L 18 Thermodynamics [3]

- Heat transfer processes
  - convection
  - conduction
  - \( \rightarrow \) radiation
- Physics of the atmosphere
  - the ozone layer
  - Greenhouse effect
  - climate change

Thermodynamics- review

- Thermodynamics is the science dealing with heat, work, and energy and the transformation of one into the other
  - Heat is disordered energy – random motion of molecules
  - Work is ordered or organized energy
- The laws of thermodynamics are a set of empirical (based on observations) rules that place limits on the transformations

Heat as moving light \( \rightarrow \) radiation

- heat can be transferred by the emission of electromagnetic waves – thermal "light waves", invisible to our eyes
- thermal radiation is a small part of the electromagnetic spectrum – called infrared radiation
- waves are characterized by their frequency or wavelength
- different colors in the visible correspond to different wavelengths from red to blue

Electromagnetic spectrum

- TV
- microwaves, cell phones
- thermal radiation
- visible
- radio waves
- x-rays
- thermal radiation

What produces thermal radiation?

- All objects whose temperature is above absolute zero emit thermal radiation
- We continuously emit thermal radiation and absorb it from objects and people around us
- If we just emitted radiation we would eventually cool to absolute zero!
- The rate \( (J/s \text{ or Watts}) \) at which thermal energy is radiated is given by \( P_{\text{radiation}} = \sigma e A T^4 \), where \( \sigma \) is a constant, \( A \) is the area of the object, \( T \) is its temperature in K, and \( e \) is a number between 0 and 1 called the emissivity (poor emitters have a small value of \( e \) and good emitters have \( e \approx 1 \).
Emission and Absorption are balanced

Thermal radiation spectrum
- The intensity of radiation increases with temperature
- The color shifts toward the blue at higher temperatures
- The UV radiation from the sun is just beyond the violet (11,000 F)

Sources of thermal radiation
- The incandescent light bulb (the ones that have a filament) are sources of both visible light and heat.
- When electricity flows through a wire, it gets hot.
- It emits radiation even though you can’t see it.
- As it gets hotter, it glows red then orange then white.
- Tungsten filament, has a very high melting point, 3400 C
- Evacuated glass bulb

Good emitters are good absorbers
- An object that is a good emitter is also a good absorber of thermal radiation.
- A poor emitter is also a poor absorber.
- Generally, dark, dull objects are the best emitters/absorbers.
- Shiny objects are poor emitters/absorbers, they are good reflectors of radiation.
- If you do not want the edges of your pie to burn, you wrap it in aluminum foil. The aluminum foil reflects the heat rather than absorbing it.

Good/bad emitters - Leslie’s cube
- Copper cube filled with hot water
- Evacuated glass bulb
- Infrared radiation sensor
- Even though all sides are at the same temperature, the black sides emit more radiation.

Practical considerations
- Wear light clothing in summer → light clothing absorbs less sunlight.
- Cover all body parts in winter → warm body parts (like your head) emit radiation → wear a hat.
Which thermos bottle is best?

Physics of the atmosphere

- How the sun warms the earth
- The ozone layer issue
- Greenhouse effect
  - Climate change: we share one planet with one atmosphere - the issues are global, and involve science, international politics, and economics

The ozone layer: blocks UV-B rays

- ozone, O$_3$ is a naturally occurring trace element in the atmosphere
- It absorbs solar ultraviolet radiation, especially the harmful UV-B rays
- Ozone is destroyed by CFC’s (chlorofluorocarbons)
- loss affects us and environment
  - Long-term observations reveal that Earth’s ozone has been strengthening following international agreements to protect this vital layer of the atmosphere.

Why is it colder at the poles than at the equator?

- More of the Sun’s energy per unit area falls on the equatorial regions compared to the polar regions
- the earth reflects about 30% of incident solar energy
- without the atmosphere the earth would be 30°C cooler!
- Seasons are due to change in tilt of the earth

The Greenhouse effect

- the sun’s visible light can penetrate through the atmosphere to the earth’s surface and heat it
- the visible light energy is converted to thermal light energy
- the thermal radiation is reflected from the greenhouse gases in the atmosphere
- CO$_2$ concentrations are about 0.04% and increasing
- CO$_2$ produced by burning fossil fuels
- Water vapor accounts for up to 66%

Effect of greenhouse gases:
H$_2$O, CO$_2$, CH$_4$, . . .
Greenhouse effect Demo

- Heat source
- Wooden box with glass window
- Glass lets visible light through, but blocks infrared heat rays from getting out

Temperature change 1880-2003

The temperature anomaly is the difference between the current temperature and a long-term average value.

No temperature rise over the last 15 years

- CO₂ levels
- Temperature change 1880-2003

What are climate forcings?

- Many factors affect the Earth’s climate
- These factors are called forcings because they can drive or force the climate system to change
- Most important forcings during the last 1000 yrs.
  - Changes in the output of energy from the sun
  - Volcanic eruptions (injects dust into the atm.)
  - Changes in the concentration of greenhouse gases in the atmosphere
- The big issues — are the changes:
  - Natural or man-made (anthropogenic)
  - Self-reversible or require intervention

Greenhouse effect and climate change

- Concentrations of CO₂ have been increasing
- → Rise in earth’s temperature
- Similar effect occurs in your car during the day.

Climate change

- Are climate changes part of a natural cycle or driven by human activity (anthropogenic)?
- A recent statement signed by 256 members of US National Academy of Science (Science, 5/7/10)
  - There is always uncertainty associated with science, science never absolutely proves anything
  - Taking no action on climate change poses a dangerous risk for our planet
- Conclusions
  - The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere
  - Most of the increase in concentration over the last century is due to human activities, especially the burning of fossil fuels and deforestation (controversial)
Climate change, continued

– Natural causes also play a role but are now being overwhelmed by human-induced changes
– Warming the planet will cause climatic patterns to change at unprecedented speeds
– Policy makers should move forward to address the causes of climate change and reduce the threat of global climate change
– Effective actions are possible, but delay is not an option

• What are the social, political, and economic repercussions of taking or not taking action?