The Photoelectric Effect:

Fundamental Principle of Digital Cameras

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Einstein's Proposal of the Photon Concept—a Translation of the *Annalen der Physik* Paper of 1905*

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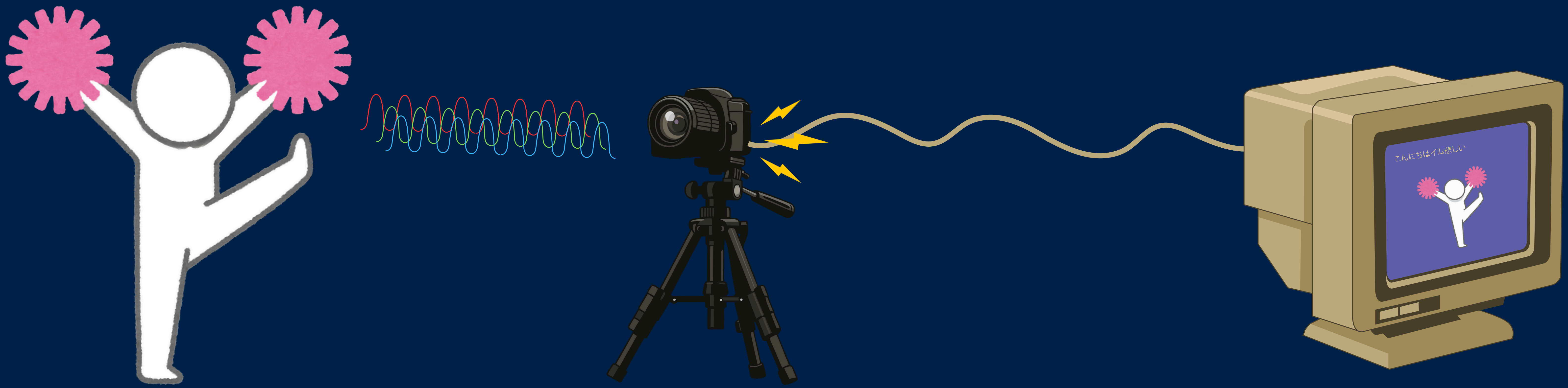
Of the trio of famous papers that Albert Einstein sent to the *Annalen der Physik* in 1905 only the paper proposing the photon concept has been unavailable in English translation. The *American Journal of Physics* is publishing the following translation in recognition of the sixtieth anniversary of the appearance of the original work. Physics teachers may take particular interest in the following aspects: (1) Einstein's keen awareness of the heuristic character of his new conception. (2) His demonstration from *thermodynamic* and *statistical* considerations that electromagnetic radiation might be conceived as consisting of finite numbers of discrete corpuscles of energy $h\nu$. (3) His *prediction* of the linear relation between the stopping potential of photoelectrons and the frequency of the incident light. This latter aspect of the photoelectric effect was not included among Lenard's early investigations. It remained for Millikan and others to develop the elegant experimental techniques that confirmed Einstein's bold prediction. Readers interested in pursuing the background in greater depth will find it rewarding to refer to the critical analyses by Martin J. Klein in "Einstein's First Paper on Quanta," in *The Natural Philosopher* (Blaisdell Publishing Company, New York, 1963), Vol. II, and "Einstein and the Wave–Particle Duality," in *The Natural Philosopher*, Vol. III, 1964. We are grateful to Professor Klein for his criticism and advice regarding this translation and for his generosity in making available to us an unpublished translation of his own.

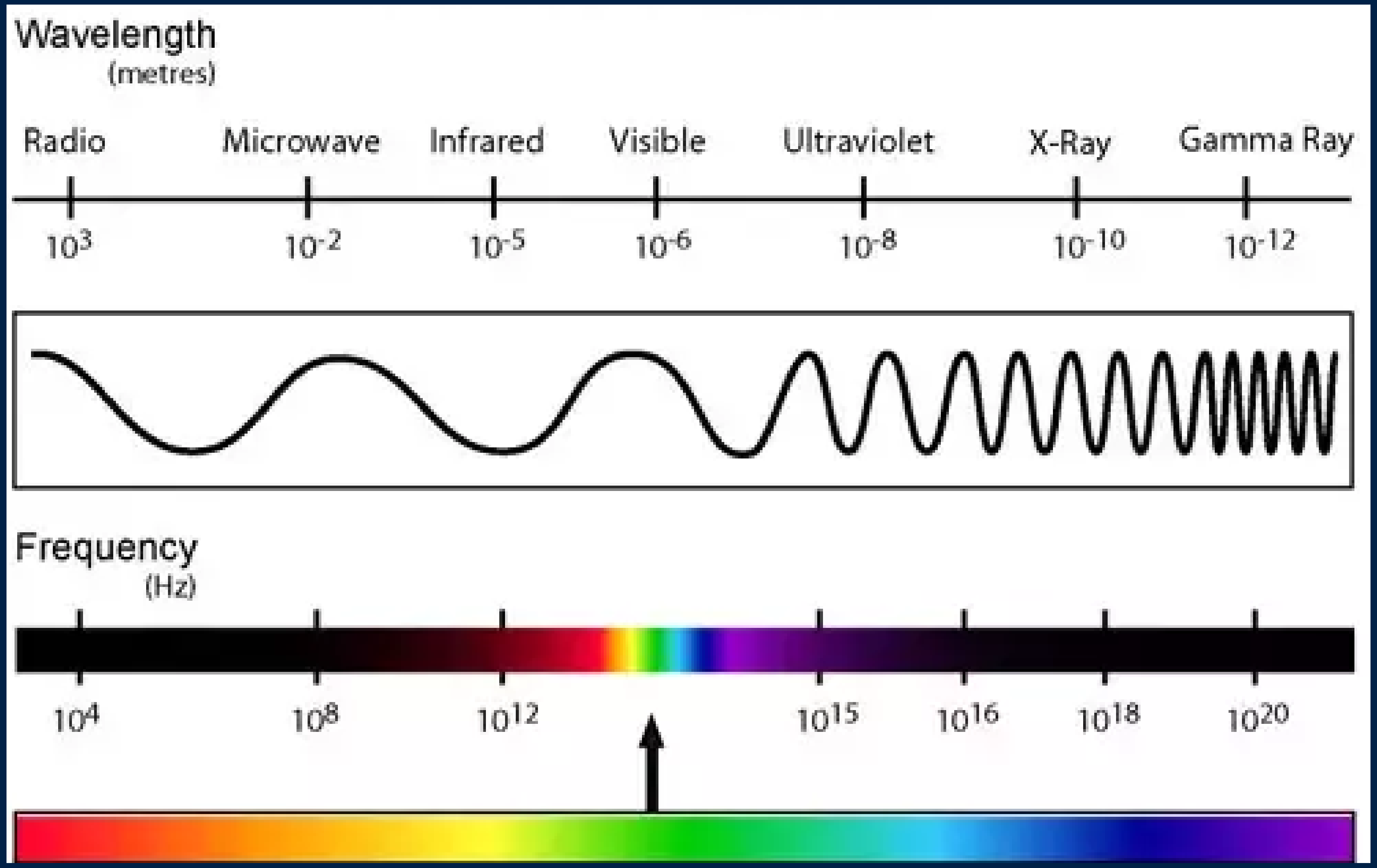
GOAL:

Build an intuition on how light is transformed into electricity and bits to create an image on a monitor.

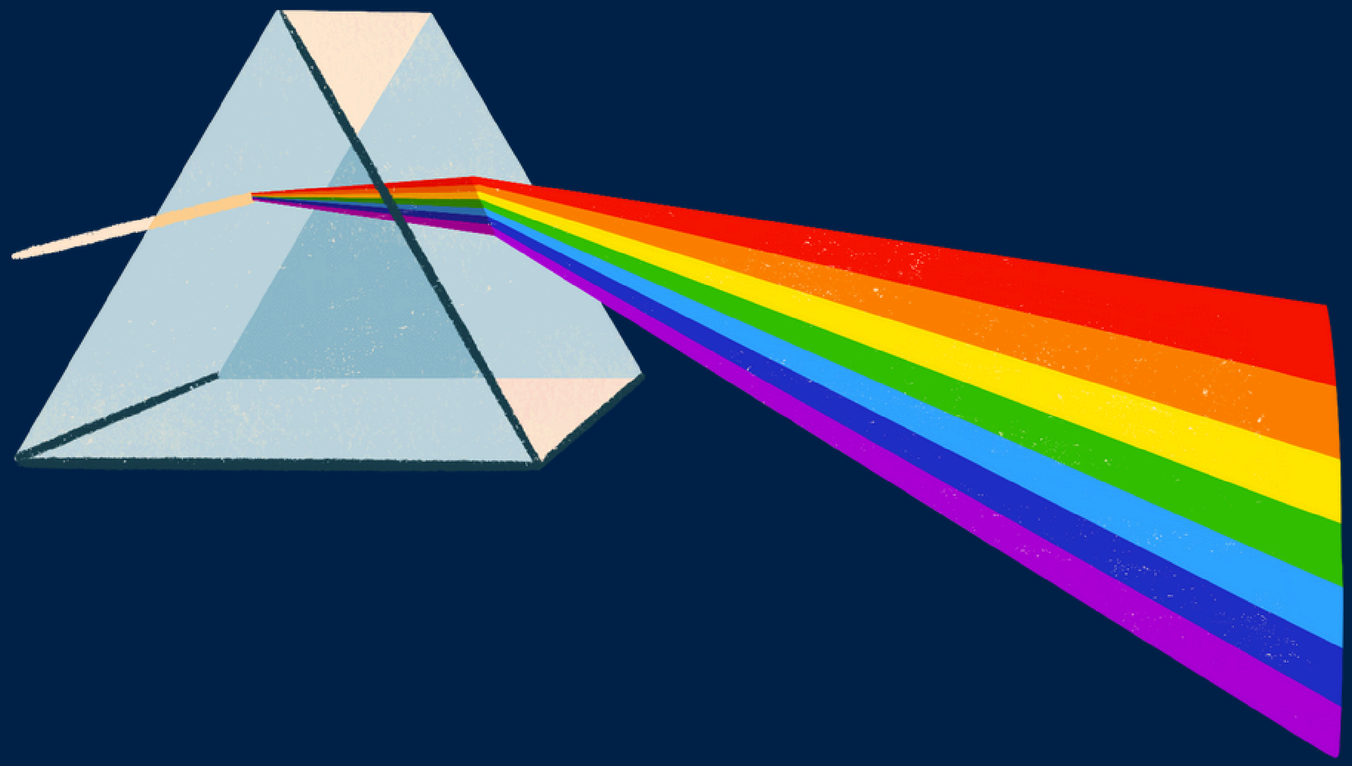


Electromagnetic Spectrum

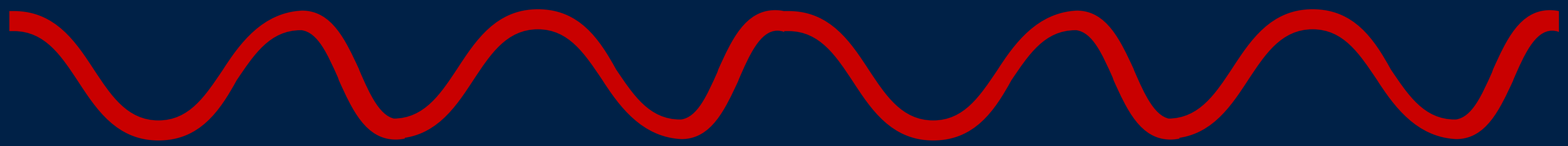
- Different colours are just different frequencies of the same concept.



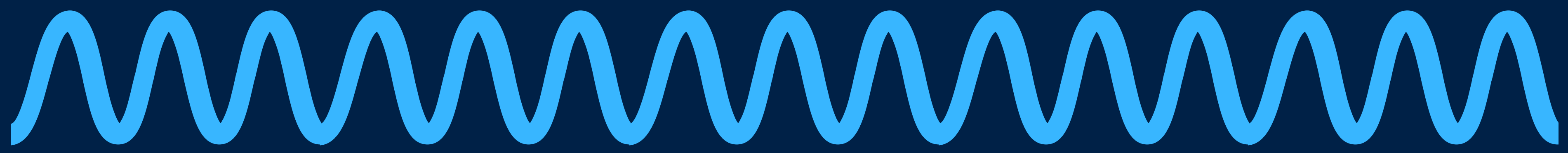
- White light is just a combination of all the colours in the visible spectrum.



Electromagnetic Spectrum

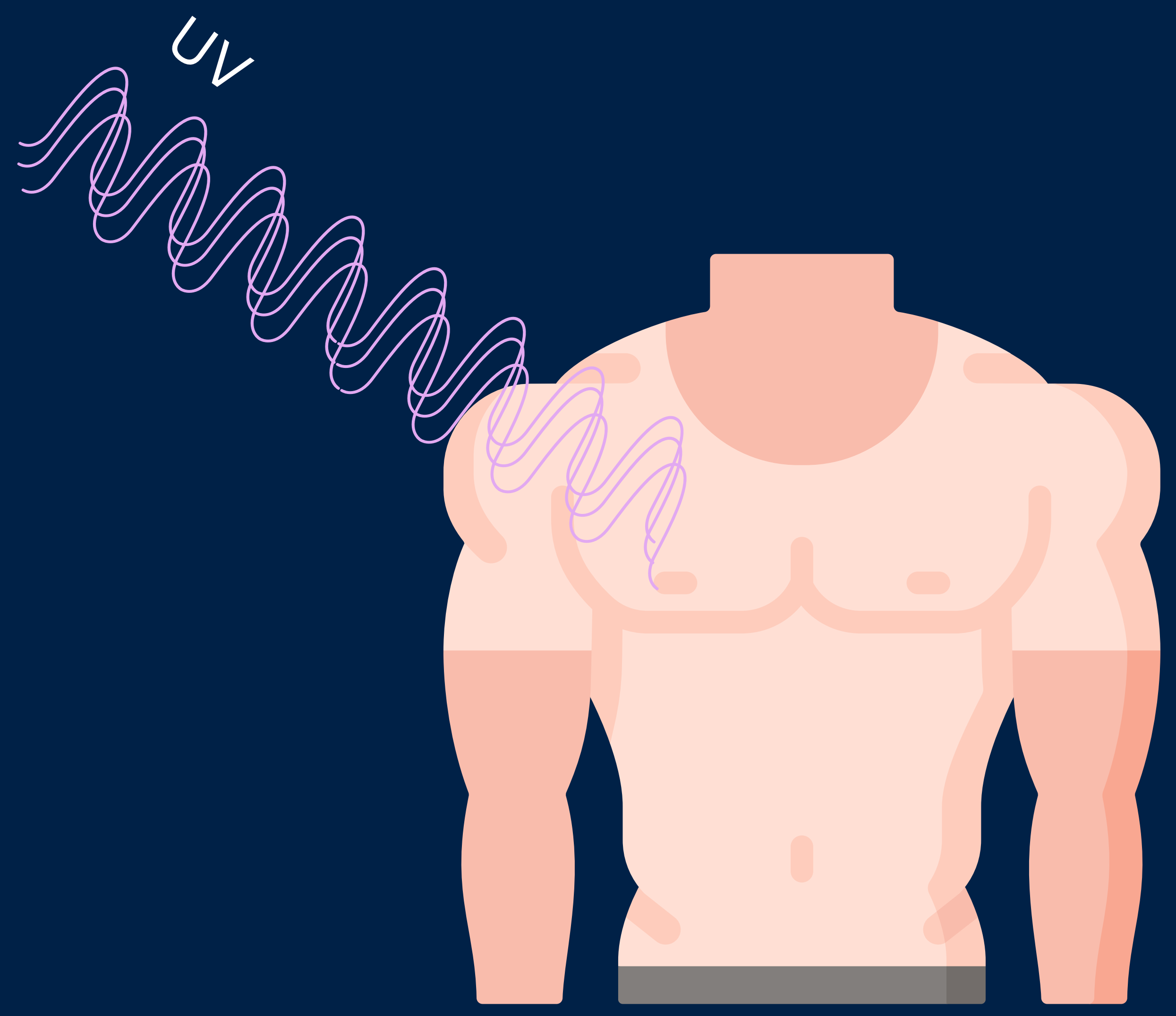


c = 299 792 458 m/s



Historically: From Light to Images

Light can trigger reactions in matter



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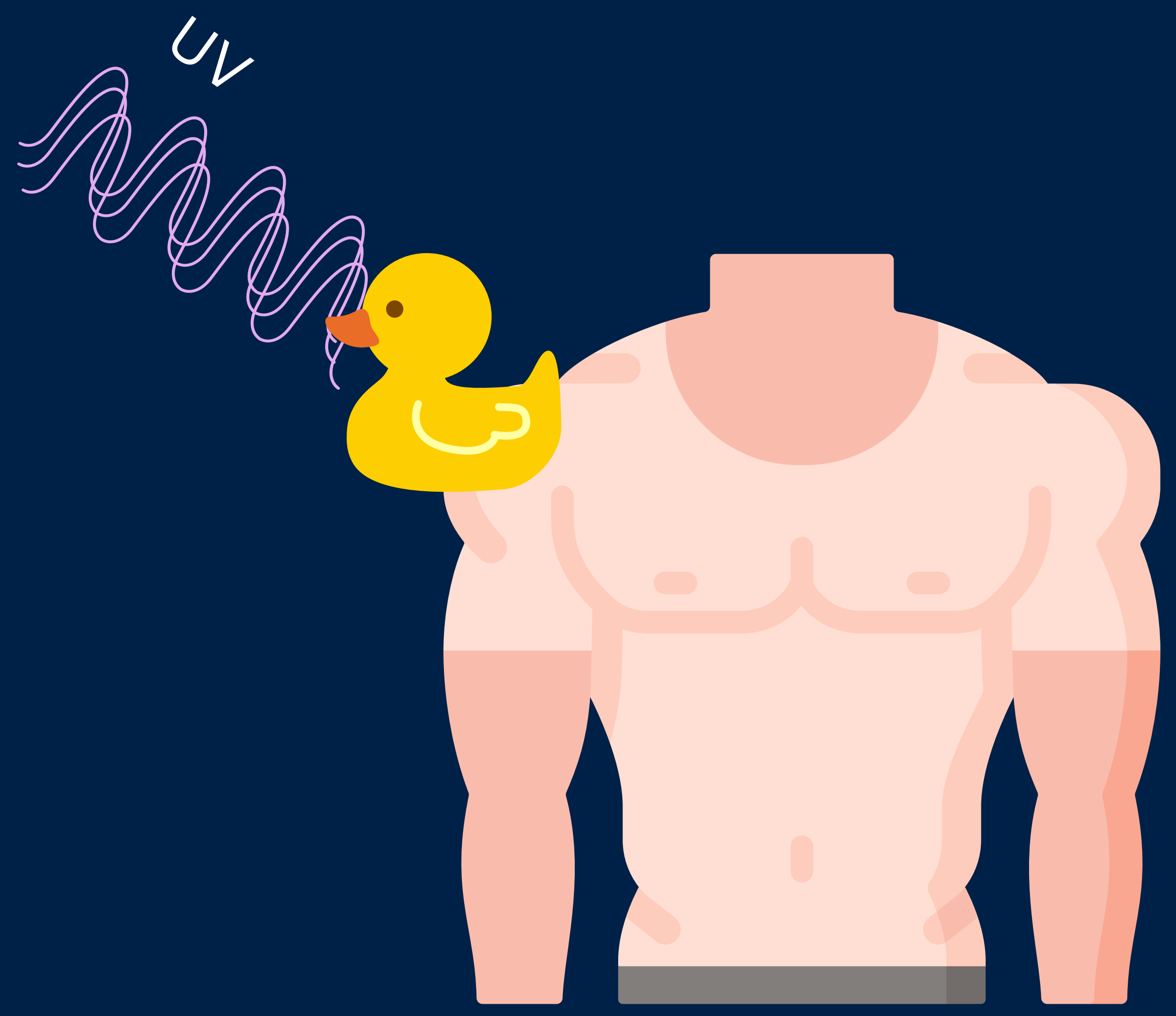

