Announcements 22 Apr 09

- Homework #11
  - **Written homework due at the start of class on Monday**
  - **Online homework due on Tuesday by 8 am**
- Exam 3
  - **Tuesday May 5 from 7 to 9 pm**
  - **Arrange makeup exams now**

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Chapter 11
Using Energy

Topics:

- Efficiency
- How energy is used in the body
- Heat, temperature, thermal energy
- First and second laws of thermodynamics
- ~~Entropy~~

Sample question:

How much energy are the fighters using? How do the masks they are wearing help us figure this out?

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Energy Transformation Question

PRS

When you walk at a constant speed on level ground, what energy transformation is taking place?

A. $E_{\text{chem}} \to U_{\text{g}}$
B. $U_{\text{g}} \to E_{\text{th}}$
C. $E_{\text{chem}} \to K$
D. $E_{\text{chem}} \to E_{\text{th}}$
E. $K \to E_{\text{th}}$

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Efficiency

While energy as whole is conserved, certain energy transformations lead to a decrease in "useful forms of energy" (e.g. increase in thermal E)

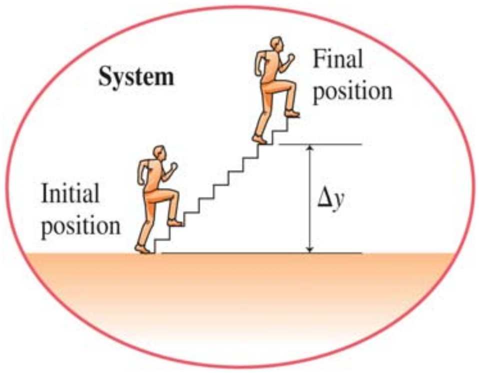
$$e = \frac{\text{what you get}}{\text{what you had to pay}}$$

General definition of efficiency

Example: walking up the stairs

What you get:
Change in potential energy, 1800 J

What you had to pay:
Energy used by the body, 7200 J



$$e = \frac{1800J}{7200J} = 0.25 = 25\%$$

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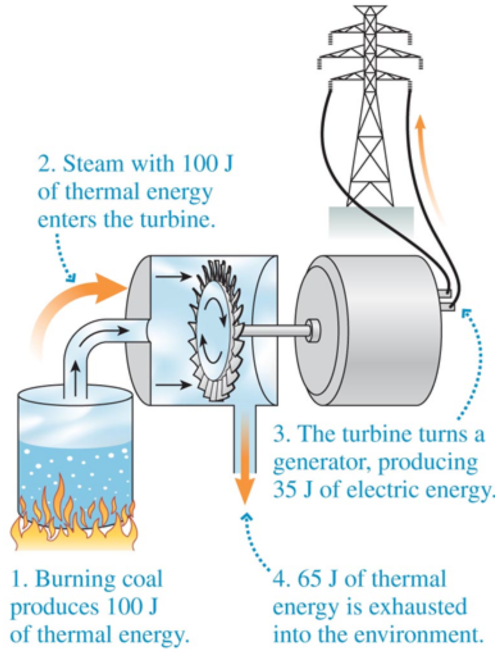
Efficiency Example

Coal-burning power plant

Efficiency for producing electric energy is

$$e = \frac{35J}{100J} = 0.35 = 35\%$$



Sample Problem 1

A person lifts a 20 kg box from the ground to a height of 1.0 m. A metabolic measurement shows that in doing this work her body has used 780 J of energy. What is her efficiency?

MP PROBLEM-SOLVING STRATEGY 11.1 Energy efficiency problems

PREPARE There are two key components to define as we prepare to compute efficiency:

1. Choose what energy to count as "what you get." This could be the useful energy output of an engine or process or the work that is done in completing a process. For example, when you climb a flight of stairs, "what you get" is your change in potential energy.
2. "What you had to pay" will generally be the total energy input needed for an engine, task, or process. For example, when you run your air conditioner, "what you had to pay" is the electric energy input.

SOLVE You may need to do additional calculations:

- Compute values for "what you get" and "what you had to pay."
- Be certain that all energy values are in the same units.

After this, compute the efficiency using $e = \frac{\text{what you get}}{\text{what you had to pay}}$.

ASSESS Check your answer to see if it is reasonable, given what you know about typical efficiencies for the process under consideration.

Sample Problem 1

A person lifts a 20 kg box from the ground to a height of 1.0 m. A metabolic measurement shows that in doing this work her body has used 780 J of energy. What is her efficiency?

What you get?

Gravitational potential energy increase due to change in height

$$\Delta U_g = \left(U_g\right)_f - \left(U_g\right)_i = mg\Delta y$$

$$\Delta U_g = (20kg) \times (9.8m/s^2) \times (1.0m) = 196J$$

What you pay?

