

BATTERY STORAGE SYSTEMS • 2YBSS

Topic 1

Introduction to Batteries

Principles, terminology and the building blocks of electrochemical energy storage

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Sustainable Transportation within the Framework of Green Deal - SPHERE

Call: ERASMUS-EDU-2023-CBHE-STRAND-2

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ABOUT THIS COURSE

What this course is about

The course gives you the knowledge to **understand, design and analyse battery systems** for engineering applications — building on basic electrical engineering and physics.

- ▶ **Principles of operation** — battery types, characteristics, and the chemical & physical processes of storing and releasing energy.
- ▶ **Key components** — battery management systems (BMS), inverters, charge controllers, thermal management.
- ▶ **Battery dynamics** — charge/discharge cycles, capacity fade, efficiency, and what affects battery life.

AT A GLANCE

Code	2YBSS
Level	Bachelor, 1st cycle
Programme	Sustainable Transportation
When	3rd year · 6th semester
Credits	6 ECTS (90 h)
Language	English
Assessment	Written exam (≥18/30)

TOPIC 1

What you will be able to do

1 Define

Match key battery terminology to correct definitions.

2 Distinguish

Tell a cell from a battery, and primary from secondary cells.

3 Explain

Describe how a cell stores and releases energy electrochemically.

4 Compute

Find pack voltage, capacity and energy from cell connections.

5 Interpret

Read nominal voltage, capacity, C-rate and energy ratings.

6 Compare

Judge why lithium-ion dominates modern applications.

TERMINOLOGY

Cell vs. battery vs. pack

1

Cell

The smallest individual electrochemical unit. Delivers a voltage set by its chemistry.

2

Battery

Two or more cells connected in series and/or parallel, often in one housing.

3

Pack

The complete assembly of cells/modules plus electronics, used in an application.

Watch the language: people (even experts) loosely call any source a “battery,” even a single cell. *An automotive 12 V lead-acid battery is really six 2 V cells in series.*

TERMINOLOGY

Primary vs. secondary cells

Primary cells

ONE-WAY

- ▶ Single use — not rechargeable
- ▶ Discharged once, then disposed/recycled
- ▶ Examples: alkaline AA, coin cells
- ▶ Low self-discharge, long shelf life

Secondary cells

REUSABLE

- ▶ Rechargeable — many charge/discharge cycles
- ▶ Reactions are reversible
- ▶ Examples: lead-acid, NiMH, lithium-ion
- ▶ Focus of this course

CELL RATINGS

Nominal voltage & capacity

NOMINAL VOLTAGE

The typical / average voltage set by the cell **chemistry**. It differs from the voltage under load.

NOMINAL CAPACITY

The quantity of charge a cell is rated to hold, in **ampere-hours (Ah)** or mAh.

TYPICAL NOMINAL VOLTAGES

Lithium-ion	$\approx 3.7 \text{ V}$
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Nickel-based (NiMH / NiCd)	$\approx 1.2 \text{ V}$
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Lead-acid cell	$\approx 2.0 \text{ V}$
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CELL RATINGS

The C-rate

The **C-rate** normalises current to a cell's capacity. **1C** is the constant current that fully charges or discharges the cell in one hour.

EXAMPLE — a 20 Ah cell

1C	= 20 A	→ ~1 hour
C/10	= 2 A	→ ~10 hours
10C	= 200 A	→ ~6 minutes

Why it matters

- ▶ Lets you compare cells of different sizes fairly
- ▶ High C-rates mean high power but more heat & stress
- ▶ Used everywhere in datasheets & BMS limits

(The current–time relationship is not strictly linear.)

CELL RATINGS

Energy & power

Energy

Stored electrochemical energy $\approx$ **nominal voltage** $\times$ **nominal capacity** (Wh, kWh).

WORKED EXAMPLE

A 3.7 V, 1.9 Ah cell stores

$$3.7 \text{ V} \times 1.9 \text{ Ah} = \mathbf{7.03 \text{ Wh}}$$

Power

The **rate** at which energy is released — the cell's instantaneous power (mW, W, kW).

Energy = how much work the cell can do.

Power = how fast it can do it.

BUILDING BATTERIES

Cells in series

In series, **voltages add**; capacity stays equal to one cell (the same current flows through all cells).



