

**1-2-1 [PB]** A mug contains 0.5 kg of liquid water at 50°C. (a) Determine the stored energy ( $E$ ) of the system, neglecting the KE and PE. If 0.1 kg of liquid water at 10°C is mixed with the warm water, determine (b) the final stored energy ( $E_f$ ) of the system assuming that no energy is lost during mixing. Use the SL state daemon. (c) How do you explain a reduction of stored energy of the system?

**TEST Solution:**

After launching the SL system-state TESTcalc, evaluate the states as described in the TEST-code (stored in the Problems module of the TEST-Pro site at thermofluids.net). In the I/O panel, calculate the answers as follows:

$$(a) \ E_1 = m_1 \cdot e_1; \quad \Rightarrow E_1 = (0.5)(104.50818); \quad \Rightarrow E_1 = 52.3 \text{ kJ}$$

$$(b) \ E_3 = (m_1 \cdot e_1) + (m_2 \cdot e_2); \quad \Rightarrow E_3 = (0.5)(104.50818) + (0.1)(-0.10163); \quad \Rightarrow E_3 = 52.2 \text{ kJ}$$

(c) Unlike entropy, zero energy is not defined in thermodynamics. Even at absolute zero temperature the internal energy of a system is not zero. All property tables therefore use a somewhat arbitrary definition of zero energy, allowing a system to have negative energy in this relative scale. When a system with positive energy is combined with a system with negative energy the total energy will be diminished in that scale. This non-intuitive fact becomes obvious if one calculates PE of a combined system consisting of two subsystems, one with a positive  $z$  (elevation) and one with a negative  $z$ . Two people can come up with two different answers for absolute energy of a system. However, because most practical problems involve  $\Delta E$  rather than the absolute value of  $E$ , the arbitrarily chosen reference energy does not affect the answer.

**1-2-2 [PS]** A cup of coffee (system mass 1 kg) at 30°C rests on a table of height 1 m. An identical cup of coffee rests on the floor at a temperature of 25°C. Determine (a) the difference (cup 2 minus cup 1) in the stored energy ( $E_2 - E_1$ ) in the two systems. (b) What fraction of the difference can be attributed to potential energy (PE)? Use the SL (solid/liquid) system state daemon. Assume properties of coffee to be similar to those of water.

**TEST Solution:**

After launching the SL system-state TESTcalc, evaluate the states as described in the TEST-code (stored in the Problems module of the TEST-Pro site at thermofluids.net). In the I/O panel, calculate the answers as follows:

(a) Cup of Coffee on the Table:

$$E_1 = m1 * e1; \quad \Rightarrow E_1 = 20.82818 \text{ kJ};$$

Cup of Coffee on the Floor:

$$E_2 = m2 * e2; \quad \Rightarrow E_2 = 4.08237 \text{ kJ};$$

$$\Delta E = E_2 - E_1; \quad \Rightarrow \Delta E = 4.08237 - 20.82818; \quad \Rightarrow \Delta E = -16.8 \text{ kJ}$$

$$(b) \Delta PE = (m1 * g * (z2 - z1)) / 1000; \quad \Rightarrow \Delta PE = \frac{(1)(9.81)(-1)}{1000}; \quad \Rightarrow \Delta PE = -0.00981 \text{ kJ};$$

$$\Rightarrow \frac{PE}{\Delta E} = \frac{-0.00981}{-16.8}; \quad \Rightarrow \frac{PE}{\Delta E} = 0.05\%$$

**1-2-3 [PA]** Using the SL system state daemon, determine the change in stored energy ( $E$ ) in a block of copper of mass 1 kg due to (a) an increase in temperature from 25°C to 100°C (b) an increase in velocity from 0 to 30 m/s (at a constant temperature) and (c) an increase in elevation by 100 m (at a constant temperature). (d) What-if Scenario: What would the answer in (a) be if the working substance were granite instead?

**TEST Solution:**

After launching the SL system-state TESTcalc, evaluate the states as described in the TEST-code (stored in the Problems module of the TEST-Pro site at thermofluids.net). In the I/O panel, calculate the answers as follows:

(a)  $\Delta E_T = m1*(e2 - e1); \quad \Rightarrow \Delta E_T = 28.93862 - 1.91862; \quad \Rightarrow \Delta E_T = 27.0 \text{ kJ}$

(b)  $\Delta E_V = m1*(e3 - e1); \quad \Rightarrow \Delta E_V = 2.36862 - 1.91862; \quad \Rightarrow \Delta E_V = 0.45 \text{ kJ}$

(c)  $\Delta E_z = m1*(e4 - e1); \quad \Rightarrow \Delta E_z = 2.89962 - 1.91862; \quad \Rightarrow \Delta E_z = 0.981 \text{ kJ}$

(d) Change the working substance to Granite and click Super-Calculate. In the I/O panel evaluate:

$\Delta E_T = m1*(e2 - e1); \quad \Rightarrow \Delta E_T = 76.23747 - 5.04747; \quad \Rightarrow \Delta E_T = 71.2 \text{ kJ}$

**1-2-4 [PH]** For a 1 kg block of copper, determine the equivalent rise in stored energy ( $E$ ) by 1 kJ in terms of (a) increase in temperature (b) increase in velocity from rest and (c) an increase in height. (d) What-if Scenario: What would the answer in (a) be if it were an aluminum block? Use the SL (Solid/Liquid) system state daemon. (Hint: enter  $e_2$  as ' $eI$ '.)

**TEST Solution:**

After launching the SL system-state TESTcalc, evaluate the states as described in the TEST-code (stored in the Problems module of the TEST-Pro site at thermofluids.net). In the I/O panel, calculate the answers as follows:

(a) For the sake of argument, we will start off with our initial specific stored energy as

$e_1 = 100 \frac{\text{kJ}}{\text{kg}}$  for state 1, and neglect kinetic and potential energies. For state 2, we set

$e_2 = 101 \frac{\text{kJ}}{\text{kg}}$ , neglect kinetic and potential energies, obtaining:

$$\Delta T = T_2 - T_1; \quad \Rightarrow \Delta T = 286.68753 - 284.09686; \quad \Rightarrow \Delta T = 2.59^\circ\text{C}$$

(b) We retain  $e_2 = 101 \frac{\text{kJ}}{\text{kg}}$ , and now set  $T_2 = T_1$  and  $z_2 = z_1$ , obtaining:

$$\Delta V = V_2 - V_1; \quad \Rightarrow \Delta V = 44.72136 - 0; \quad \Rightarrow \Delta V = 44.7 \frac{\text{m}}{\text{s}}$$

(c) Again we retain  $e_2 = 101 \frac{\text{kJ}}{\text{kg}}$ ,  $T_2 = T_1$  and now  $V_2 = V_1$ , obtaining

$$\Delta z = z_2 - z_1; \quad \Rightarrow \Delta z = 101.9368 - 0; \quad \Rightarrow \Delta z = 101.9 \frac{\text{m}}{\text{s}}$$

(d)  $\Delta T = T_2 - T_1; \quad \Rightarrow \Delta T = 137.26392 - 136.15282; \quad \Rightarrow \Delta T = 1.11^\circ\text{C}$

**1-2-5 [PN]** Use the SL system state daemon to determine specific entropy ( $s$ ) of (a) aluminum, (b) iron, and (c) gold at 100 kPa, 298 K. Discuss why the entropy of gold is the lowest among these three metals.

**TEST Solution:**

After launching the SL system-state TESTcalc, evaluate the states as described in the TEST-code (stored in the Problems module of the TEST-Pro site at thermofluids.net).

