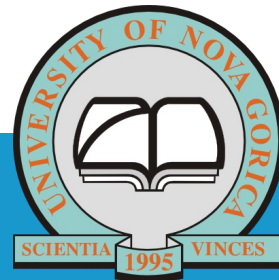


## Graphene based nanoelectronics – a practical approach

Erika Tomsić and Egon Pavlica

Univerza v Novi Gorici



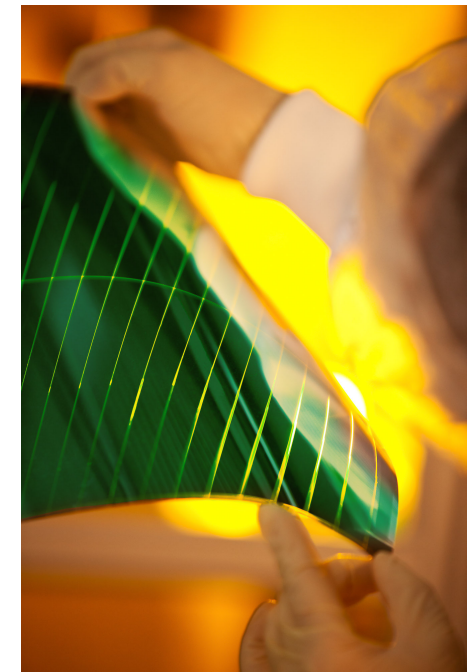
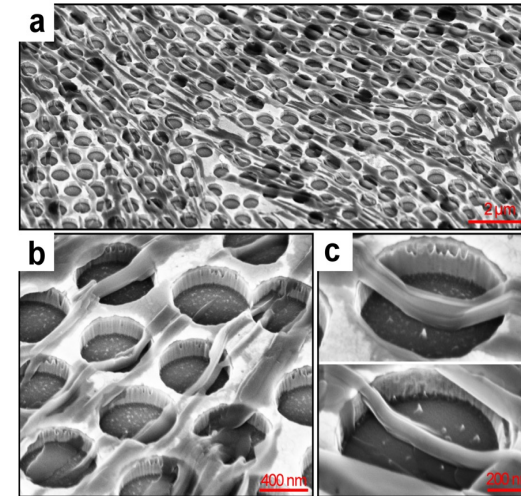
# Outline

- Basics of Graphene transistor
- Overview of fabrication process
- Demonstration of graphene transistor fabrication
- Hands on – graphene exfoliation



# Laboratory of organic matter physics

- OLEDs
- Solar cells
- Flexible electronics
- Graphene-based devices
- Photodetectors



Flexible organic solar cells  
(Solarfolie by Heliatek)

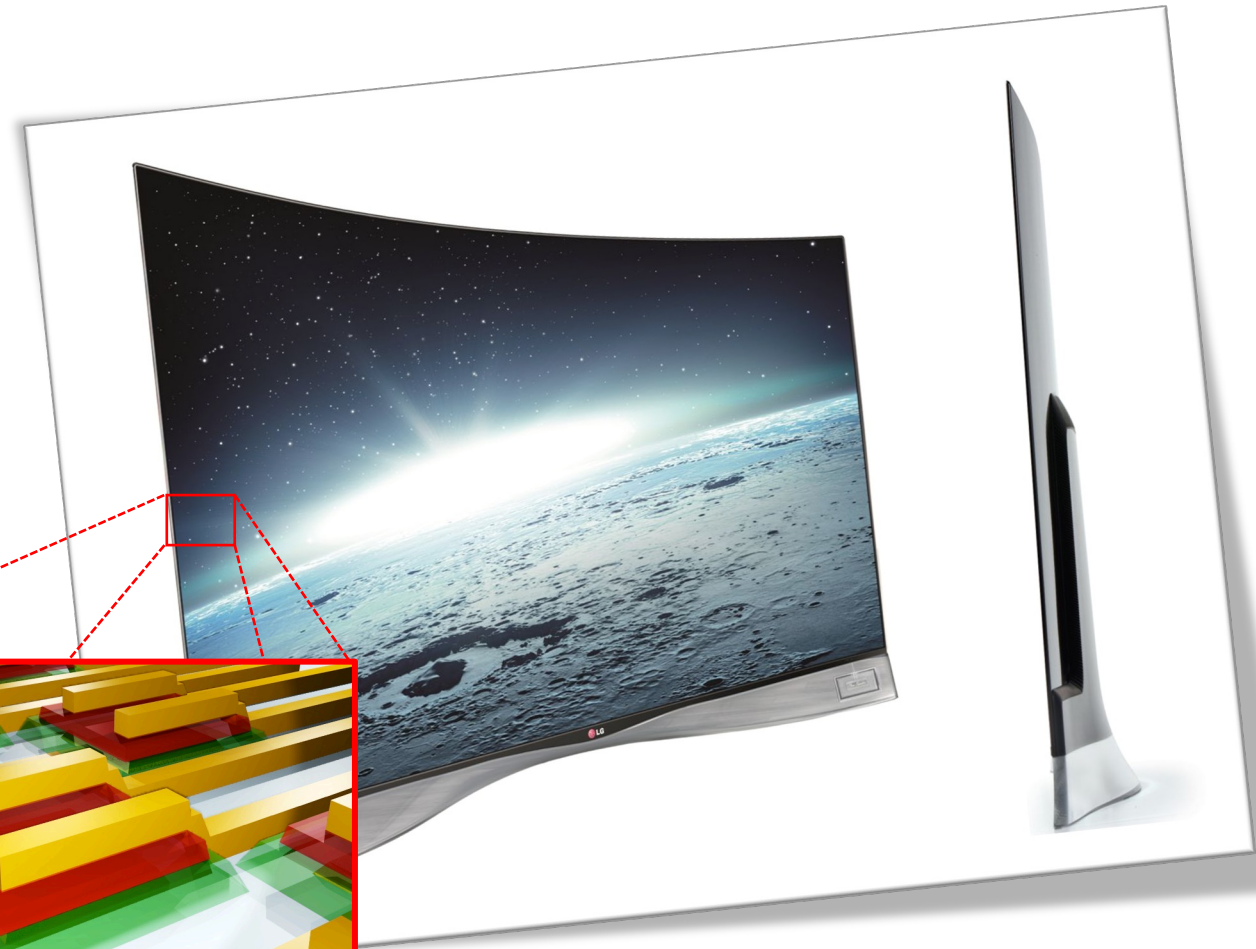
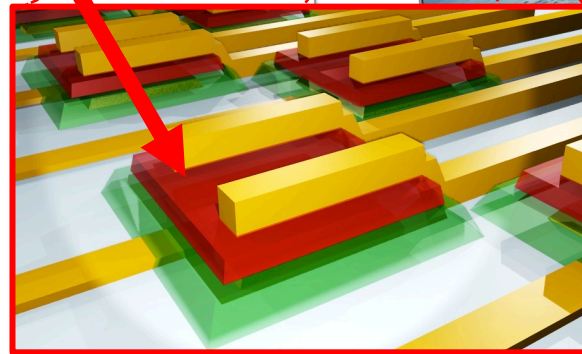
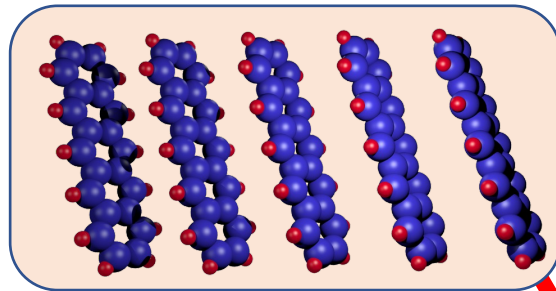


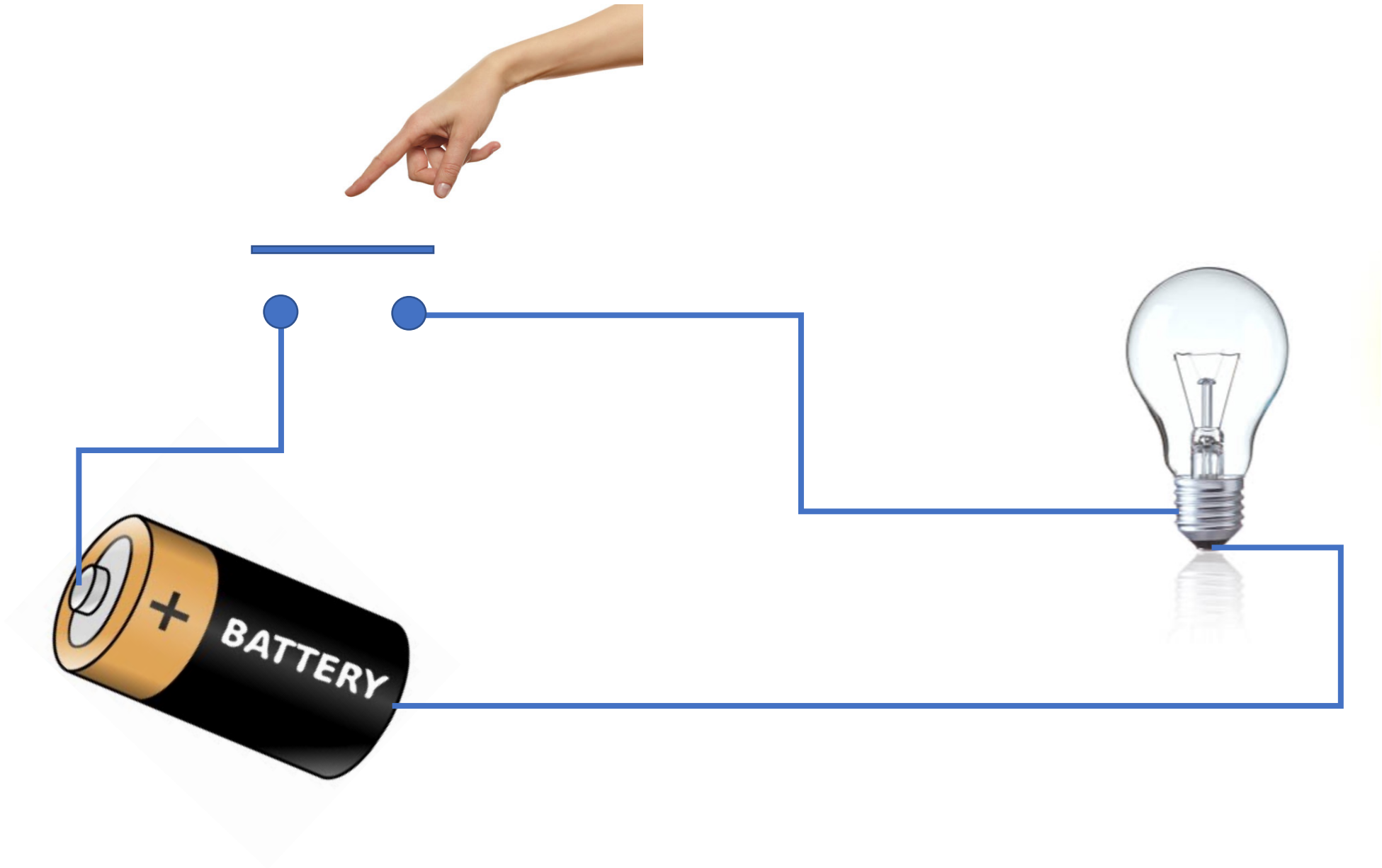
Flexible phones  
Samsung Galaxy X

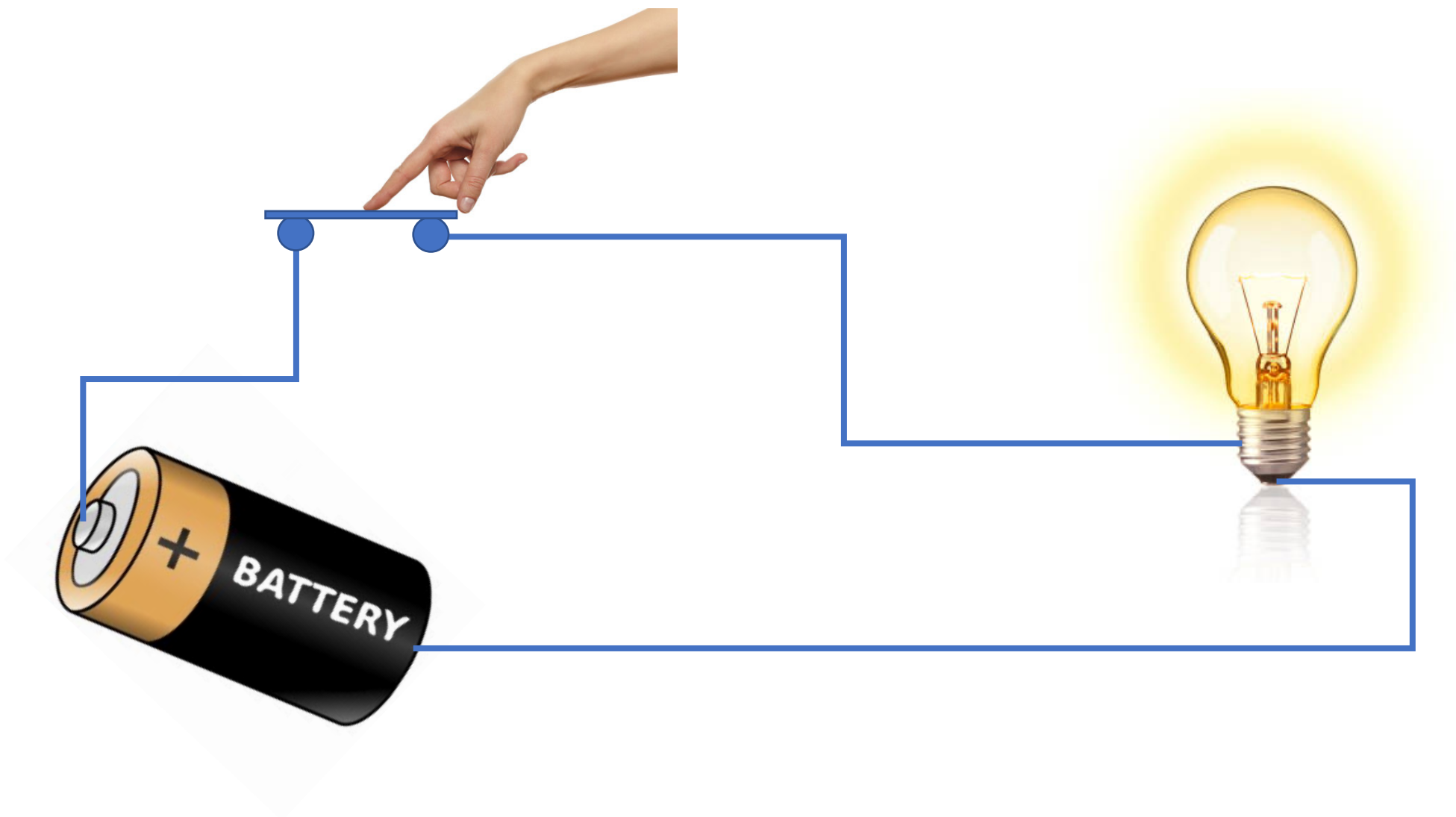


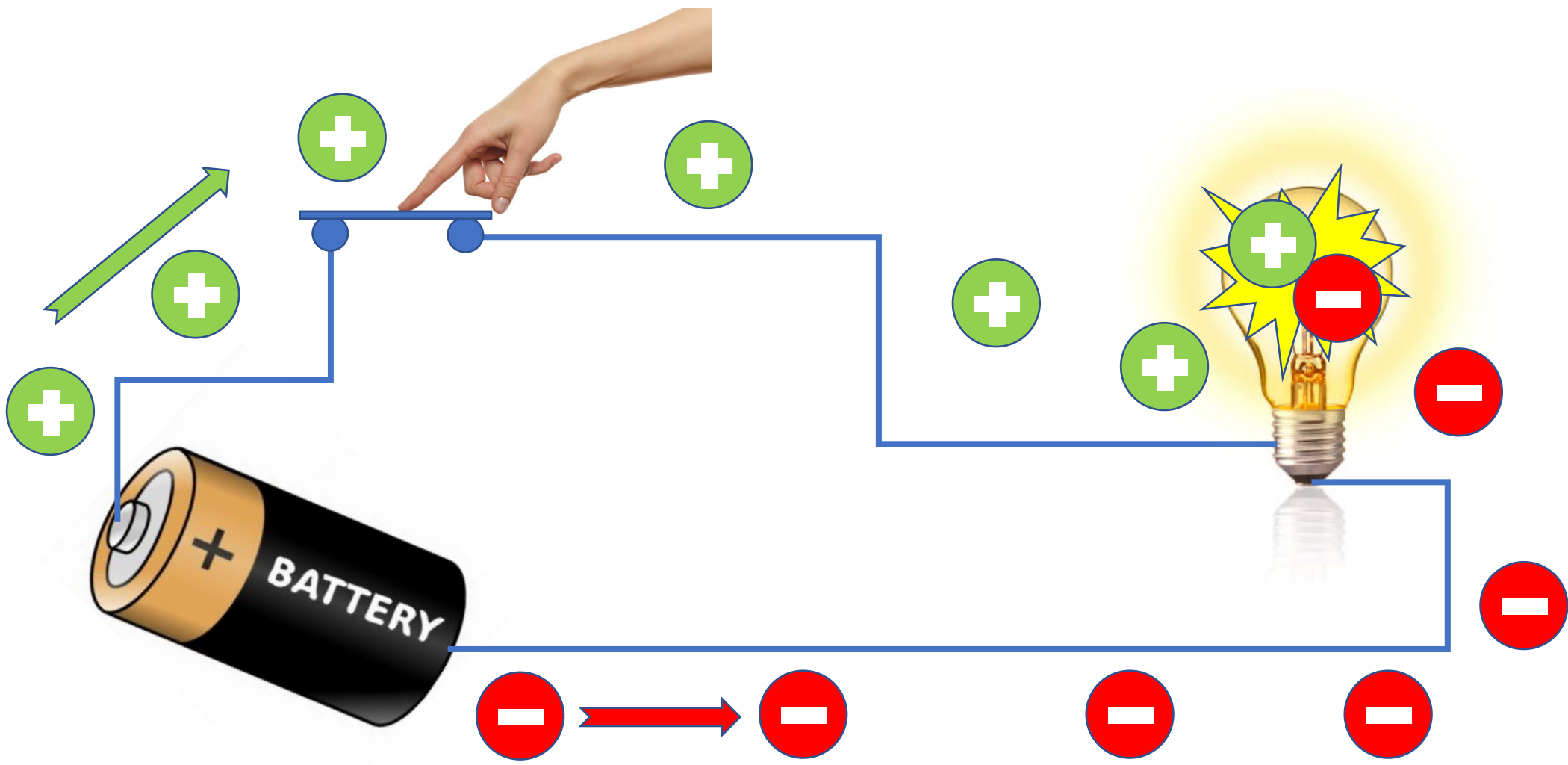
LG's and Samsung's OLED TVs  
– diagonal 197cm (77") and 140 cm(55").

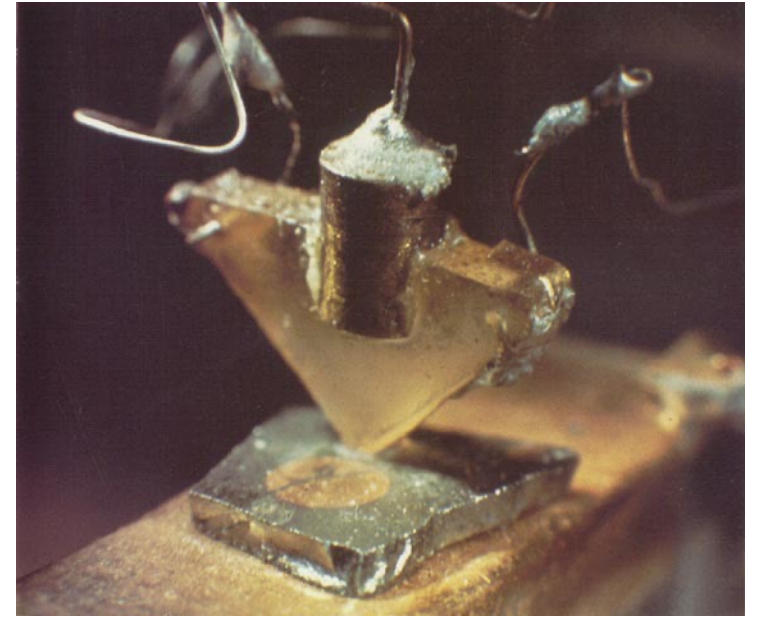
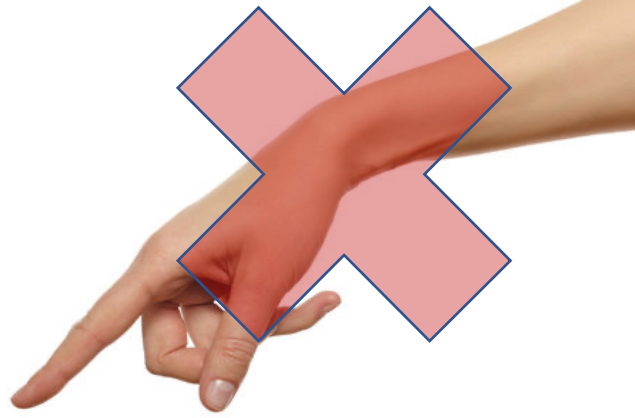
# What is transistor?



