Heat engines played a key role in the development of the modern industrial world. Steam locomotives were an important early use of the steam engine. Electric power plants today use steam turbines.

Heat Engines

What are the two main types of heat engines?

The two main types of heat engines are the external combustion engine and the internal combustion engine.

Heat Engines

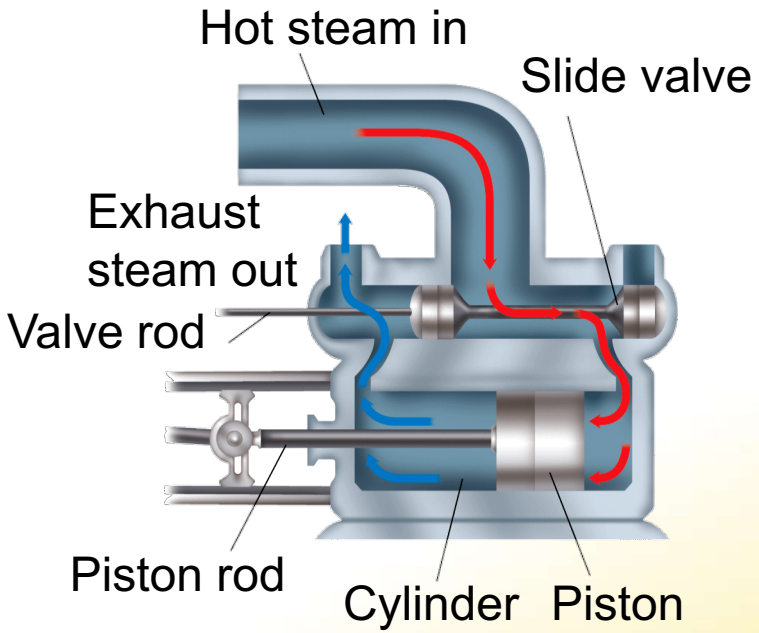
External Combustion Engine

A steam engine is an **external combustion engine**—an engine that burns fuel outside the engine.

- Thomas Newcomen developed the first practical steam engine in 1712 to pump water out of coal mines.
- James Watt designed an engine in 1765 that operated at a higher temperature and was more efficient.

Heat Engines

When the valve in a steam engine slides, steam is trapped in the cylinder. The steam expands and cools as it pushes the piston to the left.



