General Sir John Kotelawala Defence University

ET3122 Antennas and Propagation
Introduction

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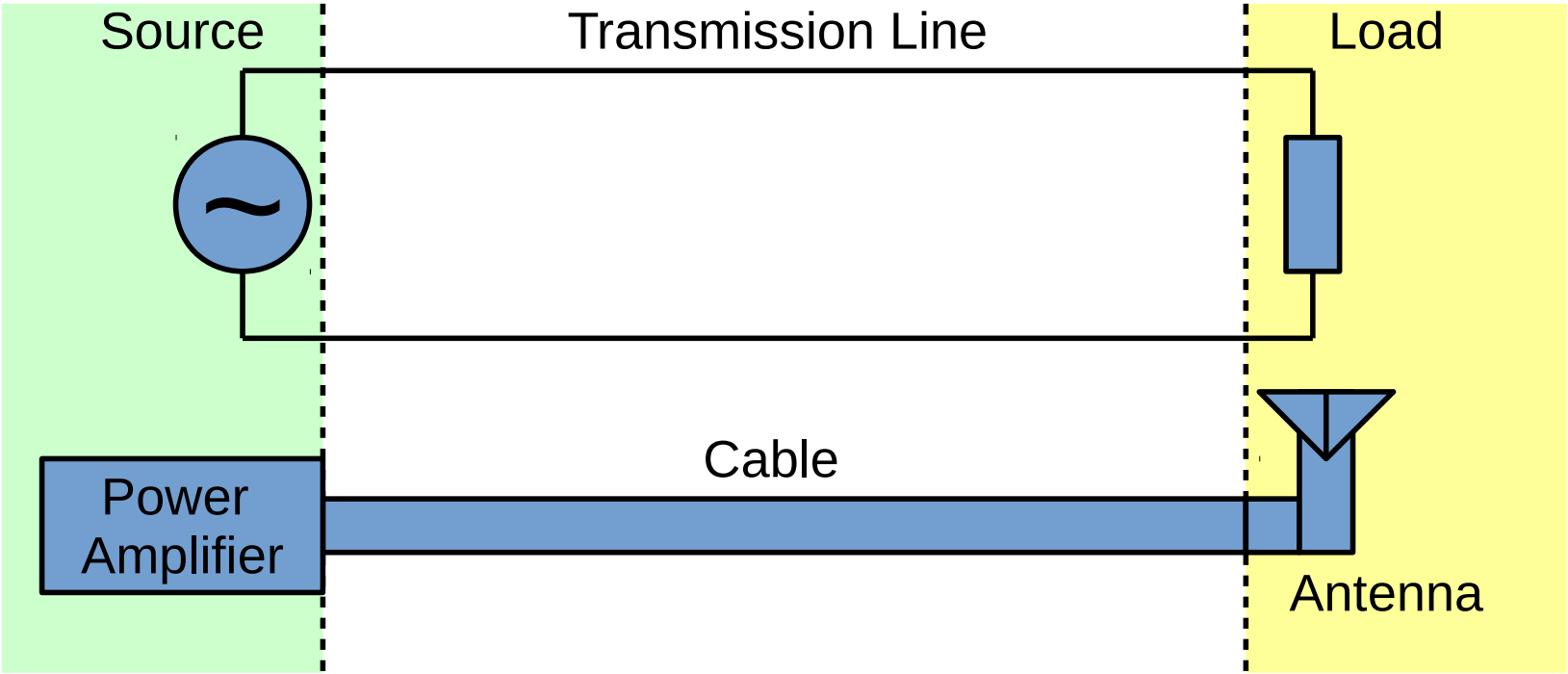
Outline

Introduction

What is an Antenna?

- An antenna is the interface between the electric signal and electromagnetic wave domains of a telecommunication system
- The antenna converts the electrical signal to an electromagnetic wave (or vice versa) through a process known as radiation
  - This lecture will explain what exactly happens

Basic Transmission System



Topics

- Antenna Basics
- Wire Antennas
- Polarization
- Aperture Antennas
- Antenna Arrays
- Radiowave Propagation

Electron Transport

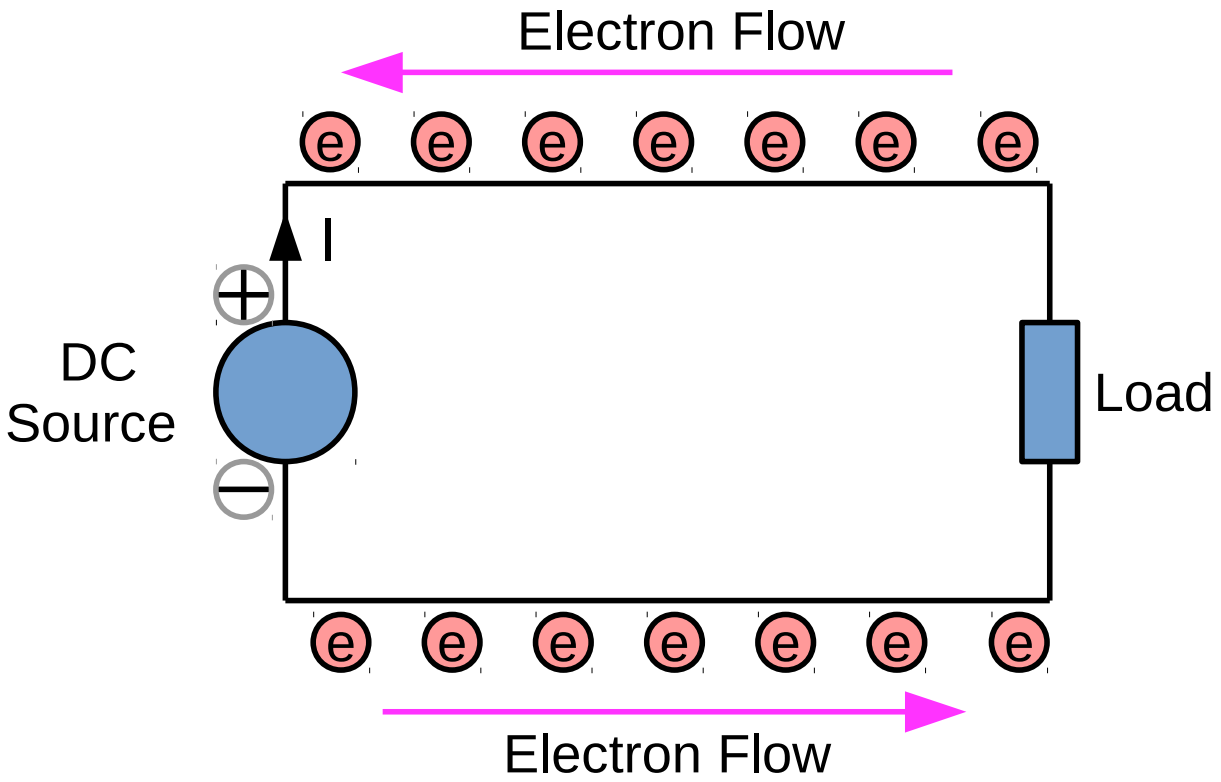
The Source and Load Circuit

- Traditional elements of circuit theory
- Under circuit theory the current flows through the load
  - Must obey Kirchoff's voltage and current laws

Constant Voltage Source

- Constant voltage source
- Constant flow of electrons from negative terminal to positive terminal through the load

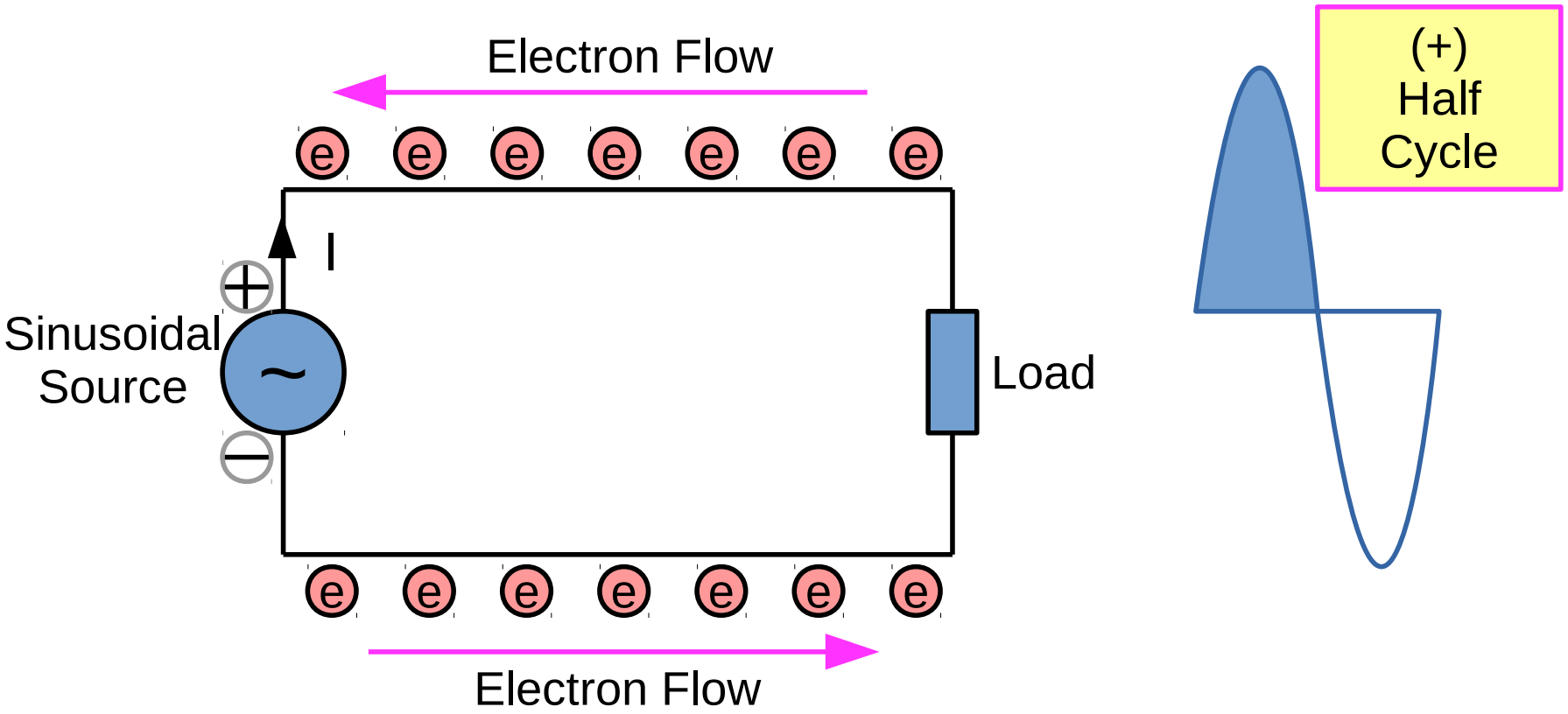
Constant Voltage Source



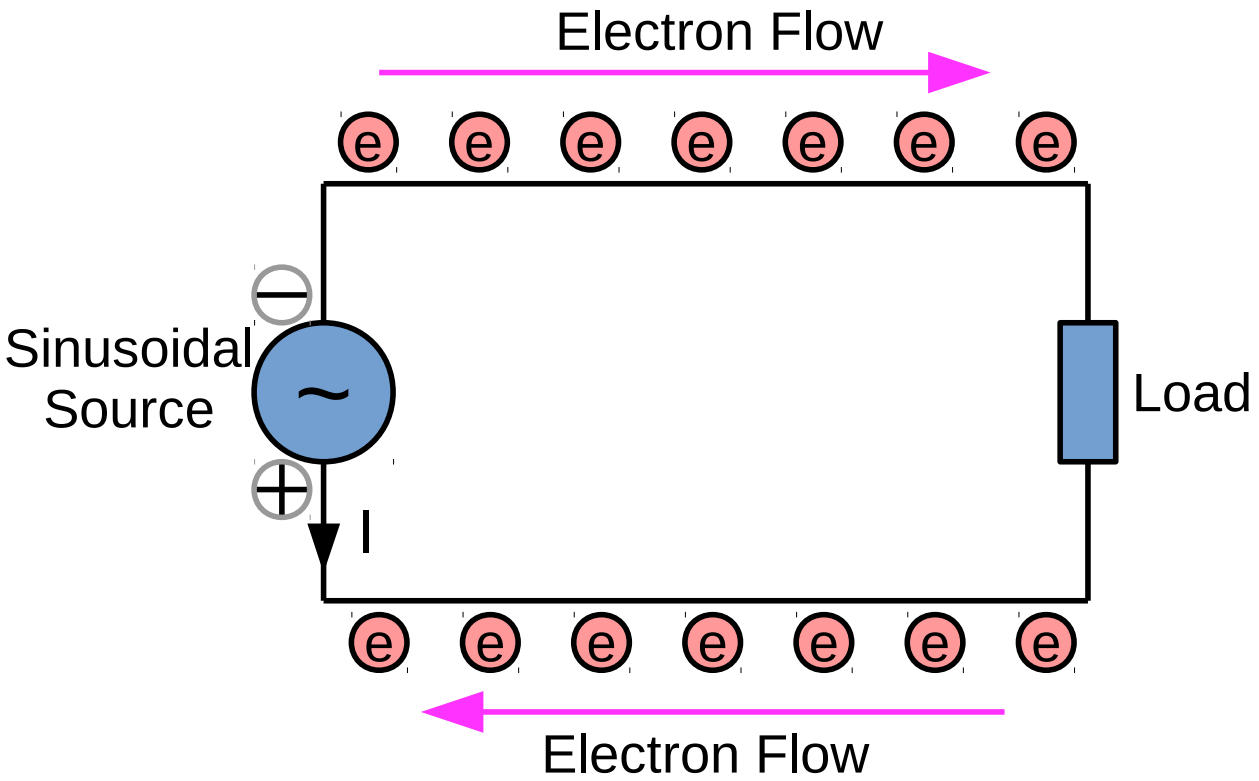
Sinusoidal Voltage Source

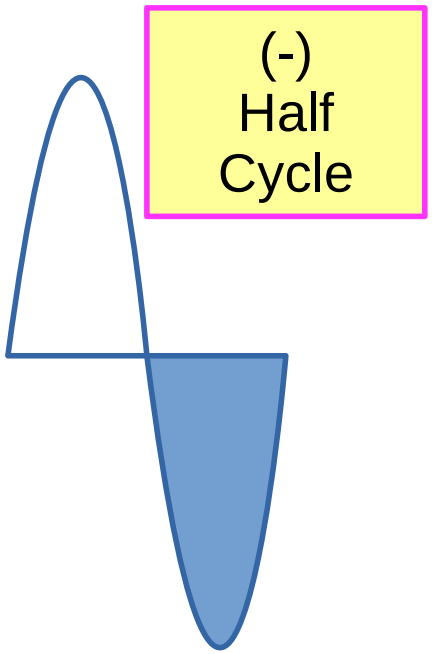
- Sinusoidal voltage source
- Alternating terminals (positive and negative half cycles)
- Alternating flow of electrons through the load

Sinusoidal Source (+) Half Cycle)



Sinusoidal Source (-) Half Cycle





Circuit Theory

- In circuit theory it is necessary for the electron to complete the circuit path
  - i.e. Travel from the negative terminal to the positive terminal
- Is this always possible?
  - Lets say the frequency is 50 Hz and the length of the circuit is 2 m and the electrons travel along the conductors at 0.7c
  - Will it still be possible if the frequency becomes 1 GHz?