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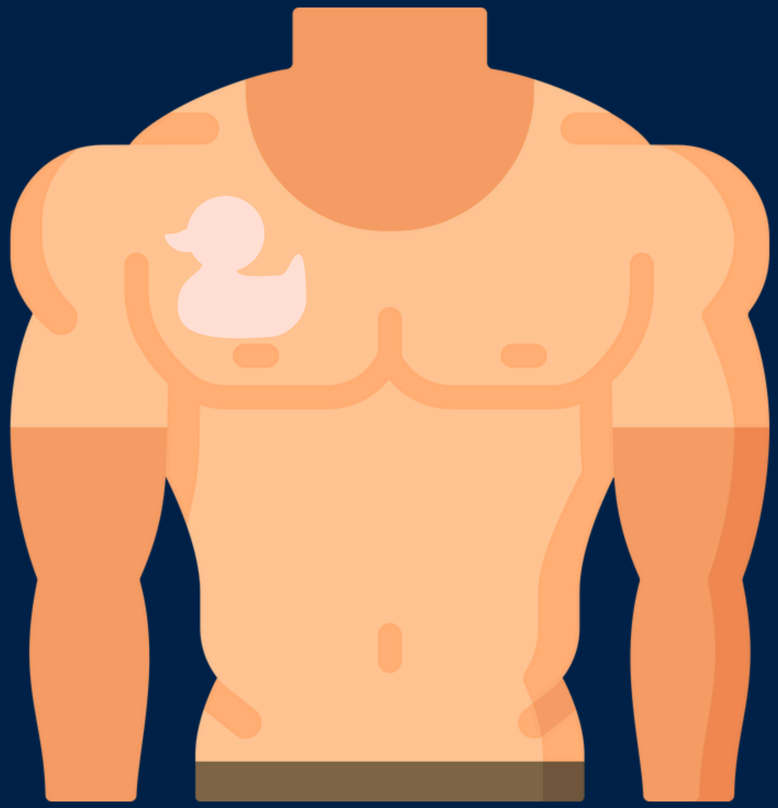

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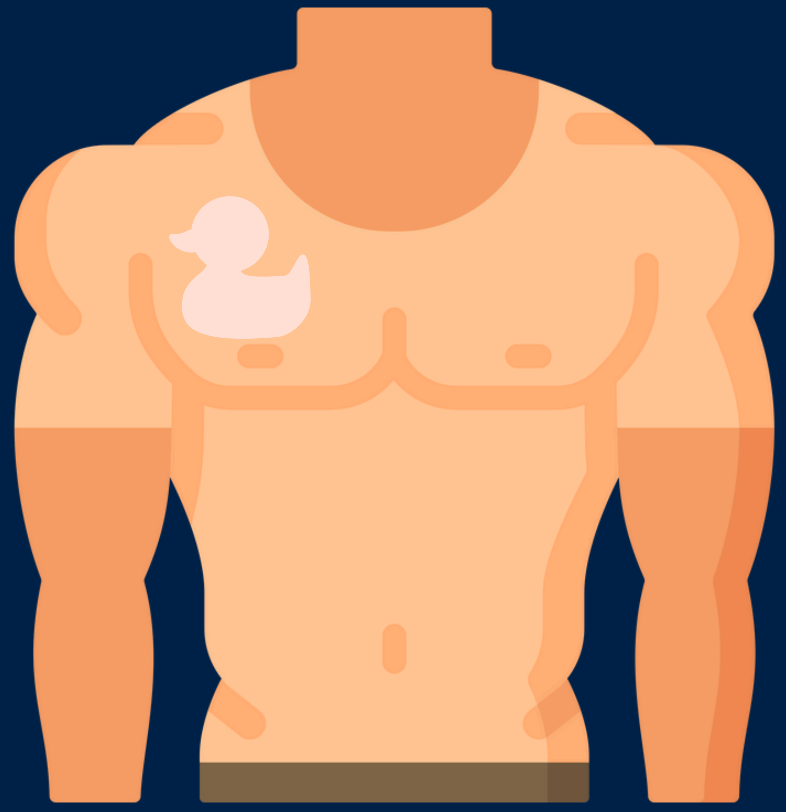

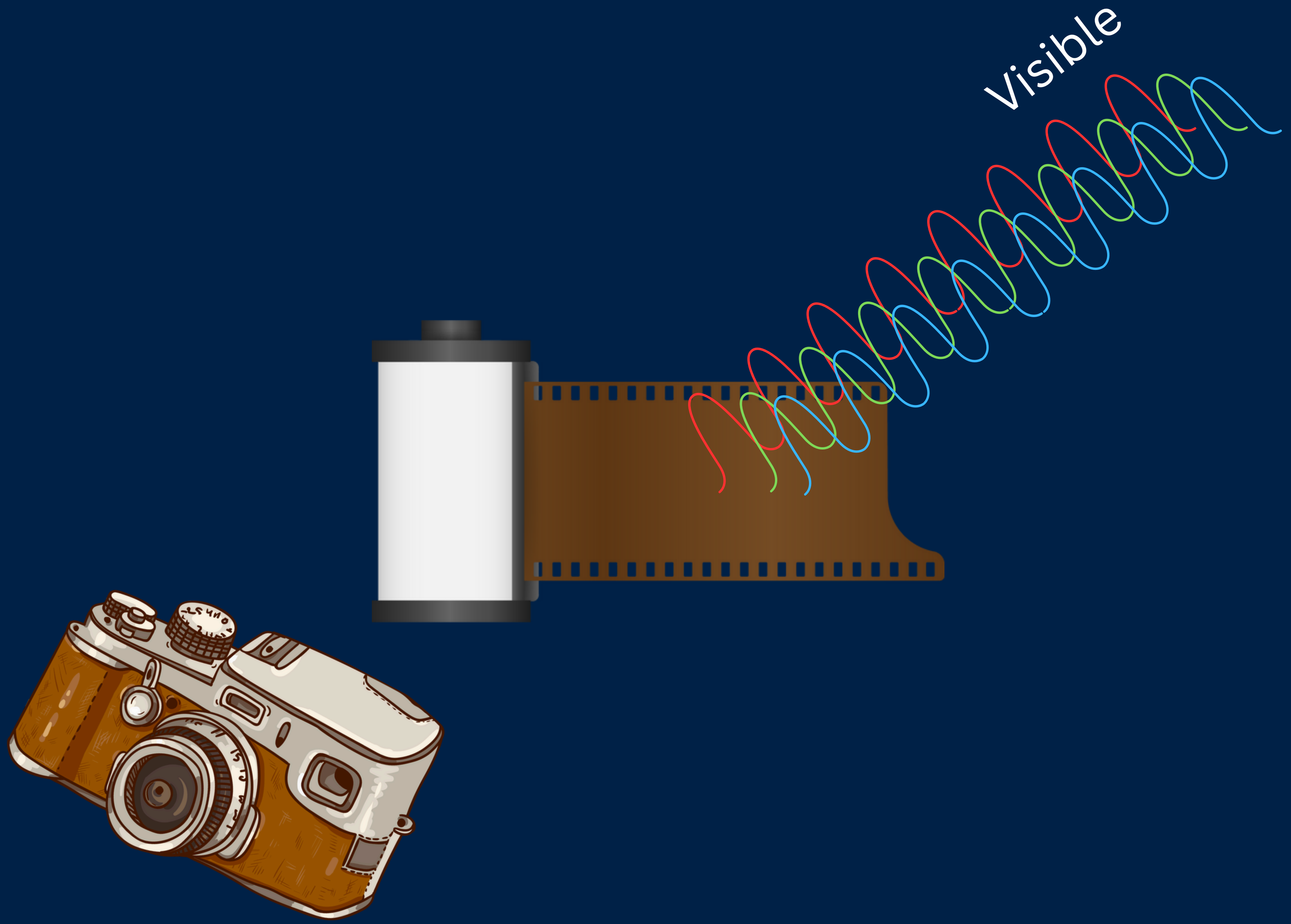

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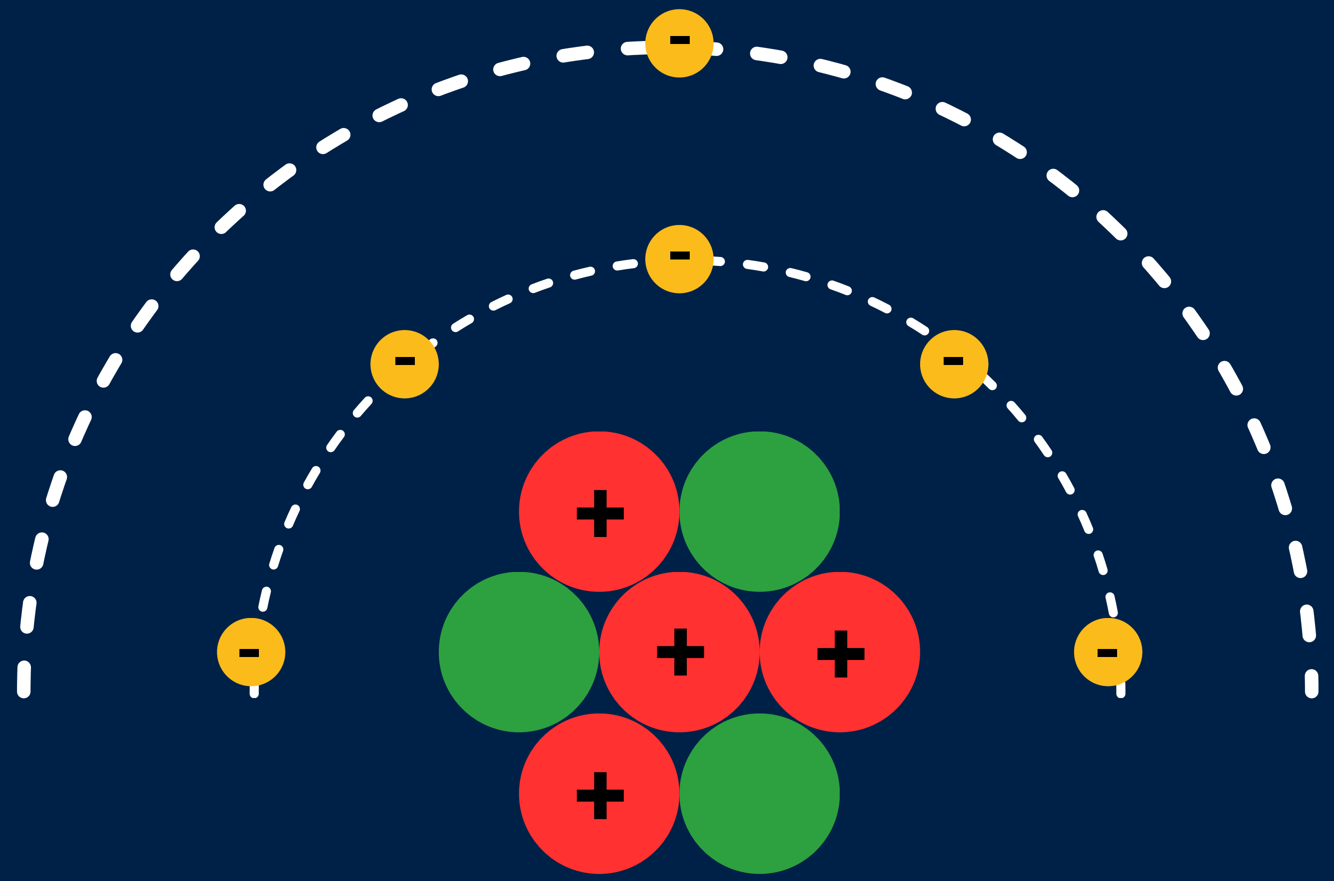

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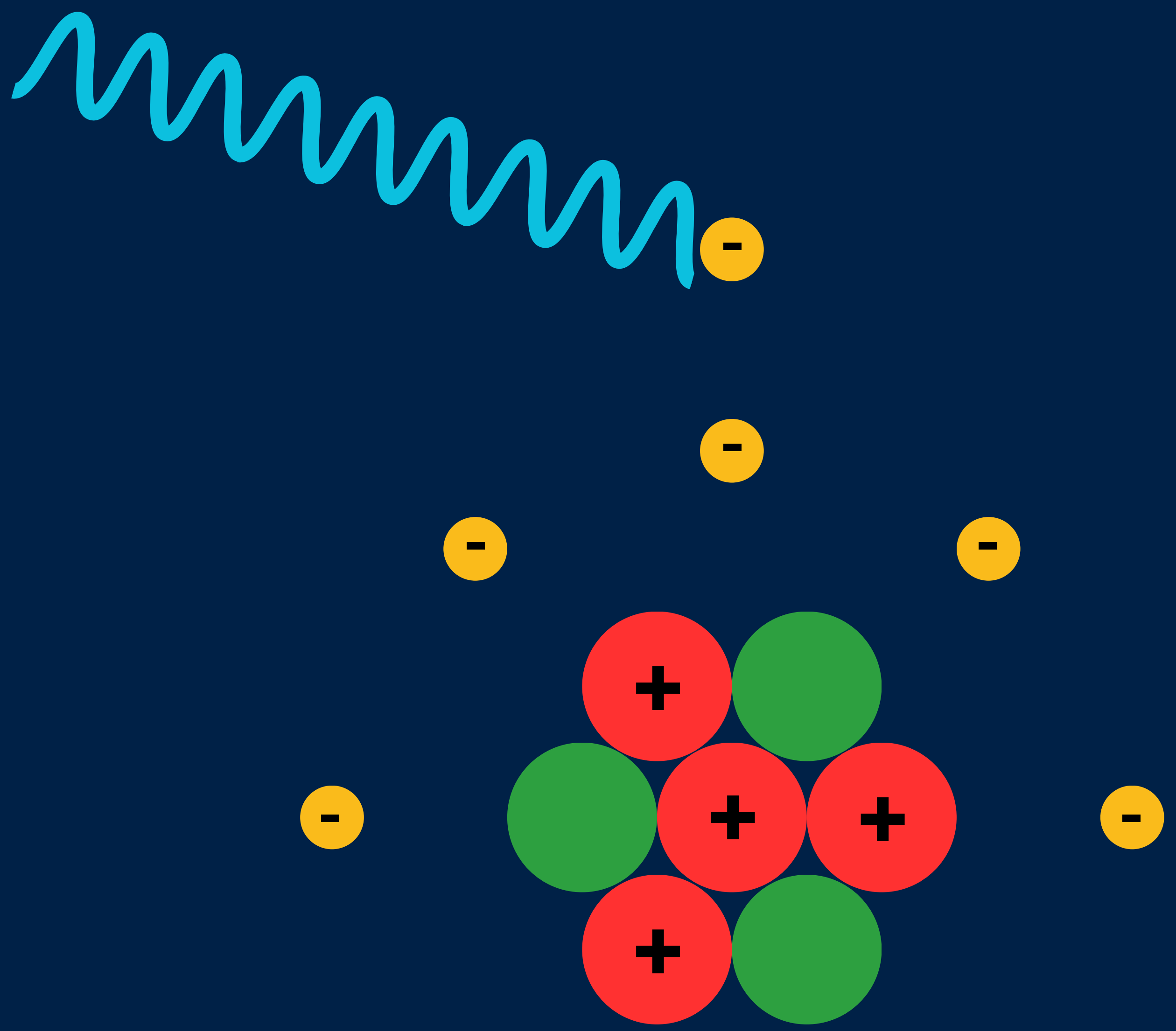

