

# EE546 Homework 1

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## Question 1:

1):

Given:

$$\text{Electromotive force (EMF) : } E = 3.7V$$

$$\text{Ohmic resistance : } R_{\Omega} = 50m\Omega = 0.05\Omega$$

$$\text{Polarization resistance : } R_f = 30m\Omega = 0.03\Omega$$

$$R_i = R_{\Omega} + R_f = 0.05 + 0.03 = 0.08\Omega$$

**1. When discharge current  $I = 2$  A:**

$$\begin{aligned} U_{cc} &= E - IR_i \\ &= 3.7 - 2 \times 0.08 = 3.7 - 0.16 = 3.54V \end{aligned}$$

**2. When discharge current  $I = 6$  A:**

$$\begin{aligned} U_{cc} &= E - IR_i \\ &= 3.7 - 6 \times 0.08 = 3.7 - 0.48 = 3.22V \end{aligned}$$

### 3. Comparison and explanation:

- When current increases from 2A to 6A, the operating voltage decreases from 3.54V to 3.22V, a drop of 0.32V
  - Reason: Higher external load current results in greater voltage drop across the internal resistance, leading to reduced output voltage
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2)

#### Primary batteries (non-rechargeable):

1. Zinc-carbon
2. Alkaline Battery
3. Li-Metal Battery

#### Secondary batteries (rechargeable):

1. Ni-Cd Battery
2. Ni-Fe Battery
3. Ni-MH Battery
4. Lead Acid Battery
5. Lithium-Ion Battery

#### Energy density comparison:

- Primary batteries typically have higher specific energy density because they don't need to consider reversibility, allowing for more active materials and optimized chemical reactions.
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3)

Given:

- Bus voltage: 800 V
- Total energy capacity: 96 kWh
- Single cell(Rated voltage,Rated capacity): 3.7 V, 3 Ah

## 1. Series and parallel configuration calculation:

$$\text{Series number : } N_s = 800V/3.7V = 216.2 \approx 217 \text{ cells}$$

$$\text{Parallel number } N_p = (96kWh/800V)/3Ah = 120Ah/3Ah = 120Ah/3Ah = 40$$

## 2. 2C discharge time:

$$\begin{aligned} t_{\text{discharge time}} &= \frac{\text{Total capacity}}{2C \text{ discharge current}} \\ &= 120Ah / (2 * 120)A \\ &= 0.5 \text{ hours} = 30 \text{ minutes} \end{aligned}$$

## 3. Maximum power at 1C discharge:

$$\begin{aligned} P_{\text{maximum}} &= V_{\text{bus voltage}} \cdot (1C \text{ discharge current}) \\ &= 800V \times 120A = 96kW \end{aligned}$$

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# Question 2:

1)

## 1. Four electrode materials(EDLC):

- Activated carbon: activated carbon has very large specific surface area.
- Carbon nanotubes : tubular nanostructure, high conductivity, stable framework.
- Carbon Aerogel: highly porous and lightweight, specific surface area 100–1000 m<sup>2</sup>/g, performance can be enhanced through surface modification.
- Carbon nanofiber: graphitized structure, can be composited with other materials to enhance electrochemical performance

Properties to a large A:

- Unique molecular structure ,porous structure.

## 2. Electric double layer distance(EDL):

The electrical double layer distance  $d$  is on the order of the ionic radius, Typical values range from 31 pm to over 200 pm .[ionic radius from wiki](#)

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2)

### 1. CV curve :

Ideal capacitor: Rectangular shape for CV curve.

Reasons for practical deviations:

1. Capacitor with resistivity lead to a diamond shape.
2. Due to influence of redox reactions, cause peaks in cv curve .

### 2. Specific capacitance :

$$\begin{aligned} \text{mass : } m &= 40g, \\ \text{voltage window : } \Delta U &= 2.5V, \\ \text{integrated charge : } \Delta Q &= 300C \\ C_s &= \Delta Q / (m \times \Delta U) \\ &= 300C / (40g \times 2.5V) = 3F/g \end{aligned}$$

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3)

### 1. ESR :

$$\begin{aligned} \text{current : } I &= 3A \\ \text{voltage drop : } \Delta V &= 0.15V \\ ESR : R_s &= \Delta V / (2I) = 0.15V / (2 \times 3)A = 0.025\Omega = 25m\Omega \end{aligned}$$

### 2. Effects of smaller ESR on supercapacitor performance:

Maximum power density analysis:

- Power:  $P = U^2 / (4 \times ESR)$  (maximum power when load resistance equals internal resistance)

$$P = \frac{U^2}{(4 \cdot R_s)}$$

- Lower ESR means:
    - Lower power loss .
    - Higher operating voltage .
    - Faster charge-discharge response.
    - Achieving higher power output under high current conditions.
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