Heat Engines

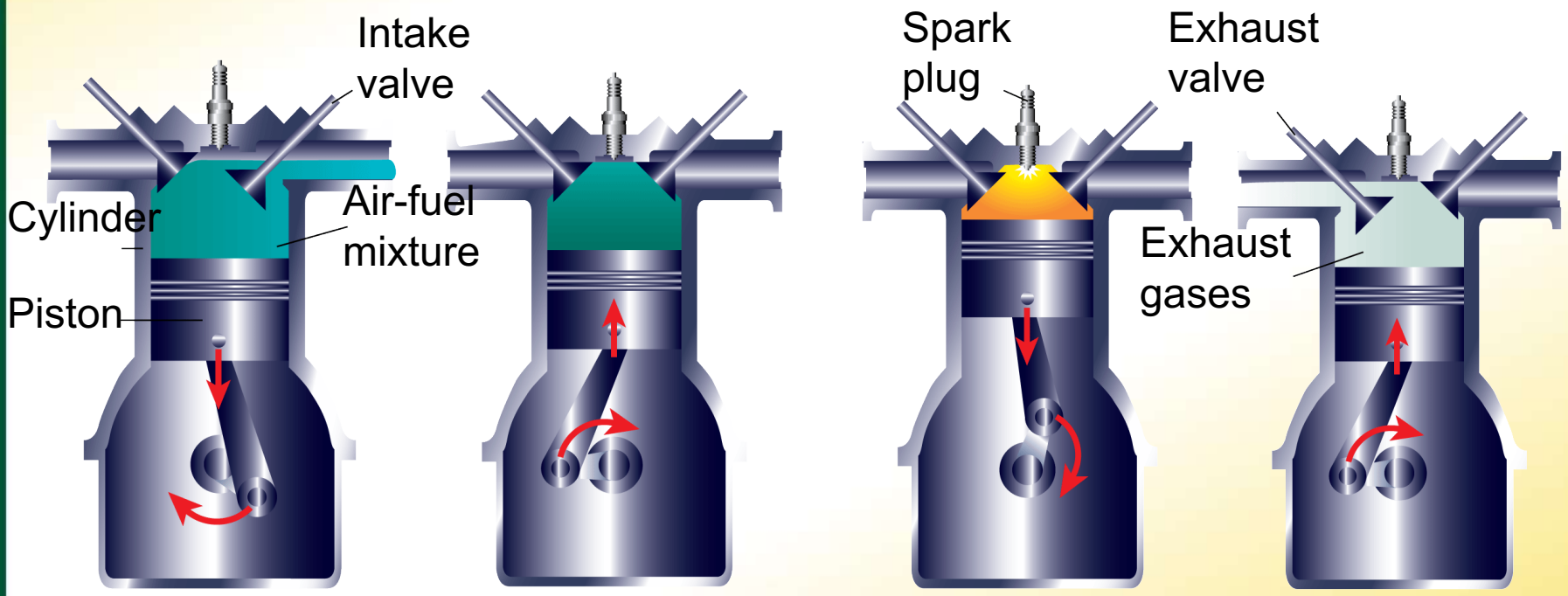
Internal Combustion Engine

An **internal combustion engine** is a heat engine in which the fuel burns inside the engine.

Most internal combustion engines use pistons that move up and down inside cylinders. Each upward or downward motion of a piston is called a stroke.

Heat Engines

Most cars have a four-stroke internal combustion engine. This diagram shows only one of the cylinders during each stroke.



Heat Engines

In an internal combustion engine, the cooling system and exhaust transfer heat from the engine to the environment.

Gasoline engines are more efficient than old-fashioned steam engines, but they still are not very efficient. About one third of the energy in a gasoline engine is converted to work.

Heating Systems

- **How do most heating systems distribute thermal energy?**
- **Most heating systems use convection to distribute thermal energy.**

Heating Systems

A **central heating system** heats many rooms from one central location.

- The most commonly used energy sources for central heating systems are electrical energy, natural gas, oil, and coal.
- Heating systems differ in how they transfer thermal energy to the rest of the building.

