Thermodynamics: Homework A – Set 1 -Answers
Jennifer West (2004)

Problem 1:
Answer 1 of 2:
A. Ohm - The terms inside the exponent *must* be dimensionless. This can be true *only* if Beta has the same dimensions as T (since T appears in the denominator). So the dimensions of Beta must be degrees Kelvin (K).

For all engineering problems, both sides of the equation must have the same units, i.e. the equation is required to be dimensionally homogeneous. If the units are not the same, the equation is invalid. Thus, dimensional homogeneity may be used to determine if the equation is wrong. However, simply because dimensional homogeniety is achieved does not assure the correctness of the equation.

The results and arguments of exponentiation must be dimensionless. Thus you can use a rearrangement of the equation with the exponential term on one side and everything else on the other; you merely need to determine what units would satisfy the equation in that form. The terms inside the exponent *must* be dimensionless. This can be true *only* if Beta has the same dimensions as T (since T appears in the denominator). So the dimensions of Beta must be degrees Kelvin (K).

Answer 2 of 2:
C. Kelvin - The terms inside the exponent *must* be dimensionless. Since this is true, then Ro must have the same dimensions as R (since R appears on the opposite side of the argument). So the dimensions of Ro must be Ohm.

The results and arguments of exponentiation must be dimensionless. Consequently, the arguments or results of **logarithmic** operations must also be unitless (Hint: use logarithms to solve for Beta!). Then you can use a rearrangement of the equation with the logarithm terms on one side and everything else on the other; you merely need to determine what units would satisfy the equation in that form.

Problem 2:
Answer 1 of 3:
All of the Above
If $Pv^n = C$ then $P_1v_1^n = C$ also, since C is a constant. The relationship during the process is $Pv^n = C$ Thus, $P_1v_1^n = C$ and $P_2v_2^n = C$ So, $P_1v_1^n = P_2v_2^n$ Rearranging, ou get: $(v_1/v_2)^n = P_2/P_1$Thus the answer is all of the above.

Answer 2 of 3:
n = 1.211
Logarithms are a useful tool in calculating unknown exponents. The main laws of logartihms are:

Source URL: http://thermodynamics.eng.usf.edu/indexA.html
Saylor URL: http://www.saylor.org/courses/ME103/#1.3

$\log(A*B) = \log(A) + \log(B)$
$\log(A/B) = \log(A) - \log(B)$
$\log(A^B) = B*\log(A)$
The relationship during the process is $Pv^n = C$
Thus, $P_1v_1^n = C$ and $P_2v_2^n = C$
So, $P_1v_1^n = P_2v_2^n$
Rearranging, you get: $(v_1/v_2)^n = P_2/P_1$
Using logarithms: $n*\log(V_1/V_2) = \log(P_2/P_1)$
Therefore: $n = \log(P_2/P_1) / \log(v_1/v_2)$
Using the values given in the problem statement, along with a final pressure of 10.442 bars:
$n = \log(10.442/2) / \log(83.54/21.34)$
$n = 1.211$

Answer 3 of 3:
None; it is a dimensionless quantity.
If: $P_1v_1^n = P_2v_2^n$
Putting units in: $(\text{bars} * \text{cm}^3/\text{g})^n = (\text{bars} * \text{cm}^3/\text{g})^n$
Thus for the equation to be dimensionally homogeneous, n must be dimensionless.
Also:Using the equation from the previous question:
$n = \log(P_2/P_1) / \log(v_1/v_2)$
Note that P_2/P_1 and v_1/v_2 must be unitless!
Therefore there can be no units for n

Problem 3:
Answer 1 of 4:
A: The ice point of water on the Celsius scale is 0 °C. The ice point of water on the Fahrenheit scale is 32 °F. The ice point of water on the Kelvin scale is 273.15 K.

Answer 2 of 4:
-66.7 °C
The Celsius temperature scale defines 0 °C as the ice point of water and 100 °C as the steam point of water.
In the new scale,
0 °C = 150 °S
100 °C = 300 °S
Therefore we can relate any temperature in °C to°S using an equation of the form:
T(°C) = a * T(°S) + b
(where a and b are constants)
In order to do this, note that with the given information you can create two equations of this form, and there will be two unknowns in each. If there exists the same number of unknons as equations, the problem has zero degrees of freedom (which means it is solvable). The equations can be solved by one of several methods, such as direct substitution, or elimination.