Three 3 V, 20 Ah cells in series

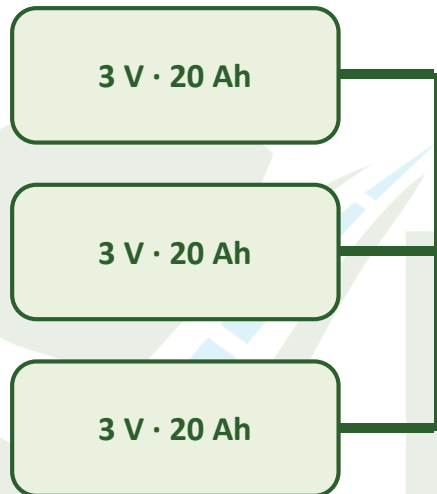
RESULT

Voltage	$3 \times 3 \text{ V}$	9 V
Capacity	(unchanged)	20 Ah
Energy	$9 \text{ V} \times 20 \text{ Ah}$	180 Wh

BUILDING BATTERIES

Cells in parallel

In parallel, **capacities add**; voltage stays equal to one cell (cell currents sum into the battery current).



(Example shown with three cells; the rule scales to any number.)

RESULT — five 3 V, 20 Ah cells

Voltage	(unchanged)	3 V
Capacity	$5 \times 20 \text{ Ah}$	100 Ah
Energy	$3 \text{ V} \times 100 \text{ Ah}$	300 Wh

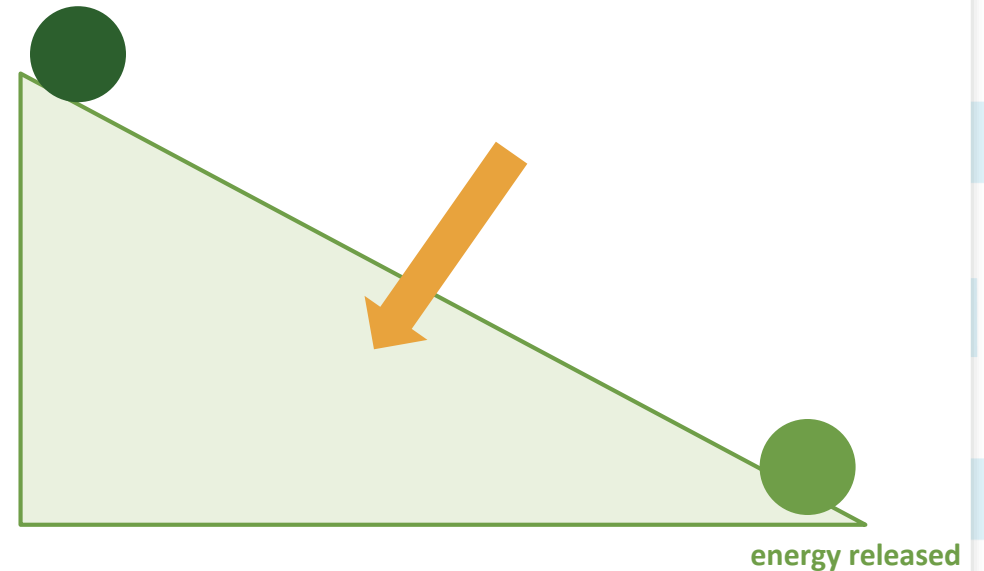
HOW A CELL WORKS

Storing energy as potential

We already understand **gravitational** potential energy — lift a skateboard to the top of a ramp and it can roll down to do work.

A cell instead stores **electrochemical potential energy**, which it later releases to drive electrons through a circuit.

