Ministry of Higher Education
Higher Institute for Engineering and Technology at Manzala
Electronics Engineering Dept.

Thermodynamics and Heat Transfer (MEC121)

Lecture 5: 2^{nd} Law of Thermodynamics

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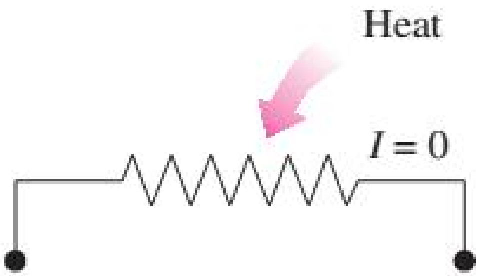
Introduction

- From the previous lectures, we studied that there is no process that occurs in contradiction with the 1st of thermodynamics. لا تحدث بشكل يتعارض مع القانون الأول

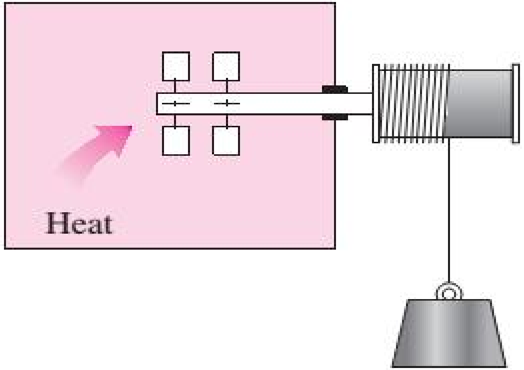
(Any process must satisfy the 1st of Thermodynamics)

- However, satisfying the first law alone does not ensure that the process will take place in real. تحقيق القانون الأول لا يعنى بالتأكيد ان العملية منطقية ويمكن أن تحدث فى الواقع

Example 1: Consider the heating of a room by passing an electric current through a resistor. 1st law dictates that the amount of **electric** energy supplied to the resistor equals the amount of energy transferred to the room as **heat**. Now, if we want to reverse this process, **transferring heat to a resistor will not generate electricity in it**.



Introduction



Example 2: Consider a paddle-wheel mechanism that is operated by the fall of a mass. As the mass falls, the paddle rotates, and an amount of heat transfers into the fluid around it due to friction. However, the reverse process, **raising the mass by transferring heat from the fluid to the paddle wheel, does not occur in nature**.

Any processes can occur in a certain direction, and not in the reverse direction.

Direction of process ← **2nd Law of Thermodynamics** → Quality of process

Thermal Energy Reservoirs

- **Thermal Energy Reservoir** is a body that can supply or absorb finite amounts of heat without undergoing any temperature change.
- Large bodies of **water** such as oceans, lakes, and rivers as well as the **atmospheric air** are examples of thermal reservoirs because they do not warm up after heat losing from systems into them.

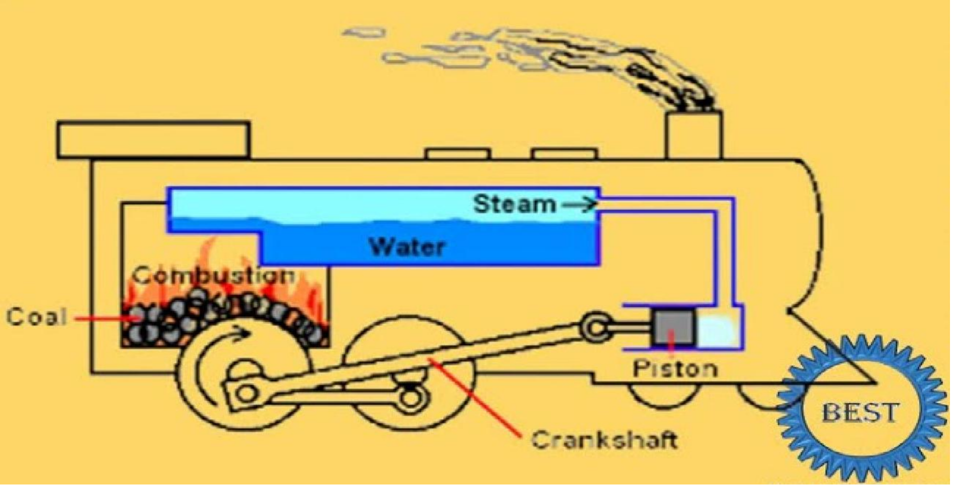
Types of Thermal Energy Reservoirs

Source

Sink

Heat Engines

- **Heat Engine** is a device used to convert heat into useful work.



