L 18 Thermodynamics [3]

- Heat transfer processes
  - convection
  - conduction
  - ➔ radiation
- Physics of the atmosphere
  - the ozone layer
  - Greenhouse effect
  - climate change

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Thermodynamics- review

- Thermodynamics is the science dealing with heat, work, and energy and the trans-formation 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

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Heat as moving light ➔ radiation

Radiation emitted by a heating element

- 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

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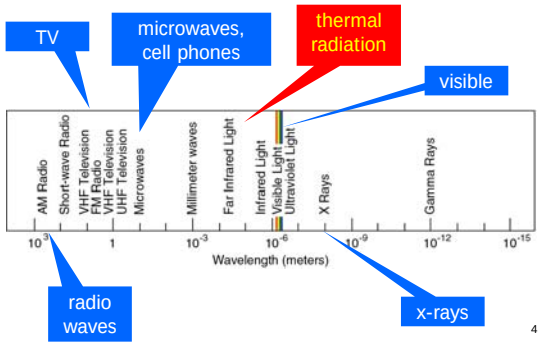
electromagnetic spectrum



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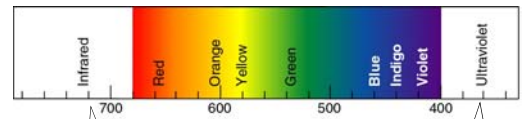
visible electromagnetic waves: LIGHT

shorter wavelength ➔ more energy



visible light

thermal radiation

UV radiation produces sunburn

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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 or Watts) at which thermal energy is radiated is given by $P_{radiation} = \sigma e A T^4$, where σ 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 ≈ 1.

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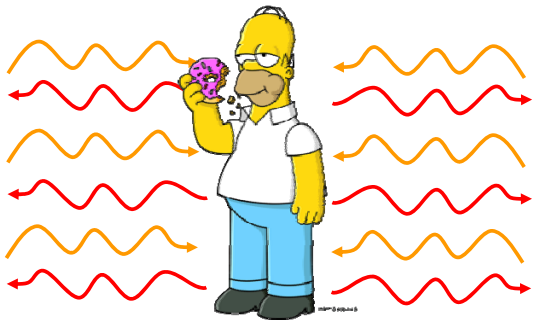
Emission and Absorption are balanced



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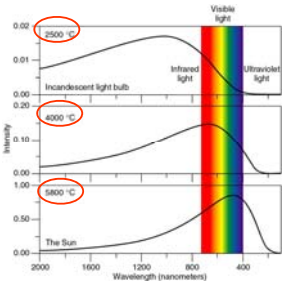
Thermal radiation spectrum



- 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)

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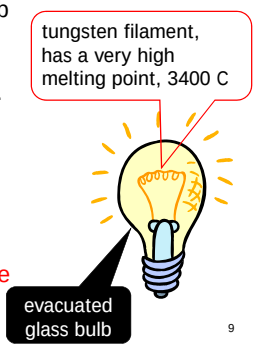
sources of thermal radiation

- 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



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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
- shinny 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.

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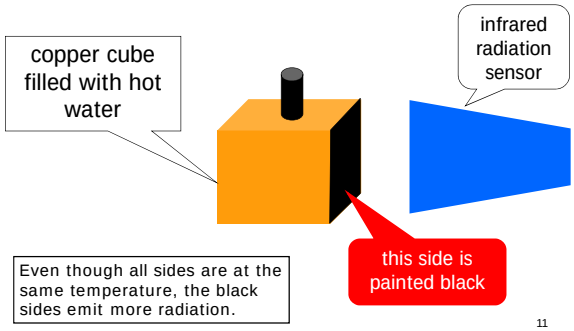
good/bad emitters-Leslie's cube



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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

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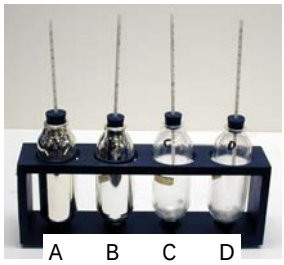
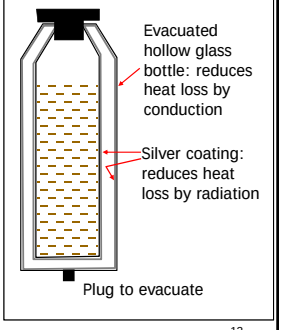
Which thermos bottle is best?



