REQUIRES ACCESS TO THE STEAM TABLES

1. 100 kg of water is contained in a piston-cylinder device. Initially, it is saturated liquid water at P=10 bar. It is heated at constant pressure until it is superheated steam at P=10 bar and T=250 °C.

   A) Determine the change in internal energy (U) of the water, in kJ.
   B) Determine the amount of work (W_{EC}) done on, or by, the water in this process.

SOLUTION:

Specific internal energy and specific volume are both available in the steam tables.

A)

$$U_{final} - U_{init} = M\left(\hat{U}_{final} - \hat{U}_{init}\right)$$

$$U_{final} - U_{init} = (100\ kg)\left(2710.4 - 761.4\ \frac{kJ}{kg}\right) = \mathbf{194.900\ kJ}$$

B)

$$W_{ec} = -\int_{V_{init}}^{V_{final}} PdV$$

For constant pressure system:

$$W_{ec} = -P\left(V_{final} - V_{init}\right) = P\left(V_{init} - V_{final}\right)$$

$$W_{ec} = (10\ bar)(100\ kg)\left(0.001127 - 0.233\ \frac{m^3}{kg}\right)\left(\frac{10^5\ Pa}{bar}\right)\left(\frac{1\ \frac{N}{m^2}}{1\ Pa}\right)\left(\frac{1\ J}{1\ Nm}\right)$$

$$W_{ec} = -2.319\ x\ 10^7\ J = \mathbf{-23,190\ kJ}$$

Negative sign represents work done by water on the surroundings.

2. A 50 kg object has kinetic energy of 100 kilojoules. What is its velocity in kilometers per hour?

SOLUTION:

$$K.E. = \frac{1}{2}Mv^2$$

$$100{,}000\,J = \frac{1}{2}(50\,kg)v^2$$

$$(100{,}000\,J)\left(\frac{1\,Nm}{1\,J}\right)\left(\frac{\frac{1\,kgm}{s^2}}{1\,N}\right) = \frac{1}{2}(50\,kg)v^2$$

$$\boldsymbol{v = 63.2\ \frac{m}{s}}$$

3. A 50 kg object has potential energy of 100 kilojoules relative to the ground. How far above the ground is it, in meters?

SOLUTION:

$$P.E. = mgh$$

$$100{,}000\,J = (50\,kg)\left(9.8\,\frac{m}{s^2}\right)h$$

$$(100{,}000\,J)\left(\frac{1\,Nm}{1\,J}\right)\left(\frac{1\,\frac{kgm}{s^2}}{1\,N}\right) = (50\,kg)\left(9.8\,\frac{m}{s^2}\right)h$$

$$\boldsymbol{h = 204\,m}$$

4. Which of the following is true?

A. Current is induced in a closed circuit by a changing magnetic field.

B. If you multiply a pressure expressed in pascals by an area expressed in square meters, the unit of the result is joules.

C. 100 kelvins is a higher temperature than 100 degrees Celsius.

D. All of the above are true.

E. None of the above are true.

Analysis:

A. Correct. This is how shaft work is converted into electricity.
B. Incorrect. Multiplying a pressure by an area produces a force. The joule is a unit of energy.
C. Incorrect. 100 kelvins are equal to -173.15 degrees Celsius, a much lower value.
D. Incorrect. Check again. Only one of the three statements is true.
E. Incorrect. Check again. One of the three statements is true.

5. Which of the statements A–D is false?

A. Kelvins are units of temperature on an absolute scale

B. One kilogram exerts a force of one newton.

C. Energy can be defined by the potential to do work.

D. Base units in the SI system include kilograms, meters and seconds.

E. None of the statements are false.

Analysis:

A. Incorrect. This statement is true. The kelvin "scale" is the SI scale of absolute thermodynamic temperature, as opposed to the Celsius.
B. Correct. Force and mass are fundamentally two different properties. The force of gravity on a one kilogram object is equal to 9.81 N on Earth. This is sometimes called the kilogram-force or kgf. In a different gravitational field a 1 kg object would have a different gravitational force.
C. Incorrect. This statement is true. At the beginning of Section 1.4 we noted that the potential to do work is what makes various forms of energy recognizable as energy.
D. Incorrect. This statement is true. Other units, like pascals, that can be derived from these are also considered SI units.
E. Incorrect. Check again. One of the statements is false.