- Car engines, jet engines, solar engines, and gas and steam turbines power plants are examples of heat engines.

- Heat engines and other cyclic devices usually involve a fluid to and from which heat is transferred while undergoing a cycle. This fluid is called the working fluid.

2nd Law of Thermodynamics

- **2nd of thermodynamics** states that <u>**it is impossible to convert heat completely to work, a part of it must be rejected to a heat sink at a low temperature**</u>.
- **Kelvin–Planck Statement**: **It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work.**

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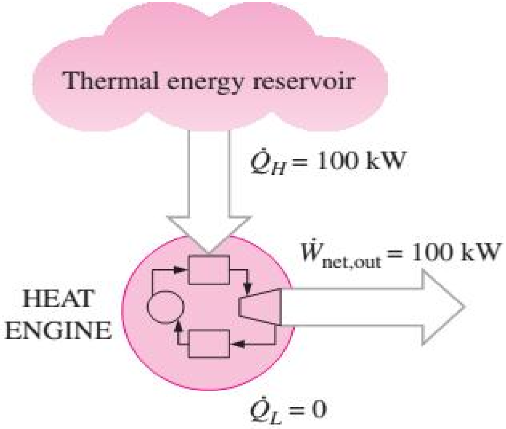

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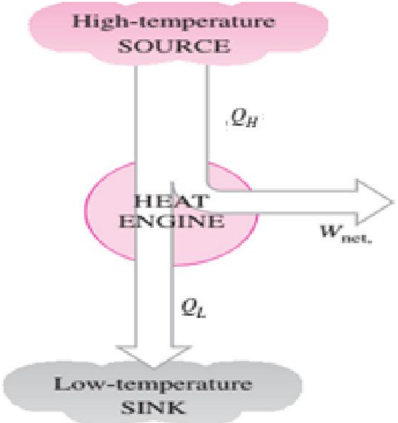
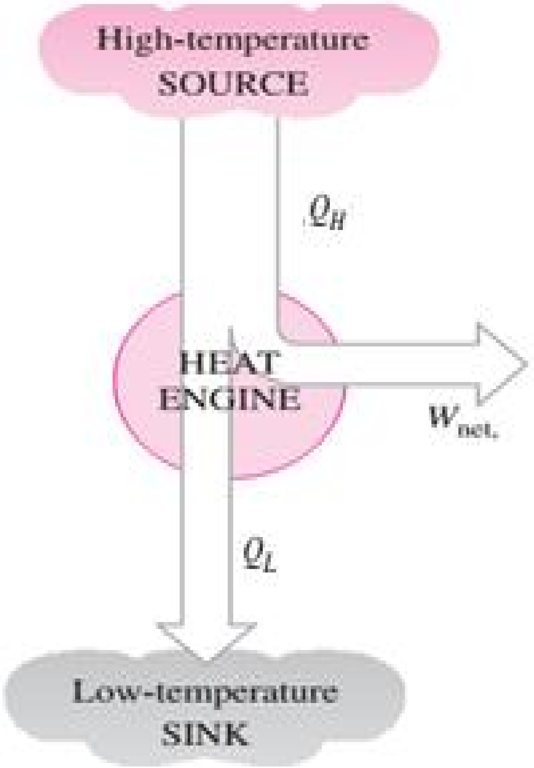


2^{nd} Law & Heat Engines

1. The engine receives heat (Q_H) from a high-temperature source (solar energy, oil furnace, nuclear reactor, etc.).
2. It converts a part of this heat into work (W_{net}).
3. It rejects the remaining amount of heat (Q_L) to a low-temperature sink (atmosphere, rivers, etc.).
4. It operates on a cycle.



