Lecture#6

Heat

We will discuss:-

- Internal Energy.
- Heat.
- Specific Heat.
- Latent Heat.
- Heat transfer.
- Radiation spectrum.

Internal Energy

- Energy of all molecules including
  - Random motion of individual molecules
  - Vibrational energy of molecules and atoms
  - Chemical energy in bonds and interactions

- DOES NOT INCLUDE
  - Macroscopic motion of object
  - Potential energy due to interactions with other objects

Heat

- Heat : energy in transit between two objects or system sue to a temperature difference between them.
- Note: similar to WORK
- Heat , like work , is a kind of energy transfer.
- Units: calorie
  - Amount of heat needed to raise 1g of water 1ºC
  - 1 Calorie = 1 kcal = 1000 calories = 4186 Joules
- The Calorie (with an uppercase letter C) used by dietitians and nutritionists is actually a kilocalorie:

Act

- After a grueling work out, you drink a liter of cold water (0 ^{o}C).

How many Calories does it take for your body to raise the water up to body temperature of 36 ^{o}C?

1) 36 2) 360 3) 3,600 4) 36,000

- 1 liter = 1,000 grams of H_20
- 1000 g x 1 calorie/(gram degree) x (36 degree) = 36,000 calories
- 36,000 calories = 36 Calories!

Specific Heat

- Heat adds energy to object/system
  - Heat increases internal energy.
  - Heat increases temperature!
- $Q = m\ c\ \Delta T$
  - Heat required to increase Temp. depends on amount of material (m) and type of material (c)
- $Q = m\ c\ \Delta T$
- $\Delta T = Q/m\ c$

Specific Heat

- Specific Heat:The number of Joules of heat required to produce a 1 K temperature change in 1 Kg of substance.

- $Q = mc\Delta T$
- T increase $\Delta T > 0$ → Heat flowing into the system $Q > 0$.

- T decrease $\Delta T < 0$ → Heat flowing out of the system $Q < 0$.
- Specific Heat The heat capacity of the water in a drinking glass is much smaller than the heat capacity of the water in Lake Superior. Since the heat capacity of a system is to the mass of the system, the specific heat capacity (symbol c).

Specific Heat ACT

- Suppose you have equal masses of aluminum and copper at the same initial temperature. You add 1000 J of heat to each of them. Which one ends up at the higher final temperature

- A) aluminum
- B) copper
- C) the same

Substance	c in J/(kg-C)
aluminum	900
copper	387
iron	452
lead	128
human body	3500
water	4186
ice	2000

Specific Heat application

- Handle :

Plastic / High specific heat capacity , poor heat conductor

- Base :

Copper / low specific heat capacity , heats up very quickly

- Body :

- Low specific heat capacity , heats up quickly

Latent Heat L

- Latent Heat :The heat required per unit mass of substance to produce a phase change is called the latent heat (L). The word latent is related to the lack of temperature change during a phase transition.
- **Definition of latent heat**

  $$|Q| = mL \qquad (14\text{-}11)$$

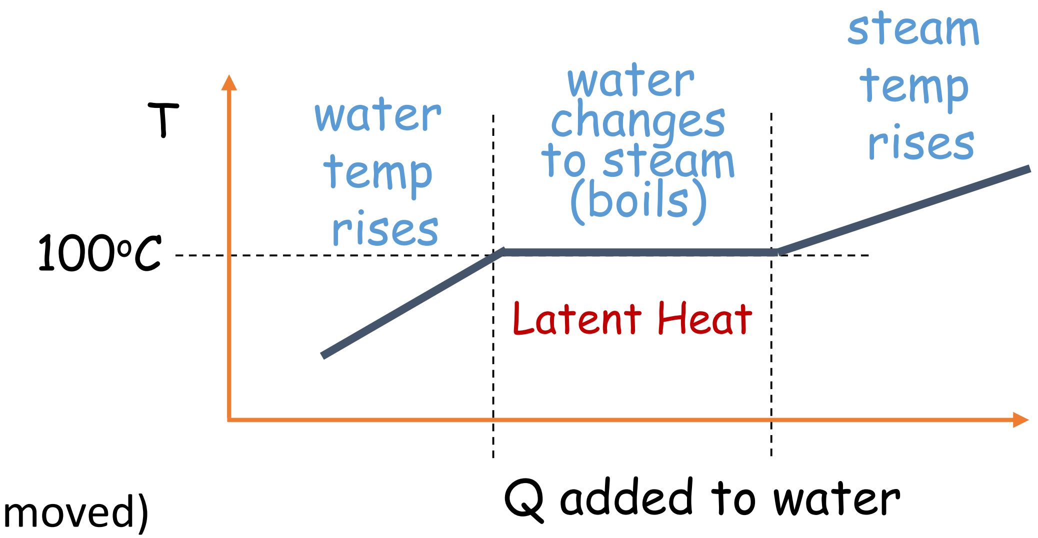
  - The heat per unit mass for the solid-liquid phase transition is called the latent heat of fusion (L_f).