6. Which of the following is true?

A. A closed system is one where no heat or mass can cross the system boundary.

B. Step 2→3 in the Rankine Cycle (re: across the turbine) is characterized as an isobaric expansion.

C. An adiabatic process is one where the temperature is constant throughout the process.

D. In step 1→2 in the Rankine Cycle (re: across the boiler), heat is added to the system in order to convert water to steam.

E. None of the above are true.

Analysis:

A. Incorrect. A closed system is one in which no mass crosses the boundaries of the system, but heat (and work) can be transferred to or from a closed system.
B. Incorrect. The word isobaric means constant pressure. The fluid experiences a significant pressure drop as it travels through a turbine.
C. Incorrect. A constant temperature process is isothermal. Adiabatic means no heat is added or removed. An adiabatic system is not necessarily isothermal. In fact, when a chemical reaction or a phase change is occurring, adding or removing heat is how a system is maintained isothermal.
D. Correct. The primary purpose of the added heat is to boil the liquid, though ordinarily a change in temperature also occurs because the entering liquid is not at its boiling point.
E. Incorrect. Check again. One of the statements is true.

7. Which of the statements A–D is false?

A. The purpose of a turbine in a steam power plant is to convert the internal energy of the steam into electrical energy.

B. The mass flow rate in a pipe is equal to the product of the fluid density, cross-sectional area of the pipe and the fluid velocity.

C. For a steady-state system with only one stream entering and one stream leaving the system, the volumetric flow rate of the entering stream must be equal to the volumetric flow rate of the exiting stream.

D. In a Rankine cycle, the condenser operates at a lower temperature than the boiler.

E. None of the above is false.

Analysis:

A. Incorrect. This statement is true. Conceptually, the shaft work in a Rankine engine can be used for anything. In a steam power plant it is used to make electricity.
B. Incorrect. This statement is true. Example 1-5 shows the use of this equation.
C. Correct. Volume is not a conserved quantity. The mass flow rates of the entering and leaving stream are equal at steady state, but if they have different densities, they will have different volumetric flow rates.
D. Incorrect. This statement is true. There is a large pressure drop in the turbine. Because the pressure of the fluid entering the condenser is lower than the pressure of the fluid leaving the boiler, the boiling point of the fluid is lower, so the condenser operates at a lower temperature.
E. Incorrect. Check again. One of the statements is false.

8. Which of the statements A–D is false?

A. For an isochoric system, W_{EC}=0, but W_S is not necessarily equal to zero.
B. For a steady state system, W_{EC}=0, but W_S is not necessarily equal to zero.
C. All isothermal systems are adiabatic, but not all adiabatic systems are isothermal.
D. All isolated systems are adiabatic systems, but not all adiabatic systems are isolated systems.
E. None of the above are false.

Analysis:

A. Incorrect. This statement is true. Isochoric means constant volume, which means there can be no expansion work. But an isochoric system can contain moving parts that add or remove shaft work.
B. Incorrect. This statement is true. In a steady state system, all properties of the system are constant with respect to time. Volume is a property of the system; a steady state system cannot be expanding or contracting. But a steady state system can involve shaft work, such as the pump and turbine in a Rankine cycle.
C. Correct. Isothermal systems are not necessarily adiabatic; in fact, adding or removing heat is often precisely the way a system is maintained as isothermal.
D. Incorrect. This statement is true. Isolated systems have neither energy nor mass crossing the boundaries of the system. Thus an isolated system cannot have heat transfer, and is therefore adiabatic. But an adiabatic system that has mass or work entering or leaving is not isolated.
E. Incorrect. Check again. One of the statements is false.

9. Which of the following statements is true?

A. In an isobaric system, no flow work can be added or removed, because flow work is equal to PAv and in an isobaric system P=0.
B. In a closed system, no flow work is added or removed, because no material is entering or leaving the system.
C. In applying the equation $W_{EC} = -\int PdV$, the P always stands for the pressure inside the system.
D. In applying the equation $W_{EC} = -\int PdV$, the P always stands for the pressure outside the system.
E. None of the above are true.

Analysis:

A. Incorrect. The word isobaric means that pressure is constant, not that pressure is 0.
B. Correct. A closed system can have shaft work or expansion work added or removed, but not flow work.
C. Incorrect. The P stands for the pressure opposing the motion. If the system is expanding, the pressure opposing the motion is the pressure outside the system.
D. Incorrect. The P stands for the pressure opposing the motion. If the system is being compressed, the pressure opposing the motion is the pressure inside the system.
E. Incorrect. Check again. One of the statements is true.

