Blackbody Spectrum SIM Homework

1) In this question, you will use the *Blackbody Spectrum Simulation* to investigate how the spectrum of electromagnetic radiation emitted by objects is affected by the object's temperature. In this simulation, you can input the temperature and observe the spectrum of the radiation emitted.

a) The temperature of stars in the universe varies with the type of star and the age of the star among other things. By looking at the shape of the spectrum of light emitted by a star, we can tell something about its average surface temperature.

i) If we observe a star's spectrum and find that the peak power occurs at the border between red and infrared light, what is the approximate surface temperature of the star? (in degrees C)

ii) If we observe a stars spectrum and find that the peak power occurs at the border between blue and ultraviolet light, what is the surface temperature of the star? (in degrees C)

b) Light bulbs operate at 2500 degrees C.

i) What is the wavelength at which the most power is emitted for a light bulb operating at 2500 C?

ii) Explain why regular incandescent bulbs waste a lot of energy. Be sure to include your reasoning.

c) Investigate how the observed spectrum responds to changing temperature. Note you are only able to change temperature here, but should consider how the spectrum (power vs. color) would change if you varied other characteristics about the object.

○ True ○ False If the only change you make is to decrease the temperature of an object, the amount of power emitted at 1000 nm will increase in some cases.

○ True ○ False If the only change you make is to decrease the temperature of an object, the total amount of power emitted decreases in all cases.

○ True ○ False If you were to increase the surface area of a bulb filament, but leave its temperature unchanged, then a larger fraction of its total power emitted would be emitted as IR radiation .

d) Use the Spectrum Simulation to investigate changes in the amount of light at visible wavelengths due to this change in temperature from 2500 C to 2000 C.

i) What is the approximate ratio between the powers emitted at 500 nm at 2000 degrees C to that at 2500 degrees C, that is, the power emitted at 500 nm at 2000 degrees C divided by the amount of power at 500 nm at degrees 2500 C?

ii) In question 1b, we found the wavelength for the peak power of a bulb

operating at 2500 degrees C. What is the approximate peak wavelength for a bulb operating at 2000 degrees C?

e) You turn up the dimmer switch so that the temperature of the filament reaches 2600 degrees C. The light bulb filament has an area of 6.45×10^{-4} m^2 (0.1 square inches) and an emissivity of 0.8. How much electrical power must it be using?

2) In this problem we will explore the greenhouse effect by using the Greenhouse Effect Simulation available from the 1010 homepage.

a) Explore the simulation.

○ True ○ False The only effect of increasing the number of clouds is to reduce the amount of sunlight absorbed by the surface of the earth.

○ True ○ False Increasing the concentration of greenhouse gases, increases the amount of radiation that Earth emits to space.

○ True ○ False When sunlight encounters a cloud, the cloud reflects about 10% of the sunlight back to space.

○ True ○ False When there is a very large concentration of greenhouse gases, most of the IR radiation reaching space has interacted with greenhouse gas molecules on its way from the surface to space.

○ True ○ False The total amount of radiation absorbed by the Earth's surface is not affected by the concentration of greenhouse gases in the atmosphere.

○ True ○ False At higher temperatures, the Earth's surface emits more IR radiation.

○ True ○ False During the ice age, the amount of sunlight absorbed by the Earth's surface decreased.

○ True ○ False All greenhouse gases are from anthropogenic sources (that is due to man's activities).

b) Explain your reasoning for your answer to the T/F question "Increasing the concentration of greenhouse gases, increases the amount of radiation that Earth emits to space." and include the physics principles that support your reasoning.

c) From your observations of the simulation and your understanding of the basic physics principles of energy and radiation, explain why the average surface temperature of the earth increases in the presence of the greenhouse gases. Be sure to include reasoning.

d) As the Sun ages, it will cool and the amount of power it produces will decrease. If at some point in the future, this power drops such that the solar power/m^2 at the earth drops by 10% to 1250 Watts/m^2, what will the surface temperature of the Earth be? (Assume that the fraction of sunlight absorbed by the Earth's surface remains the same and that the fraction of the IR radiation emitted by the Earth's surface that reaches space remains the same as it is for today (see lecture notes).)

e) If in the future, the amount of greenhouse gases in the atmosphere rise so that 10% less of the IR radiation emitted from the earth's surface is getting out through the atmosphere than at present, calculate how many degrees Kelvin hotter the surface of the earth would be? (Assume that the amount of clouds and other complicated stuff like that does not change.)

f) In class, we used the temperature sensor to measure the temperature of a hot piece of metal and then saw the effect of sticking a piece of glass in front of the metal.

i) If we look at Earth from space with temperature probe similar to the one we used in class and measure the amount of IR radiation emitted to space by the Earth, what temperature would we measure?

○ 225 K ○ 255 K ○ 280 K ○ 288 K ○ 298 K

ii) When the concentration of greenhouse gases increases, most of the IR radiation that escapes to space last interacted with a greenhouse gas molecule at a ...

○ lower altitude ○ higher altitude