Empirical status of some the axioms of Electrostatics

Note: The *E* field is unobservable so that all empirical axioms tests assume $\underline{F}=q\underline{E}$

a) Inverse square law <-> mass of photon

i) Assume $1/r^{2+\varepsilon}$ and put limits on ε

ii) Assume a Yukawa potential $V = r^{-1}e^{-\mu r}$ (with $\underline{E} = -\nabla \cdot V$) and quote a value for μ.

According to QM, $\Delta p \Delta x \approx h$ and $\Delta x \approx 1/\mu$, $\Delta p = m_\gamma c$ so $m_\gamma \approx h\mu/c$.

Experiments use the idea that $\underline{E} = 0$ inside a conductor only if $\varepsilon = m_\gamma = 0$.

D.C. Cavendish 1772: $|\varepsilon| < 0.02$

Maxwell 1879: $|\varepsilon| < 5x10^{-5}$

$4x10^6$ Hz Plimpton and Lawton 1936 $|\varepsilon| < 2x10^{-9}$

Williams et al 1971 $|\varepsilon| < 2.7 \pm 3.1x10^{-16}$ This implies $m_\gamma < 1.6x10^{-50}$Kg

Geophysical estimates

If the photon had mass, then the magnetic field of the earth would have a constant field in additiion to a dipole field. Satellites show that this is $<4\times10^{-3}$ times smaller than the dipole, hence:

$$m_\gamma \approx < 4\times10^{-51} \text{Kg, i.e. } \mu^{-1} > 10^8 \text{m}$$

Range of scales: $1/r^2$ tests from 10^7m to 10^{-18} m (100 GeV electrons)

b) Linear Superposition

i) Macroscopic level: Many phenomena including microwave transmission of thousands of calls show valid to better than 0.1%

ii) Atomic level: Huge fields: $10^{11} – 10^{17}$ V/m for e- in atoms, 10^{21} V/m in nucleus… classical linearity holds to better than one part in 10^6 even here.

iii) QM nonlinearity: arises because of "vacuum polarization" in which E-M fields can be screened by virtual e+, e- pairs (light scattering light, also virtual pair exchanges)… but this is predicted

c) Force law:

Since E is unobservable, $\underline{F} = q\underline{E}$ is needed to test axioms a,b. However if relativistic law of motion is added, then $\underline{F} = q\underline{E}$ implies particle trajectories which are extraordinarily accurate.