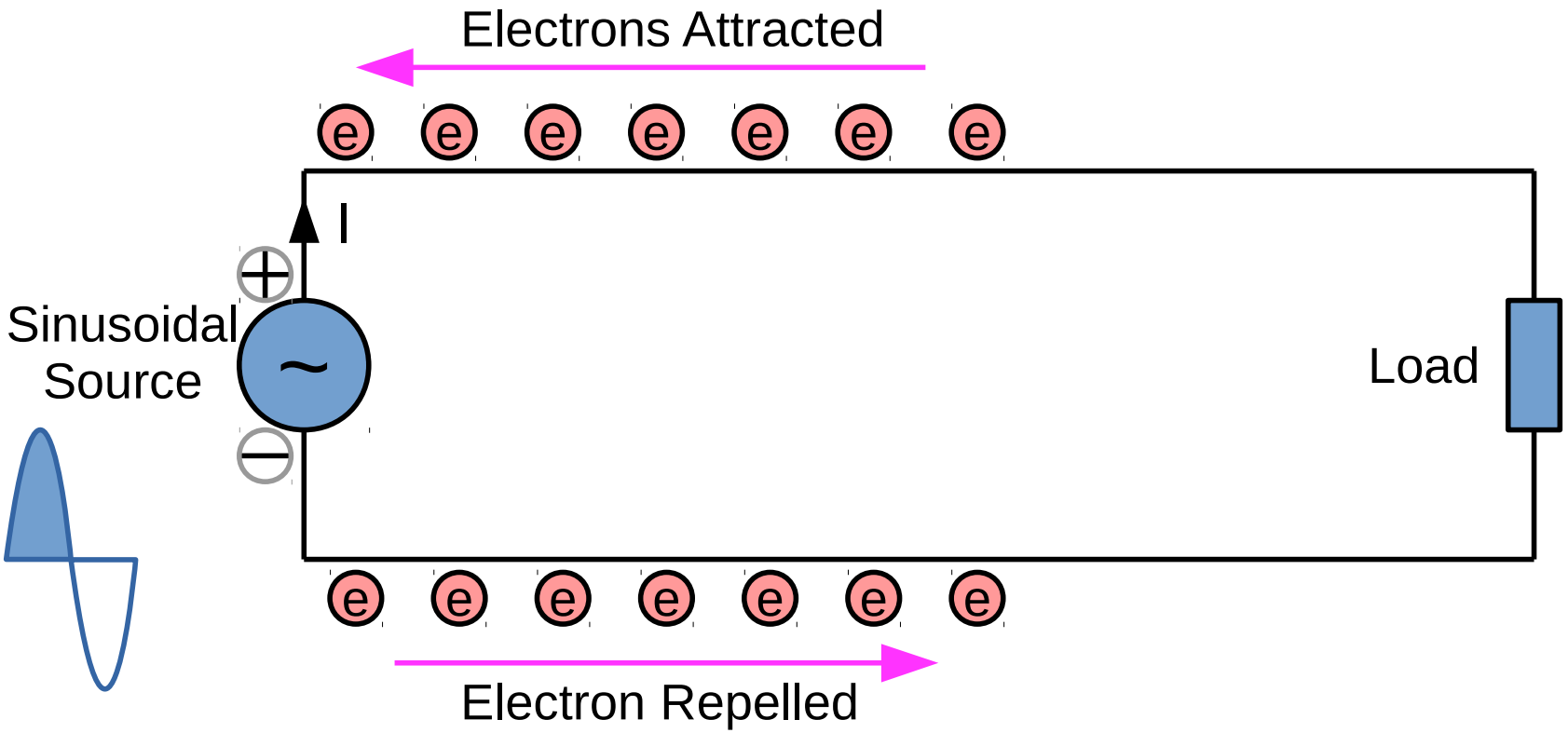
Circuit Theory (Contd..)

- At 50 Hz, the source will change polarity 50 times per second and each polarity will last for a half cycle
- The freespace wavelength of the 50 Hz electromagnetic wave is 6000 km, so during a half cycle an electron can travel a maximum of $0.7 \times 3000 = 2100$ km $\gg 2$ m
  - Circuit theory can be used
- At 1 GHz, the maximum distance an electron can travel in a half cycle is $0.7 \times 30/2 = 11.5$ cm (comparable with 2 m)

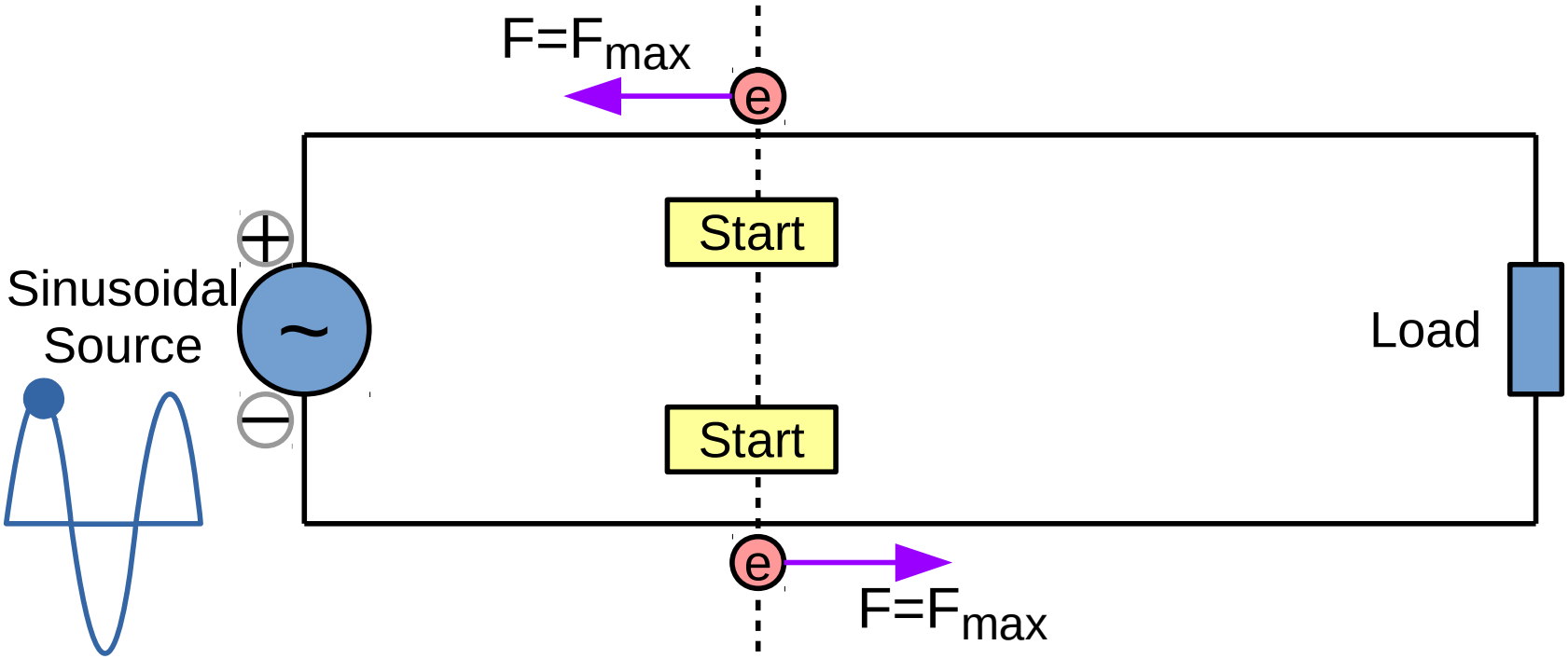
A New Paradigm

- When the length of the circuit conductors are comparable to the wavelength of the sinusoidal source circuit theory is no longer applicable
- The electrons can no longer travel the full circuit
  - Instead they undergo simple harmonic motion (SHM)
- The sinusoidal source excites the SHM by attracting and repulsing the electrons
- Distinct from Oliver Heaviside's *distributed component model*
  - Both will be used in this module