  *Change 1 kg of ice to water
- For the liquid-gas phase transition the heat per unit mass is called the latent heat of vaporization (L_v).
- * change 1 kg of water to steam

Latent heat

- As you add heat to water, the temperature increases for a while, then it remains constant, despite the additional heat!

Substance	L_f (J/kg)	L_v (J/kg)
water	33.5×10^4	22.6×10^5



Latent Heat L [J/kg] is heat which must be added (or removed) for material to change phase.

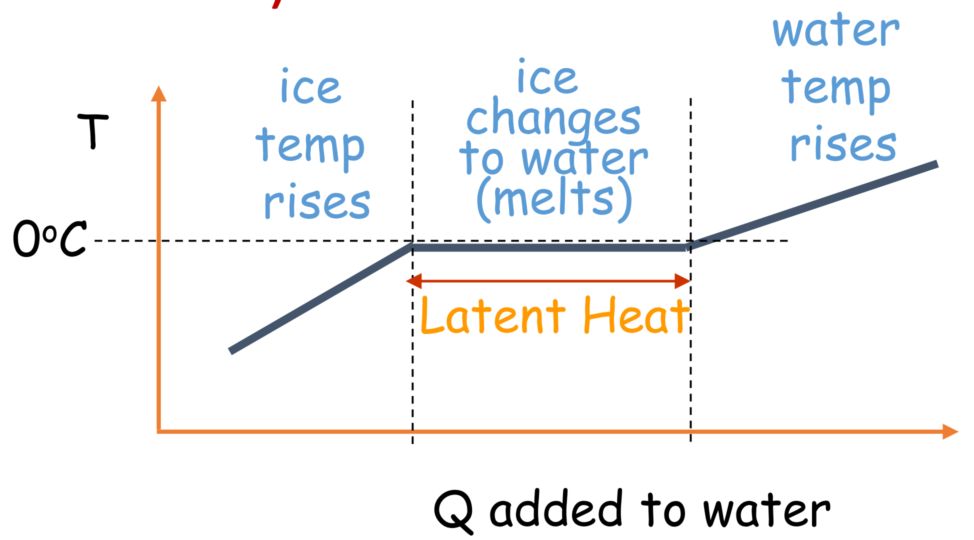
Latent heat (Example)

- If an amount of energy 3.7 x10^6 J is needed to melt 5 Kg of ice at 0^0 to water at 0^0 find the latent

Heat of fusion of water L_f?

Ice Act

- Which will do a better job cooling your soda, a "cooler" filled with water at 0 ^oC, or a cooler filled with ice at 0 ^oC.
- A) Water B) About Same C) Ice