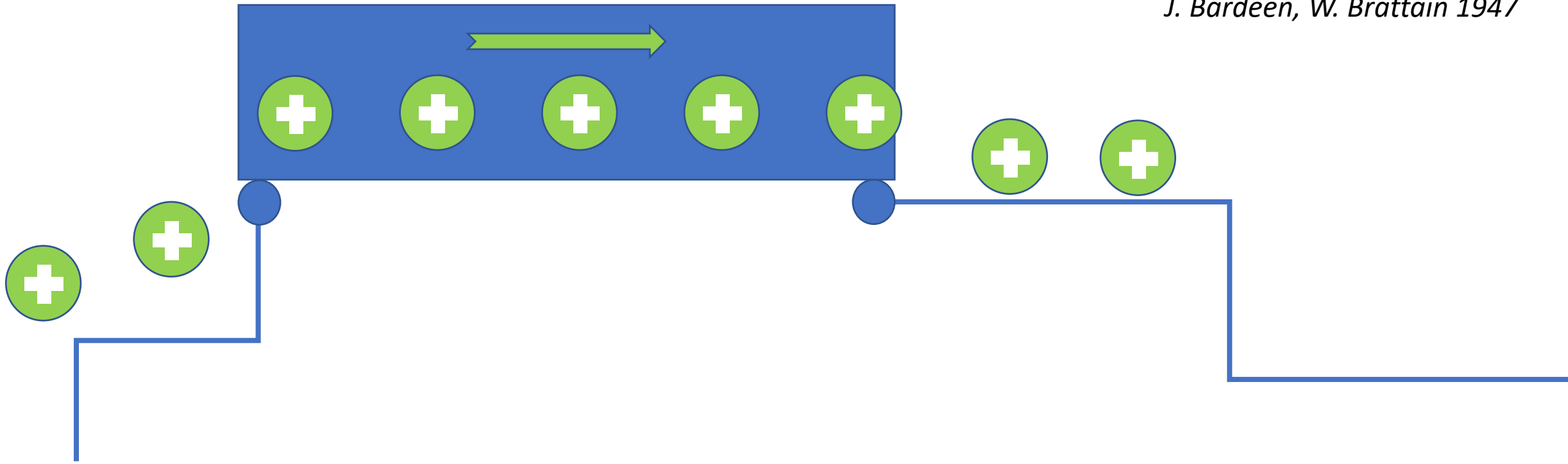




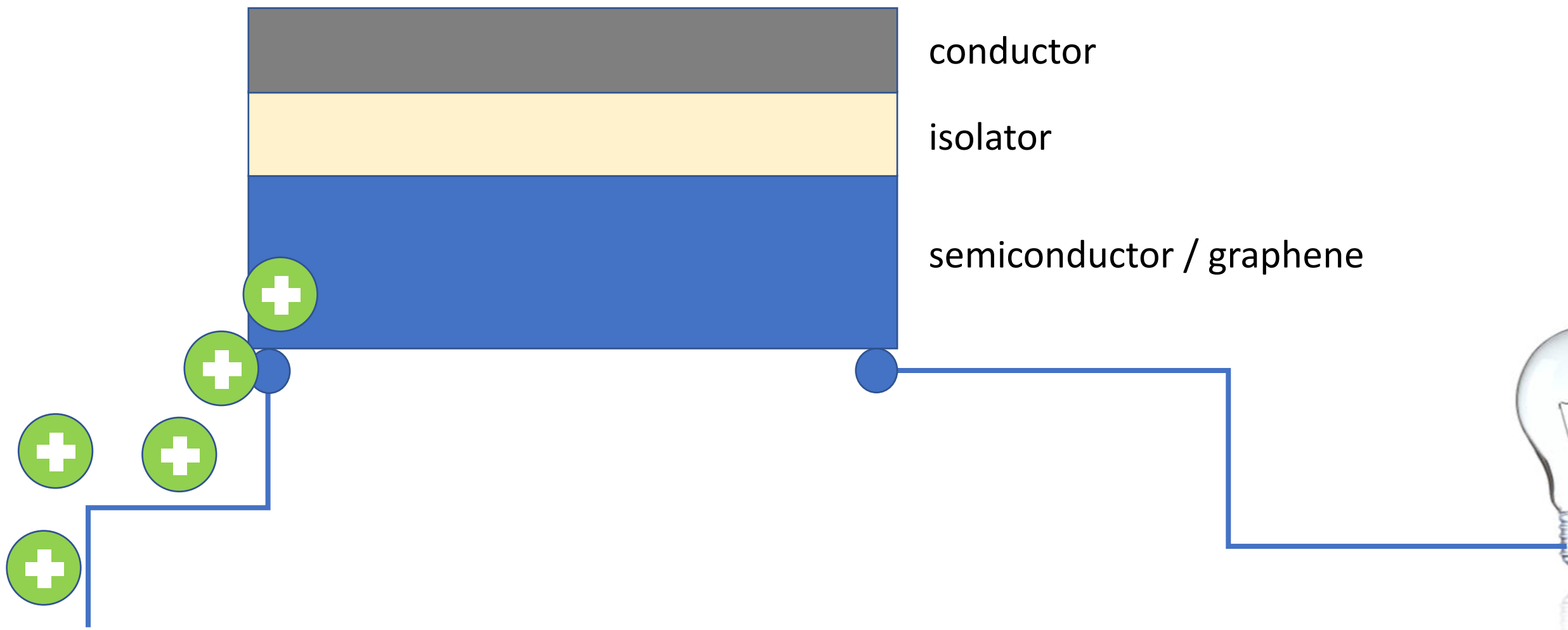


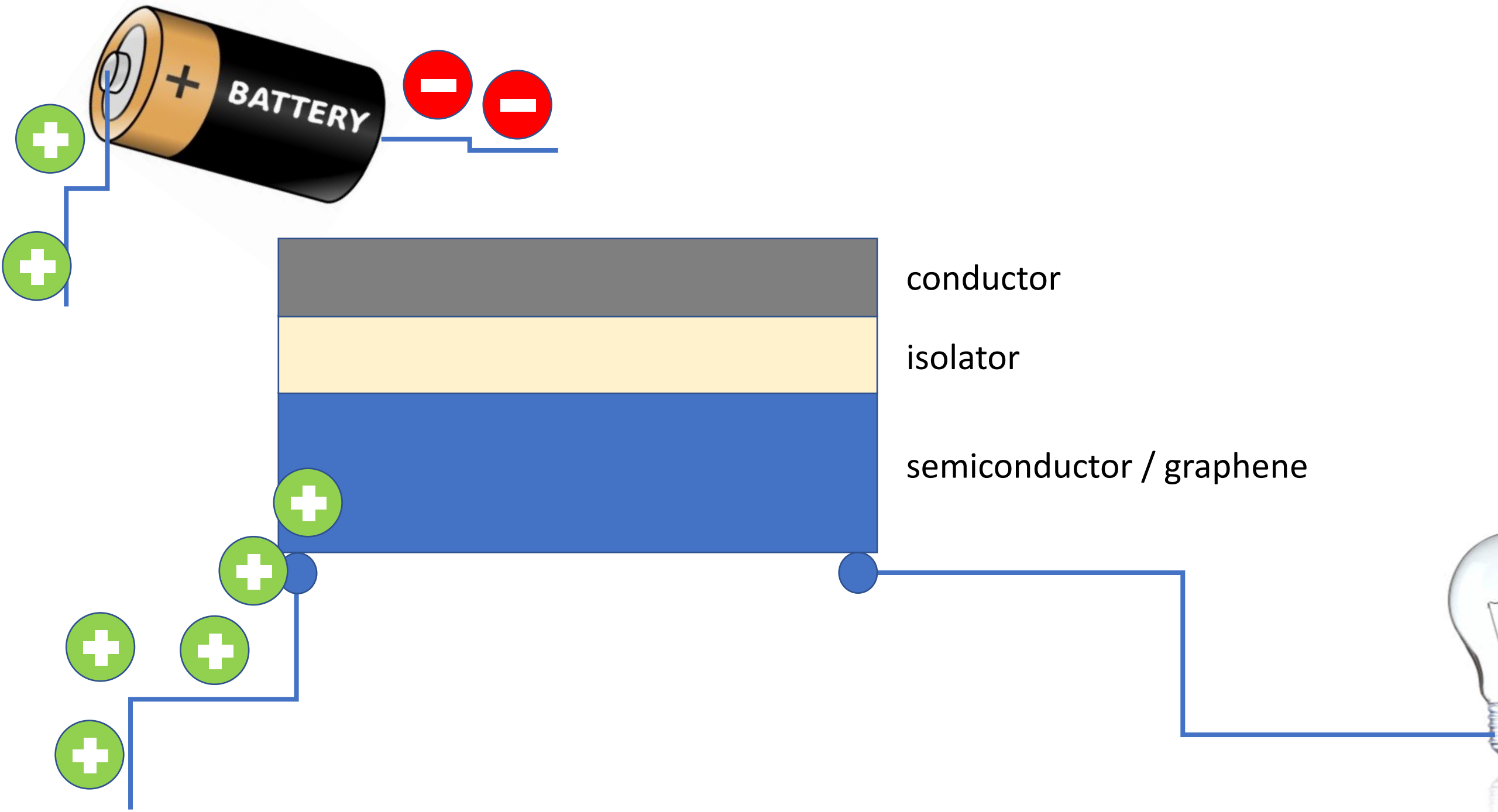


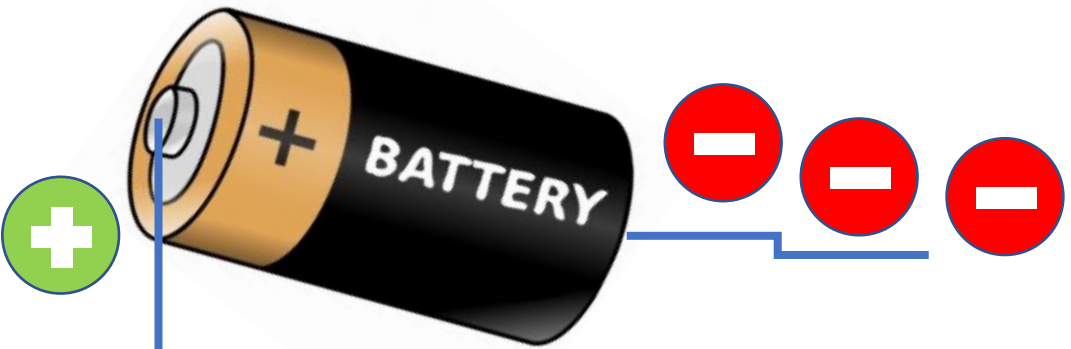
*J. Bardeen, W. Brattain 1947*









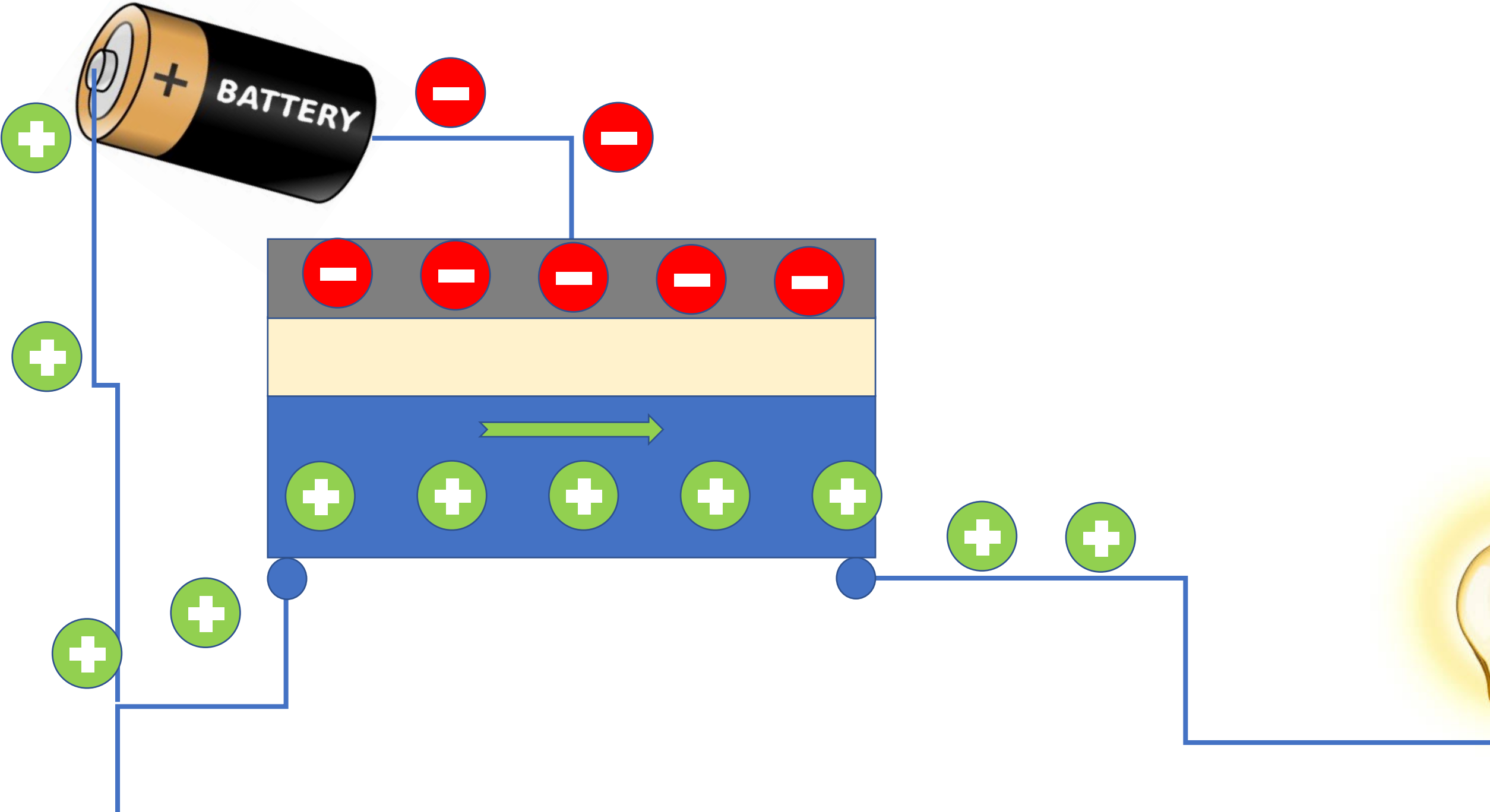


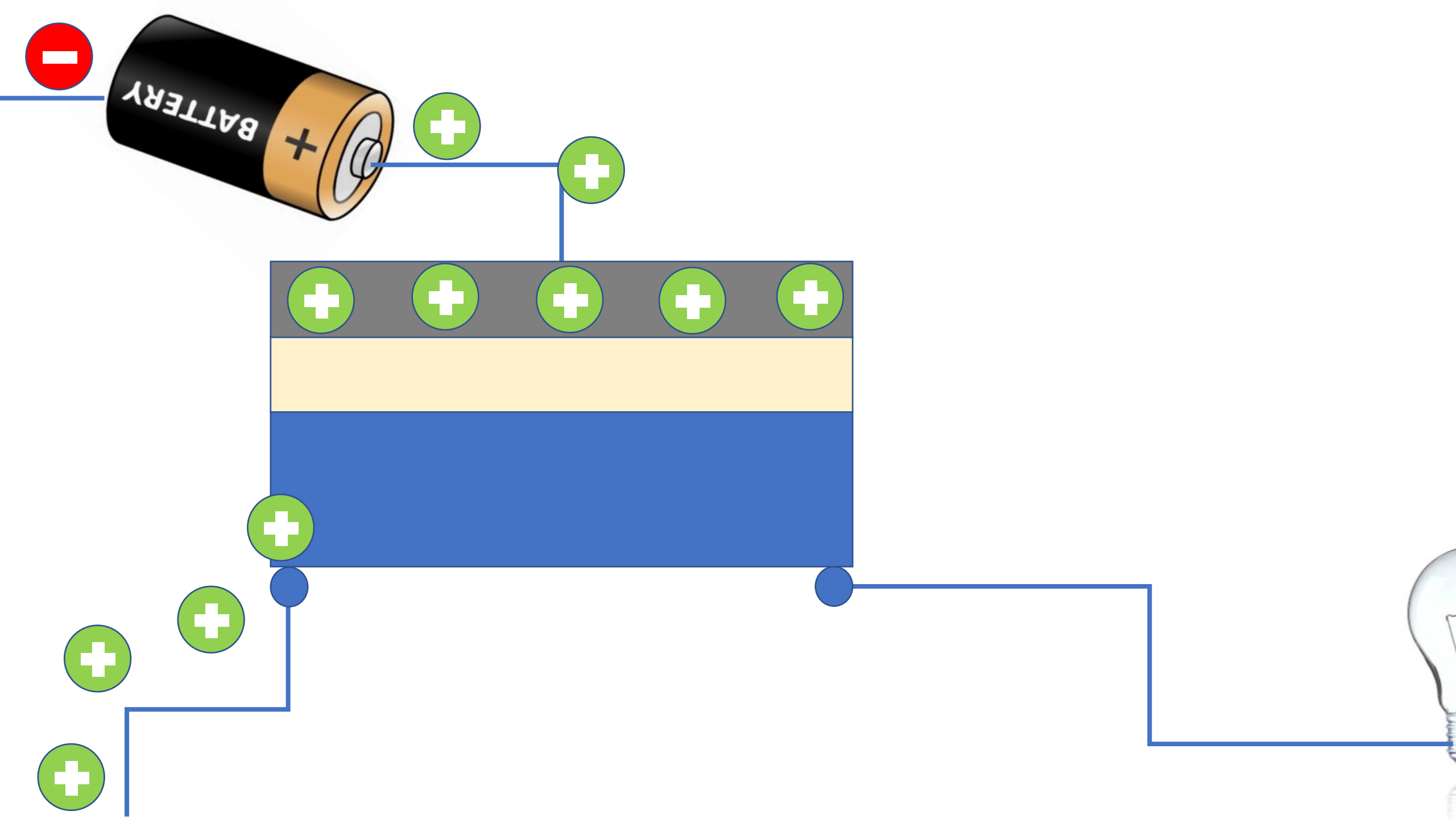
conductor

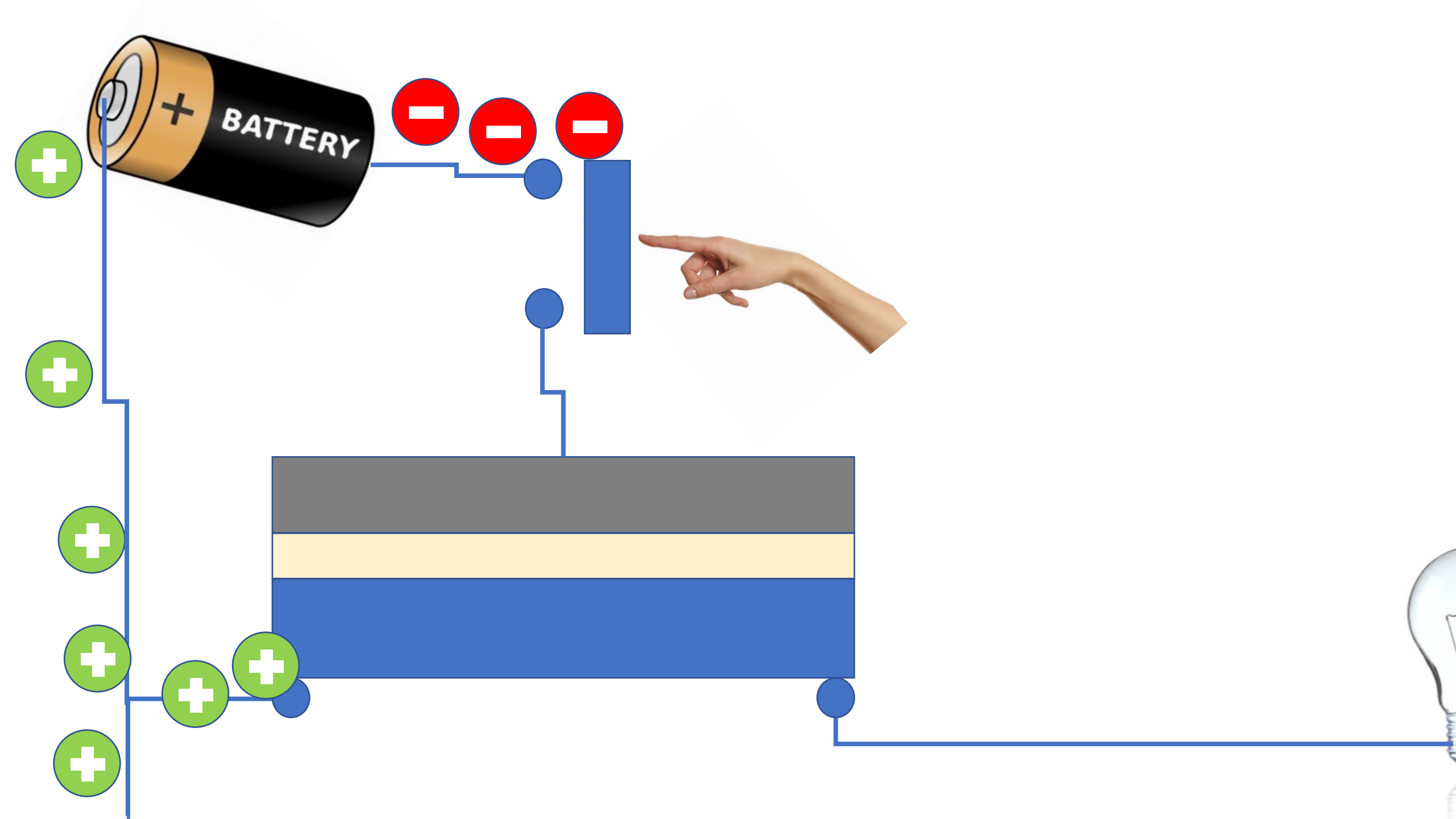
isolator

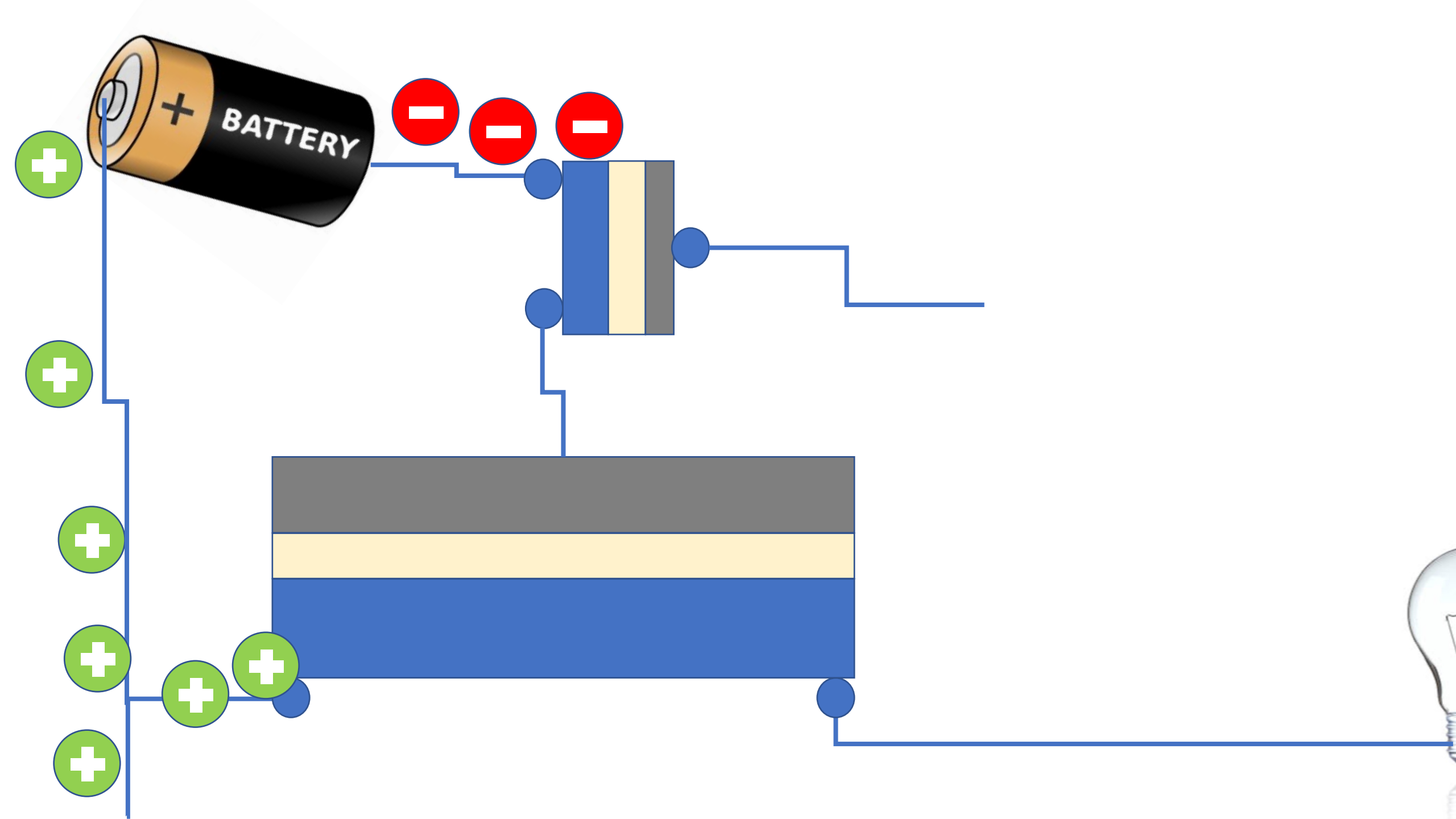
semiconductor / graphene