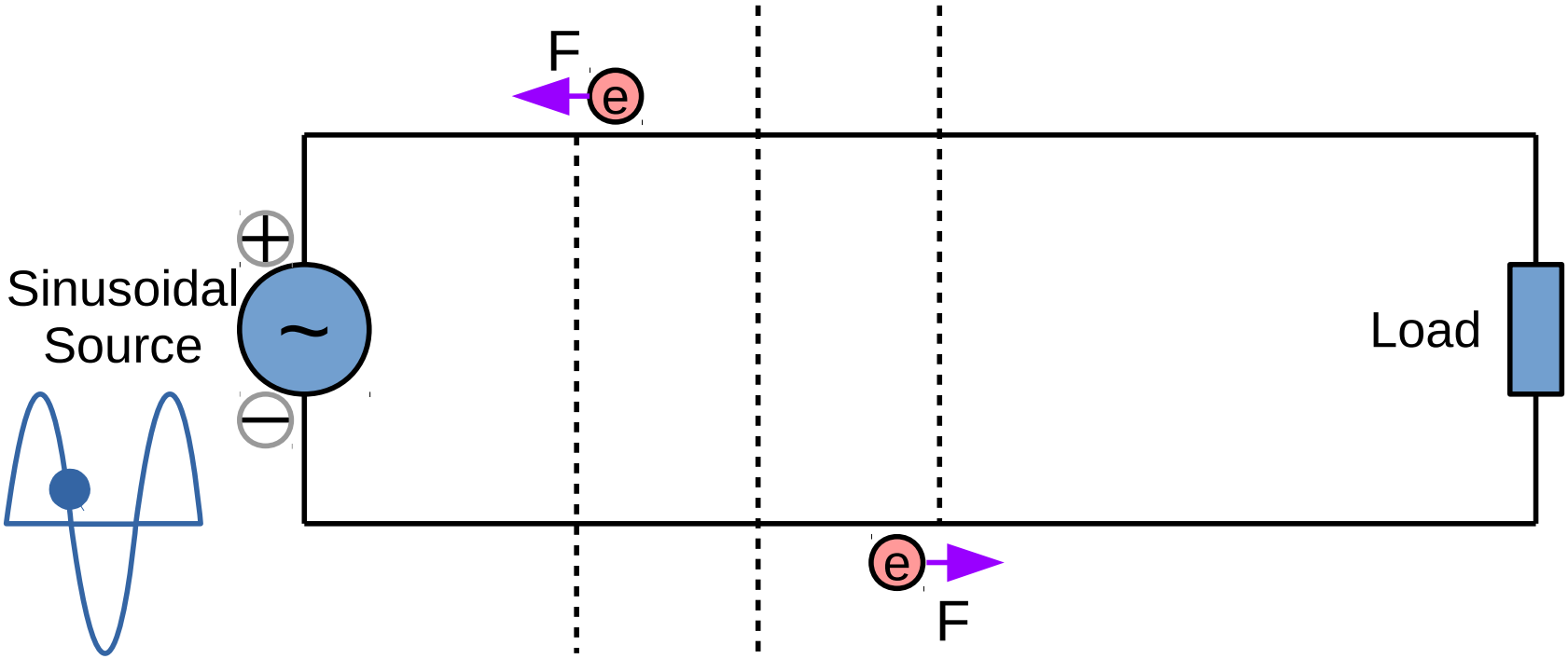
Sinusoidal Source at Higher Frequencies



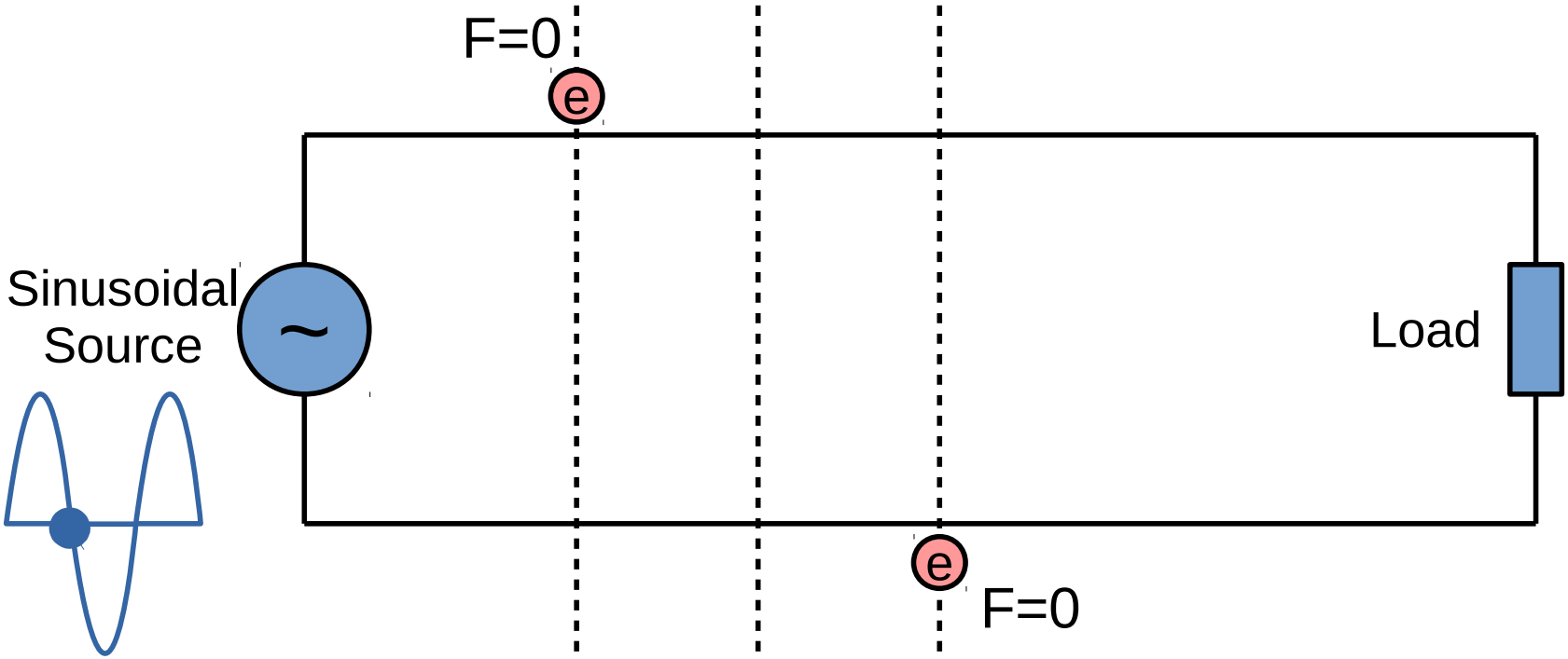
Electron Simple Harmonic Motion



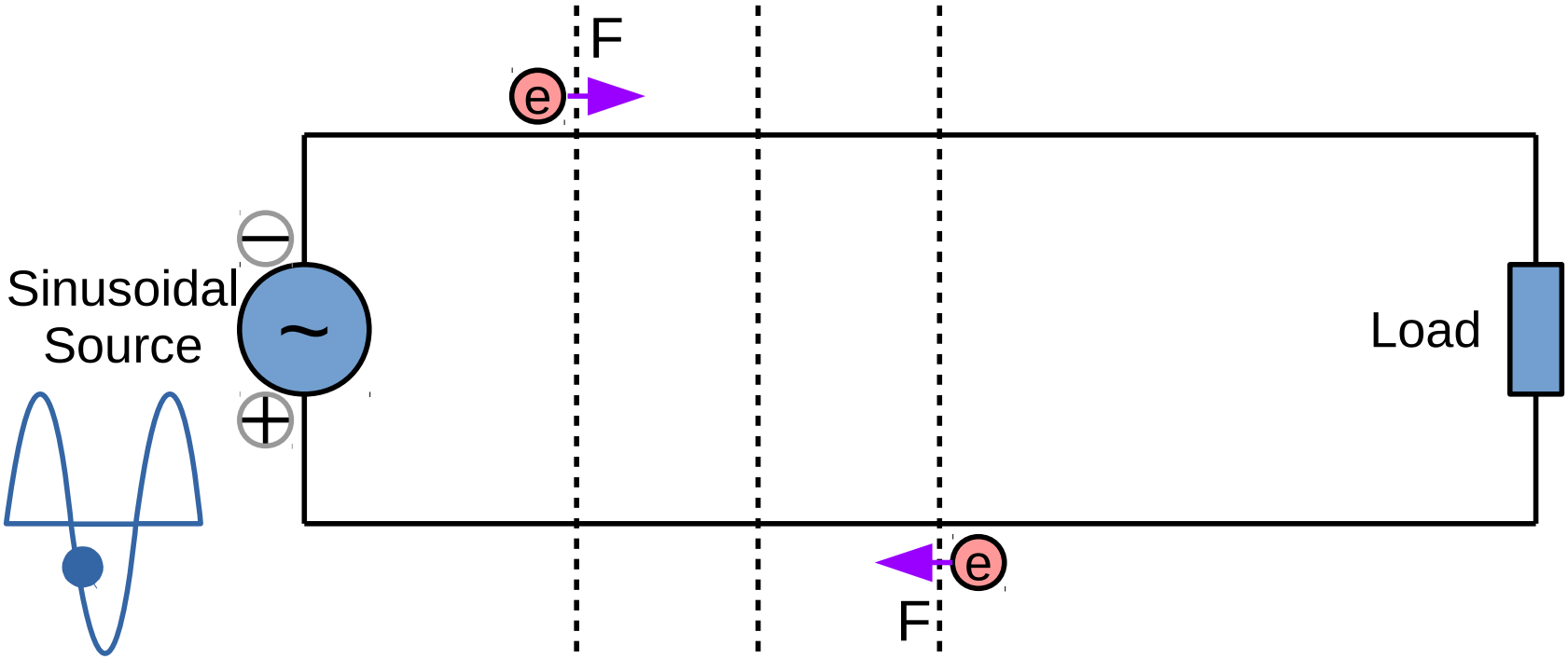
Electron Simple Harmonic Motion (Contd..)



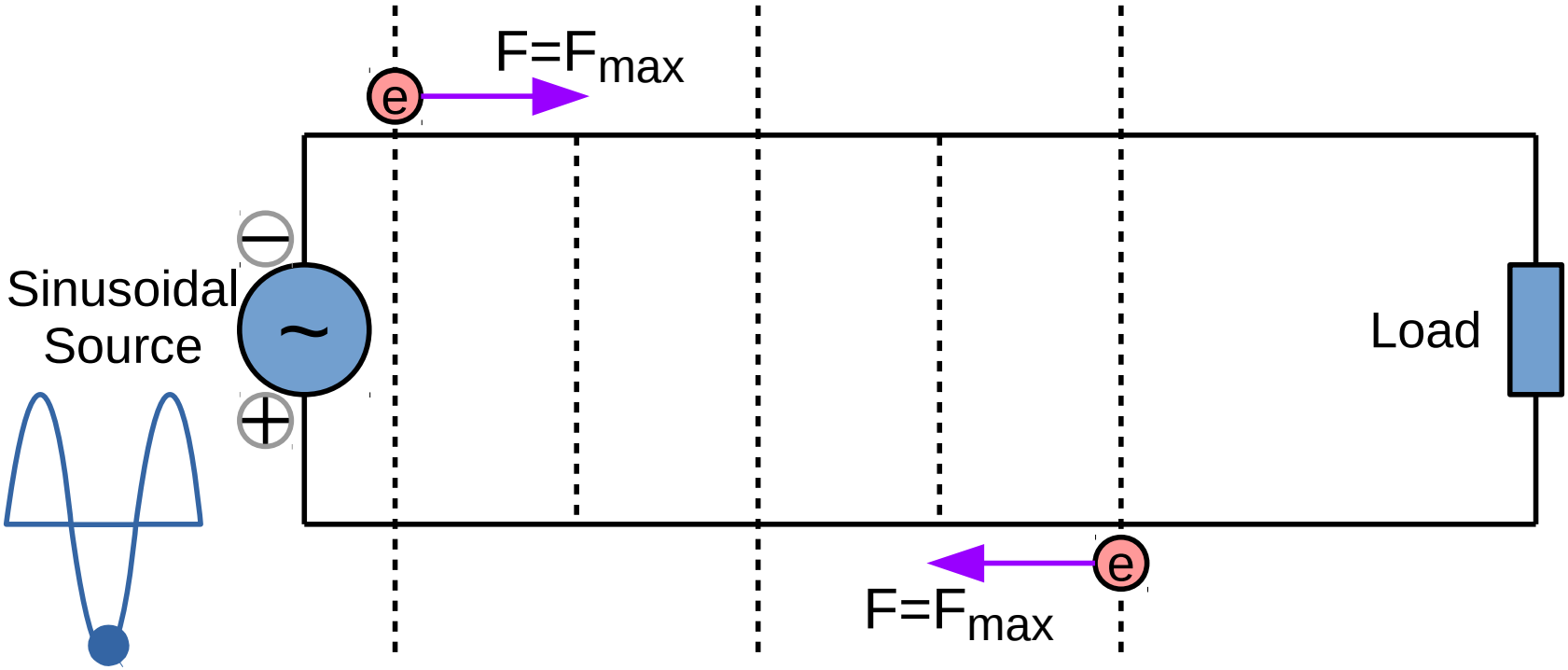
Electron Simple Harmonic Motion (Contd..)



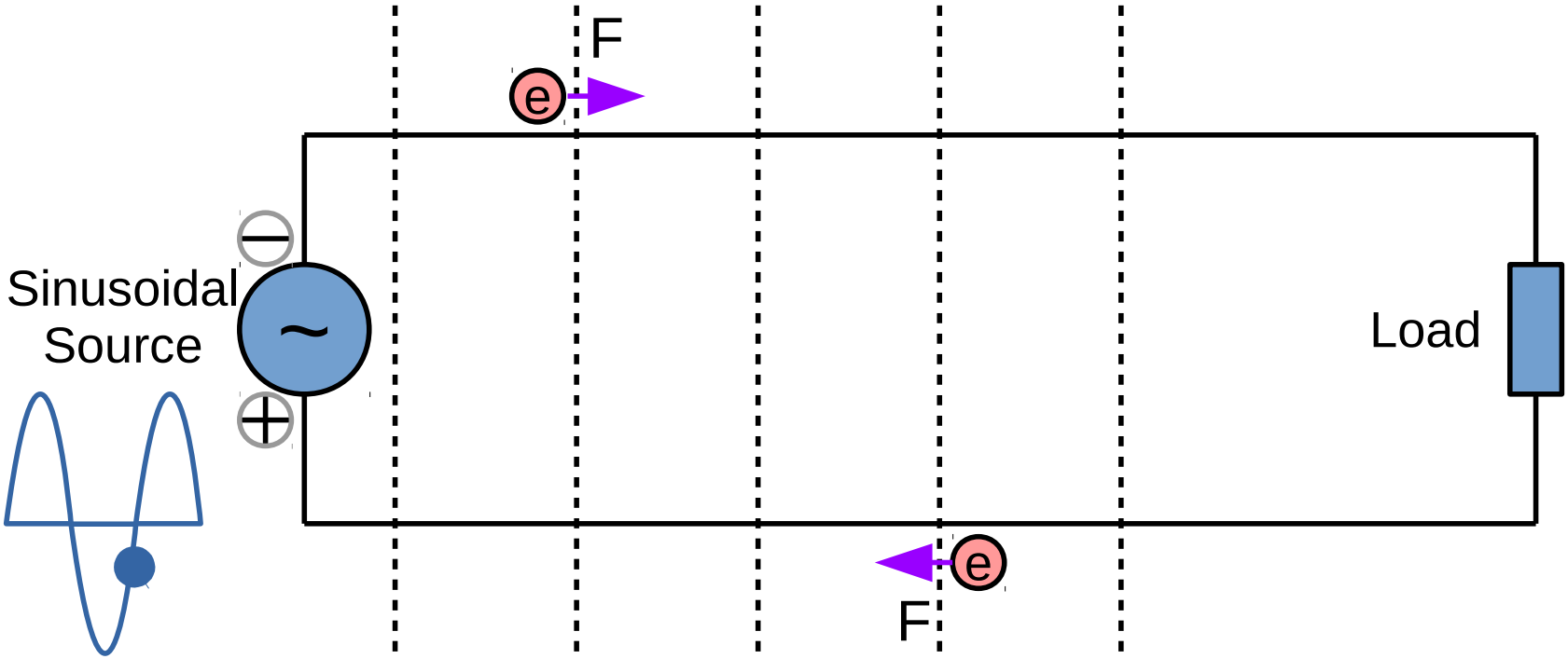
Electron Simple Harmonic Motion (Contd..)



Electron Simple Harmonic Motion (Contd..)



Electron Simple Harmonic Motion (Contd..)



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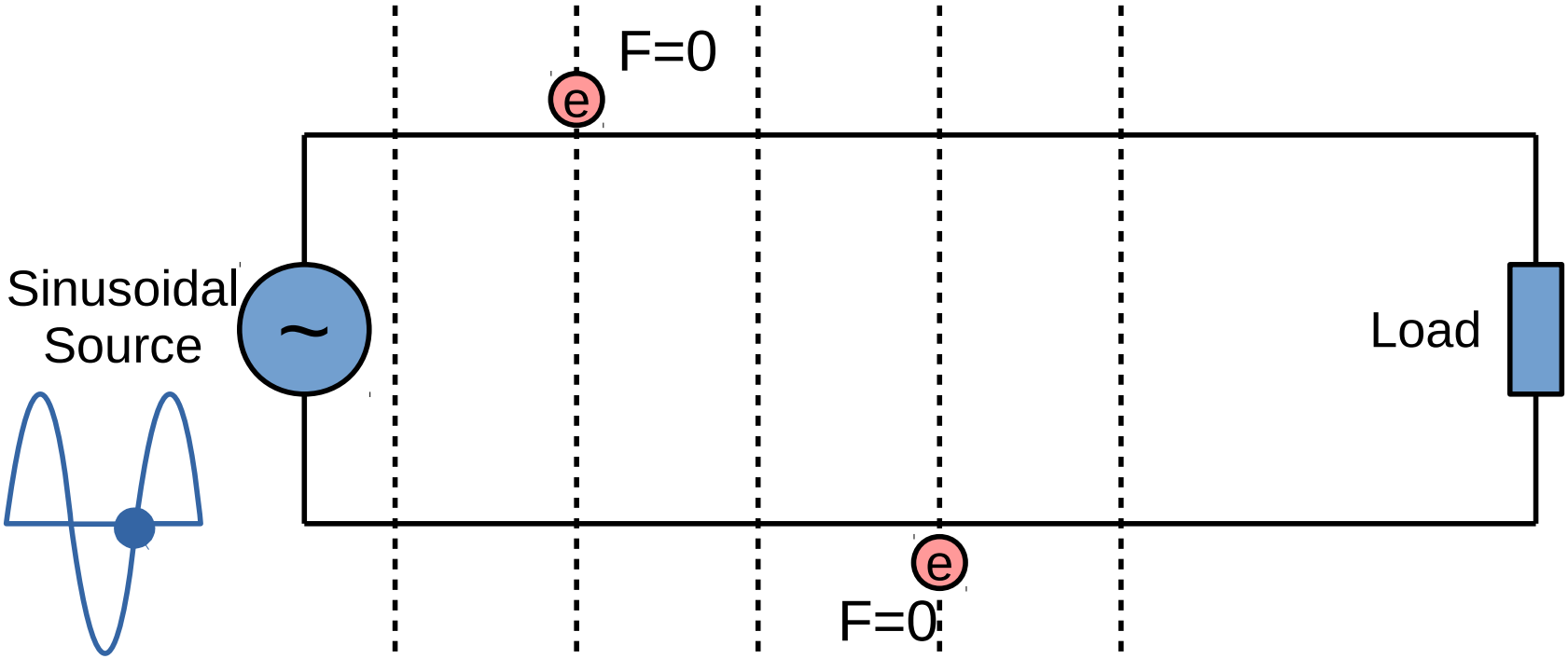
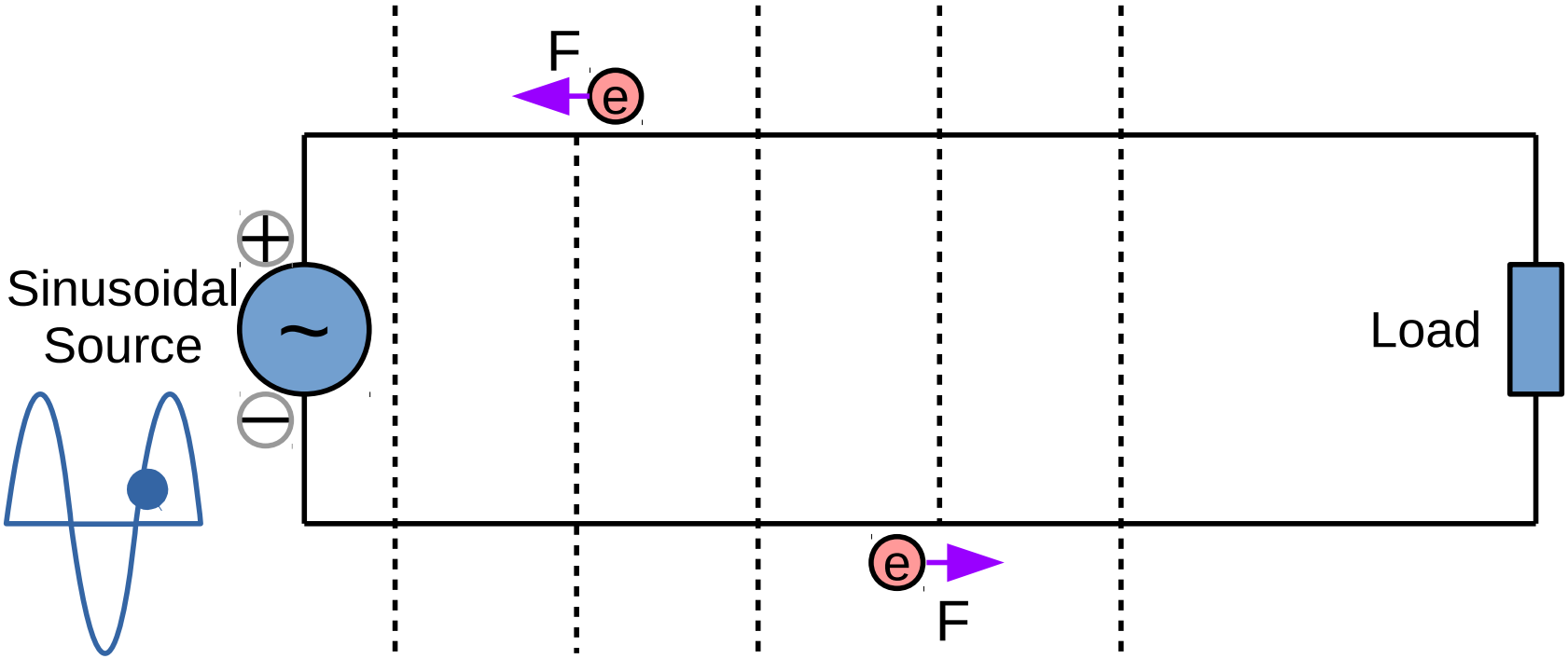


