LEARNING PLAN FOR ENERGY RADIATION

Topic/Concept: **<u>Energy Radiation / Interaction of Waves & Matter</u>** **Week___ Date_____**

Goals:

- Students will develop an understanding of the basic processes involved in radiation of energy in the form of light
- Students will hone their experimental skills through active investigation of the phenomena involved in the demonstration
- Students will be able to relate specifics of demonstration to general physics concepts
  - conservation of energy
  - energy of radiation (E=h*nu)
  - relation of radiation to temperature
  - different energy levels involved in atomic structure
  - relation of power to energy
  - interaction of waves and matter (specifically how wave deposits energy in matter)
- Students will be exposed to plasma physics concepts, and begin to appreciate details of the study of plasma physics

Learning Outcomes/Objectives:

- Describe what lights up the light bulb
- Prediction, in a short paragraph, of what effect changing at least two parameters will have (ex. type of bulb, microwave heating power, etc.)
- Description of actual effect of changing at least two parameters independently (ex. type of bulb, microwave heating power, etc.)
- Explanation of how these effects are related to at least two general physical principles.
- Explain how conservation of energy applies to this situation

Opening Activity:

Students will bring in their "burnt out" light bulbs from home. Plugging a sample into a socket in the classroom, the teacher will demonstrate the light bulb does not light up. Then, the teacher places the light bulb in a glass of water with ice in it, places it in the microwave, starts it, and shows students that it lights up. What's going on here?

Teacher may then also demonstrate using a fluorescent or neon bulb, since these are closer to the idea of having just a gas contained in a tube that acts as an emitting plasma.

Method/Learning Activity/Concept Activity/Task:

Students become familiar with physical principles through investigation:

1. Vary type of gas in container (or type of bulb: "burnt out" incandescent, fluorescent, neon, halogen) to see different colors of light emitted
   a. *concepts: atomic structure, different energy levels in different gases*
2. Vary power of microwave heating
   a. *concepts: increased input power leads to more emission, interaction of radiation (waves) with matter, possibly increased power leads to different emission wavelengths which ties into relation between radiation and temperature*
   b. Estimate the power being put into the bulb for different settings (not sure how to measure this…)
3. Determine the frequency of radiation from the microwave and the power used (most modern microwaves have %total power as an option). Estimate the frequency of light from the bulb, and calculate the intensity needed to achieve energy balance. Is this more or less than a working 100W light bulb, emitting at 600 nm, over the same time period?
   a. *concepts: conservation of energy, relation of power to energy*
   b. Example: for 2.4GHz radiation, and 1 MW power input for 5 seconds, have 5 MJ of total energy. For E=h*nu=$6.626*10^{-34}*2.4*10^{9}=1.59*10^{-24}$ J/photon. This means to get to 5MJ, would need $3.144*10^{30}$ photons. If the bulb emits light at 550nm, then energy per photon is roughly hc/lambda=$6.626*10^{-34}*3*10^{8}/550*10^{-9}=3.614*10^{-19}$ J/photon. So to have conservation of energy, should be emitting 5MJ energy/$3.614*10^{-19}$ J/ph = $1.383*10^{25}$ photons of visible light emitted.
      i. 100W bulb → for 5 seconds, gives 500J energy. Energy per photon at 600 nm is: $6.626*10^{-34}*3*10^{8}/600*10^{-9} = 3.13*10^{-19}$ J/photon. To achieve 500 J, need 500J/$3.13*10^{-19}$ J/ph = $1.597*10^{21}$ photons.
      ii. So emission rate is 8659 times larger for microwave than for ordinary bulb → that's why it melts!
4. Determine the gas inside the light bulb, either from manufacturer specifications or other means. Predict the color of radiation you'd expect based on energy level transitions, and compare to observed spectrum.
   a. *concepts: atomic structure/energy levels*

Checking for Understanding/Assessment:

1. What ignites the discharge in the bulb?
2. Suggest a mechanism for the transfer of energy from the microwaves to the plasma.
3. Why is microwave radiation suitable for this?
4. How is this effect related to the common wisdom of not putting metal into a microwave?
5. Why don't plastic or ceramic containers glow in a microwave?

[questions from "Integrating Plasma Physics into the High School Curriculum", found at: http://science-education.pppl.gov/SummerInst/curriculum2.html]

Assignment:

Write a short report describing what your predictions were, and how you tested them with experimentation with the demonstration. If possible, graph your results. Include how your results apply to at least two of the general principles discussed in class.

Materials Needed:

Household microwave
Various light bulbs (several wattages of incandescent, fluorescent, neon, halogen)
    "burnt out" light bulbs are perfectly acceptable, as long as glass remains intact
Glass of water
Some ice
Towel
Safety Equipment, if deemed necessary (goggles, oven mitts, etc.)