10. Which of the following statements is true?

A. The equation $K.E. = \frac{1}{2}Mv^2$ can only be used with SI units.
B. In the equation $K.E. = \frac{1}{2}Mv^2$, the number $\frac{1}{2}$ has no units.
C. The equation $P.E. = Mgh$ can only be used with SI units.
D. In the equation $P.E. = Mgh$, the quantity g has the same units as a velocity.
E. All of the above are true.

Analysis:

A. Incorrect. This is a fundamental equation that can be used in any system of units.
B. Correct. Mass times velocity times velocity gives a number with the dimension of energy, so the ½ has no dimensions.
C. Incorrect. This is a fundamental equation that can be used in any system of units.
D. Incorrect. The quantity g is the acceleration due to gravity. Acceleration is the derivative of velocity with respect to time and has different units than velocity.
E. Incorrect. Check again. One of the statements is false.

11. Which of the following quantities cannot be a negative number?

A. Temperature, when expressed in kelvins.
B. Pressure, when expressed as gauge pressure.
C. Potential energy, when expressed using the convention that $h = 0$ at sea level.
D. Internal energy, when expressed relative to a reference state of $T = 273.15$ K and $P = 0.1$ MPa.
E. All of the above could be negative numbers.

Analysis:

A. Correct. By definition, 0 K is absolute zero. It is not physically possible to go below this temperature, since it is the temperature at which all energy has been removed from the system.
B. Incorrect. Absolute pressures between 0 and atmospheric pressure correspond to negative gauge pressures.
C. Incorrect. Objects can be located below sea level and these have negative potential energy relative to sea level.
D. Incorrect. Internal energy is considered to be 0 at the reference state, so states with lower internal energy than the reference state (e.g., same pressure but lower temperature) have negative internal energy relative to this reference state, though they have positive internal energy in an absolute sense.
E. Incorrect. Quantities that are expressed on an absolute scale cannot be negative, and one of these is.

12. Which of the following does not produce a number with unit(s) equivalent to joules?

A. Multiplying a force in newtons by a distance in meters.
B. Multiplying a pressure in pascals by a volume in cubic meters.
C. Multiplying a mass in kilograms by a velocity in meters per second.
D. Multiplying a force in kilonewtons by a distance in millimeters.
E. All of the above produce numbers with units of joules.

Analysis:

A. Incorrect. One joule is one newton-meter, so this is the most straightforward way to calculate an energy in joules.
B. Incorrect. A pascal is a newton per square meter, so multiplying pascals by cubic meters produces a newton-meter.
C. Correct. Mass times velocity doesn't produce a number with dimensions of energy, so it can't be in joules. Mass times velocity *squared* is equivalent to energy.
D. Incorrect. A joule is one newton-meter. The conversion factors of 1000 for converting kilonewtons to newtons, and millimeters to meter, cancel each other, so the result is indeed in joules.
E. Incorrect. Check again. One of these does not produce a quantity in joules.

13. If a source says "the internal energy of the methane is $\underline{U}$ = 100 J/mol," which of the following is true?

A. In order to lower the temperature of the methane to absolute zero, you would have to remove 100 joules of heat from each mole of methane.
B. In order to convert the methane from its current state to the reference state, 100 joules of heat would need to be added to each mole of methane.
C. In order to convert the methane from its current state to the reference state, 100 moles of energy would need to be added to each mole of methane, but the energy added could take the form of either work or heat.
D. 100 joules, divided by the number of molecules in one mole, equals the average kinetic energy of the methane molecules, but the kinetic energy of individual molecules vary widely.
E. None of the above are true.

Analysis:

A. Incorrect. This is not true. The value 100 J/mol is relative to a reference state, not relative to absolute zero.
B. Incorrect. This is not true. The reference state has $\underline{U} = 0$. Adding 100 J/mol of heat would increase the internal energy to 200 J/mol, unless work was occurring concurrently.
C. Incorrect. This is not true. The reference state has $\underline{U} = 0$. Adding 100 J/mol would increase the internal energy to 200 J/mol.
D. Incorrect. This is not true. 100 J/mol is relative to a reference state; it is not a measure of the absolute quantity of kinetic energy contained in the molecules. In addition, internal energy consists of microscopic potential energy as well as kinetic energy.
E. Correct.

