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Serving Students,
Researchers & Instructors

First Time User Guide to PN Junction (Interactive)

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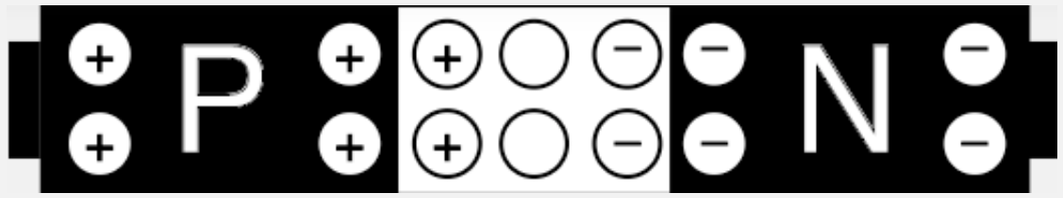

OUTLINE

- Introduction
  - What is a PN Junction?
  - Working of a PN Junction.
- What do you see by default?
- How to change the simulated device?
- Examples
  - What if the doping is changed?
  - What if there is an intrinsic region?

Limitation/Comments

- References

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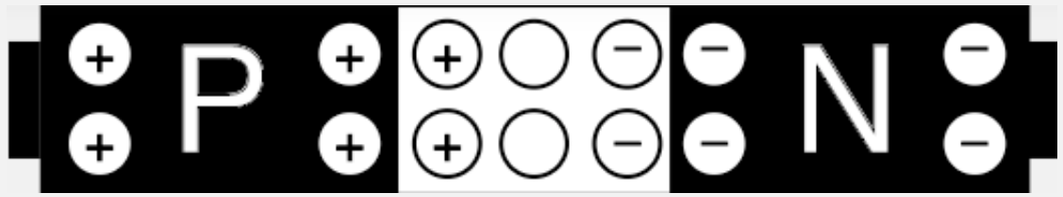
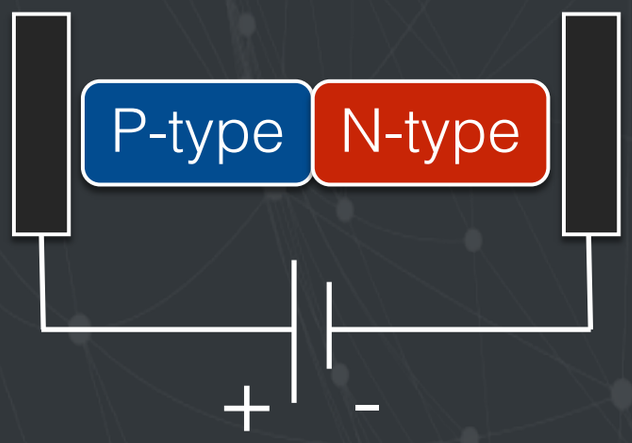


What is a PN Junction?

- A PN junction is a device formed by combining p-type (doped with B, Al) and n-type (doped with P, As, Sb) semiconductors together in close contact.
- PN junction can basically work in two modes,
  - forward bias mode (as shown below: positive terminal connected to p-region and negative terminal connected to n-region)
  - reverse bias mode (negative terminal connected to p-region and positive terminal connected to n region



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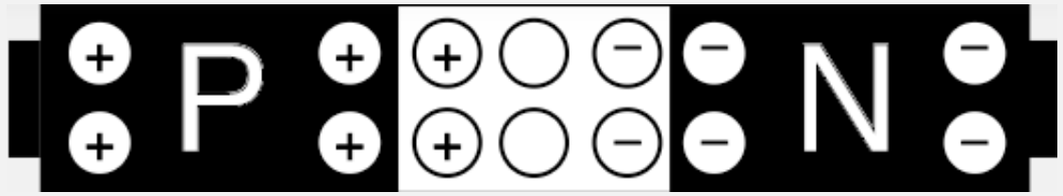
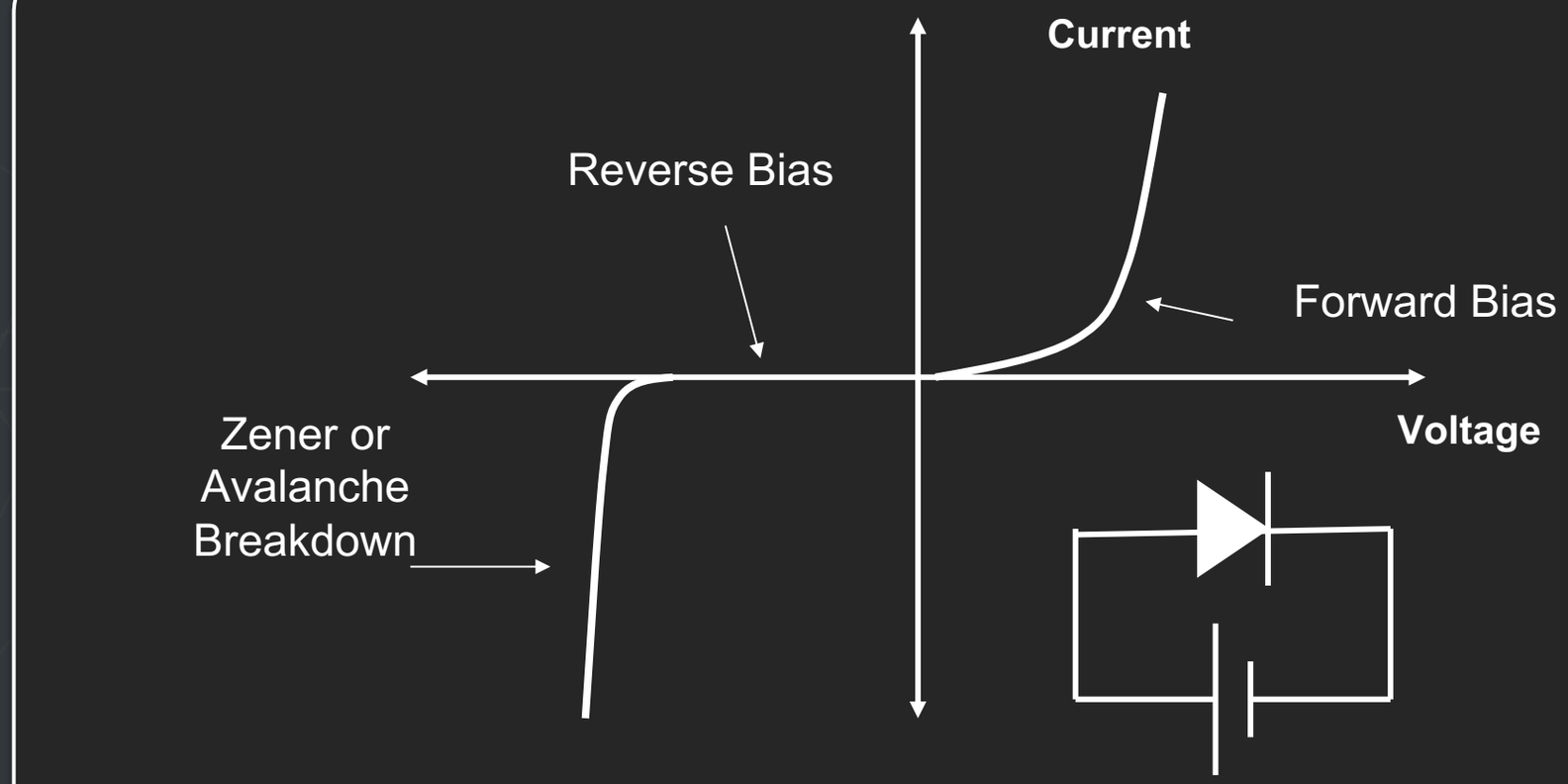
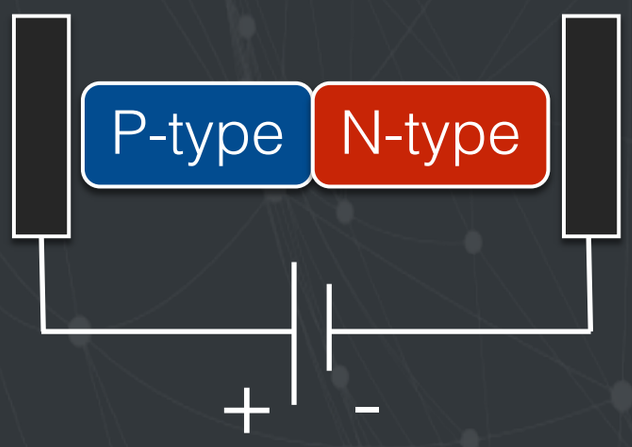


What is a PN Junction?





- PN junction diode acts as a *rectifier* as seen in the IV characteristic.
- Certain current flows in forward bias mode.
- Negligible current flows in reverse bias mode until zener or avalanche breakdown happens.

