In this section of **Resonance,** *we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. "Classroom" is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.*

Is Heaven a Pleasant Place?

G S Ranganath
Raman Research Institute
Bangalore 560 080, India

Environmentalists are always concerned about many features of the environment including its ambient temperature. Some of the inquisitive ones of this tribe were curious about the ambient temperatures in Hell and Heaven (of course, assuming their existence!). The physicists among them decided to calculate the temperatures prevailing in these places. (See *Applied Optics* in Suggested Reading for more details.) Here we recall the investigations of J Howard and K Naussau. It had been suspected for quite sometime that Hell would be cooler than Heaven. Howard came to the same conclusion from his calculations. But soon this claim was refuted by Naussau from the Bell Laboratories, USA. The essence of their arguments ran as follows.

Howard made his calculations based on the authority of the Bible:

Isaiah 30:26 reads, *Moreover the light of the moon shall be as the light of the sun and the light of the sun shall be sevenfold, as the light of seven days.*

Revelations 21:8: *But the fearful, and unbelieving ...shall have their part in the lake which burneth with fire and brimstone.*

Thus heaven receives from the moon as much radiation as we do from the sun and in addition seven times seven (forty-nine) times as much as the earth does from the sun, or fifty times in all. The light we receive from the moon is a ten-thousandth of the light we receive from the sun, so we can ignore it. With these data we can compute the temperature of heaven:

The radiation falling on heaven will heat it to the point where the heat lost by radiation is just equal to the heat received by radiation. In other words, heaven loses fifty times as much heat as the earth by radiation. Using the Stefan-Boltzmann fourth-power law for radiation

$$(T_H/T_E)^4=50,$$

where T_H and T_E are the absolute temperatures of the heaven and the earth. Now T_E = 300°K (273+27). This gives T_H as 798° K or (525°C).

The exact temperature of hell cannot be computed but it must be less than 444.6°C, the temperature at which brimstone or sulfur changes from a liquid to a gas. A lake of molten brimstone indicates that its temperature must be below the boiling point, which is 444.6°C. Above this point it would be a vapour, not a lake.

Therefore the temperature of heaven is 525°C and that of hell is less than 445°C.

But Naussau argued that in this calculation an assumption has been made, namely, that the pressure in hell is the same as that at the earth's surface. It seems reasonable that the pressure in hell – both physical and psychological – should be more than that on earth. With this assumption we do an additional calculation.

The boiling point of liquids can be raised by the application of pressure, the limit being the critical temperature which for sulfur is 1040°C. Accordingly, a temperature this high can be

reached with brimstone in the liquid state, admittedly under high pressure.

We can, in fact, estimate the minimum pressure in hell to make it hotter than heaven, by the use of the Clausius–Clapeyron equation

$$\frac{dP}{dT} = \frac{\Delta H_{vap.}}{T(V_v - V_l)}$$

Taking the latent heat of vaporization ΔH_{vap} as 2520 cal/gm atom, the boiling point T as (444.6+273) K, the atomic volume of the vapour V_v as 2.8l (assuming S_8 molecules), ignoring the liquid volume V_l as usual, and using the conversion factor 0.04129 l atm/cal.,

$$\frac{dP}{dT} \approx \frac{2{,}520 \times 0.04129}{717.6 \times 2.8} = 0.052 \text{ atm / degree}$$

For the temperature of hell to just exceed that of heaven, dT=80.4° and dP=0.052 × 80.4=4.2 atmospheres. When the pressure in hell is this high it can be hotter than heaven.

Suggested Reading

- J Howard. Notes in *Applied Optics* Vol.11. No.8. August, 1972.
- K Naussau. Notes in *Applied Optics* Vol.11. No.12. December, 1972.

For the first time in the history of astronomy, Nīlakaṇṭha arrived at a correct formulation of the equation of centre for Budha (Mercury) and Sukra (Venus). He also described a heliocentric model of planetary motion wherein the five planets (known at that time) namely Budha, Sukra, Kuja (Mars), Guru (Jupiter) and Sani (Saturn) move in eccentric orbits round the Sun. Based on this model the planetary positions relative to the Sun were obtained from earth-based observations. This was already a modern approach because even in the modern theory initial heliocentric positions are subsequently converted to geocentric positions! Nīlakaṇṭha has described all these in detail in his monograph *Tantrasangraha* published around 1500 A.D.

From *Impertinent Questions*