(a) Aluminum:

$$s = 1.05 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

(b) Iron:

$$s = 0.489 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

(c) Gold:

$$s = 0.241 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

The molar mass of gold is the highest among the three metals. Therefore the number of molecules in 1 kg of gold is the lowest. At a given temperature, the number of ways in which a given amount of internal energy can be distributed is, therefore, the lowest in 1 kg of gold. That is why the specific entropy of gold is the lowest.

**1-2-6 [PE]** Use the SL system state daemon to plot how the specific internal energy  $u$  and specific entropy  $s$  of aluminum changes with temperature at a constant pressure of 100 kPa (Hint: Evaluate three states at, say, 300 K, 700 K, and 1200 K; draw the  $u$ - $T$  and  $s$ - $T$  diagrams using the pull-down menu. Use the  $p=c$  button to see the trend line). Use the Log/Lin buttons to develop a functional relation for  $u$  and  $s$  in terms of  $T$ .

**TEST Solution:**

Launch the TESTcalc and select aluminum. Calculate multiple states holding pressure constant ( $p_1$  as 100 kPa,  $p_2$  as '=p1',  $p_3$  as '=p1' and so on) at 100 kPa and varying the temperature ( $T_2$  as '=T1+100',  $T_3$  as '=T2+100', and so on). Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel.

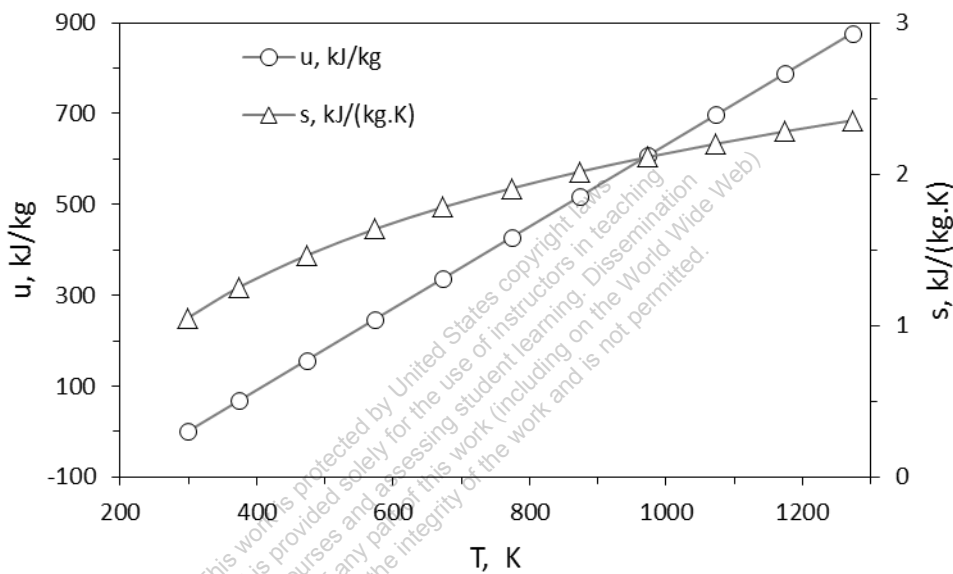


Fig. 1: Plot showing how  $u$  and  $s$  vary with  $T$  in Al at constant pressure (100 kPa).

**1-2-7 [PI]** Use the SL system state daemon to verify that  $u$  and  $s$  are independent of  $p$  for pure solids and liquids (Hint: Select a solid or a liquid; Evaluate three states at, say, 100 kPa, 1 MPa, and 10 MPa at a constant temperature of, say, 300 K; draw the  $u$ - $T$  and  $s$ - $T$  diagrams using the pull-down menu. Use the  $p=c$  button. Repeat with different working substances and different temperatures).

**TEST Solution:**

Select aluminum as a representative solid. Calculate multiple states holding pressure constant ( $p_1$  as 100 kPa,  $p_2$  as '=p1',  $p_3$  as '=p1' and so on) at 100 kPa and varying the temperature ( $T_2$  as '=T1+100',  $T_3$  as '=T2+100', and so on). Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet. Now change the pressure to a new value, say 1000 kPa and click Super-Calculate to produce the table of data in the I/O panel. Transfer the data to the spread sheet and plot  $u$  and  $s$  against  $T$ . Repeat the process for Water (L).

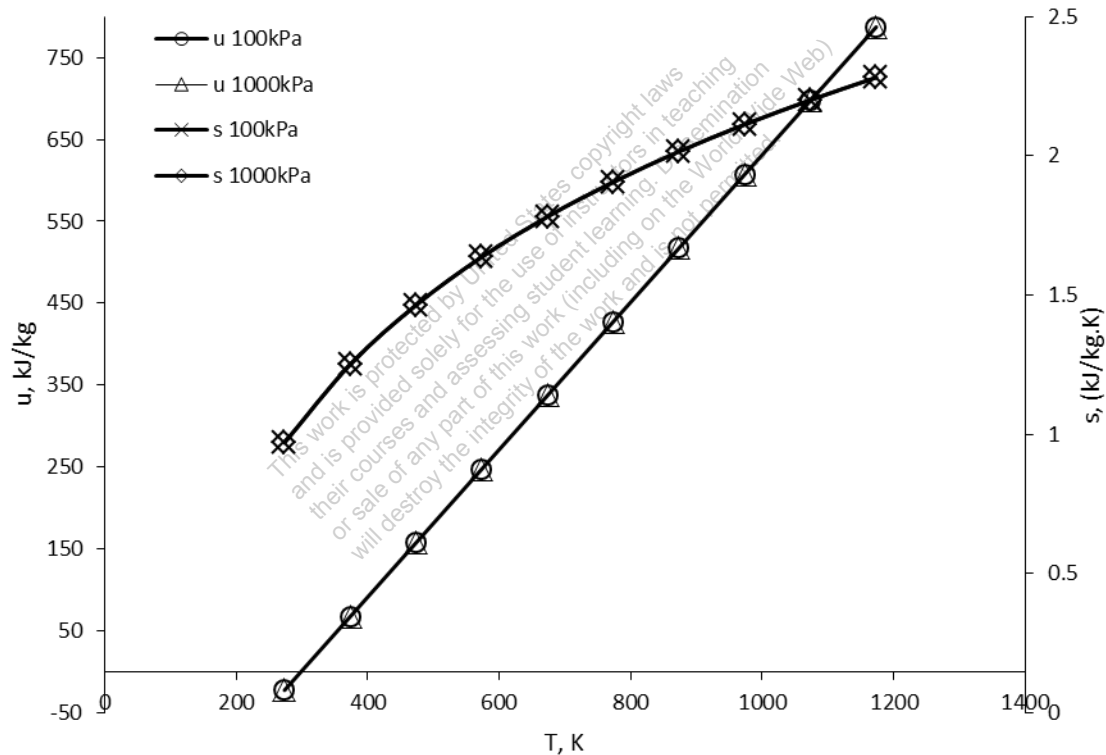


Fig. 1: Plot showing how  $u$  and  $s$  change with temperature for Aluminum.

