Electric Field

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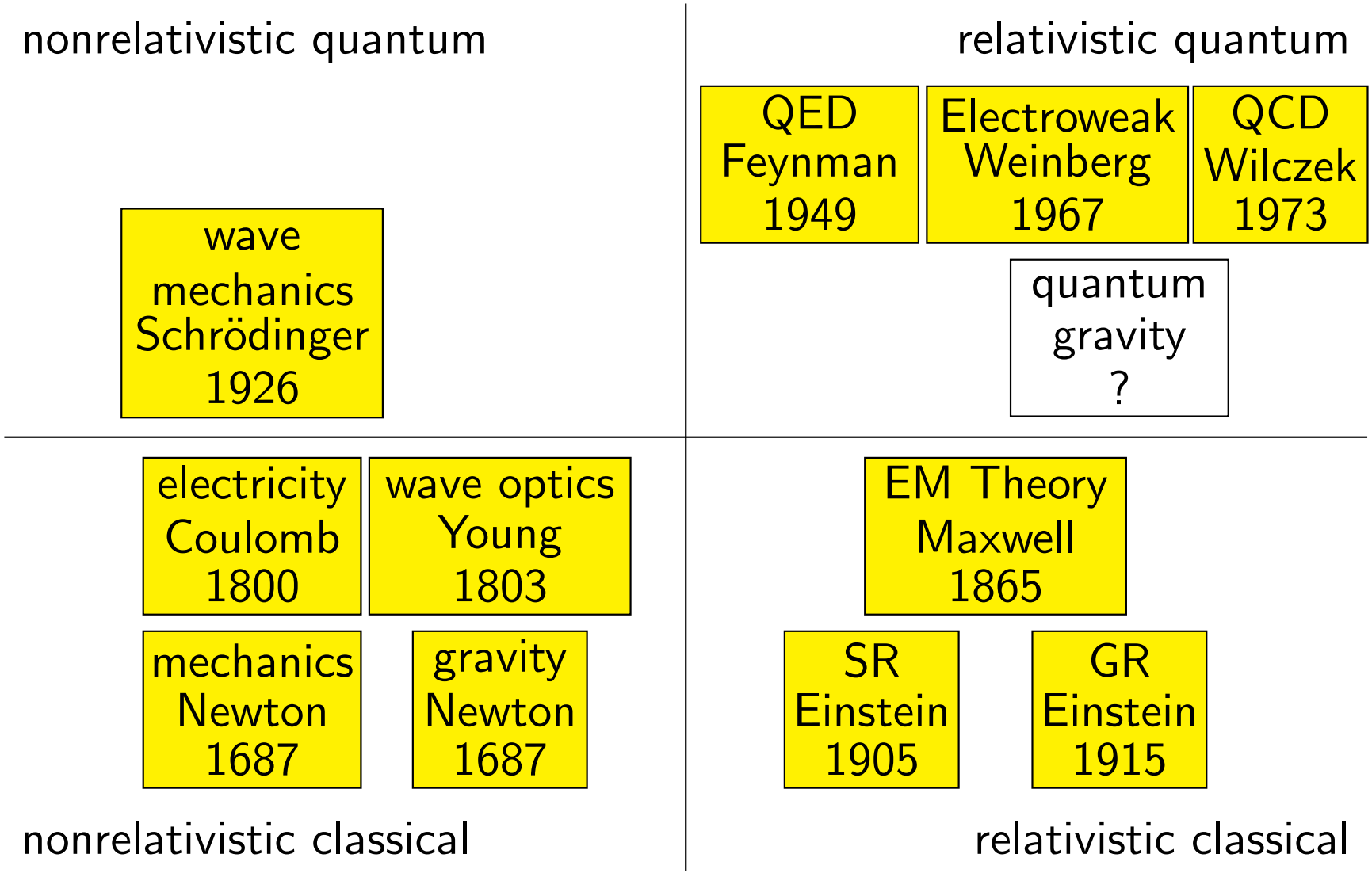
From old theory to new theory

- Old (18th century) view of electricity:
  - One particle exerts a force directly on another, even if they are not touching.
  - Force is given by Coulomb's law

$$F = k\frac{|qQ|}{r^2}$$

- New (19th century) view of electricity:
  - One particle produces an electric field.
  - The electric field exerts a force on another particle.