Electron Simple Harmonic Motion (Contd..)



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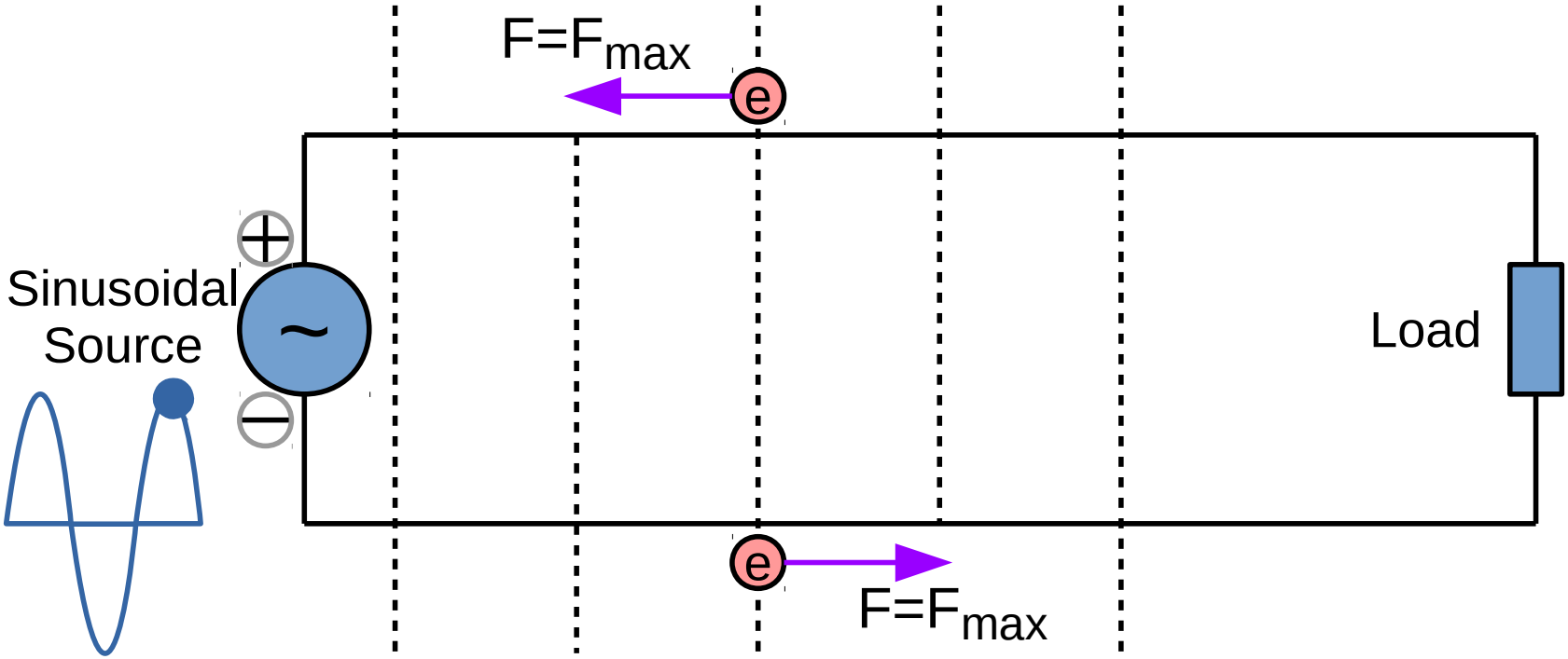
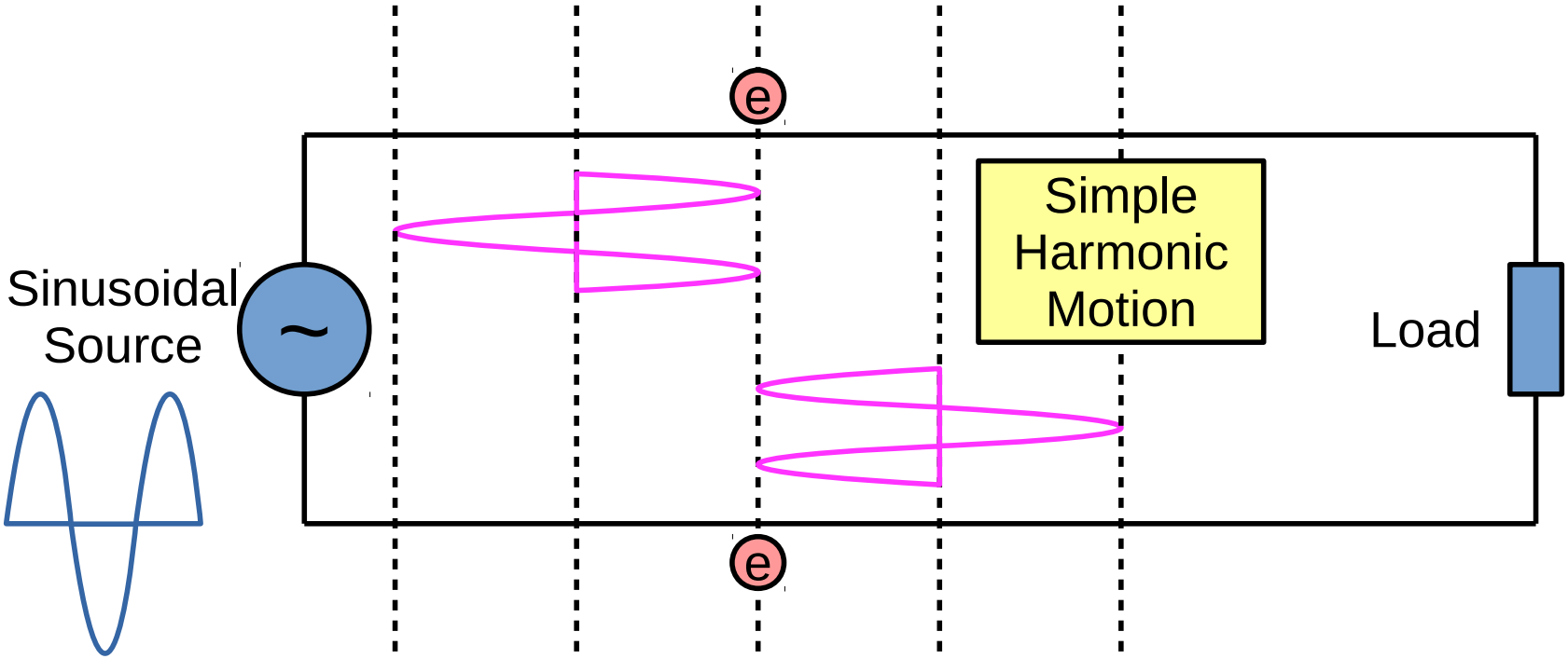


Electron Simple Harmonic Motion (Contd..)



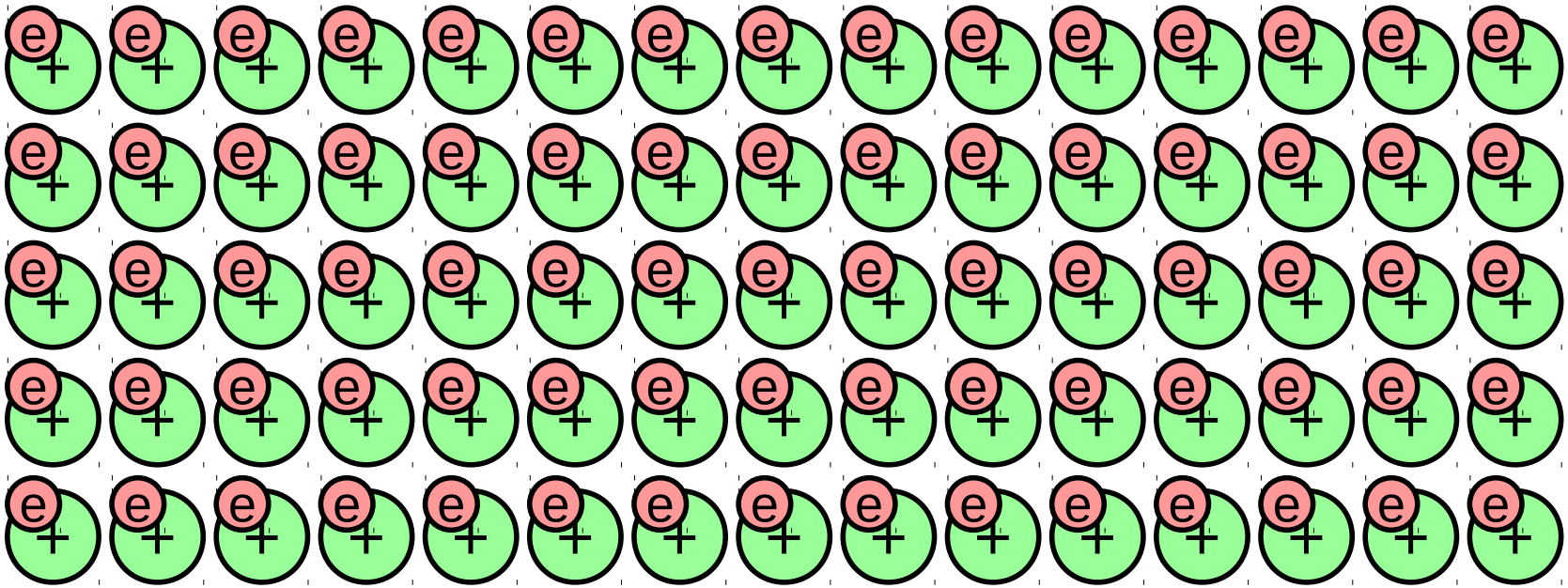
Electron Simple Harmonic Motion (Contd..)

- Electrons undergo SHM in the conductor
- During a cycle, the electron will have to swing between peak potential and kinetic energy
  - Maximum kinetic energy is limited (maximum drift velocity)
  - Amplitude of oscillation is therefore limited ($< \lambda_e/4$)
- Larger voltage amplitude will excite more electrons
- If all electrons have to undergo SHM, how can the signal propagate?

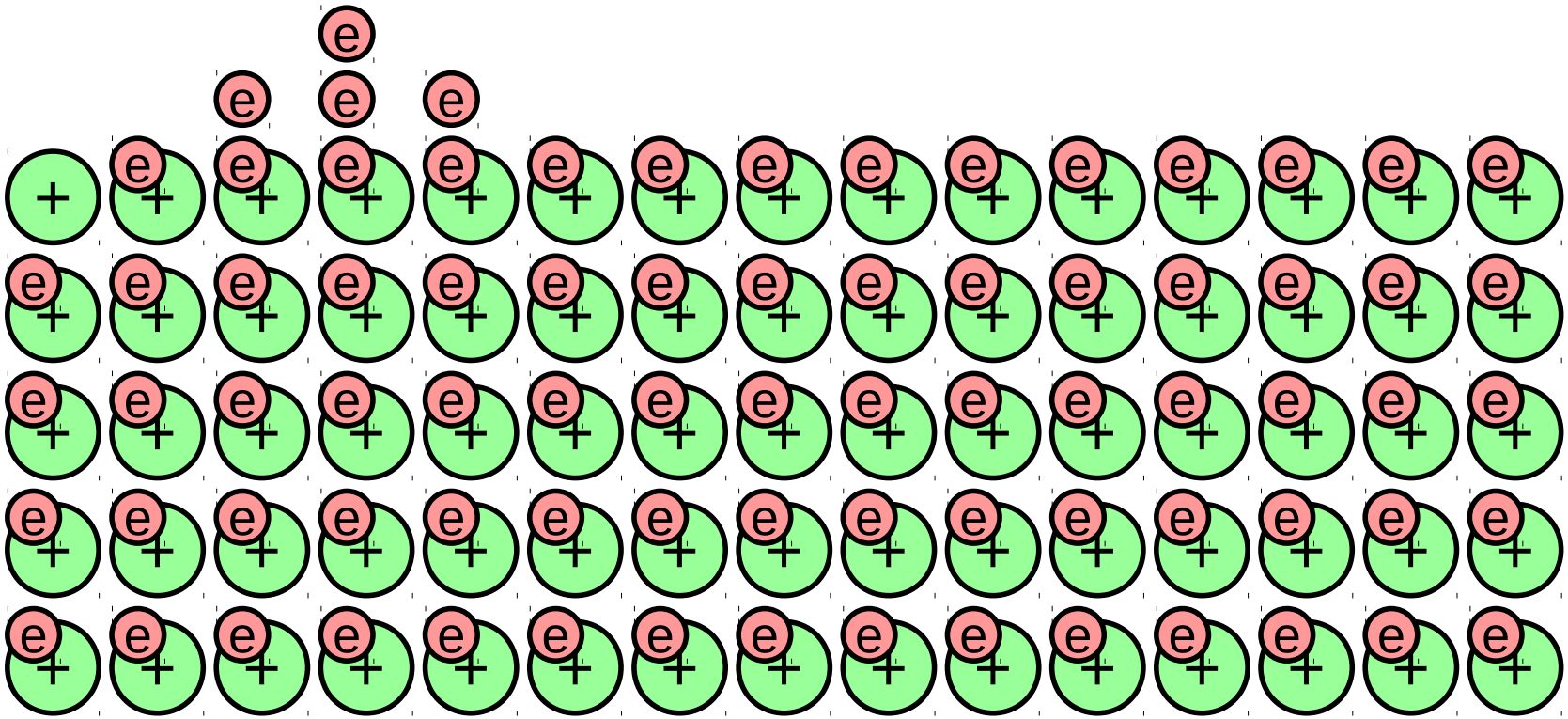
Propagation

- The sinusoidal source excites the metal lattice into a sinusoidal charge distribution
- Initially, the propagating electrons create the distribution by repulsion of electrons ahead of them
  - After sufficient cycles, a steady state is reached