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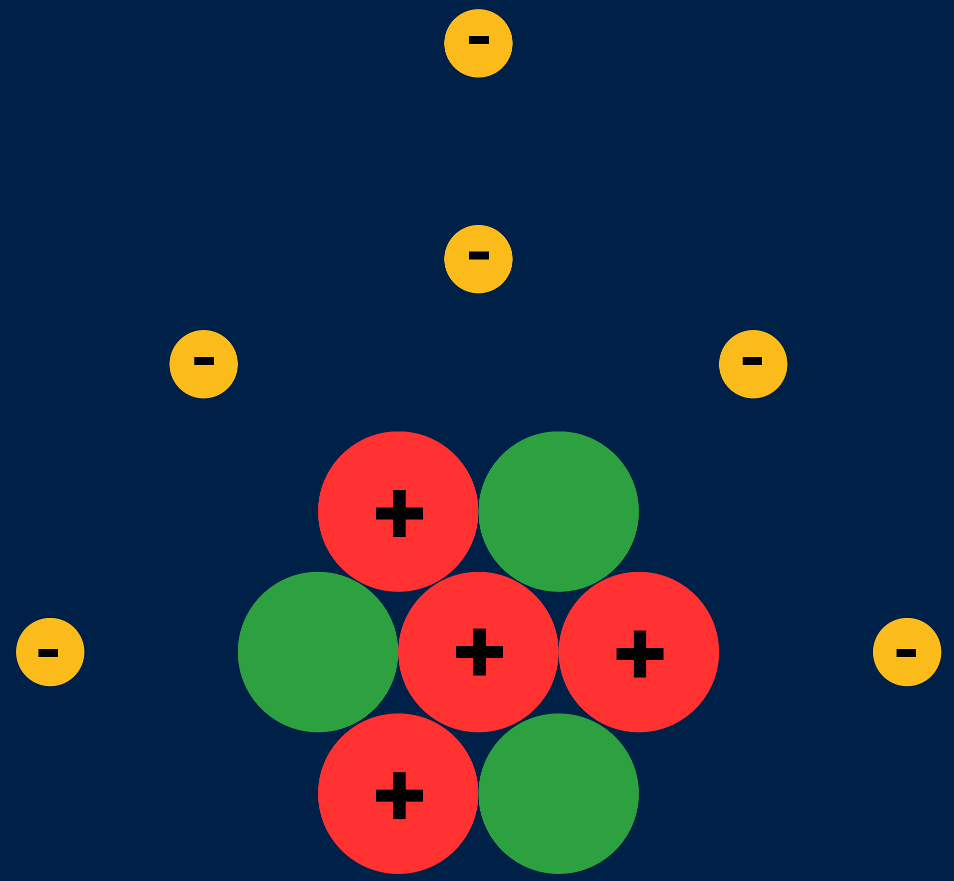
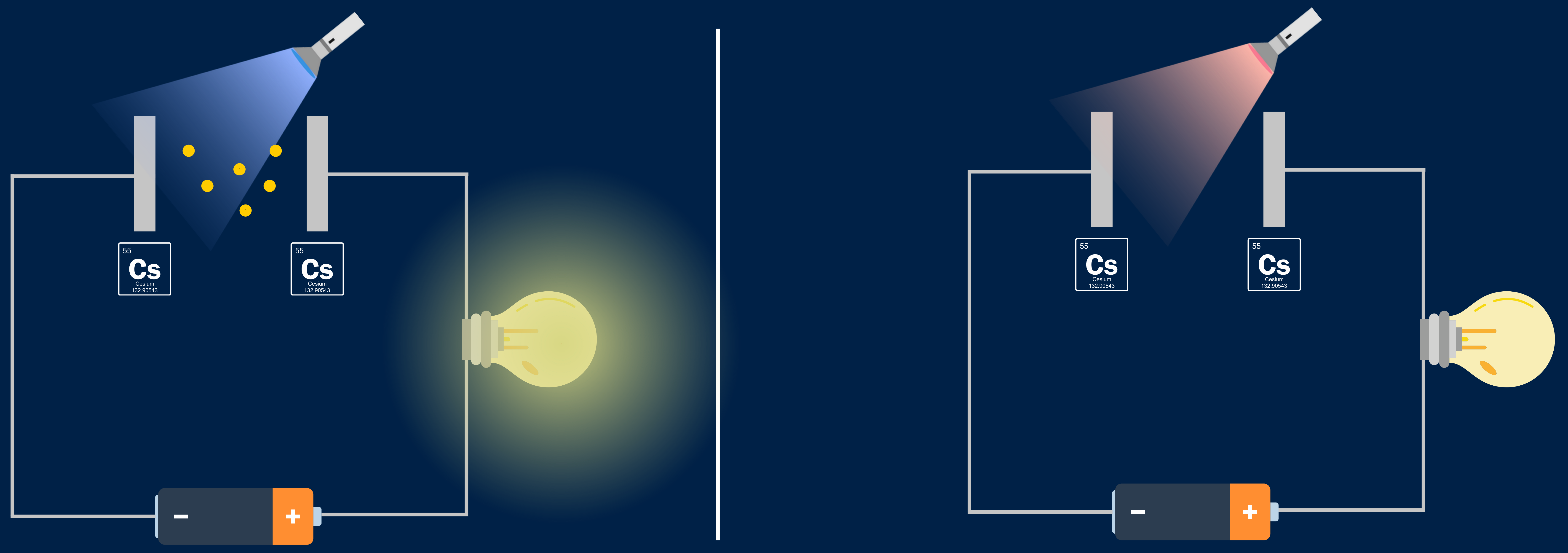


Photoelectric effect



Photoelectric effect

Photoelectric effect

Photoelectric effect

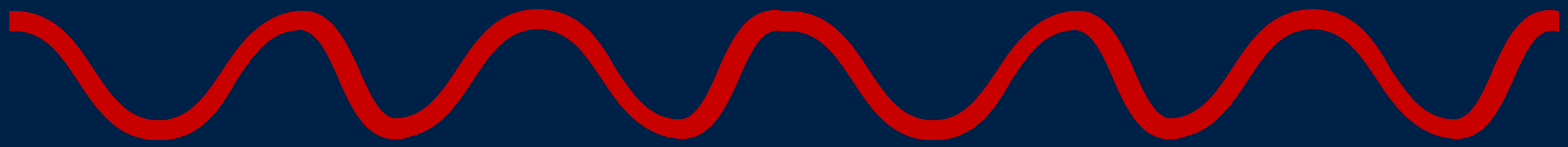
Light Comes in Quanta

- Each photon carries energy

$$E = h\nu$$

- If E is larger than the binding energy, the electron gets ejected.
- This representation explains why blue light would eject electron but not red light.

Electromagnetic Spectrum



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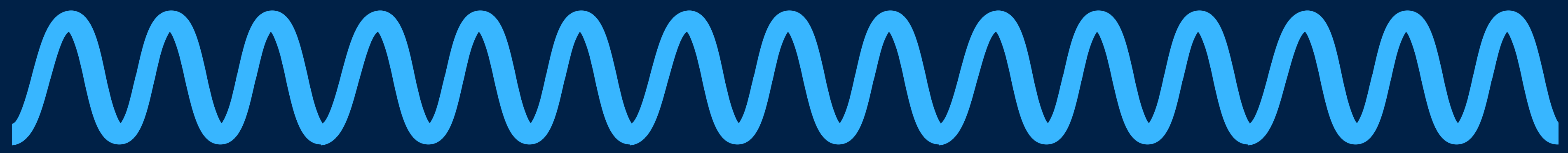

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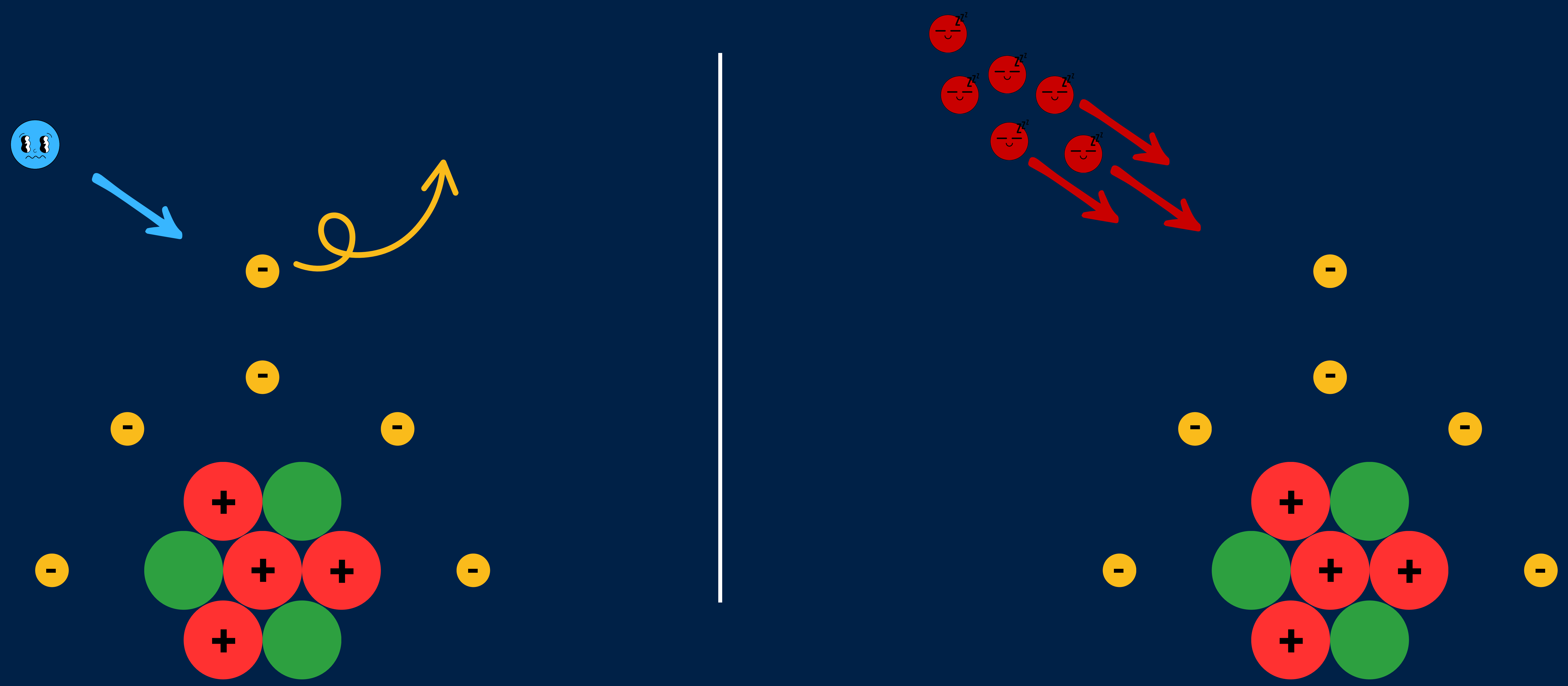
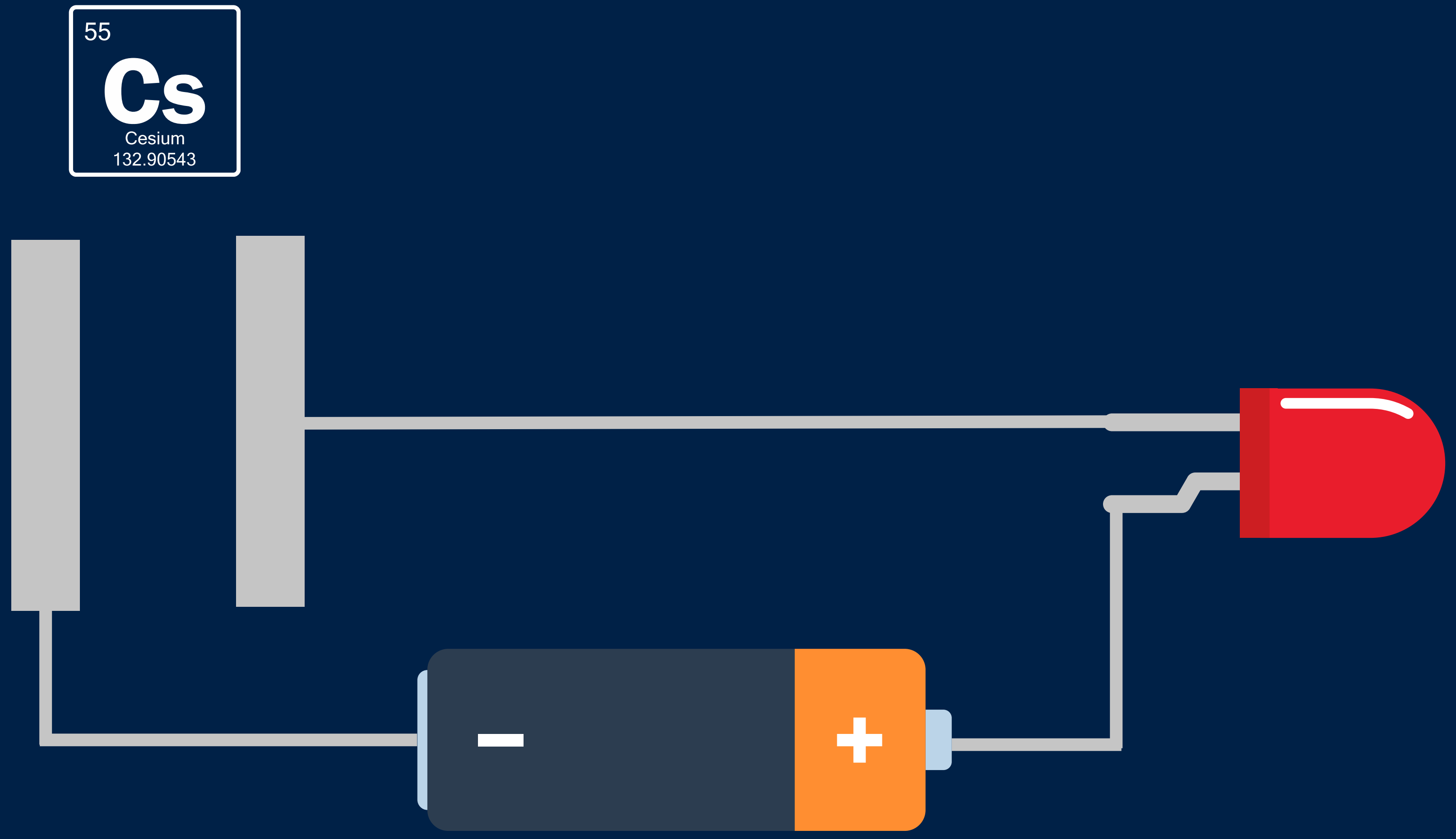


Simplified Modern Pixel



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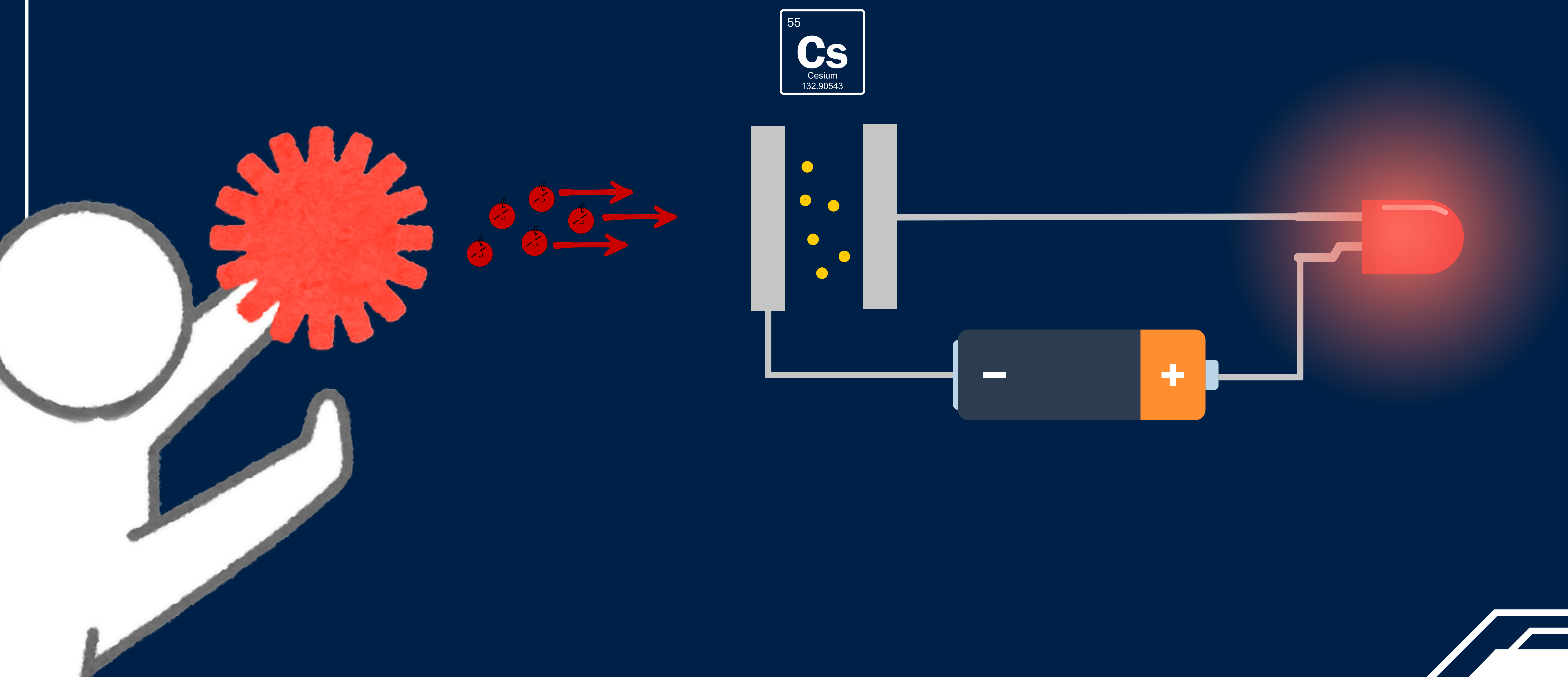

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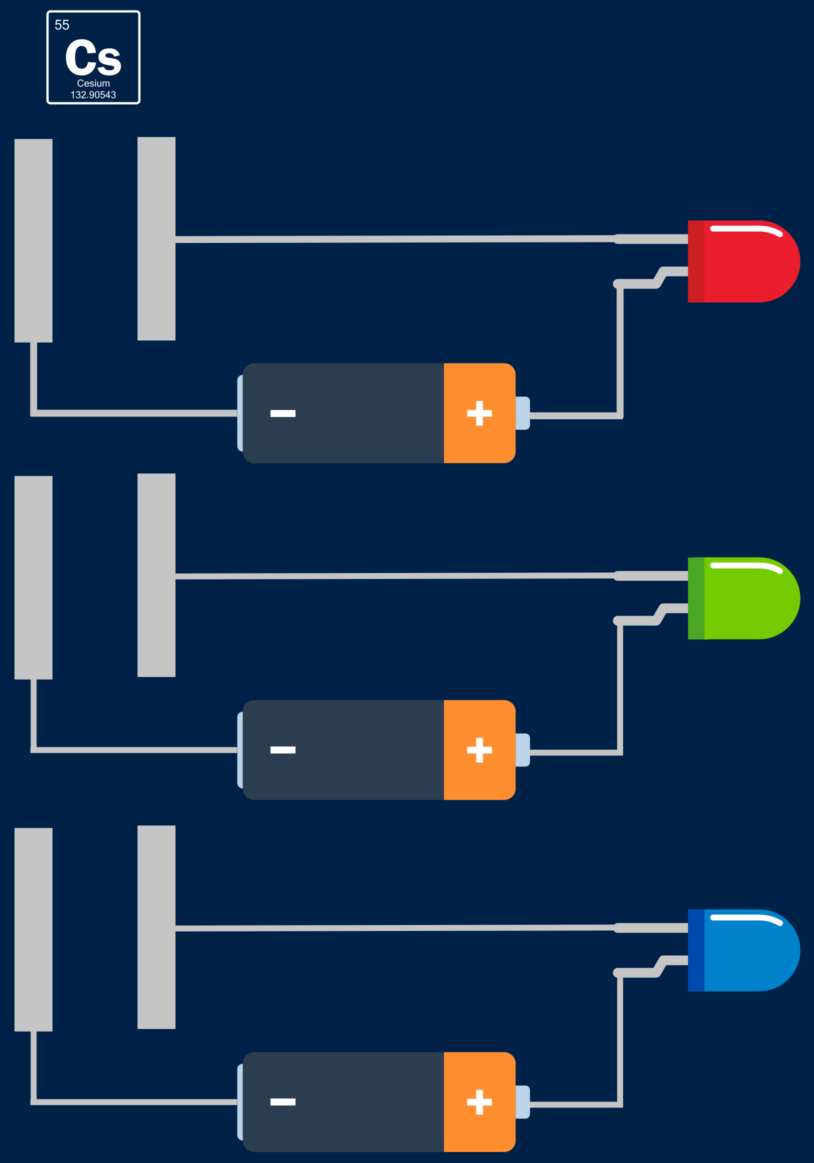