Heating Systems

Hot-Water Heating

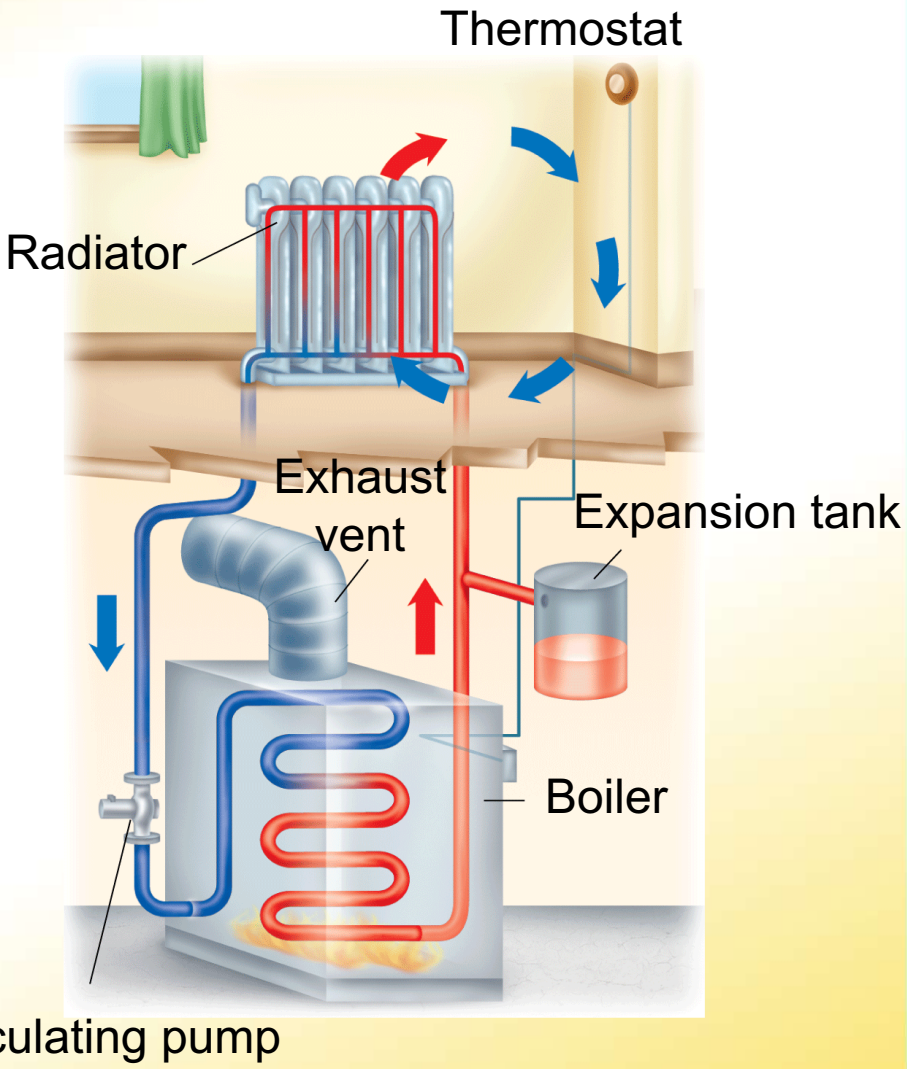
- At the boiler, heating oil or natural gas burns and heats the water.
- The circulating pump carries the hot water to radiators in each room.
- The hot water transfers thermal energy to the radiator by conduction.

Heating Systems

- The hot pipes heat the room air by conduction and radiation.
- Hot air rises and sets up a convection current in each room.
- The cooled water returns to the boiler.

Heating Systems

Within the pipes of this hot-water heating system, the water circulates in a convection current. In each room, the air moves in a convection current.



Heating Systems

Steam Heating

Steam heating is very similar to hot-water heating except that steam is used instead of hot water.

- The transfer of heat from the steam-heated radiator to the room still occurs by conduction and radiation.
- Steam heating often is used in older buildings or when many buildings are heated from one central location.

Heating Systems

Electric Baseboard Heating

An electric baseboard heater uses electrical energy to heat a room.

- A conductor is used to convert electrical energy to thermal energy.
- The hot coil heats the air near it by conduction and radiation.
- Convection circulates the warm air to heat the room.