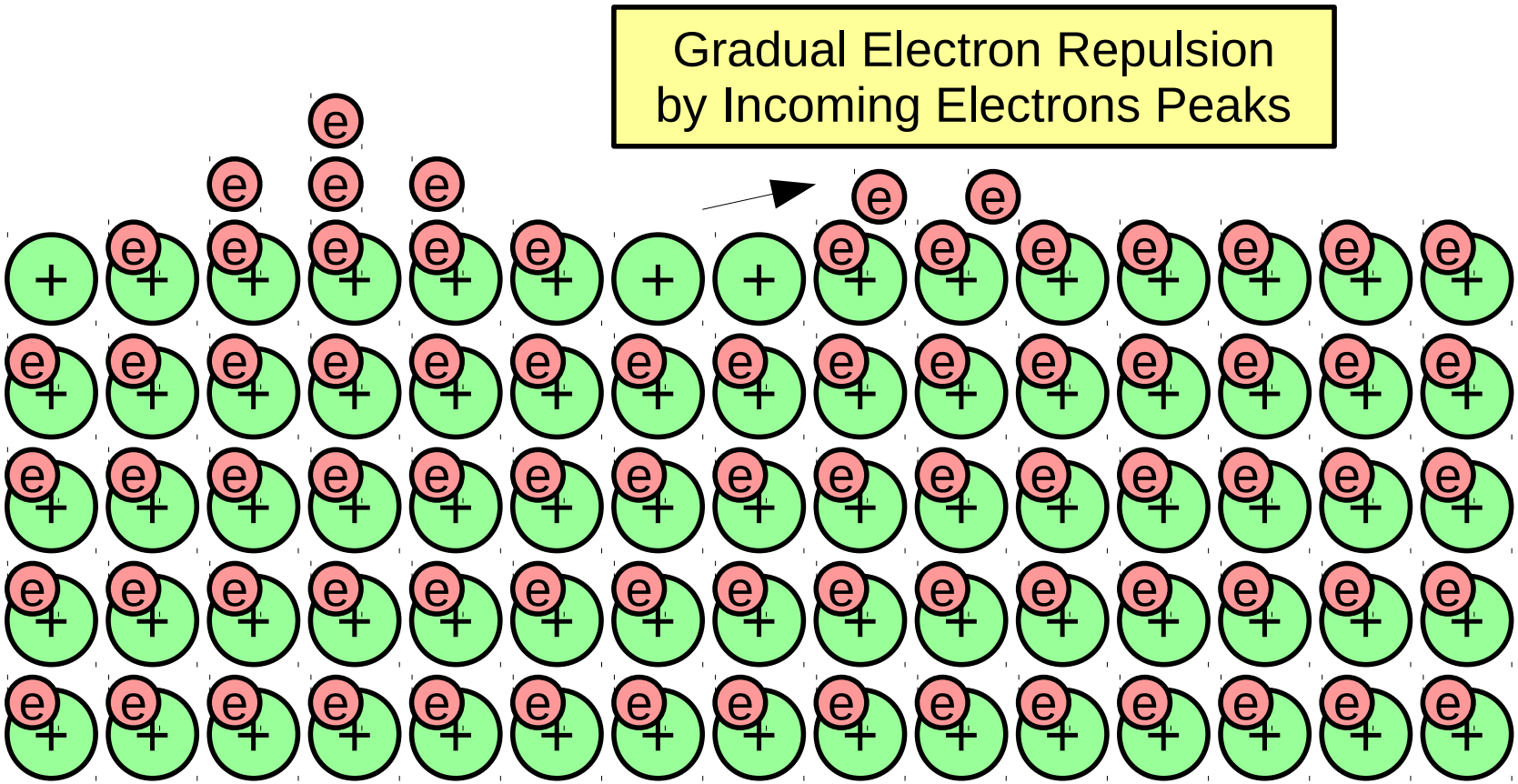
The Metal Lattice under Equilibrium



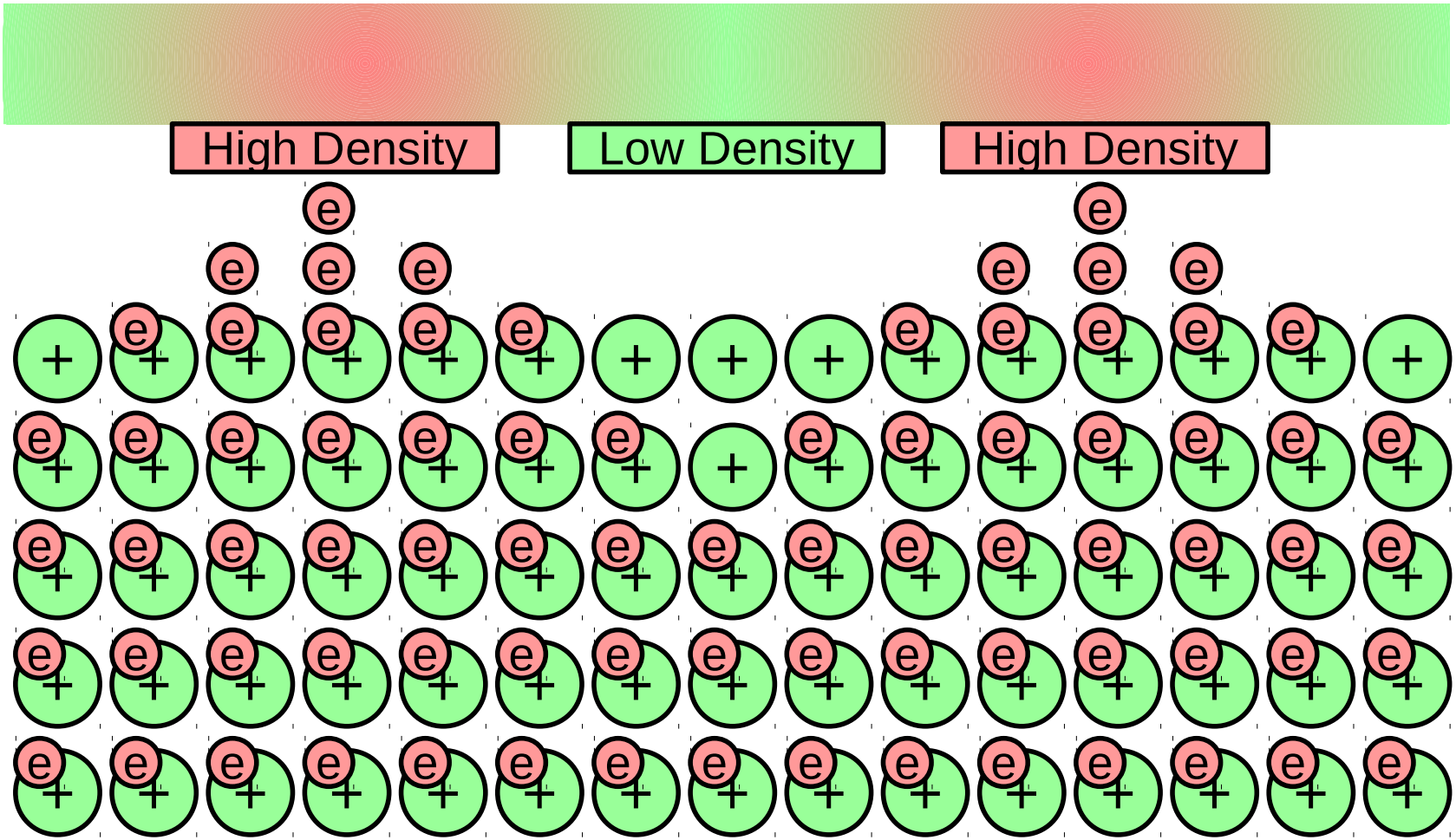
Excitation Transients



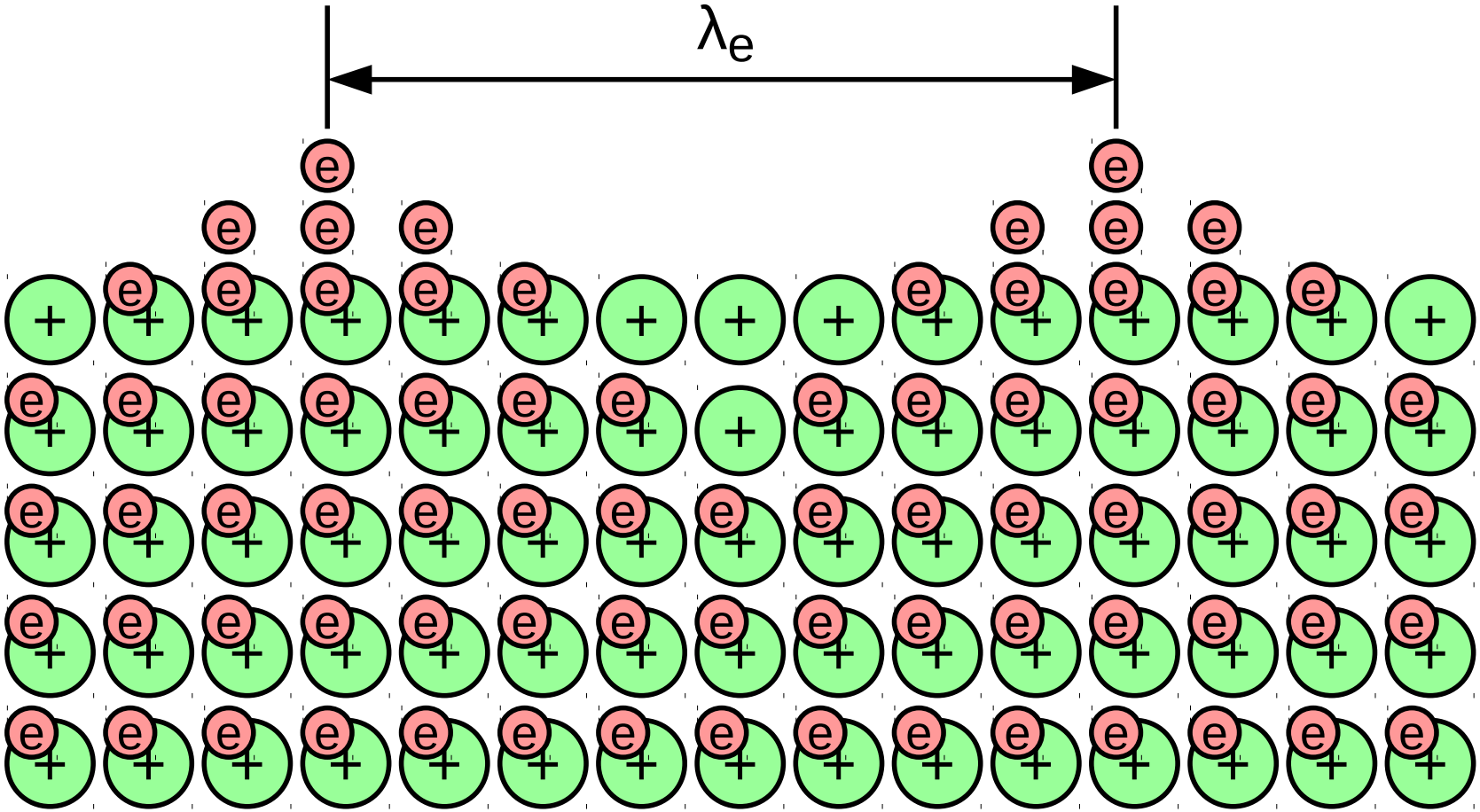
Excitation Transient (Contd..)



