Section 16
Recombination & Generation

Gerhard Klimeck

gekco@purdue.edu

PURDUE UNIVERSITY

School of Electrical and Computer Engineering

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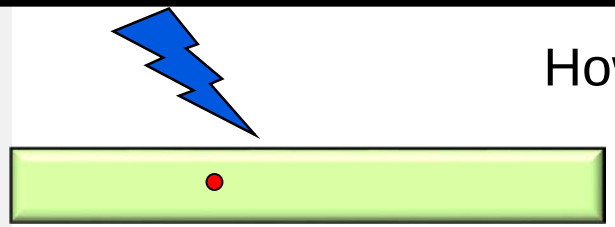
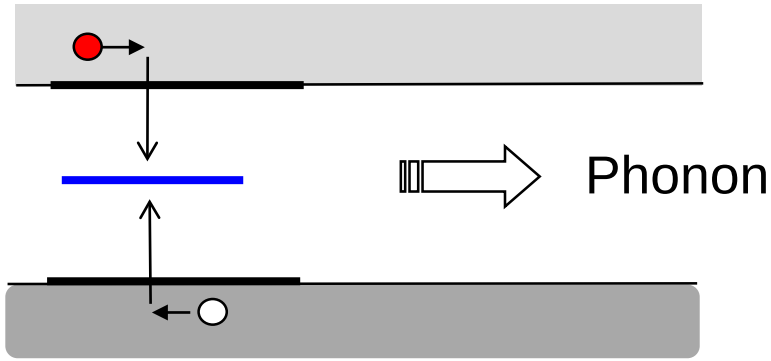


How does the system go BACK to equilibrium?



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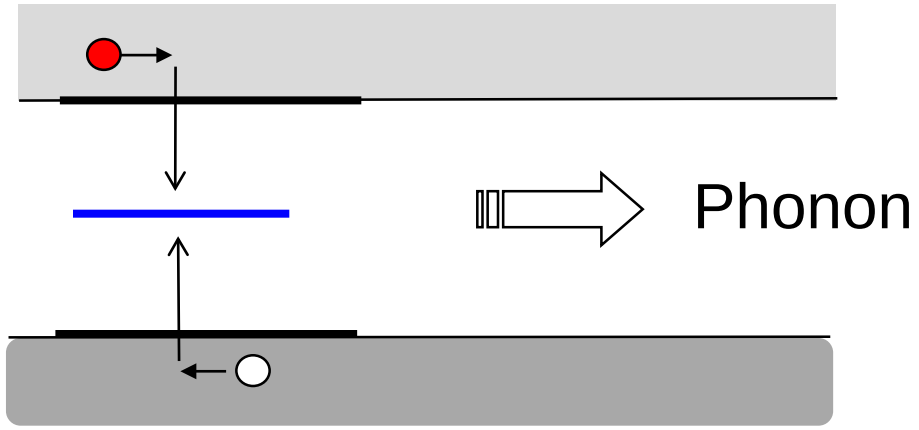
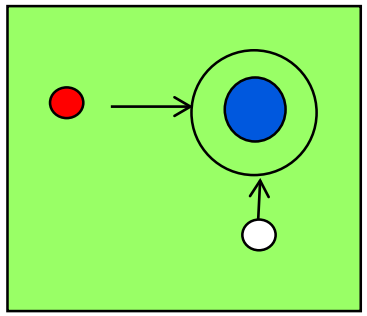
- 16.1 Capture coefficient & Capture Cross Section
- 16.2 Derivation of SRH formula (Shockley, Reed, Hall)
  - » 16.2.1 Trap Assisted Recombination Rates
  - » 16.2.2 Capture and emission relationship (n_1 and p_1)
  - » 16.2.3 Steady State Trap Population
  - » 16.2.4 Recombination-Generation Rate
- 16.3 Application of SRH formula for special cases
  - » Low level, high-level injection, depletion region
- 16.4 Direct and Auger recombination
- 16.5 Nature of interface states
- 16.6 SRH formula adapted to interface states
- 16.7 Surface recombination in depletion region

