Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question 01	**1.** Match the thermodynamics laws (Zeroth, First, And Second) with the following statements: (1) Energy is never created or destroyed. (2) The order of the universe is never decreased. (3) Energy may change forms. (4) Objects of the same temperature are in thermal equilibrium. (A) 1^{st}, 2^{nd}, 1^{st}, 0^{th} (B) 0^{th}, 2^{nd}, 0^{th}, 1^{st} (C) 1^{st}, 0^{th}, 1^{st}, 2^{nd} (D) 2^{nd}, 1^{st}, 2^{nd}, 0^{th} (E) 0^{th}, 1^{st}, 2^{nd}, 0^{th}
Feedback on Each Answer Choice	A. Correct! The Zeroth Law: Objects in thermal equilibrium are at the same temperature. If object A is in thermal equilibrium with object B and object C, then object B is also in thermal equilibrium with object C. 1^{st} Law of Thermodynamics: Energy cannot be created nor destroyed in a chemical or physical process. It can only be changed from one for to another. 2^{nd} Law of Thermodynamics: The total entropy of the universe can never decrease, only increase or remain the same.
	B. Incorrect! Review the laws of thermodynamics.
	C. Incorrect! Review the laws of thermodynamics.
	D. Incorrect! Review the laws of thermodynamics.
	E. Incorrect! Review the laws of thermodynamics
Solution	This problem is directly from the definitions of the laws of thermodynamics: The Zeroth Law: Objects in thermal equilibrium are at the same temperature. If object A is in thermal equilibrium with object B and object C, then object B is also in thermal equilibrium with object C. 1^{st} Law of Thermodynamics: Energy cannot be created nor destroyed in a chemical or physical process. It can only be changed from one for to another. 2^{nd} Law of Thermodynamics: The total entropy of the universe can never decrease, only increase or remain the same. **The correct answer is (A).**

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Question 02	**2.** If you mix a 1 L jug of water at 20 °C with another 1 L jug of water at 50 °C, what will the final temperature of the water be? (A) 20 °C (B) 50 °C (C) 70 °C (D) 35 °C (E) Insufficient information to answer.
Feedback on Each Answer Choice	A. Incorrect! Where did the extra energy go? Think about the definition of temperature and thermal equilibrium.
	B. Incorrect! Where did the extra energy come from? Think about the definition of temperature and thermal equilibrium.
	C. Incorrect! Where did the extra energy come from? Think about the definition of temperature and thermal equilibrium.
	D. Correct! When mixed together the two jugs of water will reach thermal equilibrium. Heat will flow from the warmer water to the cooler water. In the process, the warmer water loses energy and the cooler water gains energy. The molecules in the warm water lose kinetic energy and those in the cool water gain kinetic energy until all the molecules have the same average kinetic energy, the temperature will be between the original.
	E. Incorrect! All the information you need is there. Think about the definition of temperature and thermal equilibrium.
Solution	When mixed together the two jugs of water will reach thermal equilibrium. Heat will flow from the warmer water to the cooler water. In the process, the warmer water loses energy and the cooler water gains energy. The molecules in the warm water lose kinetic energy and those in the cool water gain kinetic energy until all the molecules have the same average kinetic energy. Remember temperature is a measure of the average kinetic energy. The final temperature will be between the original temperatures. In this case, since the two liquids are the same substance and have the same mass, the equilibrium temperature is a simple average of the two original temperatures. (20 °C +50 °C)/2 = 35 °C **The correct answer is (D).**

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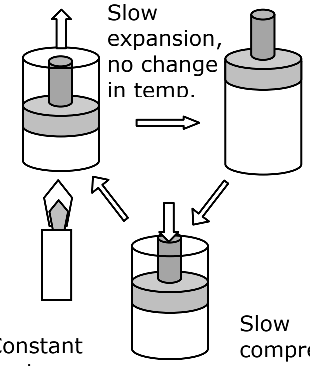
Question 03	**3.** If 1250 J of heat is added to a system and 750 J of work is done **ON** the system. What is the change in the internal energy of the system? (A) 2000 J (B) 500 J (C) -500 J (D) -2000 J (E) 1250 J
Feedback on Each Answer Choice	A. Correct! The First Law of Thermodynamics states a systems internal energy, U, is equal to the heat energy added to the system, Q, minus the work done BY the system, in this case the work is done ON the system so it is taken to be negative. U = Q – W = 1250 J – (-750 J) = 2000 J.
	B. Incorrect! Remember that the First Law of Thermodynamics W is the work done BY the system.
	C Incorrect! The First Law of Thermodynamics states a systems internal energy, U, is equal to the heat energy added to the system, Q, minus the work done BY the system. U = Q – W
	D. Incorrect! The First Law of Thermodynamics states a systems internal energy, U, is equal to the heat energy added to the system, Q, minus the work done BY the system. U = Q – W
	E. Incorrect! Use the First Law of Thermodynamics.
Solution	First Law of Thermodynamics states a systems internal energy, U, is equal to the heat energy added to the system, Q, minus the work done BY the system. U = Q – W. In this case the work is done ON the system so we must take W to be negative, -750 J. U = 1250 J – (-750 J) =2000 J **The correct answer is (A).**

