LES10A020 Engineering Physics / Home Assignment 8

Please submit the answers to the assignment task into the corresponding submission question locations on Moodle (to be available before deadline).

This assignment is due November 23th, at 23:59. Each task lists how many points it is worth.

Task 1. Let us assume air temperature is $15℃$ and the relative air humidity is 60%. The air is then heated to 30 degrees. What is the relative air humidity now if no outside vapor was added to the air? How many percentages the volume of the gas expanded due to heating? Assume 1 atm pressure and that ideal gas law applies. **[1p]**

Task 2. A refrigerator has a refrigeration coefficient of performance of 2.5. As the fridge heat engine compressor runs with 340W power, how much heat per second does it remove from the refrigerator? If this same unit would be used as a heating air pump, what would ideally be its coefficient of performance? **[2p]**

Task 3. Standard Temperature and Pressure (STP) are defined as $0℃$ and $100\ \mathrm{kPa}$. On the other hand, Normal Temperature and Pressure (NTP) are defined as $20℃$ and $101.325\ \mathrm{kPa}$. Let us assume air in STP conditions has 100 % relative humidity. Assume the air follows the ideal gas law and behavior. Also, one mole of an ideal gas has a volume of 22.41 liters in STP conditions. What is the relative humidity of the air at NTP conditions? How many grams of water vapor does one cubic meter of this air contain in NTP conditions? The molar weight of water is 18.015 g/mol. **[2p]**

Task 4. One cubic meter of nitrogen in NTP conditions is heated up to $100℃$ in constant pressure. Compare the expansion of the gas when using ideal gas law and van Der Waals equation. How many percentages does the ideal gas expand due to heating? How about when using the van Der Waals equation? How many percentage units is the difference? The van Der Waals constants for nitrogen are in Table 1 below. The Boltzmann constant is $1.381 \cdot 10^{-23}\ \frac{\mathrm{J}}{\mathrm{K}}$. Hint: When using van Der Waals gas equation, first solve the amount of gas moles using a mathematical solver (or similar tool) to make further calculations with the equation easier. **[2½p]**

Task 5. The pressure of car tire is 2.2 bar at $-5.0℃$. While driving, the temperature raises to $57℃$. Determine the pressure of the tire after the drive using ideal gas law and van Der Waals equation of state. Compare the result with what you would get using the ideal gas law. The wheel volume is 10.6 liters, and you can assume it does not change while the wheel heats up. Air has normal composition: 78.1% nitrogen, 21.0% oxygen and 0.9% argon. The van Der Waals constants for the gases are in Table 1 below.
Hint 1. When using van Der Waals gases, solve the problem for each of the gases using their partial pressures and then add them up in the end. Hint 2. You may calculate the problem first using ideal gas law so you get an idea about the result you should get. **[2½p]**

Table 1. Van Der Waals constants for selected gases

Gas	**a** [bar dm^6/mol^2]	**b** [dm^3/mol]
Argon	1.355	0.03201
Nitrogen	1.370	0.0387
Oxygen	1.382	0.03186

Please note that 1 ($m^6 \cdot Pa/mol^2$) = 10 ($liters^2 \cdot bar/mol^2$) and 1 (m^3/mol)=1000 (liters/mol).