Theories in Physics



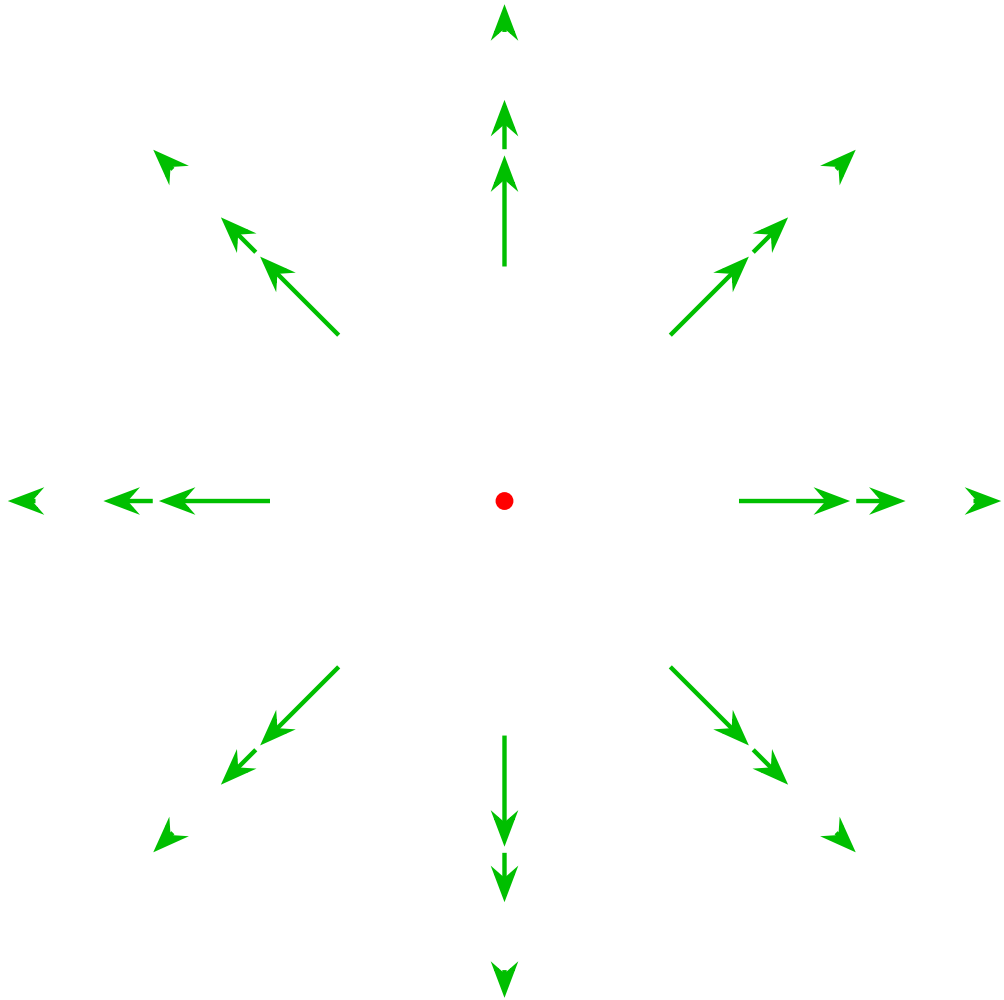
Why a new theory?

- The new theory establishes four relationships between electricity and magnetism.
- The new theory describes all electrical, magnetic, and optical phenomena that we know. The old theory only describes static electricity.
- The new theory is consistent with Einstein's special theory of relativity, even though it was constructed 40 years earlier.