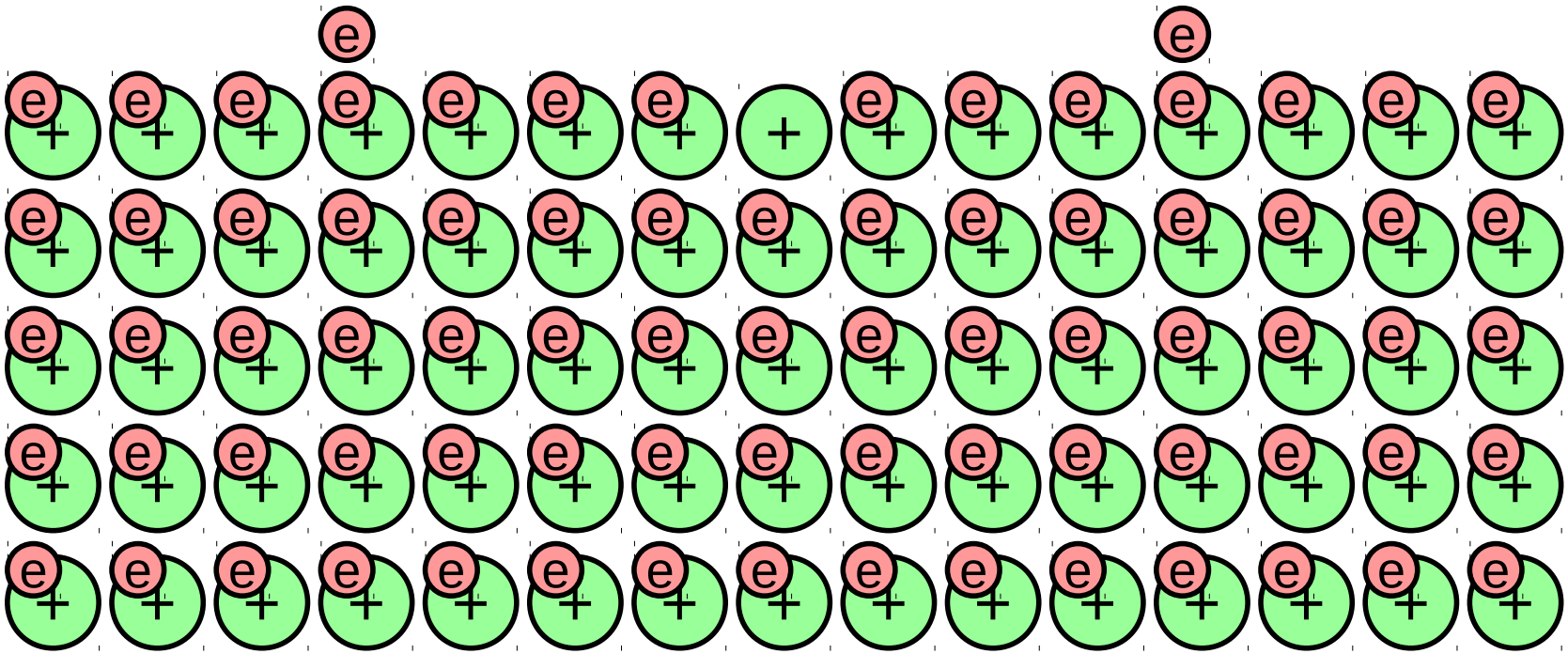
Steady State Charge Distribution



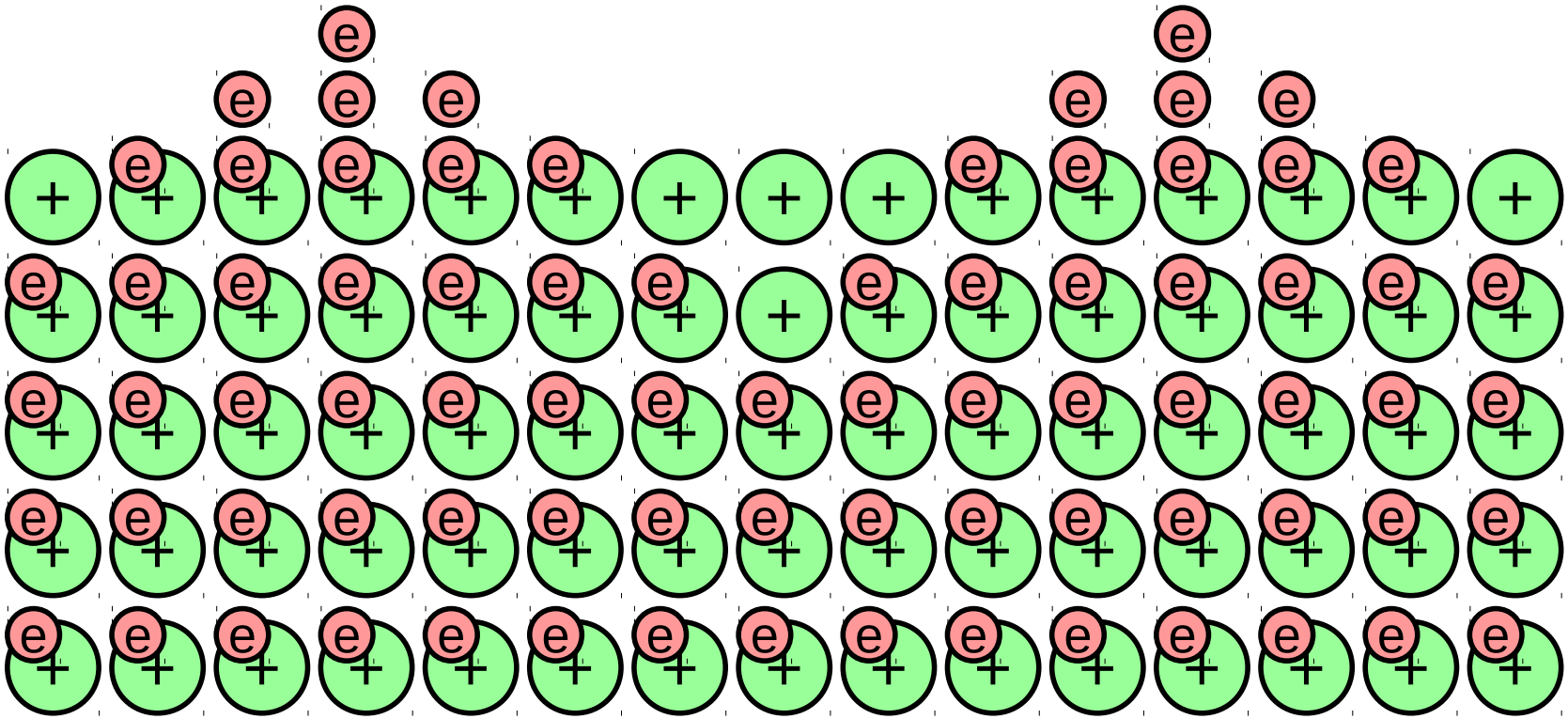
Steady State Charge Distribution (Contd..)



Modulation



Modulation (Contd..)



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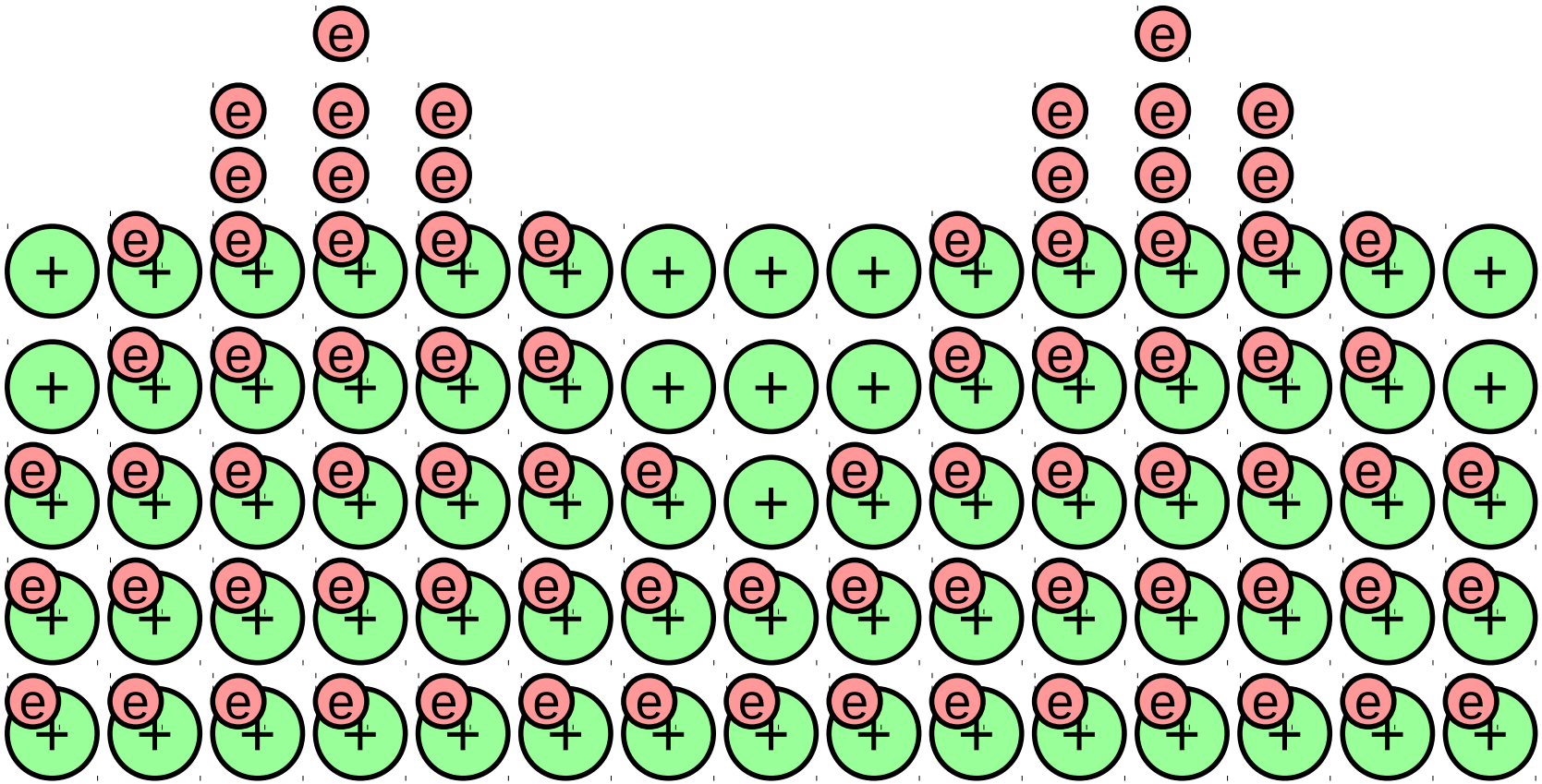
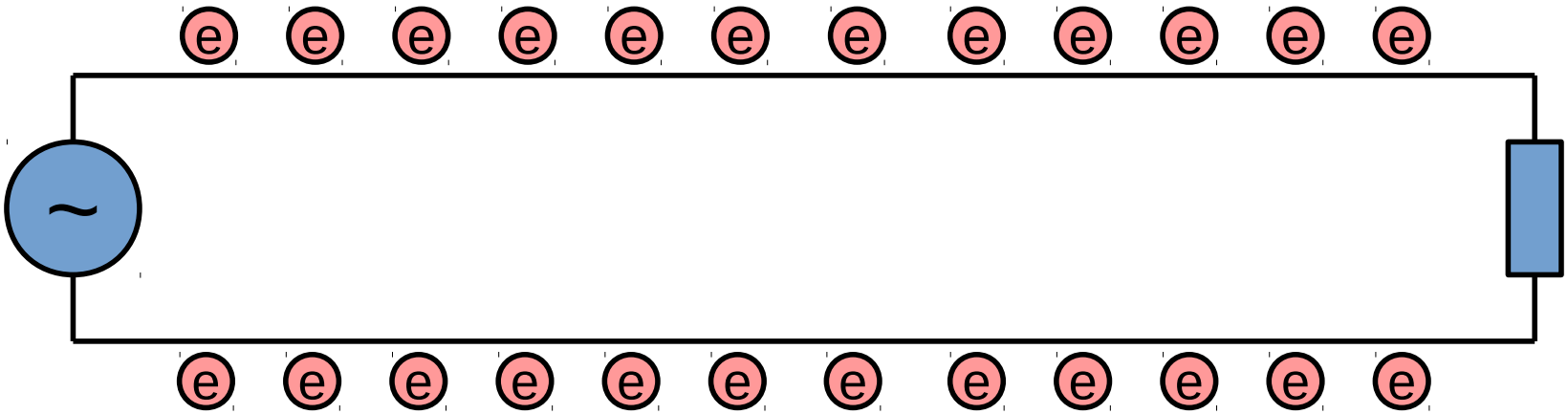
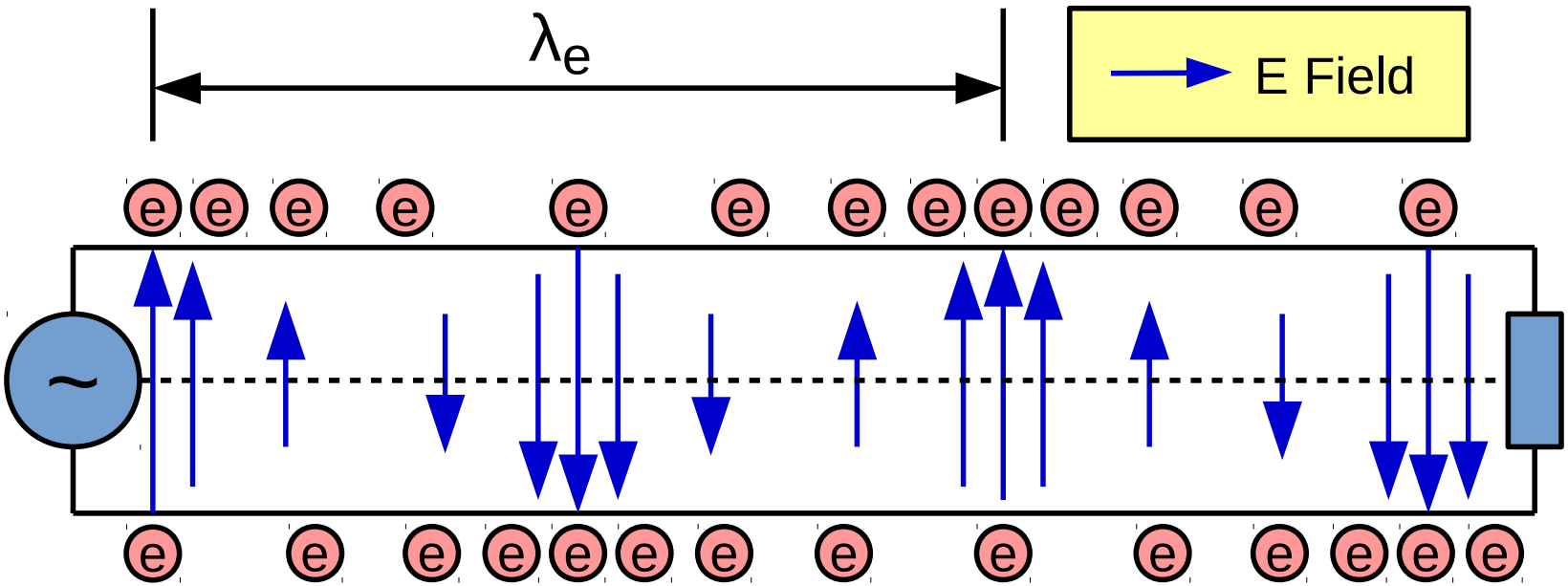


Overall Charge Distribution



Overall Charge Distribution (Contd..)