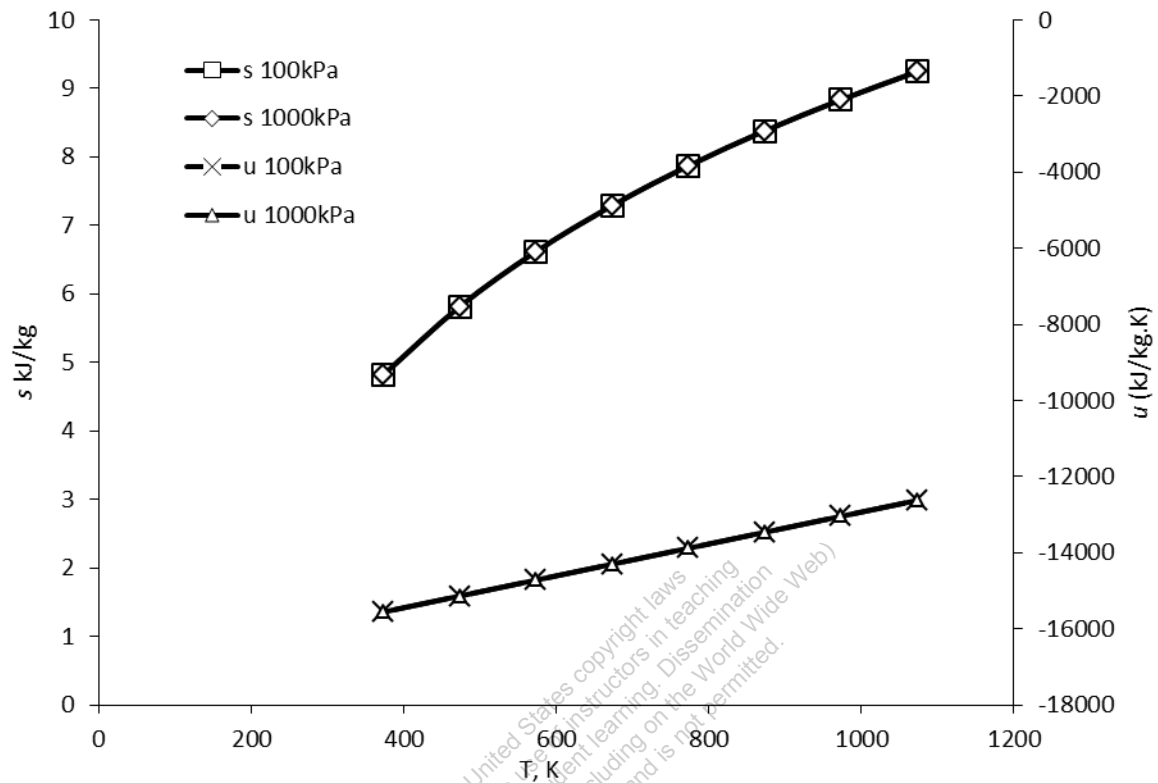


Fig. 2: Plot showing how  $u$  and  $s$  change with temperature for Water.



**1-2-8 [PL]** For copper, plot how the internal energy  $u$ , and entropy  $s$ , vary with  $T$  within the range  $25^{\circ}\text{C}$  -  $1000^{\circ}\text{C}$ . Use the SL system state daemon.

**TEST Solution:**

Launch the TESTcalc and select Copper. Calculate multiple states varying the temperature ( $T_2$  as ' $T_1+100$ ',  $T_3$  as ' $T_2+100$ ', and so on). Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $u$  and  $s$  vs.  $T$ .

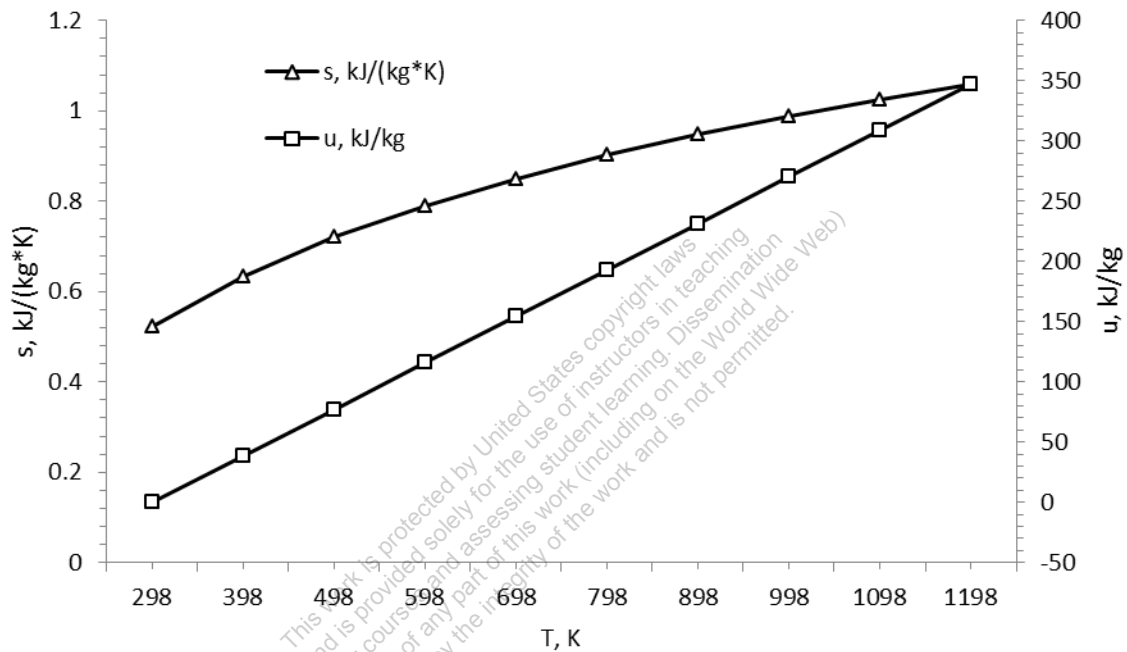


Fig. 1: Plot showing how  $u$  and  $s$  change with temperature for Copper.

**1-2-9 [PG]** For liquid water, plot how the internal energy  $u$  and entropy  $s$  vary with  $T$  within the range 25°C - 100°C. Use the SL system state daemon.

**TEST Solution:**

Launch the TESTcalc and select Water (L). Calculate multiple states varying the temperature ( $T_2$  as ' $T_1+100$ ',  $T_3$  as ' $T_2+100$ ', and so on). Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $u$  and  $s$  vs.  $T$ .

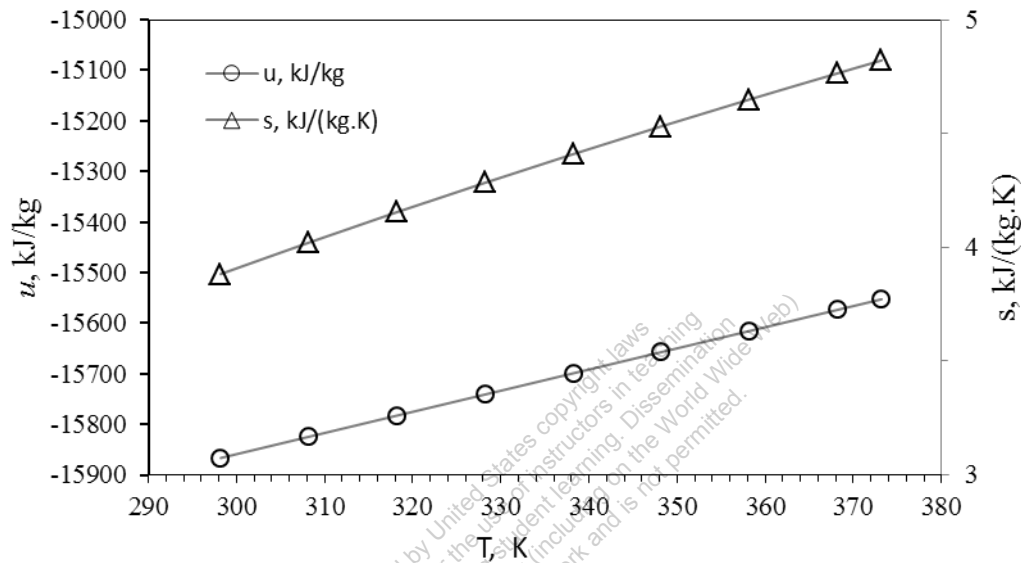


Fig. 1: Plot showing how  $u$  and  $s$  change with temperature with water.