Heating Systems

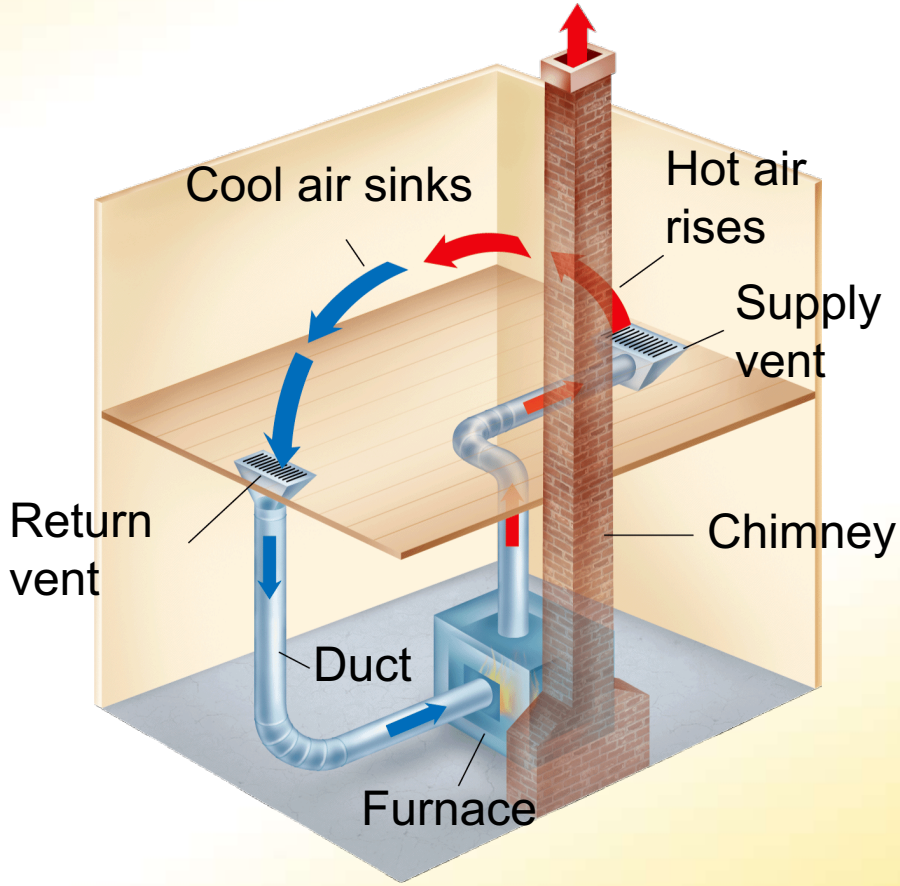
Forced-Air Heating

Forced-air heating systems use fans to circulate warm air through ducts to the rooms of a building.

- Convection circulates air in each room.
- Warm air entering the room rises toward the ceiling.
- Cool room air returns to the furnace through floor vents on the other side of the room.

Heating Systems

Hot air enters the room through a supply vent in the floor. The hot air rises as cooler, denser air in the room sinks.



Cooling Systems

How does a heat pump reverse the normal flow of heat?

A **heat pump** is a device that reverses the normal flow of thermal energy.

Heat pumps must do work on a refrigerant in order to reverse the normal flow of thermal energy.

Cooling Systems

A **refrigerant** is a fluid that vaporizes and condenses inside the tubing of a heat pump.

- When the refrigerant absorbs heat, it vaporizes, or turns into a gas.
- When the refrigerant gives off heat, it condenses, or turns back into a liquid.

Cooling Systems

Refrigerators

A refrigerator is a heat pump—it transfers thermal energy from the cold food compartment to the warm room.

- A motor must do work to move refrigerant through tubing inside the refrigerator walls.
- Coils of tubing underneath or behind the refrigerator release heat absorbed from the food compartment and thermal energy produced by the work the motor does.

Cooling Systems

When a refrigerator door is open, some thermal energy from the room enters the refrigerator. More thermal energy leaves the refrigerator through the coils.

