Announcements

• HW 1 is due Wednesday 1/31 at the beginning of class.

NOTE: For HW 1 to be complete, in addition to the individual portion, you must include Group Activities 1, 2, and 3.
Lecture 03
Content Goals

• Temperature Scales: Absolute Temperature Scale
• Thermal Energy
• Blackbody Radiation and Energy Flux
Temperature Scales

\[ T_F = \left(\frac{9}{5}\right) T_C + 32 \]

\[ T_C = (T_F - 32) \left(\frac{5}{9}\right) \]

\[ T_K = T_C + 273 \]
At $T = 273$ K

- a) water boils
- b) ice melts
- c) steam condenses
- d) a) and c)
- e) atoms cease motion
ICLICKER QUESTION

At $T = 273$ K

- a) water boils
- b) ice melts
- c) steam condenses
- d) a) and c)
- e) atoms cease motion

$T_K = 273 \Rightarrow T_C = 0^\circ C$
Temperature and Thermal Energy

The total thermal energy is proportional to the temperature (in Kelvin)

Thermal Energy ($TE$)

- proportional to (number of molecules) × (average molecular KE)

$$TE = k \times \text{(number of molecules)} \times \text{temperature}$$

$TE = k_nT = k_BT$

Boltzmann's Constant

Temperature in Kelvin

Kinetic Energy $KE = \frac{1}{2}mv^2$
ICLICHER QUESTION

At T = 0 K

a) water boils
b) ice melts
c) steam condenses
d) water freezes
e) atoms cease motion
ICLICKER QUESTION

At T = 0 K

a) water boils
b) ice melts
c) steam condenses
d) water freezes
e) atoms cease motion
Blackbody

• A blackbody is an object that absorbs all of the radiation that is incident on it.
• The Sun is a blackbody!
  • It absorbs any light that shines on it.
• A blackbody is only black when it is at absolute zero \( (T_K = 0) \).
• At any non zero temperature it will emit electromagnetic radiation.
Blackbody Power Emission

The power emitted by a blackbody depends on only two things:

• the surface temperature \((T)\) of the object and
• the surface area \((A)\) of the object.

\[
P = \sigma AT^4
\]

*S Stefan – Boltzmann's Constant*
Blackbody Radiation Basics

1. As an object gets hotter, its main color goes from red to blue.

\[ hf_{\text{max}} = 2.8k_B T \]

2. A hot object emits much more light than does a colder one

\[ I = \frac{P}{A} = \epsilon \sigma T^4 \quad \text{Stefan – Boltzmann's Law} \]
G.A. #3 Q1: DETERMINE THE POWER Emitted BY THE SUN

Data:
- Radius of the sun $R_{\text{sun}} = 7 \times 10^8 m$
- Sun’s surface temperature $T_{\text{sun}} = 5800K$
- Stefan-Boltzmann Constant $\sigma = 5 \times 10^{-8} W/m^2 \cdot K^4$

Area of a sphere $A_{\text{Sphere}} = 4\pi R^2$

Stefan-Boltzmann Law $I = \frac{P}{A} = \epsilon\sigma T^4$

$\epsilon = 1$ for a perfect blackbody
G.A. #3 Q1: Determine the power emitted by the Sun

\[
\frac{P}{A} = \varepsilon \sigma T^4 \Rightarrow P = A \varepsilon \sigma T^4
\]

\[
A_{sun} = 4\pi R_{sun}^2 = 6.15 \times 10^{18} m^2
\]

\[
P = (6.2 \times 10^{18} m^2)(5 \times 10^{-8} W/m^2 \cdot K^4)(5.8 \times 10^3 K)^4
\]

\[
P = 3.5 \times 10^{26} W = 3.5 \times 10^{12} TW
\]
Solar Energy Flux

• The power emitted by the Sun spreads out uniformly.
• The energy flux, as a function of the distance $D$ from the Sun, goes like $1/D^2$
• At the distance that the Earth is from the Sun (1AU) the energy flux is $1350 \text{ W/m}^2$
• Taking into account the Earth’s curvature and the fact that only $\frac{1}{2}$ of the Earth faces the Sun then the average flux is less by a factor of $\frac{1}{4}$ (i.e. $337.5 \text{ W/m}^2$)

$1\text{AU} = 1.5 \times 10^{11} \text{m}$
Power Absorbed by The Earth

The Earth doesn’t absorb all of the energy incident on it: water, snow, clouds etc., reflect about 30% of the incident energy.

This is called the albedo.
Power Absorbed by The Earth

Taking into account the albedo, the solar power absorbed by the earth is: \( 236 \, \text{W/m}^2 \) \( (2.4 \times 10^2 \, \text{W/m}^2) \)

Does the Earth just keep absorbing solar power getting hotter and hotter?
If you double the absolute temperature, the total radiation
a) is reduced to half
b) doubles
c) increases by 4
d) increases by 16
e) stays the same
If you double the absolute temperature, the total radiation
a) is reduced to half
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Next Time

• Thermal Balance, Blackbody Spectra
• Temperature of the Earth, Mars, Venus
• Runaway Greenhouse Effect