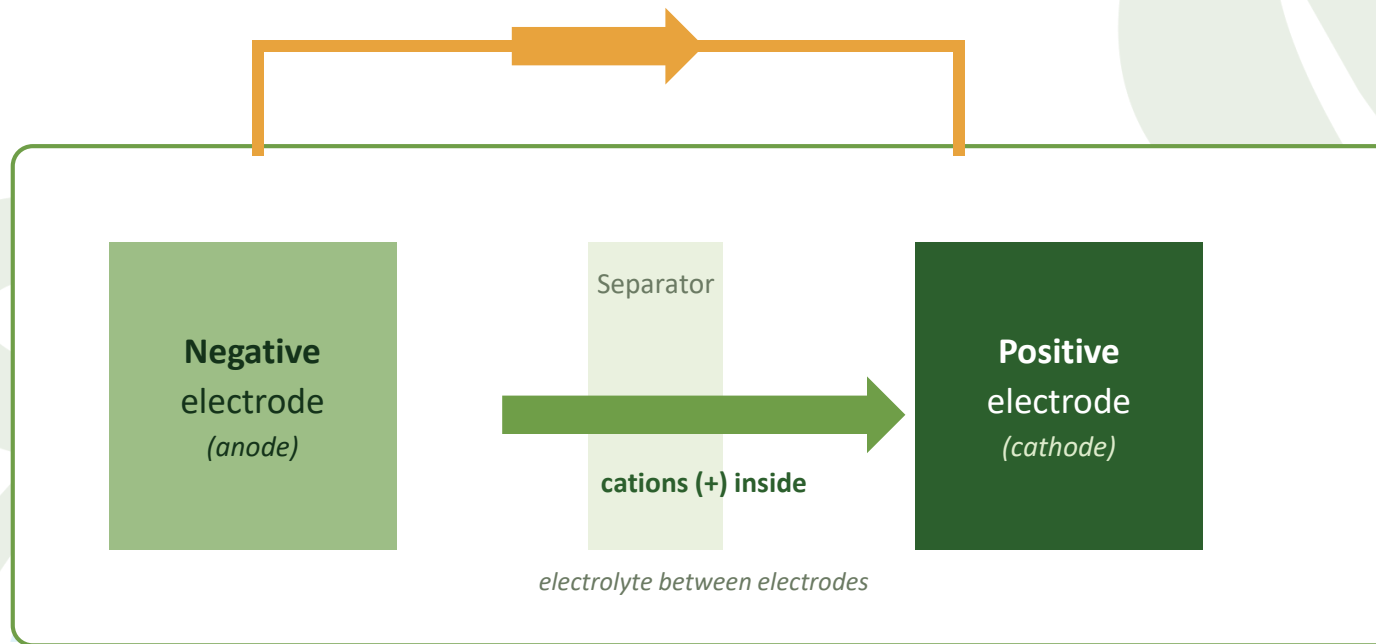
high potential



HOW A CELL WORKS

The discharge process

electrons (e^-) through external circuit → do work



- ▶ **At the negative electrode:** a reaction releases electrons to the circuit and cations to the electrolyte.
- ▶ **At the positive electrode:** a reaction accepts both electrons and cations.
- ▶ **The potential difference between terminals is the cell voltage.**
- ▶ **Completing the circuit converts stored chemical energy into electrical work.**

OVERVIEW

Common rechargeable chemistries

Chemistry	Nominal voltage	Specific energy	Self-discharge	Notes
Lead-acid	≈ 2.0 V	Low (~35 Wh/kg)	Moderate	Cheap, heavy; 12 V = 6 cells
NiMH	≈ 1.2 V	Medium (~80 Wh/kg)	1–5 % / day	Gentle hydride storage, long life
Lithium-ion	≈ 3.7 V	High (~200 Wh/kg)	Very low	Highest energy; needs a BMS

Values are typical textbook ranges for comparison; exact figures vary by cell design and manufacturer.