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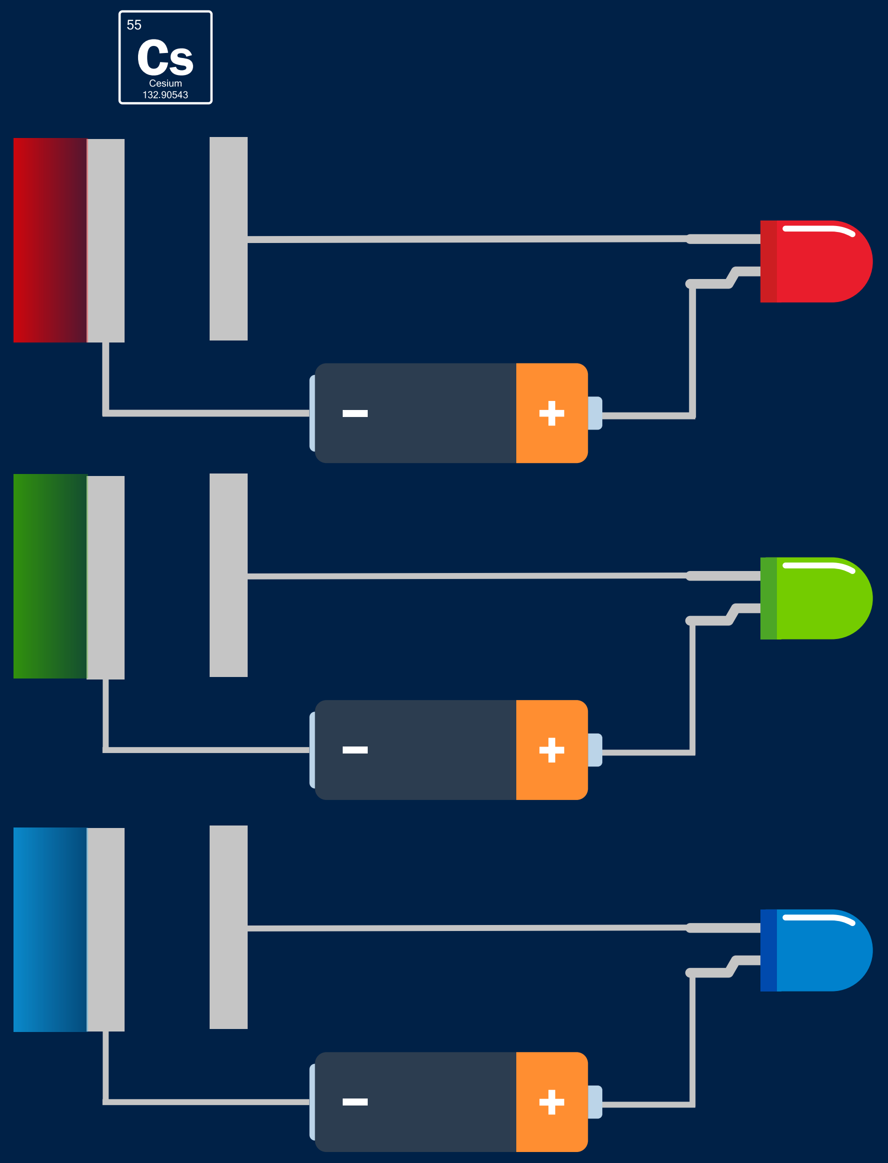

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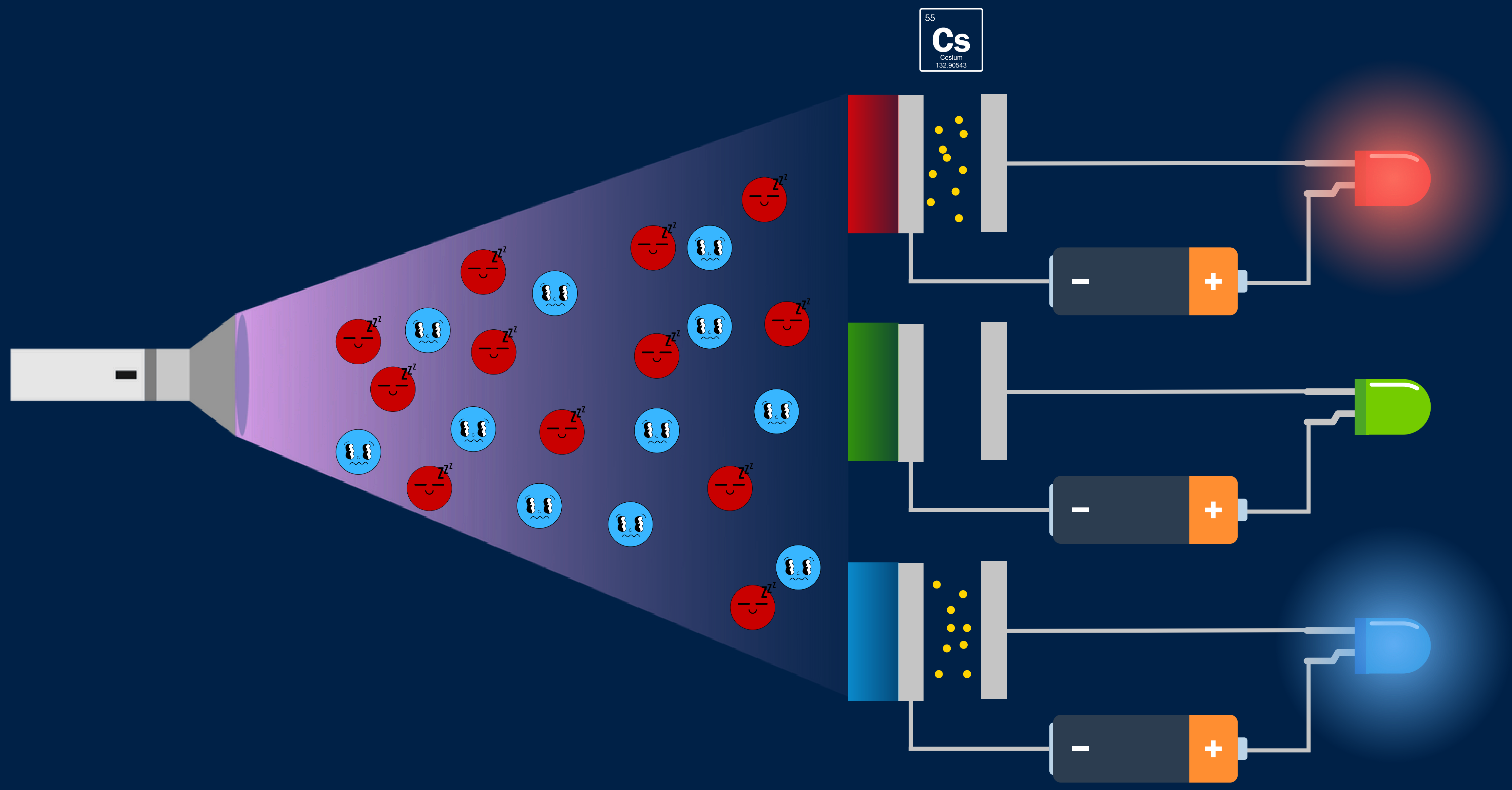

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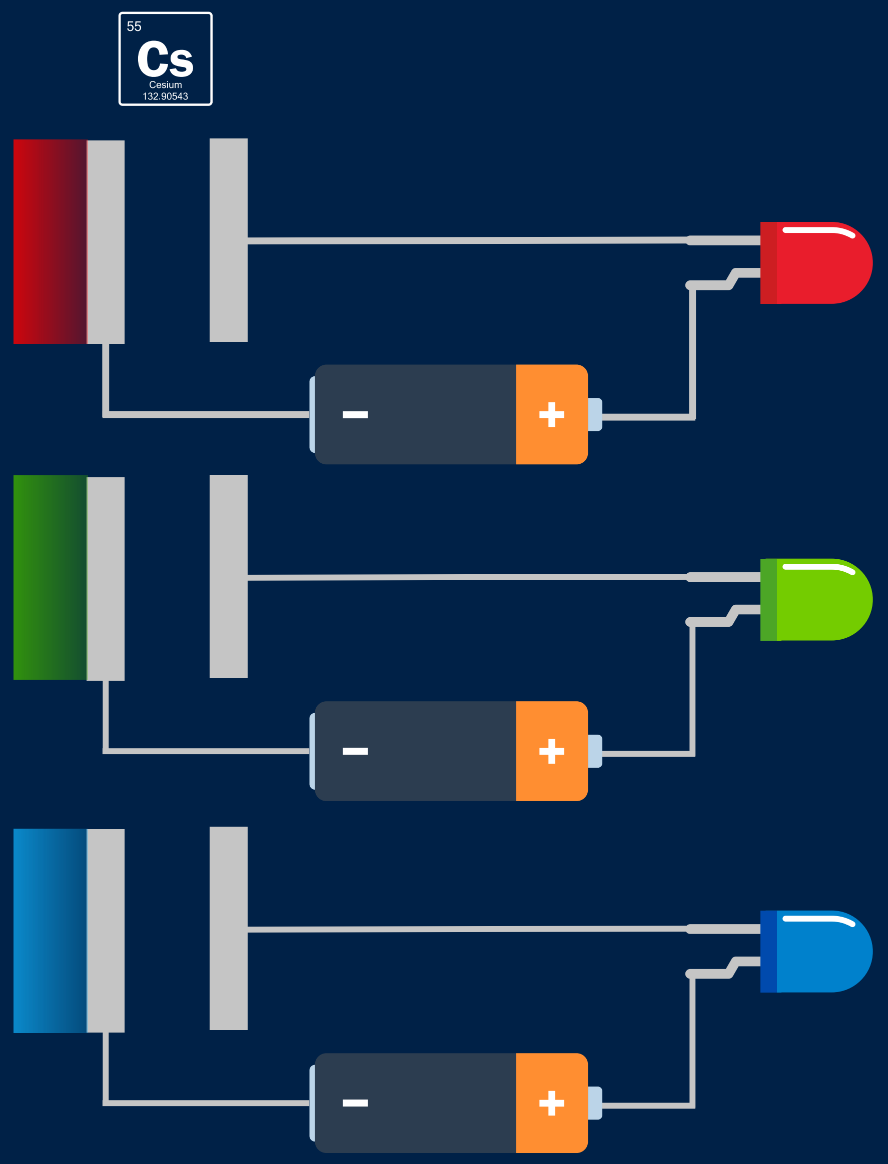

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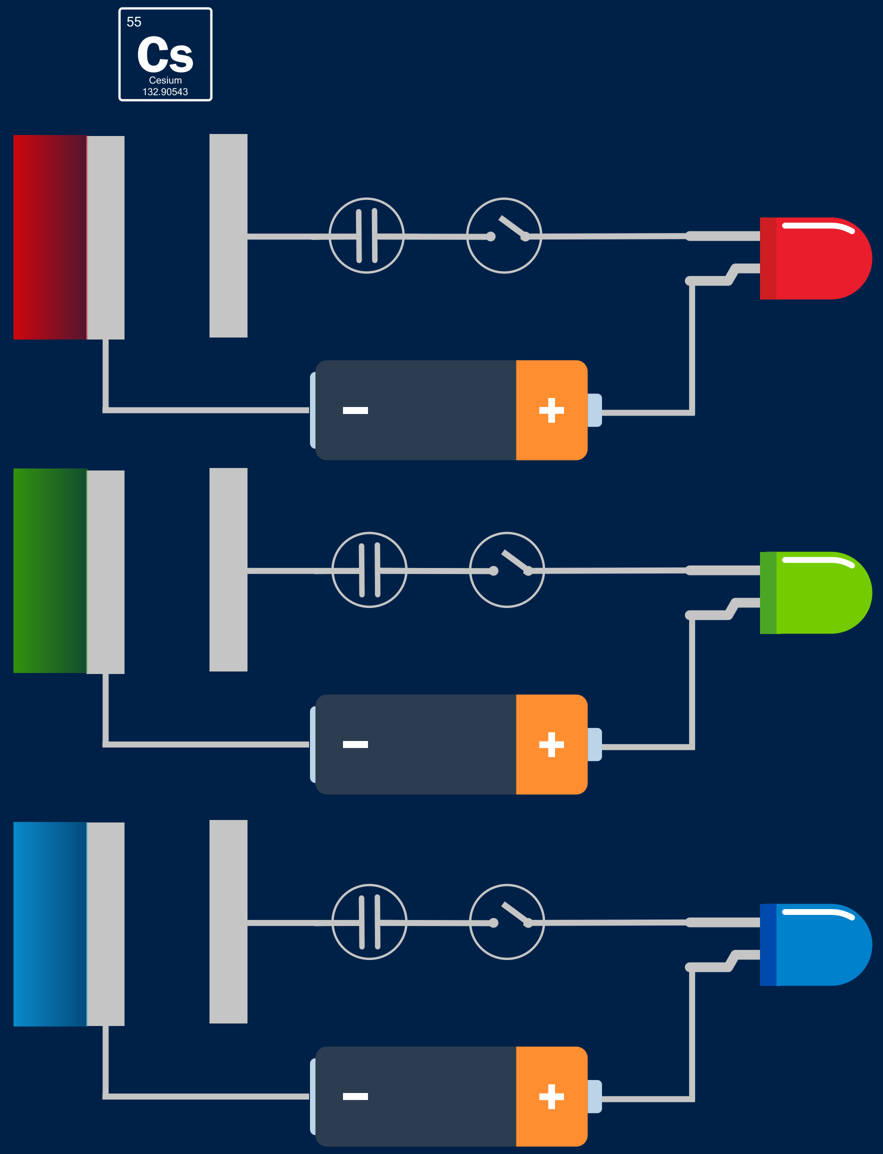

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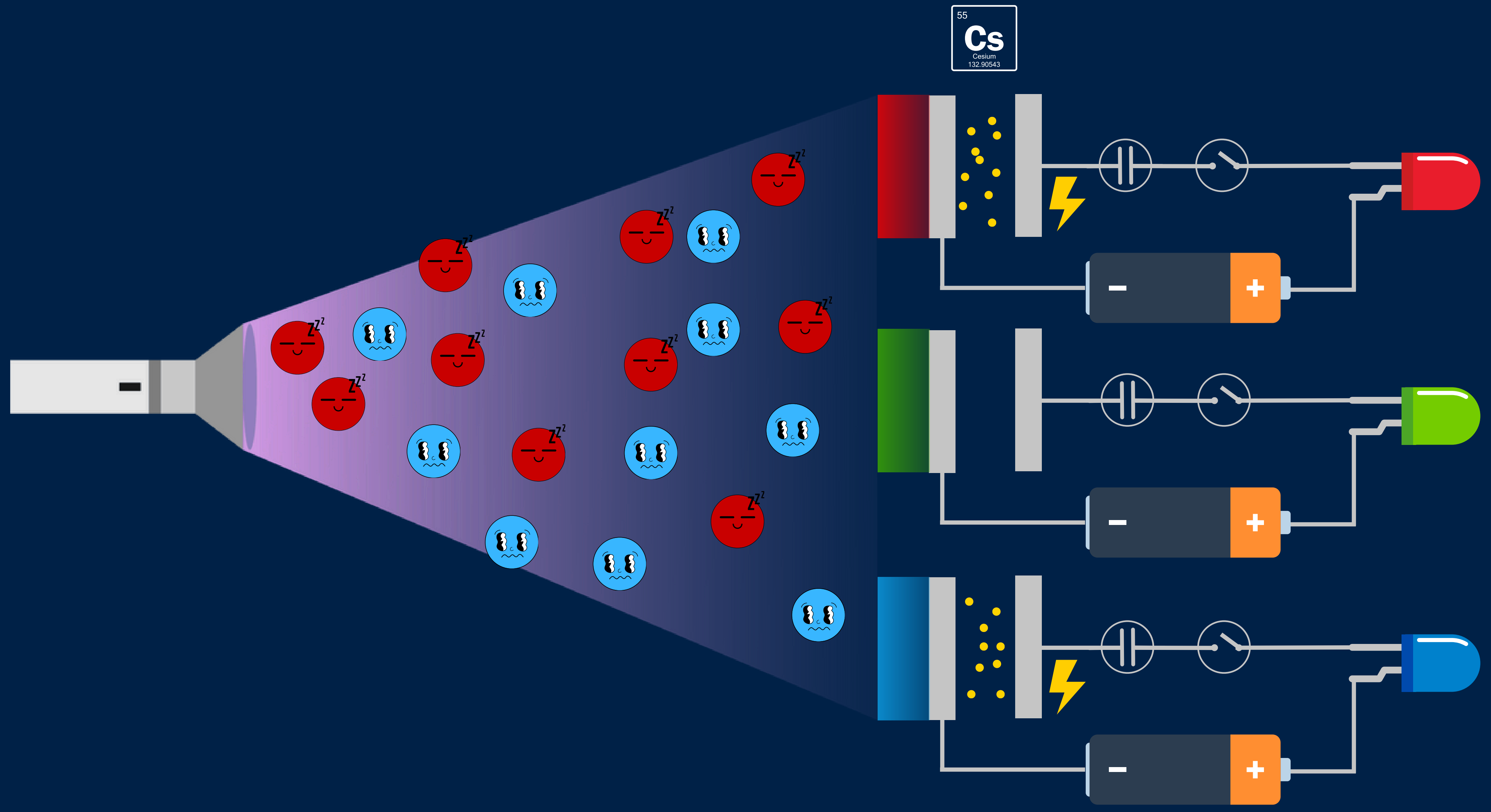

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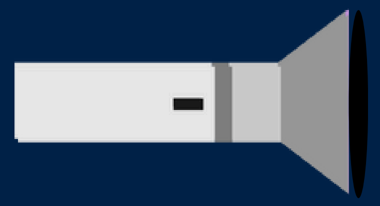

