Physics 157 Homework 4: due Wed, Oct 16th by 5pm

In this homework set, you'll get some practice with problems involving radiation. We hope this will help you develop the following specific skills:

- To be able to interpret spectrum graphs, calculating the relative power for different ranges of wavelengths and deducing the temperature of an object via Wien's law in the case of a thermal spectrum.
- To predict the power in electromagnetic radiation emitted by an object given its temperature, area, and emissivity.
- To calculate the equilibrium temperature of a radiating object when the ingoing energy is supplied directly via a power source or absorbed from some external source of radiation. To correctly take into account emissivity and albedo in these calculations.
- To be able to calculate the intensity (power per unit area) of radiation from a spherically symmetric source given the power of the source and the distance to the source

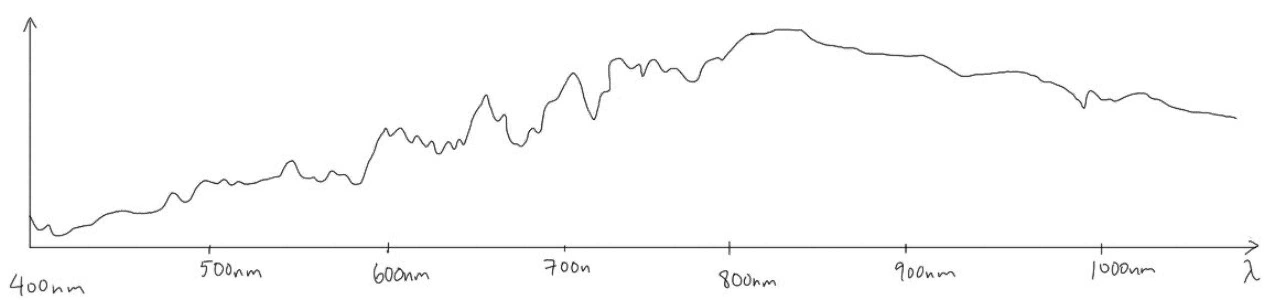
Part 1: Mastering Physics

Log in to Mastering Physics through Canvas and do Assignment 4.

Part 2: Written questions

Write up solutions and hand in the two questions below to the homework boxes.

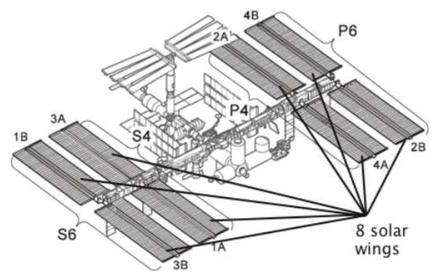
Problem 1) The graph below shows an approximation to the spectrum of electromagnetic radiation from the star Betelgeuse (brightest star in the constellation Orion). This star is known to be a distance of 643 light years from the Earth (1 light year is the distance light travels in a year). The intensity of electromagnetic radiation (power per area) from Betelgeuse as measured on Earth is 8×10^{-11} times the intensity of electromagnetic radiation from the sun (the solar constant). Using this information, estimate the radius of Betelgeuse. How many times larger is this than the Sun's radius? How does this compare to the distance between the Sun and the earth?



Problem 2) The international space station, orbiting the earth, is powered by 8 solar "wings" that rotate so that they always face perpendicular to the sun's incident radiation. Each wing is 35m long and 12m wide and 15.6% of the area is covered by silicon (Si) solar cells. The solar cells have emissivity $e_{Si} = 0.65$, and reflection coefficient, which is the same as albedo, $R_{Si} = 0.3$. The solar wings are thin, ie. the edge area is very small compared to the face area. The solar cells are 18% efficient at converting light to electrical power. The incident intensity of the sun at the distance of the earth is 1367 W/m^2.

a) How much power is produced by the station when the panels are exposed to the sun (ie. not when the station is shadowed by the earth)?

b) What temperature do the solar cells reach when they are exposed to the sun (ie. not shadowed by the earth)?



Hint: For part b), don't forget that some of the absorbed power goes to electrical power!

