Pillars of Electrostatics

1. Inverse square law: Force $\propto 1/r^2$

2. Superposition principle

IF we assume that $F_{Coulomb} \propto 1/r^{2+\epsilon}$ THEN what limit can we place on ϵ ?

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- > Williams, Faller, and Hill (1971): $\varepsilon = (2.7 \pm 3.1) \times 10^{-16}$

Inverse Square Law vs. Quantum Electrodynamics

For r << $\lambda_{Compton}$ QED renormalizes the charge of the $e^{\text{-}}$

$$V(r) = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

$$\lambda_{Compton} = \frac{h}{mc}$$

= 2.4 × 10⁻¹² m for e⁻¹²
 $\alpha \simeq \frac{1}{137}$

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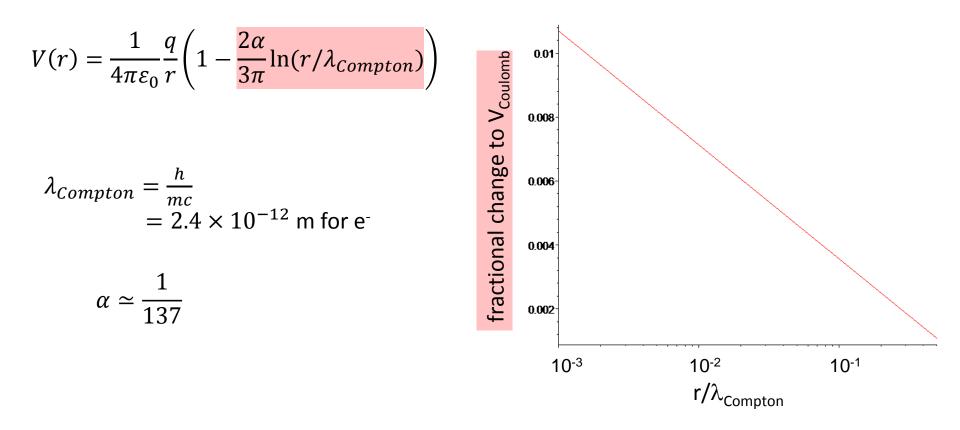
$$V(r) = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \left(1 - \frac{2\alpha}{3\pi} \ln(r/\lambda_{compton}) \right)$$

$$\lambda_{Compton} = \frac{h}{mc}$$

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Superposition Principle

In vacuum, the superposition principle ($\vec{E}_{total} = \vec{E}_1 + \vec{E}_2$) is true.

How true? QED predicts that photons begin to interact with each other (vacuum polarization effect) for

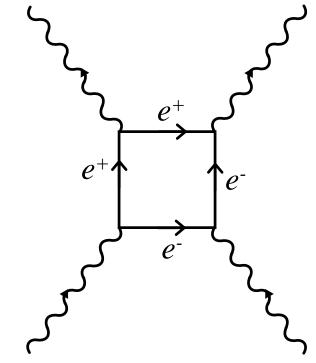
$$E - field \sim 10^{18} V/m$$

 $B - field \sim 10^9 T$

Photon-photon scattering in vacuum has NOT been detected yet.

In non-linear optical media, photonphoton scattering is a common effect.

Note : $E_{max,LAB} \sim 10^{14} V/m$ (ultrafast laser pulse)



Conclusion

1. Inverse square law: Force $\propto 1/r^2$

2. Superposition principle

Both of these statements are true over the range of experimental conditions where one would use classical electrodynamics/electrostatics.