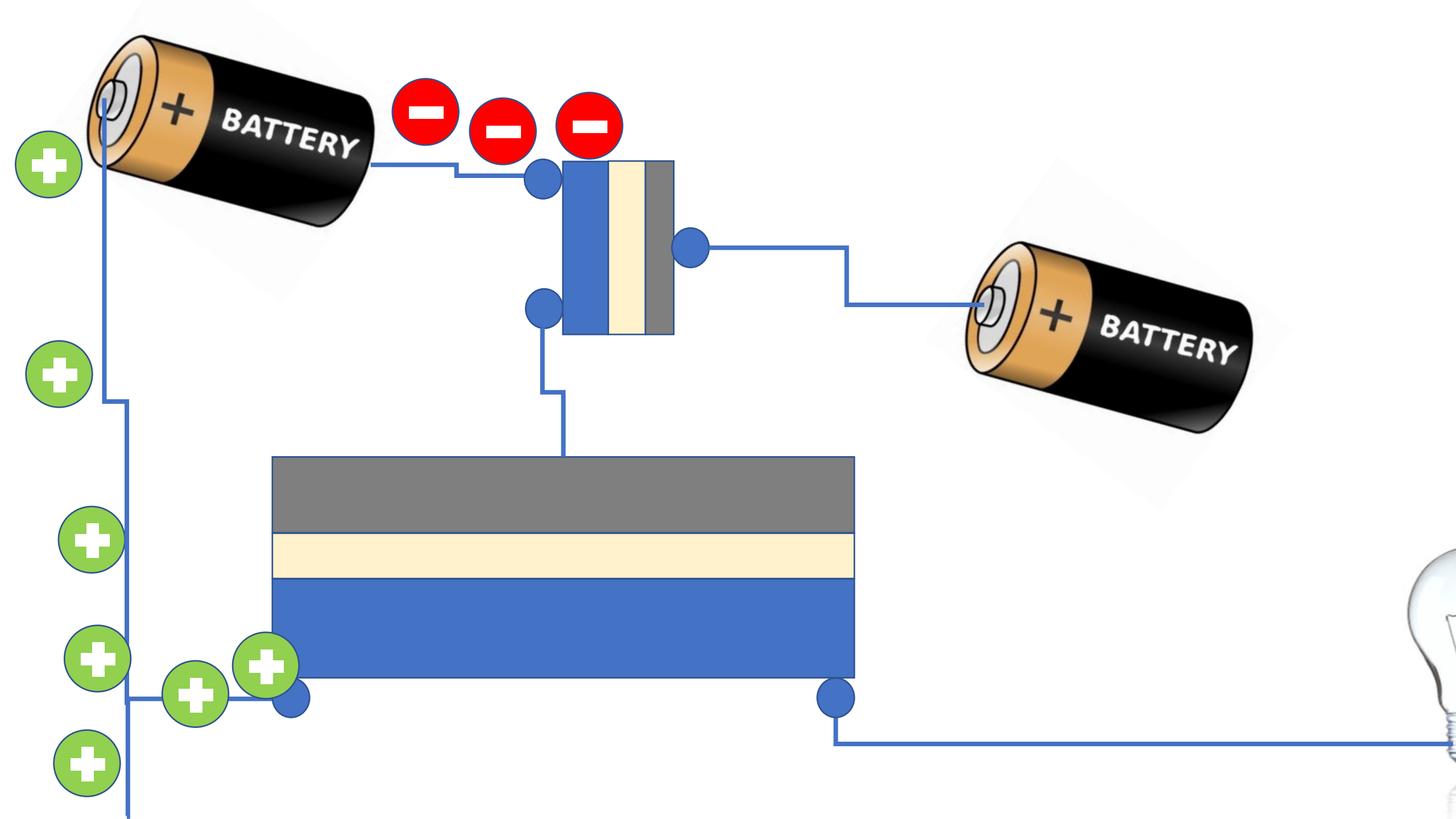




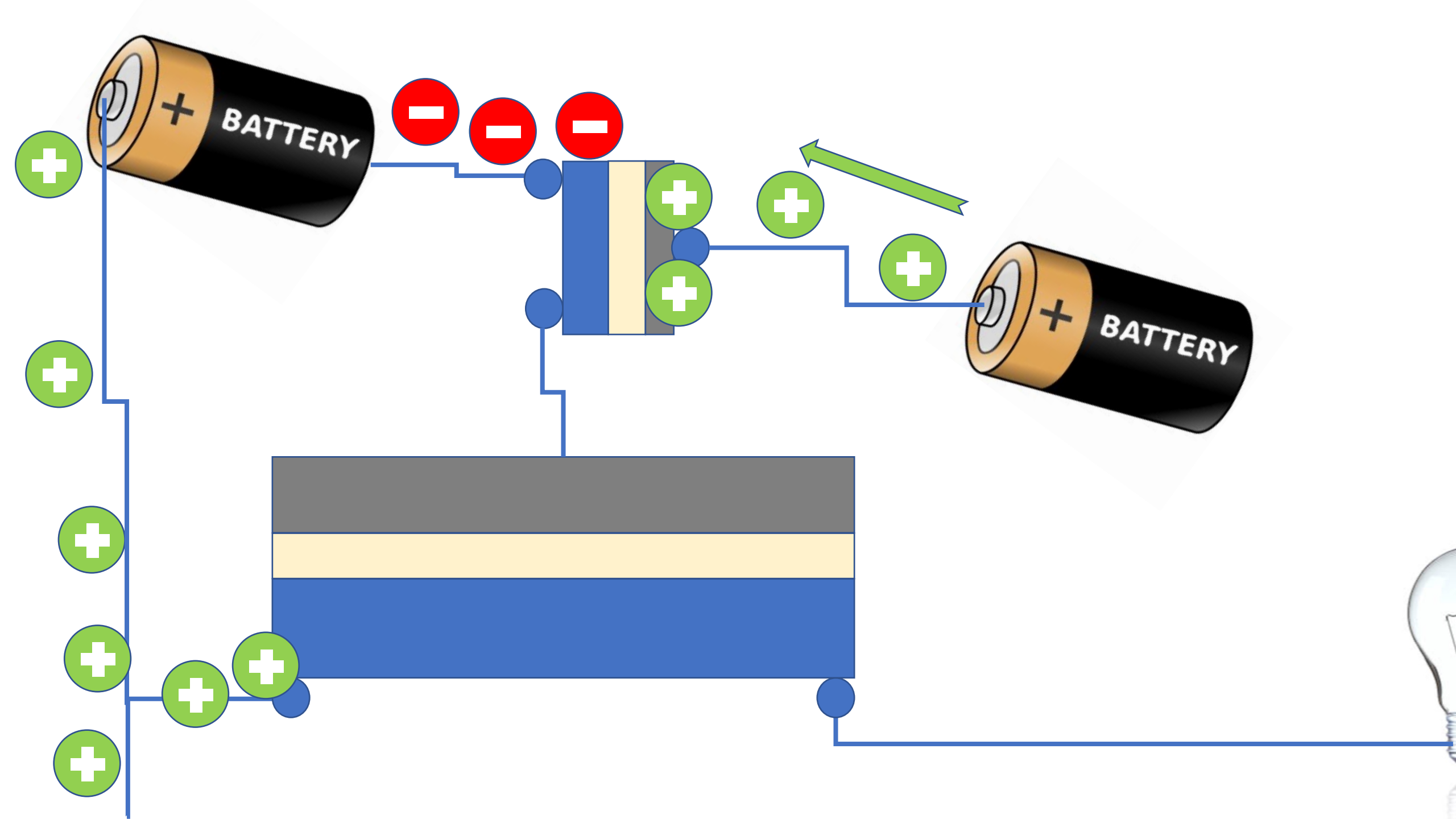


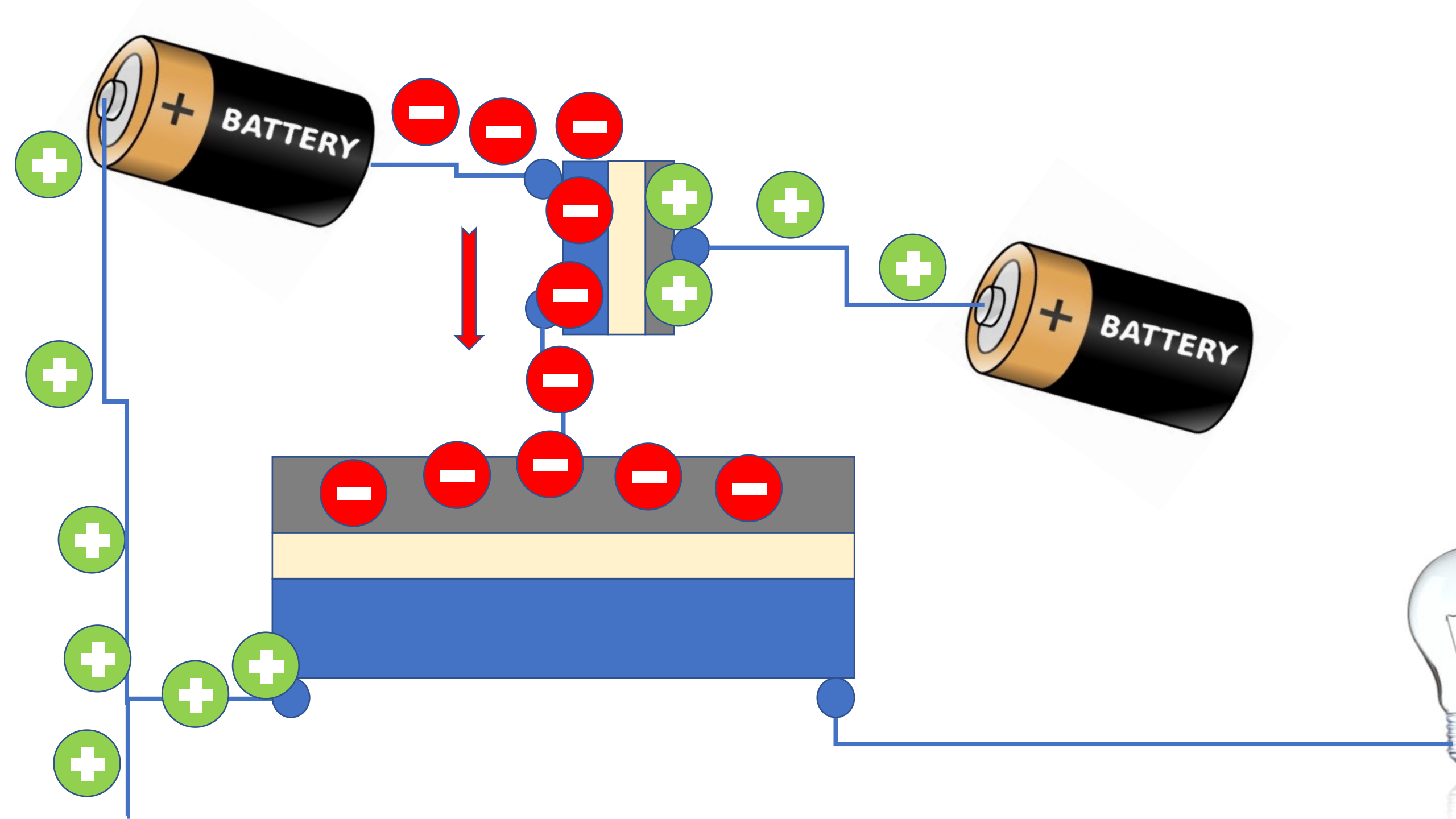


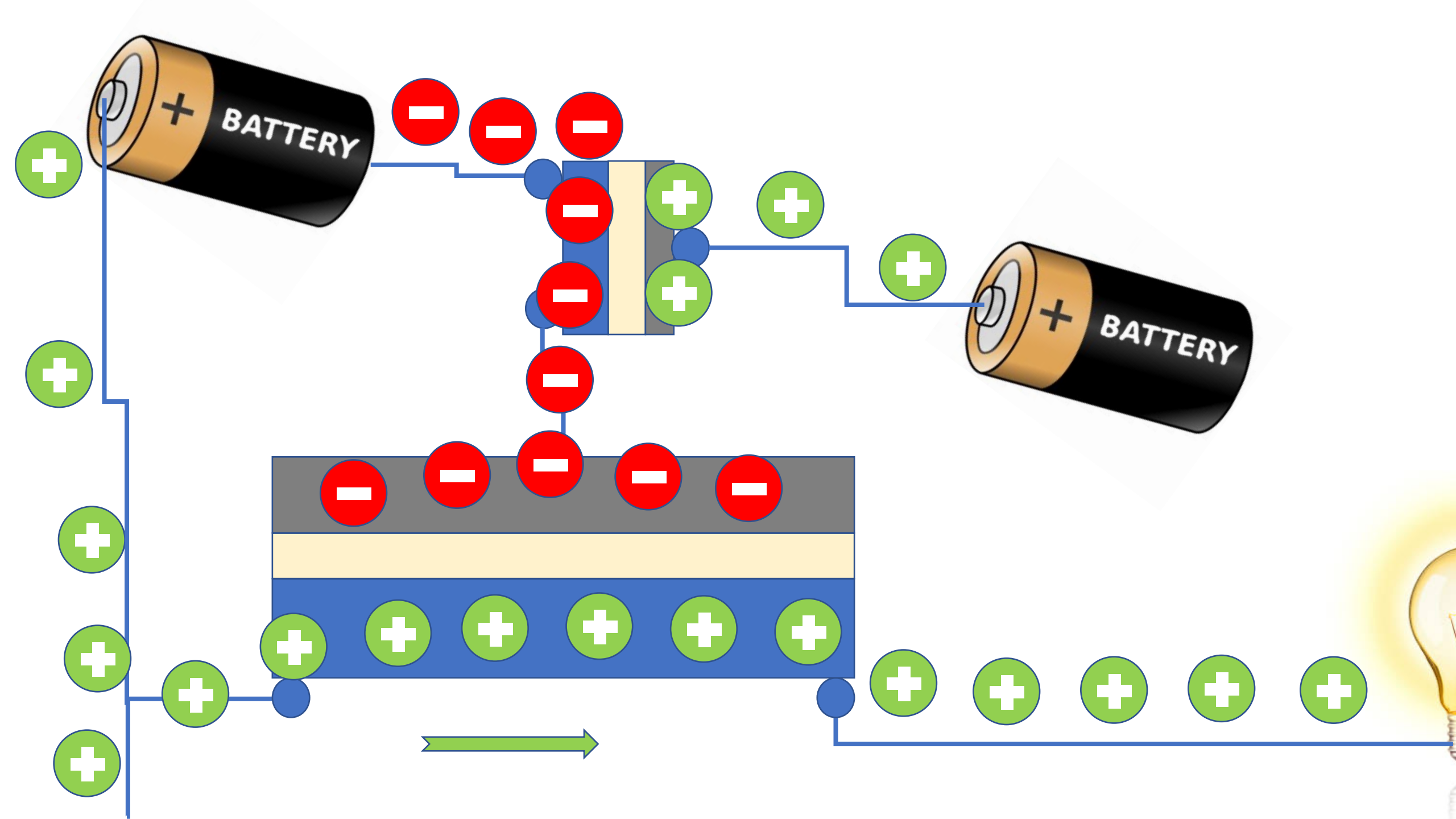


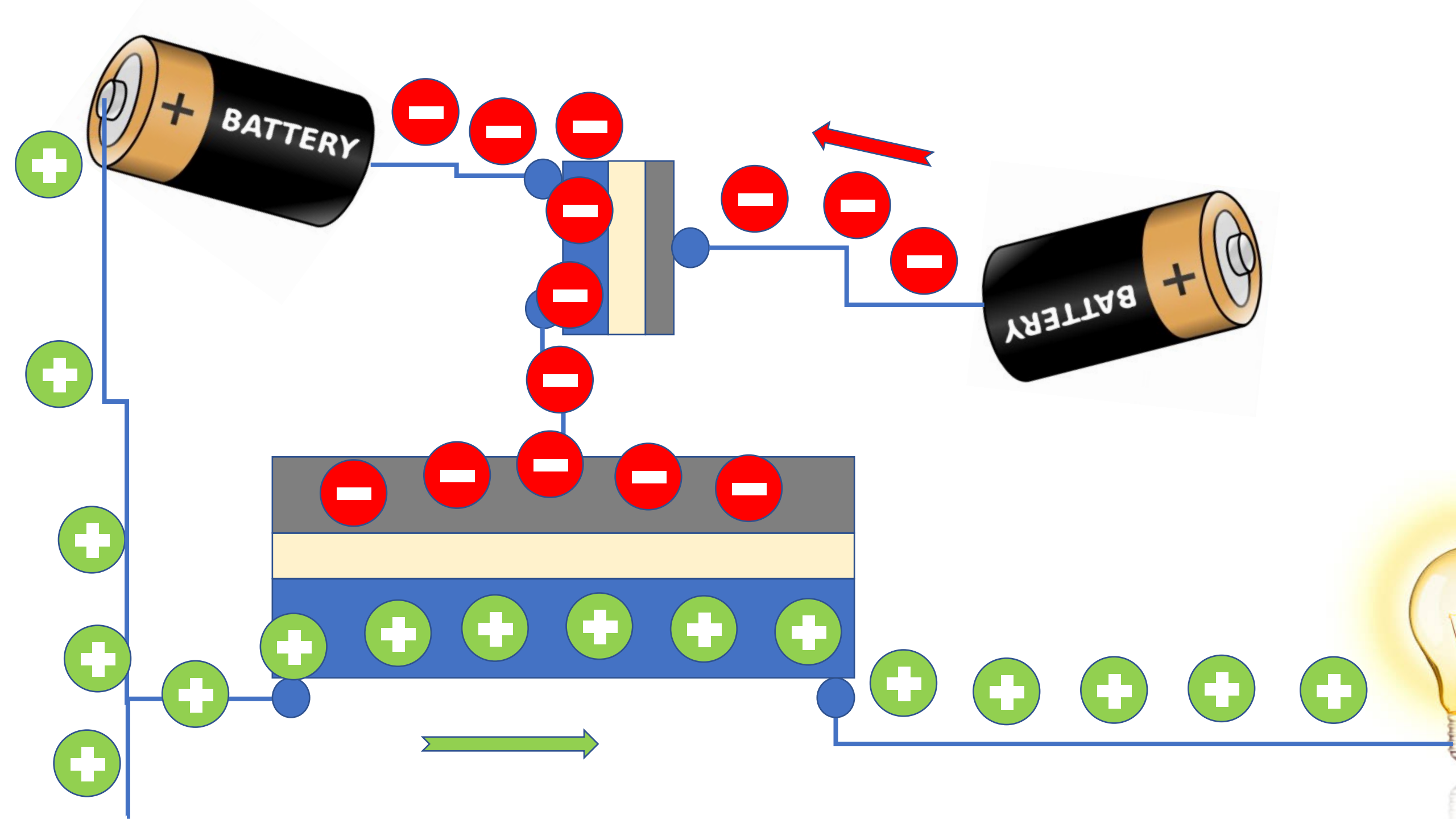


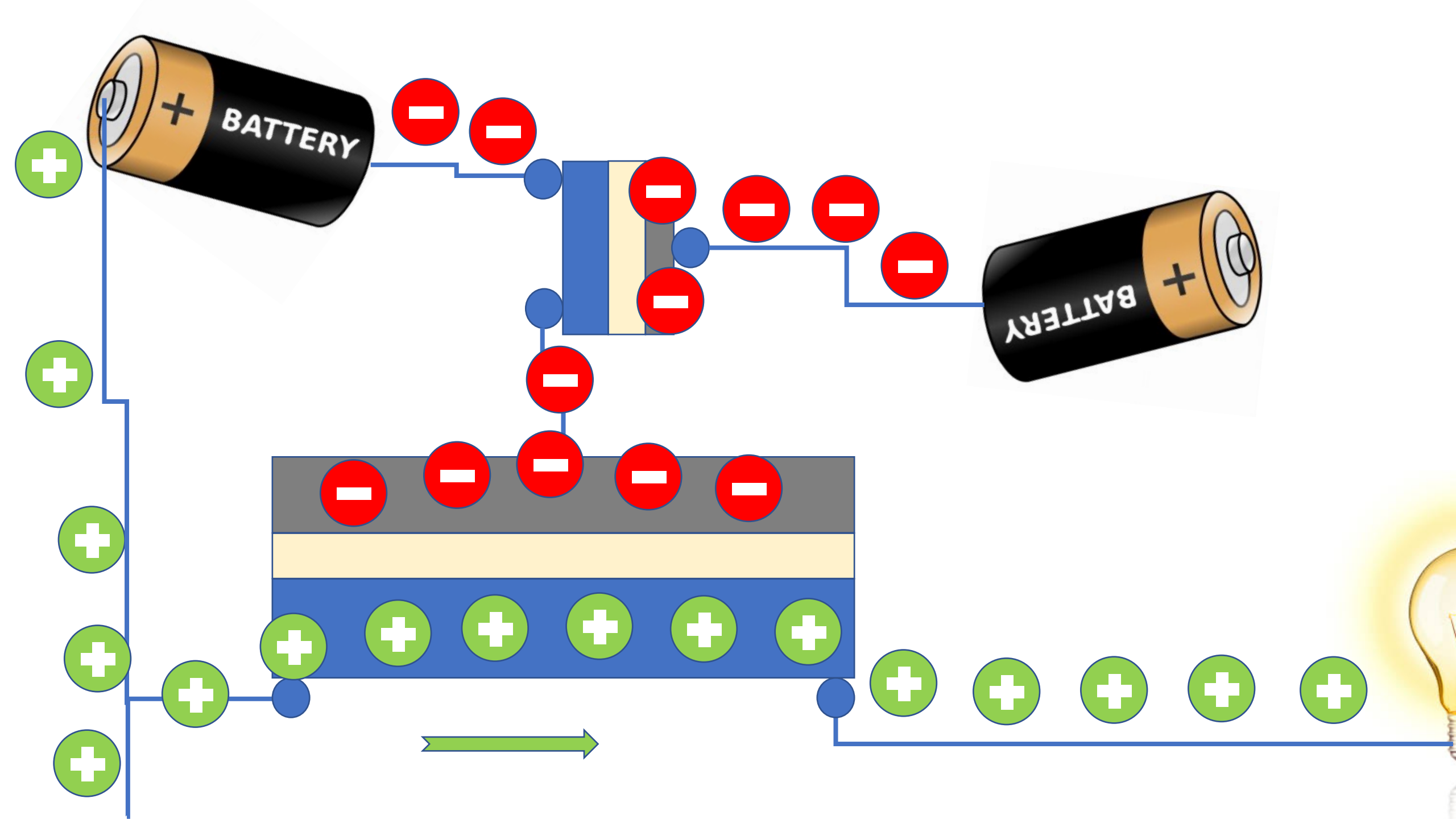


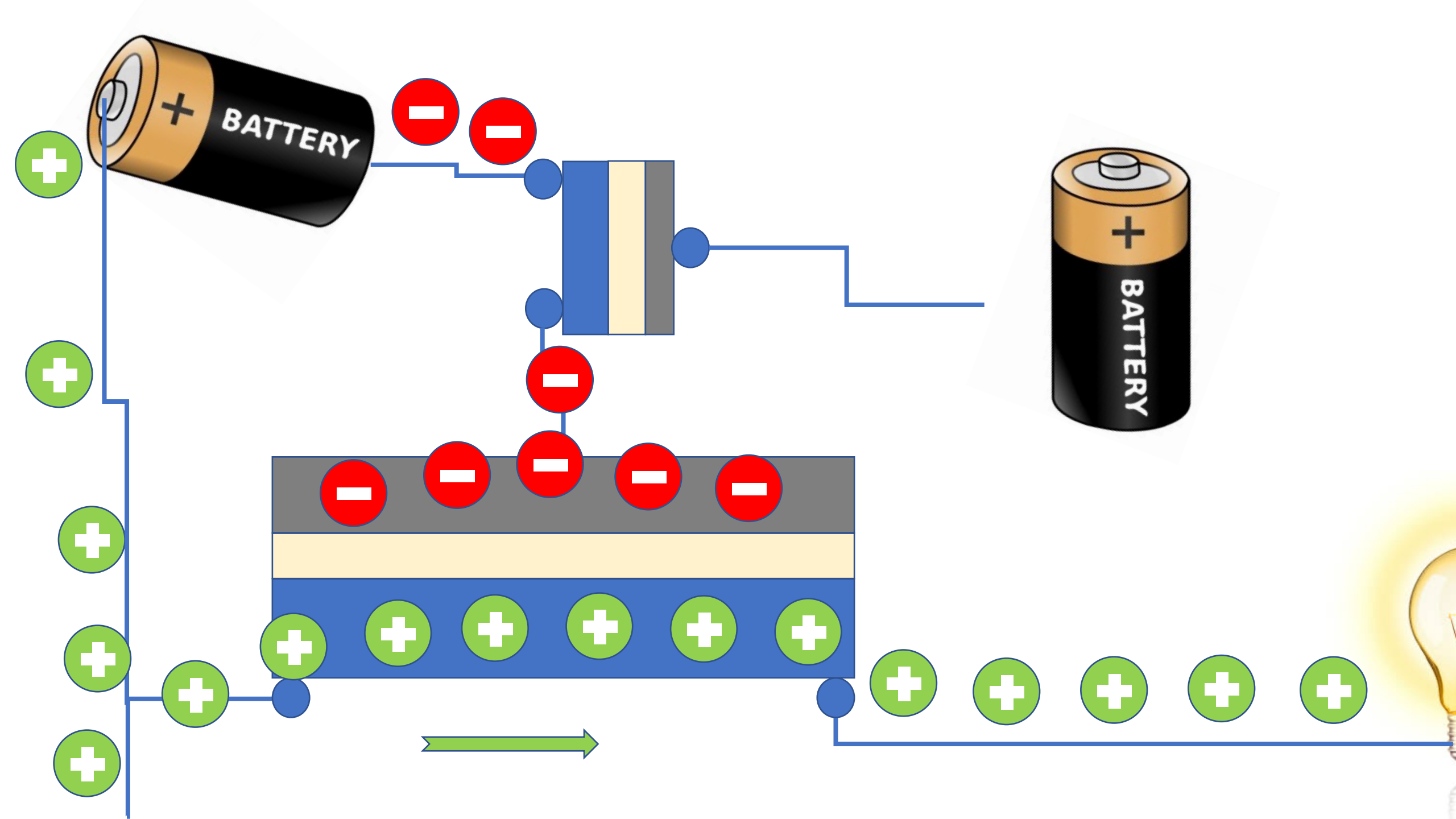


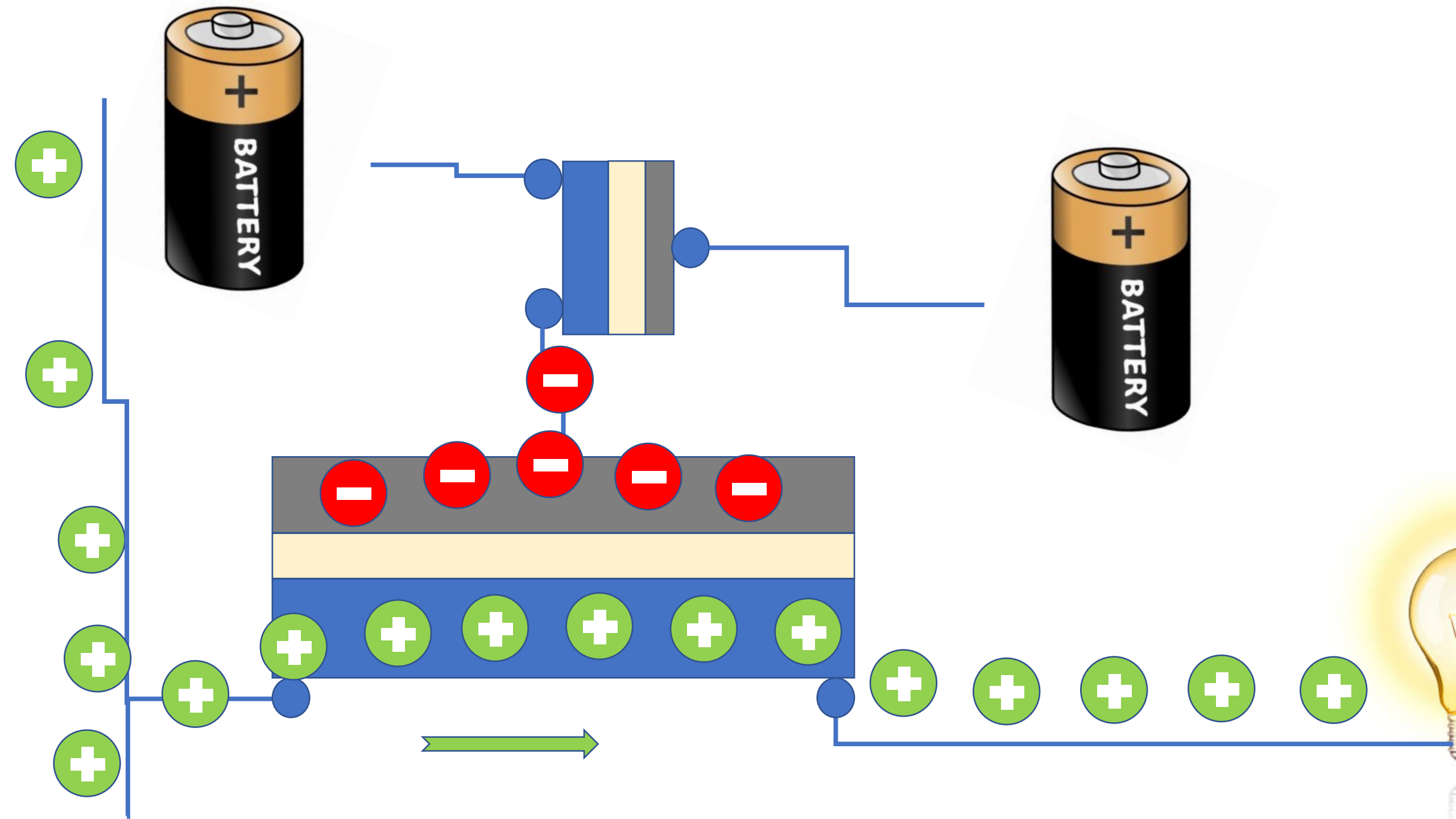


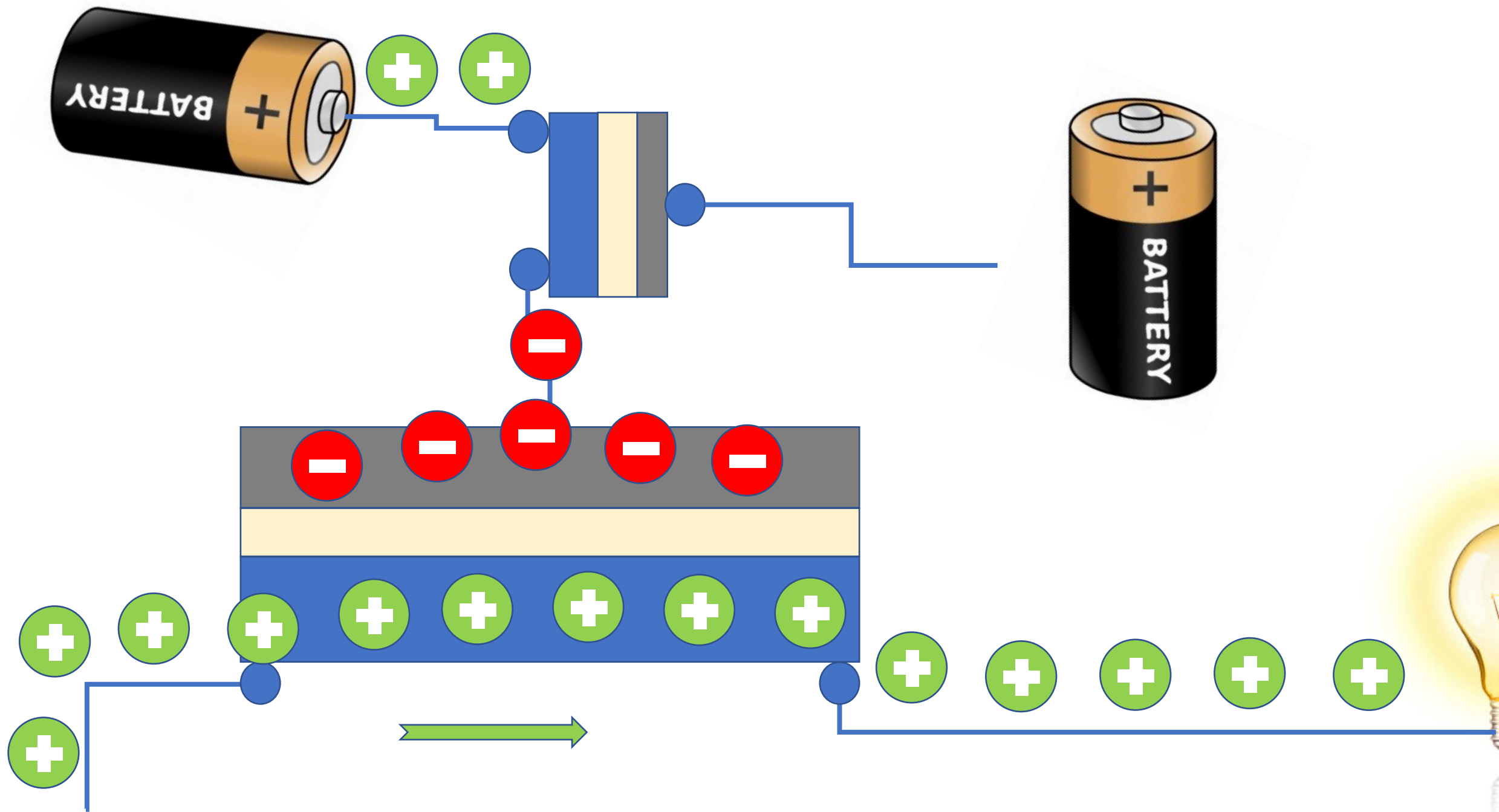




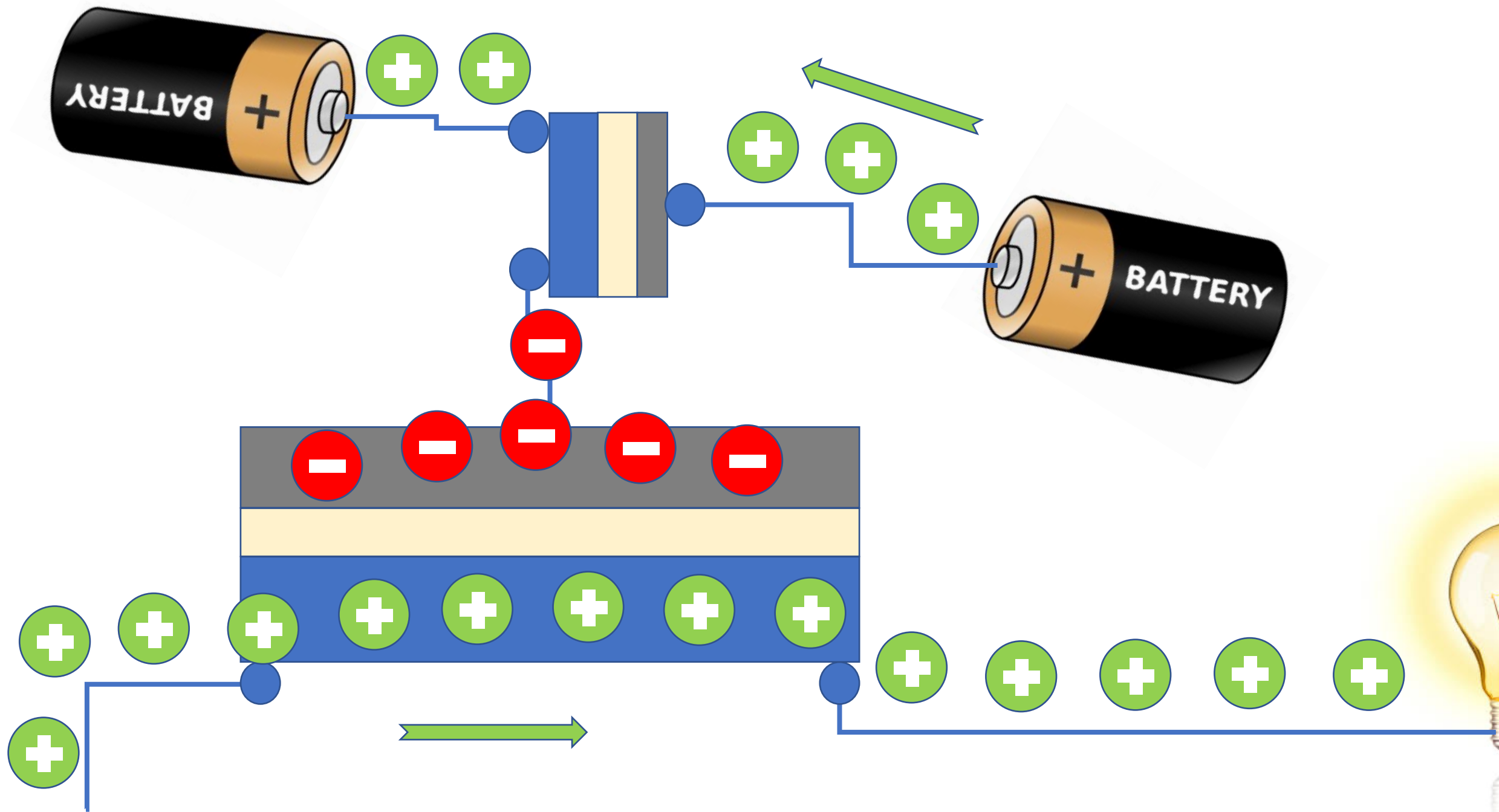


