EOSC 112: Lab1a – Week of September 10
Planetary Energy Balance

Objective: Investigate the impact of the solar flux and planetary albedo on the surface temperature of Mercury, Venus, Earth, Earth's moon and Mars. Key questions: Can the very simple model of the surface energy budget discussed in Chapter 3 predict the planets' average surface temperature? Why does the model do better for some planets than for others?

Procedure: *lab1.xls* is an Excel spreadsheet that provides several formulae needed to calculate the surface energy balance of a planet, as specified in Monday's lecture and on p. 41 of the text. In this lab you will use this spreadsheet program to calculate the annually averaged solar flux and maximum solar flux received by the inner planets (with and without accounting for reflectivity) and T_e, the *effective radiating temperature* (defined on p. 42). In the Sept. 17 lab (Lab 1b) you will extend this work to include the effect of an absorbing and emitting atmosphere.

Part 1: *Effect of sun-planet distance on surface temperature– (setting Albedo=0)*

Step 1: Download the spreadsheet lab1.xls from the server disk (Your TA will provide detailed instructions) and save to your local disk. If you are working from home, the lab is at: `http://www.eos.ubc.ca/courses/eosc112/lab1a.xls`.

Step 2: Open the spreadsheet from the start menu (Start:Open Office Document)

The spreadsheet allows you to enter values of the sun-planet distance in astronomical units (where 1 AU = 149.6×10^6 km)(box B13) and calculates the resulting average solar flux reaching the surface (S_{avg}, box F8) and the maximum solar flux reaching the surface from an overhead sun (S, box H8), and the *effective radiating temperature* of the planet (T_e, F12) i.e. the mean surface temperature for a black (completely absorbing) planet.

Hint: Note that the grey spreadsheet input cells have names, and you can go directly to these cells from anywhere on the spreadsheet by going to the *name box* in th upper left hand corner of the spreadsheet and pulling down the list of named cells with your mouse. The two names needed for this lab are *distance_black_body* (B13) and *albedo_planetary_average* (B16).

To do:

(5) **Q1:** For the planet Mercury – verify by hand that the quantities calculated in spreadsheet boxes F8, H8 and F12 are correct. To do this, use the Microsoft scientific calculator (Start:Programs:Accessories:Calculator – View:Scientific).

You will need the following information:

Solar luminosity (as defined in lecture): 3.85×10^{26} W (C16)
Distance from Sun to Mercury: 57.9×10^6 km (C22)
Albedo of black Body (A=0).

For each quantity below write down the formula you are using and your numerical answer below, with units.

S: $= Luminosity/(4\pi(R_{(sun-mercury)})^2)$=$3.85 \times 10^{26}/(4. * 3.14 * (57.9 \times 10^9)^2)$
$= 9143.5\ \mathrm{W\,m^{-2}}$.

S_{avg}: $= S(1-A)/4 = 9143.5/4. = 2285.88\ \mathrm{W\,m^{-2}}$ (since A=0 here).

T_e: $= \left(\frac{S}{4\sigma}(1-A)\right)^{\frac{1}{4}} = (2285.88/5.67 \times 10^{-8})^{0.25} = 448.1$ K

(1) **Q2:** Are these in agreement with the spreadsheet? If not, can you suggest an explanation for any discrepancy?

Expect differences of a few per cent due to roundoff errors. Very large errors are probably because they forgot to convert from km to m for the calculation of S

(4) **Q3:** Now use the spreadsheet to find S, S_{avg}, and T_e for Venus, Earth, Earth's Moon and Mars – filling your values into the table below:

Planet	Sun-Planet Distance	S	S_{avg}	T_e
units:	AU	$\mathrm{W\,m^{-2}}$	$\mathrm{W\,m^{-2}}$	K
Mercury	0.387	9128.54	2282.13	447.9
Venus	0.723	2615.45	653.86	327.7
Earth	1.000	1367.17	341.79	278.6
Moon	????	1367.17	341.79	278.6
Note: the average Earth-Moon distance is 384,403 km				
Mars	1.523	589.42	147.35	225.8

(1) **Q4:** What value did you put in for the Sun-Moon distance? Explain.

Since we are averaging over times long compared to 1 month, the the moon's orbit averages out and we can use the same distance for the moon and the earth

Part 2: T_e *Including planetary albedo* $A > 0$

(4) **Q5:** Next, go to worksheet 2 (click on "[2] With Albedo" at the bottom of the spreadsheet), and fill out the table below, inserting the appropriate values for both the planetary albedo (box B16) and the planet-sun distance (box B13):

Planet	Sun-Planet Distance	Albedo	S	S_{avg}	T_e	Observed Temp.
units:	AU	unitless	$\mathrm{W\,m^{-2}}$	$\mathrm{W\,m^{-2}}$	K	K
Mercury	0.387	0.11	8124.4	2031.1	435.	700 day/100 night
Venus	0.723	0.76	627.71	156.93	229.4	740
Earth	1.000	0.306	948.82	237.20	254.3	290
Moon	????	0.15	1162.10	290.52	267	380 day/120 night
Mars	1.523	0.25	442.06	110.52	210.1	240 day/210 night

(2) **Q6:** Of the planets and moon listed in the table, only the Earth and Venus have nearly equal night/day temperatures. Is there any relationship between the relatively high albedo for Earth and Venus and the small day/night temperature difference? Explain. (*Note that the length of a Venutian day is 243 Earth days*)

The Earth and Venus have small day/night temperature because the atmosphere (and in Earth's case ocean) are able to store and transport heat around the planet. In the earth's atmosphere most of this heat capacity comes from liquid water, in Venus it is due to liquid sulphuric acid. Liquid water and liquid sulphuric acid clouds are also the substances that are causing the high albedo.

(2) **Q7:** For which planet is the agreement between the observed daytime temperature and the calculated T_e best? Which is worst? Can you give reasons for both the good agreement and the discrepancy?

In absolute terms the agreement is worst for Venus and best for Mars. We are neglecting the greenhouse effect in this lab, which dominates the surface energy budget of Venus. Agreement is good for Mars and Earth because the greenhouse effect is much smaller, and because the short night and atmosphere/(and Earth's ocean) spreads the daytime solar energy over the entire planet. R