Cooling Systems

Air Conditioners

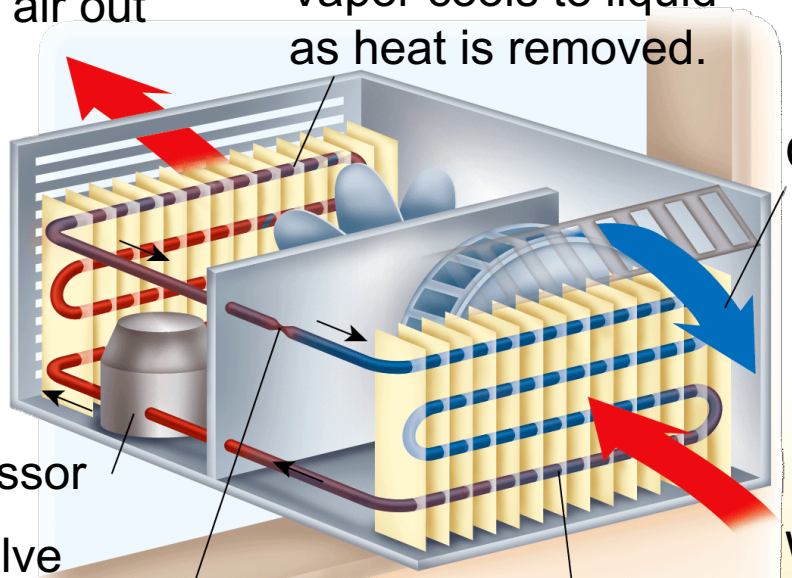
- The compressor in a room air conditioner raises the temperature and pressure of the refrigerant, turning it into a hot, high-pressure gas.
- The condenser coil is hotter than the outside air, so heat flows spontaneously to the outside air.
- The refrigerant cools and condenses into a liquid.

Cooling Systems

- The liquid refrigerant then flows through the expansion valve and decreases in temperature.
- As the cold refrigerant flows through the evaporator coil, it absorbs thermal energy from the warm room air.
- The fan sends cold air back into the room. The refrigerant becomes a vapor, and the process starts all over again.

Cooling Systems

In a window air conditioner, outside air is heated as a fan blows it through the condenser coil.



What Is the Real Cost of a Washing Machine?

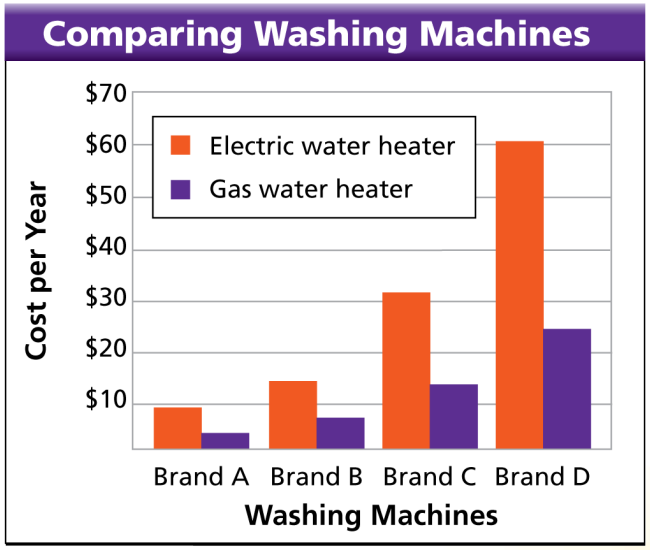
Data Analysis

If you ever shop for a new washing machine, you'll notice the bright yellow Energy Guide sticker on each machine. The sticker gives the machine's operating cost per year as estimated by the U.S. Department of Energy. The largest part of the cost for cleaning clothes is heating the water that goes into the washing machine. So a machine that uses less water is more efficient.

What Is the Real Cost of a Washing Machine?

Data Analysis

- **Using Graphs** One family uses an electric water heater. What is their cost per year for machine A? For machine D?



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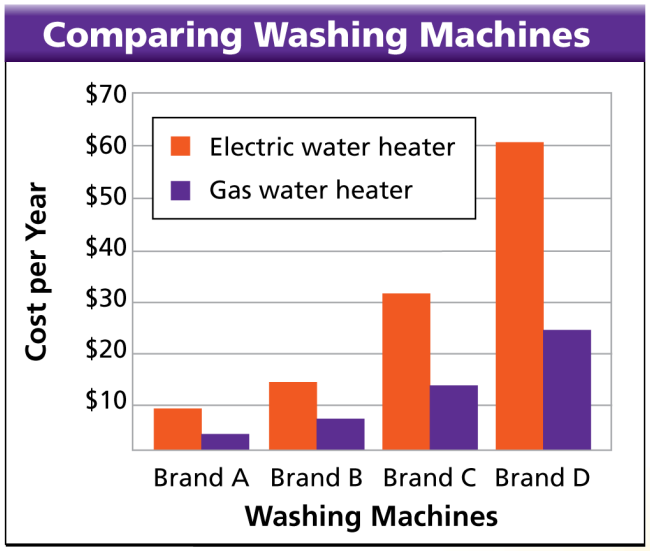

Answer: The annual cost of Brand A is about $10 per year. The annual cost of Brand D is about $60 per year.