Video

Indirect Recombination (Trap-assisted)

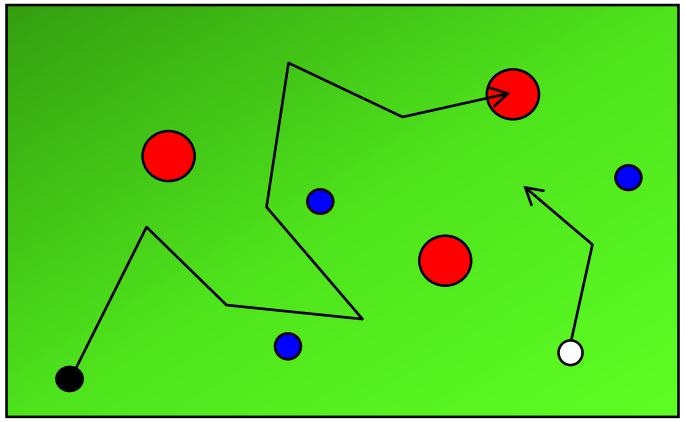




Ge, Si, ….

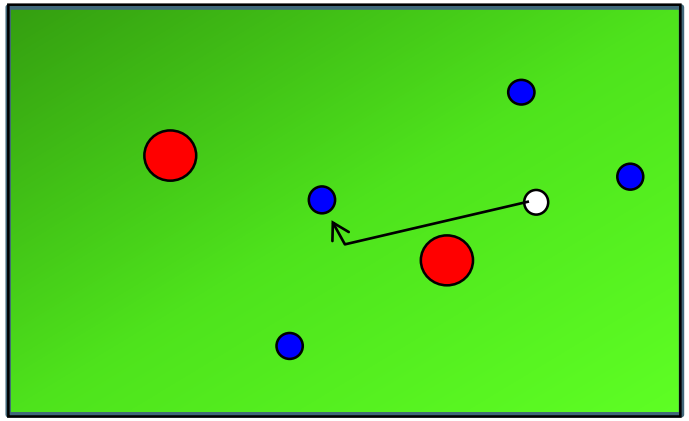
Transistors, Solar cells, etc.

Physical view of Carrier Capture/Recombination



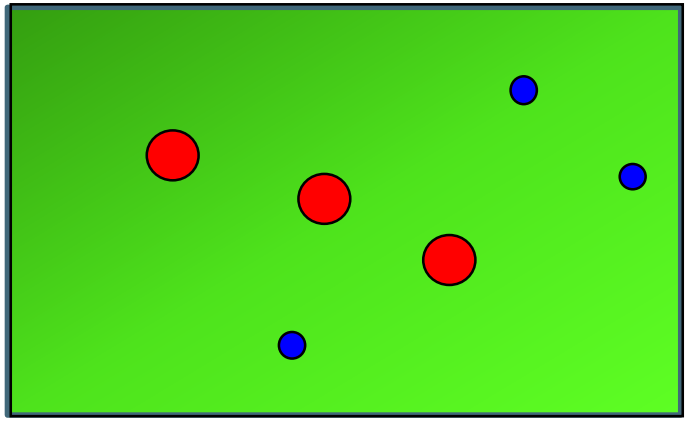
(1) Before a capture

- electron
- hole
- Crystal / atoms with vibrations
- electron-filled traps n_T
- empty traps p_T
- total traps $N_T = n_T + p_T$