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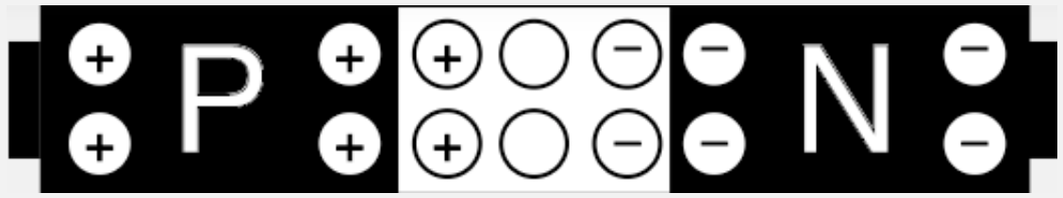
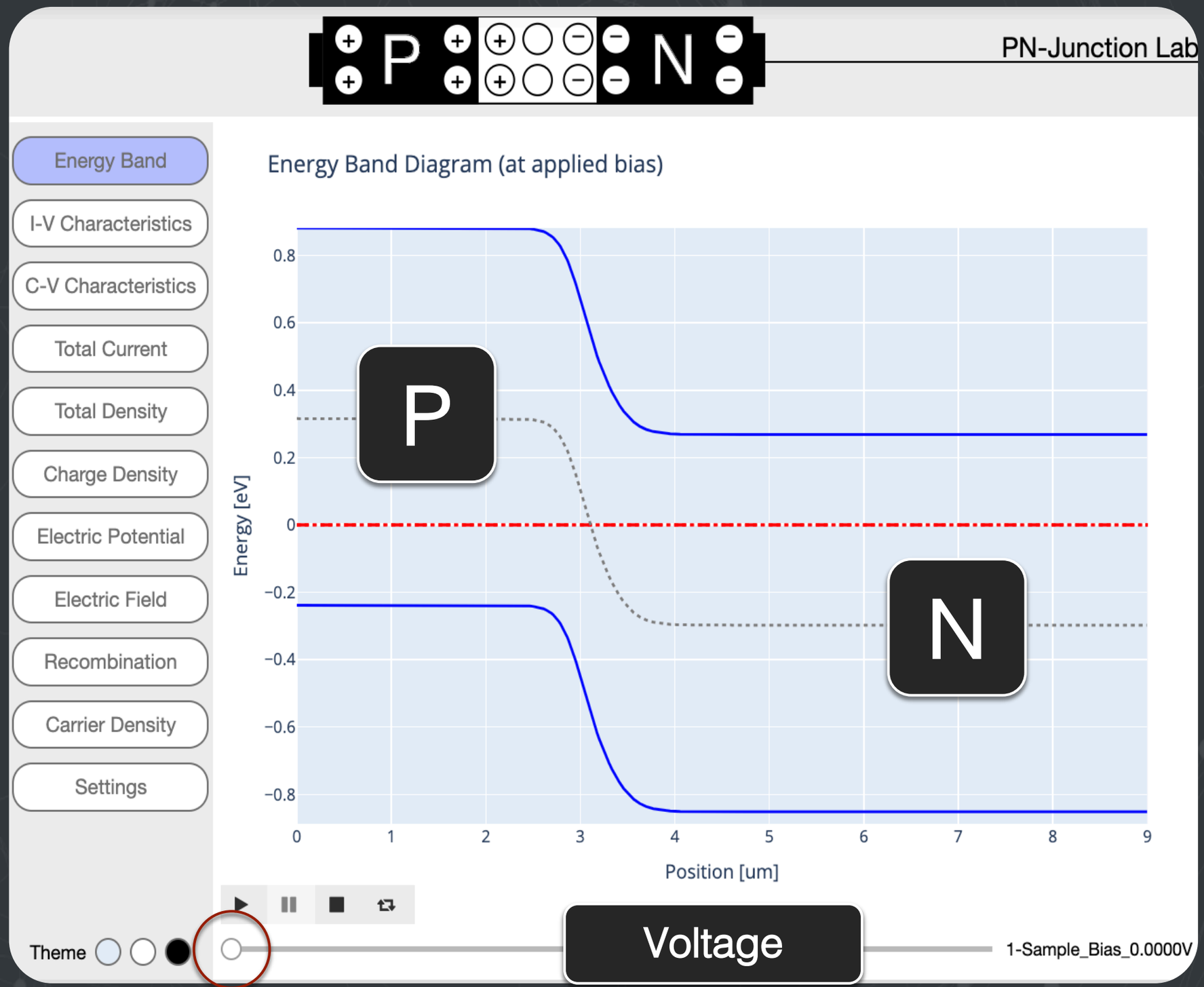


What do you see by default?



Default settings are showing energy bands of a PN junction diode in forward bias mode with 3μm long P-type and 6μm N-type, regions are doped at 1e15 and 2e15 $cm^{3.}$

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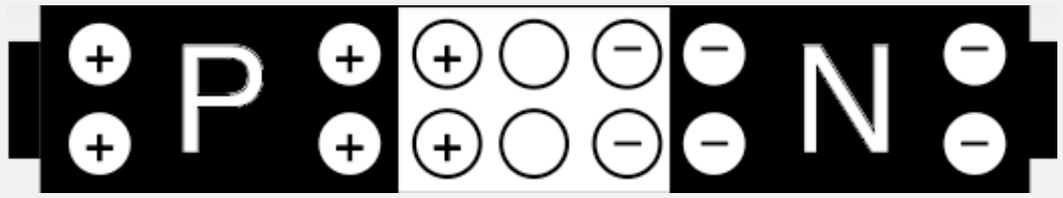

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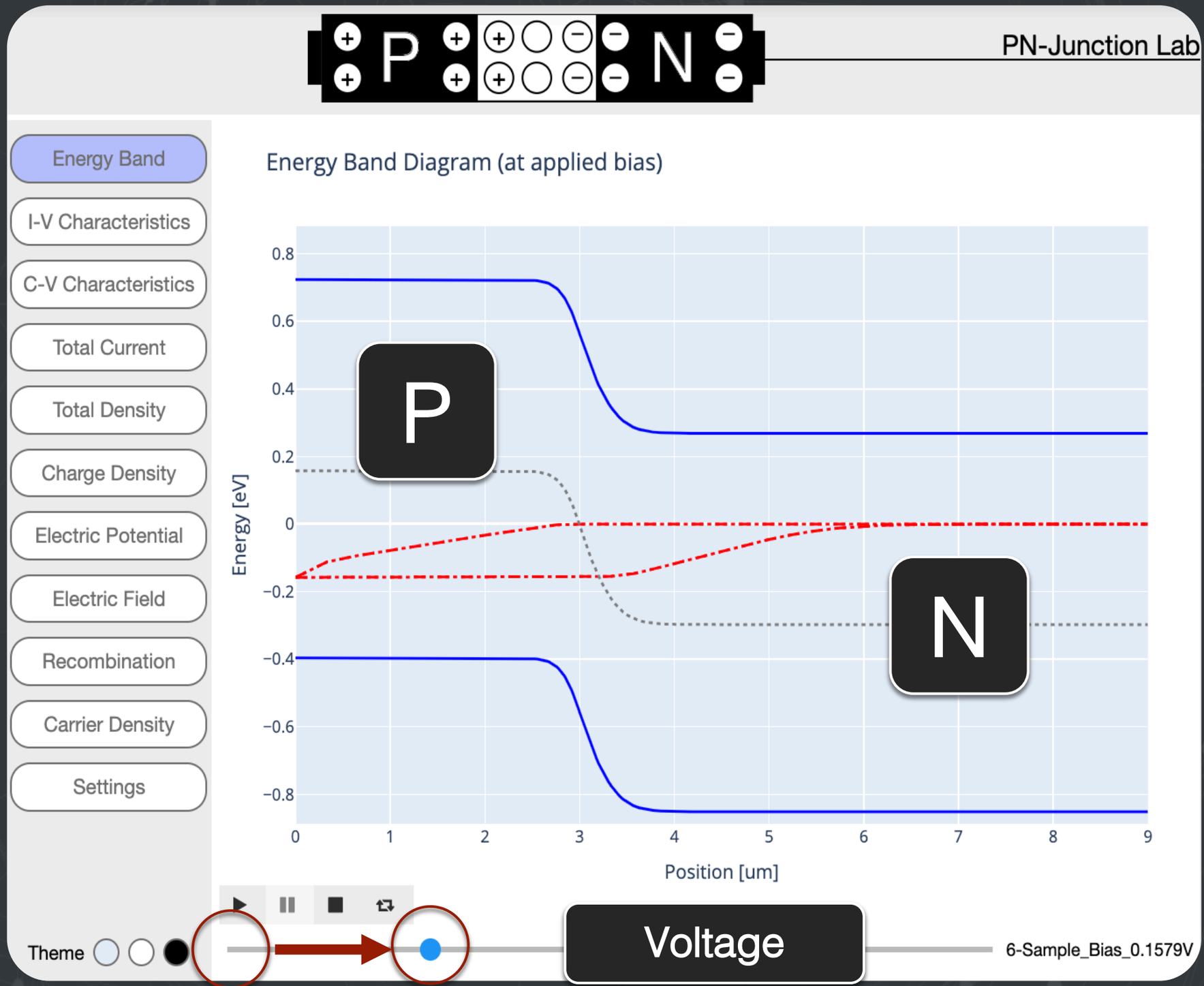

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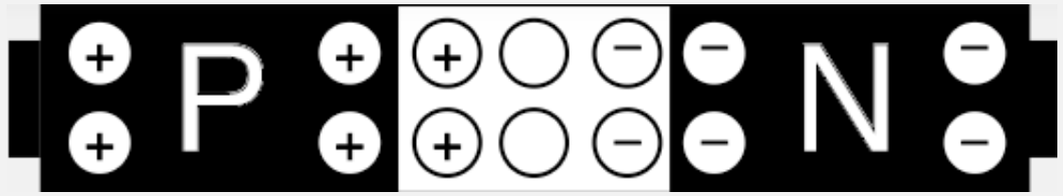

