Energy Storage: Batteries

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Battery capacity

3 unities: A, → Current: I

Ah or mAh → Charge capacity: Q
$Q = I * t$
[A * s]
[A * h]

Wh → Energy capacity: E
$E = P * t$
$E = V * I * t$ [V * A *h]
$E = V * Q$ [V * A * h]

P – power
V – voltage

Units:
$[V] = [\frac{J}{C}] = [\frac{W}{A}] \Rightarrow [W] = [V * A]$
$[C] = [A * s]$

How much electric charge can be stored in battery, for example:
Battery has 10 Ah, means → battery can deliver 1 A for 10h,
or 2A for 5h
or 10A for 1h

Specific capacity , energy density, power density

Ah/kg or mAh/g

Specific capacity: Q
Q = I * t / m
[A * h/kg]
[mA * h/g]

Wh/kg

Energy density: E
E= P * t /m
E= V * I * t / m [V * A *h/kg]
E = V * Q / m [Wh/kg]

W/kg

Power density: P
P / m
V * I /m [V * A /kg]
[W/kg]

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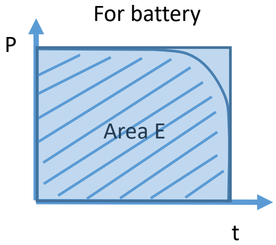
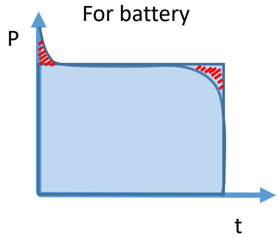
Discharge curve

For battery



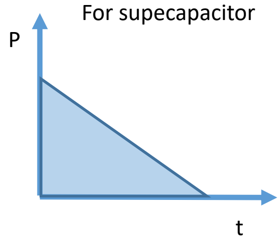
E= P * t
E = V * I * t

For battery



E= P * t

For supecapacitor



E= ½ P * t

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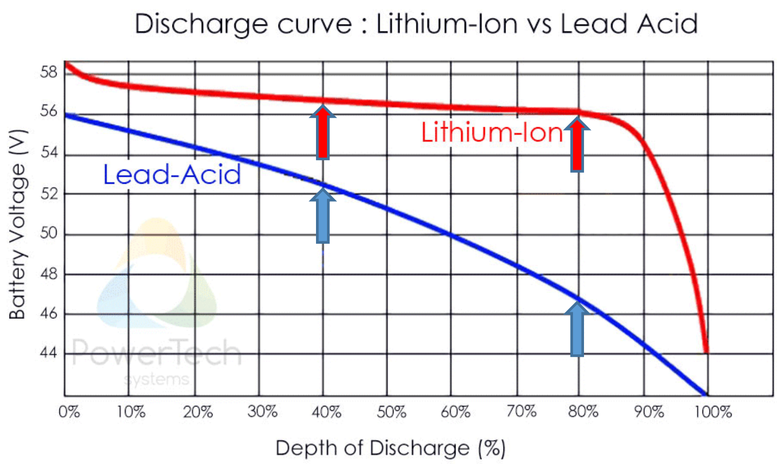
Examples



Potential difference between 40 and 80 % of DoD (Depth of Discharge):

- around 6 V for Pb-acid
- around 0.5 V for LiB

- good estimation of SoC (State of Charge) for Pb-acid

- for LiB very difficult due to flat discharge curve (the flattest one for Li iron phosphate technology)

Problem 1

A 12 V battery has a charge capacity of 30 Ah:

a) How long can this battery deliver an average current of 5 A?

b) What is the energy capacity of this battery?

a)

Q = I * t
⇒ t = Q/t
⇒ t = 30 Ah / 5 A
⇒ t = 6 h

b)

E = V *I * t
⇒ E = V * Q
⇒ E = 30 Ah * 12 V [W = V * A]
⇒ E = 360 Wh

Problem 2

6 V battery has energy capacity of 300 Wh.

a) What is the charge capacity of this battery?
b) What is current that this battery can deliver if it's used contunuosly for 25 hours?