**1-2-10 [PZ]** Liquid water at 100 kPa, 30°C, enters a pump with a flow rate ( $\dot{m}$ ) of 30 kg/s with a velocity of 2 m/s. At the exit the corresponding properties are 1000 kPa, 30.1°C, 30 kg/s, and 5 m/s. At the exit, determine (a) KE, (b)  $\dot{J}$  and (c)  $\dot{S}$ . Neglect potential energy.

**TEST Solution:**

We have the choice of either using the PC or SL flow-state TESTcalc. Because the PC model is more accurate, let us use the PC flow-state TESTcalc for this analysis. After evaluating the states (see TEST code in the Problems module of TEST-Pro at [thermofluids.net](http://thermofluids.net)), the desired transport properties can be calculated in the I/O panel.

$$\begin{aligned} \text{(a) } \dot{KE}_2 &= \dot{m}_2 (ke_2); \quad \Rightarrow \dot{KE}_2 = \dot{m}_2 (e_2 - u_2 - p e^0); \\ &\Rightarrow \dot{KE}_2 = (30)(126.21598 - 126.20348); \\ &\Rightarrow \dot{KE}_2 = \mathbf{0.375 \text{ kW}} \end{aligned}$$

$$\text{(b) } \dot{J} = \dot{m}j; \quad \Rightarrow \dot{J} = (30)(127.22); \quad \Rightarrow \dot{J} = \mathbf{3816.6 \text{ kW}}$$

$$\text{(c) } \dot{S} = \dot{m}s; \quad \Rightarrow \dot{S} = (30)(0.438); \quad \Rightarrow \dot{S} = \mathbf{13.148 \frac{\text{kW}}{\text{K}}}$$

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**1-2-11 [PK]** In problem 1-2-10[PZ], determine the flow work ( $W_F$ ) in kW at the pump inlet and exit. What do you attribute the difference between the two quantities, if any, to?

**TEST Solution:**

Continuing from the solution of 1-2-10, the flow work can be calculated in the I/O panel.

$$(a) \dot{W}_{F,\text{inlet}} = p_1 A_1 V_1; \quad \Rightarrow \dot{W}_{F,\text{inlet}} = \dot{m}1*(j1 - e1); \quad \Rightarrow \dot{W}_{F,\text{inlet}} = 3.01 \text{ kW}$$

$$(b) \dot{W}_{F,\text{exit}} = p_2 A_2 V_2; \quad \Rightarrow \dot{W}_{F,\text{exit}} = \dot{m}2*(j2 - e2); \quad \Rightarrow \dot{W}_{F,\text{exit}} = 30.1 \text{ kW}$$

Work transferred by the shaft into a pump is responsible to increase the flow energy at the exit. The KE, PE, or even the internal energy of the liquid at the exit is not very different at the exit; however, the pressure being much higher, the contribution of the flow work makes the exit flow energy substantially higher at the exit than at the inlet.

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**1-2-12 [PP]** A granite rock of mass 1000 kg is situated on a hill at an elevation of 1000 m. On a sunny day its temperature rises to 95°C. (a) Determine the maximum useful work that can be extracted from the rock if the atmospheric temperature is 30°C. (b) Compare the potential energy (PE) of the rock with its stored exergy ( $\Phi$ ). Use the SL system state daemon.

**TEST Solution:**

Use the SL system-state TESTcalc for this solution. After evaluating the states (see TEST code in the Problems module of TEST-Pro at thermofluids.net), the desired quantities can be calculated in the I/O panel.

$$(a) \quad \Phi = m\phi; \quad \Rightarrow \Phi = (1000)(16.02311); \quad \Rightarrow \Phi = 16,023 \text{ kJ}$$

$$(b) \quad PE = \frac{mgz}{1000}; \quad \Rightarrow PE = \frac{(1000)(9.81)(1000)}{1000};$$

$$\Rightarrow PE = 9,810 \text{ kJ};$$

$$\frac{PE}{\Phi} = \frac{9,810}{16,023}; \quad \Rightarrow \frac{PE}{\Phi} = 0.612; \quad \Rightarrow \frac{PE}{\Phi} = 61.2\%$$

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**1-2-13 [PU]** A tank contains 2000 kg of water at 1000 kPa and 70°C. Using the SL model, determine (a) the stored exergy and (b) the stored energy in the water. Assume standard atmospheric conditions.

**TEST Solution:**

Use the SL system-state TESTcalc for this solution. After evaluating the states (see TEST code in the Problems module of TEST-Pro at [thermofluids.net](http://thermofluids.net)), the desired quantities can be calculated in the I/O panel.

$$(a) \quad \Phi = m\phi; \quad \Rightarrow \Phi = (2000)(22.73341); \quad \Rightarrow \Phi = 45,467 \text{ kJ}$$

$$(b) \quad E = me; \quad \Rightarrow E = (2000)(197.98837); \quad \Rightarrow E = 395,976 \text{ kJ}$$

Note that while the stored exergy does not depend on the reference value of the internal energy, while the stored energy does. If the PC system-state TESTcalc is used (the PC model uses a different reference value for internal energy) the answer to part (b) can be shown to be different while the answer to part (a) remains unchanged.

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**1-2-14 [PX]** The cooling water in a power plant is discharged into a lake at a temperature of 35°C with a flow rate of 1000 kg/min. Determine the rate of discharge of exergy ( $\dot{\Psi}$ ) using the SL flow state daemon.

**TEST Solution:**

Use the SL system-state TESTcalc for this solution. After evaluating the states (see TEST code in the Problems module of TEST-Pro at [thermofluids.net](http://thermofluids.net)), the desired quantity can be calculated in the I/O panel.

$$\dot{\Psi} = \dot{m}\psi; \quad \Rightarrow \dot{\Psi} = (1000) \left( \frac{1}{60} \right) (0.68636); \quad \Rightarrow \dot{\Psi} = 11.4 \frac{\text{kJ}}{\text{min}}$$

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**1-2-15 [PC]** A piston-cylinder device contains 1 kg of air at 100 kPa, 30°C. The gas is now compressed very slowly so that the temperature remains constant (isothermal). Calculate a series of states using the IG state daemon as the volume decreases from the initial value to one tenth of the initial volume. Draw a constant-pressure line through the calculated states on a  $p$ - $v$  diagram. What kind of conic section (parabola, hyperbola, etc) does the  $p$ - $v$  diagram resemble? How does the stored energy ( $E$ ) of air changes as the volume decreases?

**TEST Solution:**

Launch the TESTcalc and select Air\*. Calculate multiple states varying the volume (Vol2 as '=Vol1\*0.9', Vol3 as '= Vol2\*0.9', and so on). Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $p$  against  $v$ . Also plot  $E$  ( $m^*e$ ) against Vol.