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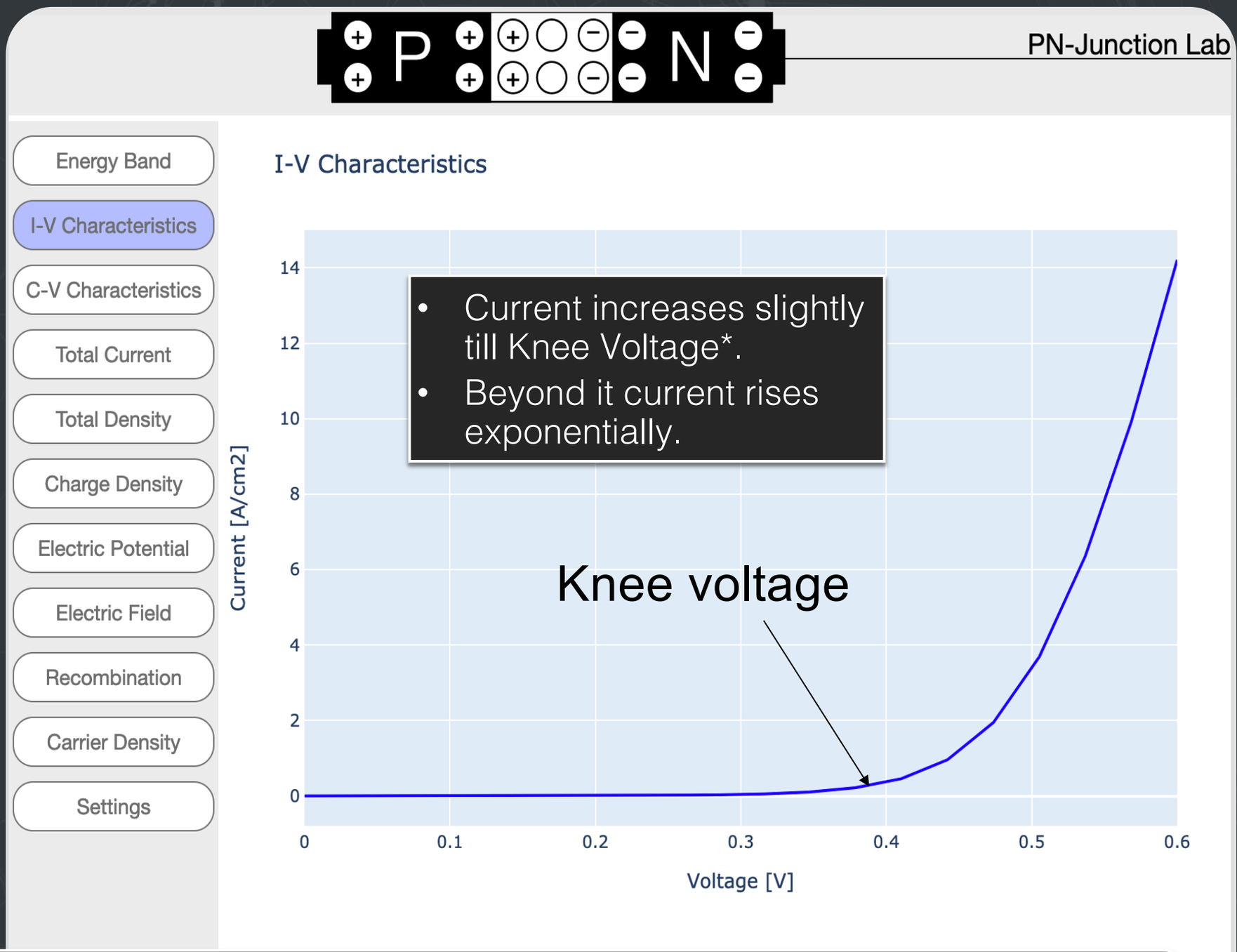

IV characteristic for PN junction in forward bias mode in default settings.

*Refer https://nanohub.org/resources/68 for a detailed discussion on operation of PN junction.

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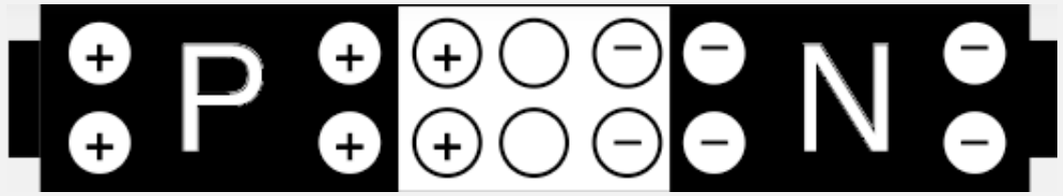

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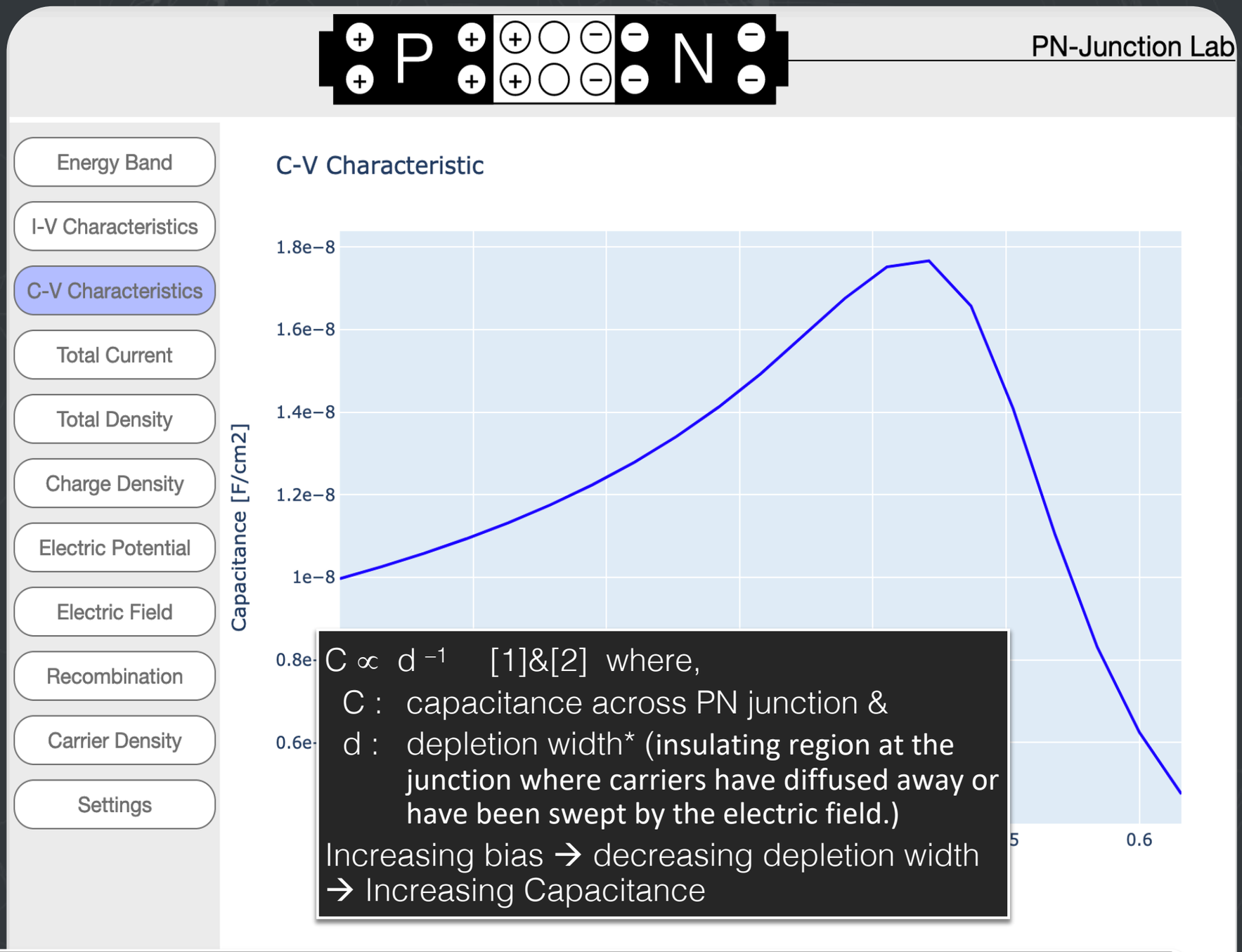

C-V characteristic for PN junction in forward bias mode in default settings.

$C \propto d^{-1}$ [1]&[2] where,

C : capacitance across PN junction &

d : depletion width* (**insulating region at the junction where carriers have diffused away or have been swept by the electric field.**)

Increasing bias → decreasing depletion width → Increasing Capacitance

*Refer https://nanohub.org/resources/68 for a detailed discussion on operation of PN junction.

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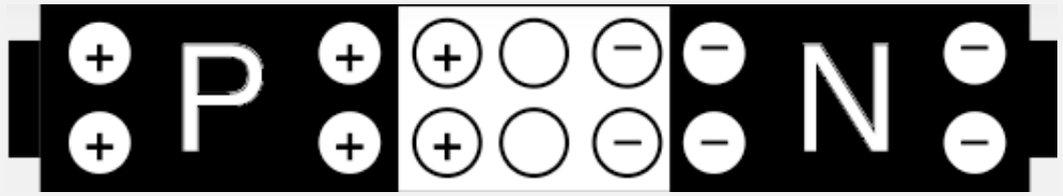