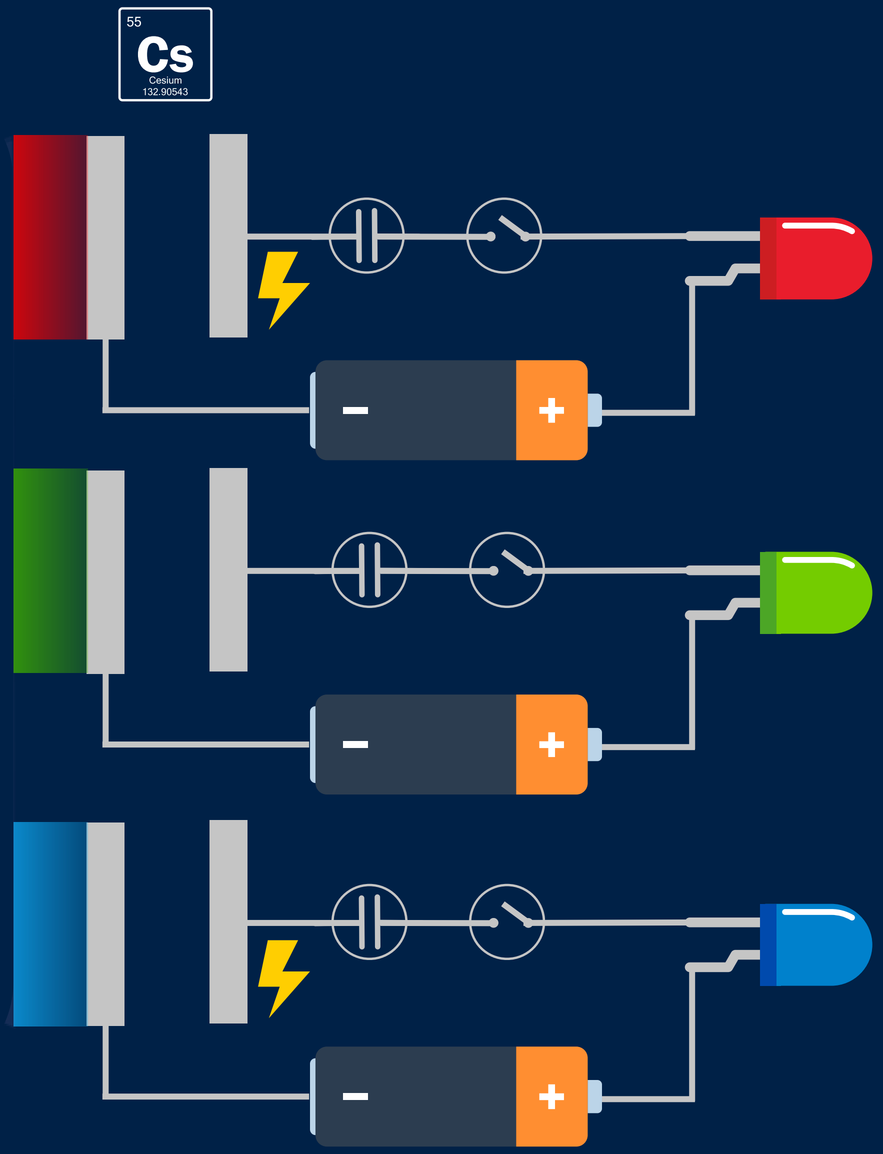

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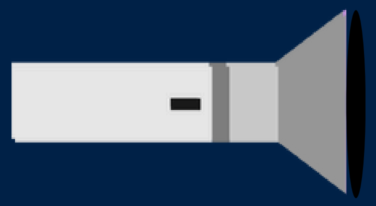
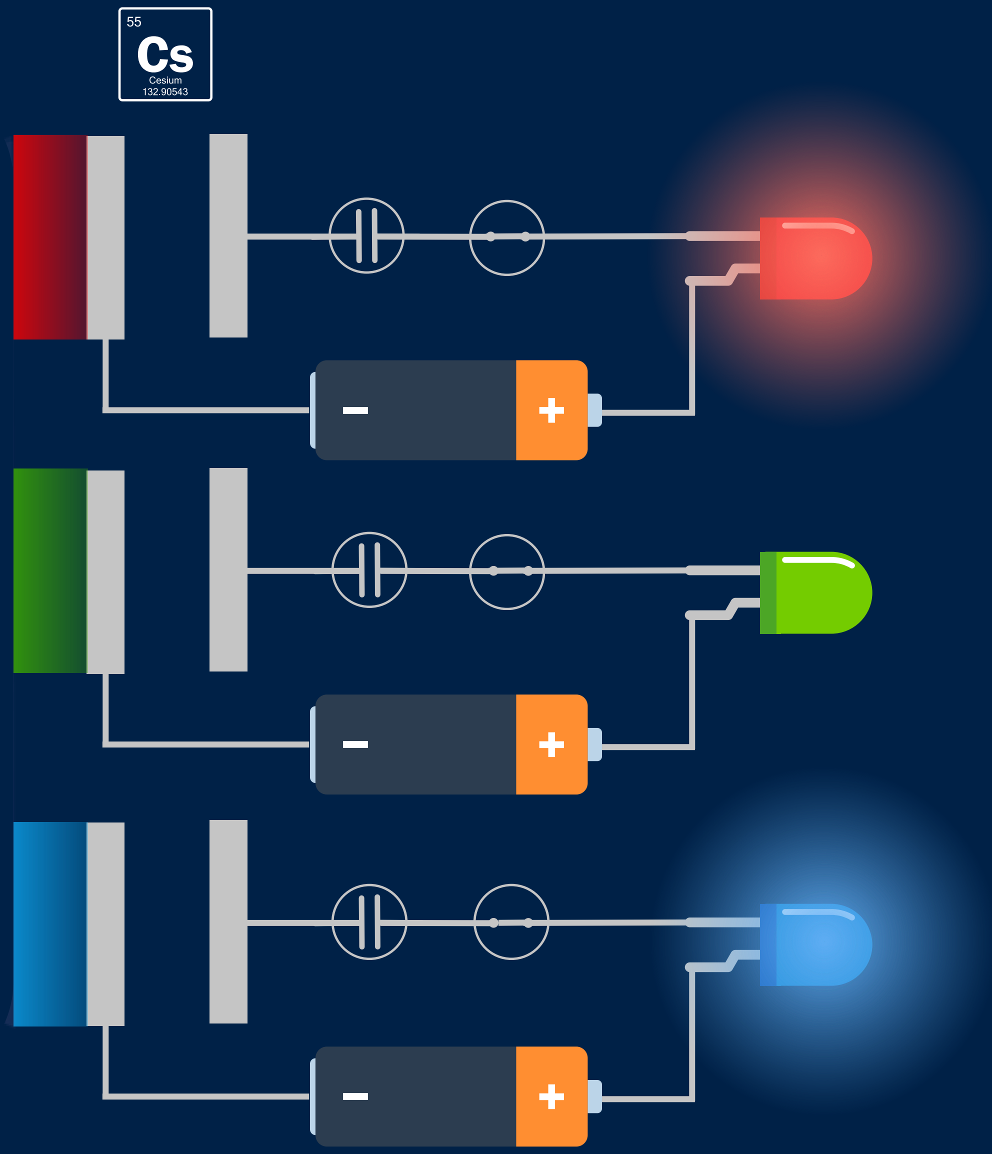
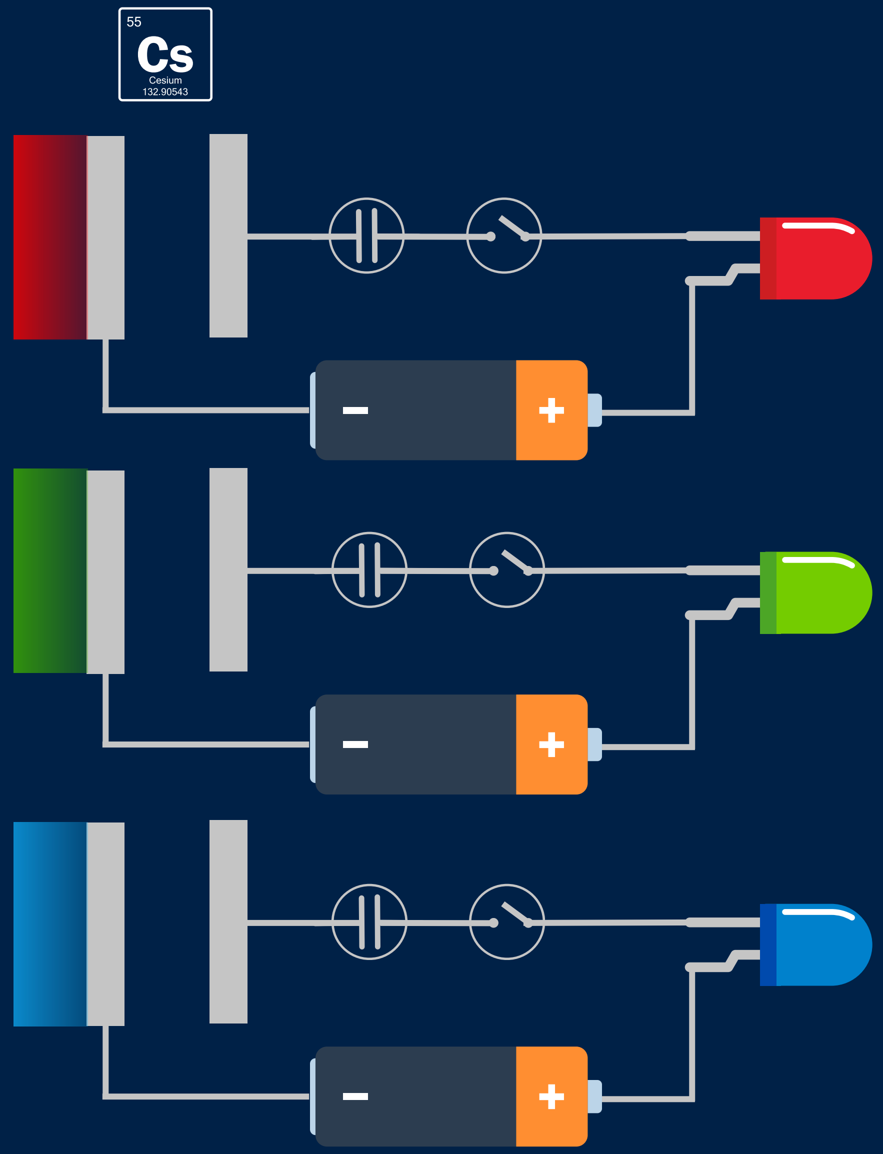




Problem #2: Not Small Enough!



Parenthesis: How Electrons Flow in a Wire

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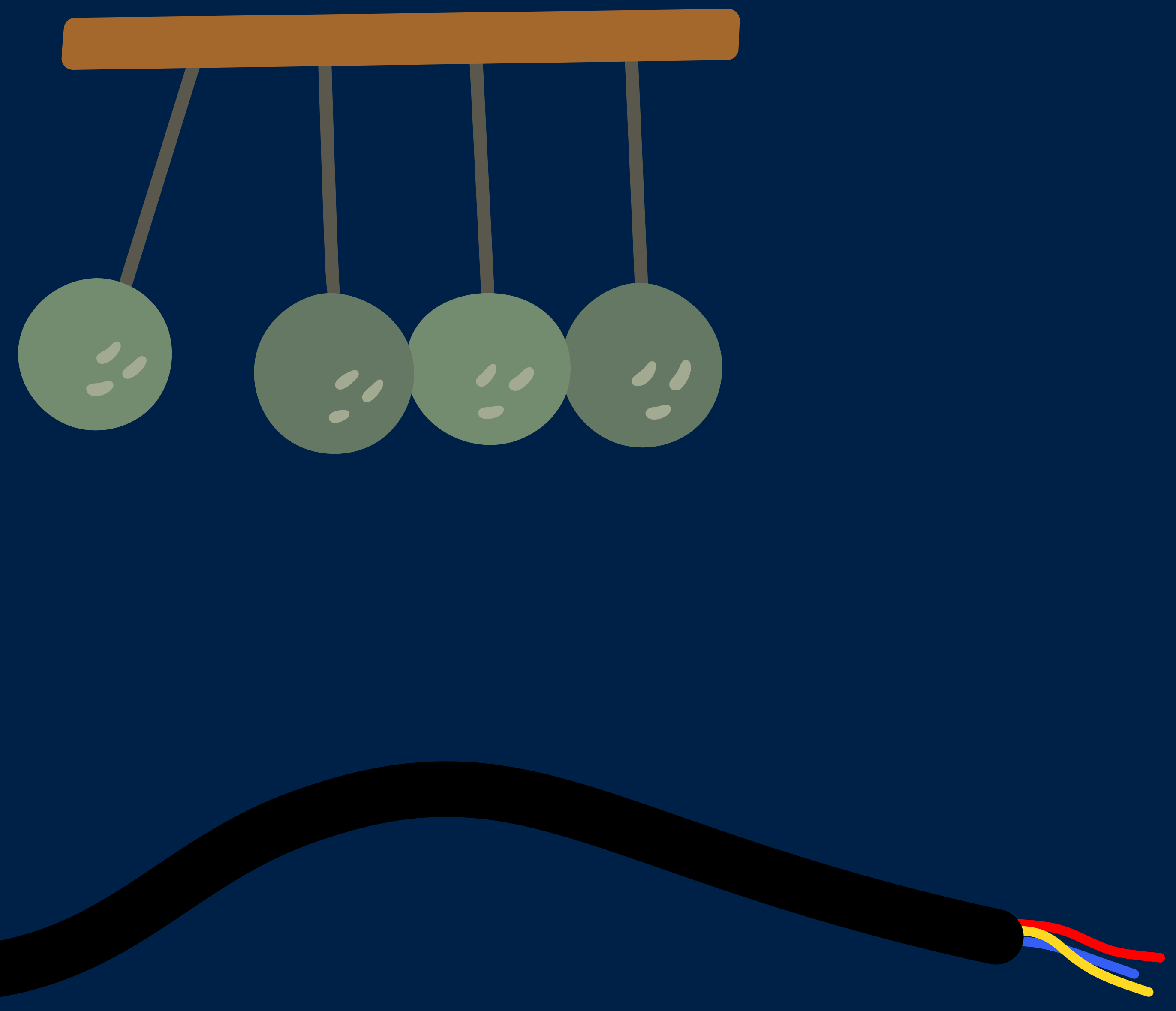

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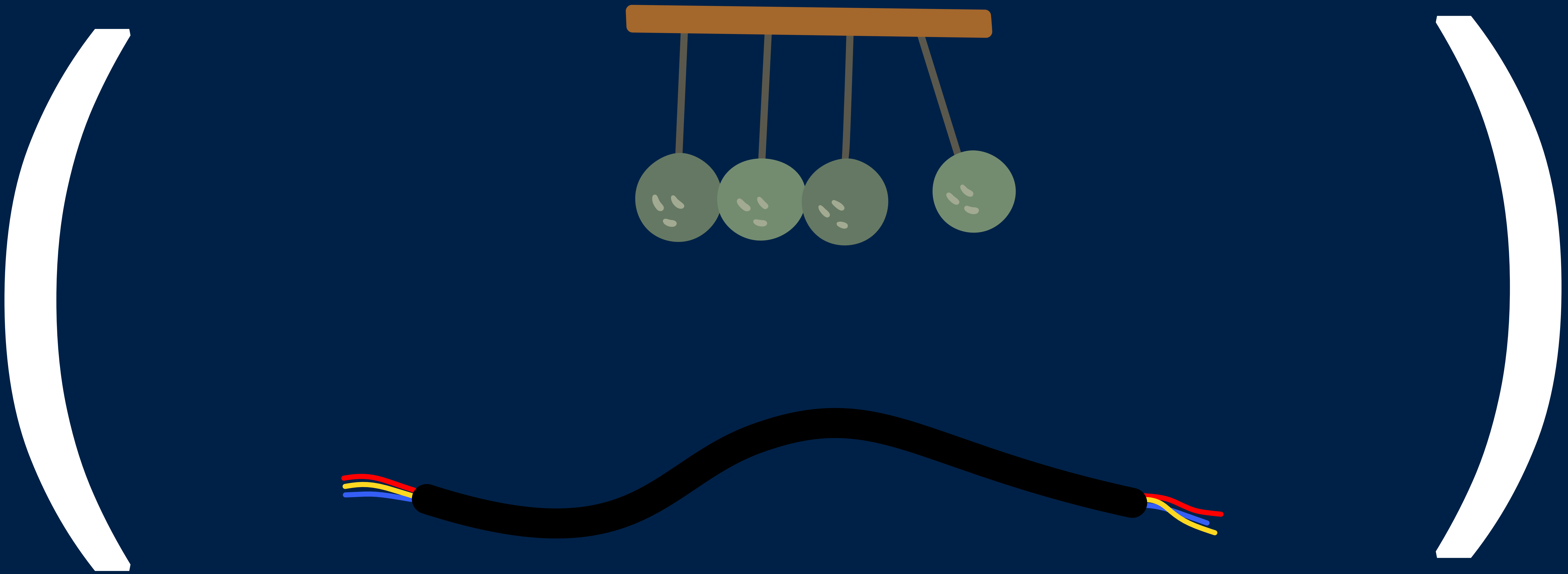

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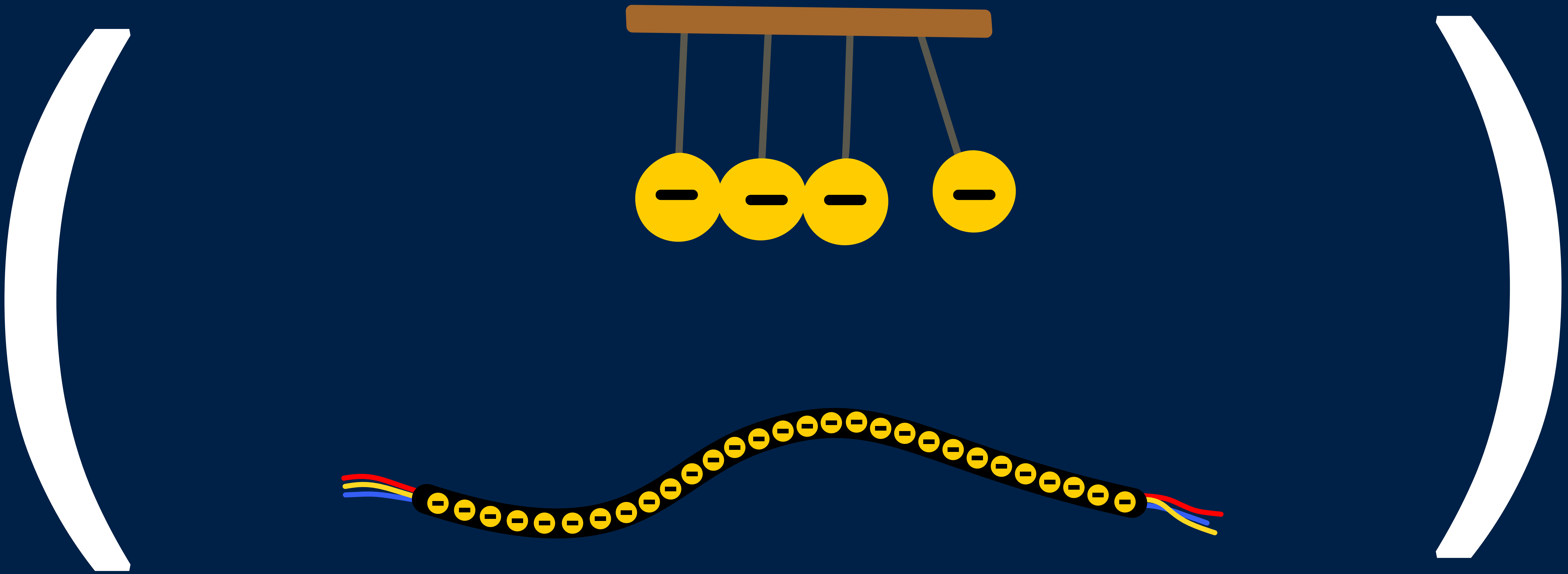

