February Monthly Math Challenge
High School Level

Instructions:

TEAMS coaches submit student answers to the question(s) below using the submission link on the TEAMS website. All submissions must be made during the month of February. Those submissions with correct answers will be entered into a drawing for a $25 Visa gift card, which will be sent to the student in care of the TEAMS coach.

Background:

The computational power of the human brain compared to a computer is a common topic of discussion both in popular media and within some research and scientific fields. Unfortunately, in many ways, comparing these systems is a lot like comparing apples and oranges. While a computer CPU is a neat, well-defined system, with the ability to follow a specific set of instructions very quickly, the human brain does not appear to be as clearly structured and is heavily networked. This means that individual neurons may be slower than a CPU, but that the overall process of finding a solution or simulating advanced cognition may be far more efficient.

One comment often made is that the human brain is extremely energy hungry, requiring around 20% of the total energy usage of a human body at any given time, unlike computer processing hardware, which requires a relatively small percentage of the total system's energy to function. However, this is also due to having a significantly less efficient/compact brain/body assembly. This being said, fundamental biological rules appear to be at work for all organisms, governing both available metabolic needs and brain mass and even when different within types of organisms, those rules appear to have similar values.

Two examples that relate directly to organism energy consumption and brain mass are the governing equations for mammalian Resting Metabolic Rate (RMR) (the total metabolic usage of an organism in one day in kiloCalories) and an accompanying equation for the limits of brain mass (in kg) for an organism.

$$RMR\ (Resting\ Metabolic\ Rate) = k1 * M^{0.75} \qquad (1)$$
$$BM(Brain\ Mass) = k2 * M^{0.667} \qquad (2)$$

Where k1 and k2 are dimensionless constants and M is the mass of the entire organism (in kg). The precise values of the coefficients in each of these questions is still a matter of debate. This is because they are empirically derived and may or may not vary across species and family boundaries), and the k component varies not only across family boundaries but across species as well. However, all organisms appear to obey these rules, or close to them. Human values are generally approximated as k1=50, and k2=0.0855, when using resting metabolic rates.

While there is significant disagreement regarding correlating observed intelligence and brain structure, one proposed method for mammals is called the Encephalization Quotient (all masses are in grams):

$$EQ = (Brain\ Mass) \div (0.12 * (Body\ Mass)^{0.67})$$

The EQ of an organism is defined as the ratio between actual brain mass, and predicted brain mass based on biological expectations for mammalian brain size, with a larger value representing a larger brain proportional to body size than expected based purely on increase in size.

Assumptions:

- Sufficient circulatory penetration to cool the brain
- 1 kiloCalorie is equivalent to 4184 joules
- Average human brain temperature (37.3 degrees Celsius)
- The laptop assembly consumes the same percentage of supplied power that the human brain does relative to the body.

Question 1:

Consider a laptop/webcam assembly being used to record and process an image that requires 60 watts to function. Assuming this power consumption and an EQ equivalent to that of an average human (6.653), determine the following physical parameters for a brain with equivalent energy costs to this laptop:

- What is the brain mass?
- What is the body mass?