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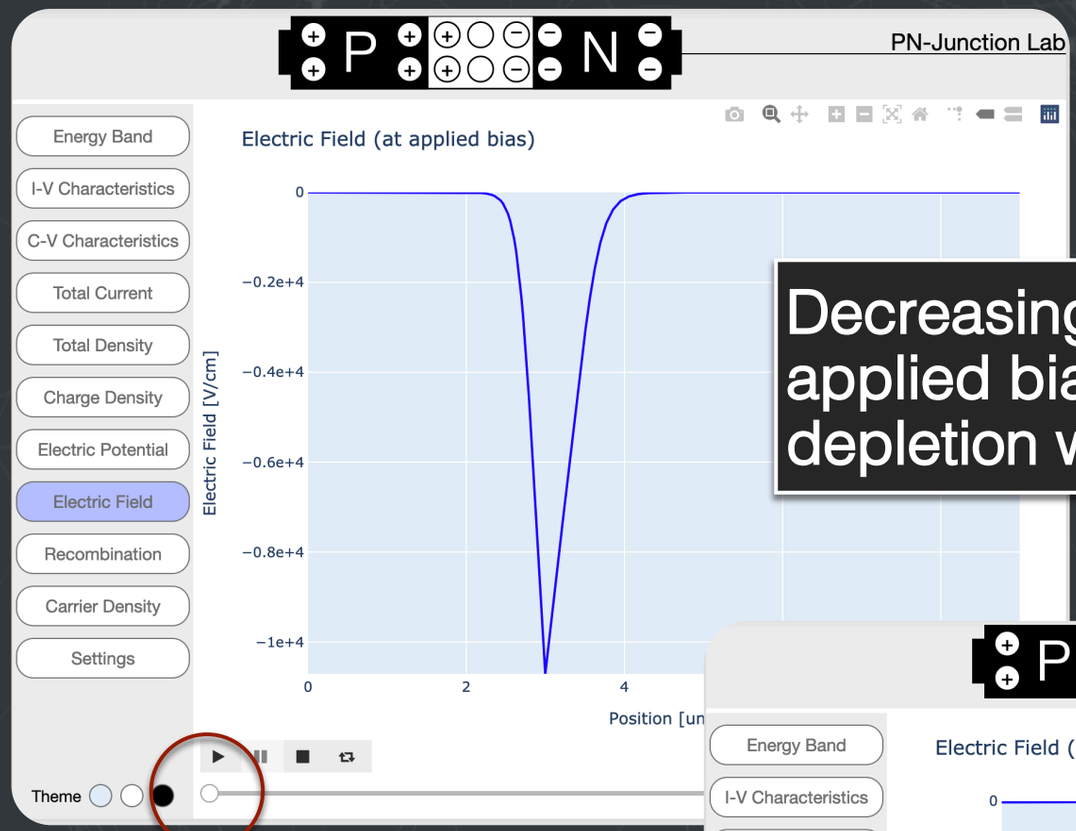
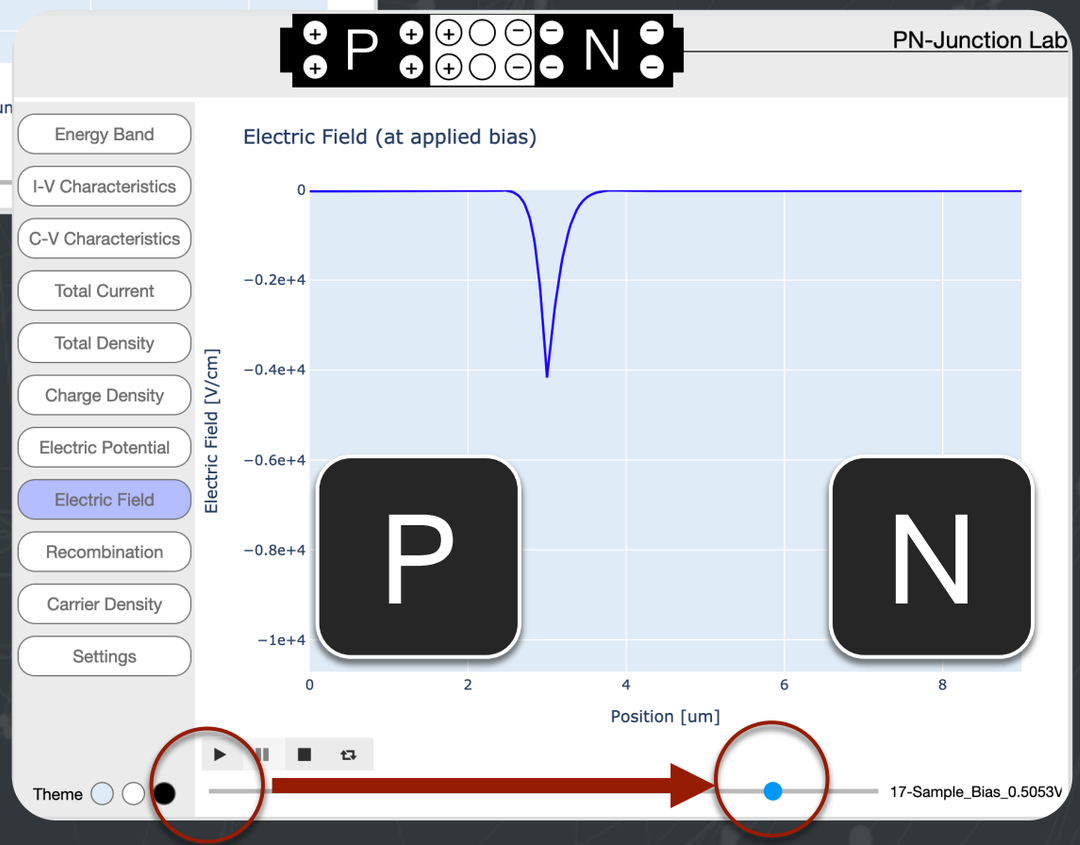


Decreasing electric field with applied bias due to thinning of depletion width.



Electric Field for PN junction in forward bias mode in default settings.

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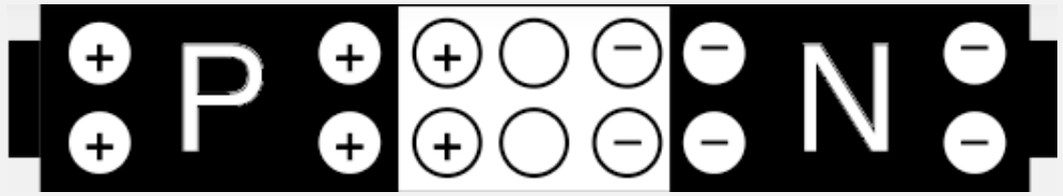

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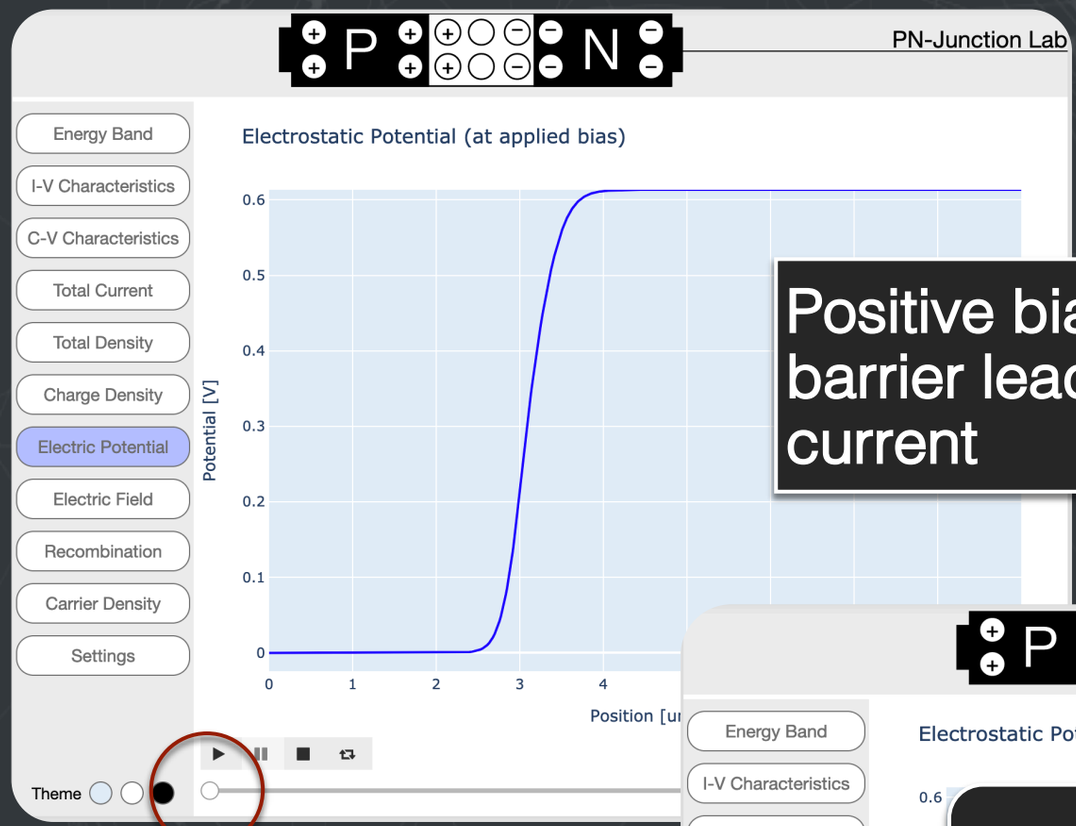
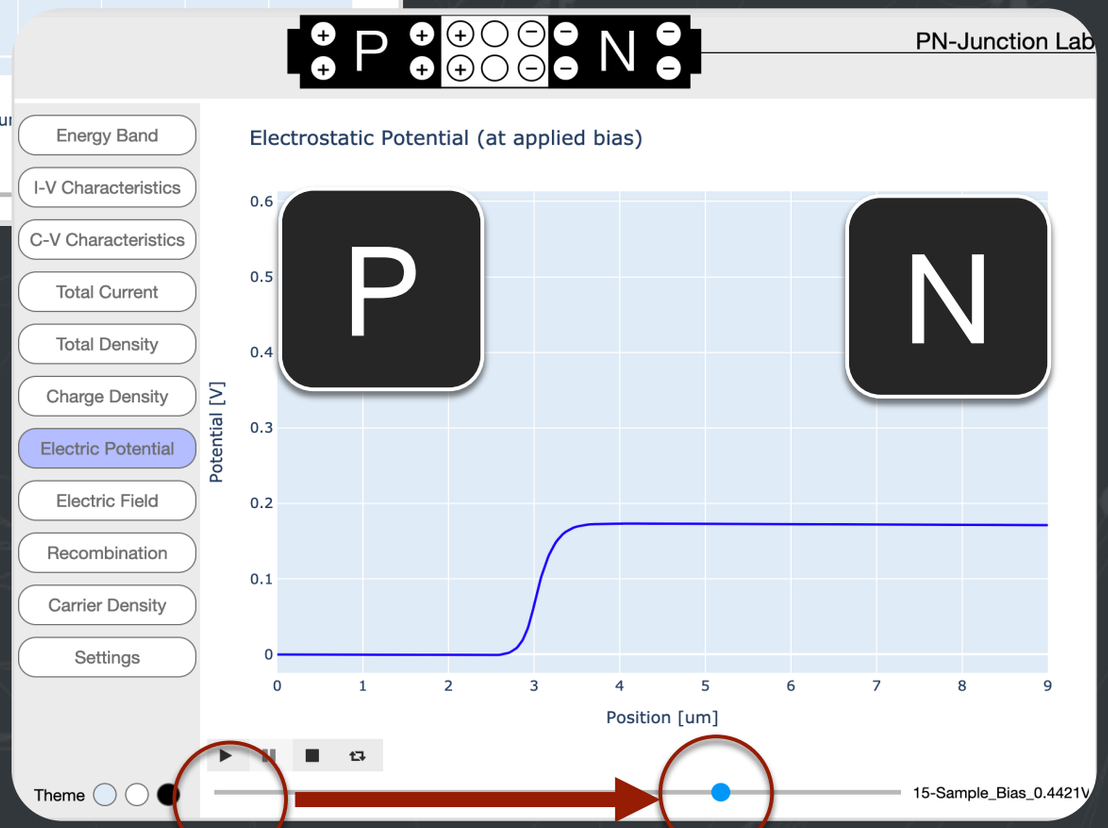


Positive bias at P side reduces the barrier leading to increase in diode current



Electric Potential for PN junction in forward bias mode in default settings.