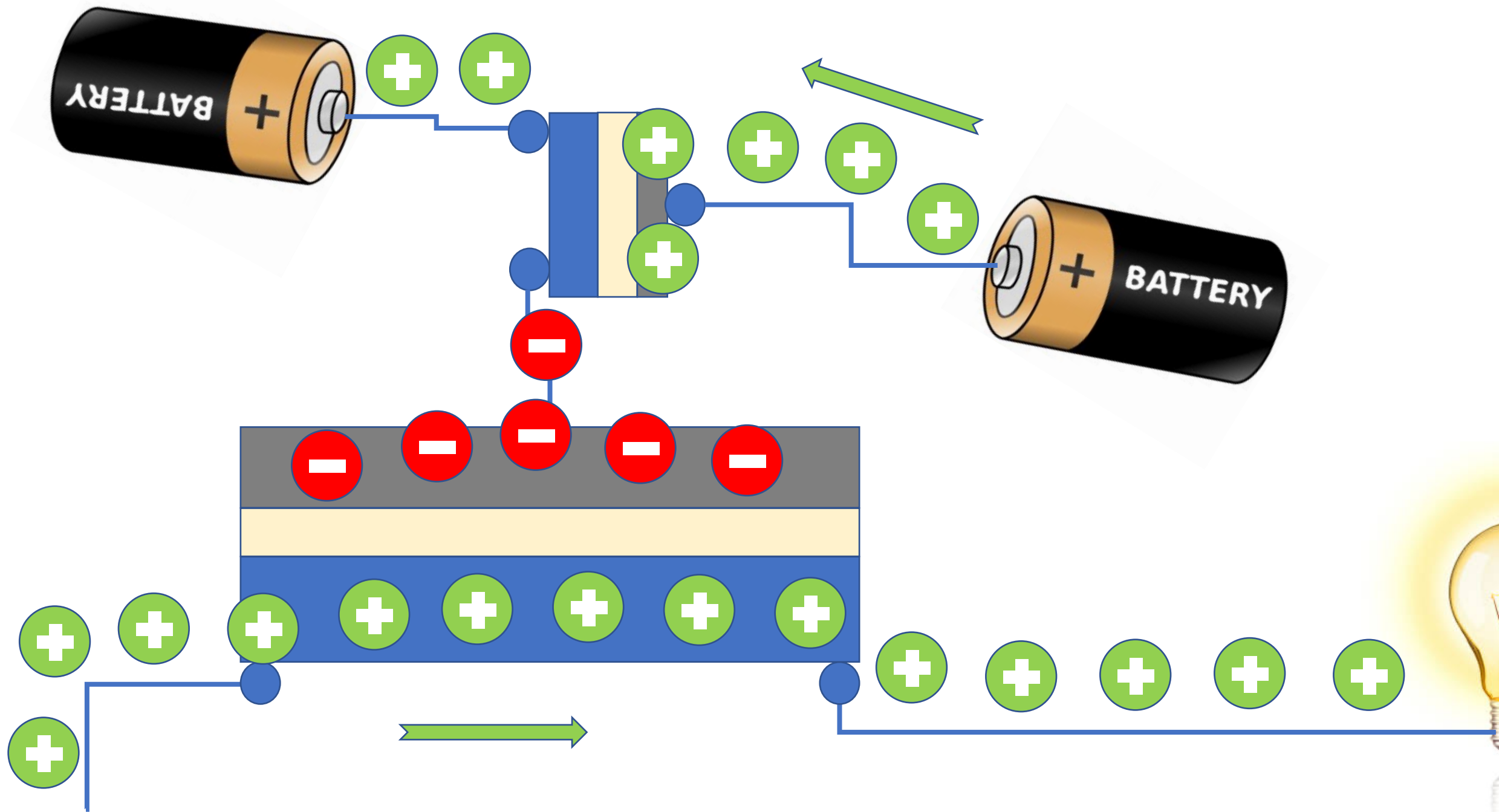


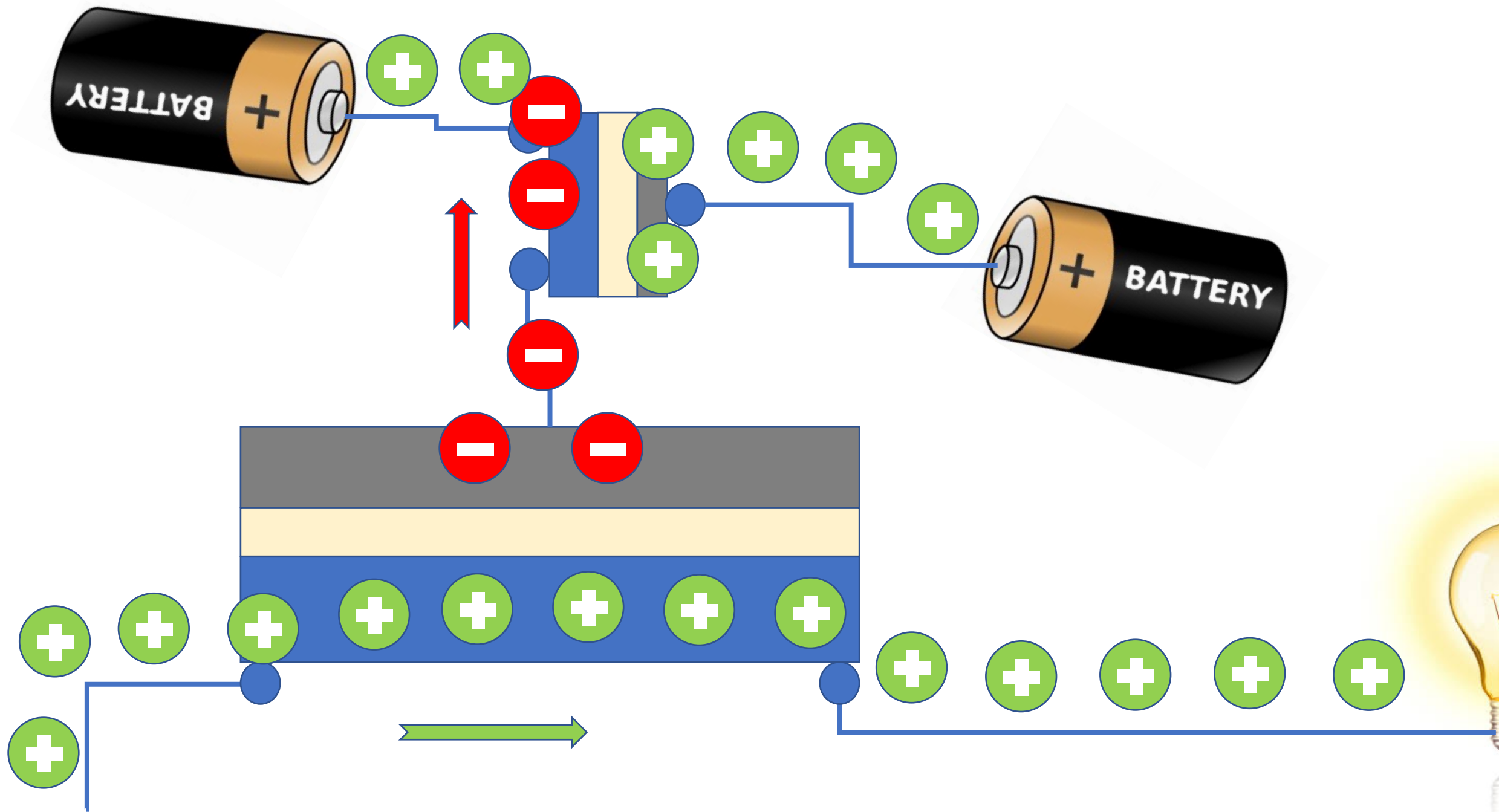


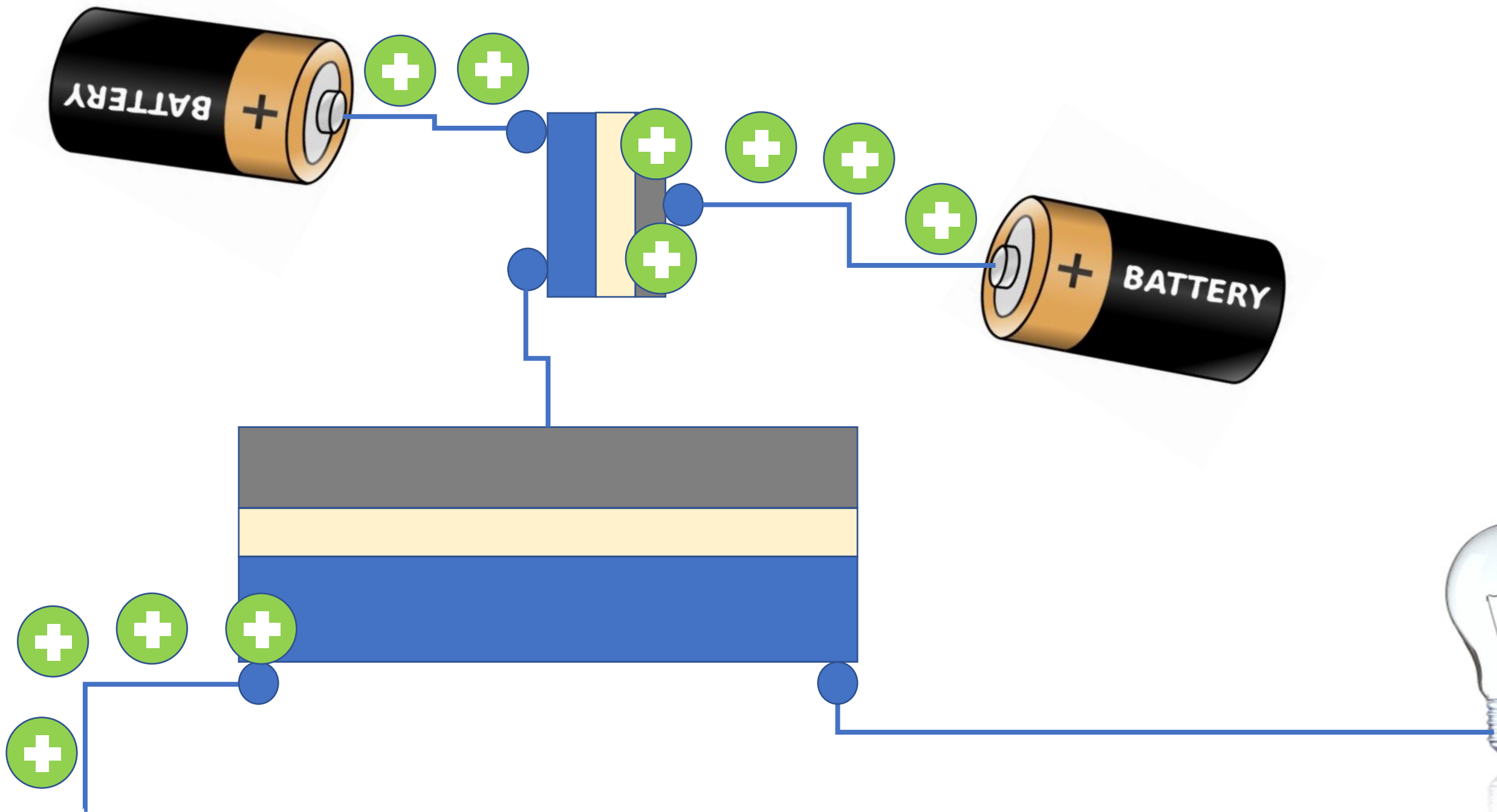


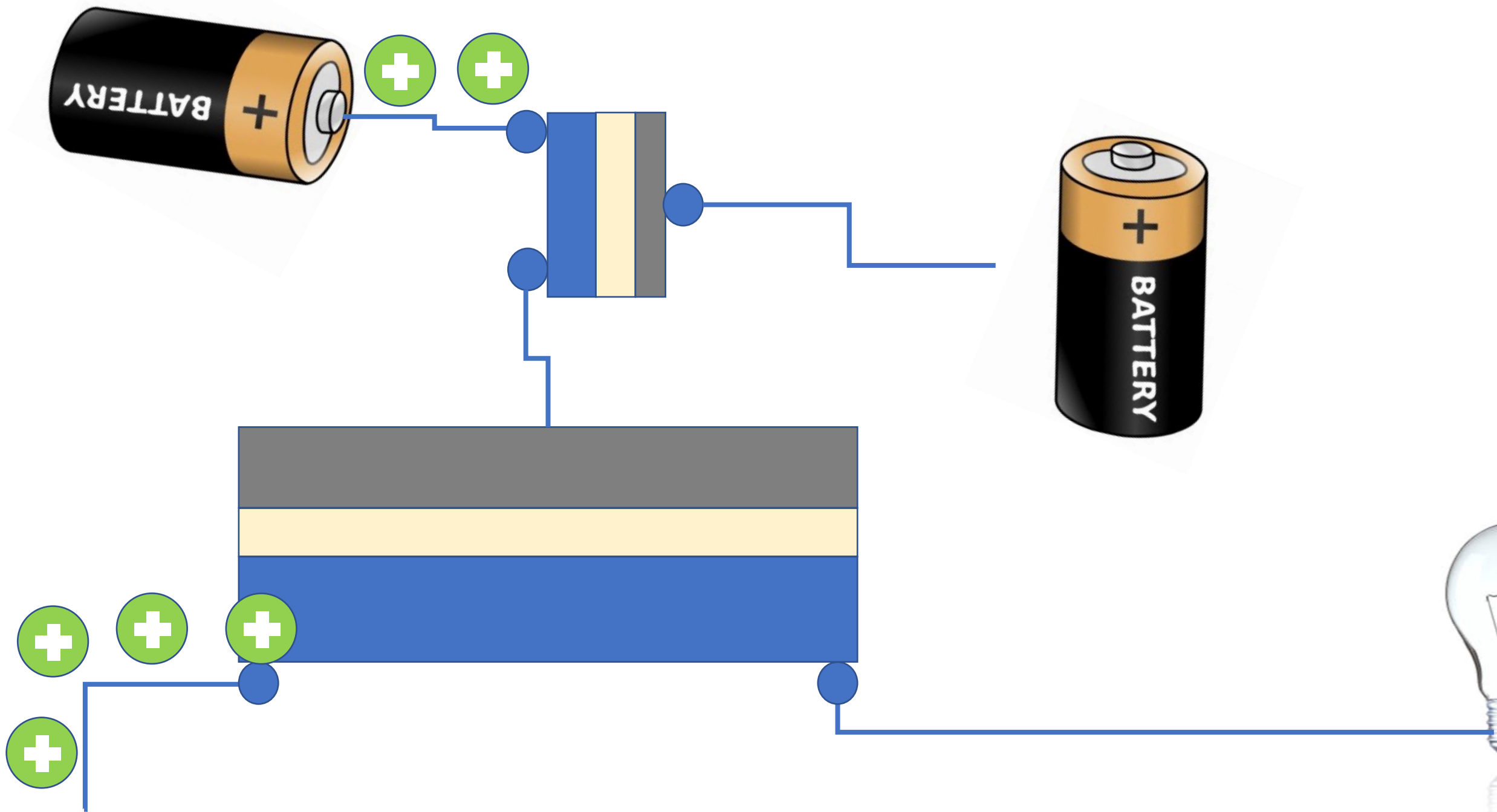


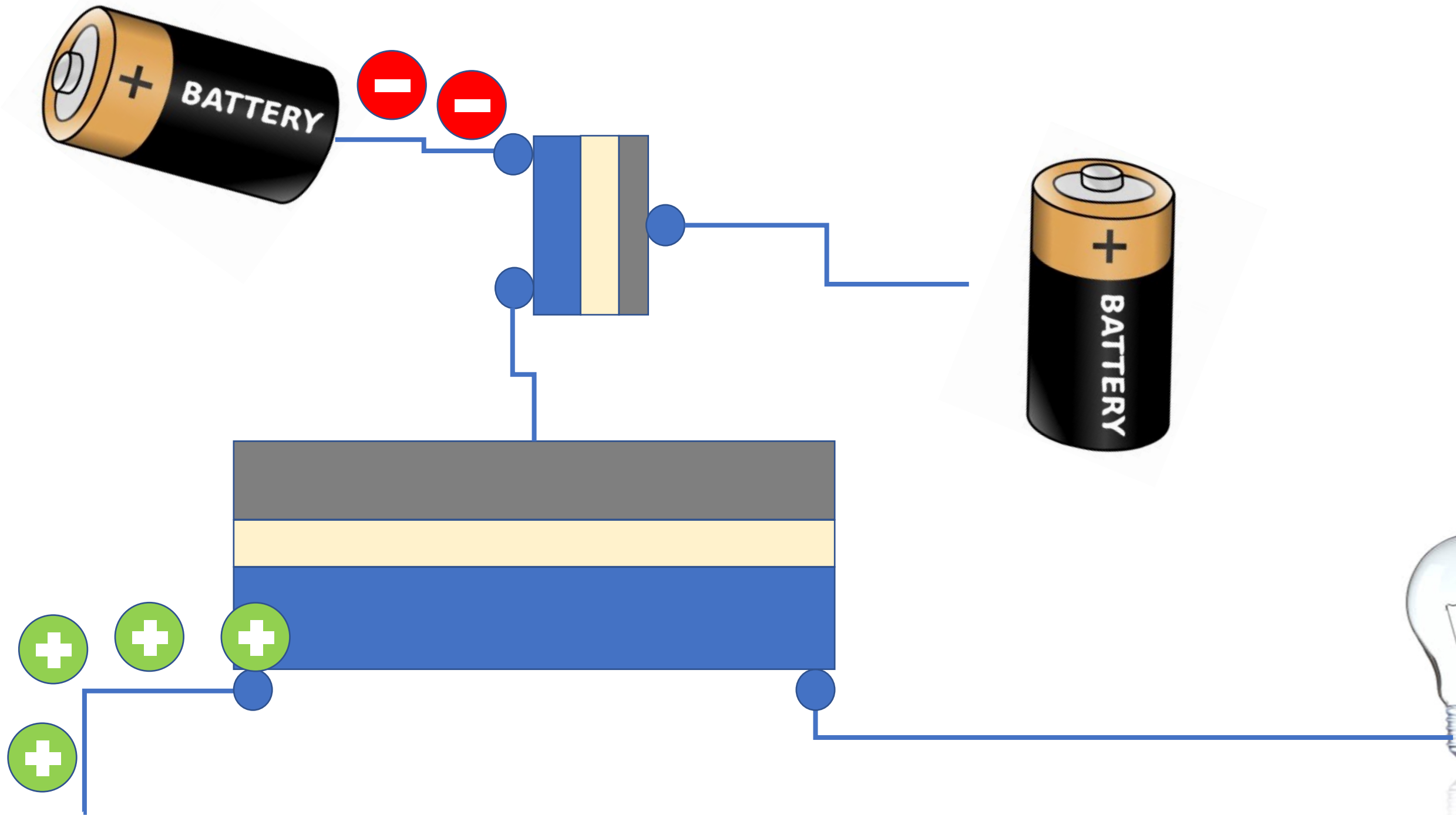


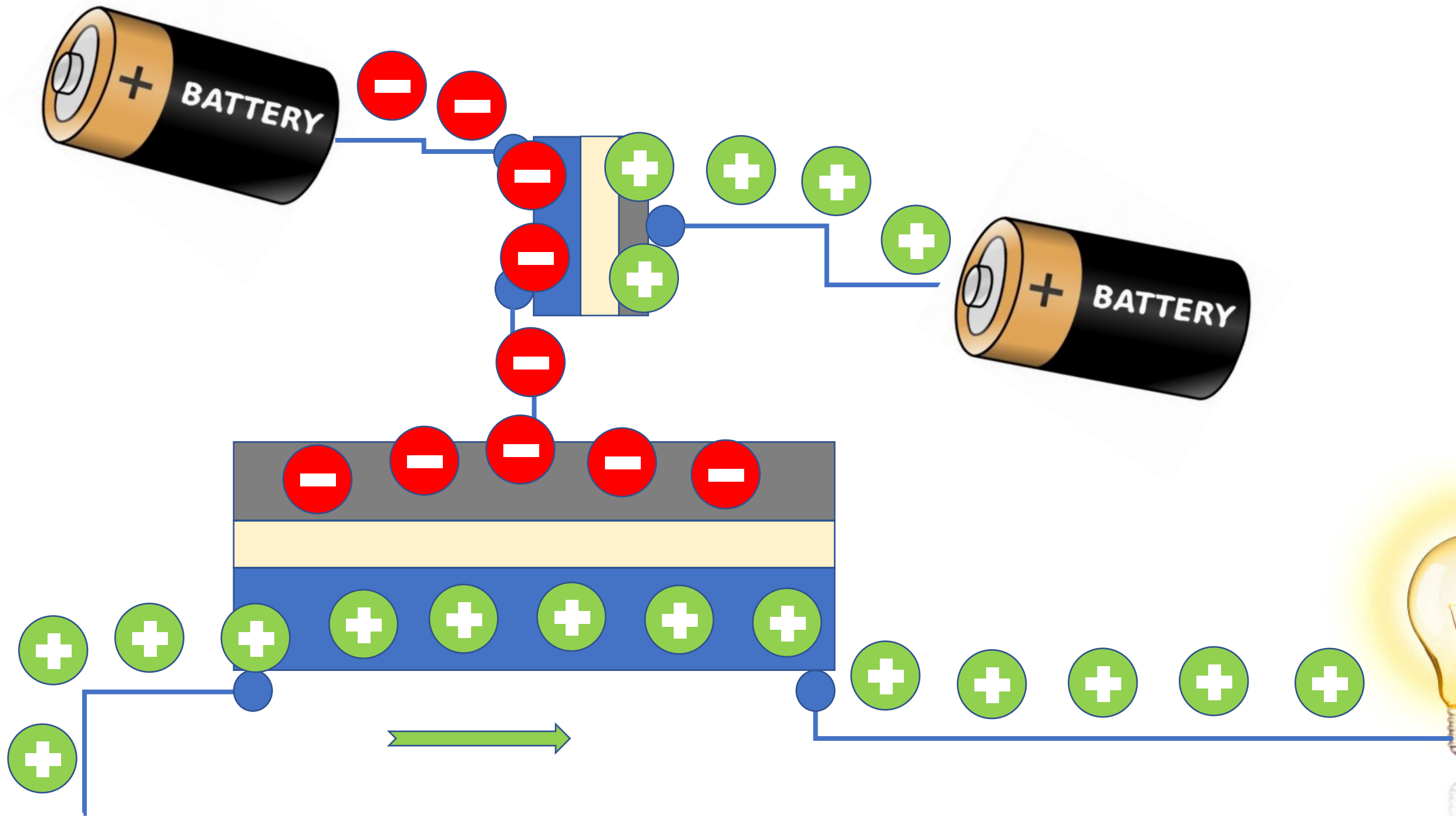


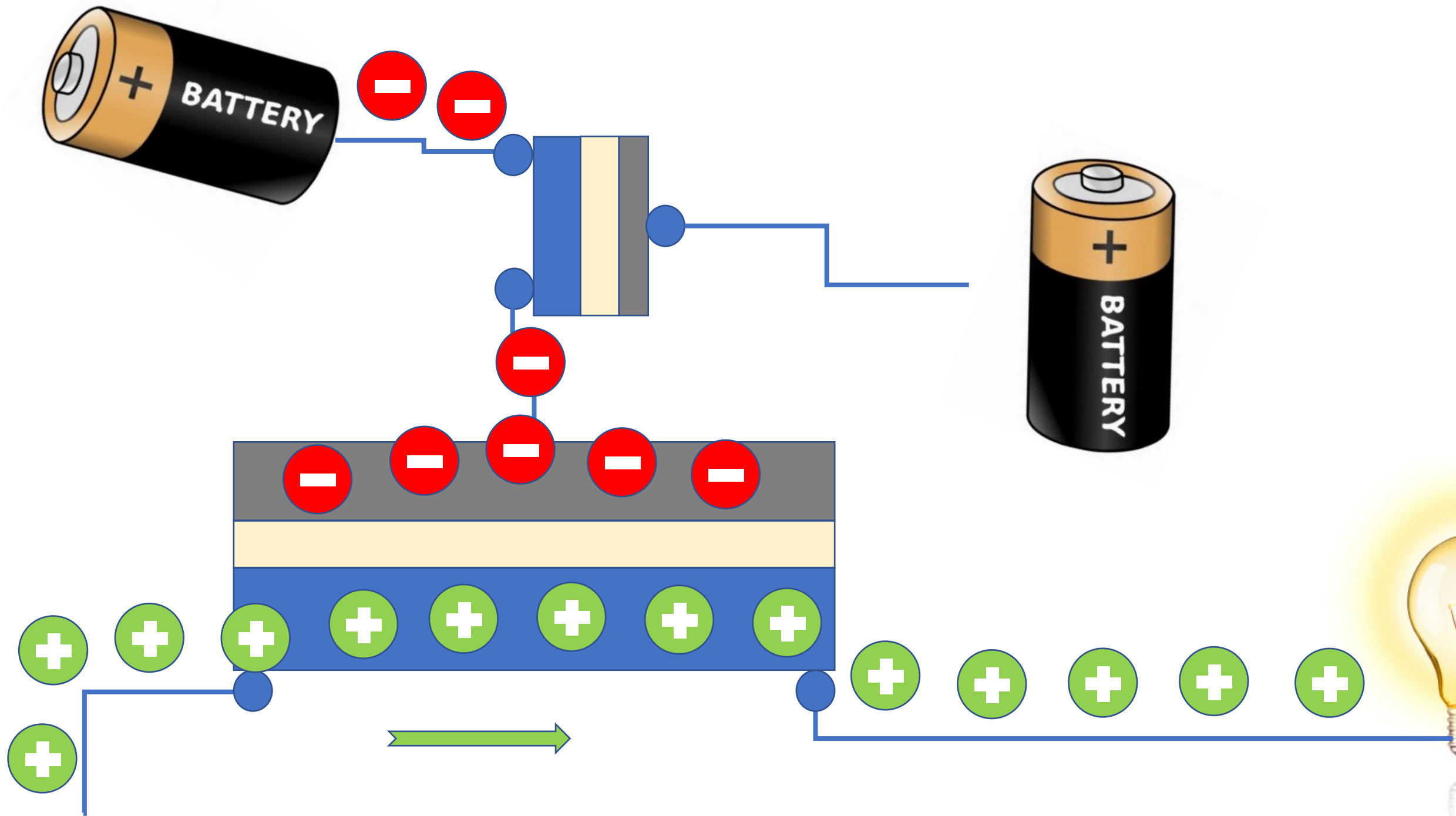




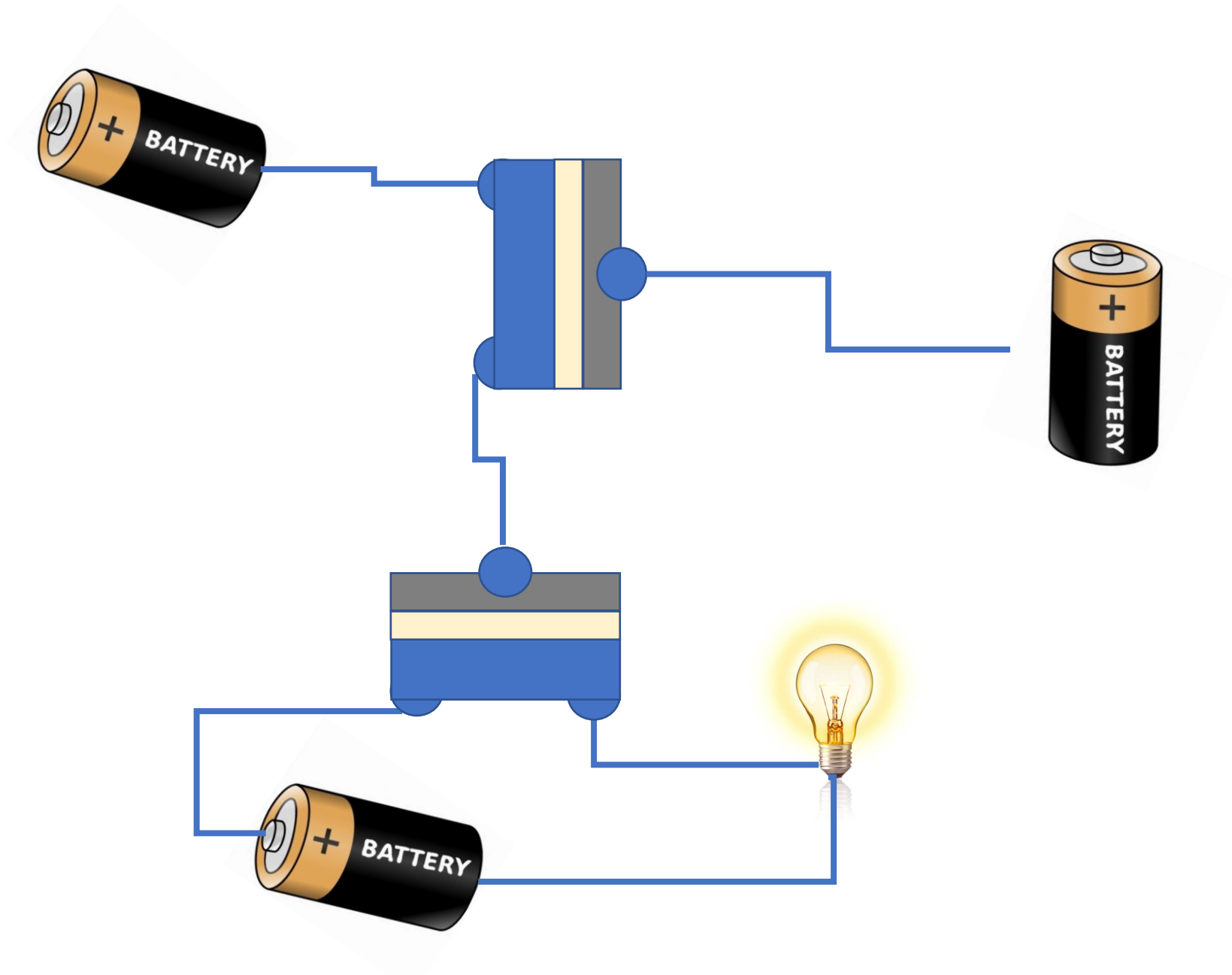


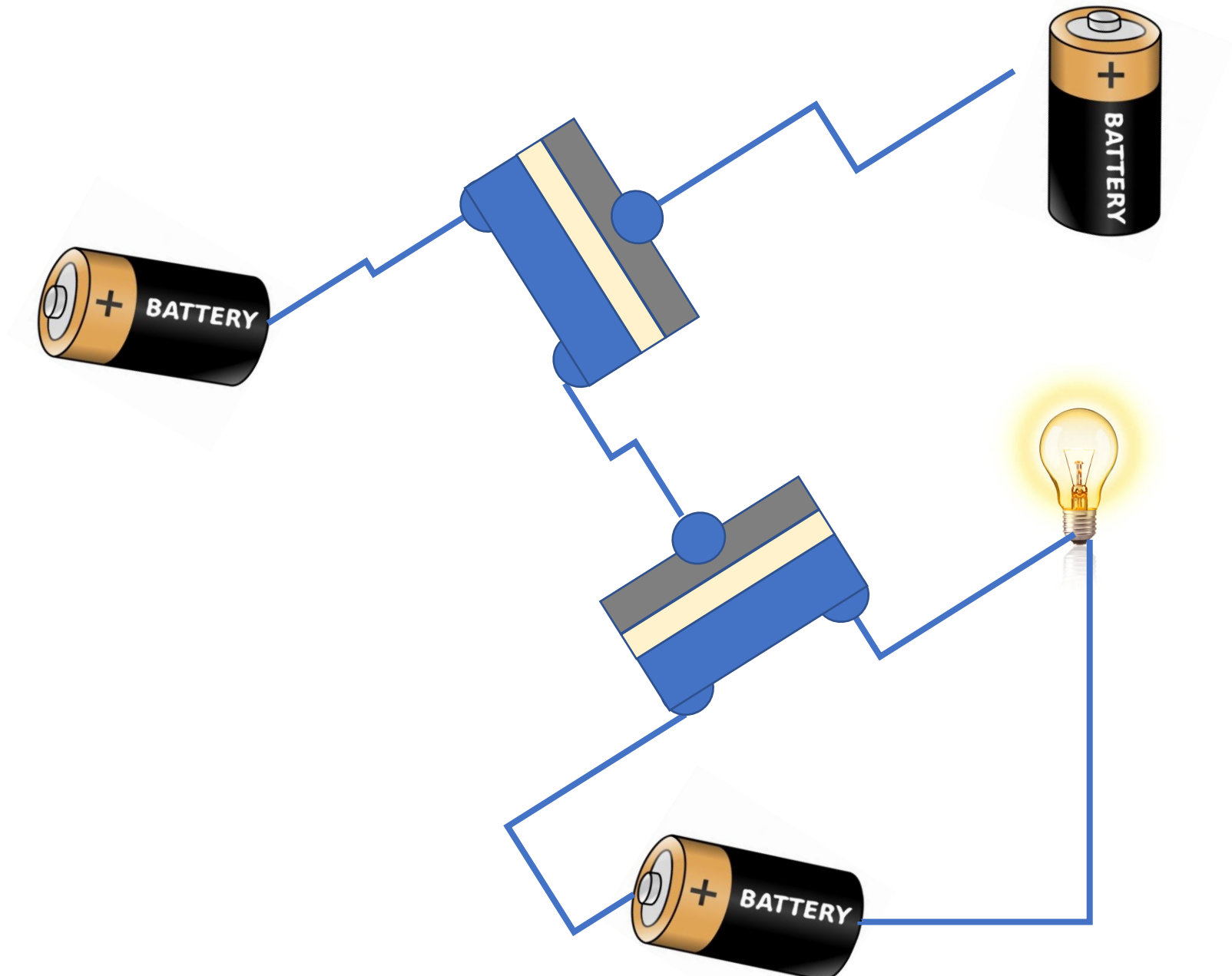


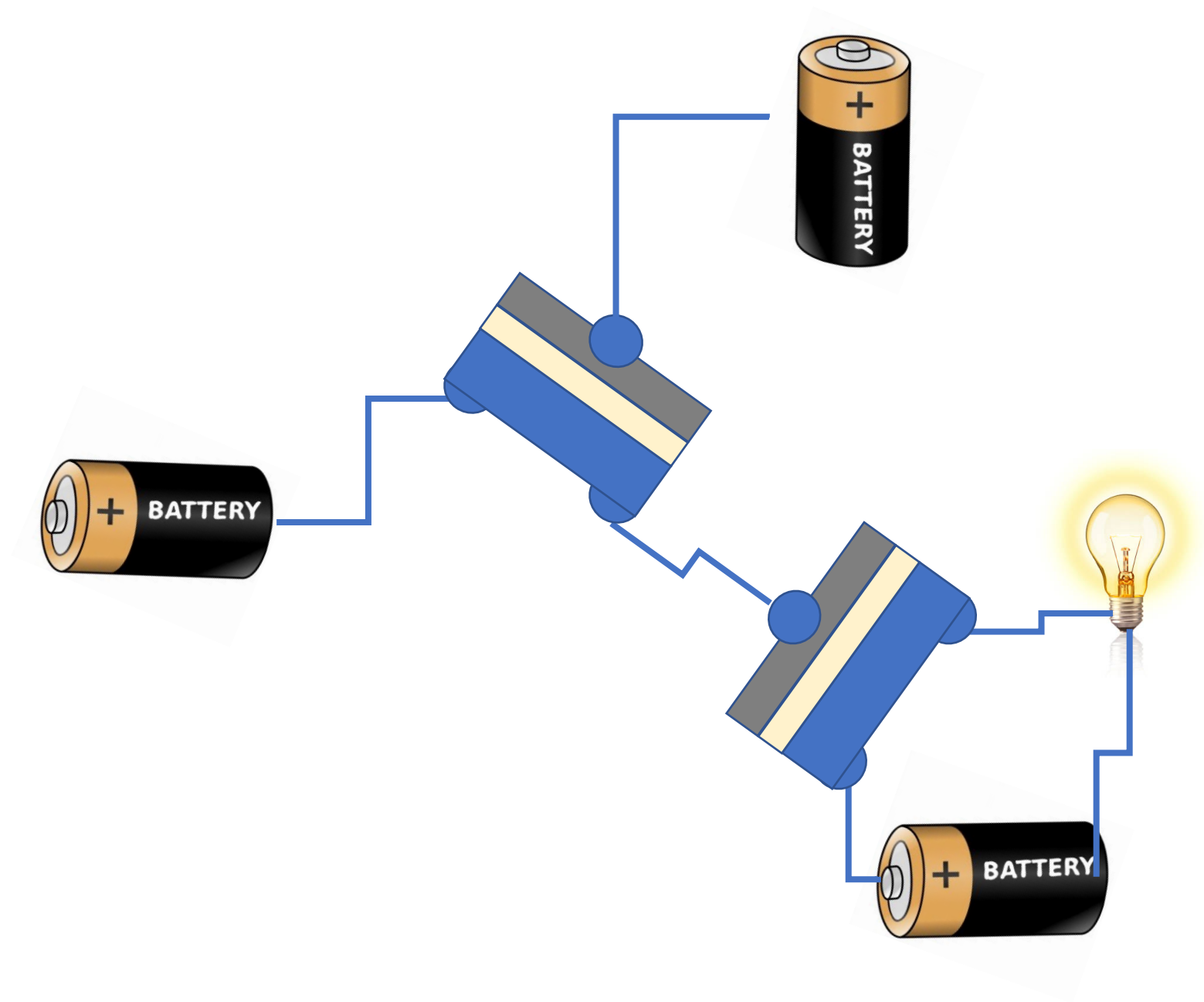