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 04	**4.** A class has been asked to find the amount of work done by a system, if the internal energy of the system increased from 5 J to 16 J when 20 J of heat were added to the system. Which of these would be the correct solution? (A) $\Delta U = Q - W$ where $\Delta U = (16\text{ J} - 5\text{ J})$ $Q = 20\text{ J}$ so $11\text{ J} = 20\text{ J} - W$, $W = 9\text{ J}$ (B) $\Delta U = Q - W$ where $\Delta U = 20\text{ J}$ $Q = (16\text{ J} - 5\text{ J})$ so $20\text{ J} = 11\text{ J} - W$, $W = -9\text{ J}$ (C) $\Delta U = Q + W$ where $\Delta U = (16\text{ J} - 5\text{ J})$ $Q = 20\text{ J}$ so $11\text{ J} = 20\text{ J} + W$, $W = -9\text{ J}$ (D) $\Delta U = Q + W$ where $\Delta U = 20\text{ J}$ $Q = (16\text{ J} - 5\text{ J})$ so $20\text{ J} = 11\text{ J} + W$, $W = 9\text{ J}$ (E) None of the above
Feedback on Each Answer Choice	A. Correct! The change in internal energy ΔU is 16 J – 5 J = 11 J, the heat added to the system is 20 J and the equation for internal energy is $\Delta U = Q - W$, where W is the work done BY the system and is positive.
	B. Incorrect! Reread the question and remember ΔU is the symbol for change in internal energy.
	C. Incorrect! The equation for internal energy is $\Delta U = Q - W$, where W is the work done BY the system and is positive.
	D. Incorrect! The equation for internal energy is $\Delta U = Q - W$, where W is the work done BY the system and is positive. Reread the question and remember ΔU is the symbol for change in internal energy.
	E. Incorrect! One of these is a correct solution; check the formula for internal energy.
Solution	**Known:** Change in internal energy = (16 J – 5 J) = 11 J Heat added, Q = 20 J **Unknown:** The work done BY the system, W =? J **Define:** The equation for internal energy is $\Delta U = Q - W$, where W is the work done BY the system. **Output:** $11\text{ J} = 20\text{ J} - W$, rearrange $11\text{ J} - 20\text{ J} = -W$ $-9\text{ J} = -W$ $W = 9\text{ J}$ **Substantiate**: Units are correct, sig figs are correct, Magnitude is correct, **The correct answer is (A).**

Question No. 5 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 05	**5.** Your sealed shampoo bottle expands as you drive from sea level up to ski at 10,000 ft. What type of process does this represent? (A) cyclical (B) constant-volume (C) free-expansion (D) adiabatic (E) entropy
Feedback on Each Answer Choice	A. Incorrect! The initial state (sea level) of the bottle is different from the final state (10,00ft). If you were to drive back down to sea level, without opening the bottle, it would return to its regular size and the process would be cyclical.
	B. Incorrect! The volume of the bottle expands so this is not a constant-volume process, the volume of the bottle changed when it expands.
	C. Incorrect! If you were to return to sea level without opening the bottle, it would return to its original volume. Thus, the process is reversible and cannot be a free expansion process.
	D. Correct! An adiabatic process is one in which there is no heat transfer; the work done depends on the pressure and volume change.
	E. Incorrect! Entropy is a measure of the disorder of a system not a process.
Solution	Recognize that this is an application of the 1st Law of Thermodynamics. $U = Q - W$ U = internal energy (in J); Q = heat (in J); W = work done by the system Examine each term. W = work Note that volume of the bottle changes. Thus, pressure-volume work is done on the bottle so $W>0$. Q = heat Note that there is no mention of heat exchange. Thus, $Q=0$. Which special case of the 1st Law has $W>0$ and $Q=0$? Adiabatic process. **The correct answer is (D).**

