Trent University: PHYS 2700H – Thermal Physics 2019 – 2020

Final Exam: Tuesday Apr 14, 2020

(Delivered online in 2020, with slightly different format, due to COVID-19 pandemic)

Allowed: Formula sheet (given), calculator, 2 hours

Answer questions 1-12 on rough paper. Take your time. Then email answers to rayfshiell@trentu.ca

For all except the first question:

If correct answer in one = **4** points; correct answer in two = **2** points; correct answer in three = **0.5** points

1) [no marks for this question] Which of the following are the first two digits of your six-digit student number (dropping any leading zeros)?

A. 64 **B.** 63 **C.** 62 **D.** 61 **E.** 60 **F.** 58

Qu's 2 – 3: The equation of state, $f\left(F, L, T\right) = 0$, for a stretched rubber band ($L \geq L_0$) is given by:

$$F = aT\left[\frac{L}{L_0} - \left(\frac{L_0}{L}\right)^2\right] \quad ,$$

where F is measured in Newtons, T in Kelvin, and $a = 4.7 \times 10^{-2}$ N/K, and L is in m.

Suppose the elastic band, with L_0 in **cm** given by the first two digits of your student number, is reversibly stretched to $1.5L_0$, at a temperature of $20\ ^\circ\mathrm{C}$.

2) How much work, W, is done on the elastic band during this extension?

A. $2.0\ \mathrm{J} < W < 2.2\ \mathrm{J}$ **B.** $2.2\ \mathrm{J} < W < 2.4\ \mathrm{J}$ **C.** $2.4\ \mathrm{J} < W < 2.6\ \mathrm{J}$ **D.** $2.6\ \mathrm{J} < W < 2.8\ \mathrm{J}$ **E.** $2.8\ \mathrm{J} < W < 3.0\ \mathrm{J}$

3) From the equation of state, what is the value of $\left(\frac{\partial F}{\partial L}\right)_T$ for the elastic band when it has length $L = L_0$?

A. between 0 and 20 N/m **B.** between 20 and 40 N/m **C.** between 40 and 60 N/m

D. between 60 and 80 N/m **E.** between 80 and 100 N/m

Qu's 4 – 5: Consider 3 moles of helium with initial volume and pressure of V_1 and $P_1 = 1$ atm, respectively. We shall treat the helium as an ideal monatomic gas. The gas undergoes an *isobaric expansion* to twice its original volume.

Here, V_1 in **dm³** is given by the first two digits of your student number (drop any leading zeros).

4) Which of the following best represents the change in internal energy, ΔU, for the gas?

A. $\Delta U <$ 10 kJ **B.** 10 kJ < $\Delta U <$ 20 kJ **C.** 20 kJ < $\Delta U <$ 30 kJ

D. 30 kJ < $\Delta U <$ 40 kJ **E.** $\Delta U >$ 40 kJ

5) Which of the following best represents the change in enthalpy, ΔH, for the gas?

A. $\Delta h <$ 10 kJ **B.** 10 kJ < $\Delta H <$ 20 kJ **C.** 20 kJ < $\Delta H <$ 30 kJ

D. 30 kJ < $\Delta H <$ 40 kJ **E.** $\Delta H >$ 40 kJ

Qu's 6 -7: A gas undergoes a *Joule-Kelvin expansion* from a high pressure to a low pressure.

6) If the gas were an ideal gas, which of the following statements is most correct?

A. The Joule-Kelvin coefficient for this gas is always negative
B. The Joule-Kelvin coefficient for this gas is always positive
C. Depending upon the range of temperature and pressure, the Joule-Kelvin coefficient for this gas may be negative at high pressure, and positive at low pressures
D. Depending upon the range of temperature and pressure, the Joule-Kelvin coefficient for this gas may be positive at high pressure, and negative at low pressures
E. The Joule-Kelvin coefficient for this gas is always zero

7) If the gas were instead a real gas, which of the following statements is most correct?

A. The Joule-Kelvin coefficient for this gas is always negative
B. The Joule-Kelvin coefficient for this gas is always positive
C. Depending upon the range of temperature and pressure, the Joule-Kelvin coefficient for this gas may be negative at high pressure, and positive at low pressures
D. Depending upon the range of temperature and pressure, the Joule-Kelvin coefficient for this gas may be positive at high pressure, and negative at low pressures
E. The Joule-Kelvin coefficient for this gas is always zero

Qu's 8 – 10: Suppose we consider n moles of an ideal, monatomic, gas, with volume V and temperature T, as a large number, N, of particles, free to occupy individual cells of phase space, each of volume h^3.

8) From Eq 6.5 .on your formula sheet, or by recollection, which of the following is the correct equation for the *average kinetic energy* of each particle?

A. $\frac{1}{2}m\bar{v} = \frac{3}{2}k_B T$ **B.** $\frac{1}{2}mv_{\text{rms}} = \frac{3}{2}k_B T$ **C.** $\frac{1}{2}mv_{\text{rms}}^2 = \frac{5}{2}k_B T$ **D.** $\frac{1}{2}mv_{\text{rms}} = \frac{5}{2}k_B T$ **E.** $\frac{1}{2}mv_{\text{rms}}^2 = \frac{3}{2}k_B T$

9) If the total number of possible ways to assign N indistinguishable particles among the permitted cells of phase space is given by $\approx \frac{eVp_{rms}^3}{Nh^3}$, where e is Euler's number (2.718…), which of the following expressions correctly gives the entropy of this ideal gas?

A. $S = nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{3/2}\right]$ **B.** $S = nR\ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{5/2}\right]$ **C.** $S = nR\ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{3/2}\right]$

D. $S = Nk_B \ln\left[\frac{eV}{N}\left(\frac{3mk_BT}{h^2}\right)^{5/2}\right]$ **E.** $S = nR\ln\left[\frac{eV}{n}\left(\frac{3mk_BT}{h^2}\right)^{5/2}\right]$

10) From the result from question 9, or from an alternative method, which of the following is the correct expression for $\left(\frac{\partial S}{\partial V}\right)_T$ for this ideal gas?

A. $\frac{nk_B}{V}$ **B.** $\frac{3nR}{2V}$ **C.** $\frac{nR}{T}$ **D.** $\frac{nR}{V}$ **E.** $\frac{NR}{V}$

Qu's 11 -12:

11) If the heat capacity of water at a constant pressure of 1 atm is 4200 J/kg/K, what entropy change occurs when 2.6 kg of water is heated from 5 °C to 95 °C at this pressure?

A. +3040 J/K **B.** +3060 J/K **C.** –3040 J/K **D.** –3060 J/K **E.** +1520 J/K

12) Suppose a fridge runs on 60 W of electrical power, while dumping 360 W of heat into the basement, what is the *coefficient of performance* of this fridge?

A. 5 **B.** 0.14 **C.** 0.86 **D.** 1.2 **E.** 0.17