By applying the 1st of thermodynamics:

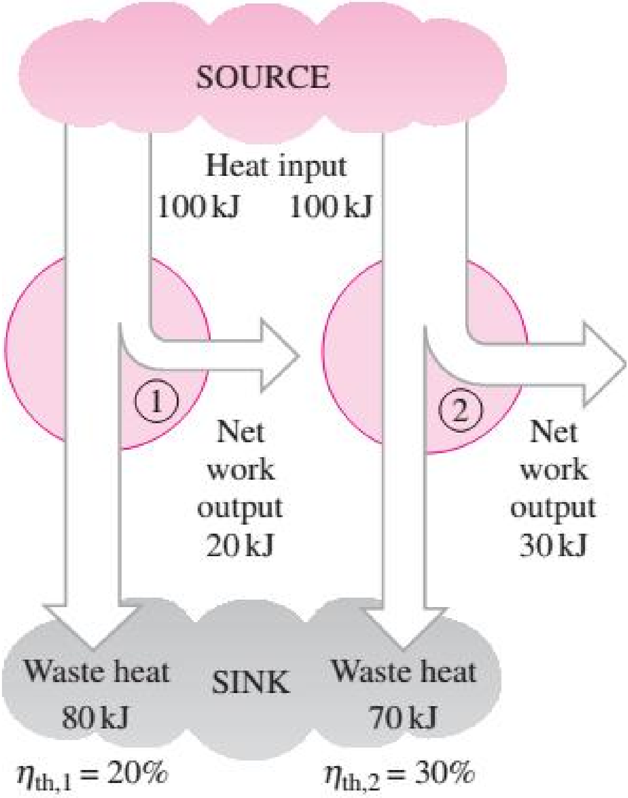
$$\boxed{W_{net} = Q_H + Q_L} \quad \ldots\ldots 1$$

Thermal Efficiency of Heat Engine

- The net work output of a heat engine (W_{net}) is always less than the amount of heat input (Q_H).
- The heat rejected (Q_L) is always considered a loss.
- **Thermal efficiency (η_{th})** is a measure of the **performance** of a heat engine and it represents fraction of the heat input that is converted to net work output.

$$\boxed{\eta_{th} = \frac{W_{net}}{Q_H}} \quad \ldots\ldots (2)$$

$$\boxed{\eta_{th} = \frac{W_{net}}{Q_H} = \frac{Q_H + Q_L}{Q_H} = 1 + \frac{Q_L}{Q_H}} \quad \ldots\ldots (3)$$

