Constants and conversions that may or may not be helpful:

- Boltzmann constant: $k = 1.38 \times 10^{-16}$ erg $K^{-1}$
- 1 Joule (J) = $10^7$ erg

1. This question probes your knowledge of solar flares.

   (a) **3 points:** The authors use a certain notation to describe the different classes of flares; for example, in §1, they mention *GOES* class C1-, M1-, and X1-flares. In general, what does this notation mean (in other words, what does each of the terms represent), and how does each class relate to the others?

   (b) **5 points:** The authors state that the total *non*-thermal electron energy is $1.6 \times 10^{25}$ joules. Calculate the temperature this energy would correspond to if it was *thermal* energy, and explain why this value is not reasonable. (Estimate the number density of electrons in the corona to be $n_e \sim 10^{10}$ cm$^{-3}$, and use a flare volume of $V \sim 10^{28}$ cm$^3$).

   (c) **2 points:** In §4, the authors mention that events with "unusually high electron energy" have been shown to be efficient particle accelerators. What is the significance of this statement, as it applies to solar physics in general?

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   Answer: Solar flares are divided into five classes: A, B, C, M, and X. These classes are scaled logarithmically; for instance, a class C flare has $10\times$ more energy than a class B flare, and $100\times$ more energy than a class A flare, etc. The classes are further subdivided into categories 1–9.

   (*1 point for the classes A, B, C, M, and X; 1 point for knowing the logarithmic scale; 1 point for knowing the subcategories 1–9*).

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   Answer: Using the equation for thermal energy density: $\frac{E}{V} = 3nkT$, and converting energy from joules to ergs, solve for $T$:

$$\begin{aligned} T &= \frac{E}{3Vnk} \\ &= \frac{10^{32}}{3(10^{28})(10^{10})(1.38 \times 10^{-16})} \\ &= \approx 2.415 \times 10^9 \text{ K} \end{aligned}$$

   We do not observe temperatures this high in the corona (the highest is $\sim 10^6$ K), so the energy cannot be thermal.

   (*3 points for knowing the equation for thermal energy, 2 points for the explanation*).

   (c) **2 points:** In §4, the authors mention that events with "unusually high electron energy" have been shown to be efficient particle accelerators. What is the significance of this statement, as it applies to solar physics in general?

   Answer: One of the biggest questions in solar physics is what drives the solar wind and the heating of the corona. The source of particle acceleration has been extensively studied, but is not firmly conclusive.

   (*1 point for addressing the coronal heating problem, and 1 for the source of the solar wind, though credit for other answers is also possible*).