$|\Delta E_{chem}| = 780$ J

Efficiency

$$e = \frac{\Delta U_g}{|\Delta E_{chem}|} = \frac{196J}{780J} = 0.251 = 25.1\%$$

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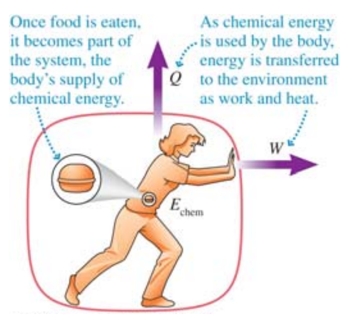
Energy In The Body

Chemical energy in food provides energy for body to function

Glucose from the digestion of food combines with oxygen that is breathed in to produce… …carbon dioxide, which is exhaled; water, which can be used by the body; and energy.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy} \quad (11.2)$$

Glucose, Oxygen, Carbon dioxide, Water



Measure energy content of food by burning it and measuring the change in thermal energy $E_{chem} \rightarrow E_{th}$

Thermal energy is measured in units of calories (cal)

1 cal = 4.19 J

1 "food calorie" is 1 Cal = 1 kcal = 4190 J

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Sample Problem 2

A 75 kg person climbs the 248 steps to the top of the Cape Hatteras lighthouse, a total climb of 59 m. How many Calories does he burn?

What you get?

Gravitational potential energy increase due to change in height

$$\Delta U_g = mg\Delta y$$

$$\Delta U_g = (75kg) \times (9.8m/s^2) \times (59m) = 43kJ$$

What you pay?

$$|\Delta E_{chem}| = \frac{\Delta U_g}{e} = \frac{43kJ}{0.25} = 170kJ = 41 \text{ kcal} = 41 \text{ Calories}$$

How much food?

1 slice of pizza contains 300 Calories

climbing up the lighthouse “burns” about 1 / 7 of a slice…

Sample Problem 2’

A 75 kg person climbs the 248 steps to the top of the Cape Hatteras lighthouse, a total climb of 59 m. *How many Calories does he burn if he now also climbs down?*

What you get?

Gravitational potential energy increase due to change in height

$$\Delta U_g = mg\Delta y$$

$$\Delta U_g = (75kg) \times (9.8m/s^2) \times (0m) = 0$$

Do you pay nothing? Where does the energy mostly go?

The chemical energy is mostly transformed into thermal energy

This process is irreversible

This energy is “lost” to our use

Thermal Energy and Temperature

What do we mean by thermal energy?

What is the difference btwn thermal energy and temperature?

Thermometer measures temperature via expansion or contraction of a small volume of mercury or alcohol inside glass tube

- Celsius scale (T_C)
  0 ^oC freezing point of pure water
  100 ^oC boiling point

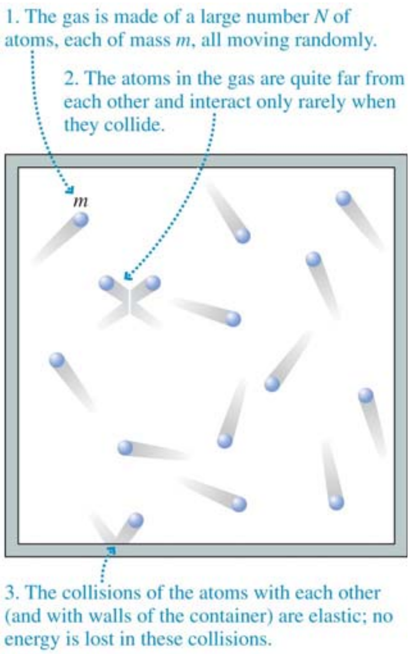
- Fahrenheit scale (T_F)

$$T_C = \frac{5}{9}\left(T_F - 32°\right)$$

Atomic View: Ideal Gas

Consider “ideal” gas of atoms

System of many non-interacting particles, the only internal energy is the total kinetic energy of the atoms making up the gas



The Ideal Gas Model

The temperature of an ideal gas is a measure of the average kinetic energy of the atoms that make up the gas

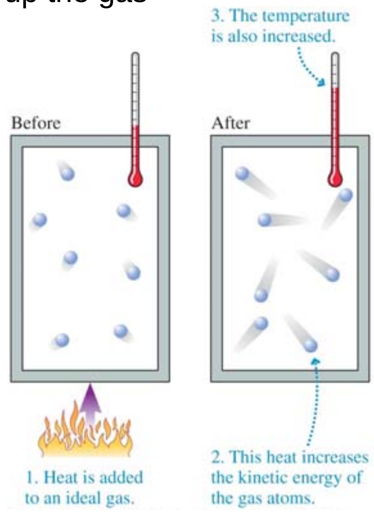
$$T = \frac{2}{3}\frac{K_{\text{avg}}}{k_{\text{B}}}$$

Typical (root mean square) speed of atoms in the gas

$$v_{\text{rms}} = \sqrt{\frac{3k_{\text{B}}T}{m}}$$

Thermal energy = total kinetic energy of N atoms

$$E_{\text{th}} = \frac{3}{2}Nk_{\text{B}}T$$



Boltzmann's constant: k_B = 1.38 x 10^{-23} J/K

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