# Homework 7

*Blackbody radiation*

*Due Friday March 8 at 5pm*

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## 1. Efficiency of a solar cell

| | A | B |
|---|---|---|
| 1 | 280 | 0.145962 |
| 2 | 285 | 0.276177 |
| 3 | 290 | 0.477193 |
| 4 | 295 | 0.5355 |
| 5 | 300 | 0.496948 |
| 6 | 305 | 0.592171 |
| 7 | 310 | 0.640309 |
| 8 | 315 | 0.690968 |
| 9 | 320 | 0.731223 |
| 10 | 325 | 0.849888 |
| 11 | 330 | 1.00566 |
| 12 | 335 | 0.941141 |
| 13 | 340 | 0.967548 |

Navigate to the "Online Resources" page of the class website (use the sidebar menu). At the "Online Resources" page, look for the subheading "Physical Reasoning Skills". Find the file called extraterr_solar.zip. Download the file and unzip (double click). Now you have a file in comma-separated-variable (csv) format. Open the csv file in excel. The data is the spectral intensity of sunlight measured by a satellite orbiting the Earth. The first column is wavelength in units of nanometers. The second column is spectral intensity in units of W/($m^2$·nm).

**a)** Use excel to perform a simple numerical integration (Riemann sum) to find the total energy flux hitting the satellite. Give your answer in units of W/$m^2$.

**b)** Consider a narrow band of wavelengths, from 552.5 nm to 557.5 nm. (The bandwidth is 5 nm and the central wavelength is 555 nm). All the photons in this bandwidth have very similar energy, ~ (1240 nm·eV)/(555 nm). How many photons per second per $m^2$ are arriving in this bandwidth of sunlight?

**c)** Use excel to calculate the number of photons per second per $m^2$ arriving in every 5 nm bandwidth of sunlight.

**d)** Silicon solar cells absorb photons if $E_{ph} > 1.1$ eV. Considering the entire spectrum of sunlight, how many photons per second per $m^2$ have sufficient energy to be absorbed by a solar cell?

**e)** The maximum electrical energy produced by a silicon solar cell is, approximately,

(1.1 eV) × (number of absorbed photons).

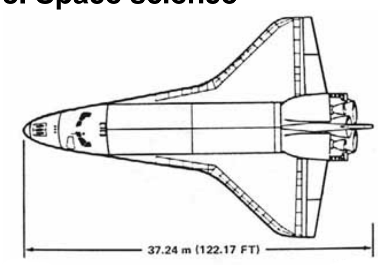
Calculate the maximum rate that electrical energy could be produced by a solar cell attached to this satellite. Give your answer in units of W/$m^2$.

**f)** Compare your answers to part a and part e. What is the maximum efficiency of the solar cell?

**2. Cosmic background radiation**

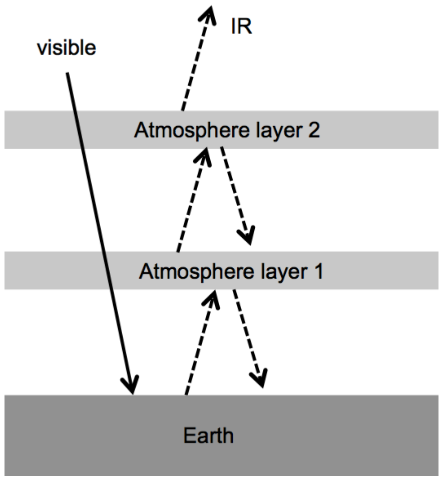
The universe is filled with thermal radiation that has a blackbody spectrum at an effective temperature of 2.7 K. What is the peak wavelength of the radiation? In what region of the electromagnetic spectrum is this peak wavelength?

**3. Space science**




Estimate the shortest time that the space shuttle (mass 100,000 kg, similar to the mass of 100 cars) can descend from top of atmosphere (100 km above sea level) to sea level without overheating? The black panels on the bottom of the space shuttle can safely reach a temperature of about 2000 K. As the space shuttle descends, gravitational potential energy must be converted into blackbody radiation. There is no other energy in the energy budget (the space shuttle does not fire any rockets during its decent, and there is not a significant change in kinetic energy). The space shuttle is about 35 m long, and has a wingspan of 25 m.

## 4. Two-layer model for estimating the Earth's temperature




The Figure shows a two-layer model, similar to the one-layer model we did in class. Both atmospheric layers are transparent to visible light. The atmospheric layers absorb, thermalize and re-emit infrared radiation.

**a)** Write the energy budgets (power in = power out) for both atmospheric layers, for the ground, and for the earth as a whole, just as we did for the one-layer model.

**b)** Manipulate the energy budget for the Earth as a whole to obtain the temperature $T_2$ of atmosphere layer 2 (the upper layer). This temperature is known as the skin temperature.

**c)** Insert the value you found for $T_2$ into the energy budget for layer 2, and solve for the $T_1$ in terms of $T_2$.

**d)** Insert $T_1$ into the budget for atmospheric layer 1, to obtain the temperature of the ground, $T_{ground}$. Is the greenhouse effect stronger or weaker because of the second layer?