Physics 1408/1420 – General Physics 1

Week of November 14th, 2022

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Hello Fellow Physicists,

I am Jorge Martinez, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring sessions, so be sure to visit the tutoring center or visit https://baylor.edu/tutoring.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Monday from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

In the past two weeks, your professors will have covered heat. This week, you will finish studying the laws of thermodynamics.

Important Notes

Important Conventions

Keywords: Laws of Thermodynamics, Thermodynamic Processes, Heat Engine, Heat Pump

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First Law of Thermodynamics:

In the last chapter, you discussed the distinction between heat and thermal energy. We saw that heat was the transfer of thermal energy from one point to another. The first law of thermodynamics relates the internal energy of a system, the heat transferred and the work performed. This law takes into account the conservation of energy for the system and provides a way to analyze thermodynamic processes in which heat leaves or comes into the system and work is done on or by the system. In equation form:

$$\Delta U = Q - W$$

Heat (Q): addition of heat (+) , Loss of heat (-) Work (W): work on the system (-), work by the system (+)

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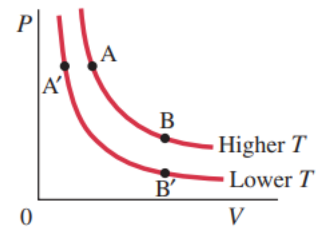
So, what is essential for this process is to assign the correct sign to each of the variables. Now, remember the purpose of each of the variables. Heat and work describe the thermodynamic processes that change the state of a system. Internal energy describes the state of a system, like mass, pressure, temperature, and volume. These variables that describe a system are called state variables.

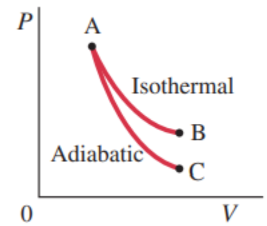
Thermodynamic Processes:

There are 4 main types of thermodynamics processes:

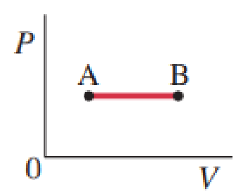
1. **Isothermal Process (ΔT=0):** In an isothermal process, the temperature of the system is kept constant. For understanding thermal processes, you will be looking at PV diagrams. In an isothermal process, the system just moves along the curve, from one point on a curve to another as there is no change in temperature. Changes in temperature cause the curves to shift up or down.



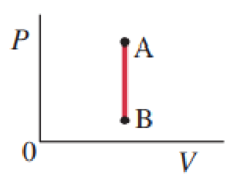
2. **Adiabatic Process (Q=0):** In an adiabatic process, there is no heat flow into or out of the system. This phenomenon typically occurs in well-insulated systems or processes that happen quickly, so that there is no time for heat to flow. Adiabatic processes seem very similar to isothermal processes but the curve is much steeper.



3. **Isobaric Process (ΔP=0):** In an isobaric process, there is no change in the pressure of the system. In a PV diagram, an isobaric process is represented by a horizontal line as the pressure is the same but the volume can change.



4. **Isovolumetric Process(ΔV=0):** In an isovolumetric process, there is no change in the volume of the system. In a PV diagram, an isovolumetric process is just a vertical line as the volume is constant, but pressure can change.



In an isobaric process, we can find the work done as the volume changes.

$$W = P\Delta V$$

In an isovolumetric process, as volume does not change, W = 0.

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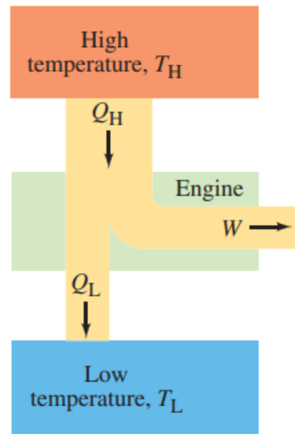
Second Law of Thermodynamics:

The second law of thermodynamics refers to the entropy for systems but a more useful restatement that helps us apply the law to understand some other process is that " heat can flow spontaneously from a hot object to a cold object; heat cannot flow spontaneously from a cold object to a hot object". This restatement will help us better understand the workings of heat engines and heat pumps.