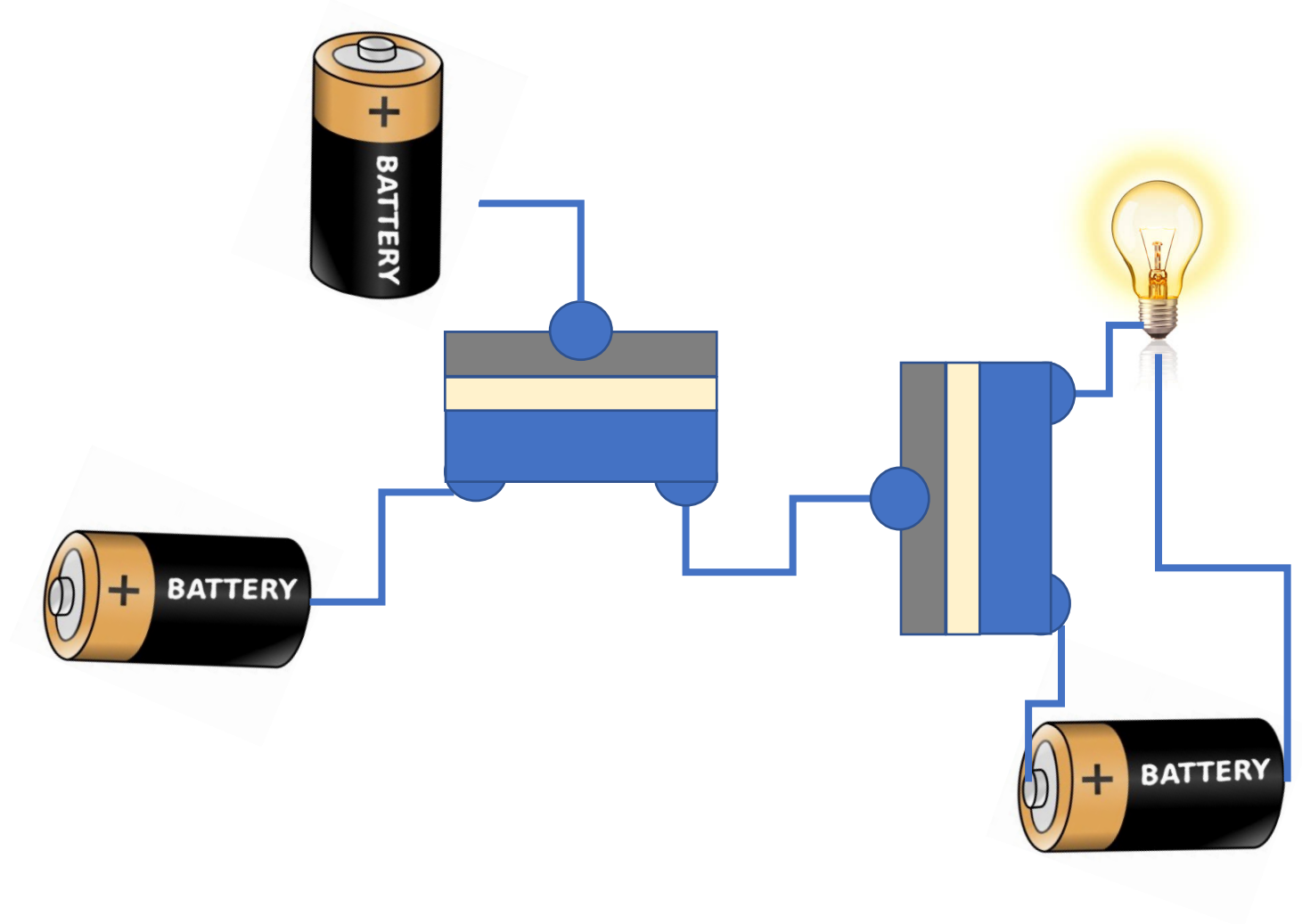


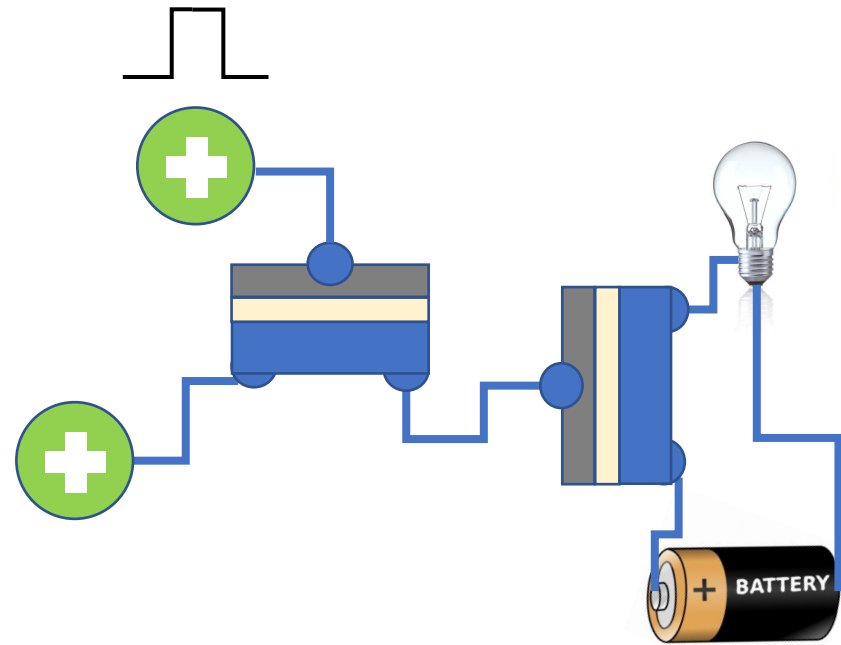
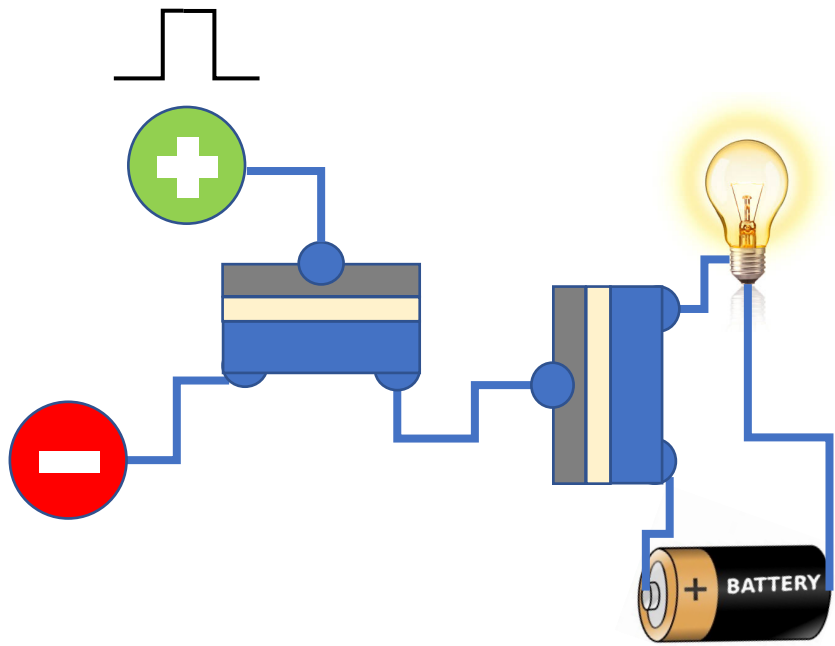


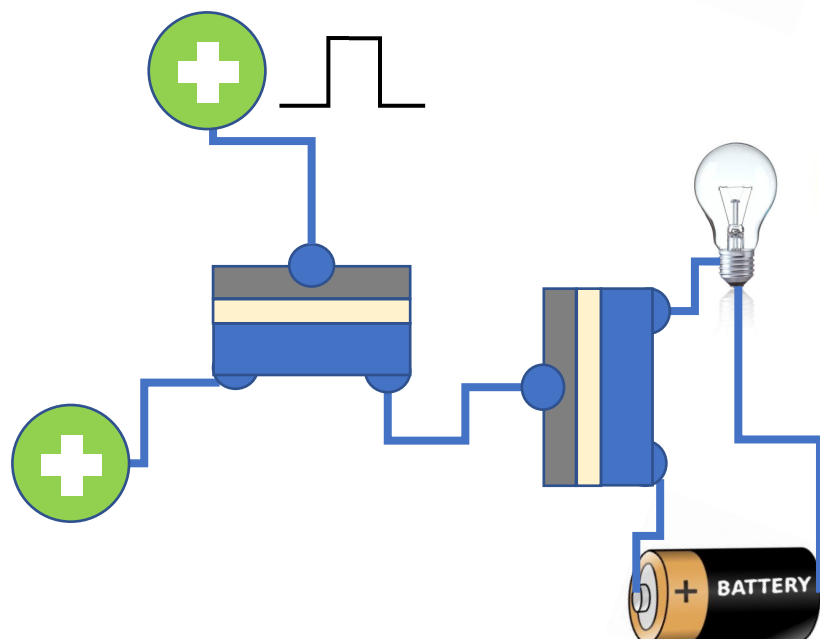
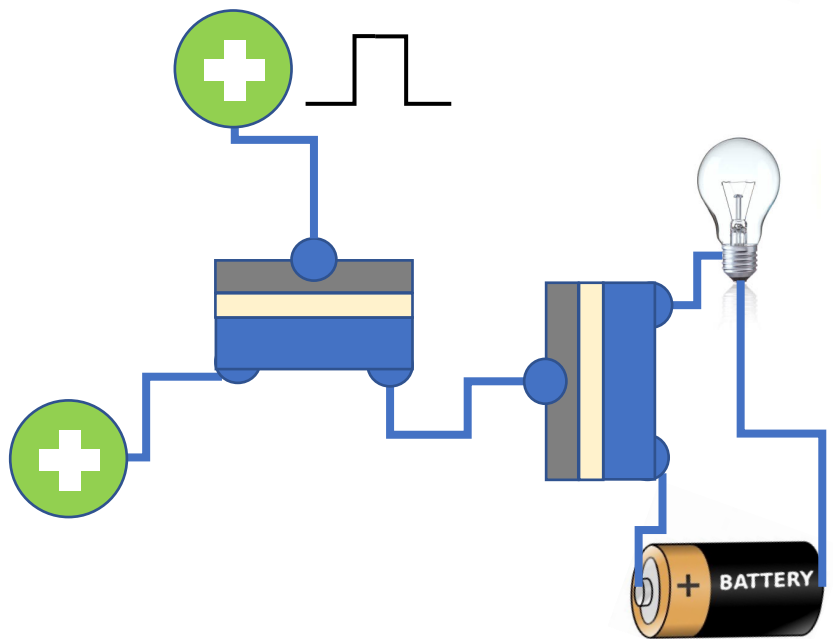
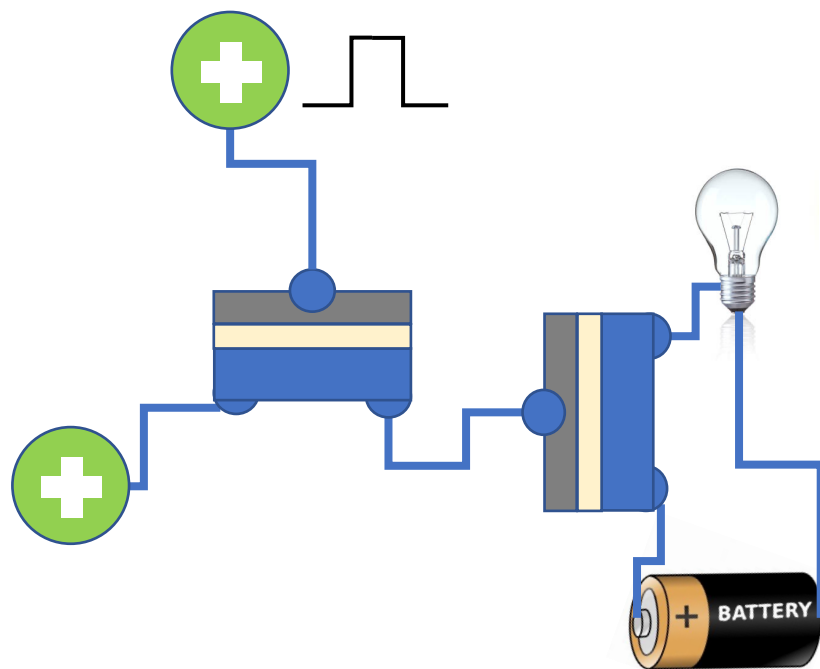
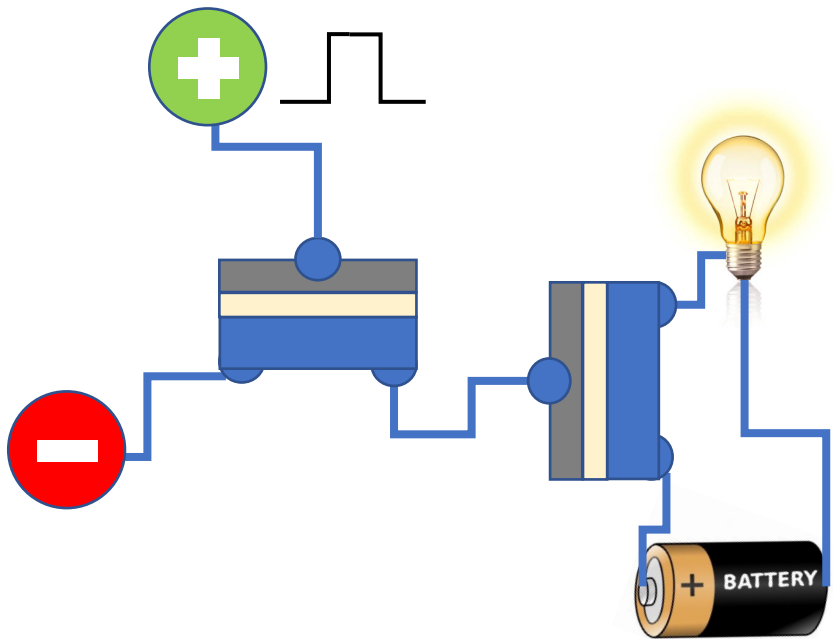


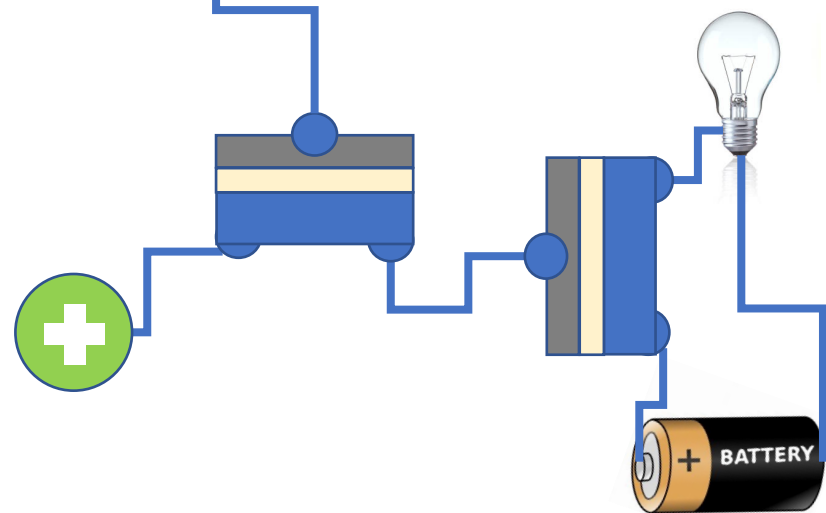
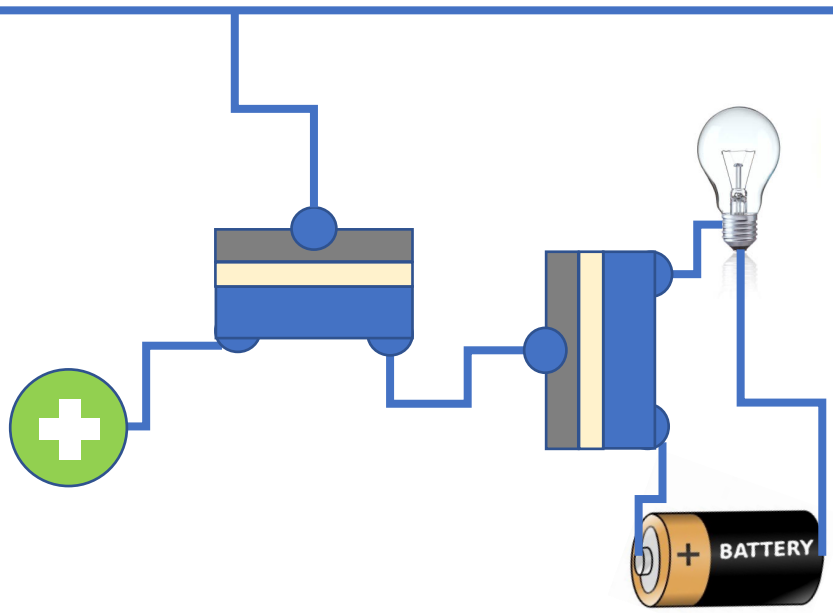
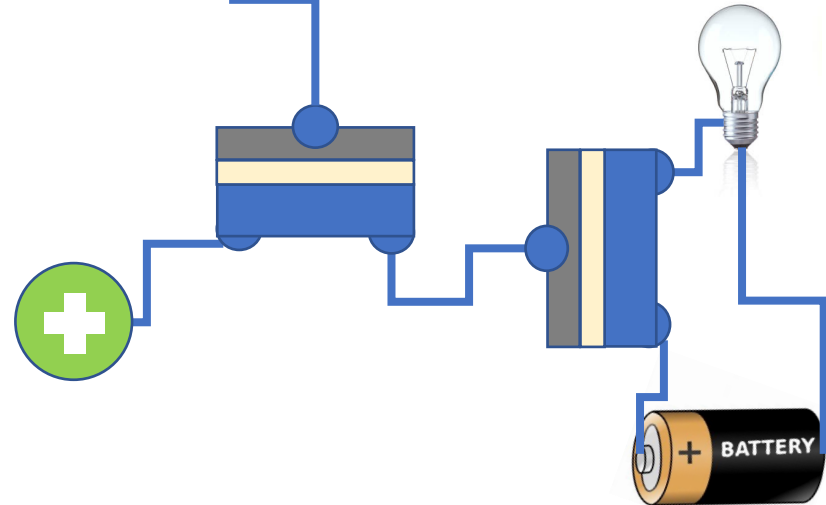
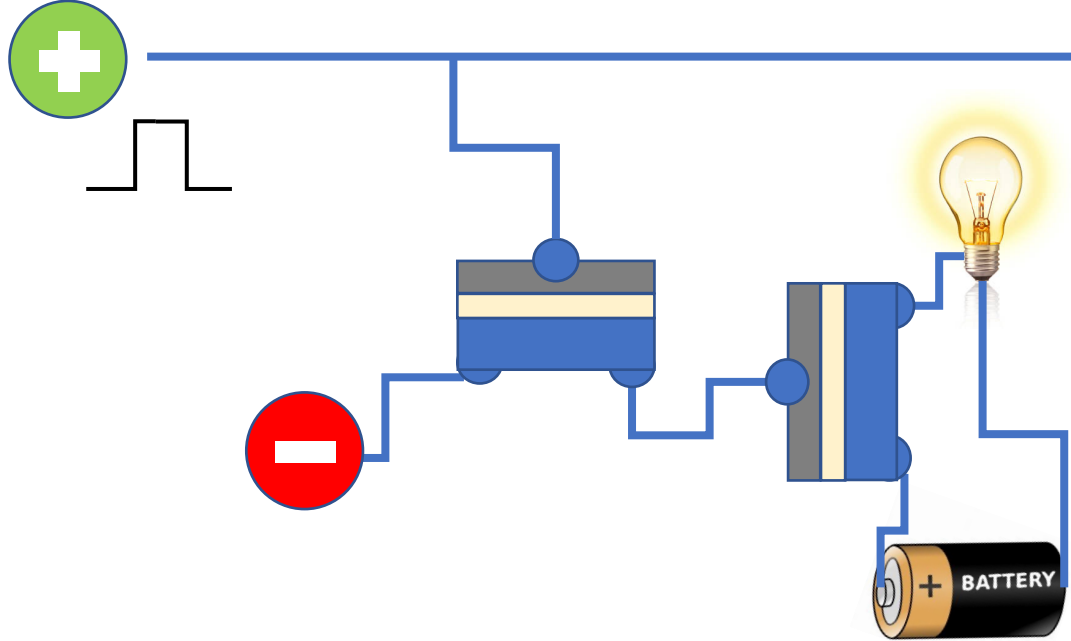


