Physics 06-09 The 2nd Law of Thermodynamics and Heat Engines **Name:** _____

- Heat _____ moves from _____ temp to _____

The 2nd Law of Thermodynamics

Heat Engine

- Uses part of the spontaneous heat transfer to do _____

$$W = Q_h - Q_c$$

- Efficiency

$$Eff = \frac{W}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

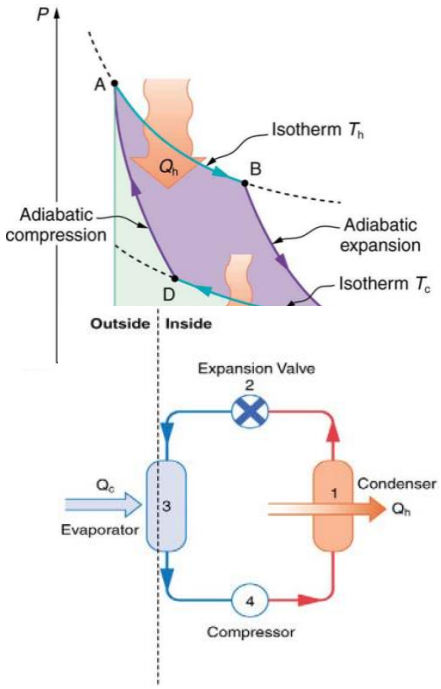
- Only 100% efficient if _____ goes to _____

The 2nd Law of Thermodynamics (Carnot Engine)

- A Carnot engine operating between two given temperatures has the _____ possible _____ of any heat engine operating between these two temperatures.
- Furthermore, all engines employing only _____ processes have this same _____ efficiency when operating between the same given temperatures.

$$Eff = 1 - \frac{T_c}{T_h} \qquad \text{(T in Kelvin)}$$

- Carnot Engines use only _____ processes



Heat Pumps

- Use Carnot cycle to move heat from _____ temp to _____

1. Gas at high _____ in _____, so heat goes to room
2. Valve lowers _____ turning gas to _____
3. Heat from _____ area is used to evaporate _____
4. Compressor raises _____ of gas

- Coefficient of Performance

$$COP_{hp} = \frac{Q_h}{W} = \frac{1}{Eff}$$

- Low _____ means high _____
- For a Carnot engine

$$Eff = 1 - \frac{T_c}{T_h} \qquad \text{(T in Kelvin)}$$

- Heat pumps work best when _____ temp difference

An automobile engine has an efficiency of 20% and produces an average of 23,000 J of mechanical work per second during operation. (a) How much heat input is required, and (b) how much heat is discharged as waste heat from this engine per second?

Refrigerators and Air Conditioners

- Similar to _____, but designed to _____

$$COP_{ref} = \frac{Q_c}{W}$$

$$COP_{ref} = COP_{hp} - 1$$

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A heat pump has a coefficient of performance of 3.0 and is rated to do work at 1500 W. (a) How much heat can it add to a room per second? (b) If the heat pump were turned around to act as an air conditioner in the summer, what would you expect its coefficient of performance to be?

Homework

1. Is a temperature difference necessary to operate a heat engine? State why or why not.
2. Can improved engineering and materials be employed in heat engines to reduce heat transfer into the environment? Can they eliminate heat transfer into the environment entirely?
3. Does the second law of thermodynamics alter the conservation of energy principle?
4. Can you cool a kitchen by leaving the refrigerator door open?
5. A certain heat engine does 10.0 kJ of work and 8.50 kJ of heat transfer occurs to the environment in a cyclical process. (a) What was the heat transfer into this engine? (b) What was the engine's efficiency? (OpenStax 15.20) **18.5 kJ, 54.1%**
6. With 2.56×10^6 J of heat transfer into this engine, a given cyclical heat engine can do only 1.50×10^5 J of work. (a) What is the engine's efficiency? (b) How much heat transfer to the environment takes place? (OpenStax 15.21) **5.86%, $\mathbf{2.41 \times 10^6}$ J**
7. (a) What is the work output of a cyclical heat engine having a 22.0% efficiency and 6.00×10^9 J of heat transfer into the engine? (b) How much heat transfer occurs to the environment? (OpenStax 15.22) **$\mathbf{1.32 \times 10^9}$ J, $\mathbf{4.68 \times 10^9}$ J**
8. (a) What is the efficiency of a cyclical heat engine in which 75.0 kJ of heat transfer occurs to the environment for every 95.0 kJ of heat transfer into the engine? (b) How much work does it produce for 100 kJ of heat transfer into the engine? (OpenStax 15.23) **21.1%, 21.1 kJ**
9. The engine of a large ship does 2.00×10^8 J of work with an efficiency of 5.00%. (a) How much heat transfer occurs to the environment? (b) How many barrels of fuel are consumed, if each barrel produces 6.00×10^9 J of heat transfer when burned? (OpenStax 15.24) **$\mathbf{3.80 \times 10^9}$ J, 0.667 barrels**
10. (a) How much heat transfer occurs to the environment by an electrical power station that uses 1.25×10^{14} J of heat transfer into the engine with an efficiency of 42.0%? (b) What is the ratio of heat transfer to the environment to work output? (c) How much work is done? (OpenStax 15.25) **$\mathbf{7.25 \times 10^{13}}$ J, 1.38, $\mathbf{5.25 \times 10^{13}}$ J**
11. Steam locomotives have an efficiency of 17.0% and operate with a hot steam temperature of 425°C . (a) What would the cold reservoir temperature be if this were a Carnot engine? (b) What would the maximum efficiency of this steam engine be if its cold reservoir temperature were 150°C? (OpenStax 15.31) **306°C, 39.4%**
12. What is the coefficient of performance of an ideal heat pump that has heat transfer from a cold temperature of −25.0°C to a hot temperature of 40.0°C? (OpenStax 15.37) **4.82**
13. What is the best coefficient of performance possible for a hypothetical refrigerator that could make liquid nitrogen at −200°C and has heat transfer to the environment at 35.0°C? (OpenStax 15.39) **0.311**
14. Suppose you want to operate an ideal refrigerator with a cold temperature of −10.0°C, and you would like it to have a coefficient of performance of 7.00. What is the hot reservoir temperature for such a refrigerator? (OpenStax 15.43) **27.6°C**