PHYSICS 103: Lecture 20

Agenda for Today:

- Blackbody Radiation
- Light Bulbs

Thermal or Blackbody Radiation

- All matter contains electric charges
- These particles are in constant motion and are accelerating
- Accelerating charge produces electromagnetic radiation
- All materials emit electromagnetic radiation

Electromagnetic Waves

Shorter wavelength light has higher energy
Blackbody Spectrum

The distribution of wavelengths emitted and the intensity (how bright) depend on the temperature of the object:

\[ P = \varepsilon \cdot \sigma \cdot T^4 \cdot \Lambda \]

1) \( \sigma \) is the Stefan-Boltzmann constant.
2) \( \sigma \approx 5.7 \times 10^{-8} \text{ W/m}^2\text{K}^4 \)

Wien’s Law

Wavelength of peak emission

\[ \propto \frac{1}{\text{temperature}} \]

or

\[ \lambda_{\text{max}} = 0.29 / T \]

Note:

... \( \lambda \) is in cm
... \( T \) is in Kelvins

Example:

- object at 6000 K \( \lambda \approx 480 \text{ nm (v)} \)
- object at 60,000 K \( \lambda \approx 48 \text{ nm (uv)} \)

Summary of Radiation

- The sun, stars, you, everything in this room radiates electromagnetic waves (light)
- The hotter the object --- the higher its temperature --- faster the motion of the constituent particles --- the greater the power radiated (ie, more light)
- The hotter the object --- the higher its temperature --- faster the motion of the constituent particles --- the shorter the wavelength at which most of the light is radiated
Example: Incandescent Bulbs

- Electrical connections deliver power to a tungsten filament
- The electrons collide with the tungsten atoms and transfer some of their energy to them
- The tungsten filament gets hot (2500 °C)
- Hot things radiate more light at shorter wavelengths
- Tungsten is used because it doesn’t melt at these temperatures
- Glass envelope is their because tungsten burns in air
- Bulb is filled with nitrogen, argon, krypton (inert) which prolong life

Operation Issues

- Filament temperature
  - determines color of bulb and efficiency of bulb
  - higher temperature = more efficient (more light emitted in visible; typical 12%)
  - higher temperature = shorter life
- Filament heating
  - filament wires need to be long and thin (so that most of electrons energy is converted to tungsten atoms)
  - filament in a typical bulb is 0.5 m of 25 micron coiled up into a length of 2 cm
- Filament lifetime
  - tungsten atoms sublime
  - filament gets thinner with time
  - inert gas added to prolong life
  - but gas adds to convective heat loss (total efficiency is 10%)
  - dark spot at top of bulb is actual tungsten atoms

3-way Bulb

- Larger filament has greater surface area so it radiates more power
Test your understanding

• If you remove the gas in an incandescent light bulb, will it become more efficient, less efficient, or stay the same

• When you operate a 50-100-150 W bulb at its lowest setting, it emits yellow-white light. If you use a dimmer switch to operate a regular 150 W bulb on only 50 W electrical power, it emits orangeish light. Why?

Main Points from Today’s Lecture

• Thermal Radiation
  You should understand that all things radiate electromagnetic waves (or light). Light comes in different “colors” (wavelengths). The hotter the object, the greater the power of radiation emitted and the shorter the wavelength at which most of the light is radiated.

• Light Bulbs
  You should understand that an incandescent light bulb produces light as thermal radiation from a very hot (2500 °C) tungsten filament. The spectrum of light emitted by the filament depends on its temperature - the hotter the filament, the whiter the light. The tungsten atoms sublime during operation and eventually the filament breaks. An inert gas is placed in the bulb to prolong its life at the expense of reducing its efficiency.