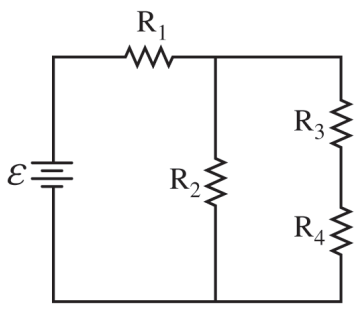

Figure 1

3. (12 points, suggested time 25 minutes)

A circuit consists of an ideal battery of emf $\mathcal{E}$ and four identical resistors R_1, R_2, R_3, and R_4, each of resistance R, as shown in Figure 1.

(a) For parts (a)(i) and (a)(ii), express your answers in terms of numerical values, $\mathcal{E}$, and R only.

i. **Derive** an expression for the current I_1 in Resistor R_1.

ii. **Derive** an expression for the current I_3 in Resistor R_3.

(b) The partially completed bar chart in Figure 2 shows a bar that represents the absolute value $|\Delta V|$ of the potential difference across the ideal battery.

- In Figure 2, **draw** a bar to represent $|\Delta V|$ across each resistor, relative to the emf $\mathcal{E}$ of the ideal battery.
- The height of each bar should be proportional to the value of $|\Delta V|$ represented by that bar. If $|\Delta V|$ is zero, write a "0" in that column.

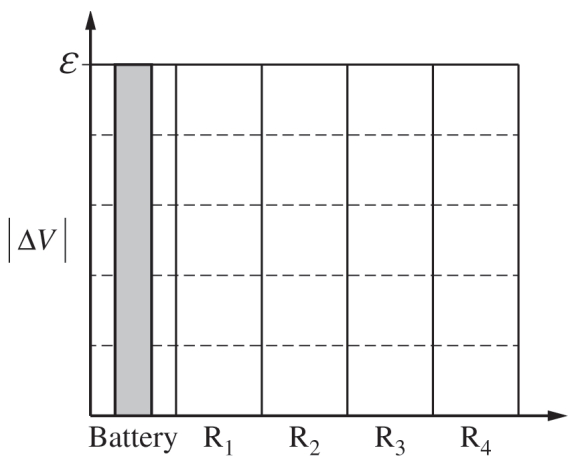

Figure 2

A student claims that the rate at which energy is dissipated (power) by the circuit can be expressed as $P = \dfrac{3\mathcal{E}^2}{5R}$.

(c) **State** whether the expression for P is correct or incorrect. **Justify** your answer by referring to the derivations from part (a) or the bar chart from part (b).

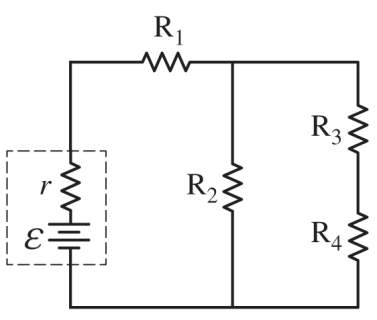

Figure 3

When the ideal battery is connected in the original circuit, the rate at which energy is dissipated by Resistor R_1 is P_{original}. The ideal battery is now replaced with a nonideal battery of emf $\mathcal{E}$ and internal resistance r to form the new circuit shown in Figure 3. The rate at which energy is dissipated by Resistor R_1 in the new circuit is P_{new}.

(d) **Indicate** whether P_{new} is greater than, less than, or equal to P_{original}.

_____ $P_{\text{new}} > P_{\text{original}}$ _____ $P_{\text{new}} < P_{\text{original}}$ _____ $P_{\text{new}} = P_{\text{original}}$

Briefly **justify** your answer.