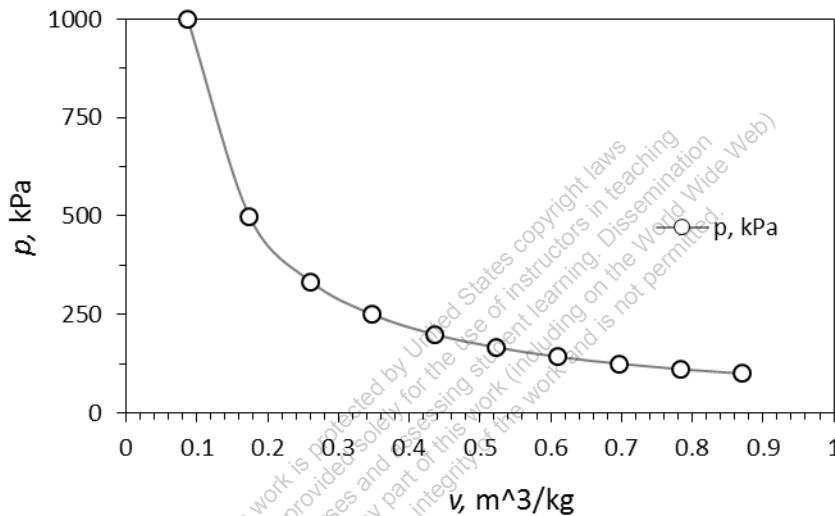


Fig. 1: Pressure vs Specific Volume when the system is held at a constant temperature of 303.2 K.



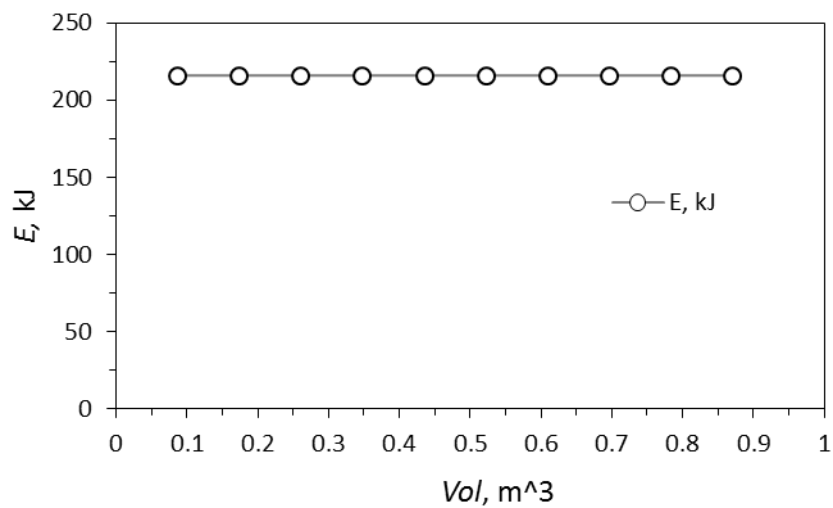


Fig. 2: Total Energy vs Volume at a constant temperature of 303.2 K

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**1-2-16 [PV]** A rigid tank contains 1 kg of air at 100 kPa, 30°C. Heat is now transferred to raise the temperature of the air. Calculate a series of states using the IG state daemon as the temperature increases from the initial value to 1000°C. Plot how the pressure, internal energy ( $U$ ), and entropy ( $S$ ) change as a function of temperature.

**TEST Solution:**

Launch the TESTcalc and select Air\*. Calculate multiple states holding pressure constant ( $p_2$  as ' $=p_1$ ',  $p_3$  as ' $=p_1$ ' and so on) and varying the temperature ( $T_2$  as ' $=T_1+100$ ',  $T_3$  as ' $=T_2+100$ ', and so on) after the first state is calculated from the given conditions. Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $p$ ,  $U$  and  $S$  against  $T$ . Note that the  $u$  and  $s$  have to be multiplied by  $m$  (in the spread sheet) to obtain  $U$  and  $S$ .

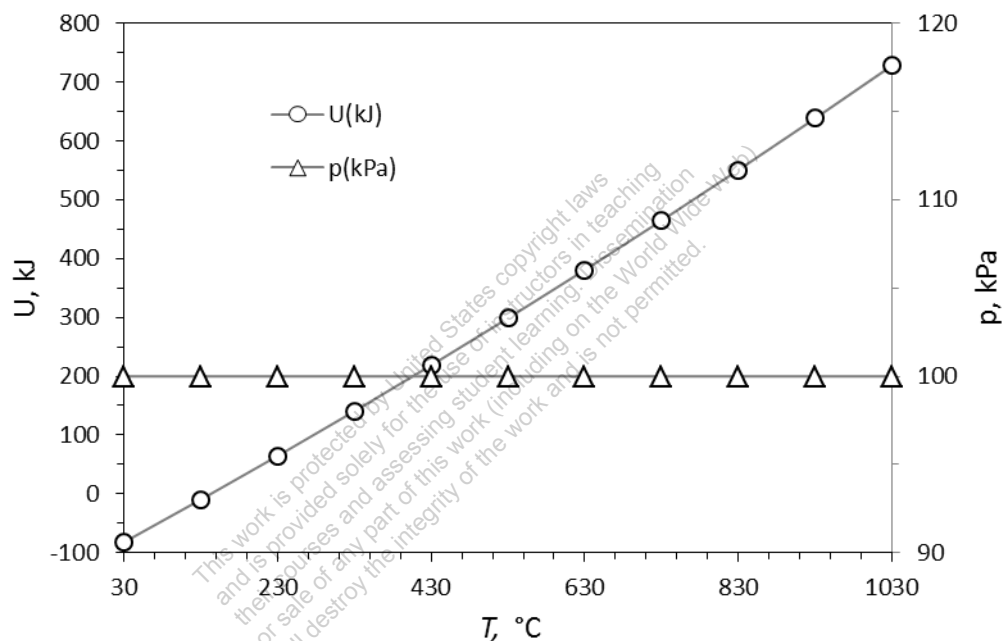


Fig. 1: Plot showing how  $U$  and  $p$  change with temperature for an ideal gas.

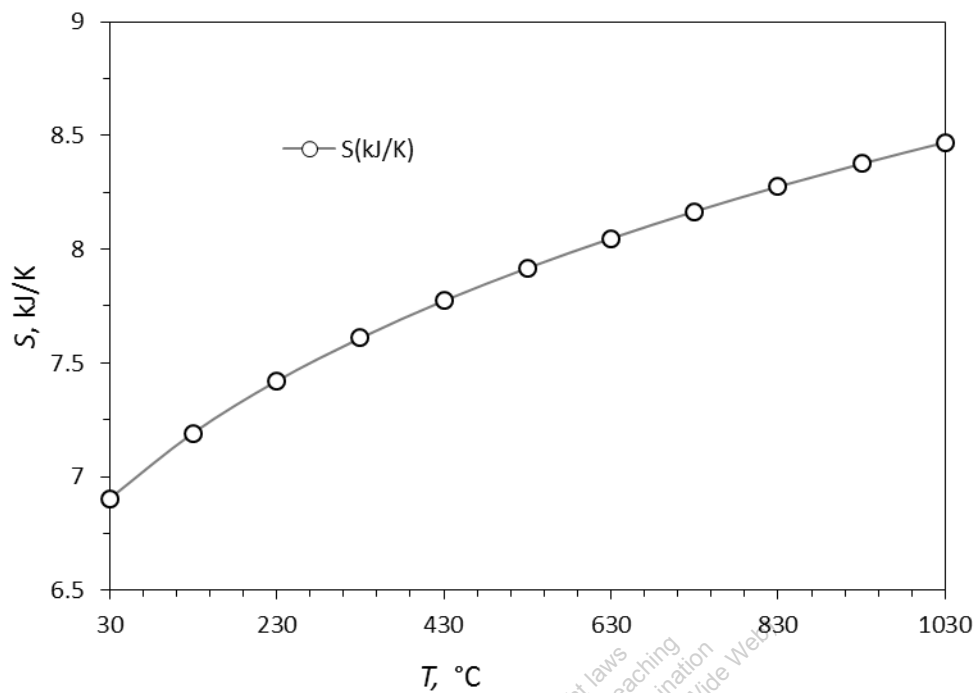


Fig. 2: Plot showing how  $S$  and  $V$  change with temperature for an ideal gas.

