# *PROBLEM SET 4*

## Due 2:40pm Wednesday 6 August

**Astro/EPS C12 -- Mike Wong**

Write your name at the top of your problem set solutions. Feel free to collaborate with other students to figure things out, but turn in your own unique, legible, handwritten solutions (DO NOT COPY). Show all your work, keep careful track of units, and box in your final answers.

### 1. **Eclipse.** 3 points.

A. Explain why we do not see a solar eclipse every time there is a new moon.

B. Imagine that the Moon has the same orbital radius as it does now, but the radius of the Moon itself is twice its current size. Would you expect partial solar eclipses to be more common, less common, or the same? Would you expect total solar eclipses to be more common, less common, or about the same? Explain your reasoning using words and/or diagrams.

### 2. **Equilibrium temperatures.** 10 points.

Saturn's moon Iapetus, like our Moon, always keeps one face pointed at Saturn. Iapetus has a very dark leading hemisphere (albedo $A = 0.03$) facing in the direction of its orbital motion, and a very bright trailing hemisphere ($A = 0.6$). The ground on Iapetus should therefore be warmer on the leading hemisphere, since it absorbs more sunlight. Let's calculate the temperature difference.

A. What is the solar flux in the Saturn system, in W m$^{-2}$? (Hint: use the same method as in Problem Set 2, but just use Saturn's orbital semimajor axis as the distance.)

B. How much sunlight is absorbed in a 1 m$^2$ patch of ground on Iapetus, on each hemisphere? Give your answer in W m$^{-2}$. If a surface has an albedo of $A$, and the incident flux is $F$, then the surface will reflect a flux of $A\,F$ and will absorb a flux of $(1 - A)\,F$. (Assume that it's noon Iapetus time in each case, so the Sun is overhead.)

C. If your two patches of Iapetus' surface are in thermal equilibrium, then they are radiating as much energy as they are receiving from the Sun. If the surface is a perfect radiator, then the thermal emission of a 1-m$^2$ patch of ground can be described by the Stefan-Boltzmann law. Use this to determine the noontime temperature for each hemisphere of Iapetus.

(Note that this problem is easier than the in-class calculations of equilibrium temperature, because here we only consider a small patch of ground, so the surface area of Iapetus does not come into this calculation.)

**3. Spectacular impacts.** 7 points.

For this problem, assume that the 30-meter object responsible for the Tunguska event had a mass of about $8 \times 10^7$ kg. Comet Tempel 1, the comet visited by the Deep Impact mission, has a mass of around $1 \times 10^{14}$ kg. The kinetic energy of a moving object is given by $E = 1/2\ mv^2$, where $m$ is the mass of the object and $v$ is its velocity. The impact velocity of the Tunguska object may have been about 35 km / sec.

A. Approximately how much more energy would be released by the impact of comet Tempel 1 compared with the Tunguska event? Assume the same impact velocity as for the Tunguska object. Do not give your answer in megatons of TNT equivalent energy or joules; just use a ratio to compare the two impact energies. In other words, if $E_1$ is the energy of the Tunguska event, and $E_2$ is the energy of Tempel 1 impacting the Earth, then don't tell me $E_1$ and $E_2$. Just tell me the ratio of $E_2 / E_1$.

B. Based on your answer in part A, use the graph below to estimate whether the impact of comet Tempel 1 with Earth would be considered a global catastrophe or not.

C. Use the graph below to determine approximately how often the Earth experiences catastrophic impacts. If the Cretaceous-Tertiary mass extinction (66 million years ago) was the most recent catastrophic impact, then is it likely or unlikely that we might experience a catastrophic impact in the near future?