What Is the Real Cost of a Washing Machine?

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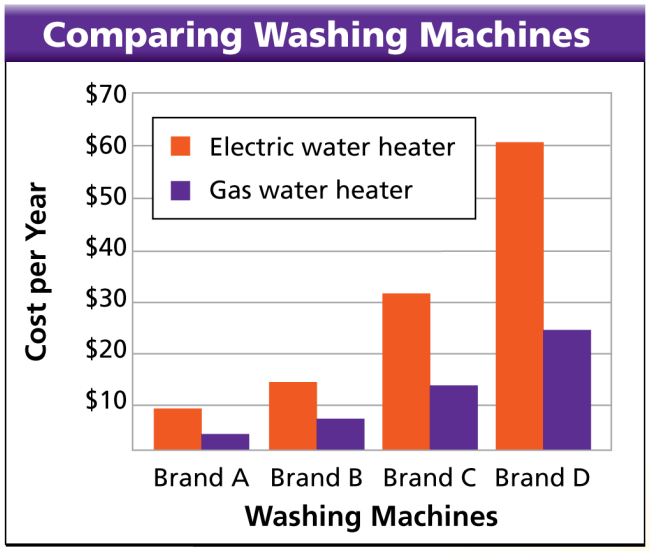
• **Calculating** One family uses an electric water heater. What is their cost per year for machine A? For machine D?



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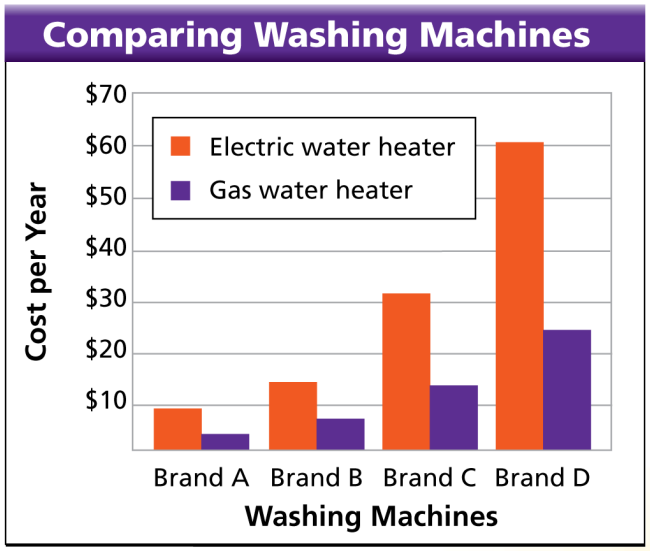


Answer: The family saves $50 each year using Brand A.

What Is the Real Cost of a Washing Machine?

Data Analysis

• **Calculating** The price of machine A is $300 more than the price of machine D. If the family uses a machine for 10 years, which one costs less overall? (*Hint:* Add the price to the operating cost for 10 years.)

Answer:

What Is the Real Cost of a Washing Machine?

Data Analysis

• **Calculating** The price of machine A is $300 more than the price of machine D. If the family uses a machine for 10 years, which one costs less overall? (*Hint:* Add the price to the operating cost for 10 years.)