(2) After electron capture

Traps have destroyed one electron-hole pair

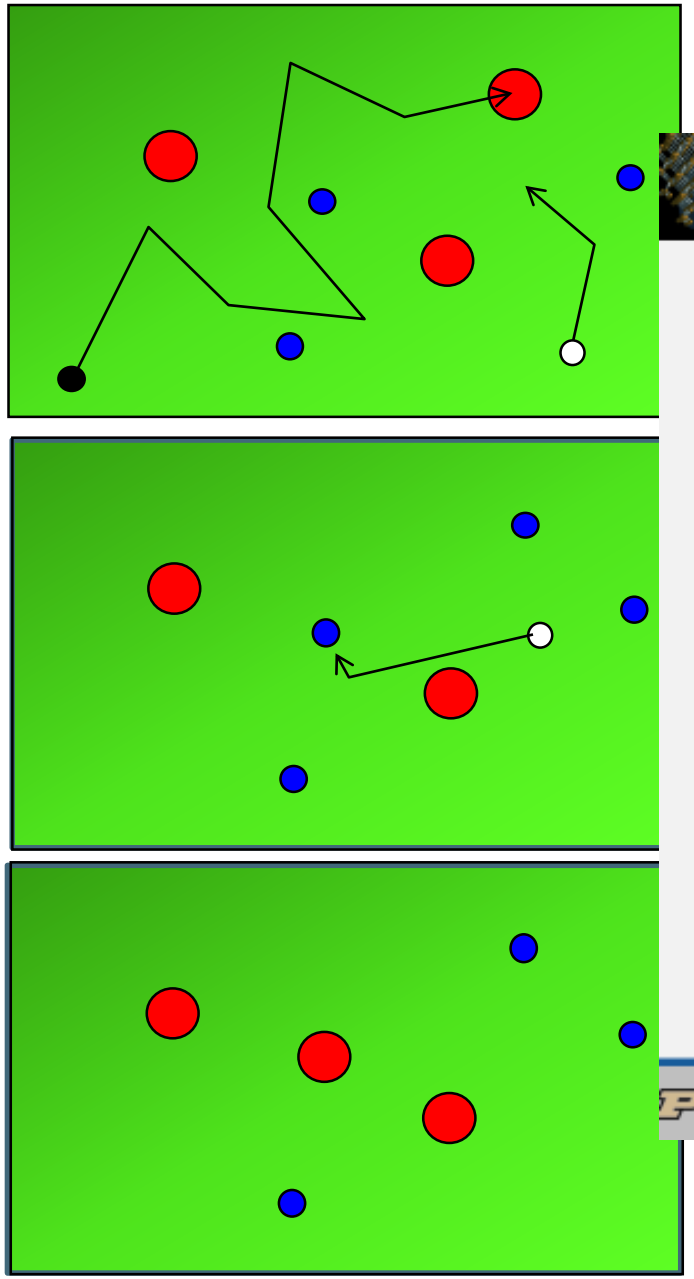


(3) After hole capture

No change in n_T and p_T

Physical process for indirect recombination

Physical view of Carrier Capture/Recombination

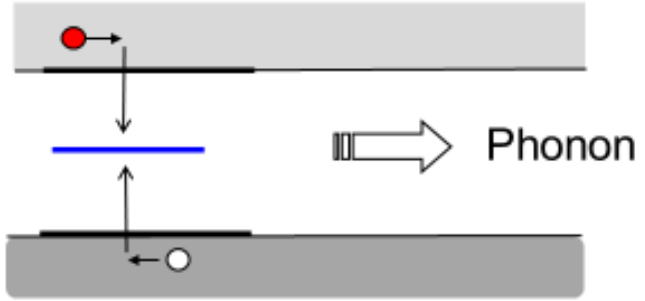


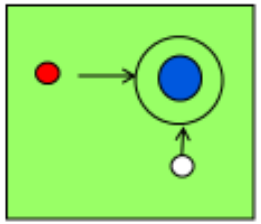
(1) Before a capture

- electron
- hole

Crystal / atoms with vibrations

Indirect Recombination (Trap-assisted)