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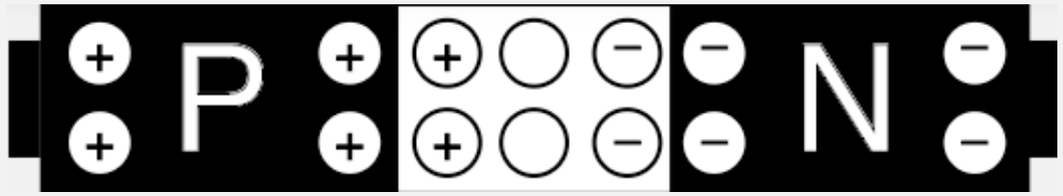

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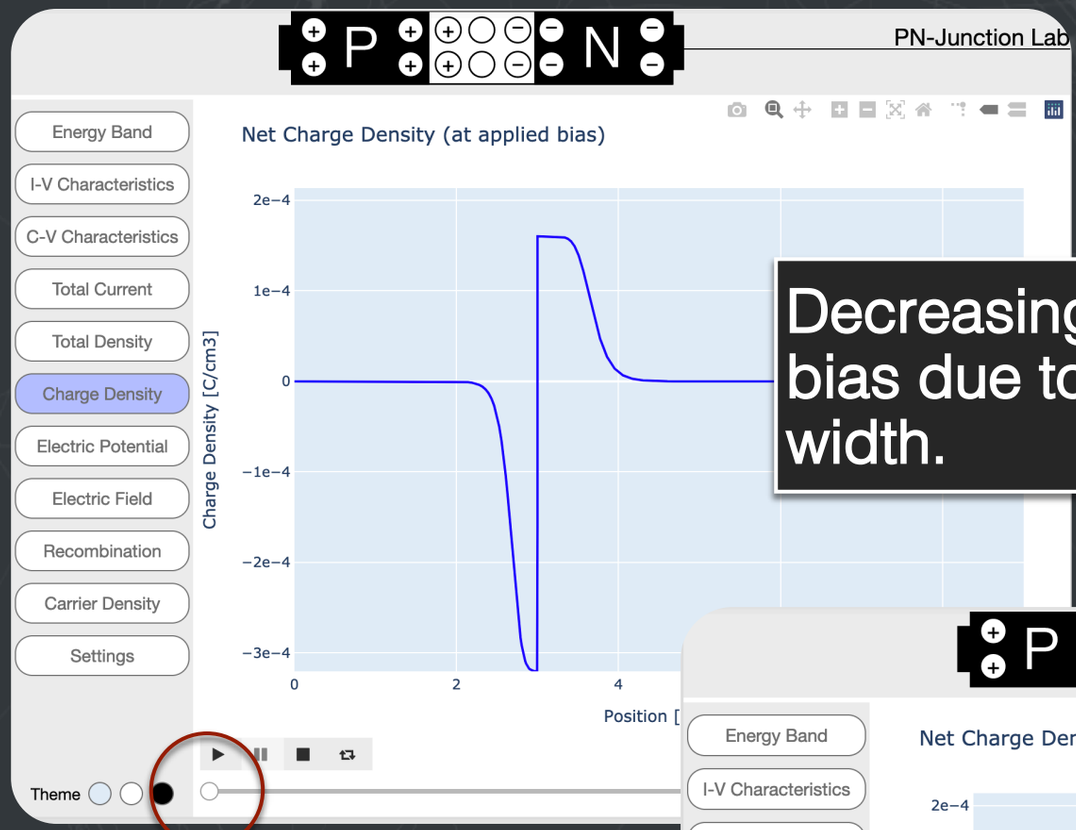
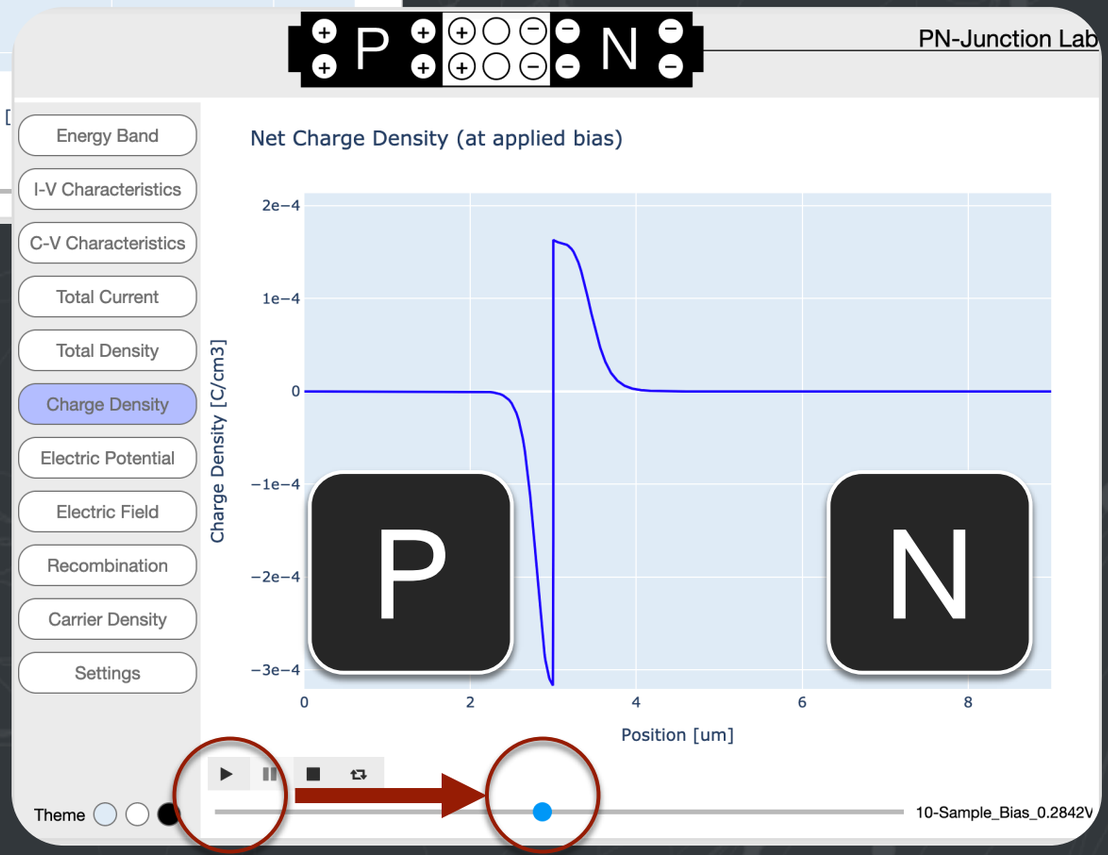


Decreasing charge with applied bias due to thinning of depletion width.



Charge density for PN junction in forward bias mode in default settings.