**1-2-17 [PQ]** A piston cylinder device contains  $0.01 \text{ m}^3$  of nitrogen at 500 kPa and  $30^\circ\text{C}$ . Determine the change in stored energy if (a) the pressure is doubled at constant temperature, (b) temperature is increased to  $60^\circ\text{C}$  at constant pressure. Use the IG (ideal gas) system state daemon.

**TEST Solution:**

Use the IG system-state TESTcalc for this solution. After evaluating the states (see TEST code in the Problems module of TEST-Pro at [thermofluids.net](http://thermofluids.net)), the desired quantities can be calculated in the I/O panel.

(a)  $\Delta E = E_2 - E_1; \quad \Rightarrow \Delta E = m(e_2 - e_1); \quad \Rightarrow \Delta E = (m1)(e2 - e1); \quad \Rightarrow \Delta E = 0 \text{ kJ}$

(b) Pressure doubled:  $p3 = 2 \cdot p1;$

$\Delta E = E_3 - E_1; \quad \Rightarrow \Delta E = m(e_3 - e_1); \quad \Rightarrow \Delta E = (m1)(e3 - e1); \quad \Rightarrow \Delta E = 12.28 \text{ kJ}$

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**1-2-18 [PT]** Determine the specific volume ( $v$ ) of the gas in a  $1 \text{ m}^3$  chamber filled with (a) hydrogen (b) carbon-dioxide. The pressure inside is 1 atm and the temperature is  $25^\circ\text{C}$ . Use the ideal gas (IG) state daemon.

**TEST Solution:**

Use the IG system-state TESTcalc for this solution. Select the gas and enter the known properties. The specific volume is calculated as part of the state.

(a) Hydrogen:

$$v = v1; \quad \Rightarrow v = 12.13 \frac{\text{m}^3}{\text{kg}}$$

(b) Carbon dioxide:

$$v = v1; \quad \Rightarrow v = 0.556 \frac{\text{m}^3}{\text{kg}}$$

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**1-2-19 [PY]** Use the IG system state daemon to determine entropy ( $s$ ) of 1 kg of (a) hydrogen, (b) oxygen, and (c) carbon dioxide at 100 kPa, 298 K. Discuss why the entropy of hydrogen is the highest among these three gases.

**TEST Solution:**

Launch the IG system-state TESTcalc. Select the gas and enter the known properties. The specific volume is calculated as part of the state.

(a) Hydrogen:

$$S = ms; \quad \Rightarrow S = m1*s1; \quad \Rightarrow S = (1)(64.87502); \quad \Rightarrow S = 64.9 \frac{\text{kJ}}{\text{K}}$$

(b) Oxygen:

$$S = ms; \quad \Rightarrow S = m1*s1; \quad \Rightarrow S = (1)(6.41138); \quad \Rightarrow S = 6.41 \frac{\text{kJ}}{\text{K}}$$

(c) Carbon Dioxide:

$$S = ms; \quad \Rightarrow S = m1*s1; \quad \Rightarrow S = (1)(4.85977); \quad \Rightarrow S = 4.86 \frac{\text{kJ}}{\text{K}}$$

The entropy of the Hydrogen is highest amongst the gases because for the given conditions of the problem. Hydrogen occupies the most amount of volume (entropy increases with volume at a given temperature).

**1-2-20 [PF]** A piston-cylinder device contains 1 kg of hydrogen at 100 kPa, 30°C (use the IG system state daemon). The gas is now compressed in such a manner that the entropy ( $s$ ) remains constant. (a) Calculate the temperature when the volume becomes half the original volume. (b) Calculate a series of states using the as the volume decreases from the initial value to one tenth of the initial volume. Plot how the pressure of the gas changes as a function of volume. Compare the plot with the isothermal curve of problem 1-2-15 [PC].

**TEST Solution:**

Calculate multiple states holding entropy constant ( $s_2$  as ' $s_1$ ',  $s_3$  as ' $s_1$ ' and so on) and varying the volume (Vol2 as ' $\text{Vol}_1 \cdot 0.9$ ', Vol3 as ' $\text{Vol}_2 \cdot 0.9$ ', and so on) after the first state is calculated from the given conditions. Plot pressure ( $p$ ) against volume ( $V$ ).

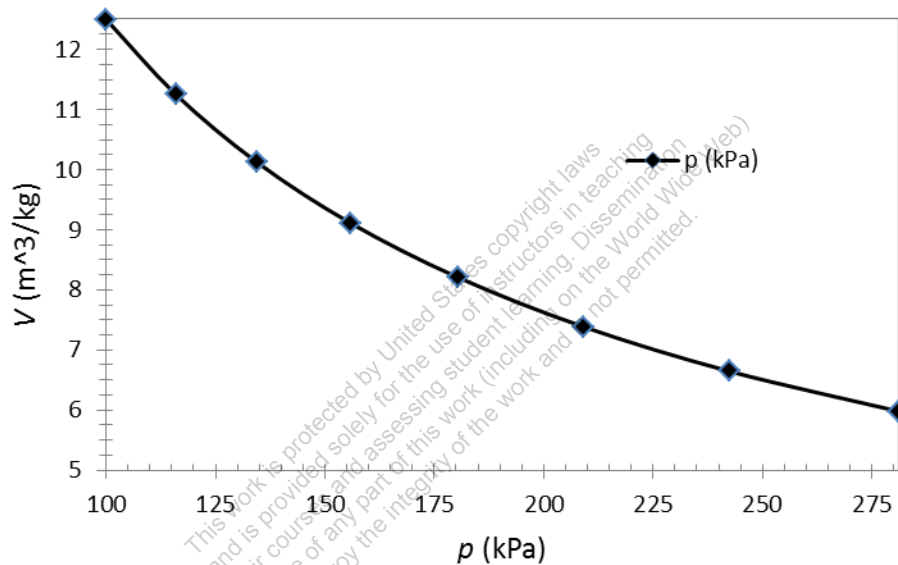


Fig. 1: Plot showing how  $p$  changes with  $s$  held constant and  $V$  decreasing by 10%.

**1-2-21 [PD]** In order to explore how the internal energy ( $u$ ) of a gas depends on temperature, volume, and pressure, evaluate the state of 1 kg of carbon dioxide at 100 kPa, 300 K using the IG state daemon. Now holding mass and volume constant (hint:  $m_2 = m_1$  and  $Vol_2 = Vol_1$  in state-2), evaluate a series of states at different temperature. Plot how the internal energy  $u$  changes with temperature. In a similar manner, plot how  $u$  changes with temperature when pressure is held constant.

Saul Montano

### TEST Solution:

Calculate multiple states holding mass and volume constant ( $m_2$  as ' $=m_1$ ',  $m_3$  as ' $=m_1$ ', and so on.  $Vol_2$  as ' $=Vol_1$ ',  $Vol_3$  as ' $=Vol_1$ ', and so on) while varying temperature ( $T_2$  as ' $=T_1+100$ ',  $T_3$  as ' $T_2+100$ ', and so on) after the first state is calculated from the given conditions. Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $u$  vs.  $T$ . For the constant-pressure data, re-do the calculations by holding pressure and mass constant.

