Physics 1408/1420 – General Physics 1

Week of November 28th, 2022

Jorge Martinez-Ortiz

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 session, 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 74. 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:

$$\Delta U = Q - W$$

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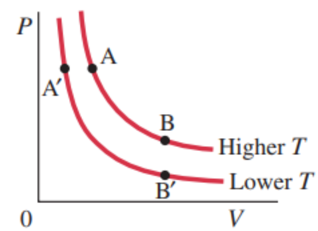
Heat (Q): addition of heat (+) , Loss of heat (-) Work (W): work on the system (-), work by the system (+)

So, what is essential for this 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. The internal energy describes the state of a system, like mass, pressure, temperature, and volume. These variables that describe a system are called state variables.

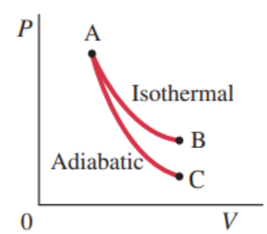
Thermodynamic Processes:

There are 4 main types of thermodynamics processes:

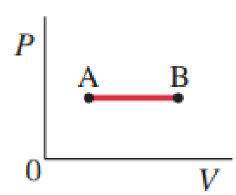
1. **Isothermal Process (ΔT=0):** In an isothermal process, the temperature of the system is kept constant. For understanding thermal processes, you will be looking at PV diagrams. In an isothermal process, the system just moves along the curve, from one point on a curve to another as there is no change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



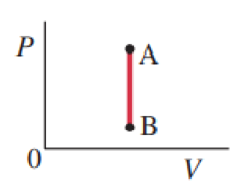
2. **Adiabatic Process (Q=0):** In an adiabatic process, there is no heat flow into or out of the system. This phenomenon typically occurs in well insulated systems or process that happen quickly, so that there is no time for heat to flow. Adiabatic processes seem very similar to isothermal processes 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 PV diagram, it corresponds to a horizontal line in the diagram as the pressure is the same but 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, it corresponds to a vertical line in the diagram as the volume is constant, but pressure can change.



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

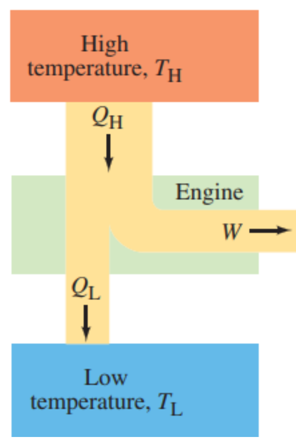
$$W = P\Delta V$$

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

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 form 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. This is the main 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 part of the engine is connected to the outside, which is comparatively a cold environment. So heat flows from the engine to the environment outside. We can divert some of this energy transferred to perform work. The temperature 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

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

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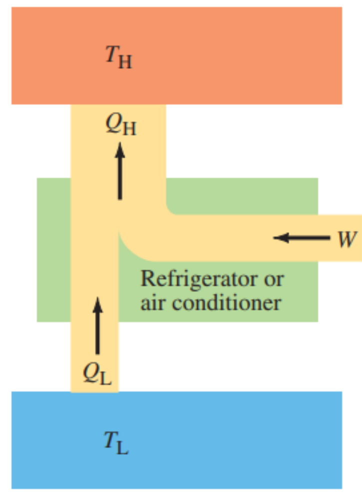
We still compare the actual efficiency to the ideal (engine is referred to as a Carnot engine), where Q~T, so

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

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. This is the main 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 is to understand 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. A gas is enclosed in a cylinder fitted with a light frictionless piston and maintained at the atmospheric pressure. When 400 kcal of heat is added to the gas, the volume is observed to increase slowly from 1 m^3 to $3m^3$. Calculate (a) the work done and (b) the change in internal energy
2. A heat engine exhausts 1000 J of heat while performing 300 J of work. What is the efficiency of the engine?
3. The low temperature of a freezer cooling coil is -12C and the maximum discharge temperature is 40C. What is the maximum theoretical coefficient of performance?

THINGS YOU MAY STRUGGLE WITH

1. It can be tricky to remember the sign convention for the formula of the first law of thermodynamics. The equation can get confusing if you rewrite the equations with different signs for work. It's best to pick a particular form of the equation and assign sign to the values you plug into the equation. What might also help is keeping in mind the effect on the internal energy of the system. How is the gain/loss of heat and work done on/by the system affecting the internal energy?
2. Identifying isothermal and adiabatic processes and distinguishing their behavior on PV diagrams. Remember that the curves for the processes look identical but the slope is steeper for adiabatic processes.
3. Remember how to interpret heat engine and heat pump flow diagrams. These are what will be incredibly useful to help you determine the direction in which energy is flowing and what direction work flows and how the operations work. Remember to understand these well conceptually.

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. 202.6 KJ, 1.471 KJ, 2. 0.23 3. 5.02

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