35 Efficiency

To carry out an energy analysis of a physical event or process, we need to identify a clear start point and an end point. We then consider and calculate the changes in the energy stores at the start point and at the end point.

It is always true that there is no overall change in the total of all the energy stores - energy is conserved.

However, it is often the case that a process results in an overall increase in less-useful thermal stores (and a corresponding decrease in the total of the more-useful stores). What is meant by the word 'useful' depends on the situation. Sometimes it will be fairly obvious; sometimes you may be told; in some situations, you may have to think carefully.

For any given process (or system) we can calculate its efficiency. Efficiency has no units. It is usually written as a decimal (generally between 0.00 and 1.00), as a fraction or as a percentage.

$$\text{efficiency} = \text{useful energy transferred} / \text{total energy transferred}$$

To express efficiency as a percentage, multiply the decimal answer by 100.

Sometimes the total energy transferred is the total electrical or mechanical work done.

Example 1 - An electric current drives an electric motor to raise a 25 N weight by a vertical distance of 1.2 m. The electrical work done by the power supply is 47 J. Calculate the efficiency of this process.

$$\text{efficiency} = \text{useful energy transferred} / \text{total energy transferred}$$

$$= \text{GPE gained (or work done against gravity)} / \text{electrical work done}$$

$$= 25 \times 1.2 / 47 = 0.64 \ (2\text{sf}) \ \text{ or } \ 64\%$$

Example 2 - A battery powered motor is used to lift a load. As the load is lifted, the increase in gravitational potential energy is 230 J. The decrease in the energy stored chemically in the battery is 290 J. Calculate the efficiency of this process.

$$\text{efficiency} = \text{useful energy transferred} / \text{total energy transferred}$$

$$= \text{increase in gravitational store} / \text{decrease in chemical store}$$

$$= 230/290 = 0.79 \text{ (2sf)} \text{ or } 79\%$$

35.1 A battery powered toy car accelerates from 0.0 m/s to 8.5 m/s. Its mass is 0.55 kg. The chemical store in its battery is decreased by 30 J. Calculate the efficiency of this process.

35.2 A mains operated motor raises an 8 500 N weight to a height of 2.7 m. The electrical work done by the mains supply is 29 000 J. Calculate the efficiency of this process.

35.3 A mains powered electric winch pulls a trolley up a ramp, raising it by a vertical distance of 1.2 m. The trolley's weight is 6 200 N. The electrical work done by the mains supply is 9 350 J. Calculate the efficiency of this system.

35.4 Work out the missing measurements from the following table, where each row is a separate situation.

Efficiency	Energy in	Useful energy out	Wasted energy out
(a)	500 J	(b)	250 J
(c)	(d)	180 J	200 J
16.0 %	1.28 kJ	(e)	(f)
2.80 %	(g)	1.68 kJ	(h)

35.5 A student plugs her phone in for an hour to charge the battery. The power supply does 11 000 J of electrical work and the energy stored chemically in her phone battery increases by 8 300 J .

(a) Calculate the efficiency of this process.

(b) Calculate the increase in thermal energy resulting from 1.0 hour of charging her phone.

In the first minute of charging, it is reasonable to assume that all of the increase in the thermal energy raises the temperature of her phone battery. The battery has a mass of 28 g and its specific heat capacity is 480 J/(kg°C).

(c) Calculate the increase in the thermal energy in the first minute.

(d) Calculate the battery's temperature rise during the first minute.

Efficiency can also be calculated by considering power for a process. Then

$$\text{efficiency} = \text{useful power output} / \text{total power input}$$

To express the efficiency as a percentage, again multiply the decimal answer by 100.

Example 3 - An electric water heater heats water with an output power of $2\,050$ W whilst its electrical power input is $2\,200$ W.

$$\text{efficiency} = \text{useful power output} / \text{total power output}$$

$$= 2\,050 / 2\,200$$

$$= 0.93 \ (\text{2sf}) \ \text{ or } \ 93\%$$

35.6 A mains transformer has an input power of 2.0 kW and is 90% efficient. How much energy would be wasted in 10 minutes?

35.7 A machine has an efficiency of 60%, the useful power output is 150 W. What is the total input power?

35.8 An electric motor has a power input of 10 watts when lifting a weight with a pulley system. The motor and pulley system is 80% efficient. Calculate how much potential energy would be gained by the weight in 5.0 s.

35.9 An electric motor has a power input of 3.0 watts when lifting a weight. The weight gains 10 joules of potential energy in 5.0 seconds.

(a) What is the useful output power of the motor?

(b) What is the motor's efficiency in carrying out the operation?

35.10 A model hydroelectric power station produces just enough electric power to light a 6.0 W lamp. The model is 80% efficient at converting the potential energy store of the water into electrical work. What is the input power of the water running through the pipes?

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Additional Efficiency Questions

35.11 An electric motor draws 2.0 A from a 12 V supply. It can lift a weight so that the weight gains 54 J of potential energy in 3.0 s. Calculate:

(a) the input power of the motor;

(b) the useful output power of the motor and;

(c) the efficiency of the motor.

35.12 A water pump, rated at 12 V; 5.0 A raises 30 kg of water through a height of 2.0 m in a time of 15 seconds. Calculate the pump's efficiency. [Assume the water has no kinetic energy on reaching the top.]

35.13 A hydroelectric power station generates 64 MW of electric power when the input power from the falling water is 70 MW. Calculate the efficiency of the system.

35.14 What is the efficiency when in standby mode of

(a) A modern television with a 'standby' electrical power of 0.30 W?

(b) An older television with a 'standby' electrical power of 5.0 W? Please note that the television in Q14.a is better than that in Q14.b, but efficiency percentages do not give you this information.