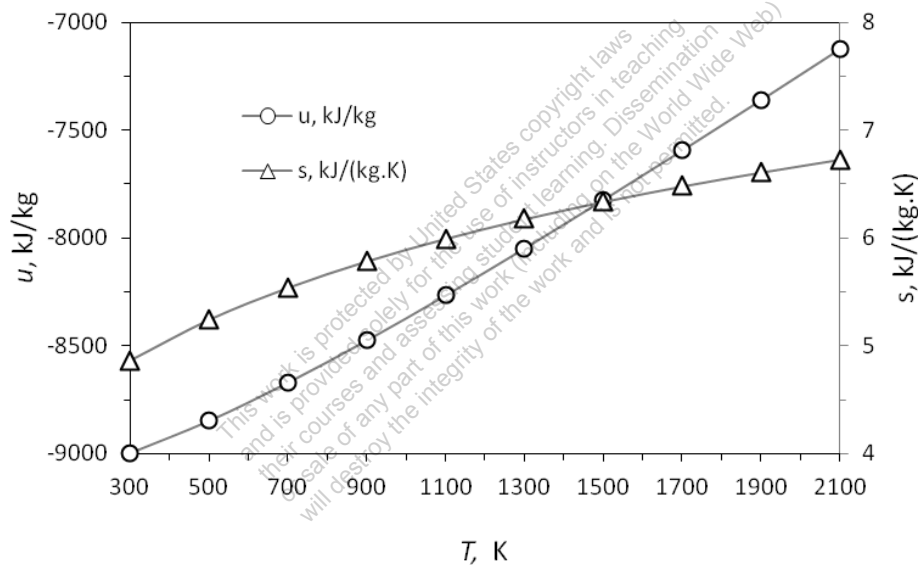


Fig.1: Plot showing how  $u$  and  $s$  change with temperature for an ideal gas.



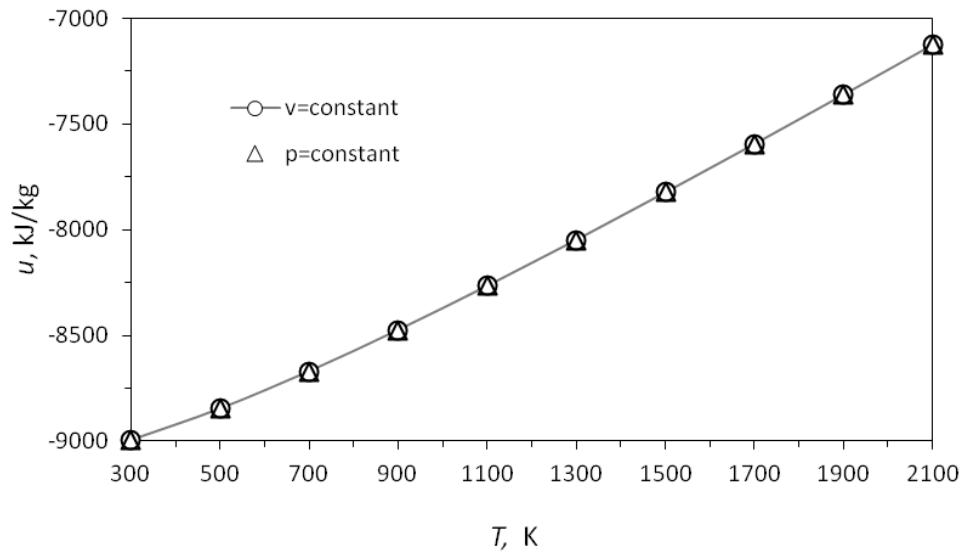


Fig.2: Plot showing how the specific internal energy changes with temperature.

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**1-2-22 [PM]** In order to explore how the entropy ( $s$ ) of a gas depends on temperature, volume, and pressure, evaluate the state of 1 kg of nitrogen at 100 kPa, 300 K using the IG state daemon. Now holding mass and volume constant (hint: Vol2 = Vol1 in state-2), evaluate a series of states at different temperatures. Plot how entropy ( $s$ ) changes with temperature. In a similar manner, plot how entropy ( $s$ ) changes with temperature when pressure is held constant.

**TEST Solution:**

Calculate multiple states holding mass and volume constant ( $m_2$  as ' $=m_1$ ',  $m_3$  as ' $=m_1$ ', and so on. Vol2 as ' $=Vol_1$ ', Vol3 as ' $=Vol_1$ ', and so on) while varying temperature ( $T_2$  as ' $=T_1+100$ ',  $T_3$  as ' $T_2+100$ ', and so on) after the first state is calculated from the given conditions. Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $s$  vs.  $T$ . For the constant-pressure data, re-do the calculations by holding pressure and mass constant.

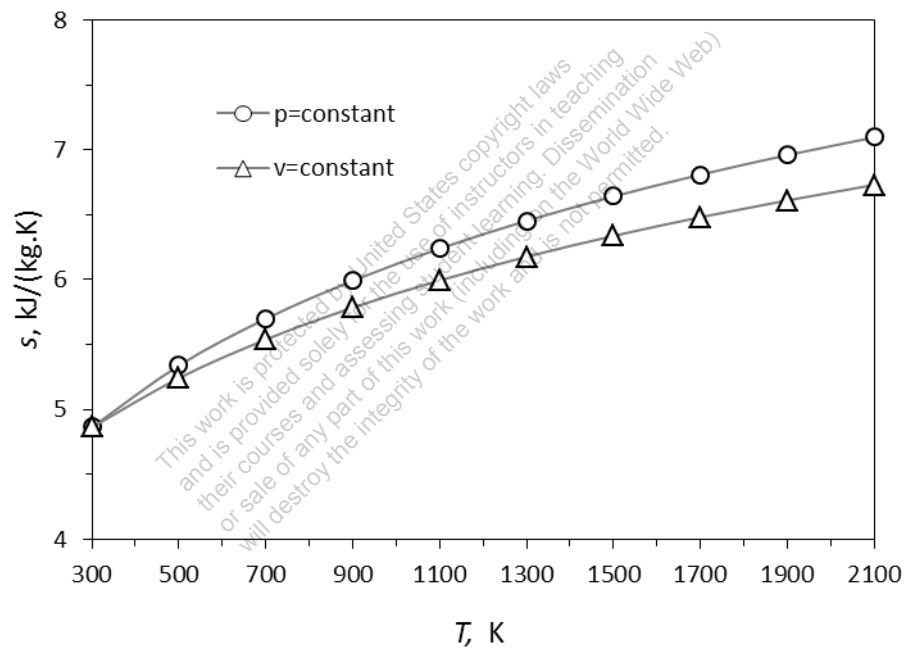


Fig. 1: Plot how entropy ( $s$ ) changes which temperature when pressure is held constant and another plot when specific volume is held constant.

**1-2-23 [PJ]** A tank contains 5 kg of carbon dioxide at 2000 kPa and 25°C. Using the IG (ideal gas) system state daemon, determine (a) the stored exergy ( $\Phi$ ) and (b) the stored energy ( $E$ ) in the gas. Assume the atmospheric conditions to be 100 kPa and 25°C. (c) How do you explain the negative sign of the stored energy calculated by the daemon?

**TEST Solution:**

After selecting the working fluid, calculate the dead state, State-0, for the given ambient conditions. Now calculate the current state using the pressure and temperature supplied. In the I/O panel calculate the total stored energy and total stored exergy ( $m1*e1$  and  $m1*\phi1$ ).

(a)  $\Phi_1 = m1*\phi1$ ;  $\Rightarrow \Phi_1 = (5)(114.51974)$ ;  $\Rightarrow \Phi_1 = 573 \text{ kJ}$

(b)  $E1 = m1*e1$ ;  $\Rightarrow E1 = -44,990 \text{ kJ}$

(c) The negative sign of the stored energy means that the energy is negative relative to an arbitrary defined zero energy reference (just like the potential energy).