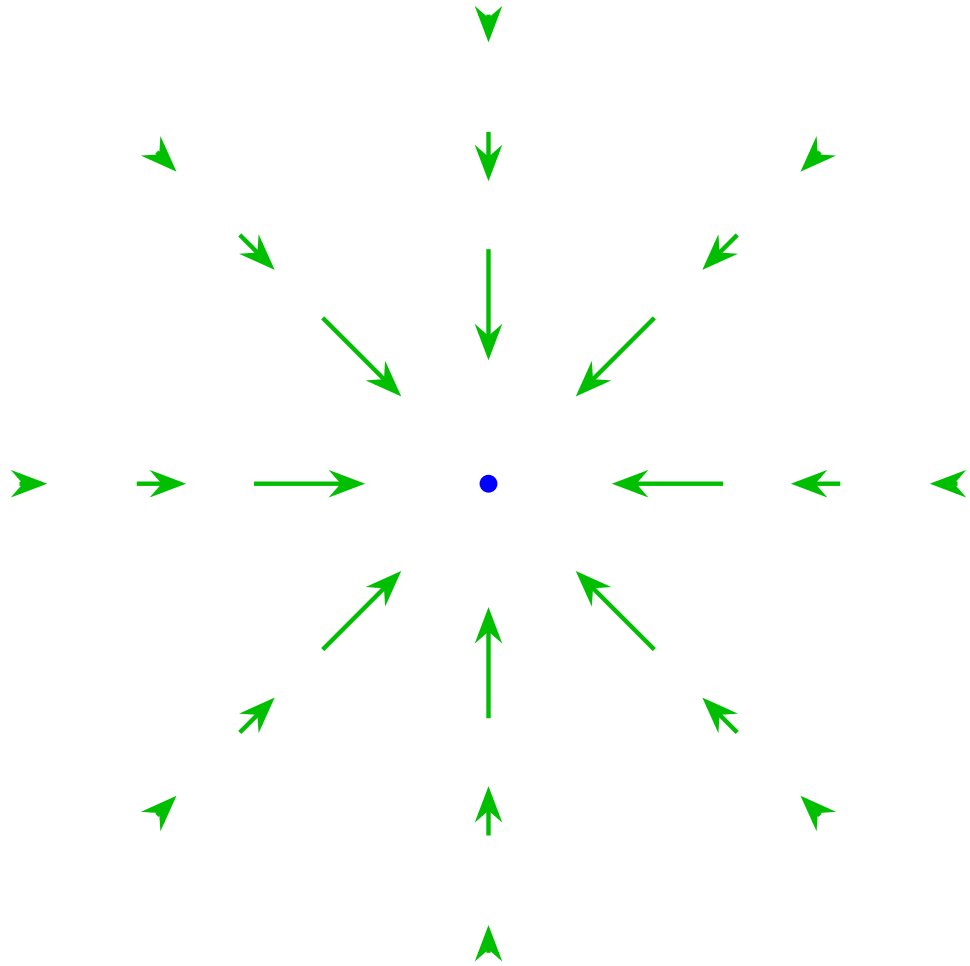
What is the electric field?

- The electric field is something that permeates all space.
- Each point in space has an electric field vector.
- Electric charge produces electric field.
- Electric field exerts force on charge.
- The electric field can change in time, so it permeates all space-time.