14. What is the kinetic energy, in joules, of a 7.0 kilogram bowling ball that is travelling 4.5 meters per second?

A. 106. J
B. 71. J
C. 31.2 J
D. 142. J
E. 100. J

Analysis:

A. Incorrect. You appear to have used the correct equation, but confused the variables. Make sure the values you are inserting in the calculator are right.
B. Correct. A straightforward use of Equation 1.29.
C. Incorrect. This is the product of the two values given, but not the answer. Review the definition of kinetic energy and try again.
D. Incorrect. The correct answer is one half of this. Remember K.E. = $(1/2)Mv^2$
E. Incorrect. This answer most likely results from making multiple errors. Check your work again.

15. What is the potential energy, in joules, of a 7.0 kg bowling ball that is 150 cm above the ground?

A. 103 J
B. 10,300 J
C. 10.5 J
D. 2415 J
E. Insufficient information to solve

Analysis:

A. Correct. This is the P.E. of the bowling ball "system".
B. Incorrect. Check the units on your variables; you have not taken prefixes (centi-, milli-, …) into account.
C. Incorrect. You have left out the acceleration of gravity from Equation 1.30. Try again.
D. Incorrect. You appear to have made multiple mistakes. Go back to Section 1.4.5 and review the subject. Then start from the equation provided that quantifies P.E. and redo the problem.
E. Incorrect. The problem can be solved. The only assumption required is a value for the acceleration due to gravity, and this is uniform enough on Earth that a single value is used routinely.

16. If a room is at 75˚C, and heat is added to double its internal energy (assume this doubles the temperature), what is the final temperature of the room in kelvins?

A. 41 000 K
B. 348.15 K
C. Temperatures on non-absolute scales cannot be related to temperatures on absolute scales without knowing the reference state(s).
D. 423.15 K
E. None of the above

Analysis:

A. Incorrect. You have followed the correction solution path, but note that conversions between temperatures in degrees Celsius and kelvins require *adding* a value, not multiplying. This is unique to temperature unit conversions.
B. Incorrect. This is 75°C converted to kelvins, not the final temperature.
C. Incorrect. It is true that thermodynamic quantities like internal energy (U) are measured relative to a reference state, and that you can't add or subtract values of *U* that are measured using different reference states. But there is nothing unknown about the reference states for these temperature scales; they all have defined relationships to each other.
D. Correct. In these conditions, the increase in internal energy must cause a rise in temperature. Doubling the internal energy *in this room* doubles the temperature. 150°C can be converted to kelvins by adding 273.15.
E. Incorrect. Check again.

17. If the mass of a coin is 2.5 g, how much work does it take to carry it from ground level to the top of a 300 m tall skyscraper?

A. 7.4 J
B. 7400 J
C. -7.4 J
D. -7400 J
E. 0 J

Analysis:

A. Correct. Although the distance traveled is high, the small mass keeps the work required low.
B. Incorrect. It appears you forgot a conversion factor. Carefully redo your calculation and watch the units.
C. Incorrect. This sign is incorrect. Energy is being added to the dime because it is moving against gravity.
D. Incorrect. This sign is incorrect. Energy is being added to the dime because it is moving against gravity.
E. Incorrect. Work is definitely being done to move the dime against the gravitational downward force.

18. A pool of water is being filled with a hose that has a 2 cm inside diameter. The water leaves the hose with a flow rate of 0.000 63 m^3/s and a pressure of 101.325 kPa absolute. How much flow work (in watts) does the water add to the pool as it enters the pool?

A. 64 W
B. 64 mW
C. 64 kW
D. 0 W
E. Dependent on the density/specific volume of the water

Analysis:

A. Correct. Using the PV equation you can calculate the flow work added. The hose diameter is unnecessary information.
B. Incorrect. You are not observing the prefixes on the units in the problem. Try again.
C. Incorrect. You cannot blindly carry over prefixes from units in the problem. Just because pressure is given in *kilo*pascals that does not mean that the work will be in *kilo*joules.
D. Incorrect. There is flow work being done. You may have been misled by the pressure, but note that it is in absolute pressure, not gage pressure.
E. Incorrect. You do not need the density or specific volume of the water because you are given a volumetric flowrate. Try again.

19. A balloon has an initial volume of 0.000 5 m^3. The air both inside and outside of the balloon is at 0.1 MPa. Defining the air in the balloon as your system, calculate (in joules) the expansion work when the balloon volume is increased to 0.001 5 m^3.

