# Definitions of Physical Quantities Worksheet Solutions

Students completed columns 2 and 4 during lab discussion.

Note: Integral notation was introduced and discussed by the instructor. No calculus background was assumed.

|  |  |  |  |
| --- | --- | --- | --- |
| **Physical Quantity** | **Unit** | **Meaning** | **How it is determined** |
| Emf E | Volts  [V] | Potential difference created by chemical reactions on anode and cathode; drives current through external circuit **if** a closed loop exists. | * Measured with multimeter; * Before start of experiment; * Measure w/out load attached |
| External resistance *Rexternal* | Ohms  [Ω] | Our load is a pure resistor (ohmic element); its resistance is constant and independent of the applied voltage | * Measure with multimeter; * Before start of experiment; * Measure w/out battery attached (multimeter is only voltage source) |
| Time *t1* | Seconds  [s] | Time stamp for 1st measurement (= highest value of external potential) | * Check data table for highest value of potential (at time t1) * Scan the next ten values to confirm that potential value decreases |
| Time *t2* | Seconds  [s] | Time stamp for last measurement used (= time  2 hours after *t1*) | t2 = t1 + 7200 s |
| **Physical Quantity** | **Unit** | **Meaning** | **How it is determined** |
| External voltage *V1* | Volts  [V] | Highest potential difference applied to load (at time *t1*) | * Read value from data table * At time t = t1 * From potential column |
| External voltage *V2* | Volts  [V] | Potential difference remaining across load after  2 hours (at time *t2*) | * Read value from data table * At time t = t2 * From potential column |
| Current *I1* | Amperes  [A] | Current through load at start of experiment (at time *t1*) | * Read value from data table * At time t = t1 * From current column |
| Current *I2* | Amperes  [A] | Current through load after  2 hours (at time *t2*) | * Read value from data table * At time t = t2 * From current column |
| Percentage of external voltage remaining  (% *Vremaining*) | X  unitless | Compares performance of battery after 2 hours to initial output. |  |
| Percentage of current remaining  (% *Iremaining*) | X  unitless | Compares performance of battery after 2 hours to initial output. |  |
| **Physical Quantity** | **Unit** | **Meaning** | **How it is determined** |
| Power delivered *Presistor* | Watts  [W] | Energy per second delivered to the load resistor. |  |
| Power converted *Ptotal* | Watts  [W] | Energy per second converted by the battery from chemical energy. | E  E is a constant value that does not depend on time *t* |
| Battery capacity = charge capacity | Ampere-seconds  [A∙s] | How much charge the battery was able to move through the circuit due to its chemical reactions (during the 2 hour time interval that we are evaluating). | * Use graph of I vs. t * Calculate integral * Between times t1 and t2 |
| Battery capacity = charge capacity given in units commonly used | Milli-ampere-hours  [mA∙h] | In order to compare the value for the battery capacity that we determined to published data, we will convert our value to the units used on the published data sheets. |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Physical Quantity** | **Unit** | **Meaning** | **How it is determined** |
| Energy delivered *Eresistor* | Joules  [J] | Total amount of energy delivered to the resistor in the 2 hour time interval that we are evaluating. | * Use graph of Presistor vs. t * Calculate integral * Between times t1 and t2 |
| Energy converted *Etotal* | Joules  [J] | Total amount of energy converted by the battery from chemical energy in the  2 hour time interval that we are evaluating. | * Use graph of Ptotal vs. t * Calculate integral * Between times t1 and t2 |
| Percentage of energy delivered to resistor  (% Edelivered) | X  unitless | Some of the converted energy is delivered to the battery itself, while some is delivered to the resistor: How much (percentage-wise) reaches the resistor? [Ideal: 100%] |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Physical Quantity** | **Unit** | **Meaning** | **How it is determined** |
| Internal voltage drop *Vinternal* | Volts  [V] | Voltage drop over the internal resistance of the battery, explaining the difference between *Vexternal* and the emf E. | E  E is a constant value that does not depend on time *t* |
| Internal resistance *rinternal* | Ohms  [Ω] | The internal resistance of the battery accounts for the decrease in external voltage as the chemical reactions on the electrodes slow down. |  |
| Factor of increase for *Vinternal*  [Factor(*Vinternal*)] | X  unitless | Describes by how much (as a multiplicative factor) the internal voltage drop *Vinterna*l has changed over the course of the 2-hour experiment. |  |
| Factor of increase for *rinternal*  [Factor(*rinternal*)] | X  unitless | Describes by how much the internal resistance of the battery *rinternal* has changed over the course of the 2-hour experiment. |  |