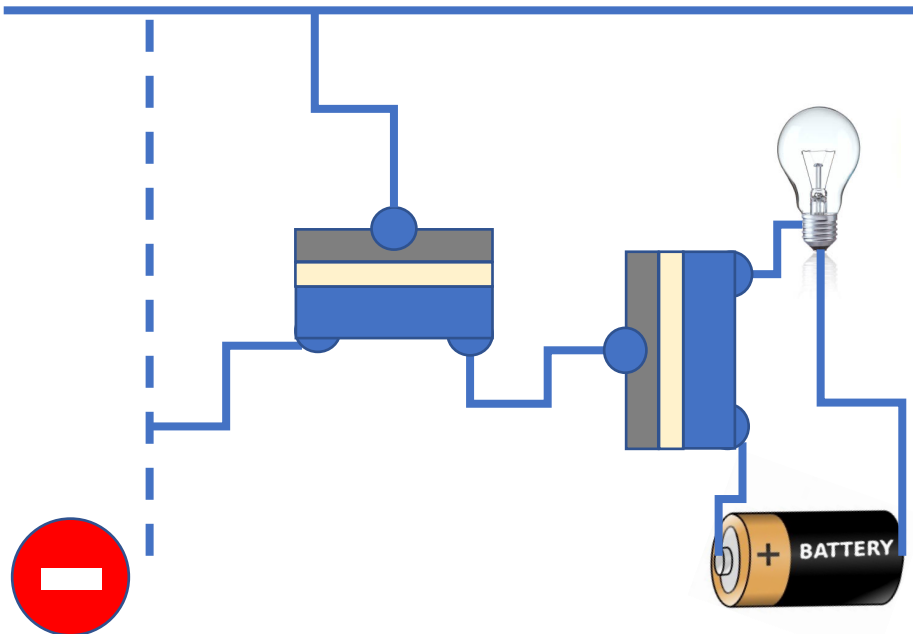
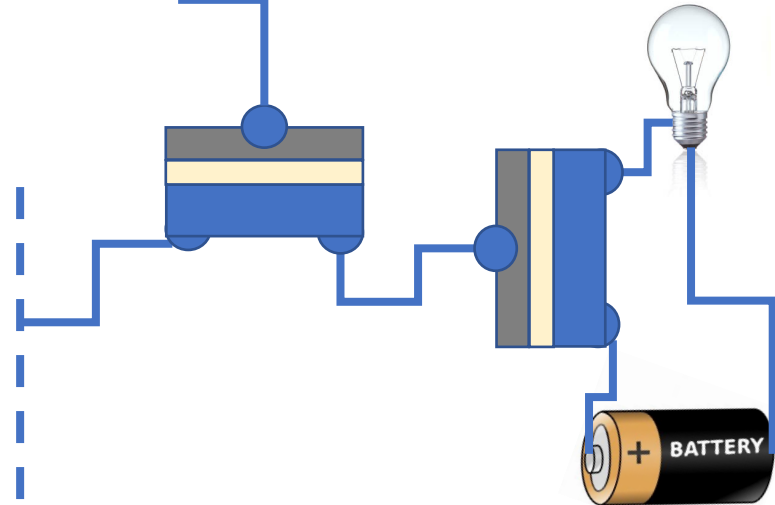
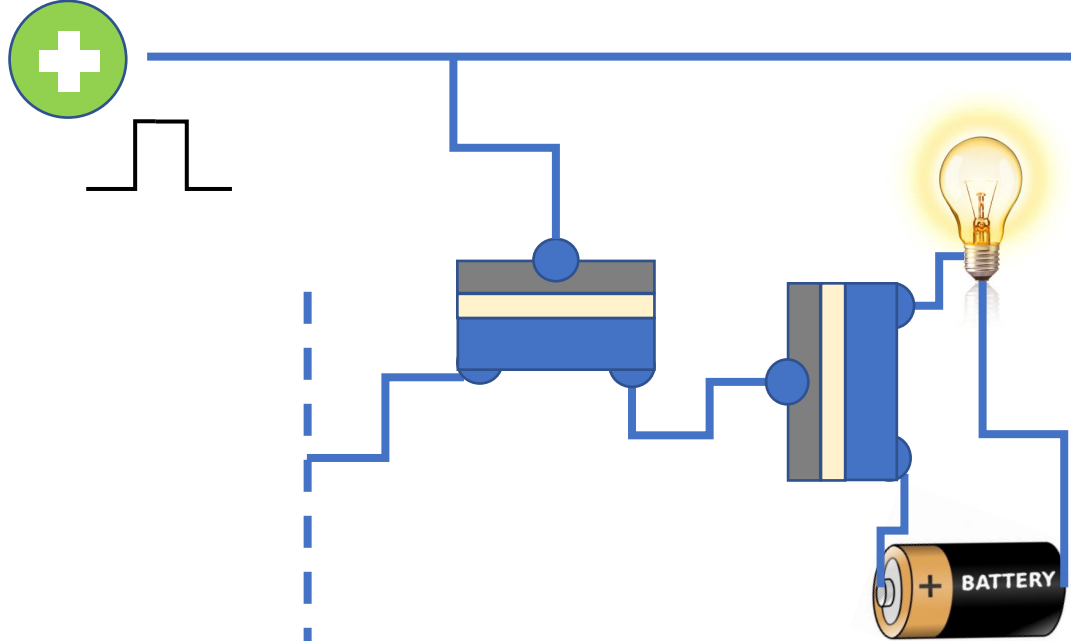




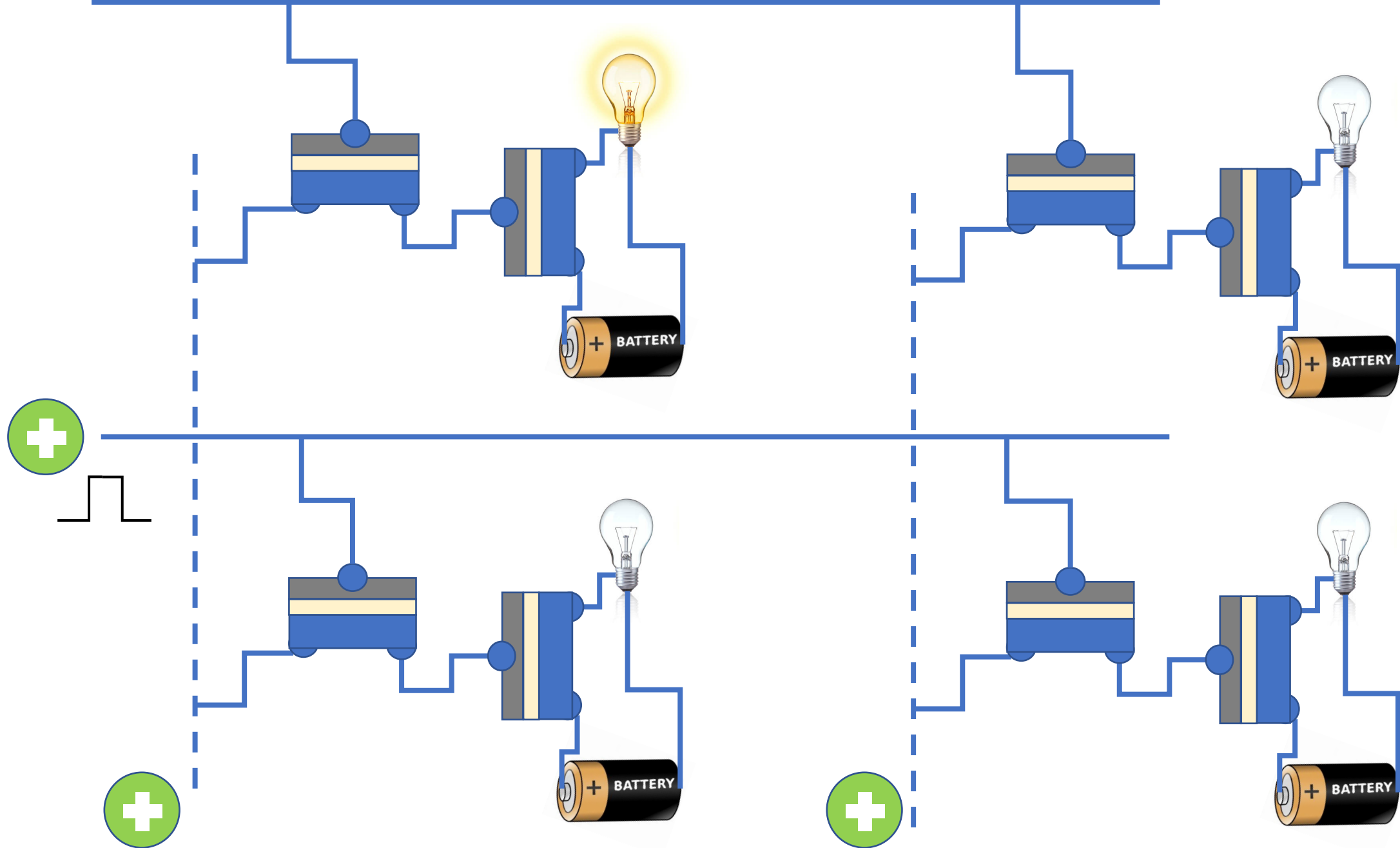


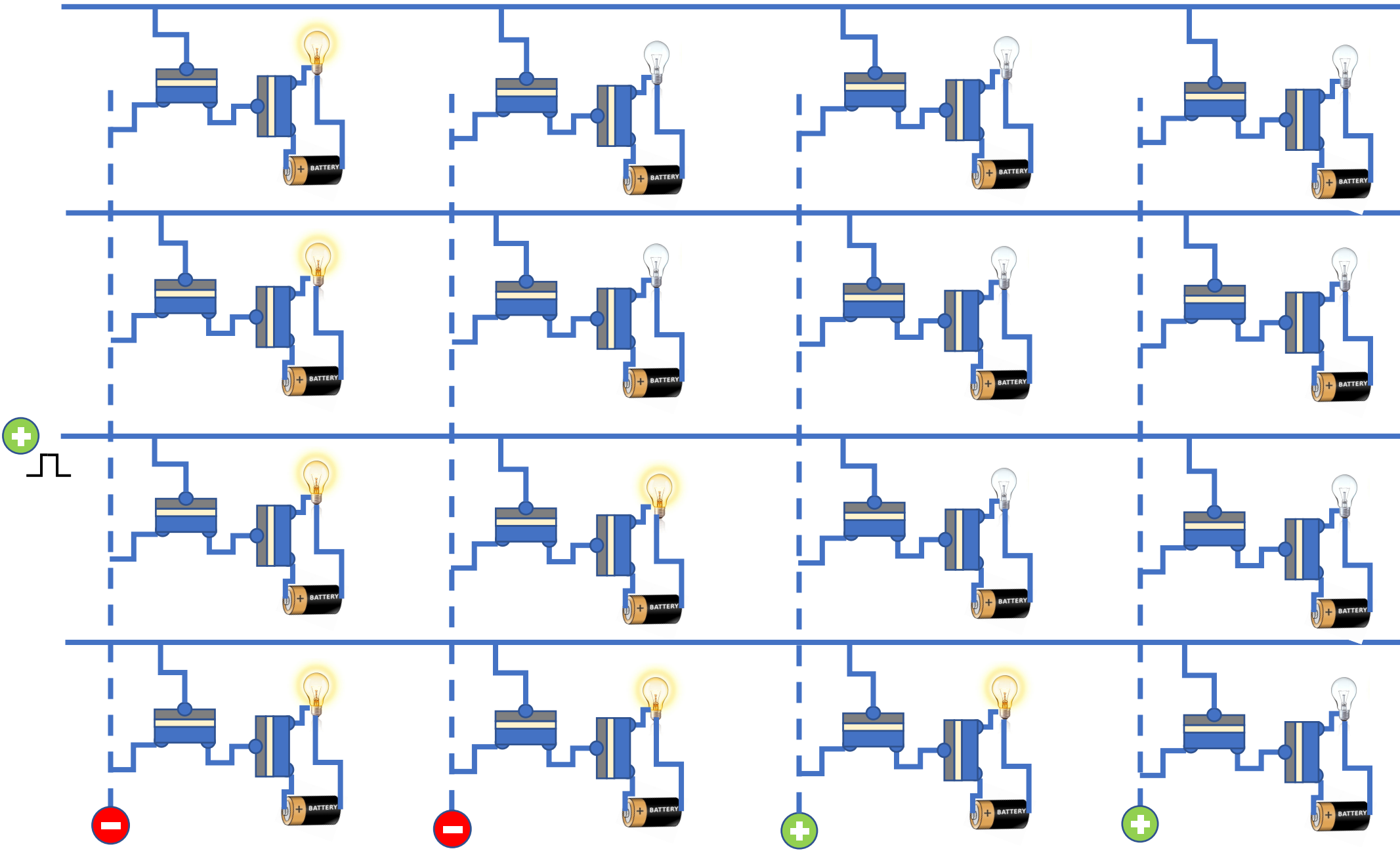


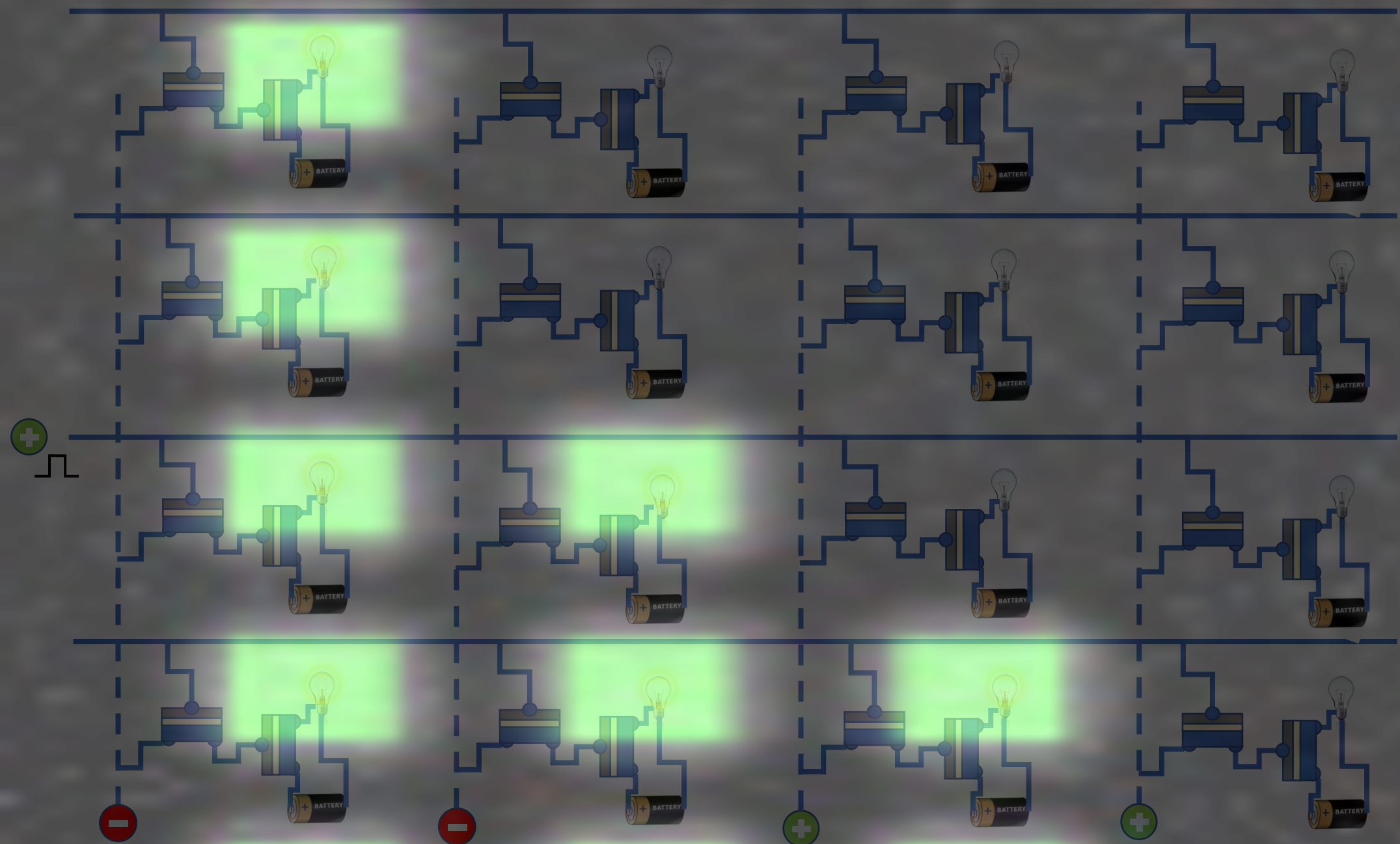












+

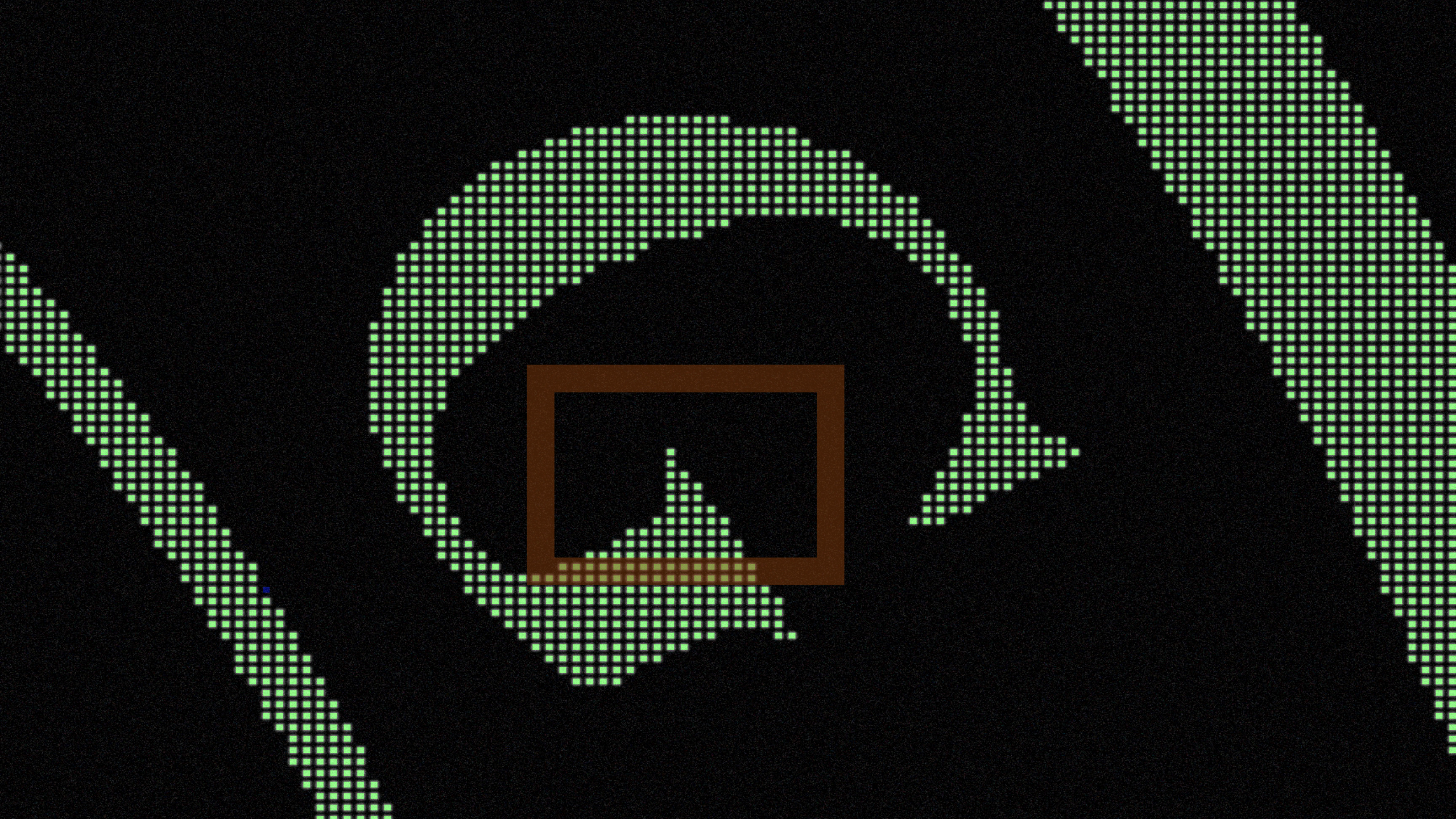
-

-

+

+

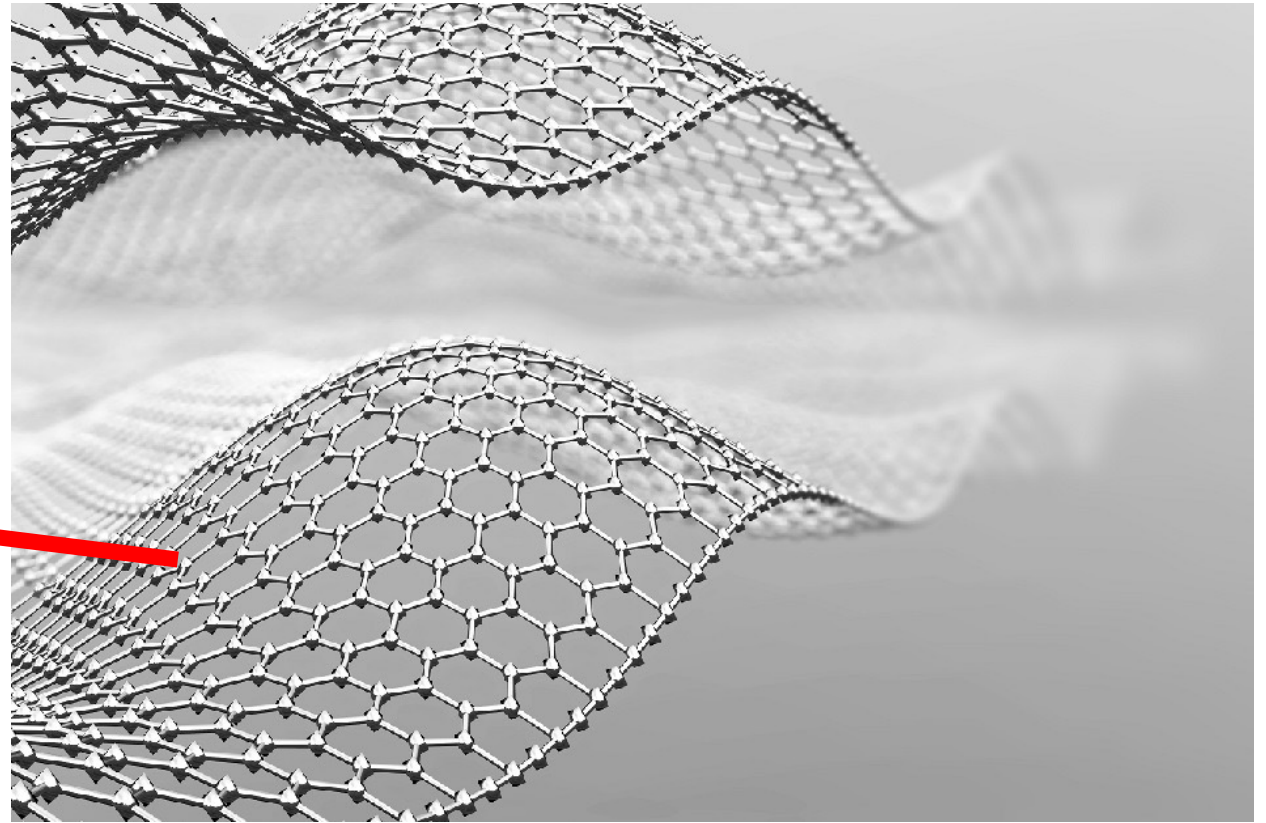
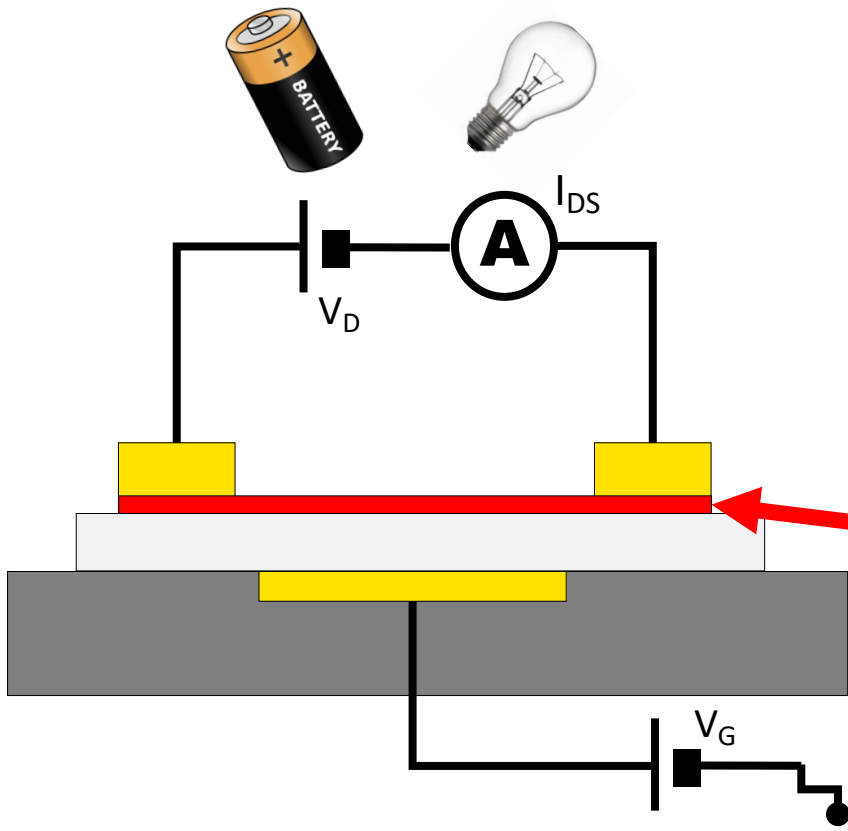