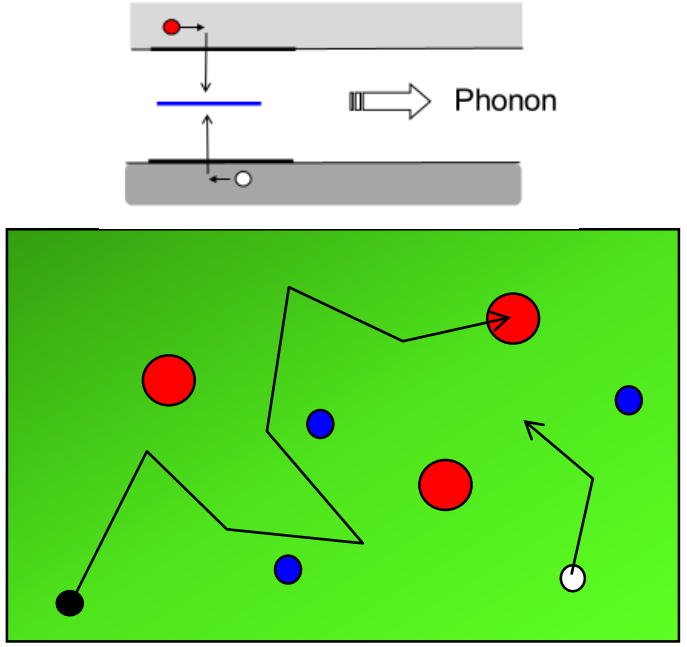


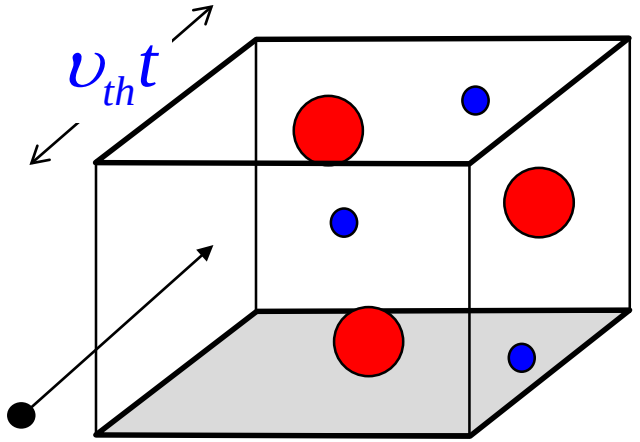
Ge, Si, ….

Transistors, Solar cells, etc.

Physical process for indirect recombination

Carrier Capture Coefficients





$$\frac{1}{2}m^{*}\upsilon_{th}^{\ 2}=\frac{3}{2}kT$$

$$\upsilon_{th}\approx 10^{7}\,\frac{cm}{s}$$

$$\frac{dn}{dt}=-n\times\left[\frac{Volume\times p_T\times RelArea}{TotalArea\times t}\right]$$

$$\frac{dn}{dt}=-n\times\left[\frac{A\times\upsilon_{th}t\times p_T\times\sigma_n}{A\times t}\right]$$

$$\equiv -c_n p_T n \qquad c_n\equiv\sigma_n\upsilon_{th}$$

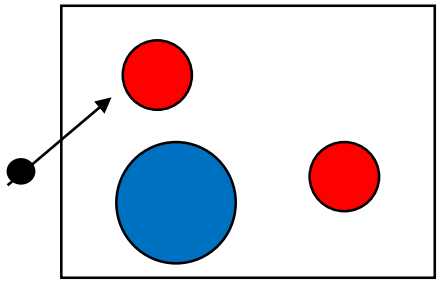
c_n electron capture coefficient
electron capture rate (unit Volume/sec)

