Period 9: Applications of the Laws of Thermodynamics

9.1 Engines and Work

1) Electric Motors

Electric motors convert electrical energy into mechanical energy of motion. An example is the electric motor in a drill that turns the drill shaft. Electricity to run a motor can be generated by a thermodynamic system as shown below.

a) Attach the thermocouple to the ammeter. Place the thermocouple on the table and warm one side with your hand. What happens?

b) What is the energy source of this current?

c) Your instructor will demonstrate a fan that uses energy from thermocouples. How does this thermodynamic system do work?

2) Internal Combustion Engines

Internal combustion engines also use thermodynamics systems to do work. Your instructor will demonstrate models of internal combustion engines.

a) What causes the pistons in an engine to move?

b) What is the energy source for an internal combustion engine?

3) External Combustion Engines

Your instructor will discuss and demonstrate external combustion engines.

a) What causes the pistons in the steam engines engine to move?
b) What is the energy source for an external combustion engine?

c) What happens to the temperature of the steam as the steam does work?

d) You instructor will demonstrate an engine that runs on liquid nitrogen. What does this engine have in common with a steam engine?

e) Why are internal and external combustion engines known as heat engines?

f) Group Discussion Question: What is the difference between a heat engine and an electric motor?

4) **Heat Engine Efficiency**

   a) What is the maximum efficiency of an ideal heat engine for which the high temperature is at 100 °C and the low temperature is at 20 °C?

   (Hint: First, convert the temperatures from Celius to Kelvin by adding 273 K.)

   b) Would a real heat engine have an efficiency this high? ______ Why or why not?
9.2 Refrigerators, Air Conditioners, and Heat Pumps

5) Air Conditioners
   a) In Period 8, you found that increasing the pressure on the gas in a liter bottle increased the temperature of the gas. What do you think happens to the temperature of a gas when it is allowed to expand? __________________

   b) Hold the palm glass upright and warm one bulb with your palm. What happens to the freon in the glass tube? Why are liquids with low boiling points, such as freon, good coolants for air conditioners?

   c) What does an air conditioner do?

   d) What is the cooling mechanism in an air conditioner (or refrigerator)?

6) Heat Pumps
   a) What is a heat pump?

   b) How is a heat pump similar to an air conditioner? How does a heat pump differ from an air conditioner?

   c) How does a geothermal source heat pump differ from an air source heat pump?

   d) Group Discussion Question: Do you think heat pumps could be used as the only source of central heating for homes? What benefit could a heat pump produce?
7) Coefficient of Performance of Heat Pumps

You use a heat pump to warm your house. If the air temperature outside of the house is –10 °C and the temperature inside is 23 °C, what is the maximum coefficient of performance for this heat pump?

First, convert the Celsius temperatures to Kelvin by adding 273 degrees.

8) Coefficient of Performance of Air Conditioners or Refrigerators

The temperature inside your refrigerator is 40 °F (4 °C) and the temperature in your kitchen is 78 °F (26 °C). What is the maximum coefficient of performance of your refrigerator?
Period 9 Exercises: Applications of the Laws of Thermodynamics

1) Understanding diagrams

Add arrows and labels to make the diagram represent an operating refrigerator that is in a warm kitchen.

a) Does this block represent the kitchen or the inside of the refrigerator?

<table>
<thead>
<tr>
<th>313 K</th>
<th>Q_H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q_L</td>
</tr>
<tr>
<td>283 K</td>
<td></td>
</tr>
</tbody>
</table>

d) Add a vertical arrow to show the direction of heat flow.

c) Add a horizontal arrow to show the direction of work. (in or out?)

b) Does this block represent the kitchen or the inside of the refrigerator?

2) Calculating coefficient of performance

a) A heat pump extracts heat from outside air at a temperature of 0 °C and pumps heat into your house which is at 22 °C. What is the coefficient of performance of this heat pump?

b) Instead of extracting heat from outside air, you use a geothermal heat pump to extract heat from underground water at a temperature of 13 °C and pump heat into your house which is at 22 °C. What is the coefficient of performance of this geothermal heat pump?

c) What is the advantage of extracting heat from a geothermal source rather than from outside air?