EE546 Homework 1

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1)

Given:

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\begin{aligned}
Electromotive force(EMF)\ &:E = 3.7V \\
Ohmic resistance\ &:R_{\Omega} = 50m\Omega = 0.05\Omega \\
Polarization resistance\ &:R_f = 30m\Omega = 0.03\Omega
\end{aligned}
$$

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

1.When discharge current I = 2 A:

$$
\begin{aligned}
U_{cc} &= E - IR_i \\
&= 3.7 - 2\times0.08 = 3.7 - 0.16 = 3.54V
\end{aligned}
$$

2.When discharge current I = 6 A:

$$
\begin{aligned}
U_{cc} &= E - IR_i \\
&= 3.7 - 6\times0.08 = 3.7 - 0.48 = 3.22V
\end{aligned}
$$

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

2) Battery Types

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) Electric Vehicle Battery System Design

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:

$$Series number : N_s = 800V/3.7V = 216.2 \approx 217 cells$$
$$Parallel number \ \ N_p \ \ = (96kWh/800V)/3Ah = 120Ah/3Ah = 120Ah/3Ah = 40$$

2. 2C discharge time:

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

3. Maximum power at 1C discharge:

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

Question 2:

1) Electric Double Layer Capacitor (EDLC)

1. Four electrode materials:

Electrode Material	Properties
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^2/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:

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) Cyclic Voltammetry (CV) Testing

1. CV curve characteristics:

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 calculation:

$$\begin{gathered} mass: \quad m = 40g, \\ voltagewindow: \Delta U = 2.5V, \\ integratedcharge: \Delta Q = 300C \end{gathered}$$

$$\begin{aligned} C_s &= \mathit{\Delta} Q/(m \times \mathit{\Delta} U) \\ &= 300C/(40g \times 2.5V) = 3F/g \end{aligned}$$

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3) Galvanostatic Charge-Discharge (GCD) Testing

i. Equivalent series resistance calculation:

$$\begin{gathered} current: \quad I = 3A \\ voltage\ \ drop: \Delta V = 0.15V \end{gathered}$$

$$ESR: R_s = \Delta V/(2I) = 0.15V/(2 \times 3)A = 0.025\mathit{\Omega} = 25m\mathit{\Omega}$$

2. ESR impact on power density:

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 (I^2R loss).
  - Higher operating voltage (reduced IR drop).
  - Faster charge-discharge response.
  - Achieving higher instantaneous power output under high current conditions.