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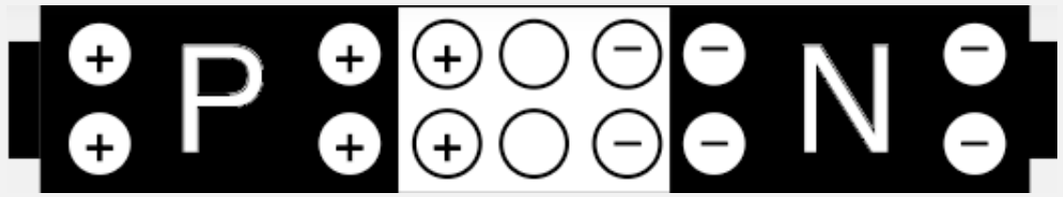
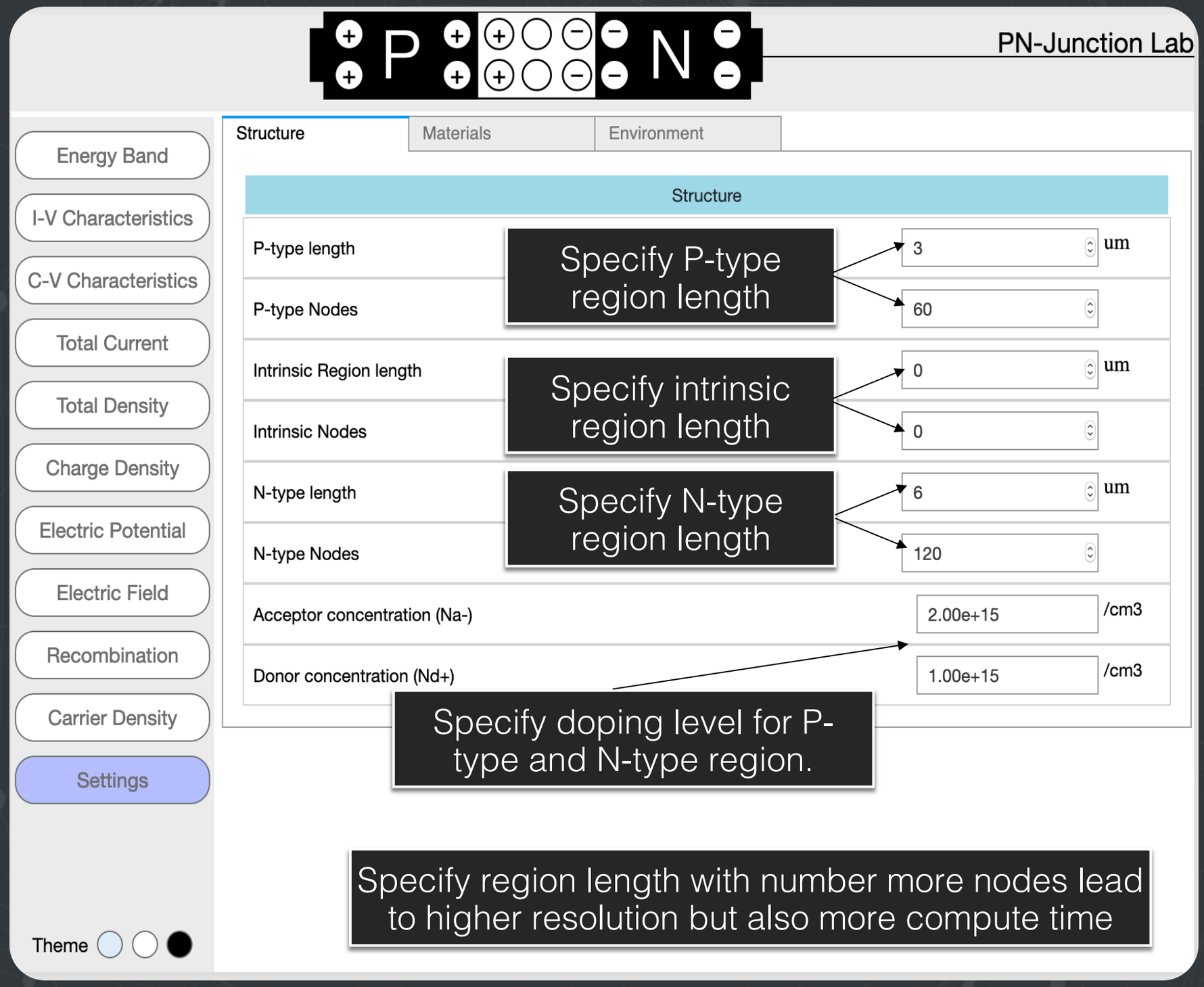


How to change simulated device?

Settings option allows to change the PN junction device structure



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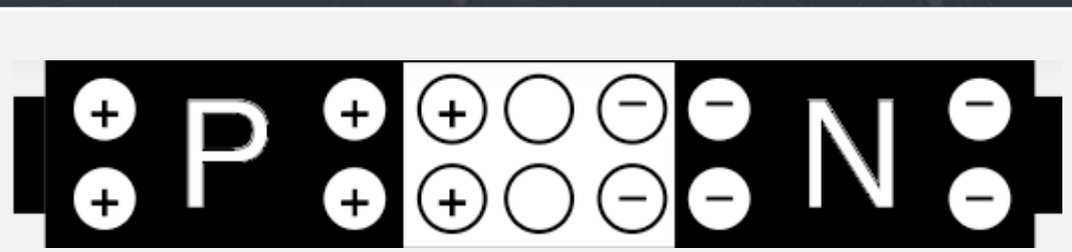

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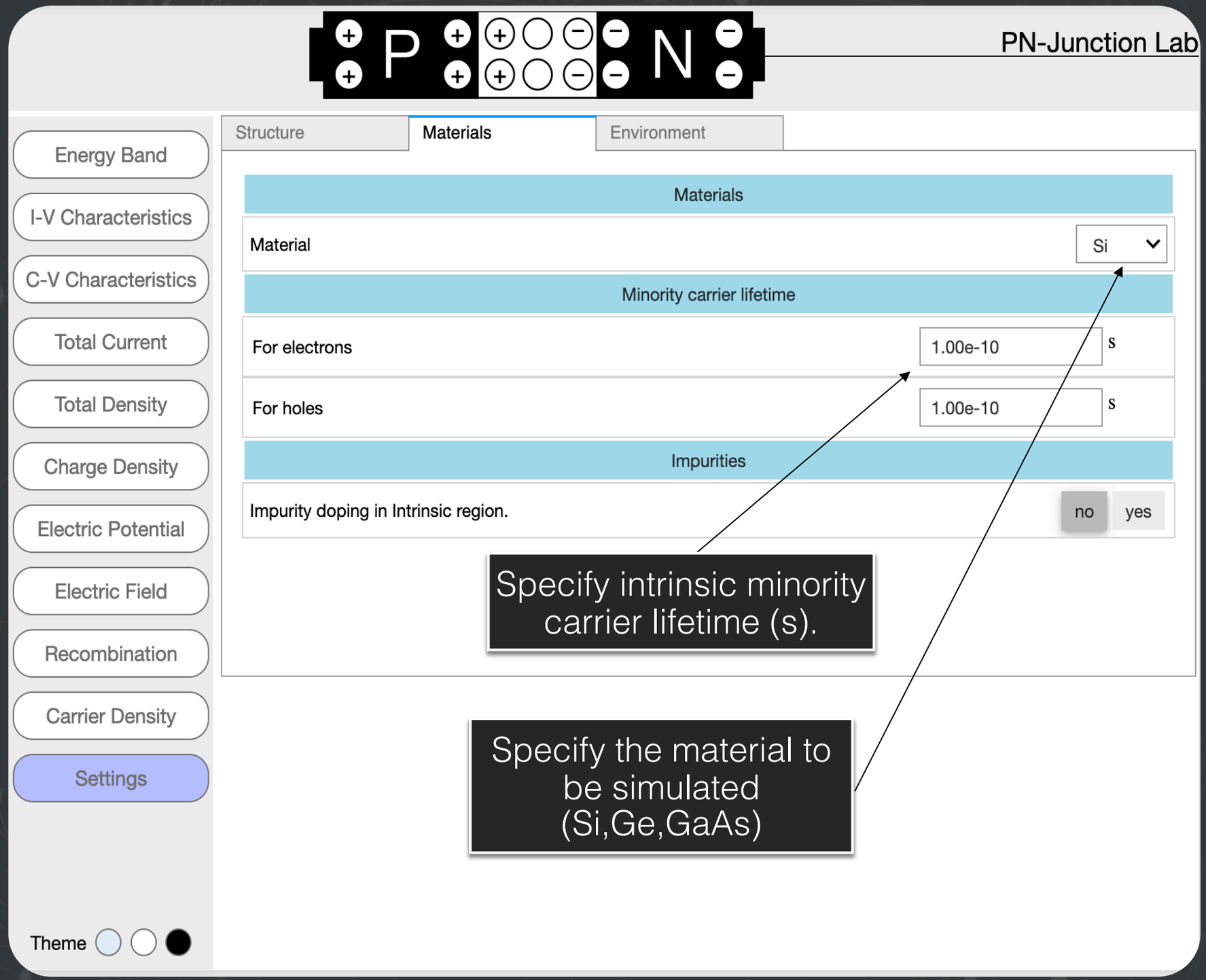

Settings option allows to change the PN junction device structure

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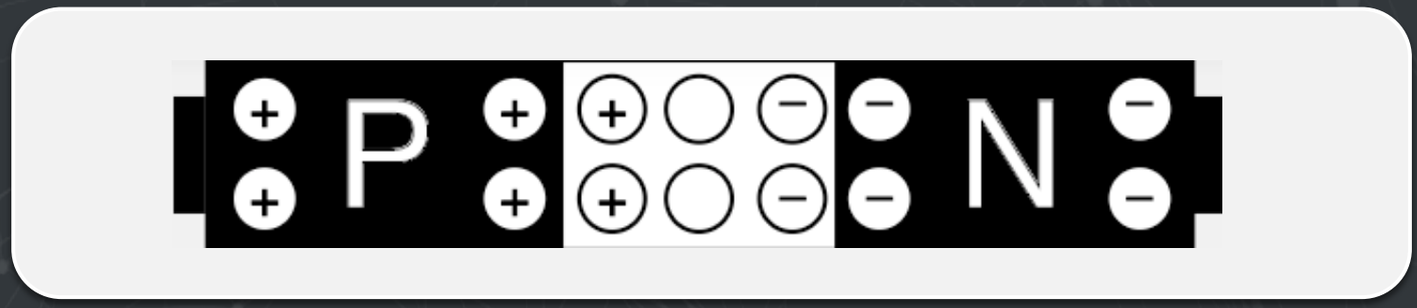