Parenthesis #2: The Atom Again

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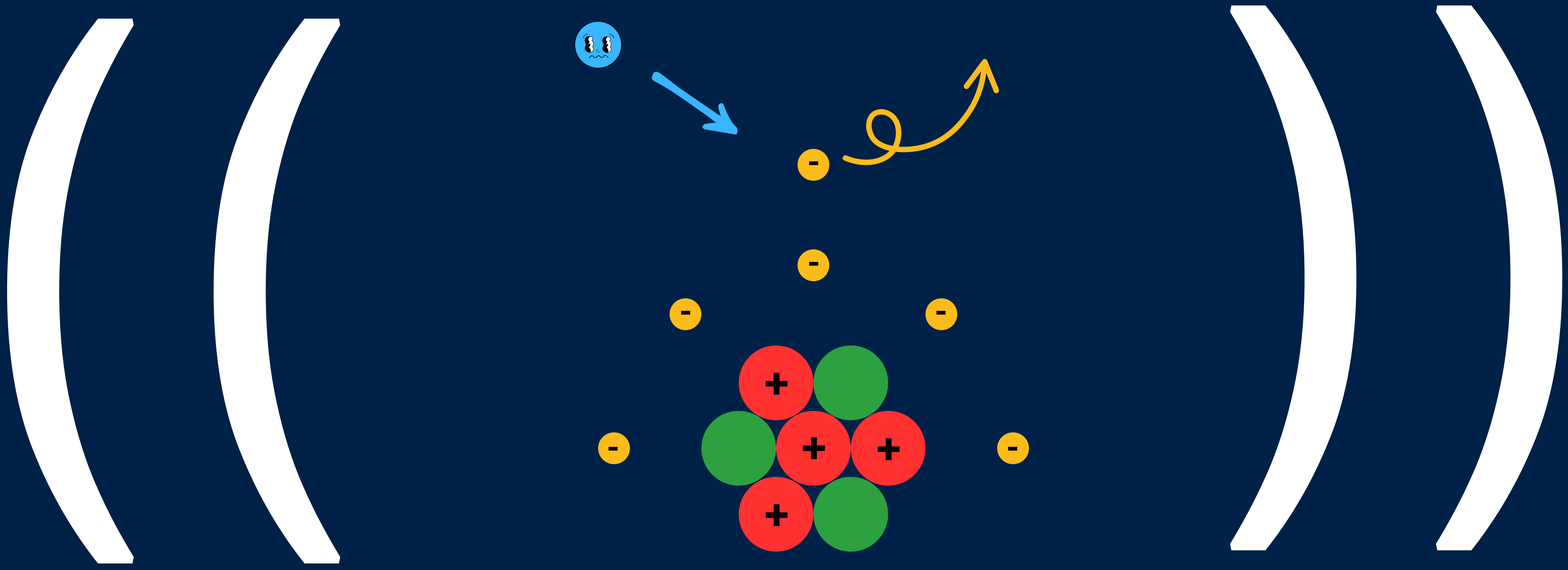

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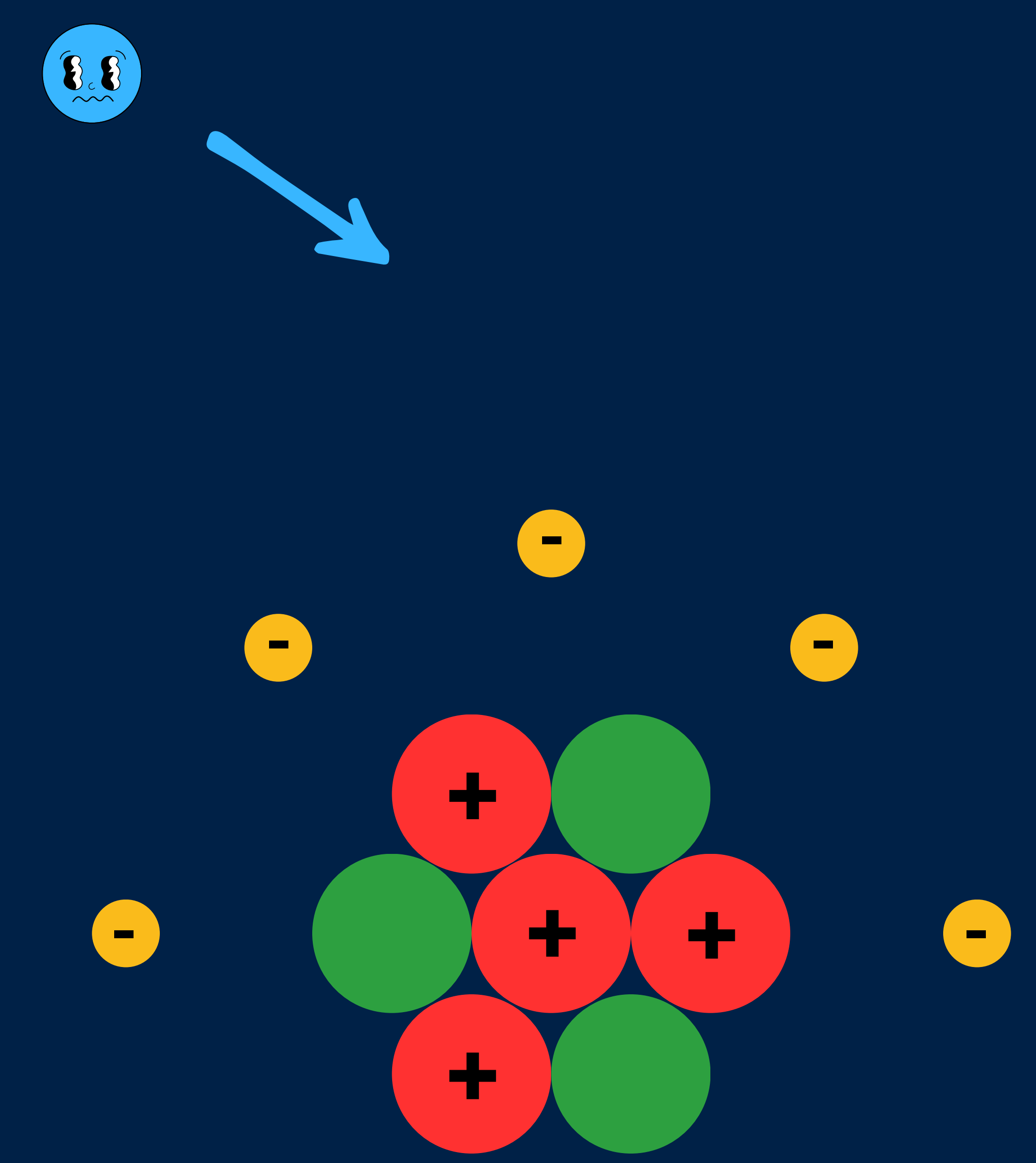

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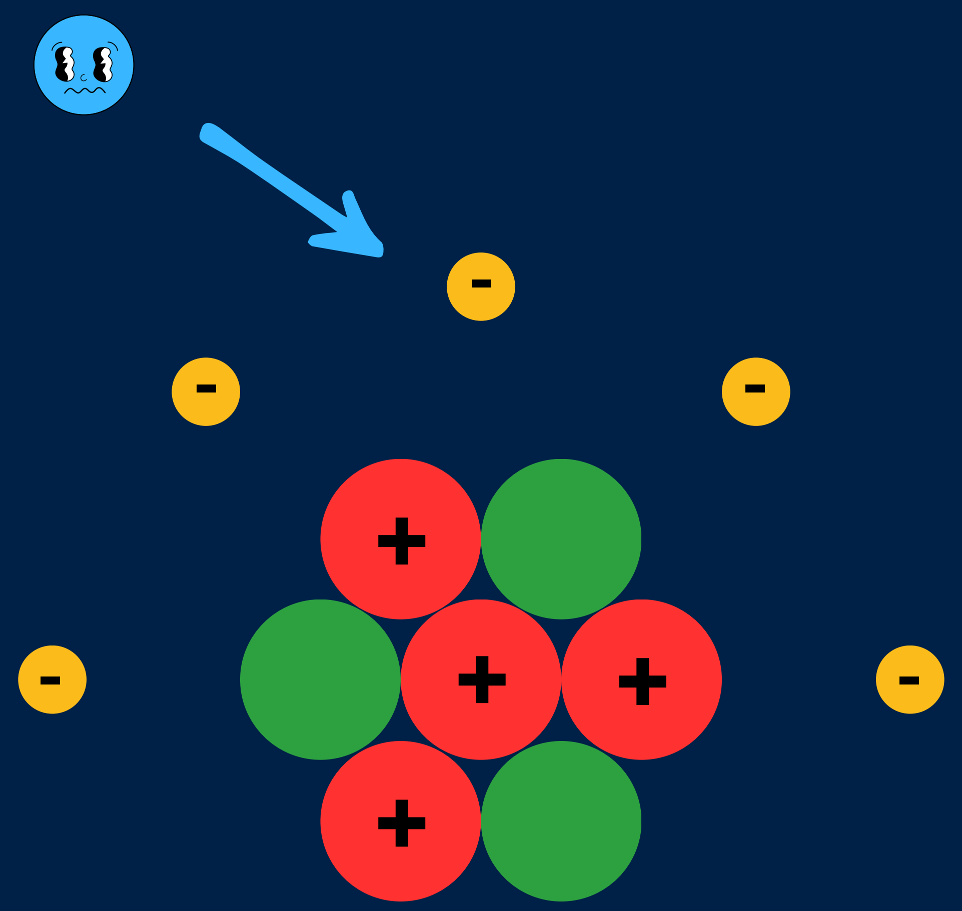

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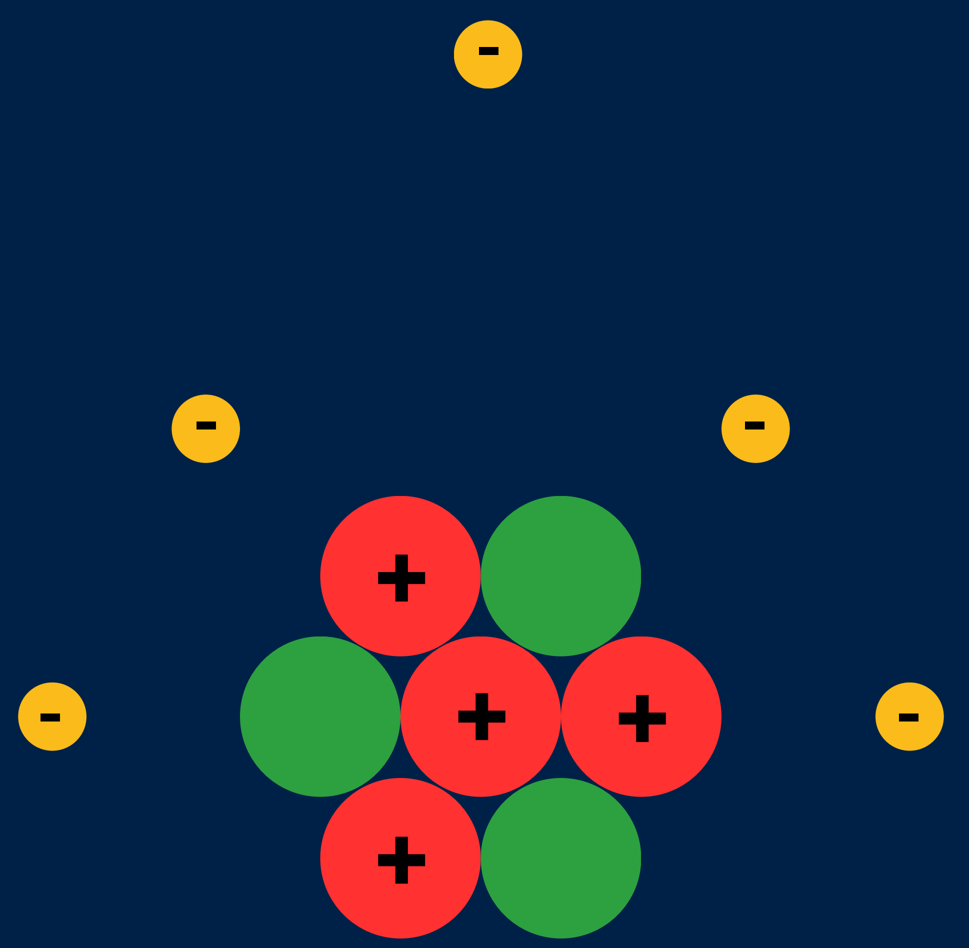

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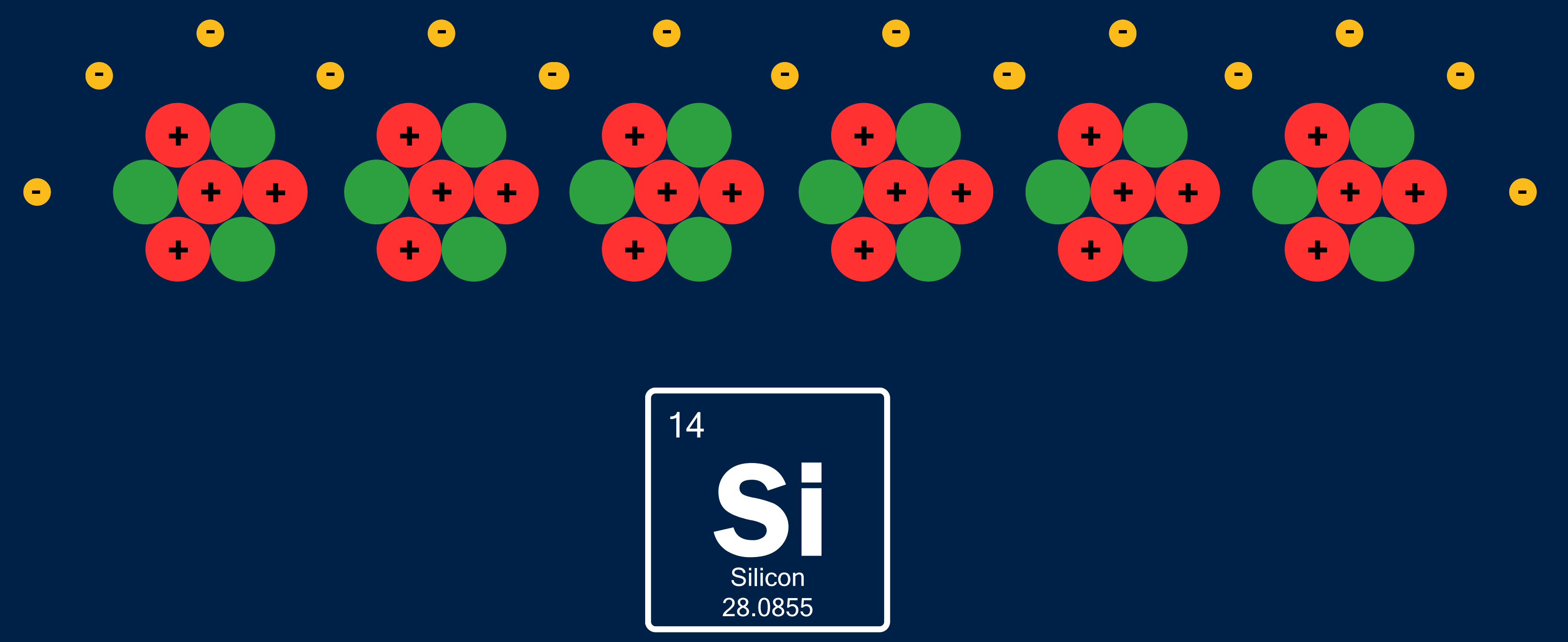

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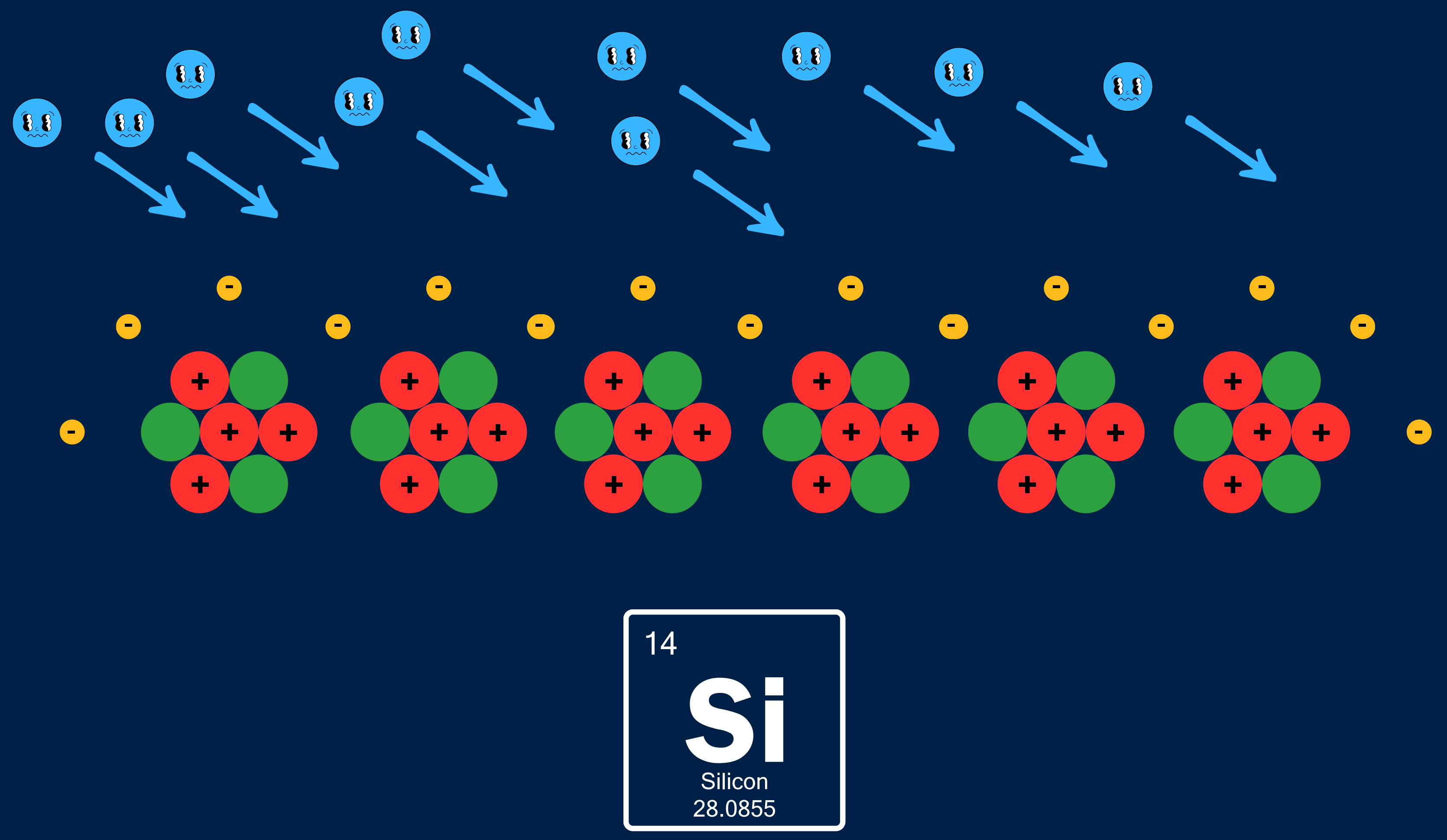