σ_n electron scattering cross section

Capture Cross-section

$$\sigma_n = \pi r_0^{\,2}$$

2D target – not a 3D target

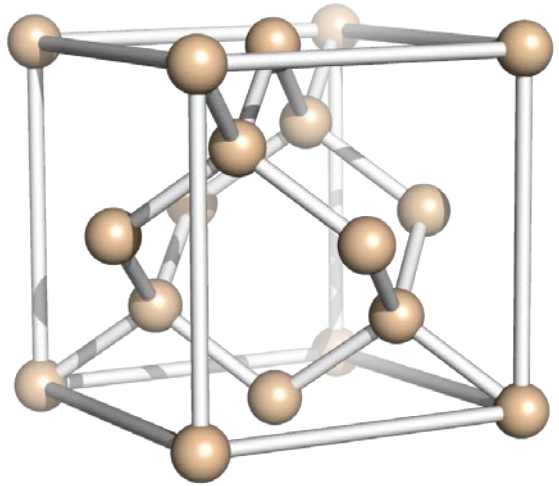


capture model (with Zn values)…

e1 → $2 \times 10^{-16}\ \mathrm{cm}^2$

Ballpark value for r:
Si unit cell / lattice constant ~0.5nm

4 atoms in one direction
~0.5nm / 4 = 0.12nm = 0.12×10^{-7}cm
$r_0 \sim 10^{-8}$cm $\pi r^2_0 \sim 3 \times 10^{-16}$cm^2



Capture Cross-section

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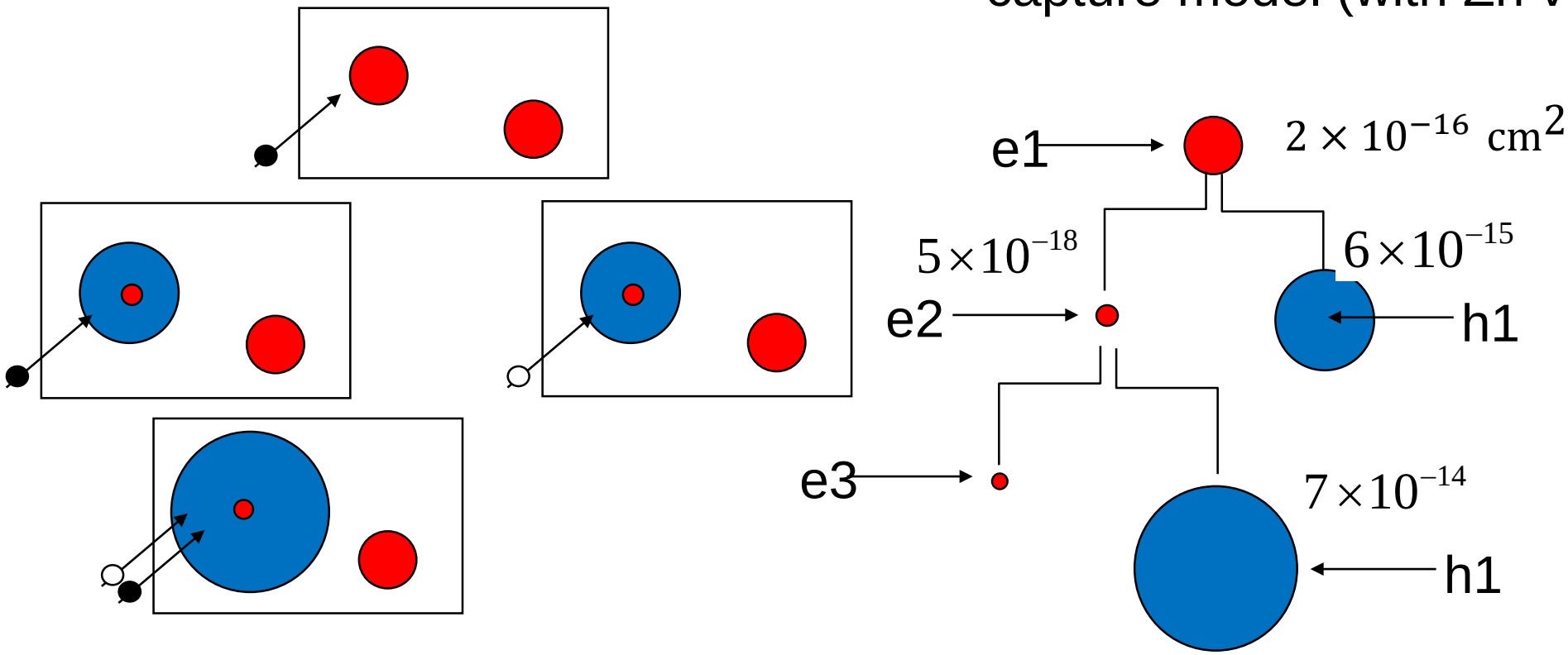
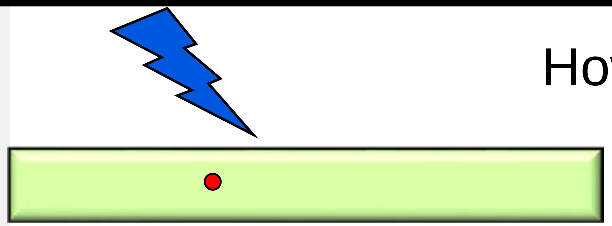
capture model (with Zn values)…