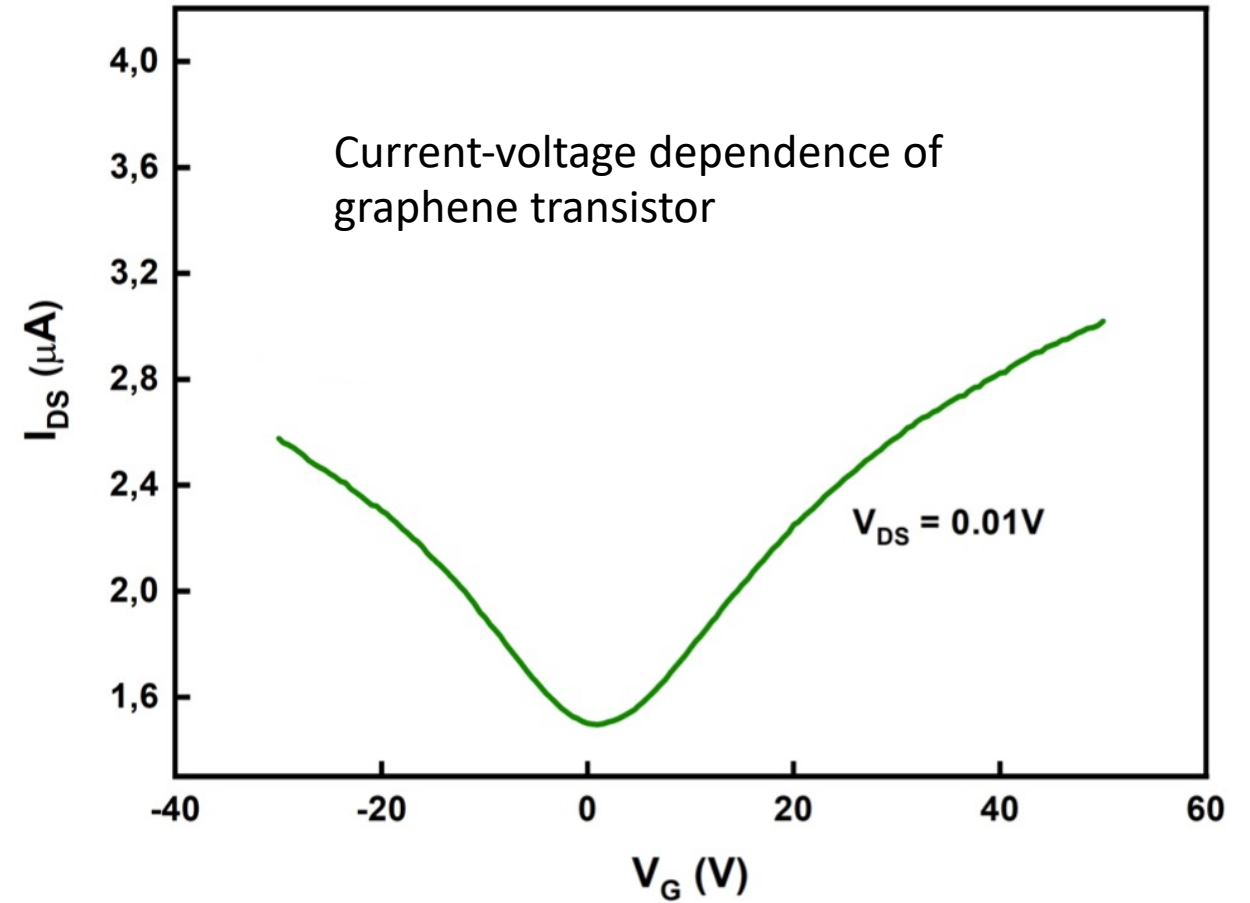
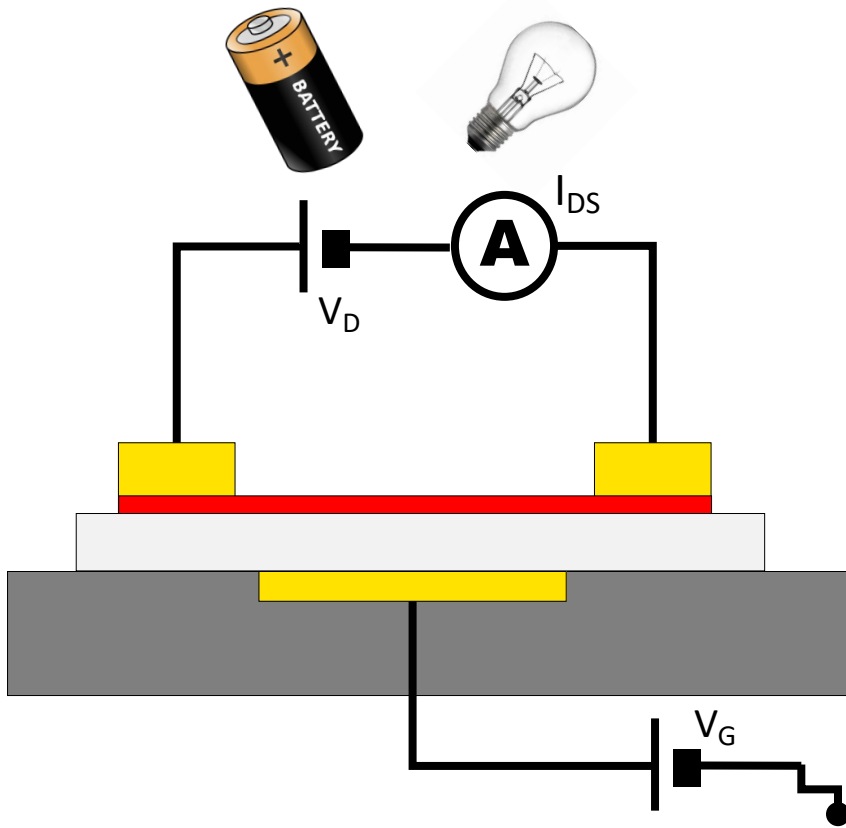


# Graphene transistor

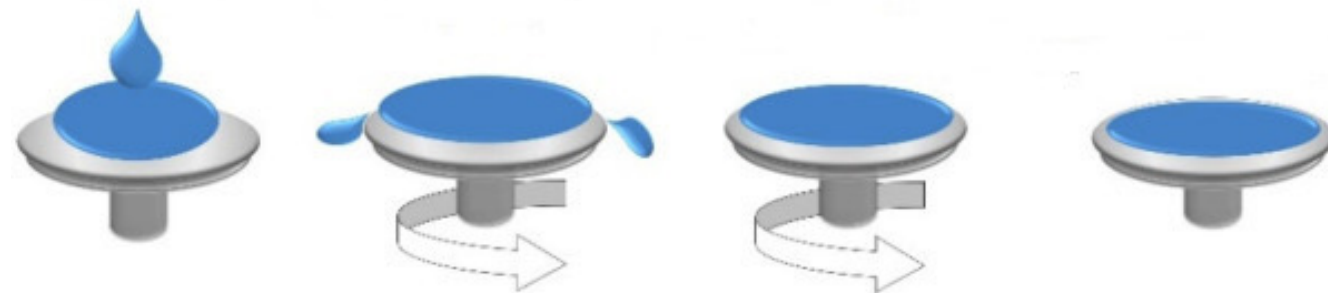
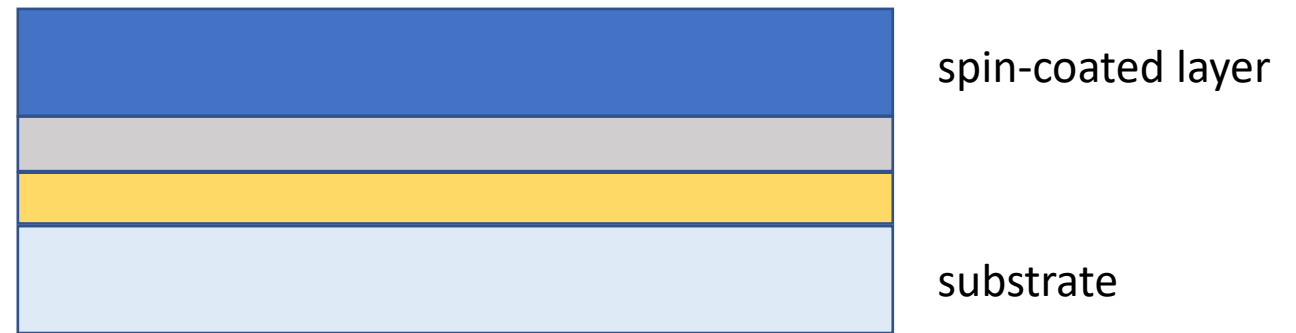




# Graphene transistor



# Spin-coating method



**MODEL WS-650MZ-23NPP**

**MOVING PARTS**  
**WARNING**  
Keep hands away from chamber area while in operation.

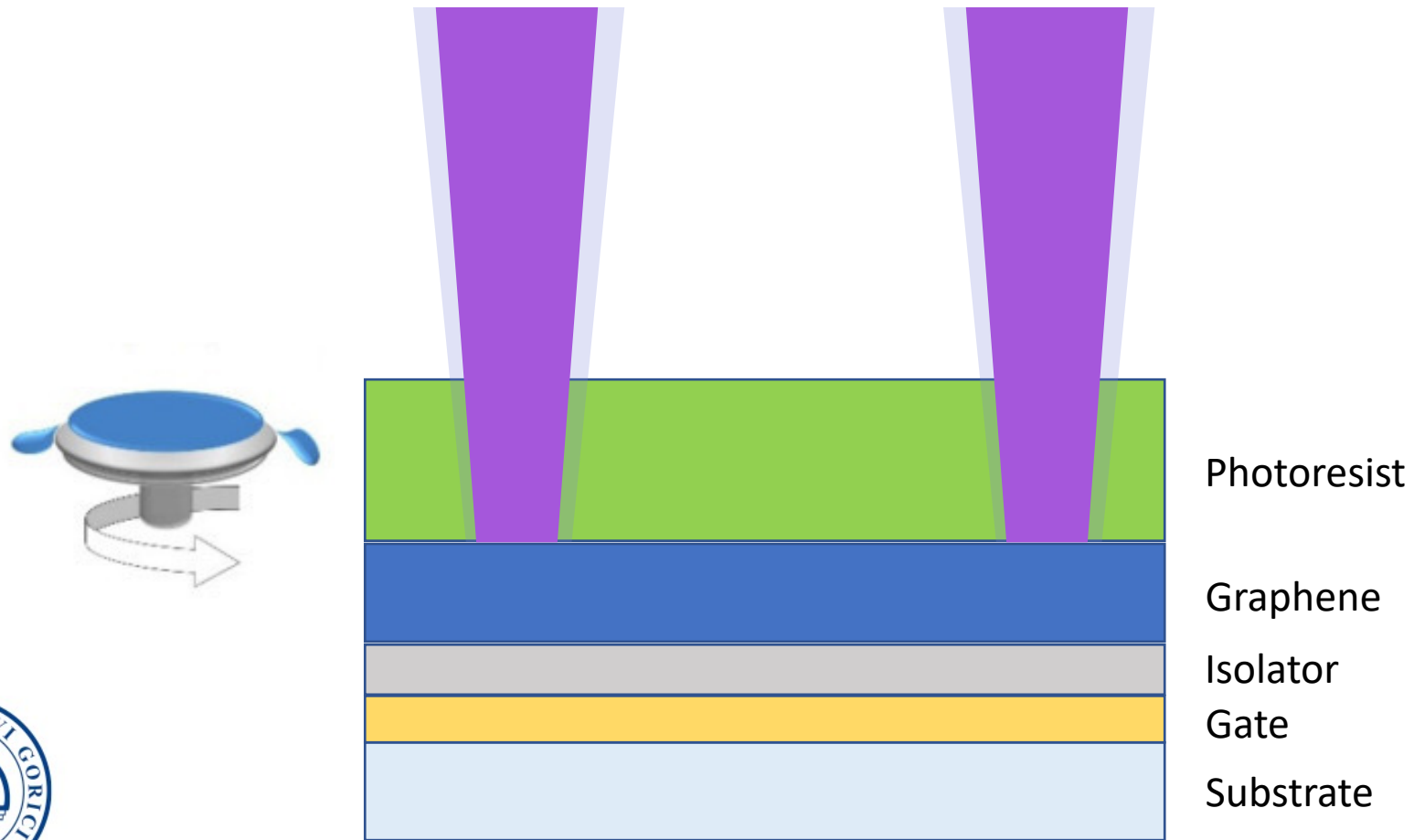
**WARNING**  
CHEMICAL SPLASH  
Wear appropriate eye protection when operating equipment.

Run: 429200-100  
SL: 48100 / 200  
Time: 1:00:12  
F1: 1:00:00 / 1:00:00  
F2: 1:00:00 / 1:00:00  
F3: 1:00:00 / 1:00:00  
F4: 1:00:00 / 1:00:00  
F5: 1:00:00 / 1:00:00  
F6: 1:00:00 / 1:00:00  
F7: 1:00:00 / 1:00:00  
F8: 1:00:00 / 1:00:00  
F9: 1:00:00 / 1:00:00  
F10: 1:00:00 / 1:00:00  
F11: 1:00:00 / 1:00:00  
F12: 1:00:00 / 1:00:00  
F13: 1:00:00 / 1:00:00  
F14: 1:00:00 / 1:00:00  
F15: 1:00:00 / 1:00:00  
F16: 1:00:00 / 1:00:00  
F17: 1:00:00 / 1:00:00  
F18: 1:00:00 / 1:00:00  
F19: 1:00:00 / 1:00:00  
F20: 1:00:00 / 1:00:00  
F21: 1:00:00 / 1:00:00  
F22: 1:00:00 / 1:00:00  
F23: 1:00:00 / 1:00:00  
F24: 1:00:00 / 1:00:00  
F25: 1:00:00 / 1:00:00  
F26: 1:00:00 / 1:00:00  
F27: 1:00:00 / 1:00:00  
F28: 1:00:00 / 1:00:00  
F29: 1:00:00 / 1:00:00  
F30: 1:00:00 / 1:00:00  
F31: 1:00:00 / 1:00:00  
F32: 1:00:00 / 1:00:00  
F33: 1:00:00 / 1:00:00  
F34: 1:00:00 / 1:00:00  
F35: 1:00:00 / 1:00:00  
F36: 1:00:00 / 1:00:00  
F37: 1:00:00 / 1:00:00  
F38: 1:00:00 / 1:00:00  
F39: 1:00:00 / 1:00:00  
F40: 1:00:00 / 1:00:00  
F41: 1:00:00 / 1:00:00  
F42: 1:00:00 / 1:00:00  
F43: 1:00:00 / 1:00:00  
F44: 1:00:00 / 1:00:00  
F45: 1:00:00 / 1:00:00  
F46: 1:00:00 / 1:00:00  
F47: 1:00:00 / 1:00:00  
F48: 1:00:00 / 1:00:00  
F49: 1:00:00 / 1:00:00  
F50: 1:00:00 / 1:00:00  
F51: 1:00:00 / 1:00:00  
F52: 1:00:00 / 1:00:00  
F53: 1:00:00 / 1:00:00  
F54: 1:00:00 / 1:00:00  
F55: 1:00:00 / 1:00:00  
F56: 1:00:00 / 1:00:00  
F57: 1:00:00 / 1:00:00  
F58: 1:00:00 / 1:00:00  
F59: 1:00:00 / 1:00:00  
F60: 1:00:00 / 1:00:00  
F61: 1:00:00 / 1:00:00  
F62: 1:00:00 / 1:00:00  
F63: 1:00:00 / 1:00:00  
F64: 1:00:00 / 1:00:00  
F65: 1:00:00 / 1:00:00  
F66: 1:00:00 / 1:00:00  
F67: 1:00:00 / 1:00:00  
F68: 1:00:00 / 1:00:00  
F69: 1:00:00 / 1:00:00  
F70: 1:00:00 / 1:00:00  
F71: 1:00:00 / 1:00:00  
F72: 1:00:00 / 1:00:00  
F73: 1:00:00 / 1:00:00  
F74: 1:00:00 / 1:00:00  
F75: 1:00:00 / 1:00:00  
F76: 1:00:00 / 1:00:00  
F77: 1:00:00 / 1:00:00  
F78: 1:00:00 / 1:00:00  
F79: 1:00:00 / 1:00:00  
F80: 1:00:00 / 1:00:00  
F81: 1:00:00 / 1:00:00  
F82: 1:00:00 / 1:00:00  
F83: 1:00:00 / 1:00:00  
F84: 1:00:00 / 1:00:00  
F85: 1:00:00 / 1:00:00  
F86: 1:00:00 / 1:00:00  
F87: 1:00:00 / 1:00:00  
F88: 1:00:00 / 1:00:00  
F89: 1:00:00 / 1:00:00  
F90: 1:00:00 / 1:00:00  
F91: 1:00:00 / 1:00:00  
F92: 1:00:00 / 1:00:00  
F93: 1:00:00 / 1:00:00  
F94: 1:00:00 / 1:00:00  
F95: 1:00:00 / 1:00:00  
F96: 1:00:00 / 1:00:00  
F97: 1:00:00 / 1:00:00  
F98: 1:00:00 / 1:00:00  
F99: 1:00:00 / 1:00:00  
F100: 1:00:00 / 1:00:00

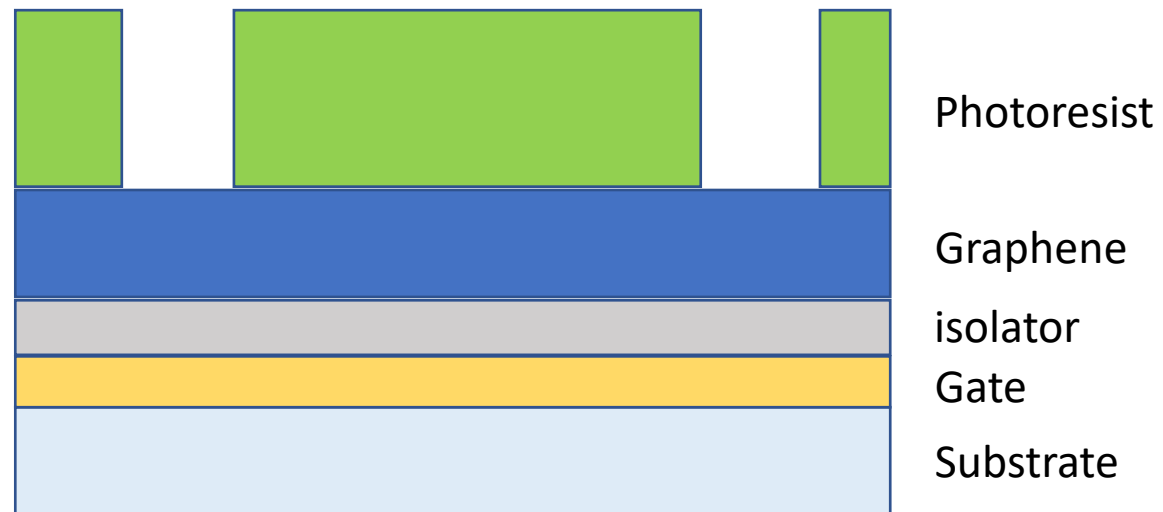
**SELECT PROCESS**  
**RUN MODE**  
**EDIT MODE**  
**INFO**

**VACUUM**  
**F1**  
**F2**  
**PG UP**  
**PG DN**  
**START**  
**STOP**  
**PAUSE**  
**REV**  
**FWD**

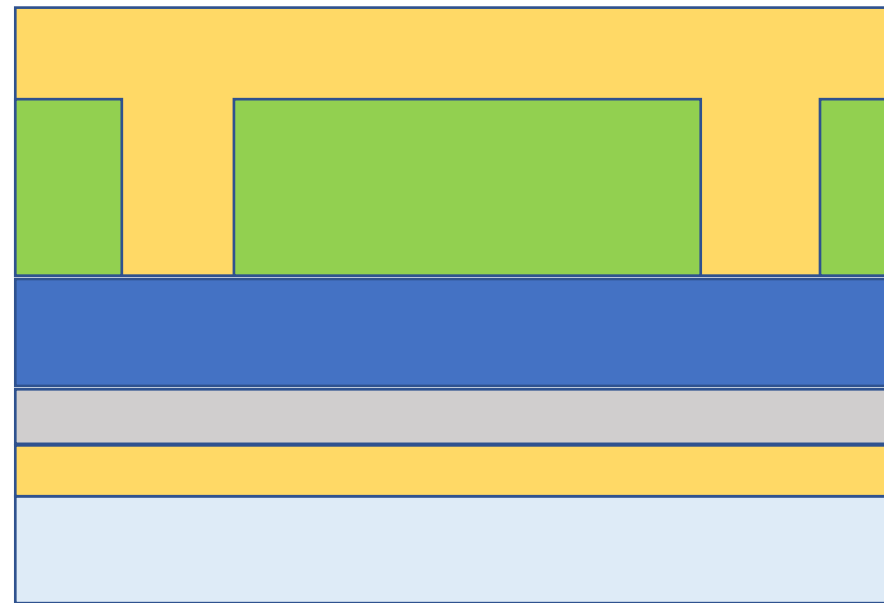
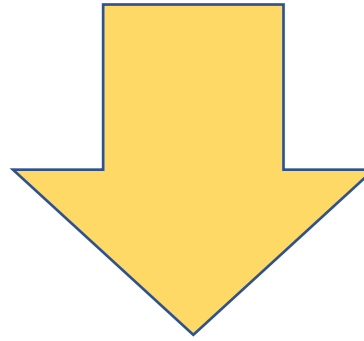
# Lithography 1st step



# Lithography 2nd step



# Lithography 3rd step

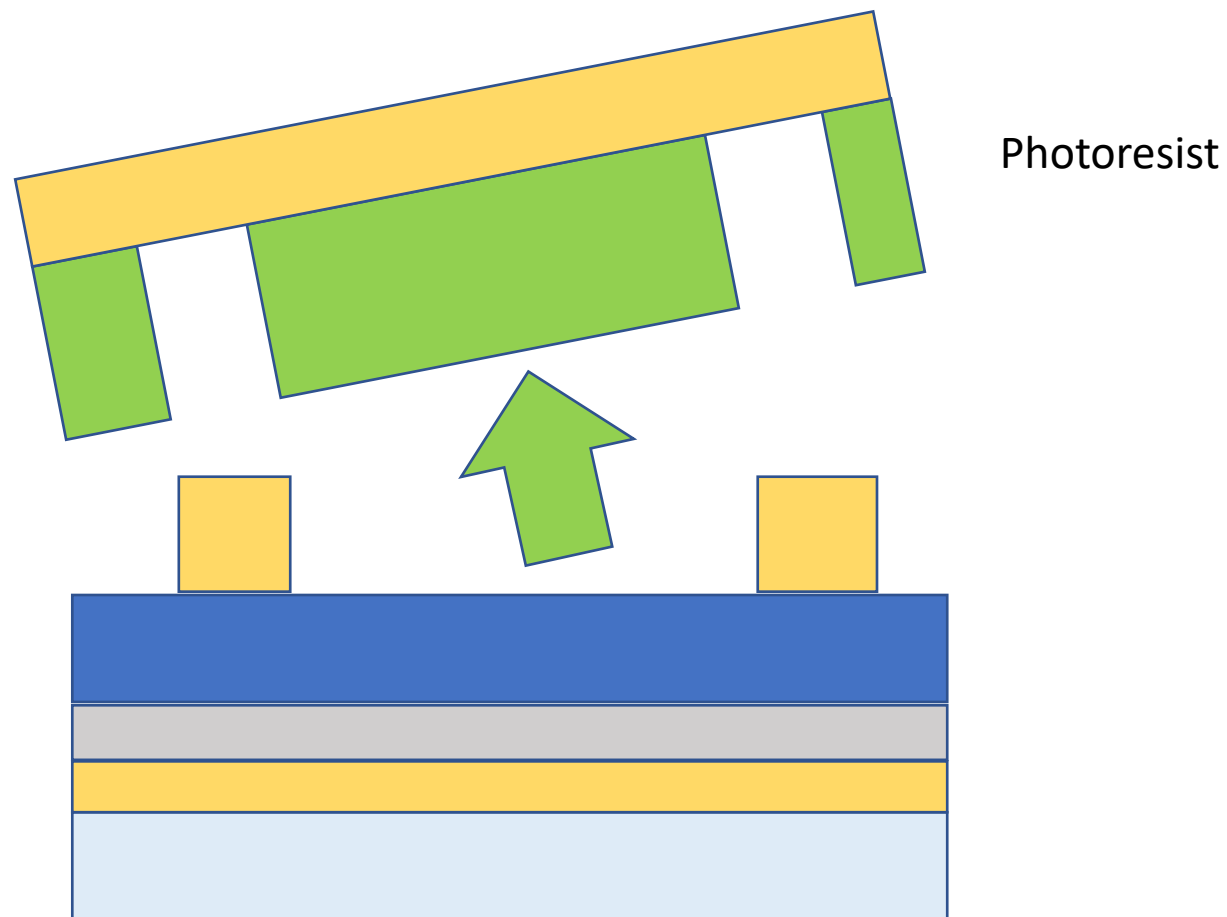


Evaporated gold

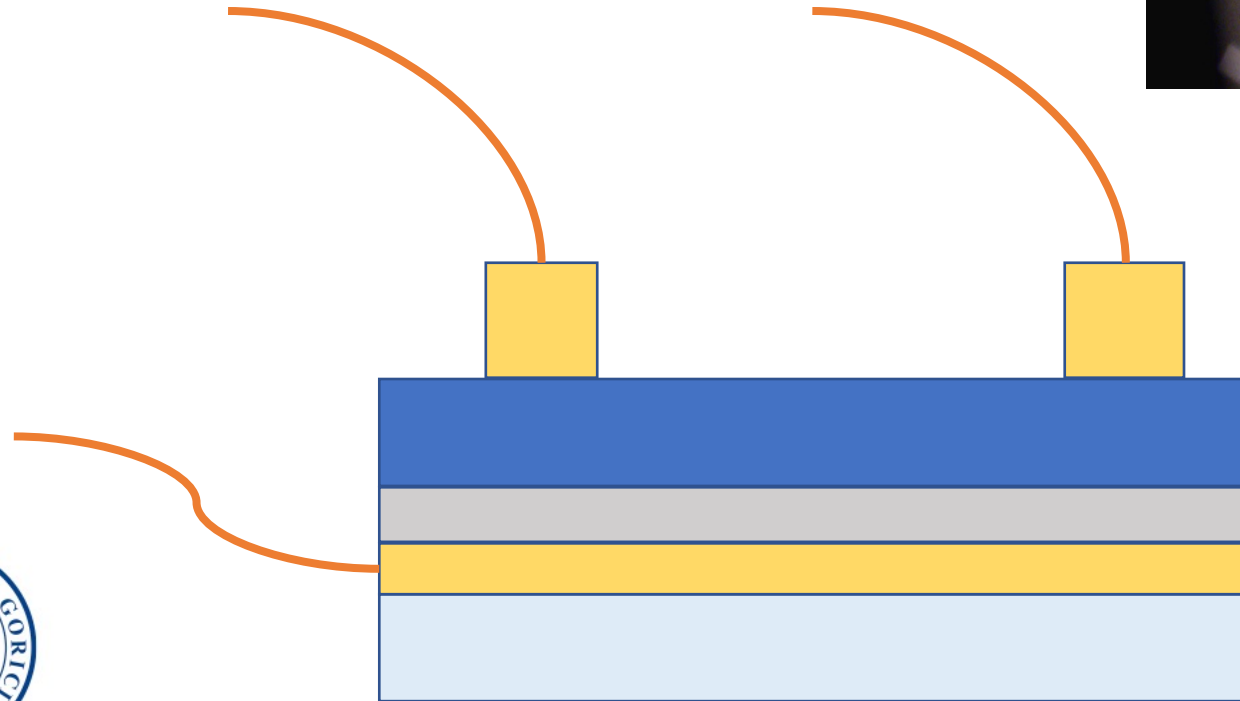
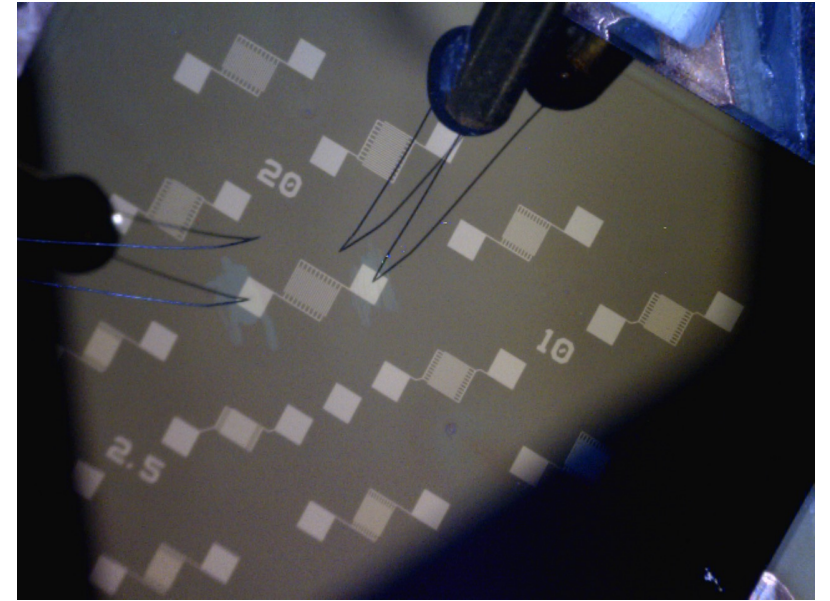
Photoresist