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**1-2-24 [PW]** A rigid tank contains 1 kg of H<sub>2</sub>O at 1000 kPa, 1000°C. Heat is now transferred to the surroundings and the steam gradually cools down to a temperature of 30°C. Use the PC state daemon to determine a series of states at intermediate temperatures, while holding the volume and mass constant. Plot how the pressure, internal energy ( $E$ ), and entropy ( $S$ ) change as a function of temperature. Compare these results with the results of problem 1-2-16 [PV].

**TEST Solution:**

Calculate multiple states holding mass and volume constant ( $m_2$  as '=m1',  $m_3$  as '=m1', and so on. Vol2 as '=Vol1', Vol3 as '=Vol1', and so on) while varying temperature ( $T_2$  as '=T1-100',  $T_3$  as '=T2-100', and so on) after the first state is calculated from the given conditions. Click Super-Calculate to produce a spread sheet friendly table at the bottom of the I/O panel. Copy and paste the table in a spread sheet and plot  $p$  vs.  $T$ ,  $E(=m \cdot e)$  vs.  $T$ , and  $S(=m \cdot s)$  vs.  $T$  diagrams.

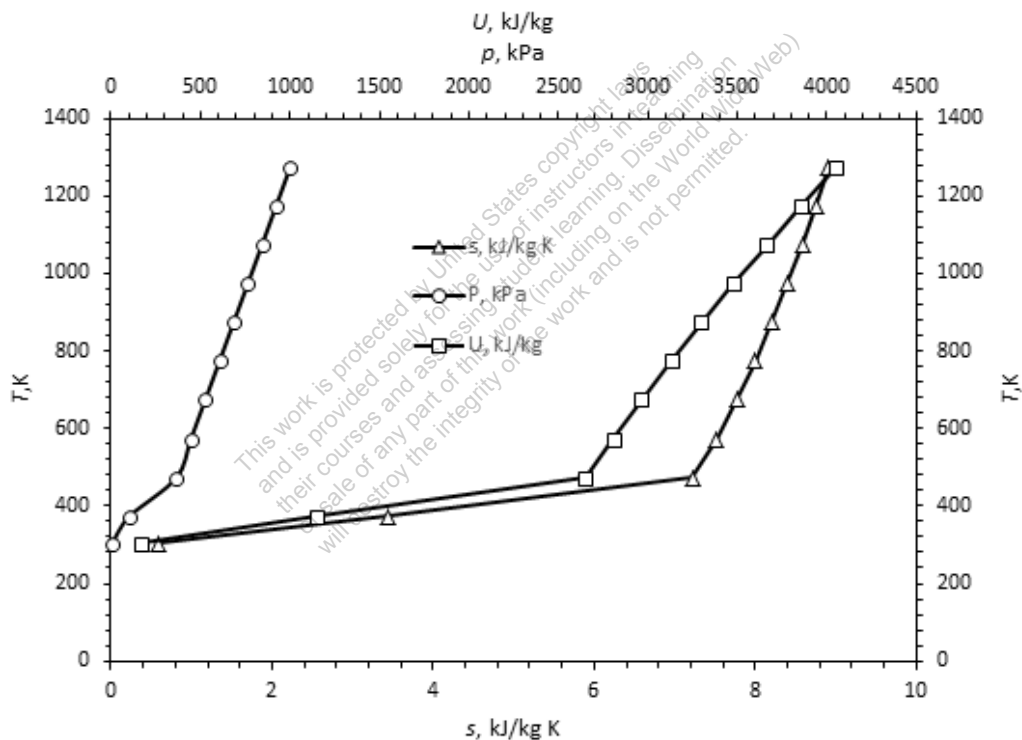


Fig. 1: Plot showing how the pressure, Internal Energy ( $U$ ), and entropy ( $s$ ) change as a function of Temperature ( $T$ ).

**1-2-25 [UR]** A piston cylinder device contains  $0.01 \text{ m}^3$  of steam at 500 kPa and  $300^\circ\text{C}$ . Determine the change in stored energy ( $E$ ) if (a) the pressure is increased to 1 MPa at constant temperature (b) temperature is increased to  $400^\circ\text{C}$  at constant pressure. Use the PC (phase-change) system state daemon.

**TEST Solution:**

Calculate the two states, the beginning state State-1, and the final states State-2 (for part a) and State-3 (for part b) from the given information. Obtain the change of stored energy in the I/O panel by evaluating the expression ' $m1*(e2-e1)$ '.

(a)  $\Delta E = m1*(e2-e1); \Rightarrow \Delta E = -0.18 \text{ kJ}$

(b)  $\Delta E = m1*(e3-e1); \Rightarrow \Delta E = 3.1 \text{ kJ}$

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**1-2-26 [UO]** Steam flows into a turbine with a mass flow rate of 6 kg/s at a temperature of 500°C and a pressure of 1500 kPa. If the inlet area is 0.25 m<sup>2</sup>, determine the transport properties (a)  $\dot{J}$ , (b)  $\dot{KE}$ , (c)  $\dot{U}$ , (d)  $\dot{E}$ , (e)  $\dot{H}$ , and (f)  $\dot{W}_F$  at the inlet. Use the PC (phase-change) flow state daemon. Neglect potential energy.

**TEST Solution:**

Calculate the flow state, State-1, from the given information. Obtain the transport properties in the I/O panel as follows:

$$(a) \quad \dot{J} = \dot{m} \cdot j_1; \quad \Rightarrow \dot{J} = (6)(3,473.0142); \quad \Rightarrow \dot{J} = 20,838 \text{ kW}$$

$$(b) \quad \dot{KE} = \dot{m} \cdot (e_1 - u_1); \quad \Rightarrow \dot{KE} = 0.0956 \text{ kW}$$

$$(c) \quad \dot{U} = \dot{m} \cdot u_1; \quad \Rightarrow \dot{U} = (6)(3,120.266); \quad \Rightarrow \dot{U} = 18,722 \text{ kW}$$

$$(d) \quad \dot{E} = \dot{m} \cdot e_1; \quad \Rightarrow \dot{E} = (6)(3,120.282); \quad \Rightarrow \dot{E} = 18,722 \text{ kW}$$

$$(e) \quad \dot{H} = \dot{m} \cdot h_1; \quad \Rightarrow \dot{H} = (6)(3,472.9983); \quad \Rightarrow \dot{H} = 20,838 \text{ kW}$$

$$(f) \quad \dot{W}_F = p_1 \cdot A_1 \cdot V_{el1}; \quad \Rightarrow \dot{W}_F = (1,500,000)(0.25)(5.64372); \quad \Rightarrow \dot{W}_F = 2,116 \text{ kW}$$

**1-2-27 [UB]** In problem 1-2-26 [UO], determine the flow rate of (a) entropy ( $\dot{S}$ ) and (b) exergy ( $\dot{\Psi}$ ) into the turbine if the atmospheric conditions are 100 kPa and 25°C.

**TEST Solution:**

Calculate dead state, State-0, from the ambient conditions and the flow state, State-1, from the given information. Obtain the transport properties in the I/O panel as follows:

$$(a) \quad \dot{S} = \dot{m} s_1; \quad \Rightarrow \dot{S} = 45.4 \frac{\text{kW}}{\text{K}}$$

$$(b) \quad \dot{\Psi} = \dot{m} \psi_1; \quad \Rightarrow \dot{\Psi} = 7324 \text{ kW}$$

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