A. silvered and evacuated
B. silvered and un-evacuated
C. evacuated
D. un-silvered and un-evacuated



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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

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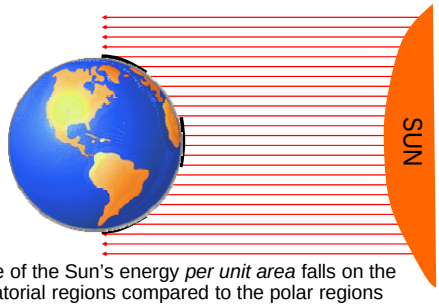
Why is it colder at the poles than at the equator?



- 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

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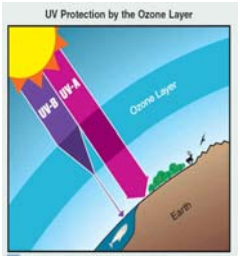
The ozone layer: blocks UV-B rays



- 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.

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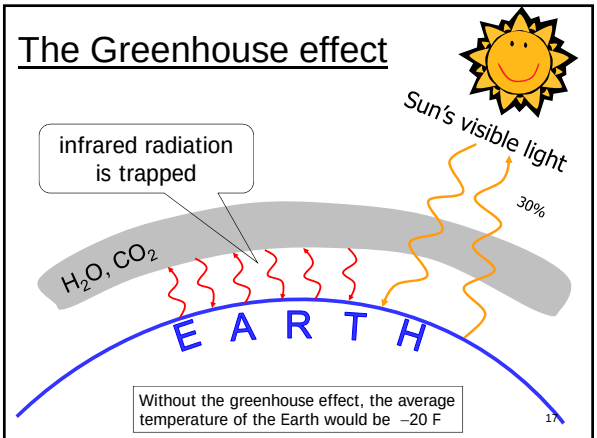
The Greenhouse effect



Without the greenhouse effect, the average temperature of the Earth would be –20 F

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Effect of greenhouse gases: H_2O, CO_2, CH_4, . . .

- 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%

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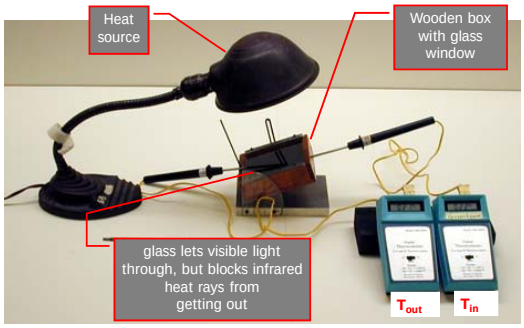
Greenhouse effect Demo



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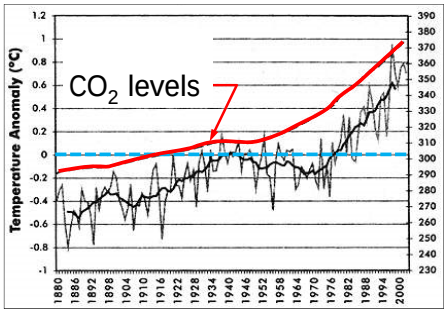
Temperature change 1880-2003

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



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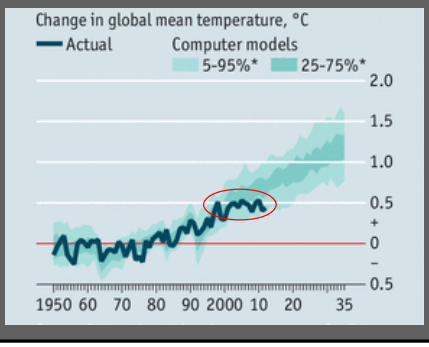
No temperature rise over the last 15 years



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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

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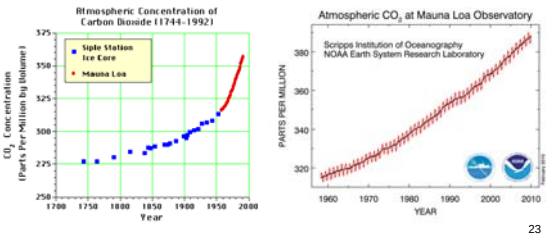
Greenhouse effect and climate change

- concentrations of CO_2 have been increasing
- → rise in earth's temperature
- similar effect occurs in your car during the day.



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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 the concentration over the last century is due to human activities, especially the burning of fossil fuels and deforestation *(controversial)*

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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?

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