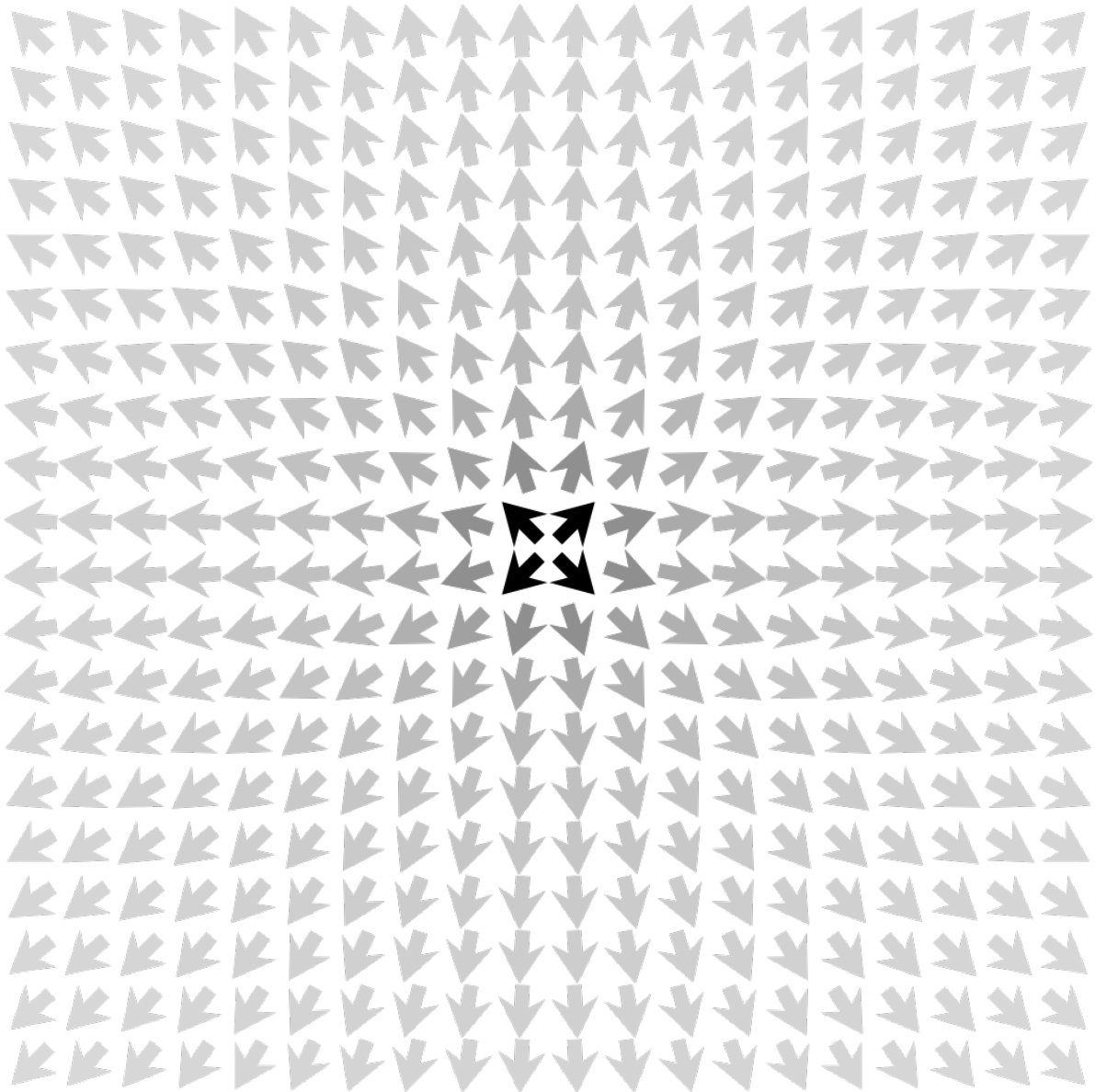
Electric field produced by a positively charged particle