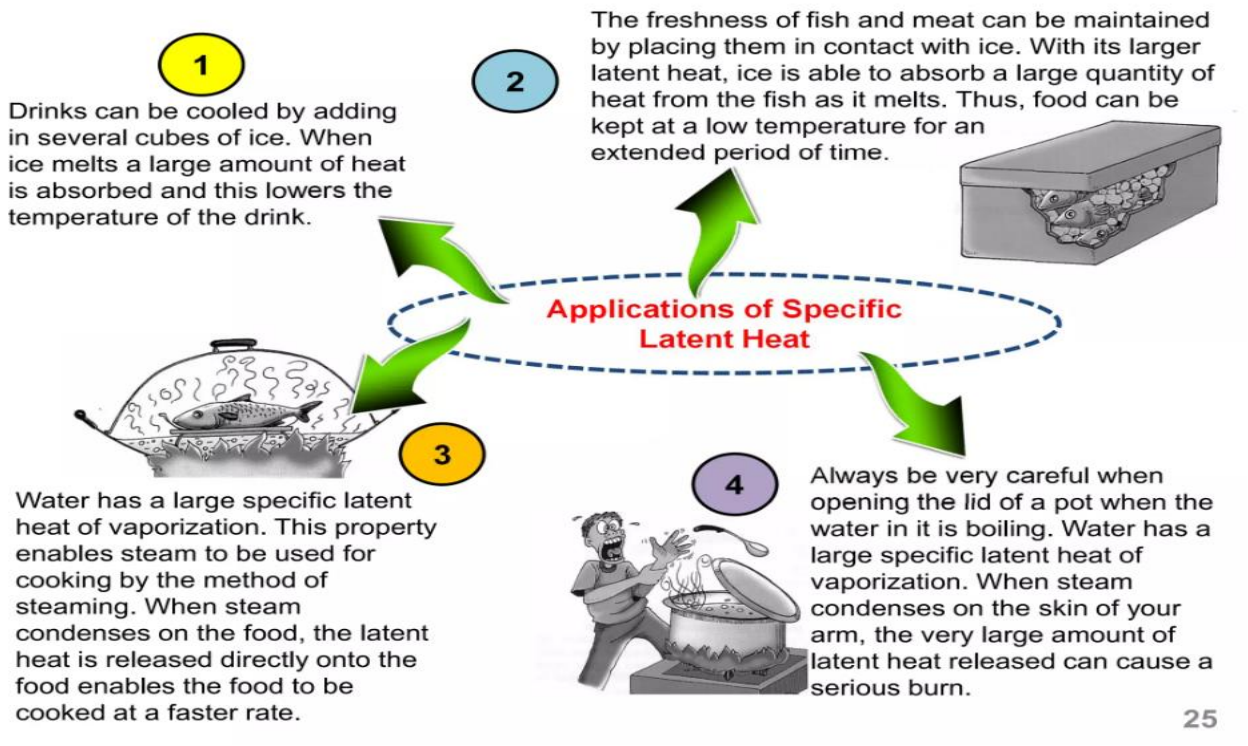
Example

- How much ice (at 0 ^oC) do you need to add to 0.5 liters of a water at 25 ^oC, to cool it down to

10 ^oC?

(L = 80 cal/g, c = 1 cal/g ^oC)

Application of latent heat



Which burns more !

WHAT PRODUCES MORE SEVERE BURNS

Boiling Water

Steam

Answer

The temperature of both, boiling water and steam, is 100°C.

But, **burns caused by steam are more severe** than burns caused by boiling water.

This is because when water gets converted into steam at 100° C, it **absorbs latent heat of vaporization.**

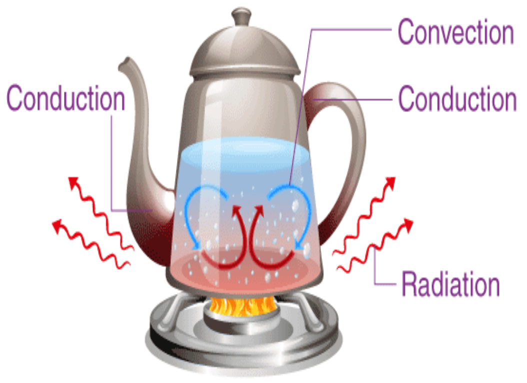
Hence, **steam has more heat** than water at the same temperature.

Therefore, steam gives out much more heat to the skin as compared to the boiling water, thus causing more severe burns.

Heat transfer

- Heat can travel from one place to another in several ways. The different modes of heat transfer include:
- Conduction
- Convection
- Radiation

Meanwhile, if the temperature difference exists between the two systems, heat will find a way to transfer from the higher to the lower system.