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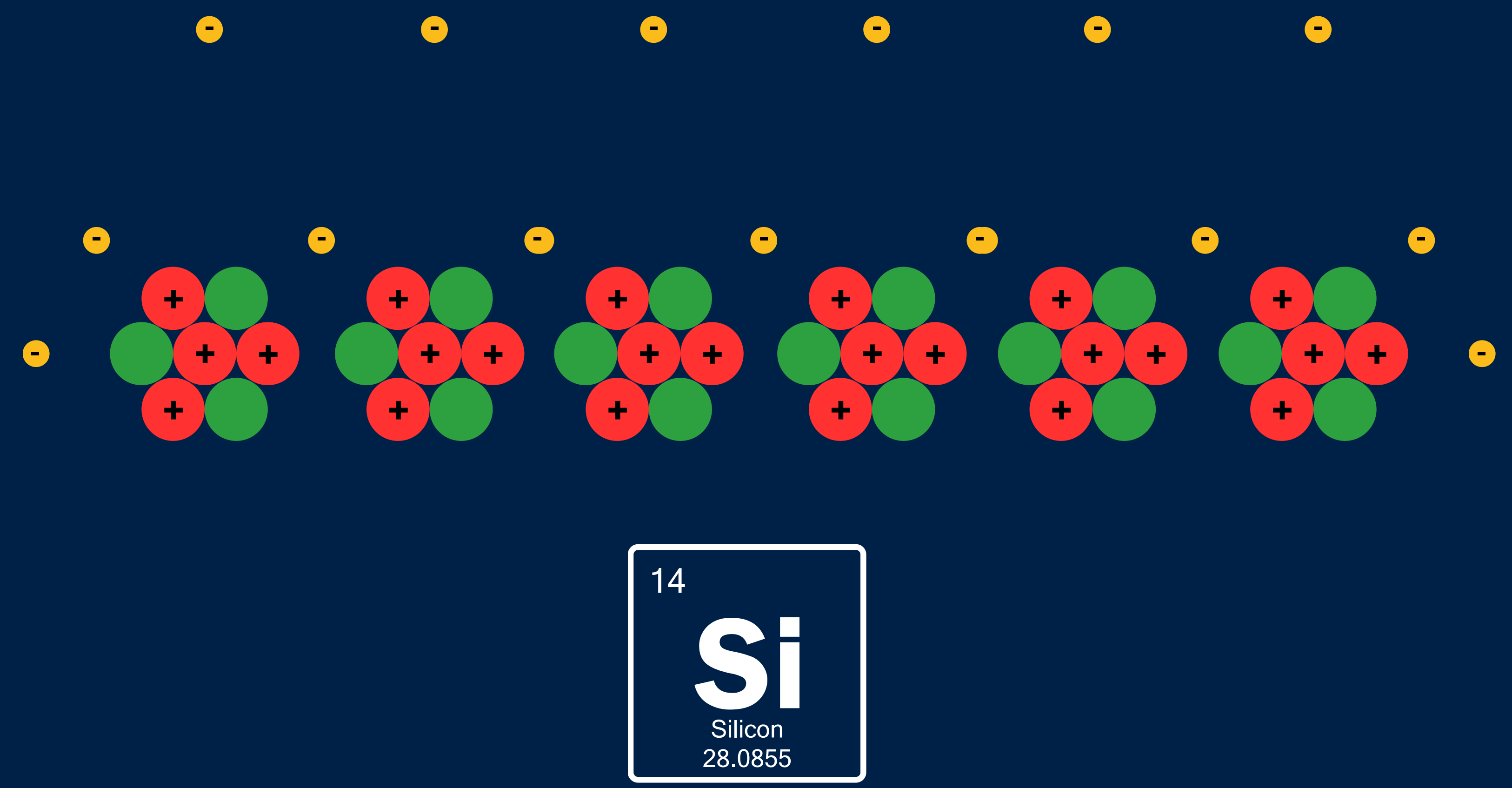

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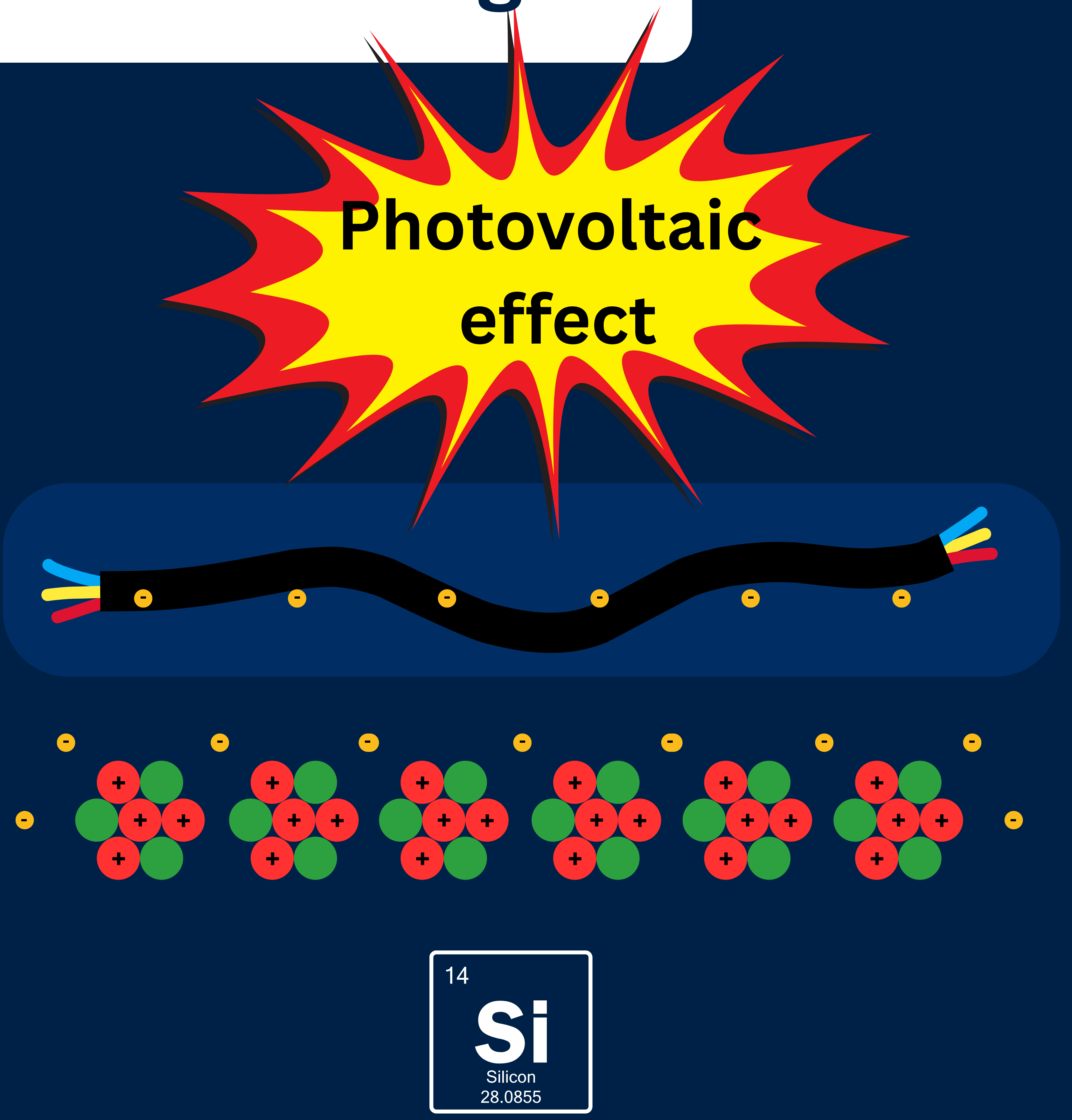

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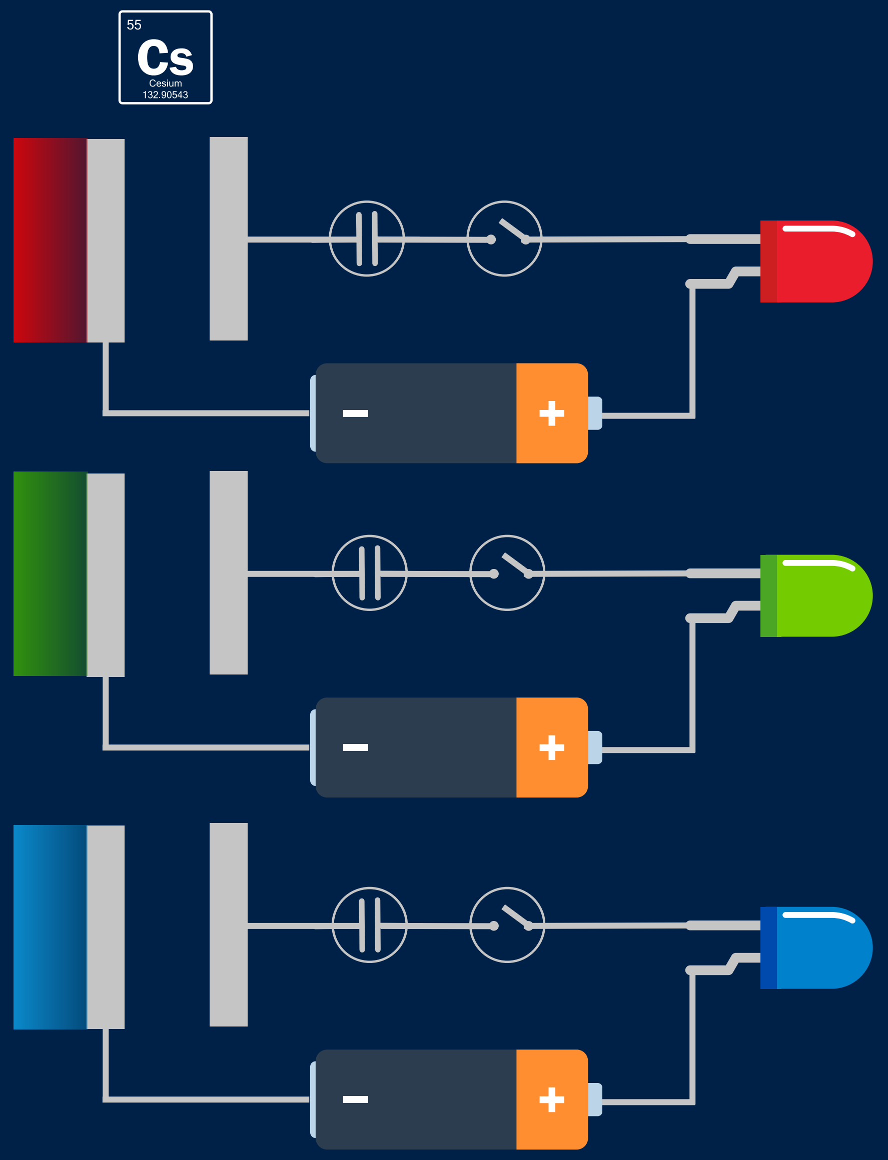

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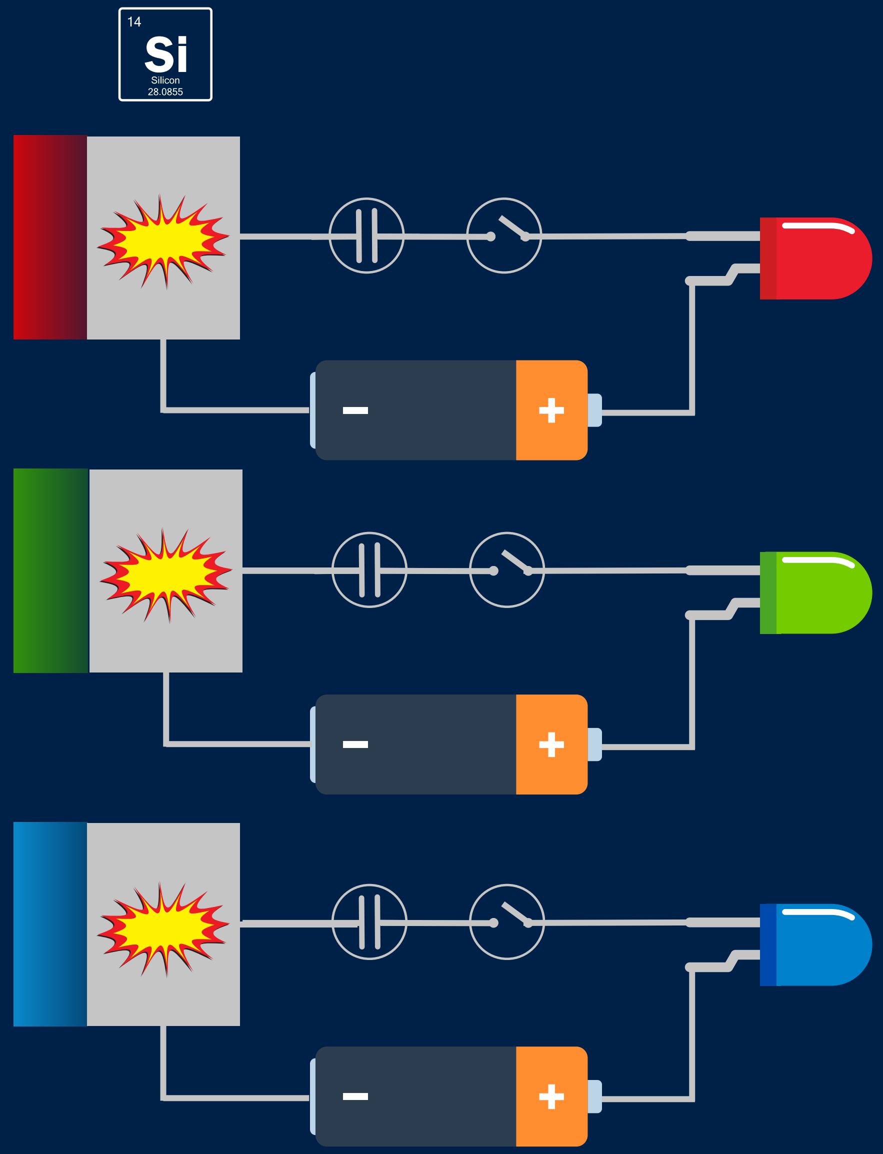

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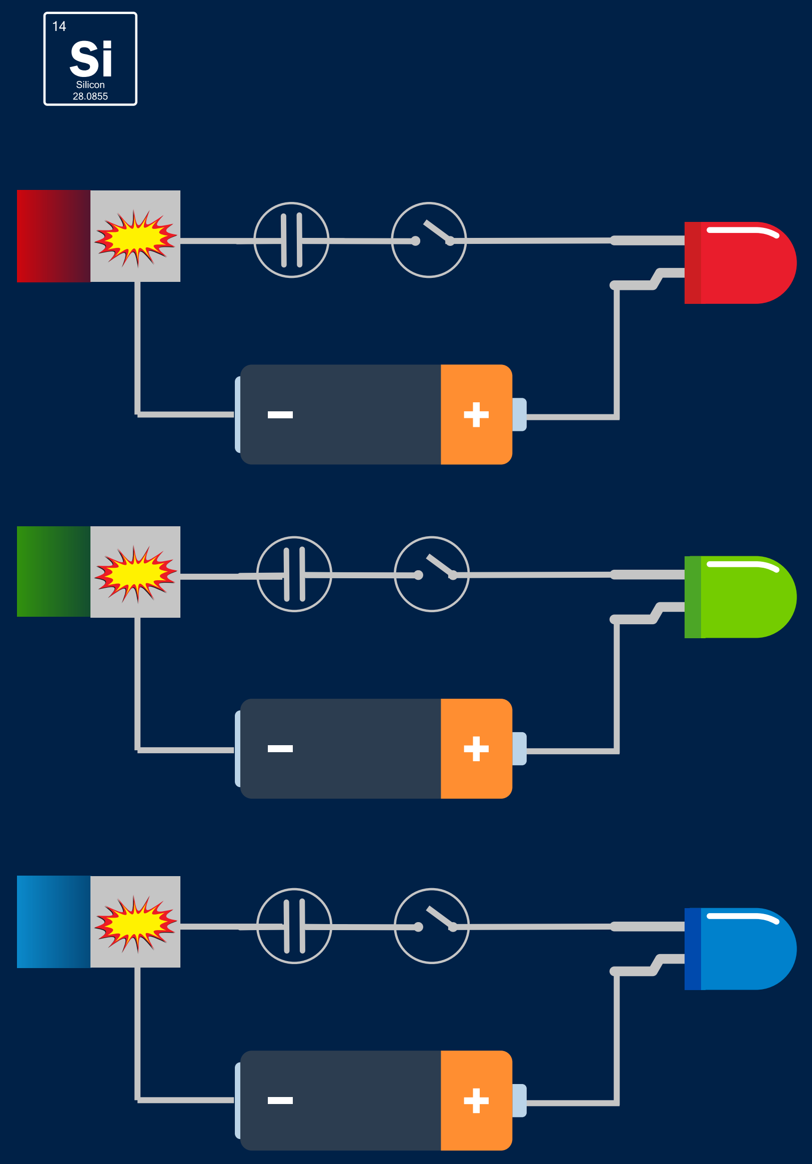

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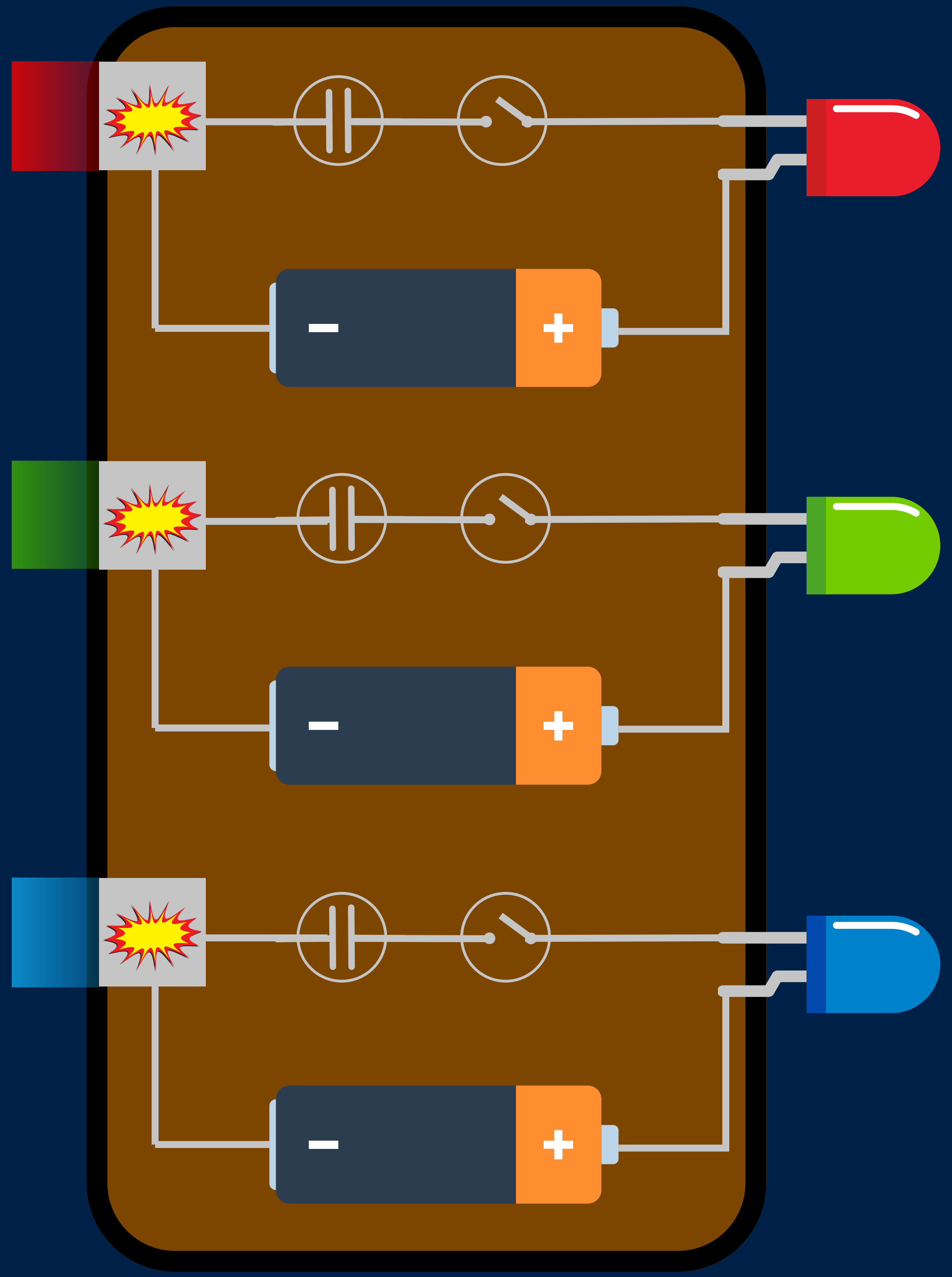