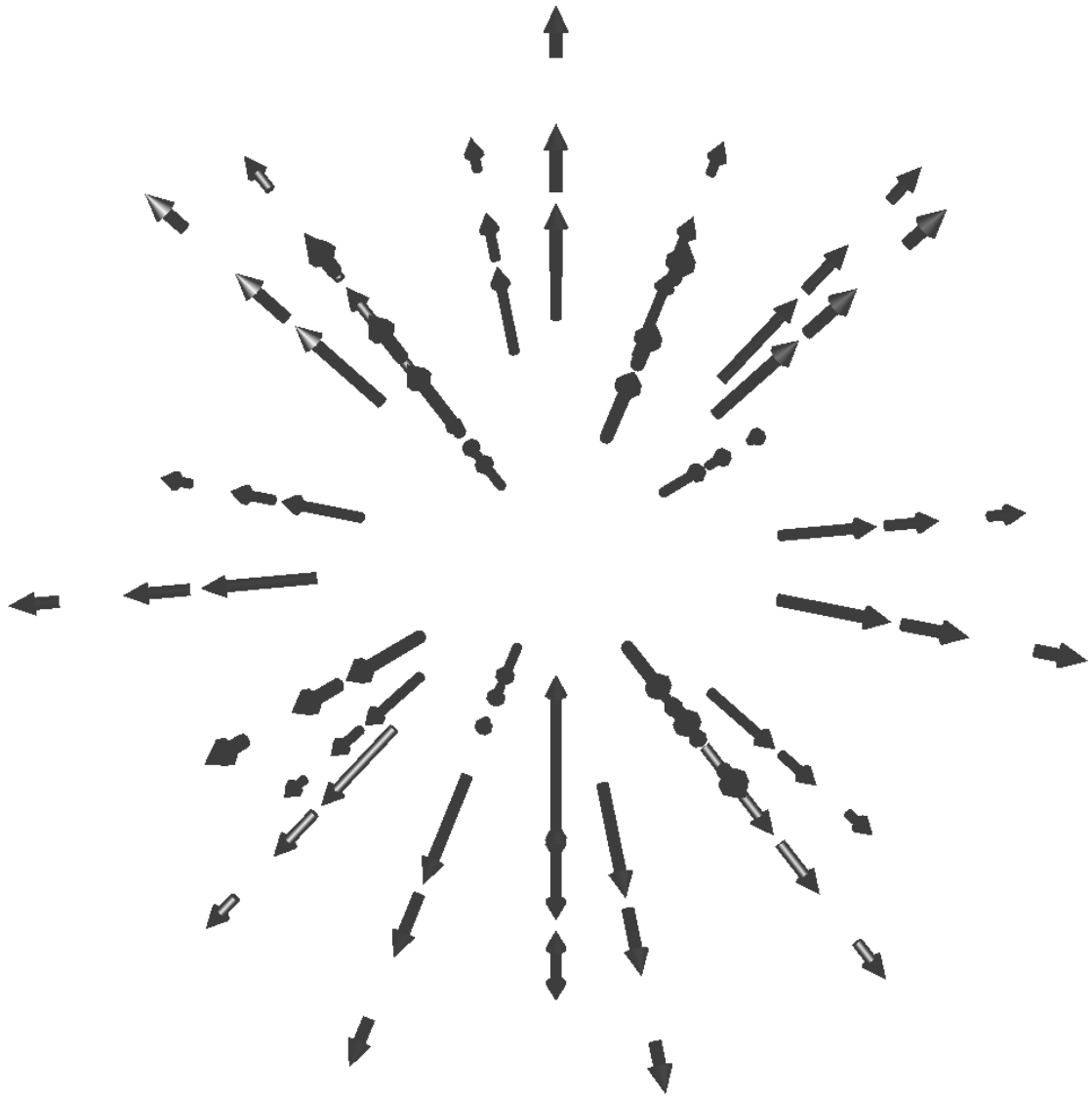
Electric field produced by a negatively charged particle



Electric field produced by a positively charged particle



Electric field produced by a positively charged particle



Electric field produced by a particle

The magnitude of the electric field produced by a particle with charge Q at a distance r from the particle is

$$E = k\frac{|Q|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|Q|}{r^2}.$$

$$\epsilon_0 = 8.8541878128 \times 10^{-12}\,\frac{\mathrm{C}^2}{\mathrm{N\ m}^2}$$

