}}] - [\cancel{Q_{out}} - \cancel{W_{out}}]$

$Q_{in} = U_2 - U_1$

$Q_{in} = m(u_2 - u_1)$

First we need to find mass, we can use the specific volume and table A11E

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

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

$v = 0.01156 + 0.277(3.4424 - 0.01156)$

$v = 0.961902\ ft^3/lbm$

$m = \frac{1\ \cancel{ft^3}}{0.961902\ \cancel{ft^3}/lbm} = 1.03960\ lbm$

Now we can also find $u_1$ in a similar way we found $v$

$$u = u_f + x\,u_{fg}$$
$$u = 6.014 + 0.277(85.887)$$
$$u = 29.8046 \, \frac{Btu}{lbm}$$

Now in the same table we can go to $T = 100°F$ in an effort to find $u_2$, but since our $V$ and $m$ remain constant, our $v$ must also remain constant, If we compare $v$ with $v_f$ and $v_g$, we notice that our substance is superheated, so we need to go to table A-13E. We notice that our $v$ at 100°F is betwen $P = 50$ psia and $P = 60$ psi which means our $u_2$ is between $111.56 \frac{Btu}{lbm}$ and $111.17 \frac{Btu}{lbm}$, so we need to interpolate:

$$\frac{u_2 - 111.17}{0.961902 - 0.9072} = \frac{111.56 - 111.17}{1.1043 - 0.9072}$$

$$u_2 = 111.278 \, \frac{Btu}{lbm}$$

Now we can plug back in our energy equation

$$Q_{in} = 1.03960(111.278 - 29.8046)$$

$$Q_{in} = 84.7003 \simeq \boxed{84.7\ Btu}$$

4–72 A mass of 15 kg of air in a piston–cylinder device is heated from 25 to 95°C by passing current through a resistance heater inside the cylinder. The pressure inside the cylinder is held constant at 300 kPa during the process, and a heat loss of 60 kJ occurs. Determine the electric energy supplied, in kWh. Answer: 0.310 kWh

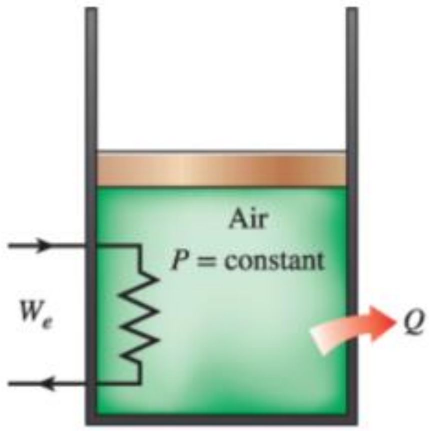
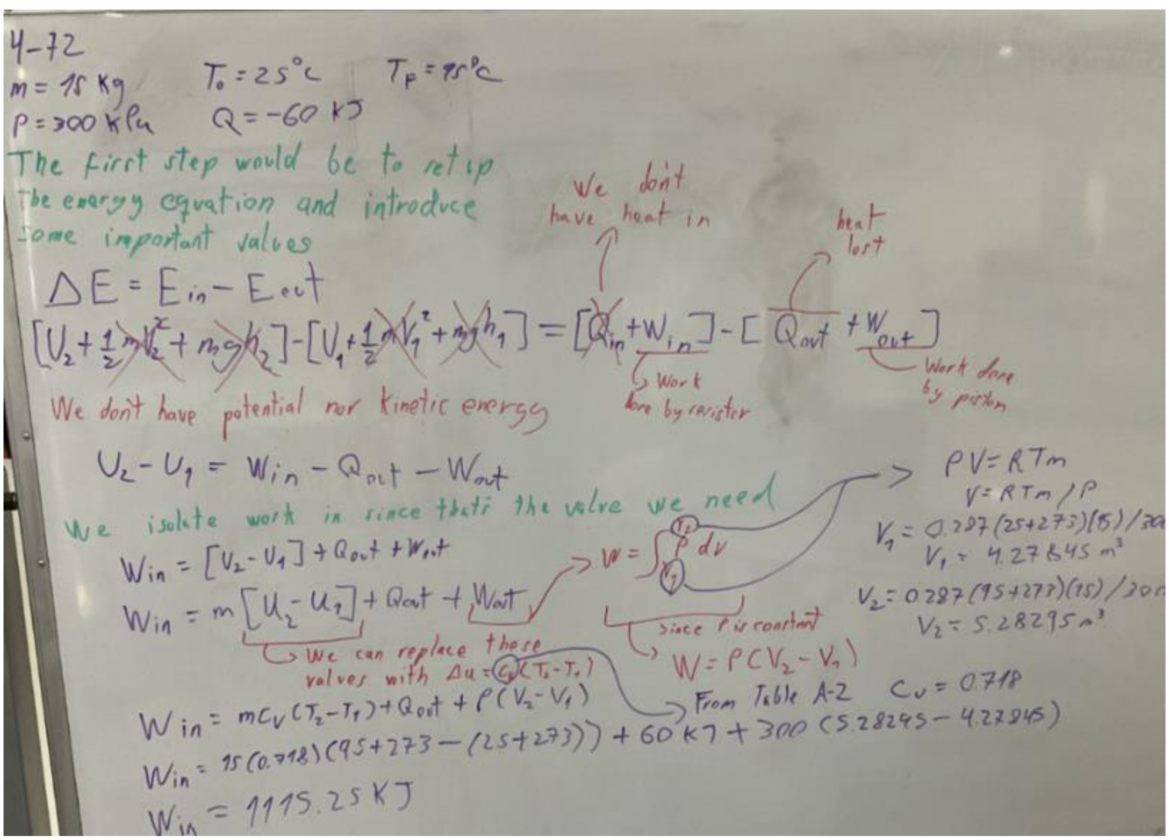



FIGURE P4–72



Now we just have to convert to kWh

$$1115.52\,\cancel{kJ}\left(\frac{1\,kWh}{3600\,\cancel{kJ}}\right) = 0.309797\,kWh$$

$$\boxed{\approx 0.310\,kWh}$$

$(1h)\ 1\,kW = \frac{1\,kJ}{s}\,(1h)$

$1\,kWh = \frac{1\,kJ}{\cancel{s}}\,(3600\,\cancel{s})$

$1\,kWh = 3600\,kJ$

$1h = 3600\,s$