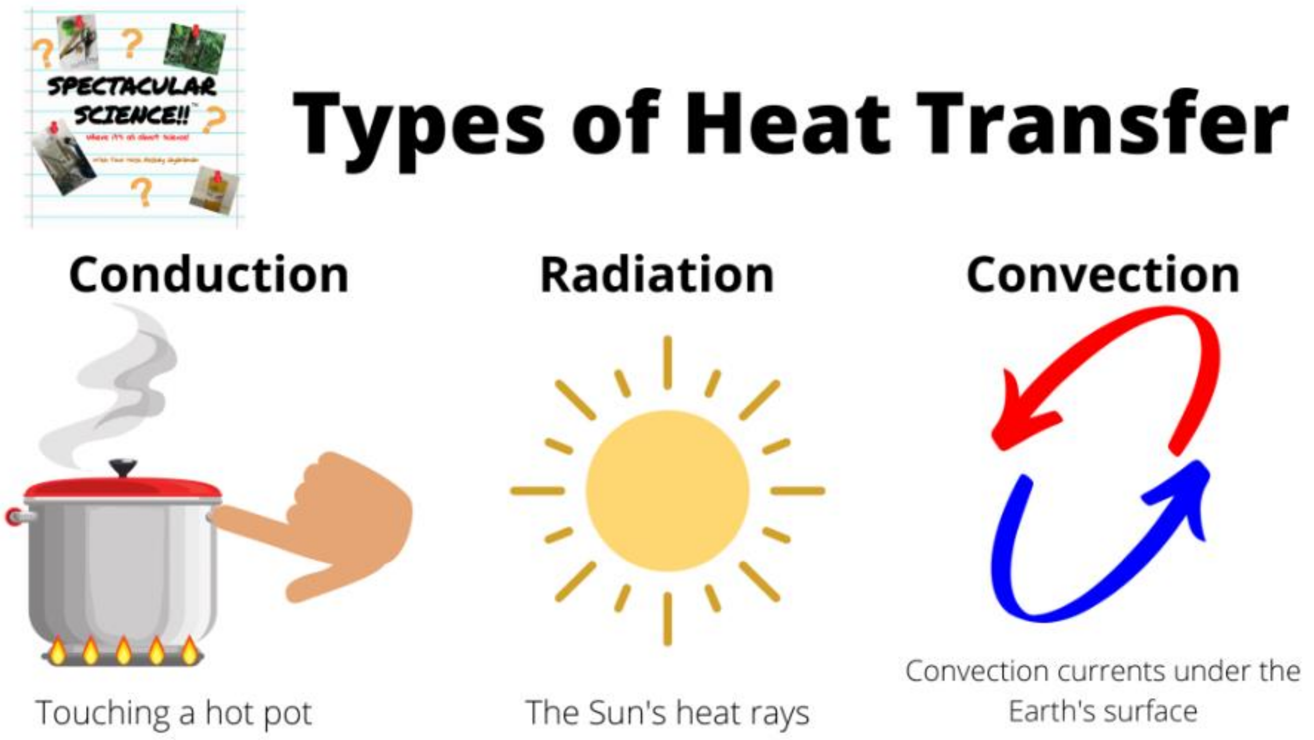


Heat transfer

- **Conduction** : The process of transmission of energy from one particle of the medium to another with the particles being in direct contact with each other.
- **Convection** : The movement of fluid molecules from higher temperature regions to lower temperature regions.
- **Radiation** : All bodies emit energy through electromagnetic radiation. Thermal radiation consists of electromagnetic waves that travel at speed of light.

Unlike conduction and convection, radiation does not require a material medium .

Heat transfer

- 

Heat Transfer

Conduction

Which of the following is an example of **conductive** heat transfer?

1. You stir some hot soup with a silver spoon and notice that the spoon warms up.

2. You stand watching a bonfire, but cant get too close because of the heat.

3. Its hard for central air-conditioning in an old house to cool the attic.

ACT

Touch base of chair (metal), and desk top (wood), which feels colder?