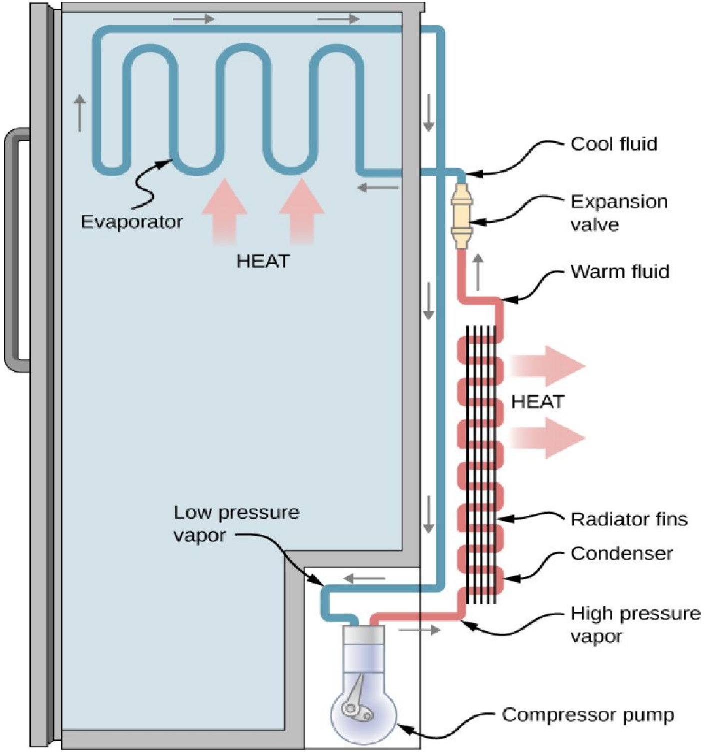


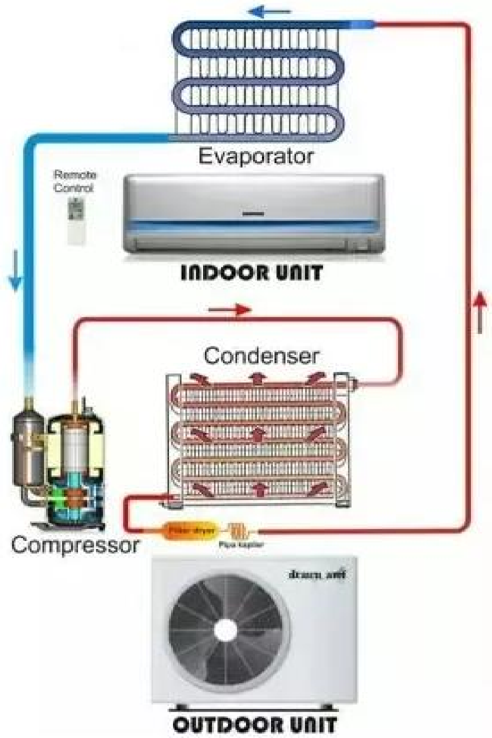
Example

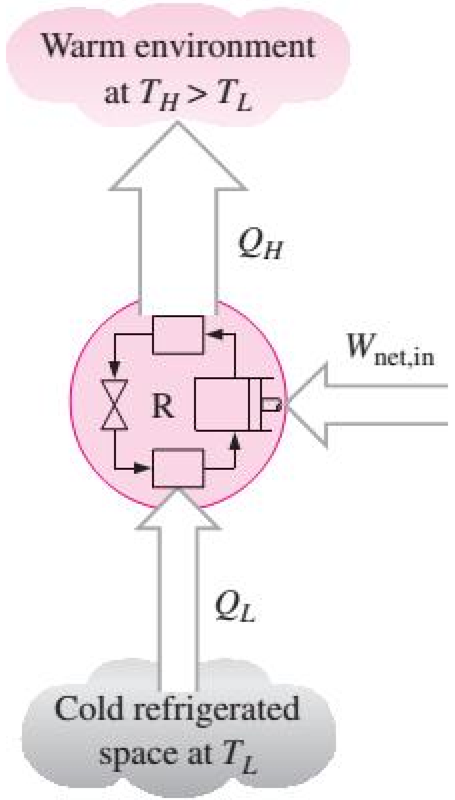
Heat is transferred to a heat engine from a furnace at a rate of 80 MW. If the rate of waste heat rejection to a nearby river is 50 MW, determine the net power output and the thermal efficiency for this heat engine.

(Ans. = 30 MW and 37.5%)

Refrigerator and Heat Pump





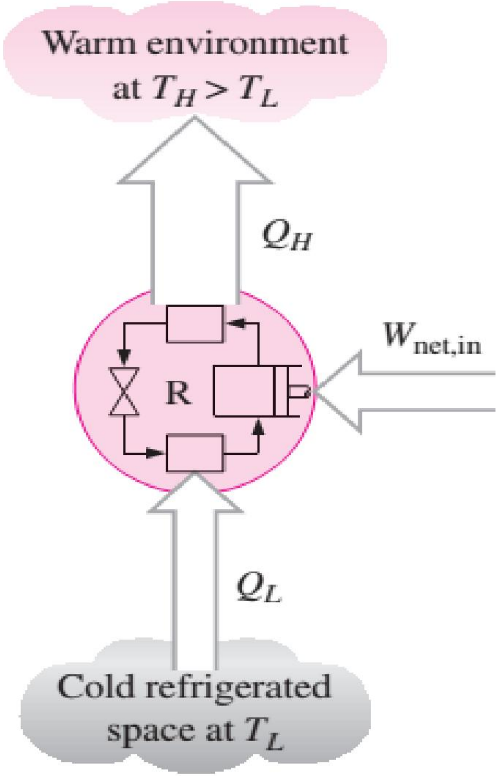


Refrigerator and Heat Pump

- Generally, heat is transferred from high-temperature mediums to low temperature ones. This heat transfer process occurs in nature without requiring any devices. However, the reverse process cannot occur by itself.

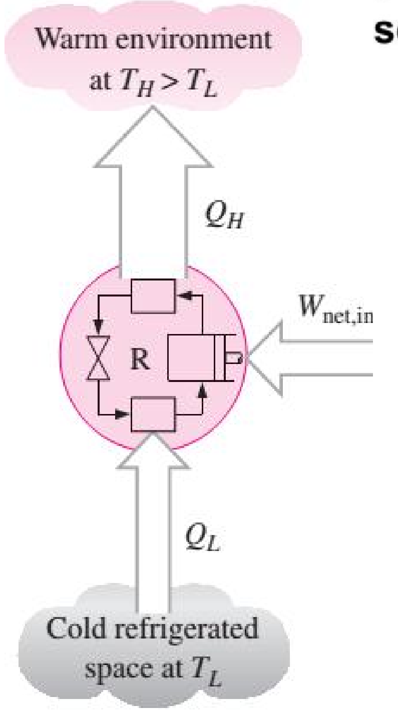
- Refrigerator and heat pump are devices used to transfer heat from a low-temperature medium to a high-temperature one.

