Name:______________________________

Biology 3550
Physical Principles in Biology
Fall Semester 2017

Quiz 3
3 November 2017

25 points total.
Please write your name on each page.
In your answers you should:

- Show your work or provide an explanation for an answer.
- Use correct units and the correct number of significant figures (One extra significant figure is allowable.)
- Express numerical answers as decimal values, using scientific notation for numbers outside of the range from 0.01 to 1,000 or -0.01 to -1,000.

Some possibly useful constants:

The Boltzmann constant: $1.3806 \times 10^{-23}\,\mathrm{J \cdot K^{-1}}$
The gas constant: $8.314\,\mathrm{J \cdot mol^{-1} K^{-1}} = 0.082\,06\,\mathrm{L \cdot atm \cdot K^{-1} mol^{-1}}$
Avogadro's number: 6.02×10^{23}

The engineers at the Ideal Gas and Free Energy Company have designed and built a deluxe instrument for studying the thermodynamics of (nearly) ideal gasses. This device includes a frictionless piston and cylinder and sensors that precisely measure the work applied to or done by the piston and the heat flow into and out of the otherwise insulated cylinder. The force applied to the piston can be regulated, as can the flow of heat into and out of the cylinder. The temperature of the gas can also be measured precisely. These features allow one to cary out just about any gas expansion or compression experiment.

1. A student using the deluxe gas compression/expansion instrument has placed 0.25 mole of N_2 gas into the cylinder and set the piston position so that the volume available to the gas is 0.50 L. The temperature has equilibrated to 25°C. The student then programs the instrument to reduce the volume to 0.050 L. During the compression, no heat is allowed to flow in or out of the cylinder, but after the volume is reduced, heat is allowed to flow in or out so as to return the temperature to 25°C. For the following assume that N_2 can be treated as an ideal gas under these conditions.

   (a) (4 pts) Calculate the pressure of the N_2 gas at the beginning and end of the process described above.(Additional space is available on the next page.)

(b) (4 pts) Calculate the minimum amount of work that would theoretically be required to compress the gas from 0.5 to 0.05 L while maintaining the temperature at 25°C.

(c) (4 pts) The measurements from the instrument indicate that the actual work required for the compression was about five times the calculated minimum. Briefly explain why more work was required for this process.

(d) (4 pts) Briefly explain how the procedure for compressing the gas could be modified to decrease the amount of work required. Also explain why this procedure would lead to less work being required.

2. (9 pts.) Next, the student allows the gas to expand back to its original volume of 0.5 L. During this process, heat is allowed to flow freely into or out of the cylinder and, at the end of the process, the temperature is allowed to return to 25°C. The total amount of heat that flows into the cylinder is measured to be 1000 J.

   Calculate (or infer) the following quantities for the expansion and re-equilibration of the gas. You do not need to show detailed calculations, but you should indicate where your answer come from. Units and sign count!

   (a) ΔE

   (b) w

   (c) ΔS_{sys}

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(d) ΔS_{surr}

(e) ΔS_{univ}

(f) ΔF