PhyzSpringboard: The Heat Elevator

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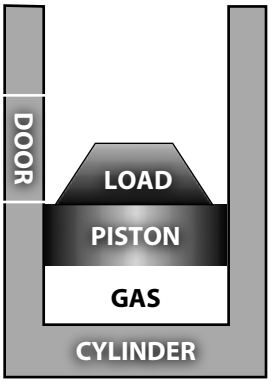
A SIMPLE HEAT ENGINE

Consider the arrangement shown to the right. A sample of gas is enclosed in a cylinder. The cylinder has a piston that can move up or down within the cylinder.



A door in the cylinder allows access to the piston when the piston is in the position shown.

The piston is supported by gas trapped between the cylinder and the piston.

1. A load is moved onto the piston.
a. What happens when a load is added to the piston?

The volume of the gas decreases because it is compressed.

b. What is the solution to this problem?

Heat the gas while the load is added.

c. During this process, the _____pressure_____ increases while the _____volume_____ remains constant.

2. Once the load is completely on the cylinder, the door is closed.
a. How can the load be lifted using the transfer of thermal energy?

Heat the gas.

b. During this process, the _____volume_____ increases while the _____pressure_____ remains constant.

3. Once the load lifted,
a. how can it be safely removed from the piston?

Cool the gas while the load is removed.

b. During this process the pressure _____decreases_____ and the volume _____remains constant_____.

4. Another load is waiting to be lifted in a similar manner.
a. How can the arrangement be returned to its original state?

Cool the gas.

b. During this process, the pressure _____remains constant_____ and the volume _____decreases_____.

5. Discuss the difference between an **engine** and a **motor**. Include examples of the misuse of either term.

Engine turns thermal energy into mechanical energy.
Motor turns electrical energy into mechanical energy
General Motors, Bavarian Motor Works, ...

HEAT ENGINE MATH

Heat added to an engine while the gas is heated is given the symbol Q_H. The heat ejected from the engine while the gas is cooled is given the symbol Q_L. The work done by the engine in a cycle of operation is given the symbol W and is related to Q_H and Q_L as follows.

$$W = Q_H - Q_L$$

4. a. If $Q_H = 240$ J and $Q_L = 180$ J, what is W?

$W = 240\ J - 180\ J = 60\ J$

b. If $W = 90$ J and $Q_L = 120$ J, what is Q_H?

$Q_H = W + Q_L = 90\ J + 120\ J = 210\ J$

c. If $Q_H = 450$ J and $W = 150$ J, what is Q_L?

$Q_L = Q_H - W = 450\ J - 150\ J = 300\ J$

5. If 100 J of heat were added to the engine and 40 J were then removed to complete the cycle, how much work did the engine do?

$W = 100\ J - 40\ J = 60\ J$

6. If an engine does 50 J of work in each cycle and ejects 50 J in each cycle, how much heat has to be added in each cycle?

$Q_H = W + Q_L = 50\ J + 50\ J = 100\ J$

7. How much heat is ejected in each cycle by a heat engine that does 60 J of work in each cycle and absorbs 90 J of heat in each cycle?

$Q_L = Q_H - W = 90\ J - 60\ J = 30\ J$

8. How much heat is ejected in each cycle by a heat engine that does 60 J of work in each cycle and absorbs 30 J of heat in each cycle?

$Q_L = Q_H - W = 30\ J - 60\ J = -30\ J$ [NOT POSSIBLE: This engine cannot exist.]