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 06	**6.** Look at the picture and identify what type of process is occurring? (A) Adiabatic (B) Isothermal cyclical (C) Free expansion (D) Isovolumetric (E) Constant pressure 
Feedback on Each Answer Choice	A. Incorrect! In an adiabatic process, the piston is depressed quickly but no heat is added to the system, the work increases the internal energy of the system. $\Delta U = - W$
	B. Correct! A process in which there is no temperature change is referred to as an isothermal process. The process returns to its original state, so it is a cycle.
	C. Incorrect! This process is a reversible one, it returns to its original state. A free –expansion process is irreversible.
	D. Incorrect! The prefix iso means constant, is the volume constant?
	E. Incorrect! Is the pressure remaining constant throughout the process?
Solution	A process in which there is no temperature change is referred to as an isothermal process. In this case, we see that work is first done by the system in increasing the volume in the cylinder, if this happens slowly so that there is not temperature change then the internal energy does not increase, all the heat is being used by the system to do work. Next pressure is applied to the piston to compress the gas, so work is being done on the system. If the compression happens slowly so there is, no change in temperature, the internal energy will not change and the amount of work done is equal to the amount of heat that had to be added for the system to do the work. The system returns to its original state. So is cyclical, not the process could be done in reverse. **The correct answer is (B).**

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 07	**7.** Cyclists carry cartridge filled with pressurized carbon dioxide. When changing a flat tire on the road, a cyclist will break the seal of the cartridge and use it to fill a replacement. The cartridge fills the tire so rapidly that frost may form around the cartridge. What special case of the 1^{st} Law of thermodynamics does this represent? (A) Adiabatic (B) Constant-Volume (C) Isothermal cyclical (D) Free expansion (E) None of these
Feedback on Each Answer Choice	A. Incorrect! In an adiabatic process, there is no heat exchange. The tube may become covered in frost so there is an exchange of heat energy.
	B. Incorrect! The volume of the cartridge is combined with the volume of the tube, which is inconstant and expands rapidly.
	C. Incorrect! There is no cycle. The process is irreversible.
	D. Correct! Good job. The contents of the cartridge are emptied into the tube, which expands freely. The process is irreversible.
	E. Incorrect! One of these processes describes what is happening.
Solution	Step 1) Examine the situation. The cartridge is initially at a high pressure. The tube is at essentially zero pressure. The tube expands rapidly. The cartridge may become covered in frost so there is an exchange of heat energy. Step 2) What are the conditions for each of the special cases of the 1^{st} Law? Adiabatic: $Q = 0$, $\Delta U = -W$, reversible Constant-volume: $W = 0$, $\Delta U = Q$ Isothermal cyclical: $\Delta U = 0$, $Q = W$, no change in temperature, reversible Free expansion processes: $\Delta U = Q = W$, irreversible Step 3) Examine each of the cases with respect to this case. Adiabatic: Adiabatic work must occur with no heat exchange. The tube may become covered in frost so there is an exchange of heat energy. Constant-Volume: The volume of the cartridge is combined with the volume of the tube, which is not constant and expands rapidly. Isothermal Cyclical: There is no cycle and there is a change in temperature. . Free Expansion: The contents of the cartridge are emptied into the tube, which expands freely. The process is irreversible. **The correct answer is (D).**

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 08	**8.** Place the following in order of increasing entropy: salt solution at 300K, salt crystals in water, salt solution at 280K, salt crystals partially dissolved in water. (A) Salt solution at 280K, salt crystals in pure water, salt crystals partially dissolved in water, salt crystals in water at 300K. (B) Salt crystals partially dissolved in water, salt crystals in pure water, salt solution at 280K, and salt solution at 300K. (C) Salt crystals in pure water, salt crystals partially dissolved in water, salt solution at 280K, and salt solution at 300K. (D) Salt solution at 300K, salt solution at 280K, salt crystals partially dissolved in water, salt crystals in pure water. (E) Salt solution at 300K, salt crystals in water, salt solution at 280K, salt crystals partially dissolved in water.
Feedback on Each Answer Choice	A. Incorrect! Remember that entropy is a measure of disorder or randomness. Salt solution is composed of completely dissolved crystals so that the entire crystalline order has been disturbed. In addition, as molecules heat up, they move more rapidly, leading to increased disorder.
	B. Incorrect! Increasing entropy means increasing disorder. If salt crystals are in pure water then there is a state of order because the salt crystal is highly ordered and the water is pure.
	C. Correct! Good job. See complete solution for more detail.
	D. Incorrect! Increasing entropy means increasing disorder. The items are arranged in decreasing order.
	E. Incorrect! Remember that entropy is a measure of disorder or randomness, and higher temperatures correspond to higher entropy.
Solution	Step 1) Define entropy. Entropy is a measure of disorder. Step 2) Categorize the items in terms of orderliness. Salt crystals in pure water: The molecules in a crystal are highly ordered and arranged in a very regular pattern. Similarly, pure water is also highly ordered so having crystals in pure water is a highly ordered (and short-lived) state! Salt crystals partially dissolved in water: The crystals are highly ordered but since they are partially dissolved, the water is no longer pure and less orderly. Salt solution at 280K: This is a completely mixed solution at slightly higher than freezing. A completely mixed solution is highly disordered, sort of like a box full of unmatched socks. Salt crystals at 300K. This is a mixed solution as mentioned in the above case. The temperature, however, is slightly higher. Thus, the molecules are moving around faster and the solution is slightly less ordered. Step 3) Rank. Salt crystals in pure water < salt crystals partially dissolved < solution at 280K < solution at 300K **The correct answer is (C).**