Extra practice (old midterm and exam questions), not to be handed in:

2. Mars albedo, the reflection coefficient for sunlight from Mars, is 0.250. The radius of Mars is 3397 km. The Solar constant at Earth is 1367 W/m^2 and the distance from Mars to the Sun is 1.52 times the Earth to Sun distance.

a) Find the temperature of Mars.

Some scientists propose terraforming Mars to make it more human friendly. One proposal is to raise the temperature of Mars by either covering Mars' surface in black dust mined from Mars' two moons or by using bioengineered dark plants on the surface to lower Mars' albedo.

b) Find the highest temperature one could obtain by lowering Mars' albedo.

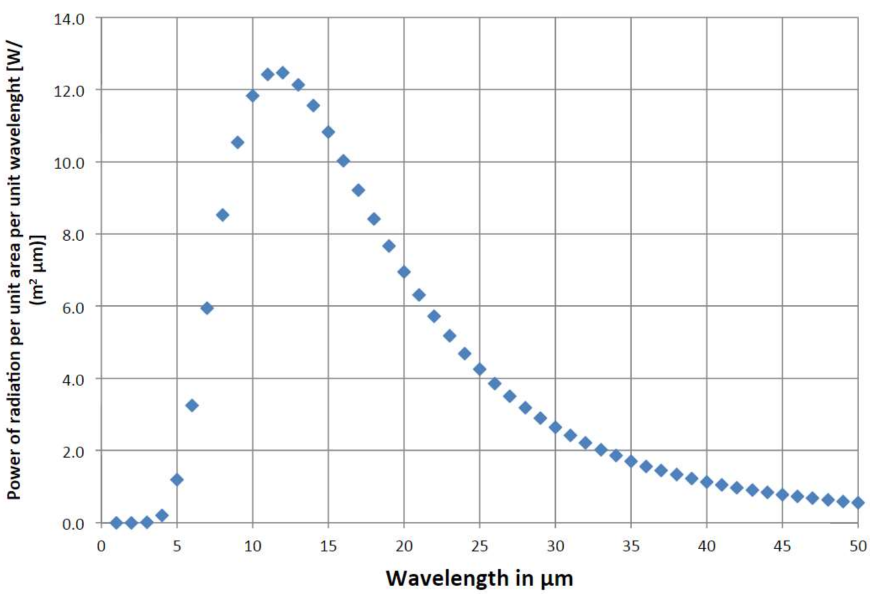
Problem 3. The spectrum of radiation emitted by an approximately spherical satellite of a diameter 2.5 m is shown below. The emissivity of the surface of this satellite is close to 1.

a) What is the temperature of this satellite?

b) What is the total power of radiation emitted by this satellite.

An infrared camera operating in the wavelength range 6-10 μm is used to search for this satellite. The camera has the sensitivity (the minimum intensity of radiation detected) of $4\ nW/m^2$.

c) What is the maximum distance at which this satellite can be detected by this camera?



Problem 4. A thin plate (1.5 m by 1.5 m by 1 mm) with albedo of 0.3 (it reflects 30% of solar radiation) is mounted on the satellite orbiting Earth on a low orbit. You can assume that the plate emits like a black body and that the emissivity of the plate is equal to 1. The solar constant (irradiance) is $1400 W/m^2$.
(a) What is the temperature of the plate when it is tilted at 45 degrees to the direction from the plate to the Sun.
(b) Calculate the function which describes the dependence of the temperature of the plate on the angle between the plane of the plate and the direction from the plate to the Sun.

Problem 2. An approximately spherical, black asteroid (emissivity equal to one) of diameter of 2 km is orbiting the Sun at a distance from the Sun 10 times larger than the distance from the Sun to the Earth.

a) What is the temperature of this asteroid?

b) What is the wavelength of radiation it emits with maximum intensity?

c) What radiation intensity emitted by the asteroid would be observed on Earth?

Solar constant (solar power per unit area as measured above the Earth atmosphere is 1400 W/m^2). Distance from the Sun to the Earth is 1.5×10^{11} m.