Heat Engine:



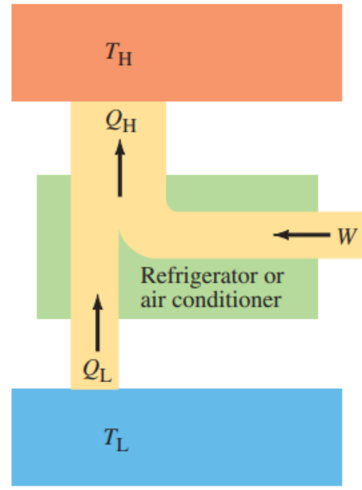
Heat engines use the first part of the restated second law of thermodynamics. Heat flows spontaneously from a hot object to a cold object, and that is the major idea of how engines (yes, like the ones in cars!) work. In engines, we combust fuel in a portion of the engine, which creates a high-temperature environment. This portion is connected to the outside, which is comparatively a cold environment. Heat flows from the engine to the environment outside. We can divert some of this energy transferred to perform work. The temperatures for the high-temperature and low-temperature environments are called the operating temperatures. Heat that flows out of the high temperature environment is equal to the sum of the work done and the heat going into the low temperature environment. Ideally, we would want to be able to use all the heat release for work, but this is not possible as a low temperature environment is necessary to cause heat flow. So we consider the efficiency of the engine, which is

$$e = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

We still compare the actual efficiency to the ideal (engine is referred to as a Carnot engine), where Q~T, so

$$e_{ideal} = \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H}$$

Heat Pumps:



Heat pumps use the second part of the restated second law of thermodynamics. Heat does not flow spontaneously from cold object to hot objects, and this is the major idea of how refrigerators work! In refrigerators, we want to create a low temperature environment and deprive it of as much thermal energy as possible to maintain a low temperature. So, we need heat to flow from a low temperature environment, the inside of the fridge, to a high temperature, the outside. Now, since the direction of flow is not spontaneous, we must put in energy to cause the heat to flow. Now, the heat going into the high temperature reservoir is the sum of the work and the heat that leaves the low temperature reservoir. To judge how well a heat pump works, we use the ratio of the heat that leaves the low temperature environment and the work put into the system. The objective is to get as much heat out and with the least amount of work put in.

$$\text{COP} = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$$

For ideal conditions, the Q~T (directly proportional) so,

$$\text{COP}_{\text{ideal}} = \frac{T_L}{T_H - T_L}$$

Air conditioners also work on this principle. What is essential to understand is the distinction between heat engines and heat pumps. Make sure to understand the diagrams of the heat and work flow for each as shown in the diagrams above.

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CHECK YOUR LEARNING

1. To what temperature will 4000 J of heat raise 1 kg of water that is initially at 1°C?
2. What specific heat of a metal substance if 120 kJ of heat is needed to raise 2 kg of the metal form 25 C to 37 C?
3. A cube of ice is taken from the freezer at -20°C and placed in a 100-g aluminum calorimeter filled with 200 g of water at room temperature of 25°C. The final situation is all water at 19°C. what was the mass of the cube?

THINGS YOU MAY STRUGGLE WITH

1. Remember the distinction between temperature, internal energy, and heat. Remember, internal energy describes all the energy of the molecules present in the system. Temperature is the average kinetic energy of the system. Heat is the TRANSFER of energy. That means, whenever energy is moving, it does so in the form of heat.
2. Latent heat is another addition to thermal systems that makes heat confusing. Remember that latent heat applies every time the phase of matter changes, which is whenever the temperature reaches the boiling point and melting point. The heat of fusion applies for the melting point and the heat of vaporization applies to the boiling point. Both of these are dependent on mass. The changes in temperature have to occur in a range. And breaking points are the melting and boiling points, which is when you get to use the specific heat equation.

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring.

Answers: 1) 1.96 °C 2) 5000 J/(kg*C) 3) 12.3 kg