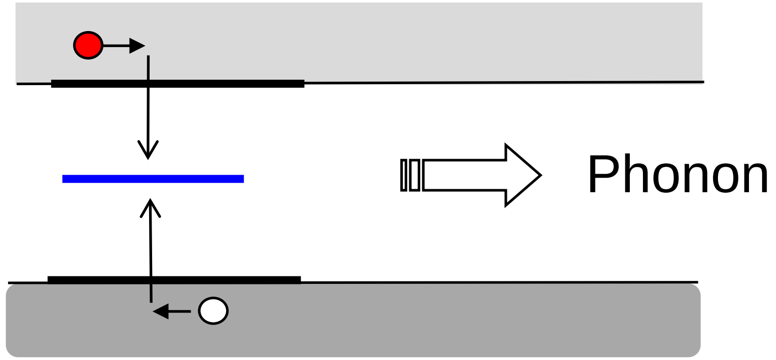


Cascade model for capture



How does the system go BACK to equilibrium?

$$\sigma_n = \pi r_0^{\,2}$$



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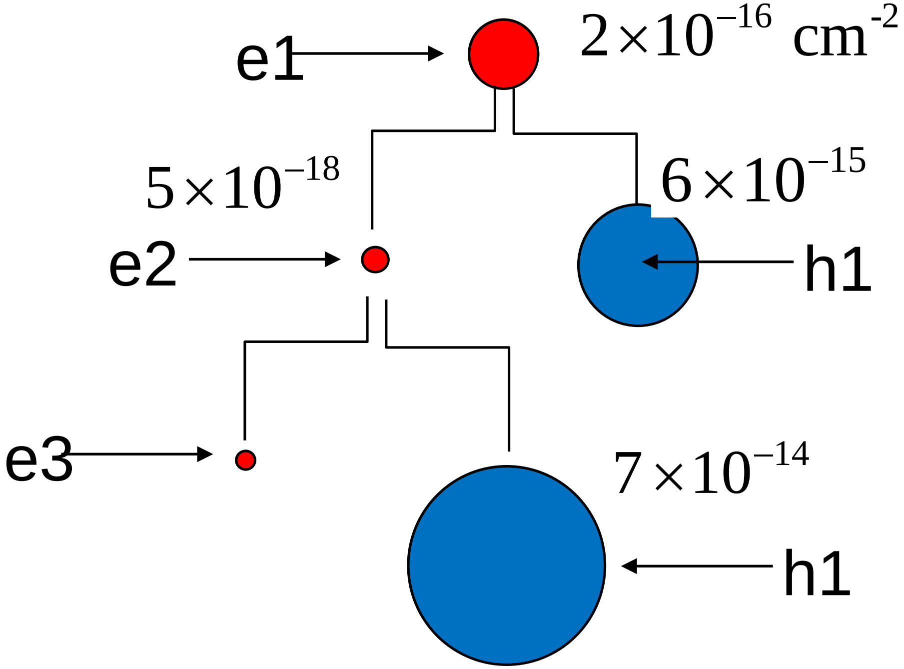