A. -100 J
B. 100 J
C. 101 kJ
D. -101 kJ
E. 1 kJ

Analysis:

A. Correct. Using the "PdV" equation you can calculate that 100 joules of energy were transmitted to the surroundings.
B. Incorrect. Review the expansion/contraction work equation paying particular attention to the sign convention we establish in Section 1.4.3.
C. Incorrect. Review the problem statement and your calculations, paying particular attention to decimal points.
D. Incorrect. Review the problem statement and your calculations, paying particular attention to decimal points and signs.
E. Incorrect. Check your calculations. You are off by an order of magnitude.

20. If a person's body temperature changes from 310.15 K to 311 K, what was the change in temperature, in degrees Celsius?

A. 1.4 °C
B. 2.5 °C
C. 1.4 K
D. 0.85 °C
E. 0.95 °C

Analysis:

A. Incorrect. This is too great a temperature interval.
B. Incorrect. Re-check the relationships between the temperature scales.
C. Incorrect. This is a temperature different in kelvins; you were asked for Celsius. Also the number is too large— this would be correct if you were converting into Fahrenheit or Rankine.
D. Correct. Because of the origin of the units called kelvin and degree Celsius, a temperature difference of one kelvin is equal to one Celsius degree.
E. Incorrect. Check your arithmetic.

21. If an object is at rest 500 m above the ground and it falls to the ground, what is its velocity when it hits the ground (neglecting air resistance)?

A. 70 m/s
B. 99 m/s
C. 9810 m/s
D. 9.81 m/s
E. Insufficient information to solve

Analysis:

A. Incorrect. You forgot a factor in your calculation. Reexamine your work.
B. Correct. All potential energy will have been transformed to kinetic energy at the ground.
C. Incorrect. You made a mistake in your algebra. Check how you solved for velocity.
D. Incorrect. The number (9.81) is the common acceleration due to gravity, but the units are incorrect for that. It is also not the answer to the question, which seeks velocity.
E. Incorrect. This problem can be solved from the given information. Note that answer is the same for any mass object, so the mass of the object doesn't need to be known.

22. A glass initially contains 0.1 kg of ice and 0.05 kg of water. The ice, the water, the glass and the air surrounding them are all at T = 273.15 K and P = 0.1 MPa. The water is evaporating very gradually. Which of the following is true?

A. The ice and water are at equilibrium with each other and with the surroundings.
B. The ice and water are not in equilibrium with each other, but if 0.025 kg of ice melted, making the masses of the ice and water equal, they would then be in equilibrium with each other.
C. The water is in thermal and mechanical equilibrium with the air, but not in chemical equilibrium.
D. The system is at steady state but not in equilibrium.
E. None of the above are true.

Analysis:

A. Incorrect. If the water was at equilibrium with its surroundings, it would not be evaporating at all. Try again.
B. Incorrect. There is no reason why phases in equilibrium need to have the same mass. If no water is freezing and no ice is melting, then the water and ice are in chemical equilibrium with each other regardless of the masses of the phases.
C. Correct. The water and air are at the same temperature and pressure, but they are not in chemical equilibrium; there is a driving force for water to evaporate. In practical terms, the air is not fully saturated with water vapor (relative humidity is less than 100%). Vapor–liquid equilibrium is addressed for pure components in Chapter 8 and for multi-component mixtures in Chapters 12 and 13.
D. Incorrect. Because water is evaporating from the glass and not being replenished from any source, we cannot say it is at steady state. Try again.
E. Incorrect. One of the statements is correct. Try again.

23. The air inside an oven is at a temperature of 500 K. A turkey inside the oven is in equilibrium with the air inside the oven. Which of the following is false?

A. There is no heat transfer from the air to the turkey, because there is no driving force for heat transfer.
B. The turkey is not expanding, because there is no driving force for expansion.
C. The moisture in the turkey is not evaporating, because there is no driving force for evaporation.
D. The temperature of the turkey is 500 K at the surface of the turkey, but needn't be 500 K in the center of the turkey.
E. None of the above statements are false.

Analysis:

A. Incorrect. This statement is true. If the turkey and air are in equilibrium, then there are no driving forces for heat transfer. Try again.
B. Incorrect. This statement is true. If the turkey is at equilibrium with the air, then they are at identical pressures and there is no driving force for expansion. Try again.
C. Incorrect. This statement is true. If the turkey and air are in equilibrium, then there are no driving forces present for chemical reactions or phase changes. Try again.
D. Correct. If we say the turkey is in equilibrium with the air, we are stating that the entire turkey-as-a-system is in equilibrium, outside and inside. If the turkey had a non-uniform temperature, then there would be driving forces for heat transfer within the turkey.
E. Incorrect. One of these statements can be determined to be false. Try again.