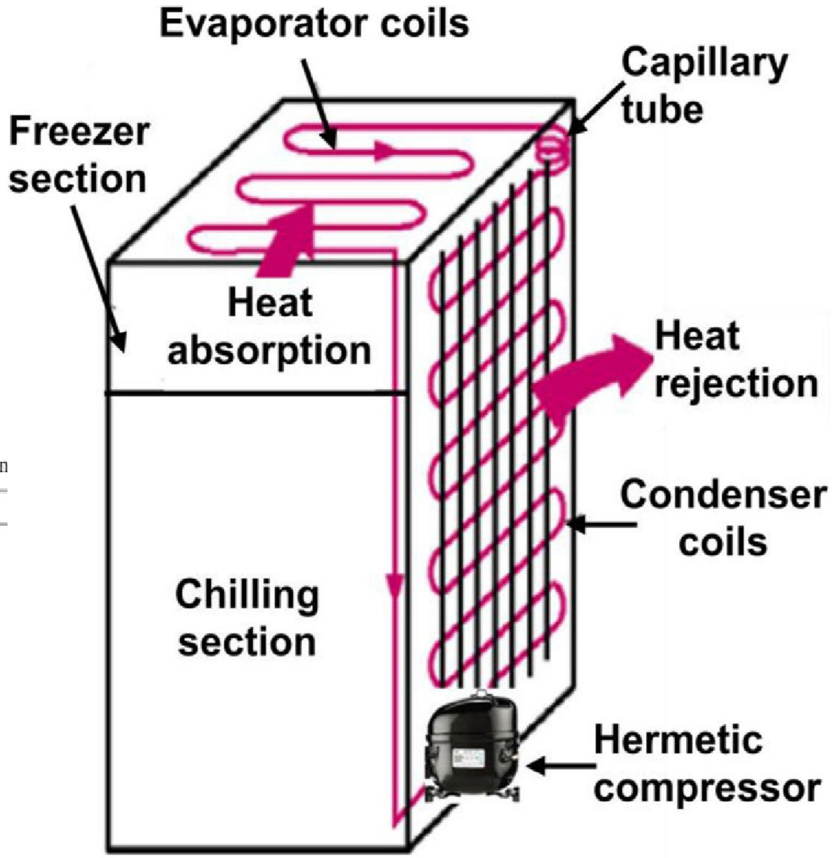
- Refrigerator and heat pump are cyclic devices like heat engine.



Refrigerator

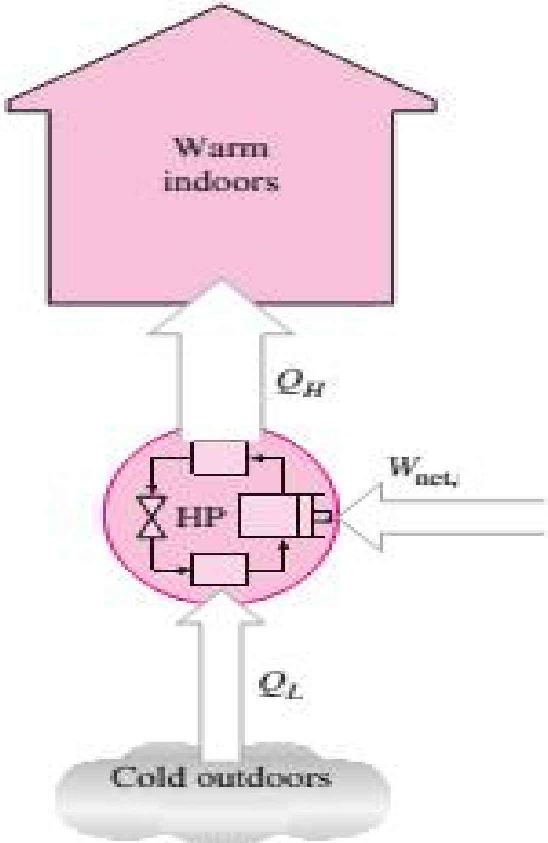
- The main purpose of the refrigerator is to absorb heat from the low-temperature medium (reservoir).





Heat Pump

- The main purpose of the heat pump is to heat up a specific medium (space).