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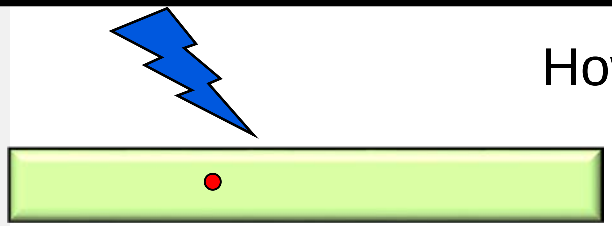

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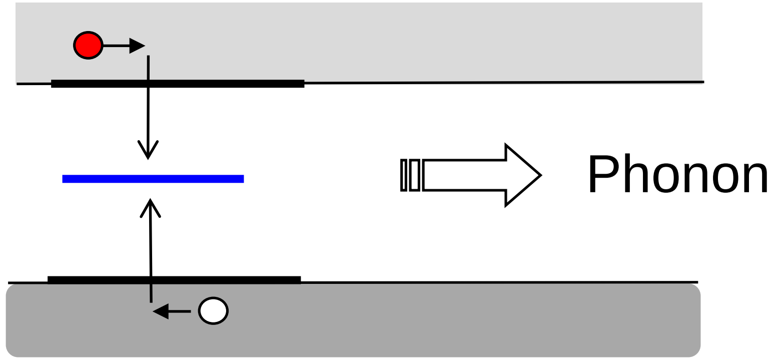
$$\sigma_n = \pi r_0^2$$



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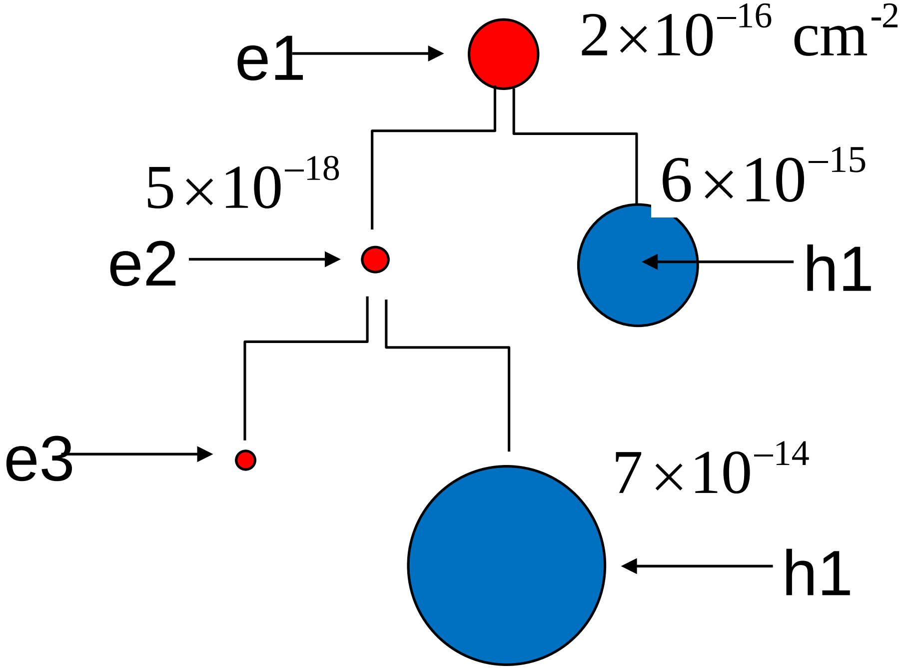

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