Using the general relationship:
*T(°C) = a * T(°S) + b*
We know:
*0 °C = a * 150 °S + b*
*100 °C = a * 300 °S + b*
Solveing these two equations, we obtain:
a = 100 °C / 150 °S = 0.333 (°C/°S)
b = -100 °C
If, for example, T1 = 50 °S, then
*T(°C) = (0.333 °C/°S) * 50 °S - 100 °C*
T(°C) = -66.7 °C

Answer 3 of 4:
166.667 °C
Suppose that T2 is 400 °S.
Then:
(300 °S - 150 °S)/(100 °C - 0 °C) = 1.5 °S/ 1 °C
Therefore:
400 °S - 150 °S = 250 °S
*250 S * 1 °C/ 1.5 °S =* ***166.667 °C***

Answer 4 of 4:
Ice point = 0 °C = 150 °S
Steam point = 100 °C = 300 °S

$$\frac{300\ °S - 150\ °S}{100\ °C - 0\ °C} = \frac{dTS}{dTC} = 1.5$$

Problem 4:
Answer 1 of 6:
All of the Above
Conversion Factor Usage:
Conversion factors are used to convert quantities from one unit to another. Conversion factors always equal one because the numerator and denominator are equal. Since this factor is equal to one, any quantitiy multiplied by it changes only in units, not in physical amount. Dimensional analysis must be employed: units are treated like numbers, in that they may be multiplied and divided, and thus may cancel. For example:
1 kg = 2.2046226 lbm
So:
15 kg * (2.2046226 lbm/1 kg) = 33.069339 lbm
The *quantity of matter* remains unchanged; only the *units* have altered.
Check your conversion tables for the desired conversion factors.

Answer 2 of 6:
6823 lbm/min
If "G" were 50,000 BPD, the solution would be:
50,000 barrels/day * 42 gallons/barrel * 1 day/(1440 min) * 13368 ft^3/gallon * **35 lbm/ft^3** = 6823 lbm/min

Notice the use of density in **lbm/ft^3** after barrels have been converted to ft^3 and days have been converted to minutes
Must convert ***volume flow*** to ***mass flow*** using density either at the beginning or at the end of the unit conversion.
Density is listed in the thermodynamic tables indirectly: it is the inverse of the sepcific volume of a substance.
Density may also defined as the product of specific gravity and the density of a refrence fluid.
The density (***p***) of a gas can be estimated by:
$p_{gas} = M_W*P/RT$
(where M_W is the molecular weight of the gas, P is the pressure, T is temperature, and R is the universal gas constant)

Answer 3 of 6:
92.0 L/s
If "G" were 50,000 BPD, the solution would be:
50,000 barrels/day * 42 gallons/barrel * 1 day/(86400 s) * 3.7854 L/gallon = 92.0 L/s
Notice the use of density was not necessary!

Answer 4 of 6:
If "G" were 50,000 BPD, the solution would be:
50,000 barrels/day * 42 gallons/barrel * 1 day/(1440 min) = 1458 gallons/min or gpm
Notice the use of density is not necessary!

Answer 5 of 6:
195 ft^3/min or cfm
If "G" were 50,000 BPD, the solution would be:
50,000 barrels/day * 42 gallons/barrel * 1 day/(1440 min) * 0.13368 ft^3/gallon = 195 ft^3/min or cfm
Notice the use of density is not necessary!

Answer 6 of 6:
16.5 ft/s
If "G" were 50,000 BPD, the solution would be:
50,000 barrels/day * 42 gallons/barrel * 1 day/(86400s) * 0.13368 ft^3/gallon = 3.2492 ft^3/s
Note: 3.2492 ft^3/s is the Volumetric flow rate, NOT the velocity!