Coefficient of Performance (COP)

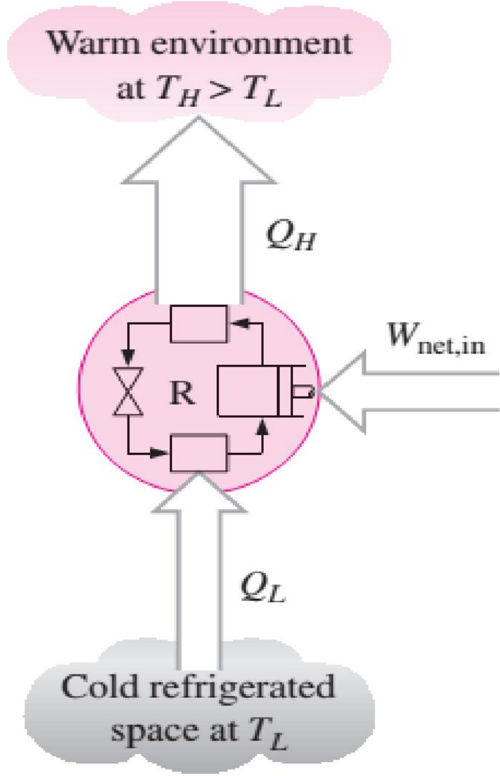
- **Coefficient of Performance (COP)** is a measure of the **performance** of a refrigerator and heat pump. It represents the ratio of the useful term to the input term.

- **For Refrigerator**:

$$\boxed{COP_R = \frac{Q_L}{W_{net}}} \quad \ldots\ldots\ (4)$$

- **For Heat Pump**:

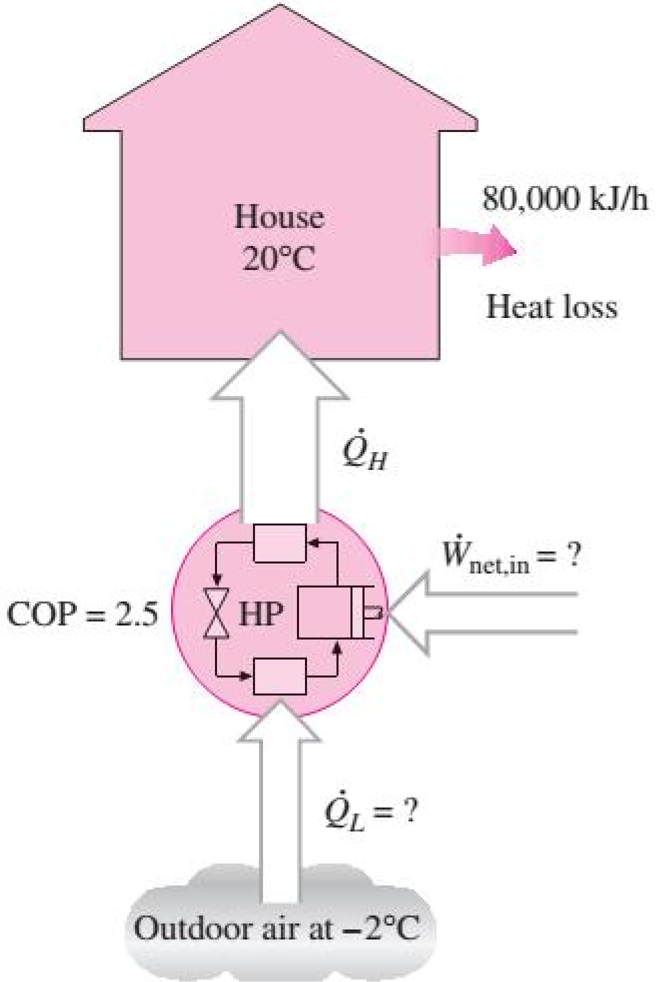
$$\boxed{COP_{HP} = \frac{Q_H}{W_{net}}} \quad \ldots\ldots\ (5)$$



Example

A heat pump is used to meet the heating requirements of a house and maintain it at 20°C. On a day when the outdoor air temperature drops to -2°C,the house is estimated to lose heat at a rate of 80,000 kJ/h. If the heat pump under these conditions has a COP of 2.5, determine (a) the power consumed by the heat pump and (b) the rate at which heat is absorbed from the cold outdoor air..

(Ans. = 8.9 kW and 48,000kJ/h)



Discussion About

- Any questions?