A) Base

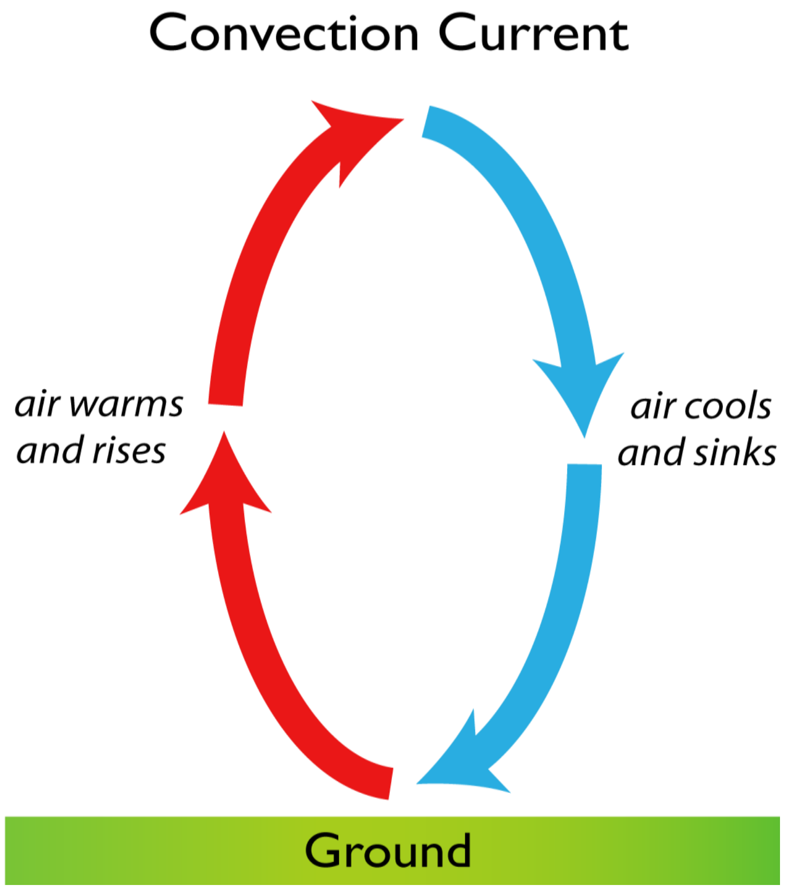
B) Same

C) Desk

Heat Transfer

Convection

- Air heats at bottom
- Thermal expansion…density gets smaller
- Lower density air rises
    - Archimedes: low density floats on high density
- Cooler air pushed down
- Cycle continues with net result of circulation of air
- Practical aspects
    - heater ducts on floor
    - A/C ducts on ceiling
    - stove heats water from bottom

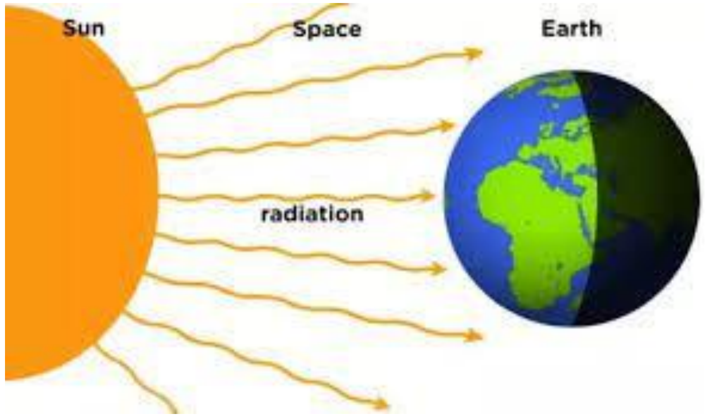


Heat Transfer

Radiation

- Which of the following is an example of **radiative** heat transfer?

1. You stir some hot soup with a silver spoon and notice that the spoon warms up.
2. You stand watching a fire, but cant get too close because of the heat.
3. Its hard for central air-conditioning in an old house to cool the attic.