a)

E = Q * V
$\Rightarrow$ Q = E/ V
$\Rightarrow$ Q = 300 [V*A*h]/ 6V
$\Rightarrow$ Q= 50 Ah

b)

Q = I * t
$\Rightarrow$ I = Q/ t
$\Rightarrow$ I = 50 [Ah]/ 25h
$\Rightarrow$ I = 2 A

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Problem 3

A 1.2 V Ni-MeH battery has a charge capacity of 300 mAh. The battery is connected to a device with a load resistance of 200 Ohms.

a) How much current is flowing in the circuit?
b) Estimate how long this battery can sustain this current?
c) What is the energy capacity of this battery?

a)

Ohm law
V= I *R
$\Rightarrow$ I = V/R
$\Rightarrow$ I =1.2 [V]/ 200 [Ohm]
$\Rightarrow$ I = 0.006 [A] = 6 mA

b)

Q = I * t
$\Rightarrow$ t = Q/ I
$\Rightarrow$ t = 300 [mAh]/ 6 [mA]
$\Rightarrow$ t= 50 h

c)

E = Q *V
E = 0.3 [Ah] * 1.2 [V]   [W = V * A]
E= 0.36 Wh

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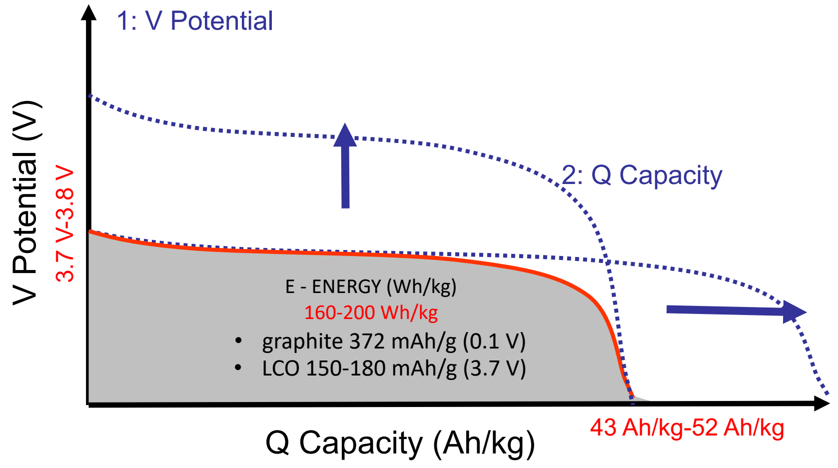
Discharge curve for LiB – Energy density



E = V * Q [V * A * h] enery capacity

If Q is a specific capacity in [Ah/kg]
Then E is energy density in [Wh/kg]

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Energy density of LiB = V * Q

1: **V Potential** $V_{cathode}$ (3.8 [V]) – V_{anode} (0.1 [V]) = 3.7 V

2: **Q Capacity**

Q_{anode}=372 [mAh/g], $1/Q_a$=1000/372=2.7 [g/Ah]
$Q_{cathode}$=170 [mAh/g], $1/Q_c$=1000/170=5.9 [g/Ah]
$1/Q_a+1/Q_c$=2.7 +5.9 = 8.6 [g/Ah]
Q_{total}= 1/8.6 * 1000= 116 [mAh/g]

But it should be devided by 2, which is the weight of Al (for cathode) and Cu (for anode) current collectors, so

Q_{total}= 116/2 = 58 [mAh/g]

3. **E Energy density**
E = V * Q
E= 3.7 [V]* 58 [mAh/g] = 214.6 [Wh/kg]

Theoretical capacity of electrode materials:

$$Q_{th} = \frac{n F * 1000}{M * 3600} \quad \text{(mAh/g ou Ah/kg)}$$

$$E_{bat} = \frac{V_{cathode} - V_{anode}}{1/Q_{cathode} + 1/Q_{anode}} \quad \text{(Wh/kg)}$$

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