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Question 09	**9.** A friend tells you they are going to buy a machine that will help them clean their room. The manufactures claims that it will output is 837 kJ for an input of 200 kcal. What would be the best response? (A) It defies the second law of thermodynamics. (B) Did you know that 1k cal is equivalent to 4.186 kJ? (C) No engine can be that efficient. (D) Save your money. (E) All of the above
Feedback on Each Answer Choice	A. Incorrect! This is a true statement but there is a better response.
	B. Incorrect! This is a true statement but there is a better response.
	C. Incorrect! This is a true statement but there is a better response.
	D. Incorrect! This is a true statement but there is a better response.
	E. Correct! One of the statements of the second law of thermodynamics states that no heat engine can be 100% efficient, 200 kcal is the same as 837 kJ. This implies the machine is 100% efficient.
Solution	One way to state the second law of thermodynamics states is, no heat engine can be 100% efficient. 200 kcal is the same as 837 kJ. (Multiply 200 kcal by 4.186 kJ). This implies the machine is 100% efficient which we know is not possible, so it would be good advice to tell your friend to pick up their room and save some money. **The correct answer is (E).**

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<table>
<tr><td colspan="2">Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.</td></tr>
<tr><td>Question 10</td><td>10. 500 Joules of heat energy from combustion per cylinder are delivered to an engine. The engine outputs 500 Joules of work. What is the efficiency if the engine has 4-cylinders? 6-cylinders?

(A) Cannot determine from the given data.
(B) The 4-cylinder engine is more efficient, ε =0.25.
(C) The 6-cylinder engine is more efficient ε = 0.17.
(D) Both engines have an equal efficiency of, ε =1.0.
(E) The 4-cylinder engine is more efficient, ε = 1.25.</td></tr>
<tr><td rowspan="5">Feedback on Each Answer Choice</td><td>A. Incorrect!
Try using the equation for the efficiency of an engine: efficiency = (work output)/ (work input).</td></tr>
<tr><td>B. Correct!
Efficiency is defined as the work output divided by the work input. In both cases, the output would be 500 J. The work input is the number of cylinders times 500 J.</td></tr>
<tr><td>C. Incorrect!
The 6-cylinder engine puts in 6 x 500 J = 3000 J while the 4-cylinder engine puts in 4 x 500 J = 2000 J. Since both engines output 500 J, which engine has a higher ratio of work in to work out?</td></tr>
<tr><td>D. Incorrect!
Note that the engines each have multiple cylinders with each cylinder adding 500 J of energy.</td></tr>
<tr><td>E. Incorrect!
Efficiency = (work output)/ (work input), the efficiency can never be greater than 1. You would be very rich if you could build this engine.</td></tr>
<tr><td>Solution</td><td>Known: Each cylinder outputs 500 J.
The engine outputs 500 J.
One engine has 4-cylinders while the other has 6-cylinders.

Unknown: Which engine has a higher efficiency ε?

Define: $\varepsilon = \frac{W_{output}}{W_{input}}$

Output: W_{output} = 500 J for both engines
W_{input} = 4 x 500 J = 2000 J for the 4-cylinder engine
W_{input} = 6 x 500 J = 3000 J for the 6-cylinder engine

$\varepsilon=\frac{500\ J}{2000\ J}$ For the 4-cylinder, ε = 0.25

$\varepsilon = \frac{500\ J}{3000\ J}$ For the 6-cylinder, ε = 0.17

Substantiate: Units are correct, sig figs are correct, magnitude is reasonable

The correct answer is (B).</td></tr>
</table>