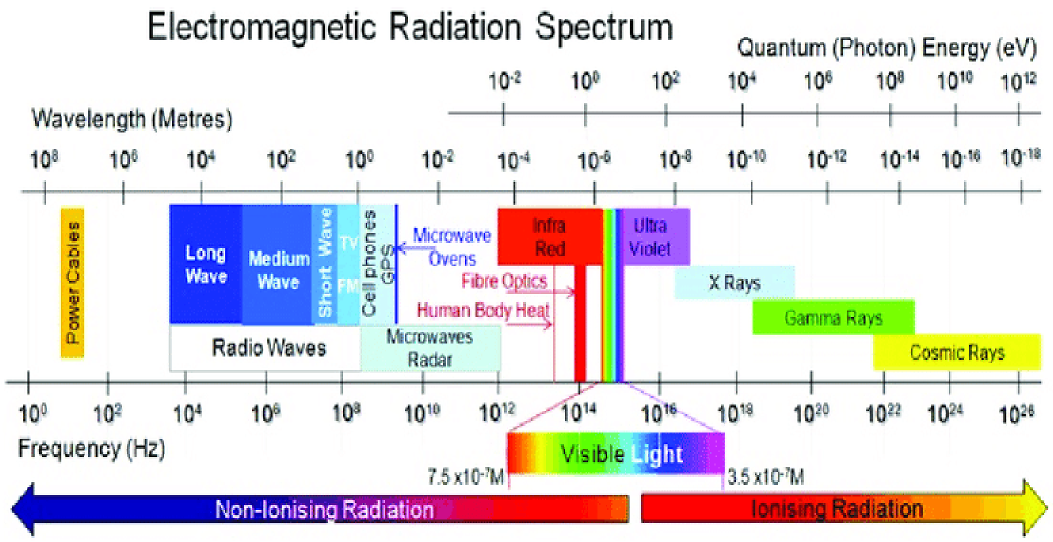
Radiation spectrum

- The electromagnetic radiation we are concerned with falls into three wavelength ranges

Infrared radiation includes wavelengths from about 100µm down to 0.7µm

The wavelengths of visible light range from about 0.7µm to about 0.4µm

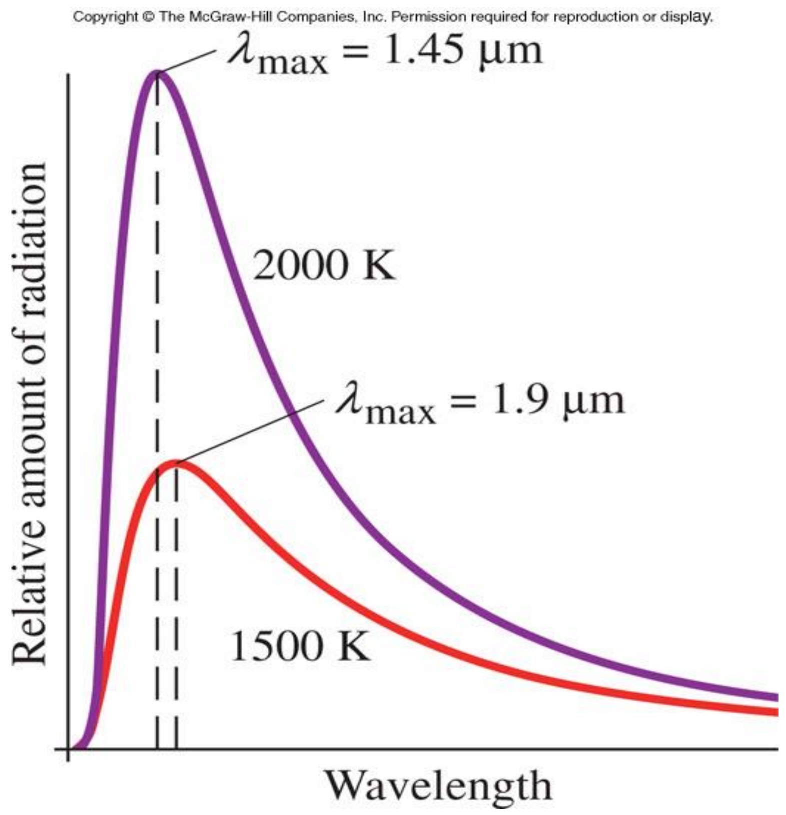
Ultraviolet wavelengths are less than 0.4µm



Radiation spectrum

A spectrum shows the amount of radiation emitted at a particular wavelength. For a blackbody, the peak of the spectrum is determined only by its temperature.

An idealized body that absorbs all the radiation incident upon it is called a blackbody.