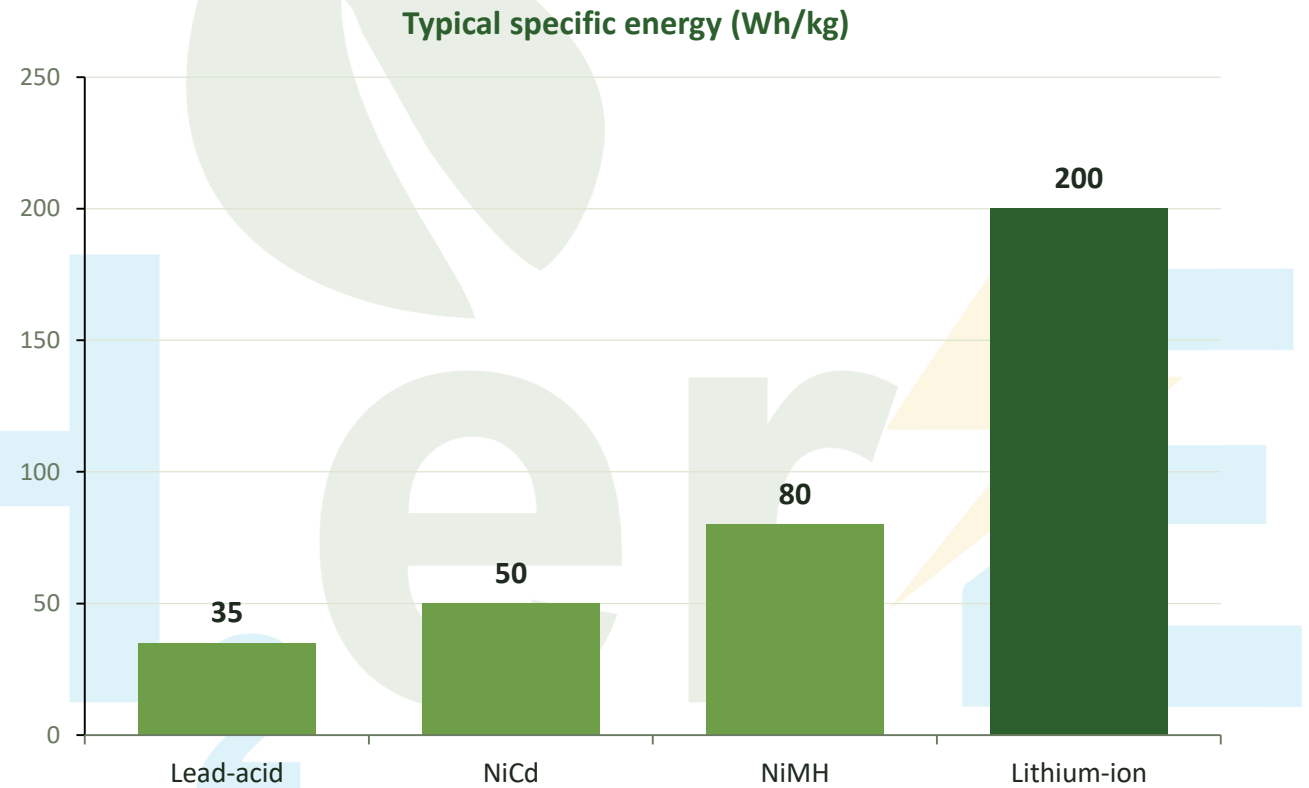
WHY LITHIUM-ION

Specific energy by chemistry

Specific energy = stored energy per unit **weight** (Wh/kg).

Energy density = stored energy per unit **volume** (Wh/L).

Higher values mean **lighter and smaller** batteries for the same stored energy — a key reason lithium-ion dominates.



WHY LITHIUM-ION

Advantages of lithium-ion



Higher energy density

More energy per kg and per litre than most other rechargeables.



Higher voltage

≈ 3.7 V per cell vs ≈ 1.2 V for NiMH/NiCd — often one cell does the job.



Low self-discharge

Holds most of its charge for months; NiMH/NiCd lose 1–5 % per day.



Long life

Gentle intercalation in both electrodes means many cycles.

WHY LITHIUM-ION

...but there are trade-offs



Cost

Presently more expensive than NiMH/NiCd of similar capacity.



Manufacturing

More complex to produce; quality and purity strongly affect performance.



Safety

Reactive chemistry is less stable — requires special handling and precautions.



Protection needed

Must have circuitry to prevent over- and under-charge damage.

The takeaway: *the very thing that makes lithium-ion great (energy) is what makes management essential.*

APPLICATIONS

Where large battery packs matter

HEV

Hybrid EV

Battery + another source
(e.g. engine); ~zero electric-
only range.

PHEV

Plug-in hybrid

Bigger battery allows some
all-electric range.

E-REV

Extended-range EV

Larger battery; all-electric
even under full load.

BEV

Battery-electric

Battery provides all motive
power.

Grid

Storage & backup

Large-scale stationary
storage and backup power.

These are all **large, high-voltage, high-current** packs. Their commonalities outweigh the differences — collectively we call them **xEV**.

LOOKING AHEAD

Why every large pack needs a BMS

Unmanaged lithium-ion cells can catch fire or explode. A **battery management system (BMS)** is the embedded electronics + algorithms that keep a pack safe and useful.

1

Protect

Detect unsafe conditions; guard operator and cells.

2

Prolong

Keep cells healthy to extend battery life.

3

Estimate

Track state of charge (SOC) and state of health (SOH).

4

Balance

Equalise cells so the pack works as one.

5

Inform

Give the controller power limits; manage charging.

CHECK YOURSELF

In-class questions

Q1

A battery is built from four 3.6 V, 10 Ah cells in series. What are its nominal voltage, capacity and energy?

Q2

What current corresponds to a C/5 discharge of a 40 Ah cell, and how long would it last?

Q3

Give two reasons lithium-ion is preferred over NiMH — and one reason it is harder to use safely.

Q4

In one sentence, explain the difference between a cell, a battery and a pack.

Discuss with a neighbour, then we solve Q1 together on the board.

WORKED SOLUTION

Q1 — step by step

Given: four 3.6 V, 10 Ah cells in **series**.

1

Voltage

Series → voltages add

$$4 \times 3.6 \text{ V} = 14.4 \text{ V}$$

2

Capacity

Series → capacity unchanged

10 Ah

3

Energy

Voltage × capacity

$$14.4 \text{ V} \times 10 \text{ Ah} = 144 \text{ Wh}$$

WRAP-UP

Key takeaways

- ▶ A cell is the smallest electrochemical unit; batteries and packs are built from cells.
- ▶ Primary cells are single-use; secondary cells are rechargeable.
- ▶ Cells have nominal voltage and capacity; the C-rate normalises current.
- ▶ Energy $\approx$ voltage $\times$ capacity; power is the rate of energy release.
- ▶ Series adds voltage; parallel adds capacity.
- ▶ A cell converts stored electrochemical potential into electrical work on discharge.
- ▶ Lithium-ion offers high energy, long life and low self-discharge — but needs a BMS.

Thank you for your attention!

A large, faded version of the SPHER2 logo, featuring the word "SPHER2" in a stylized font with a green leaf icon above the "H" and a blue and orange graphic element to the right.