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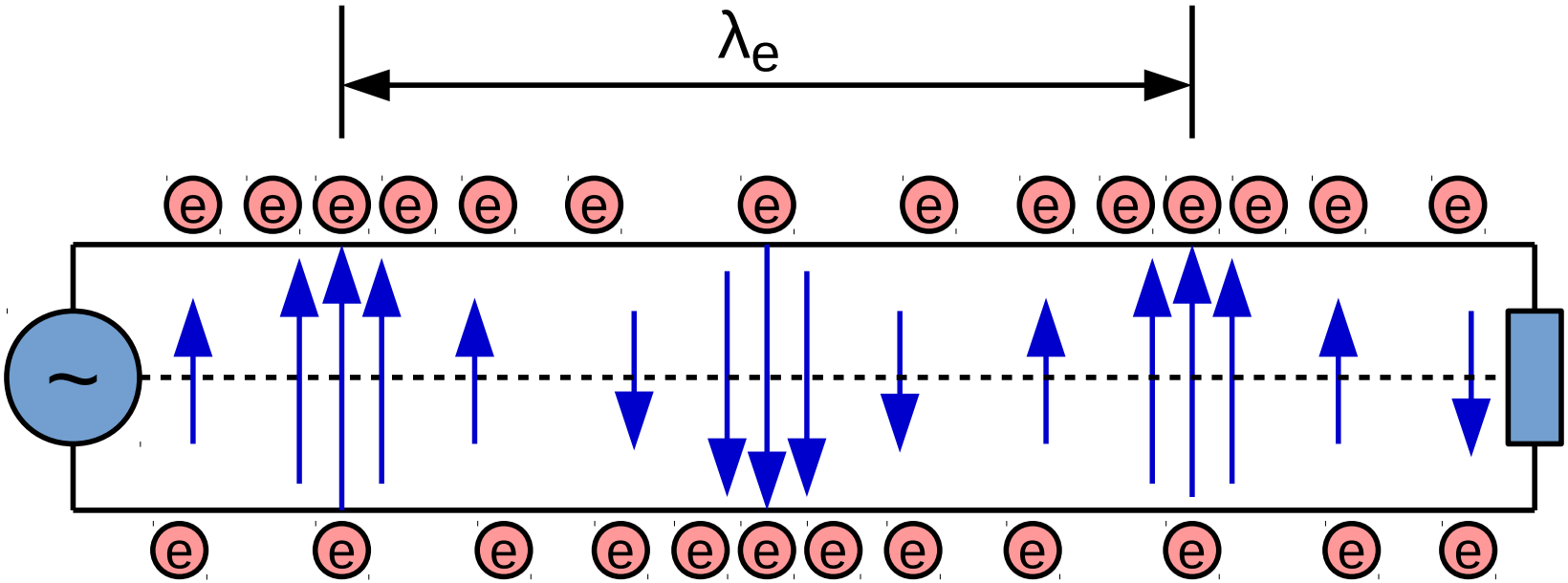

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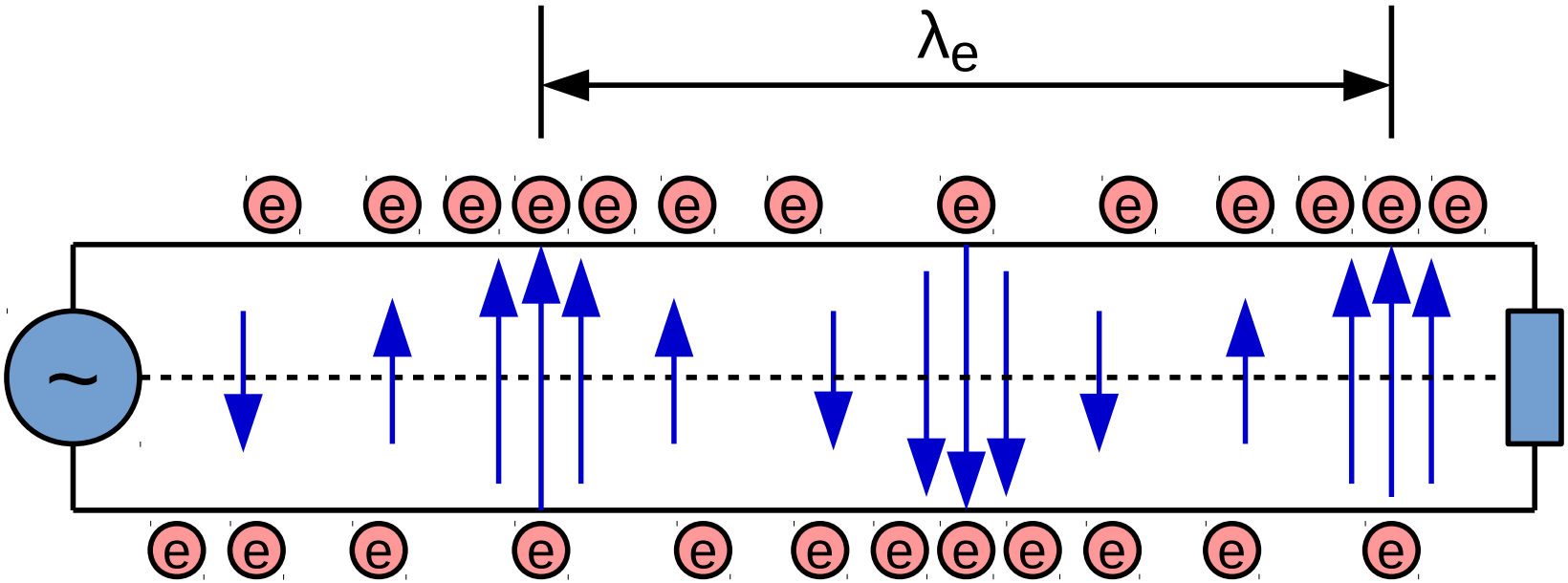
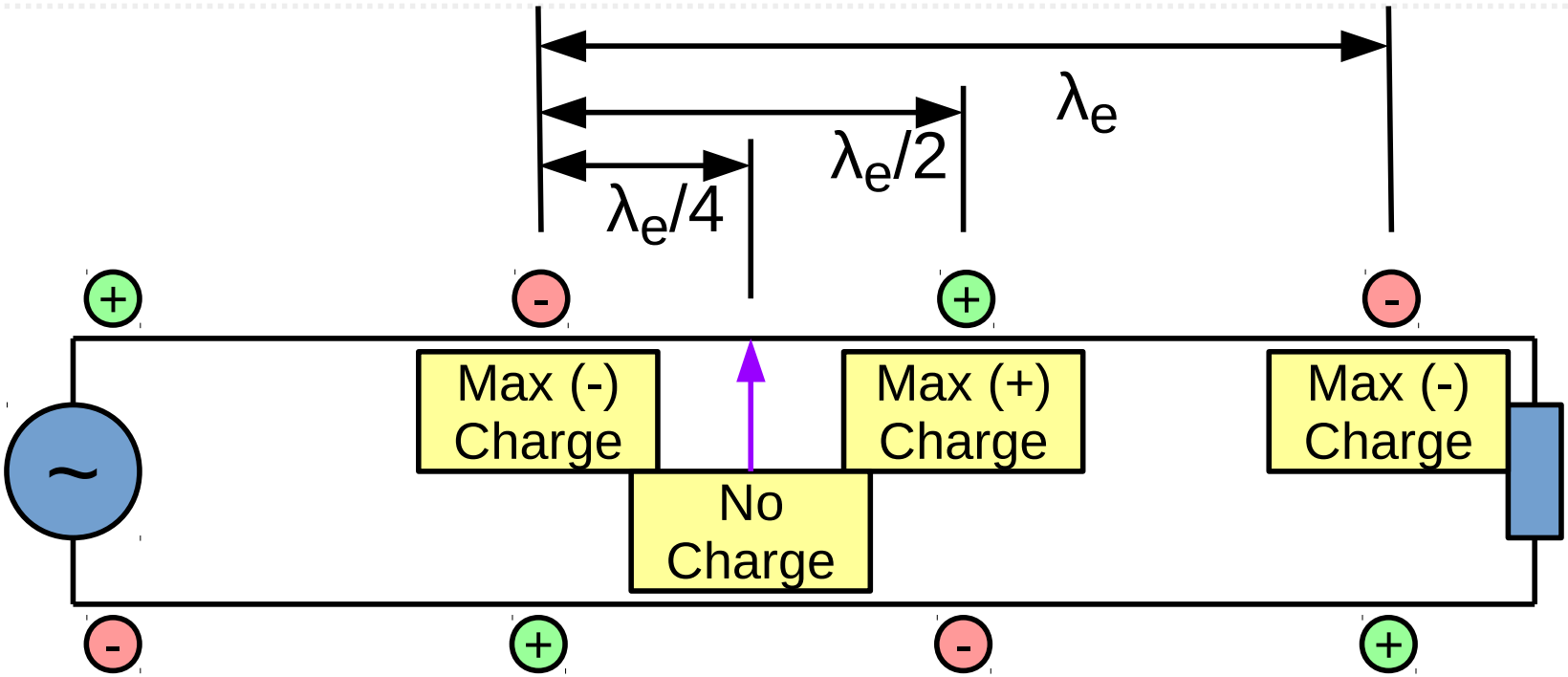
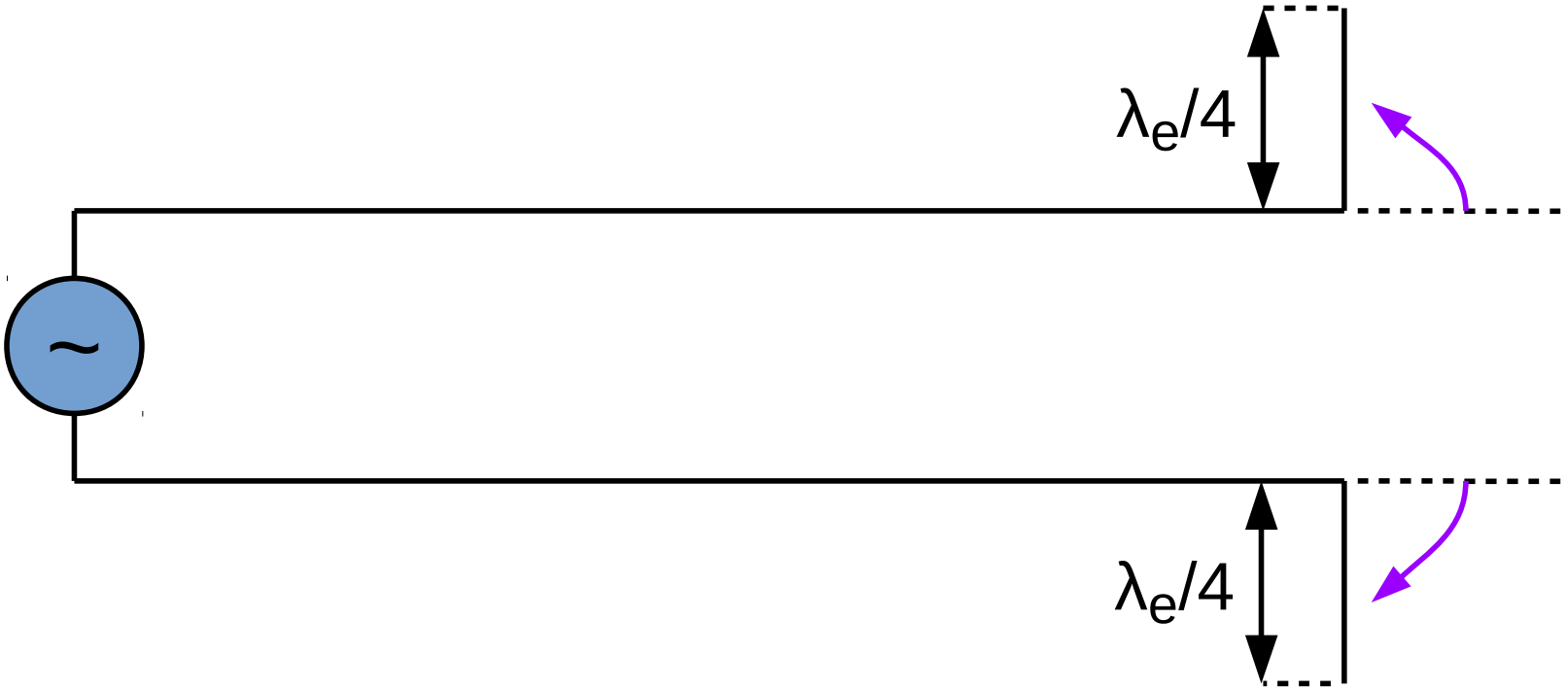