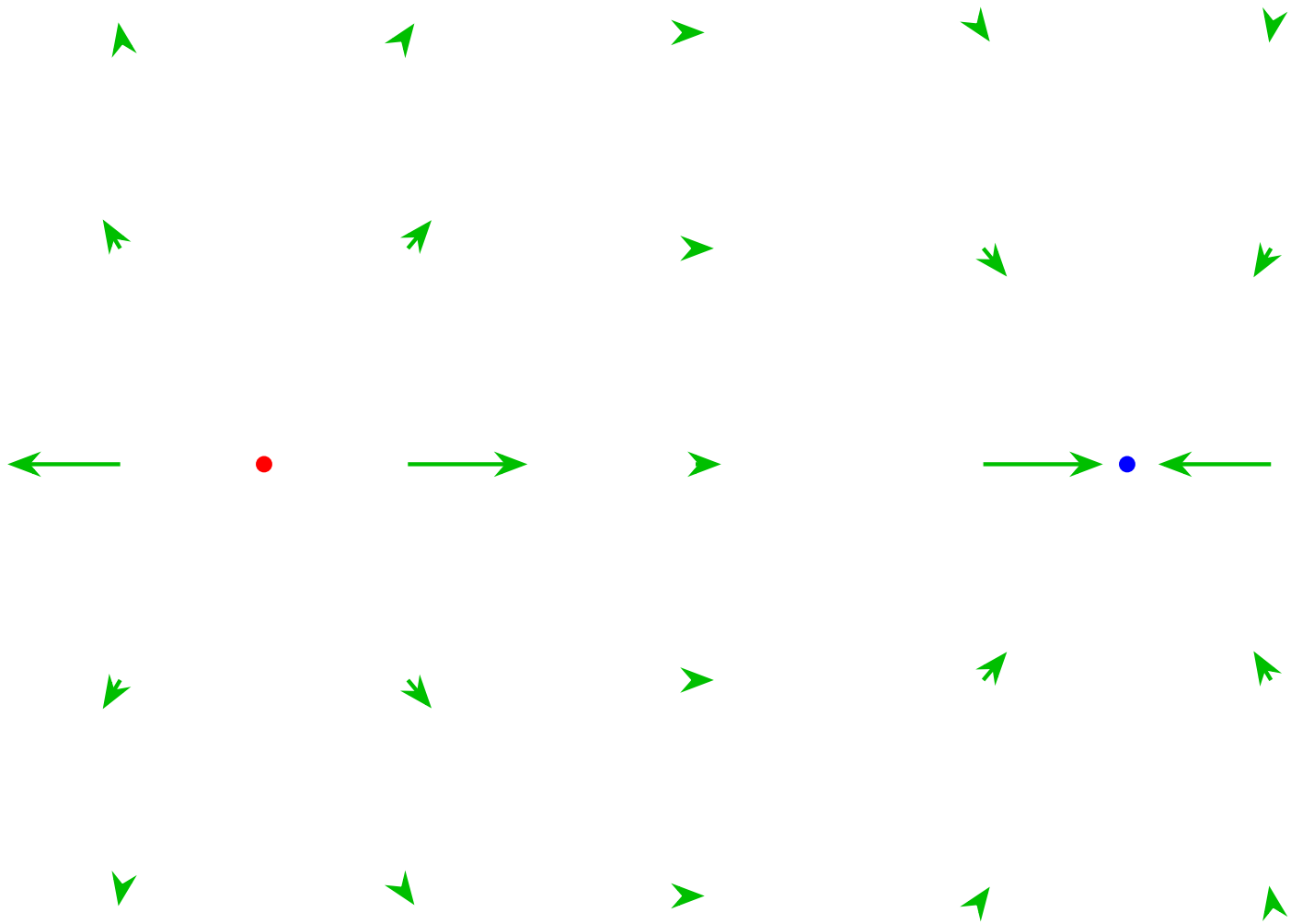
$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{\mathrm{N\ m}^2}{\mathrm{C}^2}$$

- Electric field points away from positive charge.
- Electric field points toward negative charge.

Superposition

- To find the electric field produced by two or more particles, add the electric field vectors produced by each particle alone.

Electric field produced by two particles



- Compare to Giancoli 7th, Figure 16-32(a)