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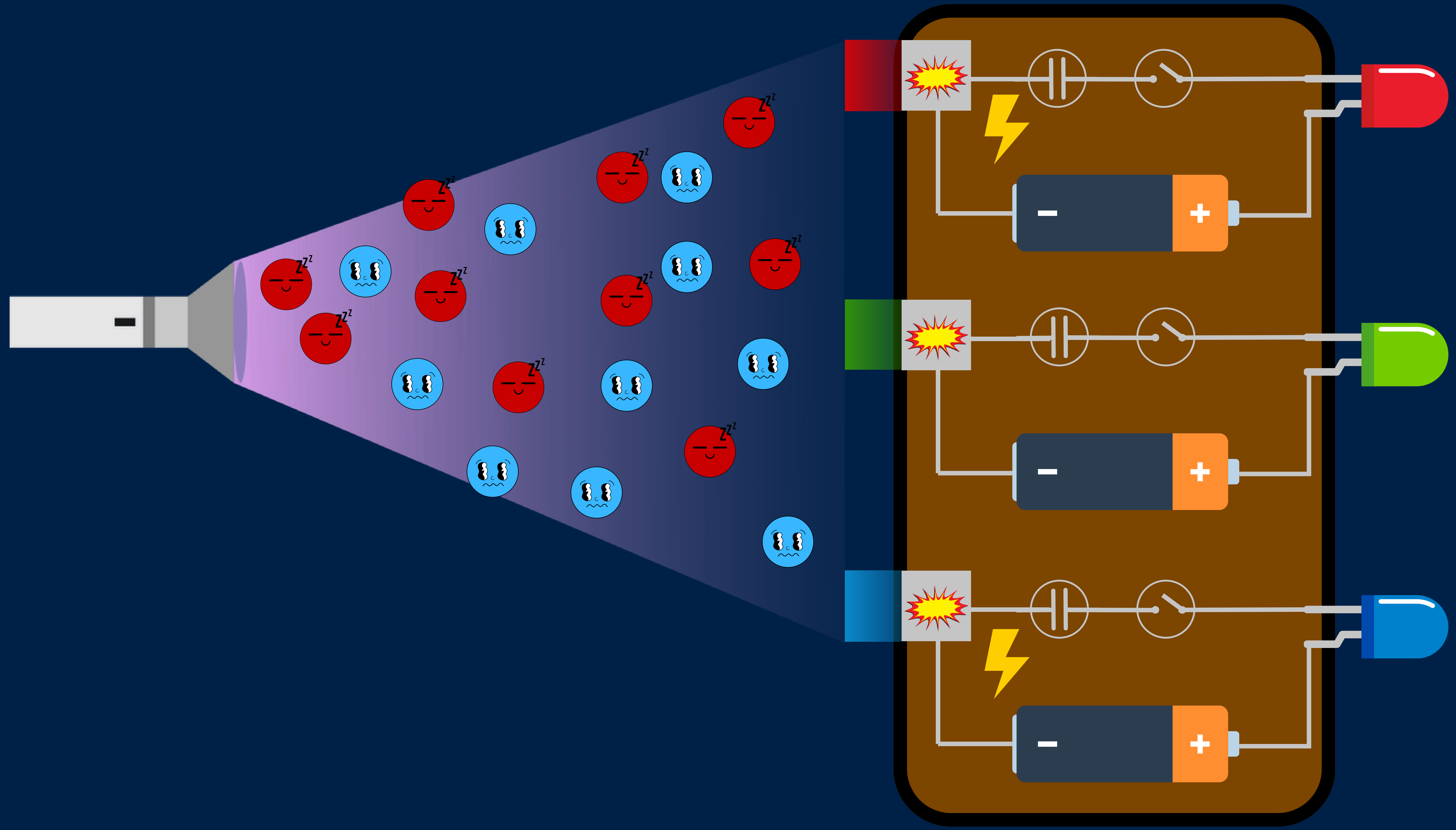

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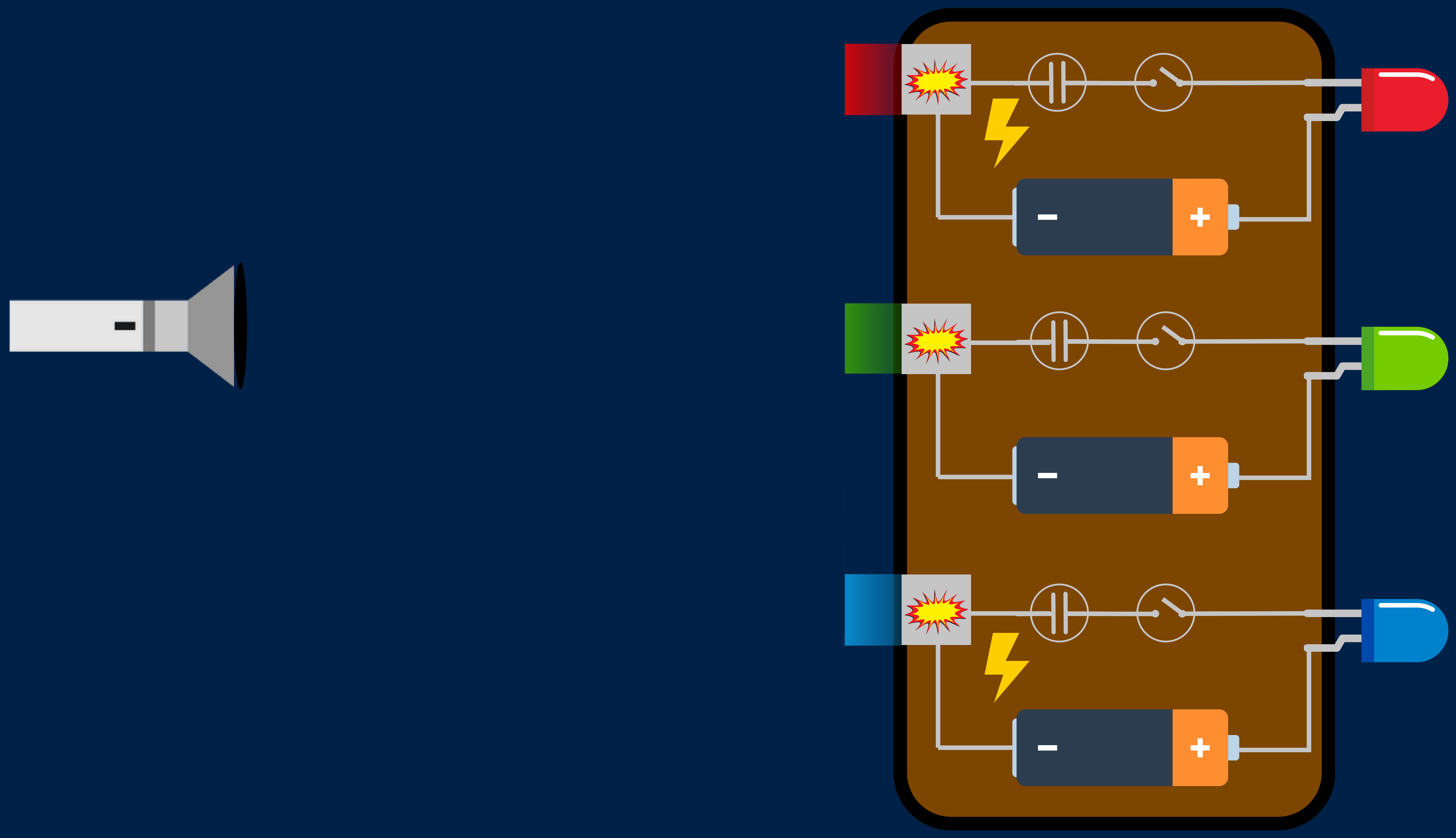

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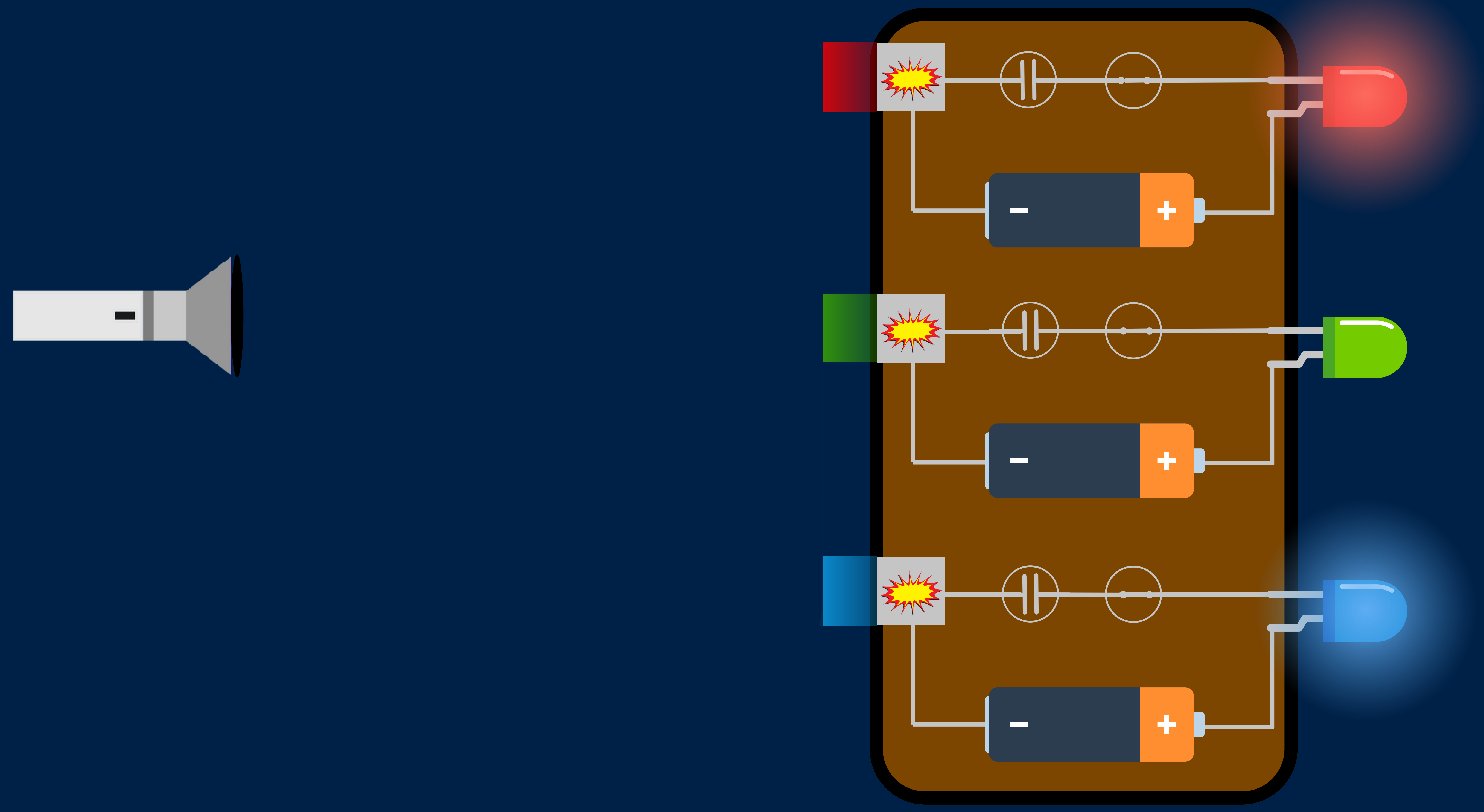

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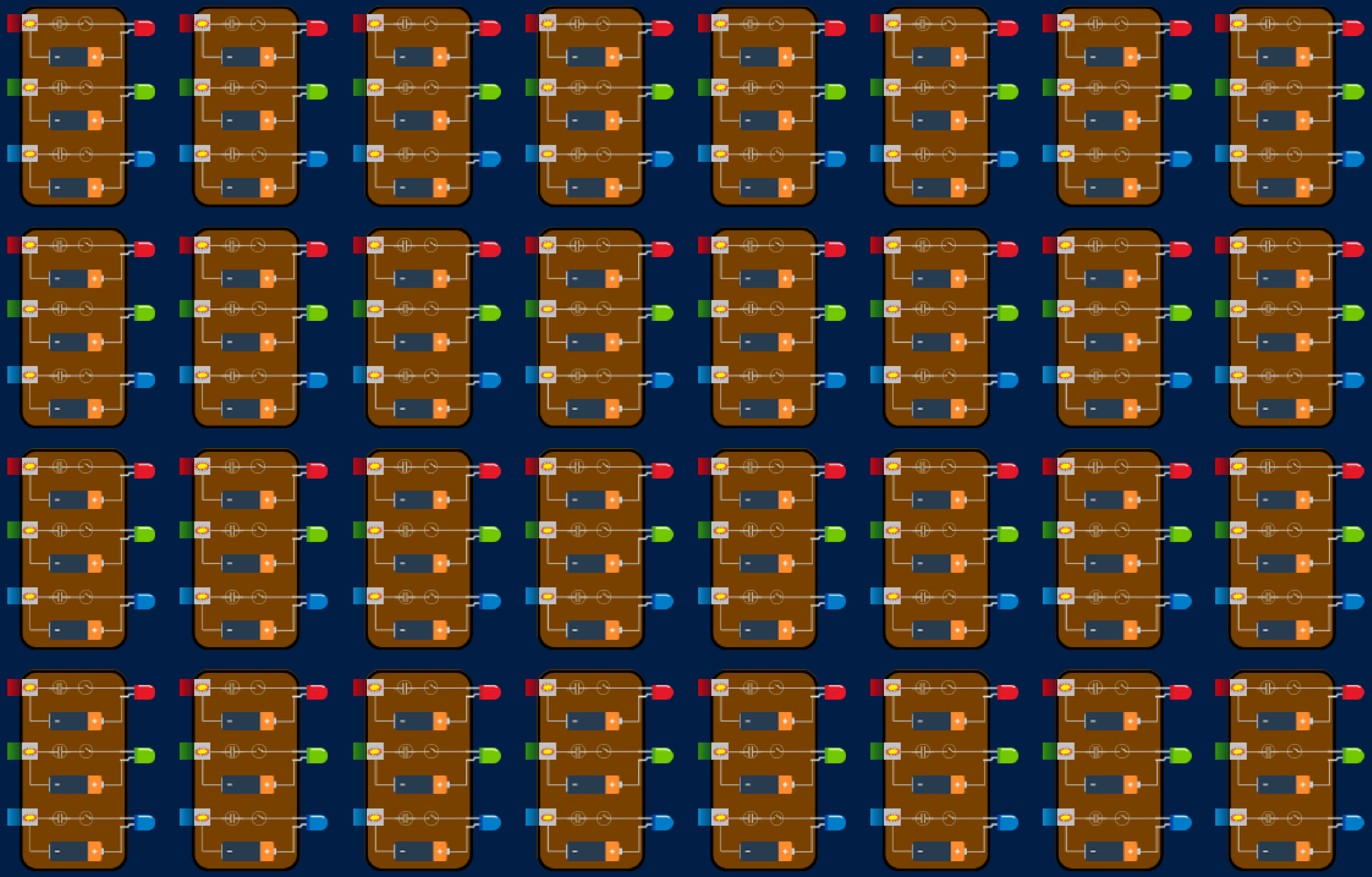

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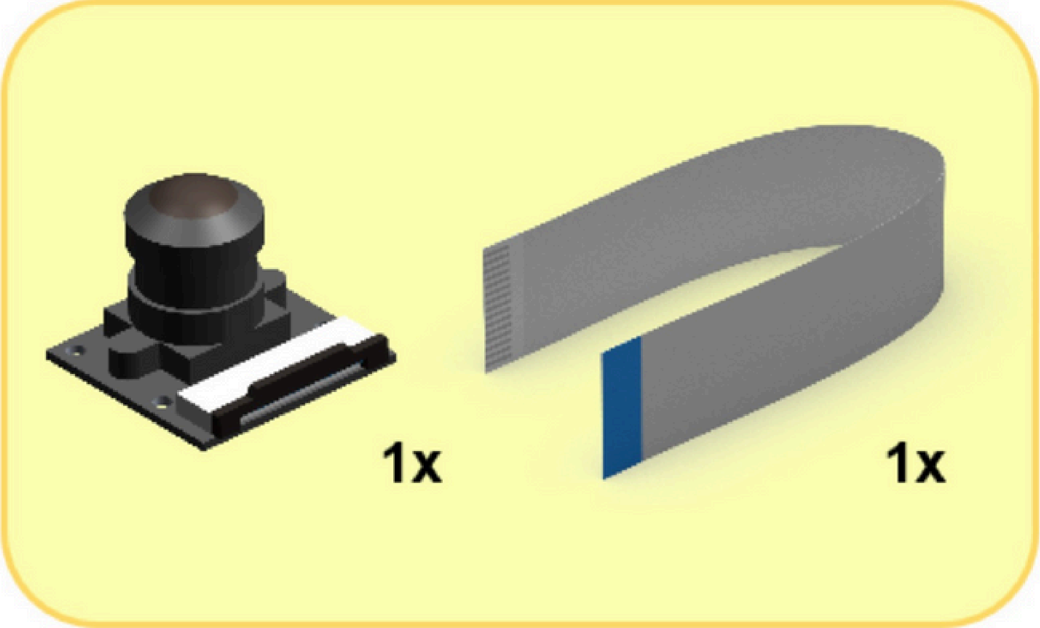

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