# Lithography 4th step

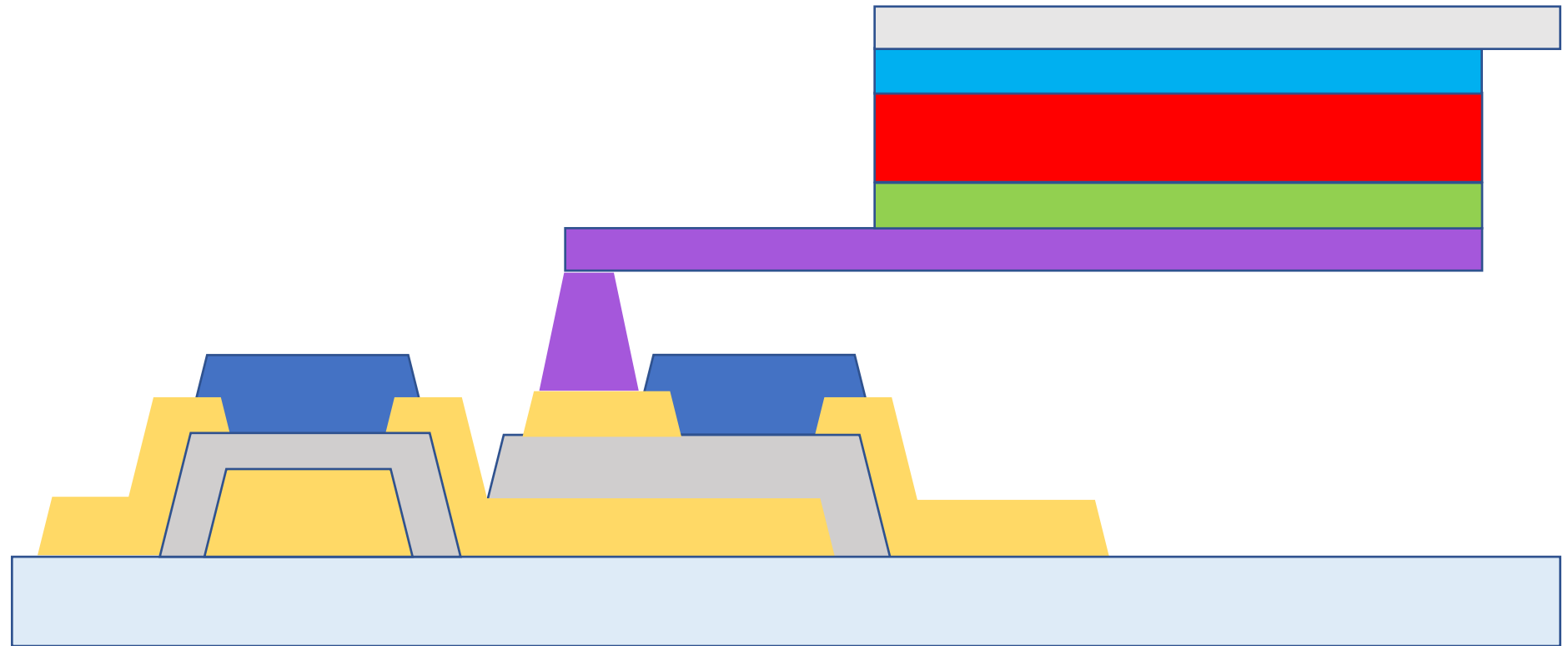


# Transistor

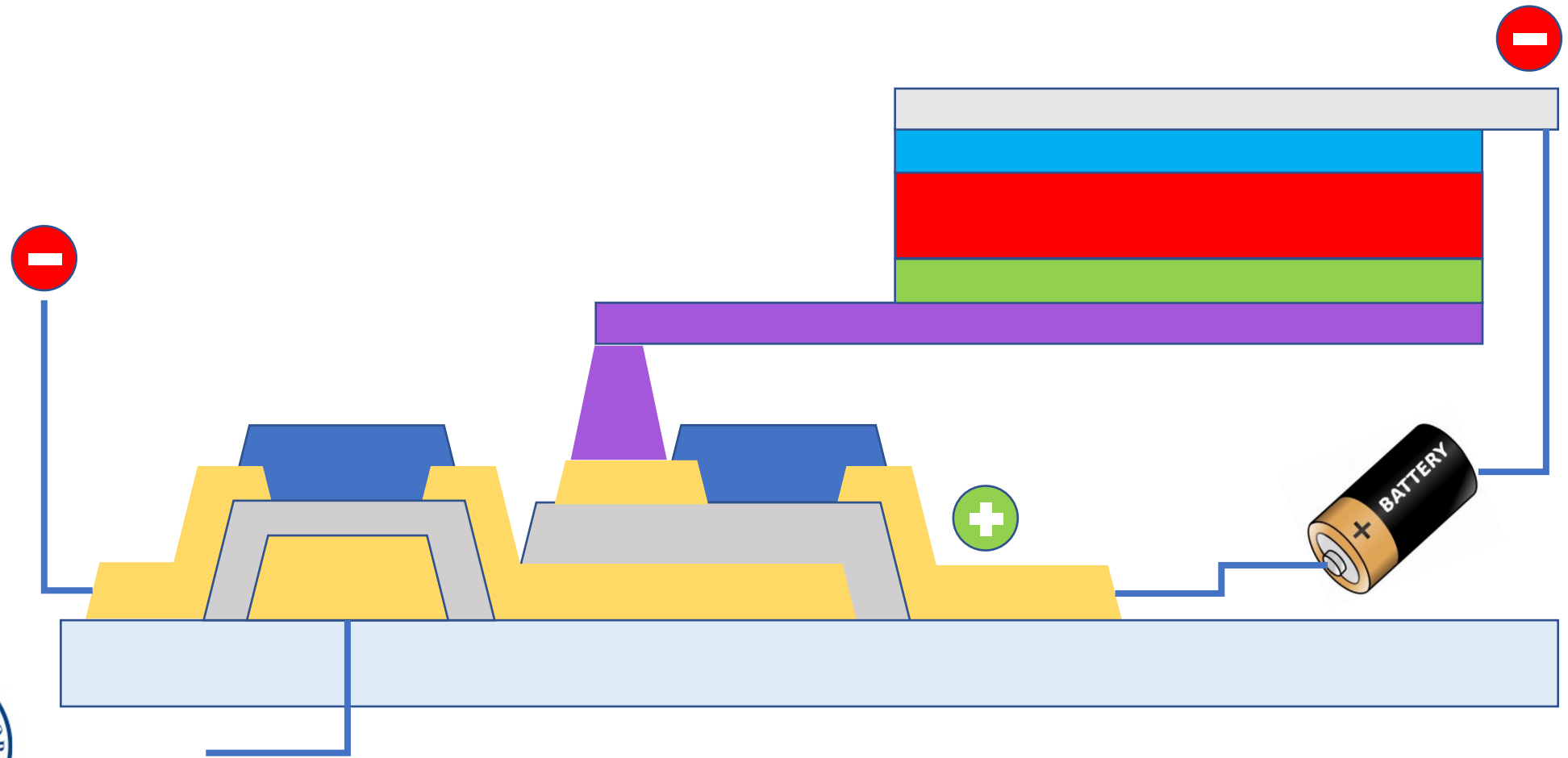




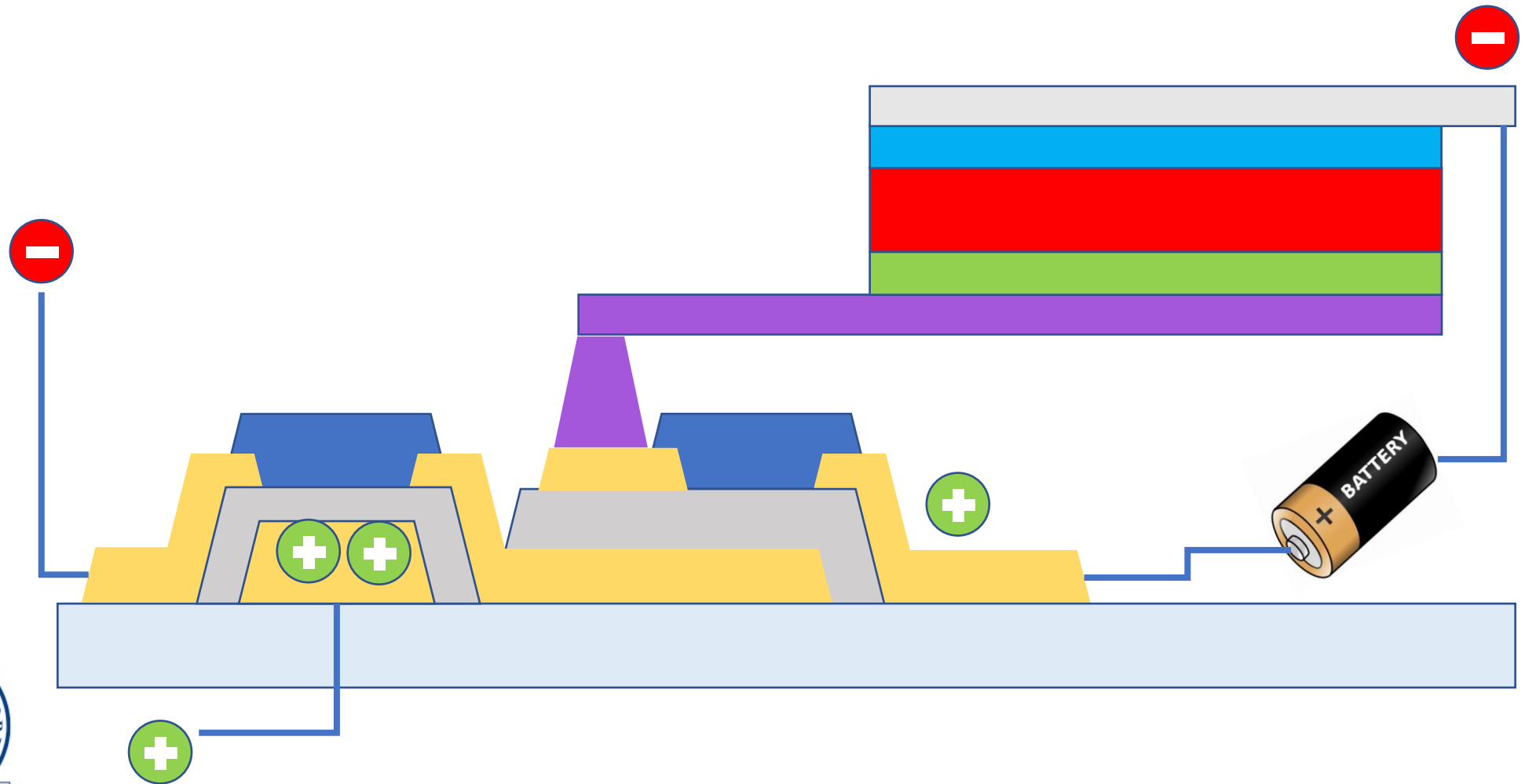
# Two transistors and OLED



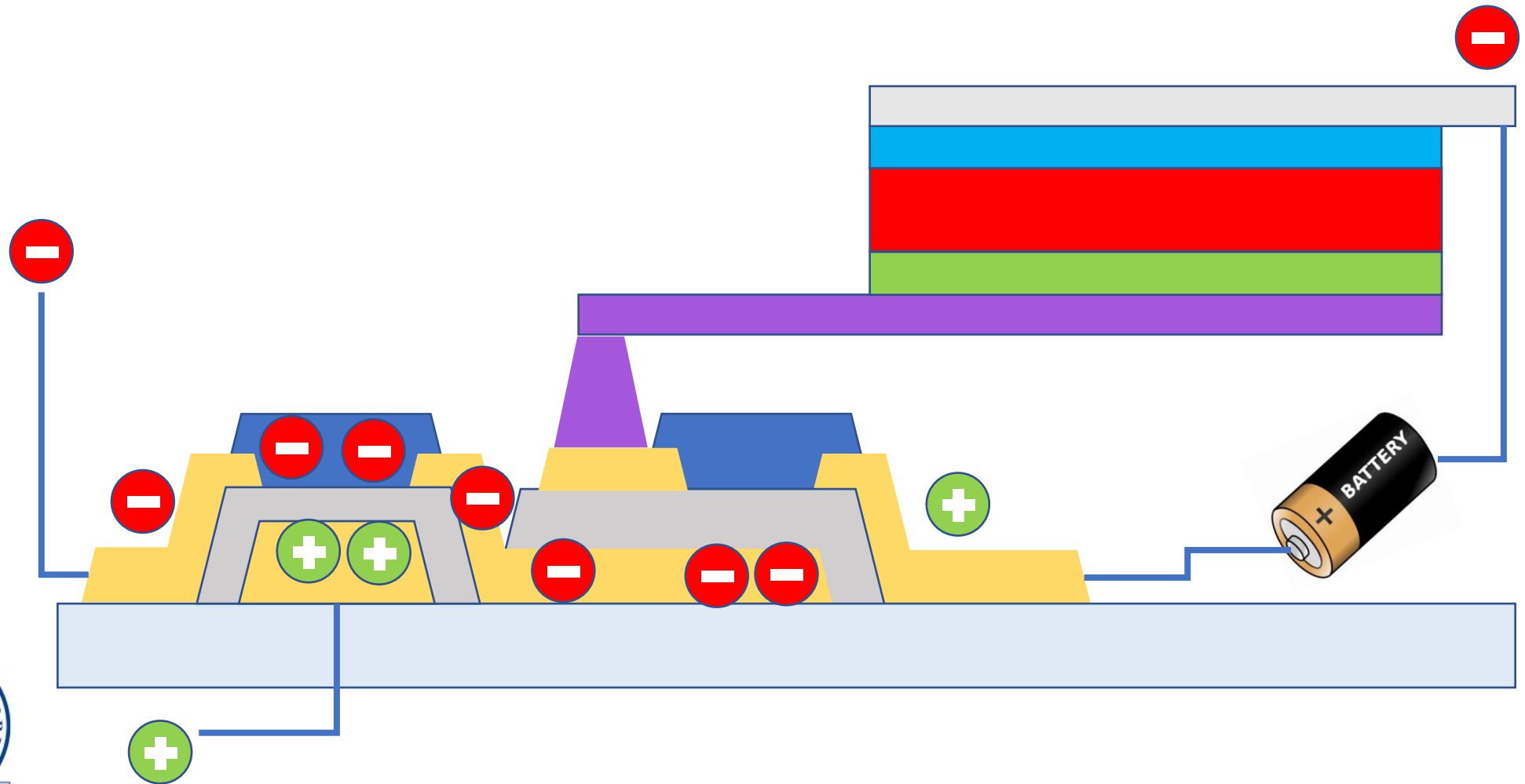
# Two transistors and OLED



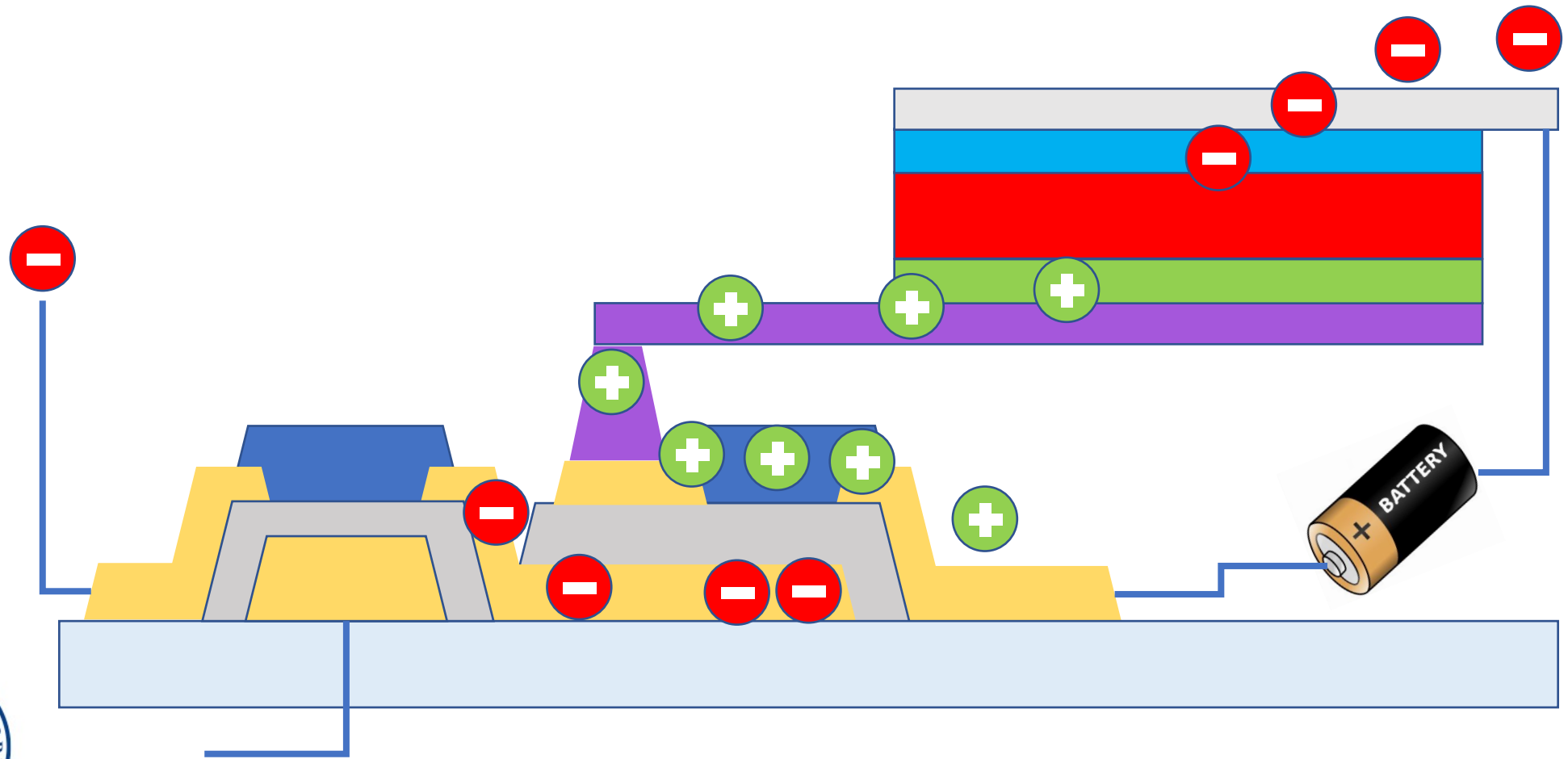
# Two transistors and OLED



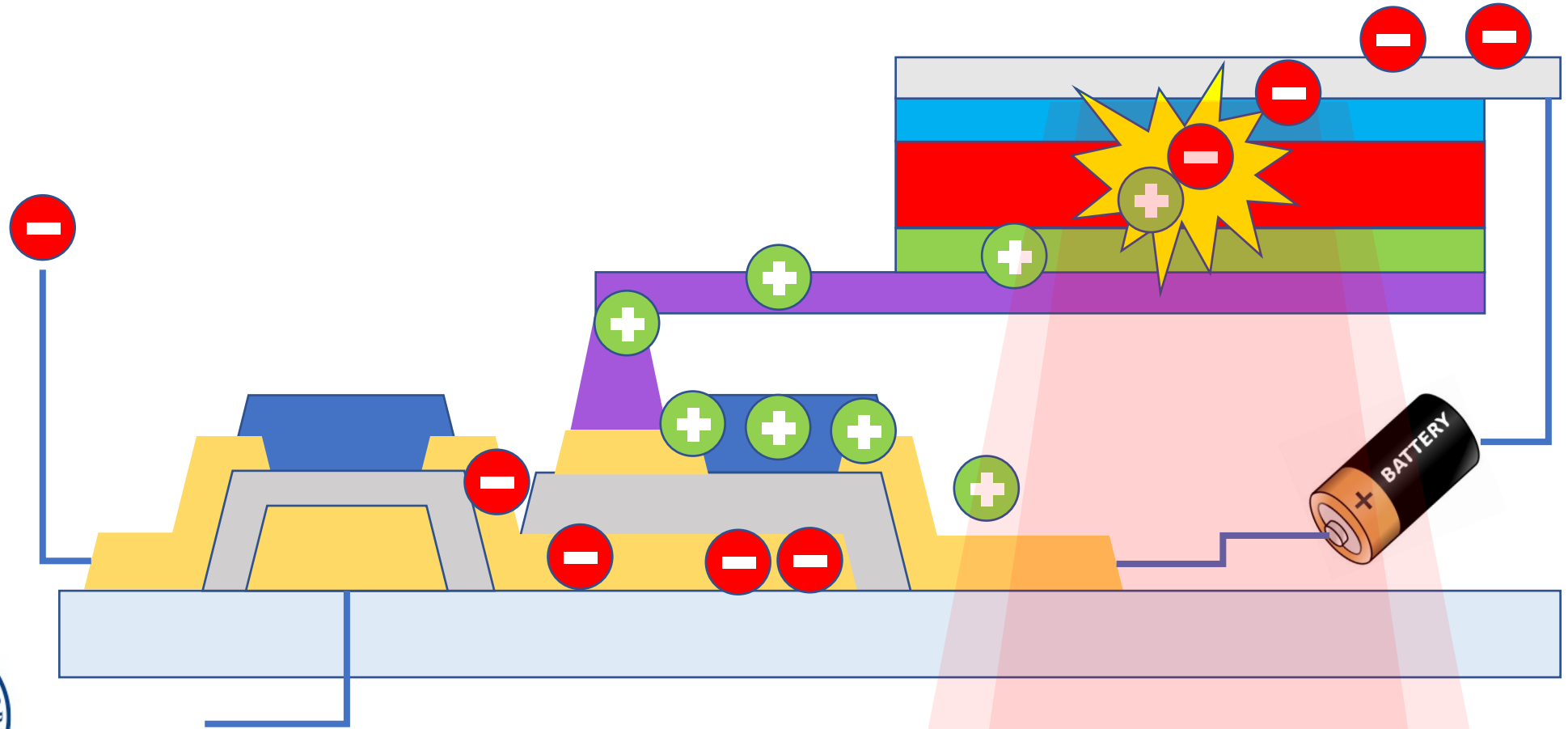
# Two transistors and OLED



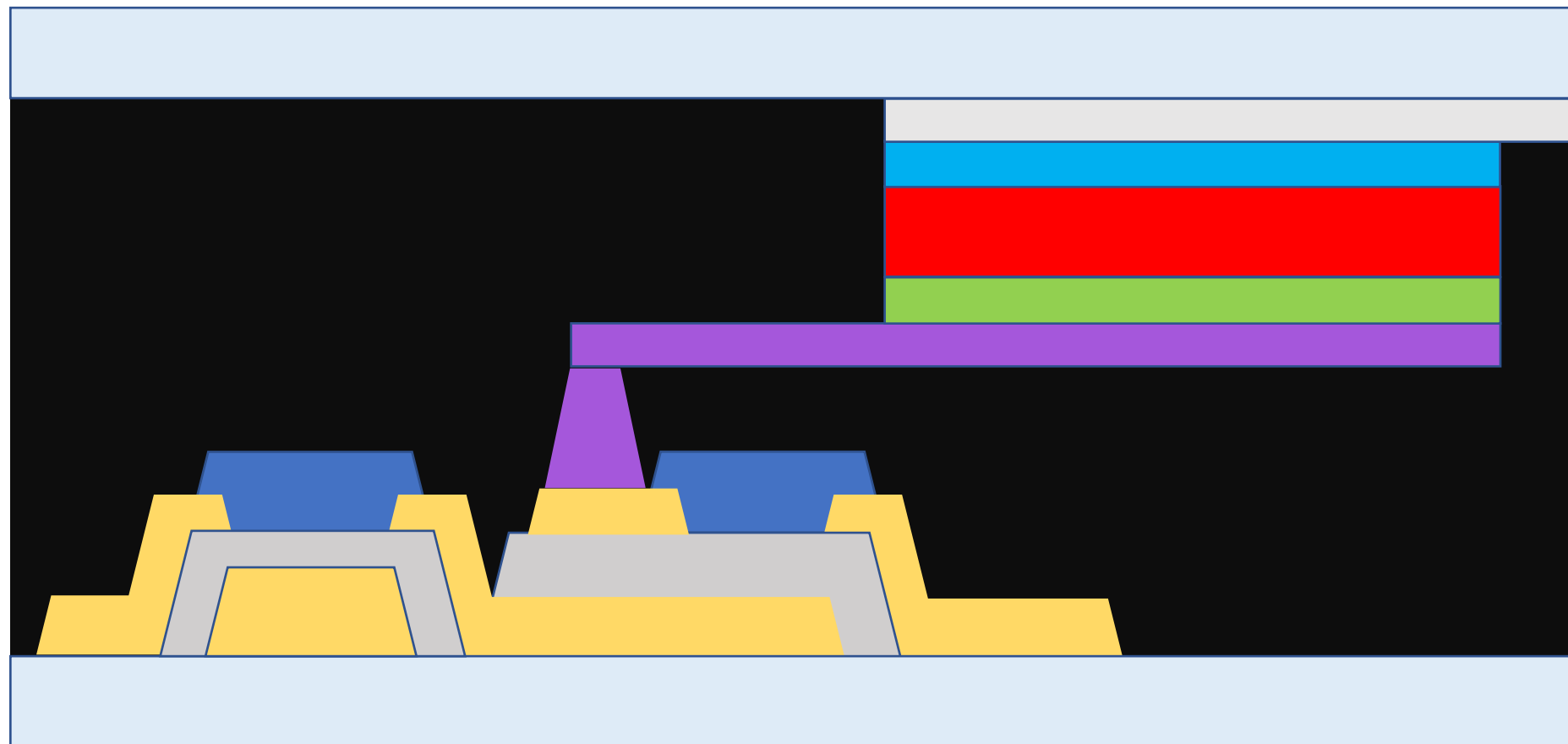
# Two transistors and OLED

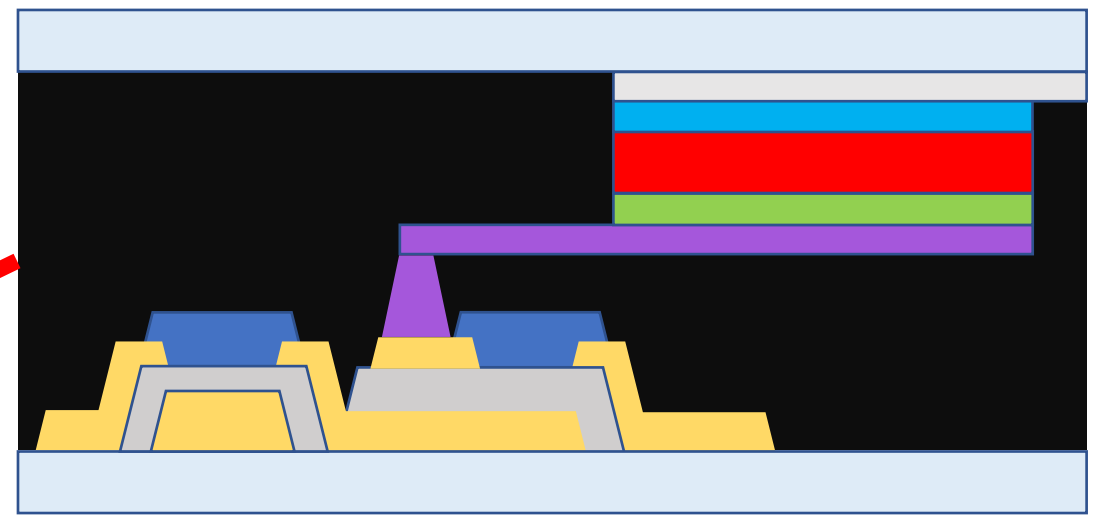


# Two transistors and OLED



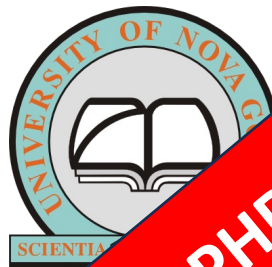
# Encapsulation







# REGINNA<sup>4.0</sup>



**ONE PHD POSITION IS OPEN –  
APPLY NOW!**



**LABORATORY FOR  
ORGANIC MATTER PHYSICS**



Supported by



Funded by the  
European Union



[www.reginna4-0.eu](http://www.reginna4-0.eu)