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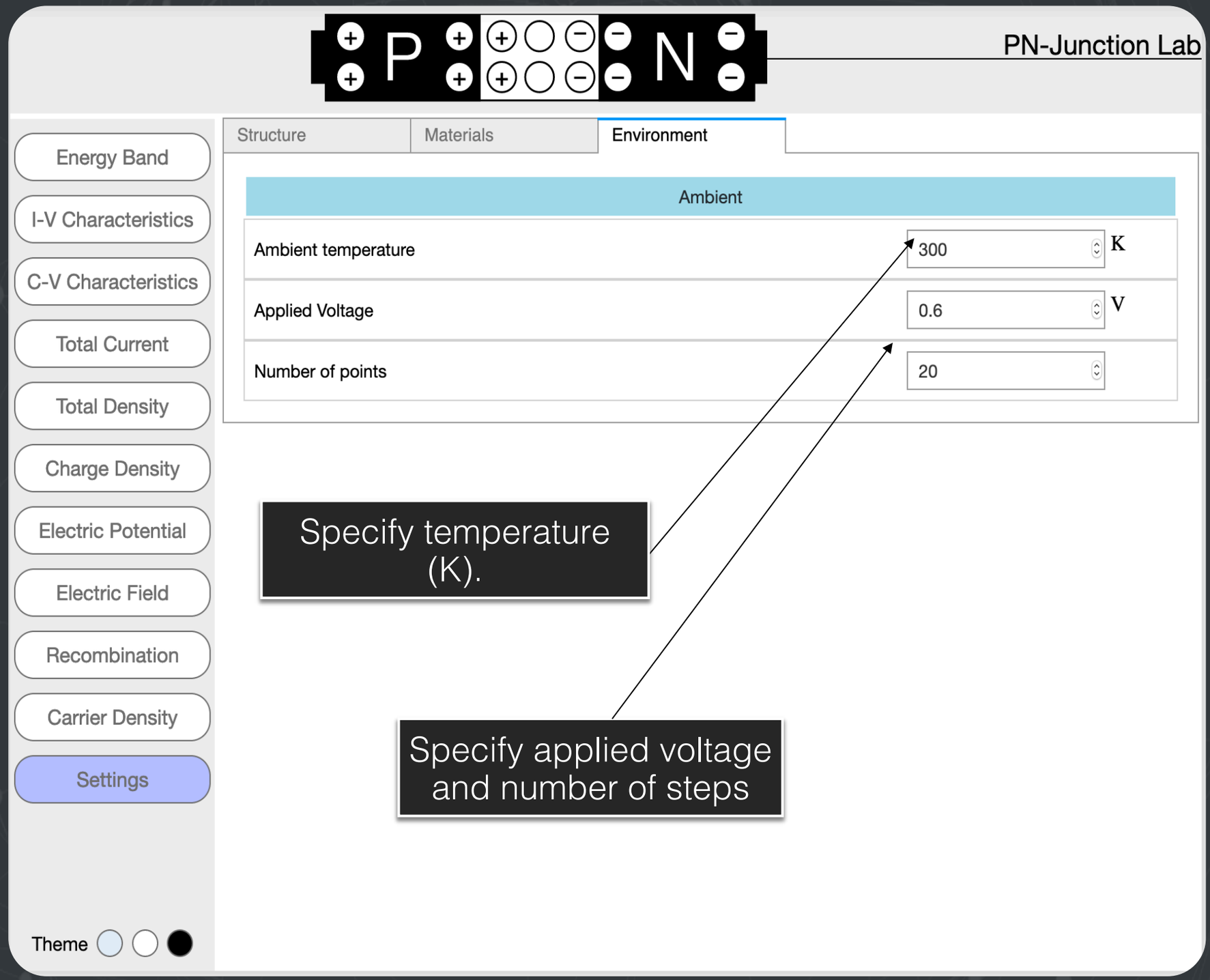

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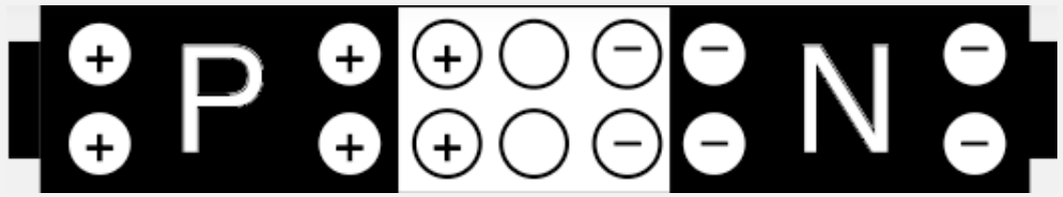
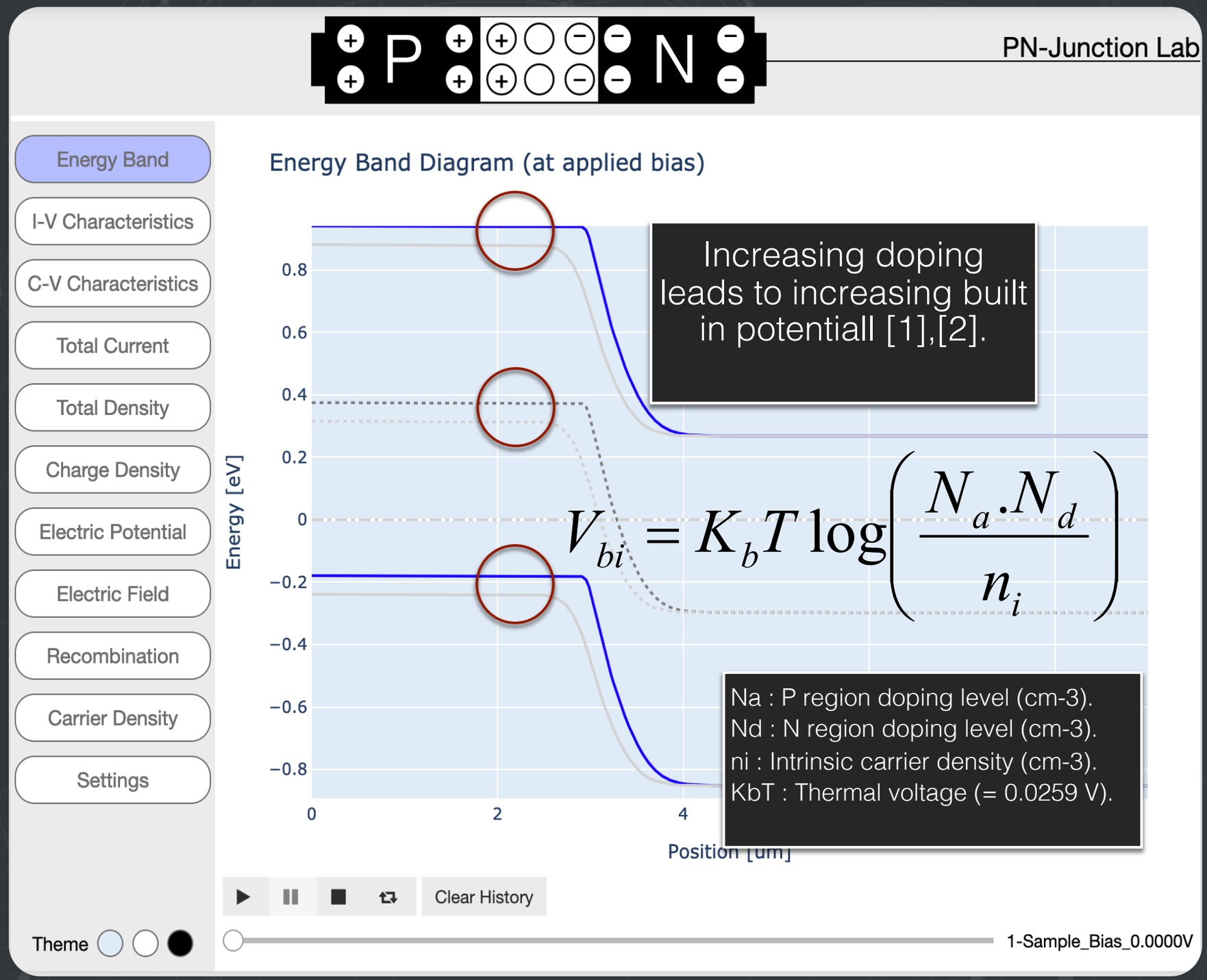


What if doping is changed?

On changing doping for n-type regions from 2e15 cm3 to 2e16 cm3. “Compare” button