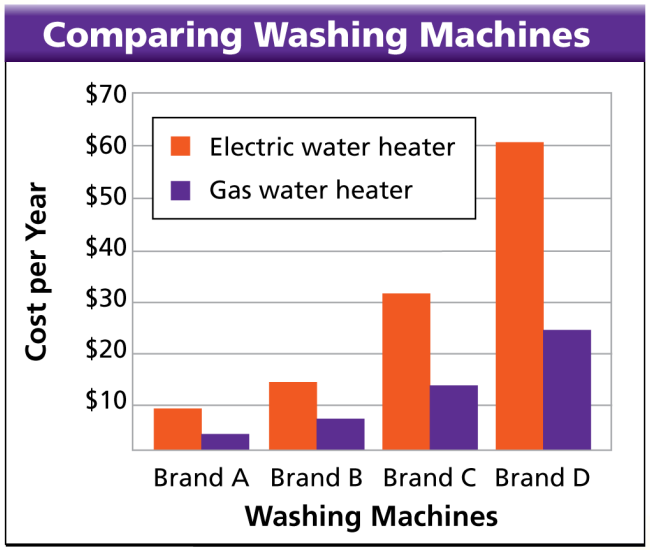
Answer: The operation cost of Brand A for 10 years is 10 × $10 = $100. The operation cost of Brand D for 10 years is 10 × $60 = $600. Brand A costs less overall because although the initial price is $300 higher, the machine saves $500 in operating costs.

What Is the Real Cost of a Washing Machine?

Data Analysis

• **Calculating** Another family uses a gas water heater. Which machine should this family choose? Explain your thinking.

Answer:



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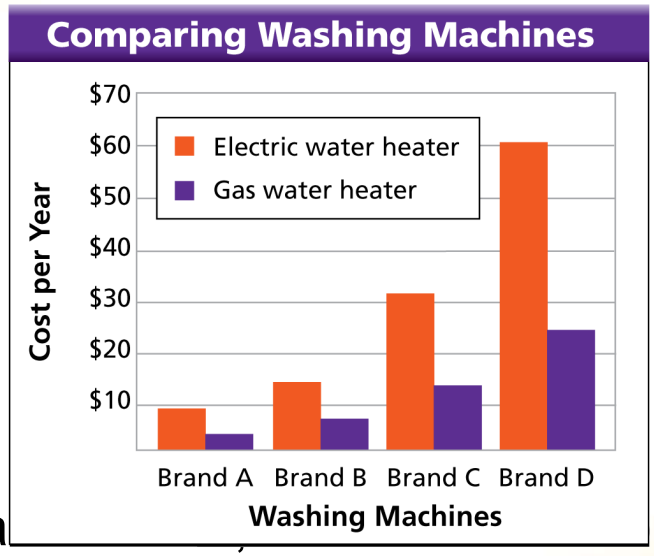

Answer: Using a gas wa nly $20 in operating costs each year. Based only on cost, the family should choose Brand D because it will cost $100 less to own and operate for 10 years.

What Is the Real Cost of a Washing Machine?

Data Analysis

- **Evaluating and Revising** A washing machine advertisement states that the annual cost assumes an electric water heater is used. Why would an advertisement include only this cost?

What Is the Real Cost of a Washing Machine?

Data Analysis

- **Evaluating and Revising** A washing machine advertisement states that the annual cost assumes an electric water heater is used. Why would an advertisement include only this cost?

Answer: The goal of the advertisement is to convince as many people as possible to buy the machine. Therefore, the advertisement emphasizes the money that could be saved under the best of circumstances (using an electric water heater).

Assessment Questions

- Only about one-third of the energy in gasoline is converted to work in an internal combustion engine. The rest of the chemical energy is
  - lost as unused mechanical energy.
  - destroyed by the engine.
  - converted to potential energy.
  - discharged as waste heat.

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  ANS:D

Assessment Questions

- How is a room heated by an electric baseboard heating system?
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    vaporizing and condensing a refrigerant
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Assessment Questions

- Forced air heating systems are often used to heat many buildings from a central location.

  True
  False

-

Assessment Questions

- Forced air heating systems are often used to heat many buildings from a central location.

  True
  False

-

  ANS:F, Steam