Velocity = Volumetric flow rate / Cross-sectional area
$A = pi * (3^2 in^2)*(1 ft^2/144 in^2) = 0.1963495 ft^2$
(where A is area)
Therefore:
velocity = $(3.2492 ft^3/s) / (0.1963495 ft^2) = 16.5 ft/s$

Problem 5:
Answer 1 of 2:
P_{vacuum} & P_{atm}
The problem statement indicates that a vacuum gauge is used; therefore, P_{vacuum} is given as P1.
A barometric pressure reading is given in the problem statement; thus, P_{atm} is given as well.
No absolute pressure is given.
While a gauge pressure is given, it is indicated that it is a vacuum reading so there is no P_{gauge} (the pressure that would be given if the gauge pressure were greater than the atmospheric reading).

Answer 2 of 2:
Suppose P_{vac} = 5.4 psi
$P_{vac} = P_{atm} - P_{abs}$
Therefore:
$P_{abs} = P_{atm} - P_{vac}$
$P_{atm} = 28.5 \text{ in Hg} * (848 \text{ lb}/1 \text{ ft}^3) * (1 \text{ ft}^3/12^3 \text{ in}^3) = 14.0 \text{ lb/in}^2 = 14.0 \text{ psi}$
P_{abs} = 14.0 psi - 5.4 psi = **8.6 psi**

Problem 6:
Answer 1 of 5:
B. 1571 m^3
Using the formula:
$V = (pi * D^2/4) * H$
$V = (3.14 * ((10 m)^2/4) * (20 m)$
$V = 1571 m^3$
Note that the gas is contained in a cylinder, which may be assumed to be rigid. Gas fills the space in which it is enclosed. Thus if you know the volume of the cylinder you will know the volume of the gas.

Answer 2 of 5:
n = 1817.5 lbmol
It is important to know the Ideal Gas Law:
PV = nRT
$V = (pi*D^2/4)*H$
psig + 14.7 = psia

T should be in Rankine
n will be in lbmoles
Rearranging the Ideal Gas equation:
n = PV/(RT)

$$n = \frac{(325\ lb/in^2 * (144\ lbf/ft^2)/(1\ lb/in^2)) * (1571\ m^3 * (35.315\ ft^3)/(1\ m^3))}{(1545\ ft*lbft/(lbmol*R)) * (465 + 459.67\ R)}$$

n = 1817.5 lbmol

Answer 3 of 5:
Using a molecular weight of 50:
1817.5 lbmol * 50 lbm/lbmol = 90875 lbm

Answer 4 of 5:
The mass density is the mass per unit volume. We know the total mass and the total volume of the cylinder. Using a molecular weight of 50 to get the mass from the previous question:
Mass density = 90875 lbm / 55480 ft^3
Mass density = 1.6838 lbm/ft^3

Answer 5 of 5:
The molar density is found using the total number of moles per total volume:
Molar density = 1817.5 lbmol / 55480 ft^3
Molar density = 0.328 $lbmol/ft^3$

Problem 7:
Answer 1 of 3:
Second Law
Newton's Laws are comprised of such observations as action-reaction, inertial motion, and force as a result of a mass times and acceleration. You should know which law goes with which observation. If not, consult a reference text.
First Law: (Law of Inertia) An object in a state of motion tends to remain in that state unless acted upon by an external force.
Second Law: F = ma (Force = mass * acceleration)
Third Law: For every action there is an equal and opposite reaction.
Thus, this is an example of an application of Newton's second law.

Answer 2 of 3:
2198 lbm
Weight = Force due to gravity = mass * gravity
(where g = acceleration due to gravity)
If W is 2200. lb force:
*F = m*a*
m = F / a
*2200 lbf * 32.174 (lbm*ft/s²)/ 1 lbf / 32.20 ft/s² = m = 2198 lbm*

Answer 3 of 3:
341.6 lb force
Using Newton's second law, use the equation to solve for force.

If W = 2200. lb force
*F = m * a*
m = 2198 from question 2
So, using conversion factor in table:
*F = 2198 lbm * 5 ft/s^2 * [1 lbf/ 32.174 (lbm*ft/s^2)]*
F = 341.6 lb force