Blackbody Spectrum & Lasers SIM Homework

1) (6 pts total) The Sun provides most of the energy that makes life on earth possible. The Sun's surface reaches a temperature of about 5800 °C and emits sunlight which travels the 150,000,000 km to Earth at a speed of 3*10^8 m/sec in about 8 minutes.

a) (1.5 pts) Electromagnetic radiation is emitted when charged particles accelerate. Sunlight is a blend of electromagnetic waves of different wavelengths.

i) Describe the distribution of electromagnetic radiation emitted from the sun (what wavelengths are emitted? is it all visible light? is there more blue light than red light?). Click here for the blackbody spectrum simulation

ii) Why you get a distribution of wavelengths instead of just one wavelength?

iii) How does the temperature of the sun affect this distribution?

b) (1 pt) It is the thermal motion of charged particles at the sun's surface that produces the electromagnetic radiation emitted by the sun.

i) (0.5 pts) To generate a green light at 550nm, at what frequency would a charged particle have to be vibrating back and forth?

ii) (0.5 pts)Even in the most advanced circuits, we cannot oscillate electrons back and forth at that rate through wires. But we can oscillate charges back and forth quickly enough to broadcast TV using radio wave signals. At what frequency does that electronics at the TV station need to have the charges oscillate back and forth on a TV broadcast antenna to transmit a typical TV signal (say a radio wave transmission signal with a wavelength of 1 meter)?

c) (2.5 pts) The sun provides the energy that powers life on our planet everyday (even the energy stored in fossil fuels came from the sun). At noon on a typical mid-June day in Boulder, each 1 cm2 of the surface is exposure to 20 mW (milliWatts) of visible radiation. You are considering adding solar panels to your house and want to see whether they will provide enough energy for your household needs.

i) (0.5 pts) If your solar panels covered an area of 1 meter by 5 meters, how much solar power would be hitting the surface of the panels at noon on a clear day? (in Watts …. check your answer with your fellow students!)

ii) (0.5 pts) Over the period of 1 hour, what is the total amount of energy of the visible light that has hit the solar panels? (assume that the exposure is pretty steady for that hour at 20 mW).

iii) (1 pt) Red photons and violet photons have slightly different energies. If we take the average energy of the visible light photon hitting the solar panels as that of a green photon (550 nm), how many visible light photons hit the solar panels during that hour?

iv) (0.5 pts) If the solar panels were 15% efficient at converting this energy into electrical energy, how much electrical energy would have been harnessed in 1 hour?

v) (1 pt) For how long could this amount of energy power a 60 W bulb (in hours)?

d) (1 pt) As we stated above, in Boulder at noontime in the summer there is 20 mW of visible light hitting each 1 cm2 of the surface. However, there is only about 0.022 mW (milliWatts) of UV radiation between 290 nm and 320 nm (UV B) hitting each 1 cm2 of the surface. (Only a small portion of the sunlight's energy is at UV wavelengths.) Explain why it is that 0.022 mW of UV exposure can cause damage to our DNA and result in skin cancer, but exposure to 20 mW of visible radiation leaves our DNA unharmed? Why doesn't exposure to so much more visible radiation harm our DNA?

2) (4 pts) A laser involves the various processes by which light interacts with atoms' (1) absorption – the process by which the light is absorbed and the energy causes the atomic electron to go to a higher energy level (2) spontaneous emission – the process in which the electron jumps back down and spits out a photon of the corresponding energy as it does so, and finally, (3) stimulated emission – the process where a photon hits an atom that is in a higher energy level already and this causes the atom to spit out a photon that is identical to the one that hit the atom so there are two identical photons. Not every photon that hits a ground state atom will be absorbed, and not every photon that hits an excited atom will cause stimulated emission, but the probability of the event occurring during a photon encounter is the same for both conditions. That means that if a photon is going through a gas of atoms and it encounters single ground state atom its chance of being absorbed by that atom is exactly the same as its chance of causing stimulated emission if it had encountered a given single atom in an excited state. So, if there are twice as many atoms in the ground state as in the excited state the photon is twice as likely to be absorbed as it is to stimulate an atom to emit.

a) (1 pt) Explain why it would be impossible to achieve a population inversion and hence impossible to make a laser work if your design used an atom where only two energy levels were involved (the lowest or ground level and one higher level) and in your design you were "pumping" atoms into the excited state using light at the exact wavelength where the photon energy matched the energy separation between the lower and upper energy levels of the atom. (Note that: This is the reason that in actual lasers that use light to pump the atoms into the upper levels, three or four atomic energy levels are involved.)

b) (1 pt) Explain the function of the mirrors at each end of a laser. Why do you need them to have a functioning laser? What would happen if one mirror was removed?

c) (1 pt) If you set up all the parts for a laser and then just barely turn on the pump that puts atoms into the excited state nothing very interesting happens. As you gradually increase the pumping you still do not get any laser light out. However, once you reach a certain point (called the “threshold”) suddenly laser light comes out and as you increase above that the amount of laser light produced increases rapidly. This behavior can be observed in the PhET laser applet as well as in any real laser. Explain this behavior of a threshold for laser operation in terms of the underlying physics of lasers.

d) (1 pt) Lasers are used in all sorts of modern technology. What characteristics of laser light make it special and especially useful in technology (try to give examples of where this feature is made use of in your everyday life)? In your description of the characteristics, explain why the physics of how lasers work produce these characteristics.