Maximum Charge Difference



Radiation

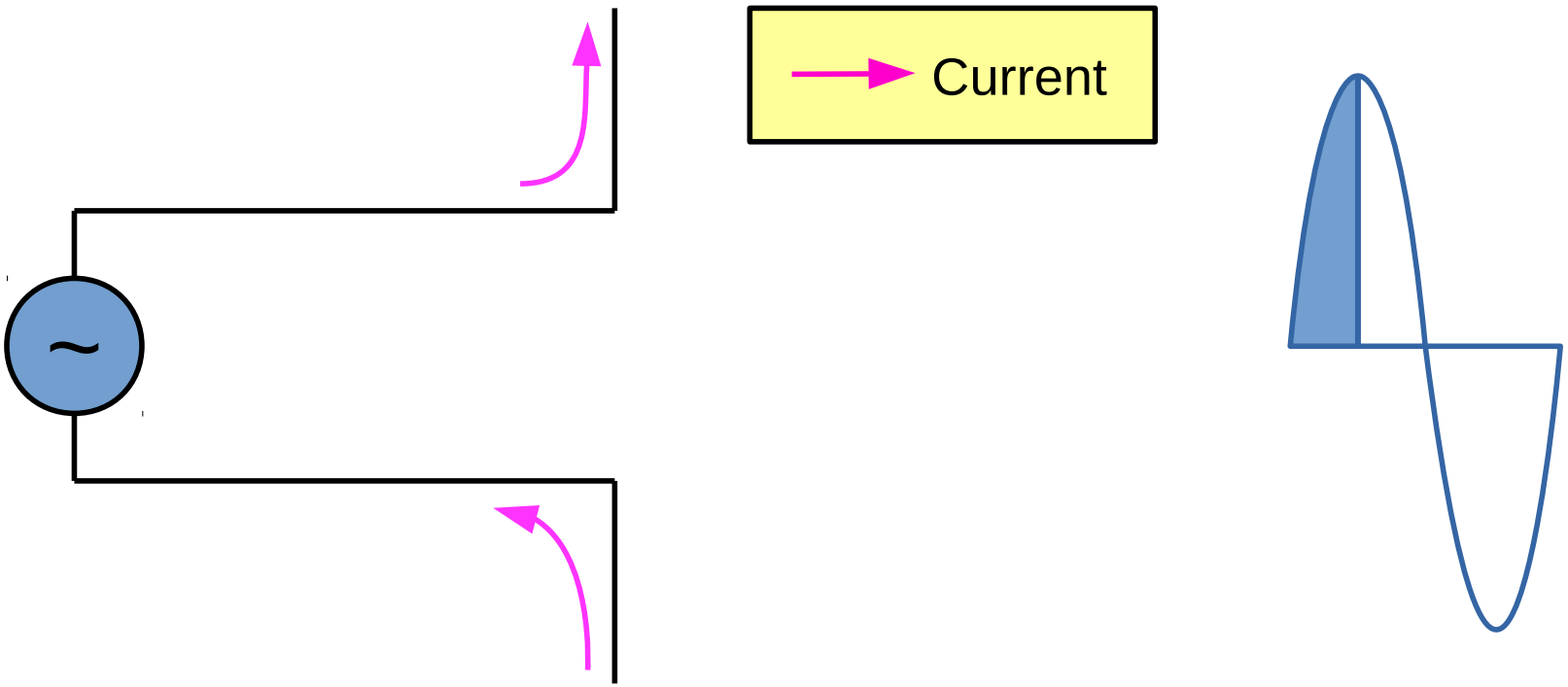
The $\lambda_e/4$ Dipole



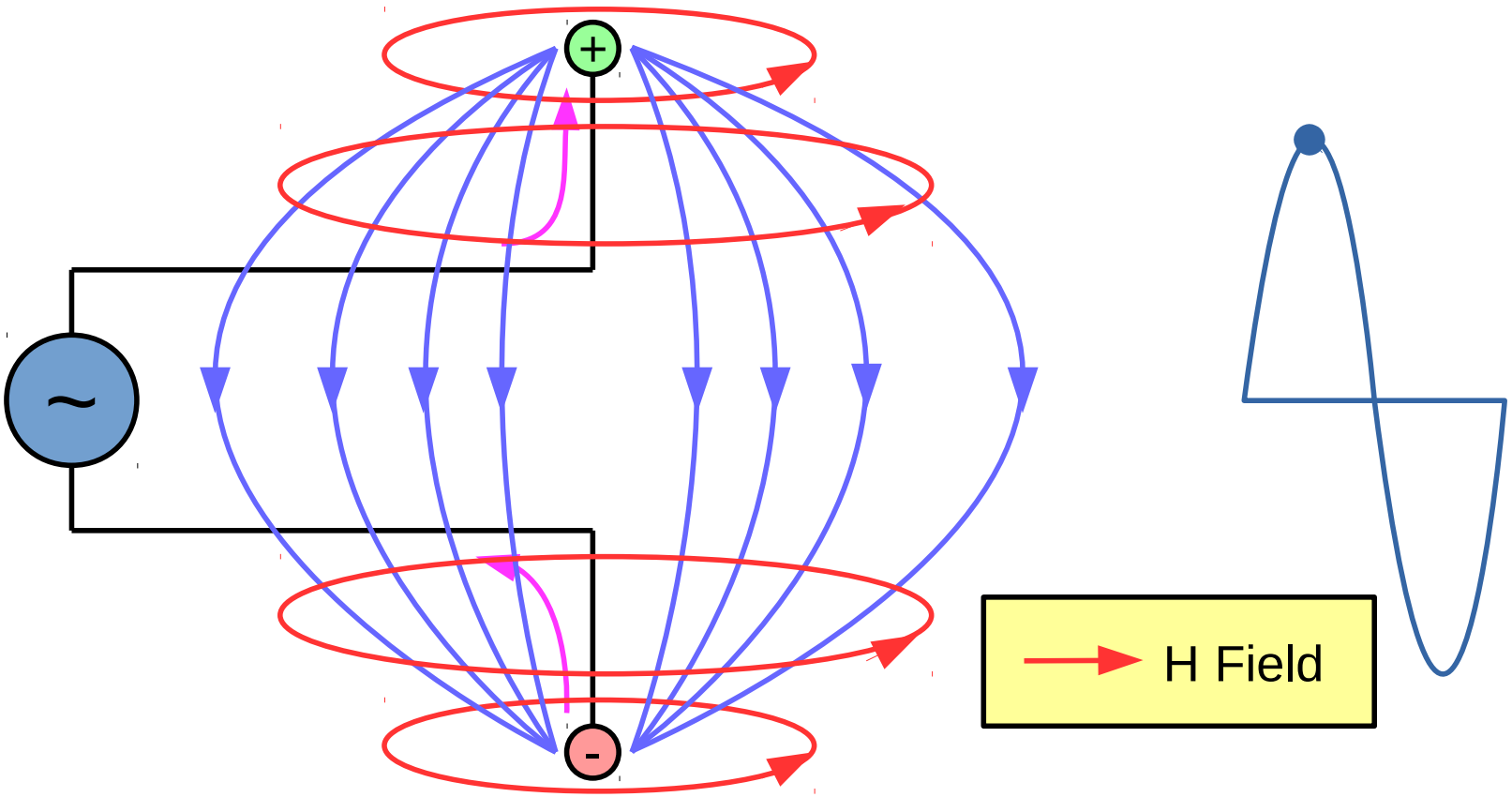
The $\lambda_e/4$ Dipole

- The radiating element
  - Converts the electrical signal into an electromagnetic wave
- The fields are generated by cyclic dipole formation
- A reversible process
  - An electromagnetic field can induce a dipole in an antenna
  - Known as the reciprocity theorem

Dipole Formation Cycle



Dipole Formation Cycle (Contd..)



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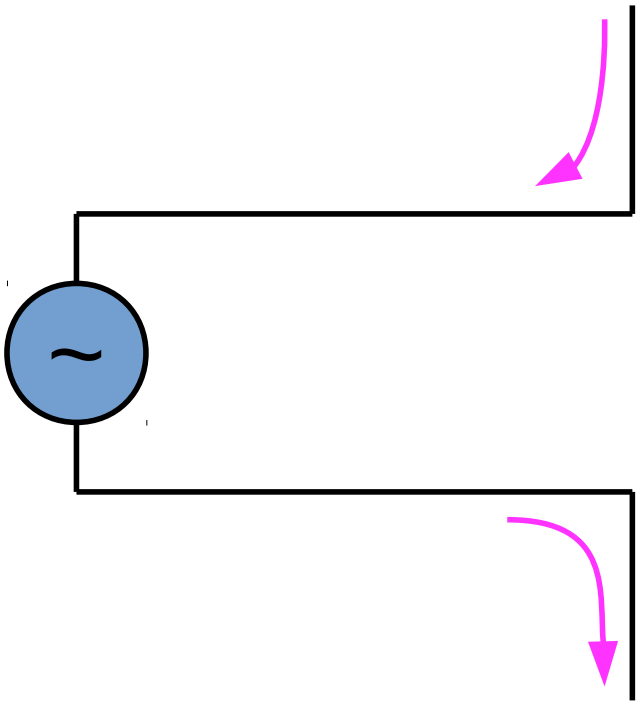

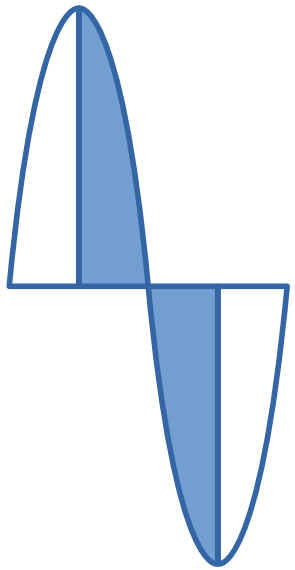

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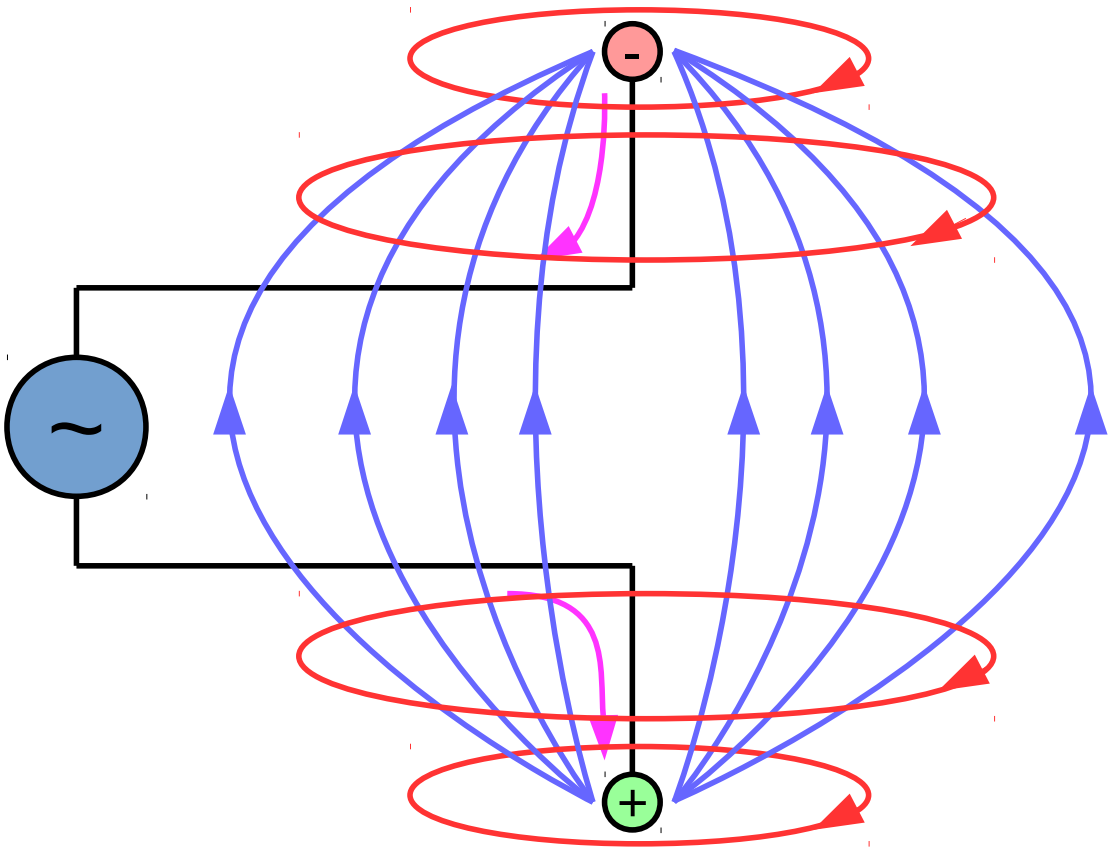

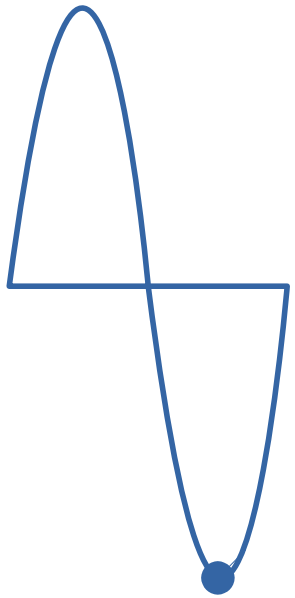

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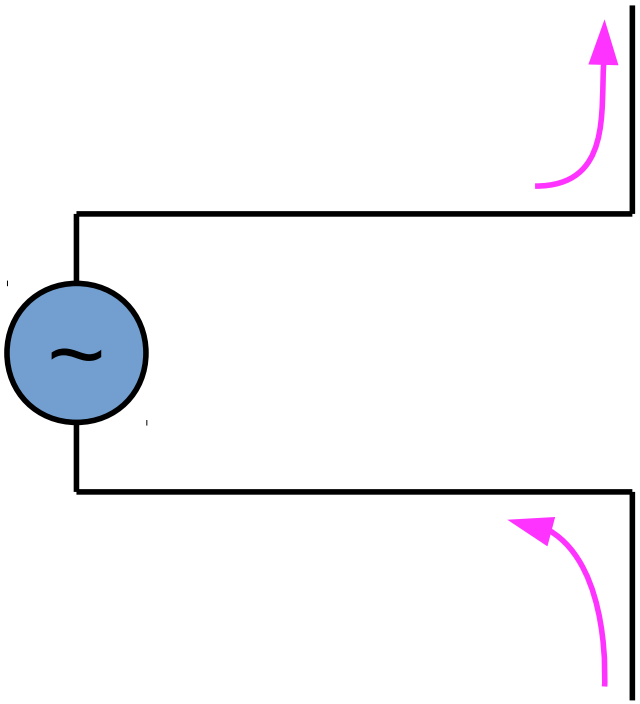
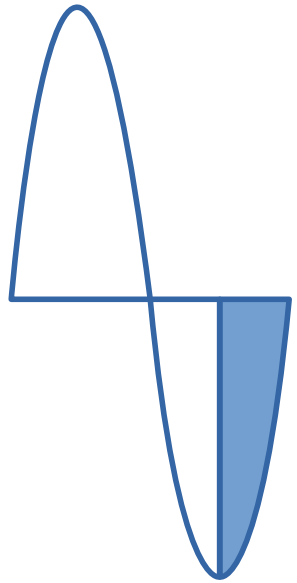
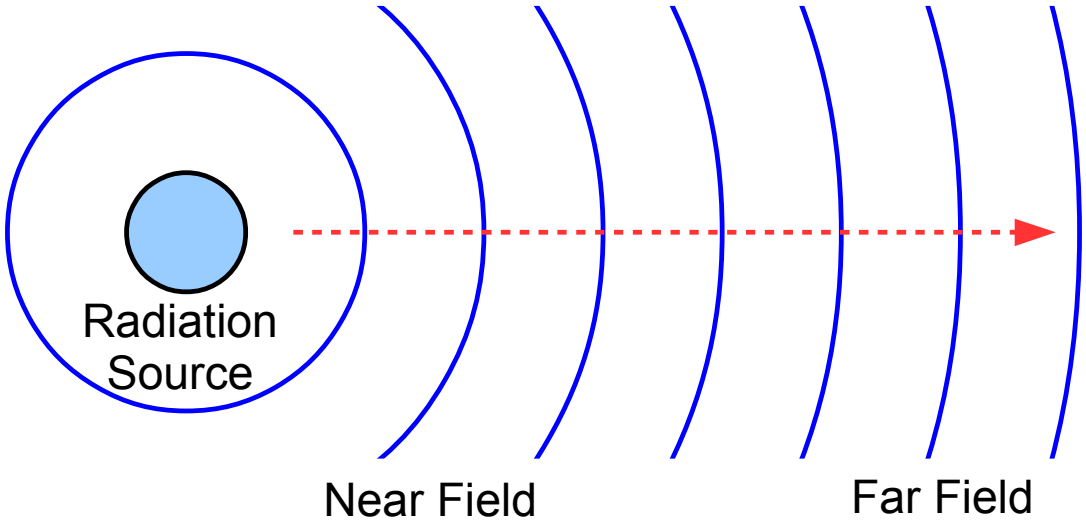




Near and Far Fields



- At the source, the fields are spherical (i.e., near field)
  - The fields get approximately planer in the far field
- The power density follows the inverse square law

Conclusion

Conclusion

- An antenna is a device that converts an electrical signal into an electromagnetic wave
  - Also vice versa (reciprocity theorem)
- The basic requirement for radiation is the formation of dipoles due to high frequency electron transport
- Most modern antennas are made for microwave frequencies
  - Low frequency radiowaves are fast becoming obsolete