Efficiency measures how well an engine operates

A cyclic process cannot completely convert energy transferred as heat into work, nor can it transfer energy as heat from a low-temperature body to a high-temperature body without work being done in the process. However, we can measure how closely a cyclic process approaches these ideal situations. A measure of how well an engine operates is given by the engine's *efficiency* (*eff*). In general, efficiency is a measure of the useful energy taken out of a process relative to the total energy that is put into the process. Efficiencies for different types of engines are listed in **Table 3.**

Recall from the first law of thermodynamics that the work done on the environment by the engine is equal to the difference between the energy transferred to and from the system as heat. For a heat engine, the efficiency is the ratio of work done by the engine to the energy added to the system as heat during one cycle.

EQUATION FOR THE EFFICIENCY OF A HEAT ENGINE

$$eff = \frac{W_{net}}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

$$\text{efficiency} = \frac{\text{net work done by engine}}{\text{energy added to engine as heat}}$$

$$= \frac{\text{energy added as heat} - \text{energy removed as heat}}{\text{energy added as heat}}$$

$$= 1 - \frac{\text{energy removed as heat}}{\text{energy added as heat}}$$

Notice that efficiency is a unitless quantity that can be calculated using only the *magnitudes* for the energies added to and taken away from the engine.

This equation confirms that a heat engine has 100 percent efficiency ($eff = 1$) only if there is no energy transferred away from the engine as heat ($Q_c = 0$).

Table 3
Typical Efficiencies for Engines

Engine type	*eff* (calculated maximum values)
steam engine	0.29
steam turbine	0.40
gasoline engine	0.60
diesel engine	0.56

Engine type	*eff* (measured values)
steam engine	0.17
steam turbine	0.30
gasoline engine	0.25
diesel engine	0.35

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Why it Matters

Conceptual Challenge

1. Cooling Engines Use the second law of thermodynamics to explain why an automobile engine requires a cooling system to operate.

2. Power Plants Why are many coal-burning and nuclear power plants located near rivers?