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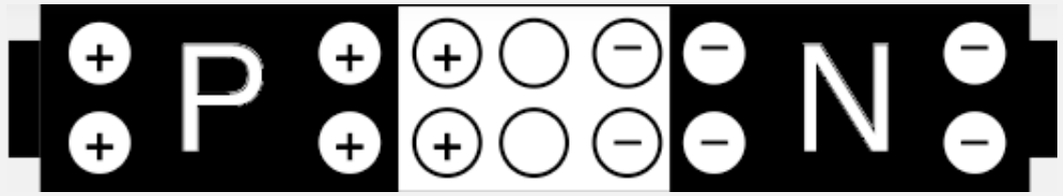
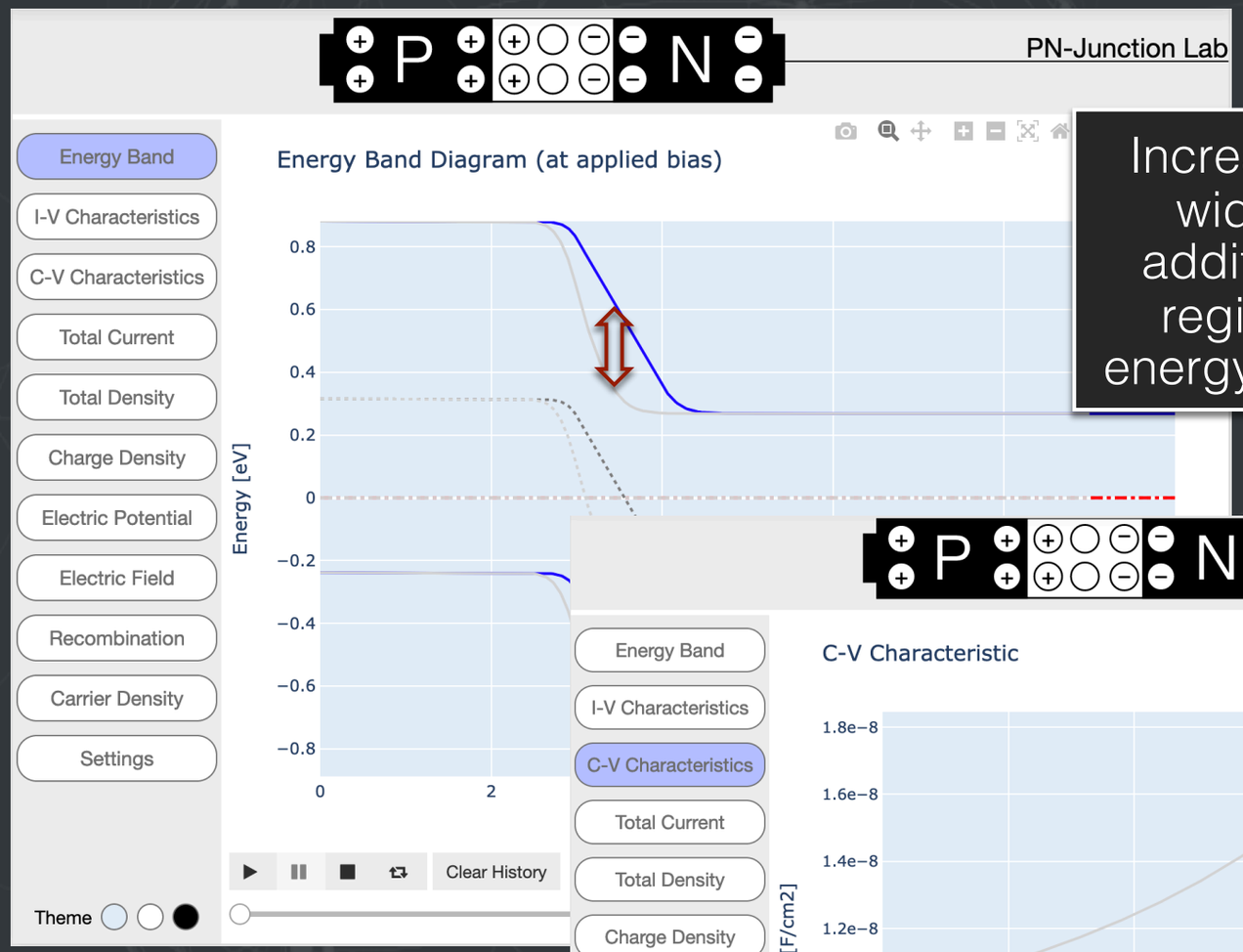
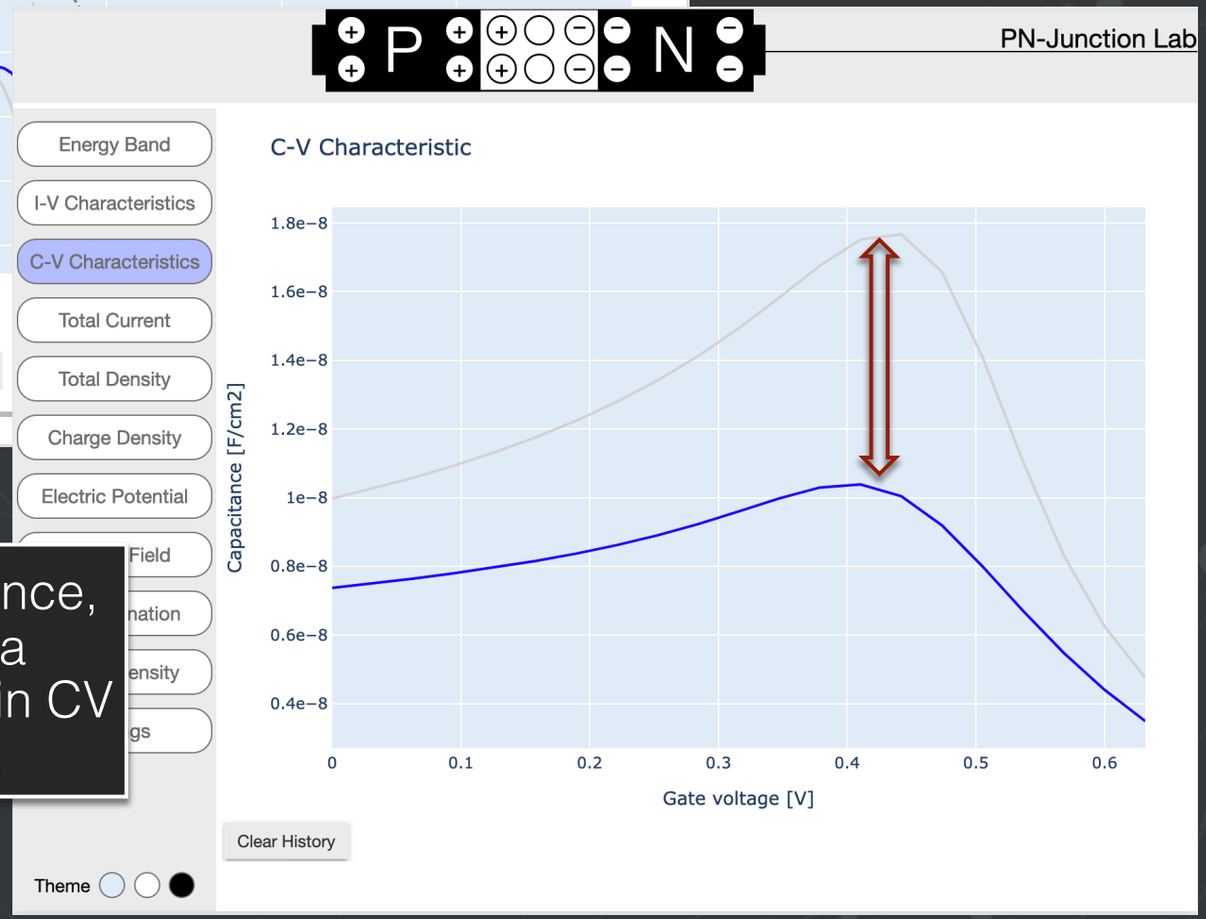


What if there is an intrinsic region?



Increased depletion width (d) due to addition of intrinsic region as seen in energy band diagram.

Default settings PIN junction diode in forward bias mode with 2μm long intrinsic region



Junction Capacitance, $C_j \propto d^{-1}$ shows a decrease as seen in CV characteristic.

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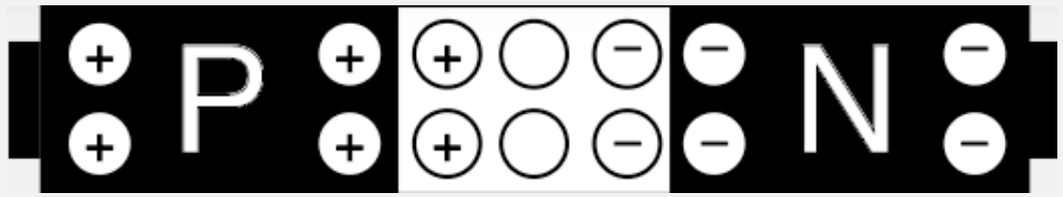
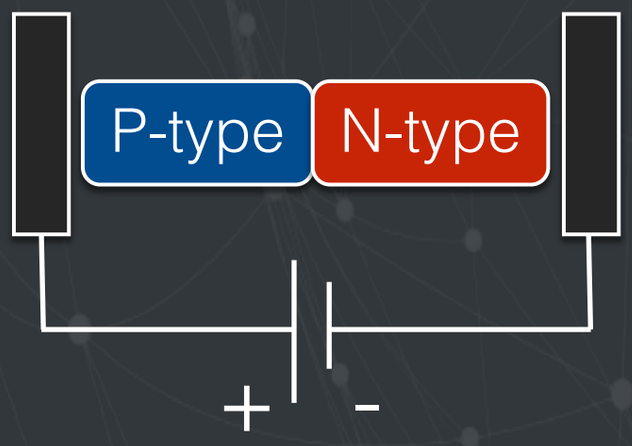


Limitations Comments

- Large physical dimensions (>10um) might lead to non convergence or large compute time.
- More nodes might be required for better convergence in some cases i.e. high doping in PN junction.
- PN junction currently performs steady state simulations only, no time dependent simulations are possible.
- Contacts during the simulation are considered to be ohmic (i.e. Current-Voltage,I-V curve is linear and symmetric).



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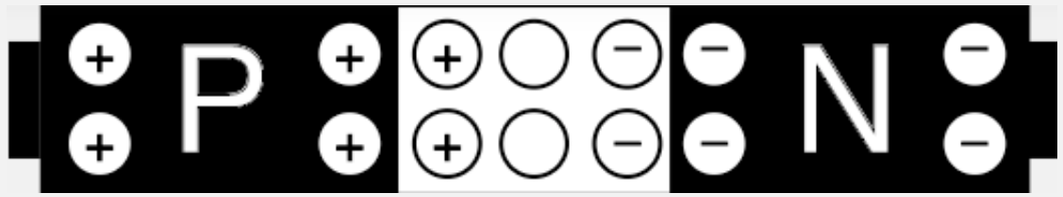


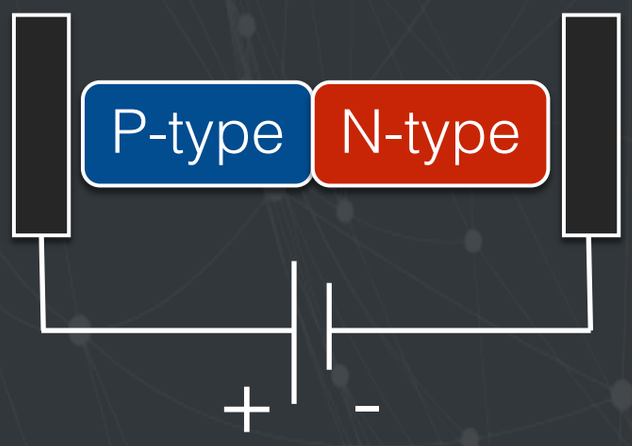
References

- PN junction theory

  [1] PN junction OPERATION : https://nanohub.org/resources/68
  [2] “Semiconductor Device Fundamentals”, by R.F. Pierret

- PADRE

  [3] Dragica Vasileska; Gerhard Klimeck (2006), "Padre," DOI: 10254/ nanohub-r941.3.
  [4] PADRE MANUAL : http://nanohub.org/resource_files/tools/padre/doc/ index.html



THANK YOU!

Original slides (First Time User Guide to PN Junction V1.31):
Saumitra R Mehrotra, Ben Haley & Gerhard Klimeck
Adapted by Daniel Mejia