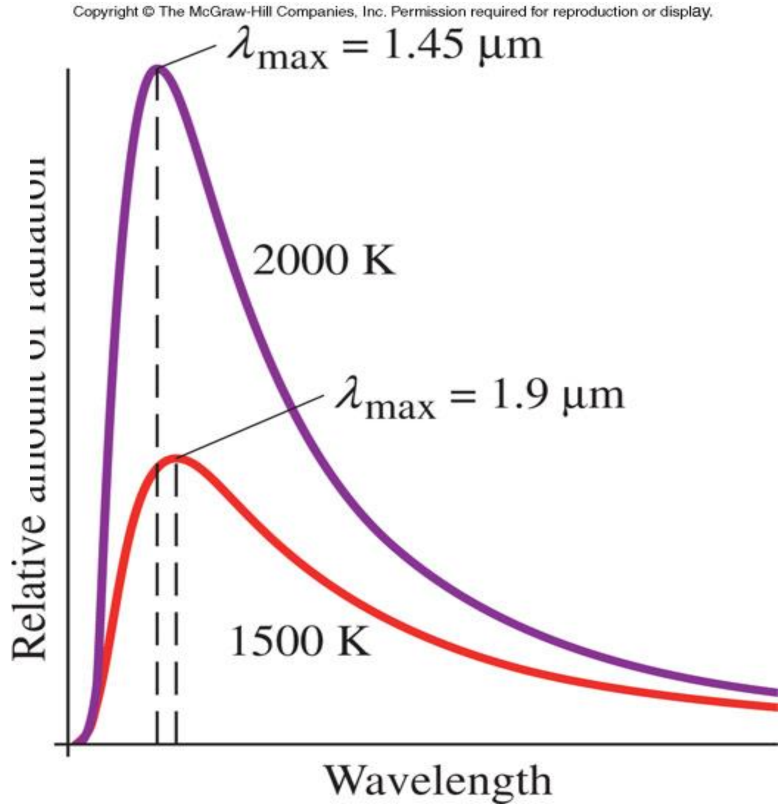
Radiation spectrum

The wavelength of maximum radiation is inversely proportional to the absolute temperature

Wien's law

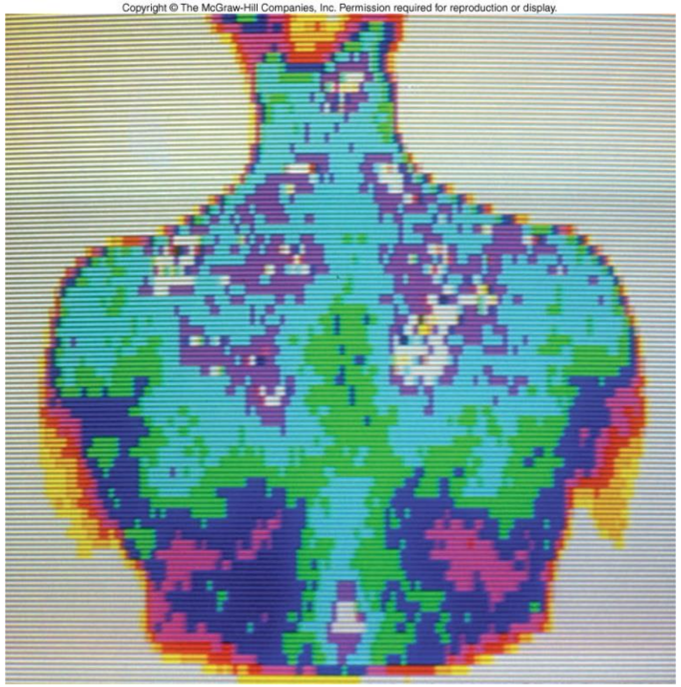
$$\lambda_{max} T = 2.898 \times 10^{-3}\ \mathrm{m \cdot K} \qquad \textbf{(14-24)}$$

where the temperature T is the temperature in kelvins and λ_{max} is the wavelength of maximum radiation in meters. This relationship is named for the German physicist Wilhelm Wien (1864–1928).



Example

- If your skin is radiating at a temperature of 307 K, at what wavelength is the maximum intensity?



Example

- The maximum rate of energy emission from the Sun occurs in the middle of the visible range—at about $\lambda = 0.5\ \mu m$. Estimate the temperature of the Sun's surface.