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Gauss' Law: Choice of the Gaussian Surface and Form of the Electric-Field Vector

*Syed Arif Kamal**
Department of Mathematics, University of Karachi, Karachi, Pakistan; profdrakamal@gmail.com

Gauss' law is one of the fundamental laws of electromagnetism, which is, primarily, used to determine the electric-field vector, if the system possesses certain symmetries. This is possible, provided a proper gaussian surface is selected, according to the following criteria:

a) Field point (where the electric-field vector needs to be determined) must lie on the gaussian surface.
b) It should be a closed surface (well-defined interior and exterior) — *most common types of gaussian surfaces are spheres, cylinders and boxes.*
c) It could be a real (coinciding with a physical boundary) or an imaginary surface — *for example, spherical surface with center at origin could lie inside a spherical charge distribution of uniform density (imaginary) or the boundary (real)*.
d) It should be chosen considering symmetries of the system, as suggested by strong Noether's theorem (http://www.ngds-ku.org/pub/confabst.htm#C61:) — *for example, spheres, cylinders or boxes are chosen for spherical, line or surface charge distributions, respectively*.
e) Direction of the electric-field vector should either be tangential or normal to any chosen section of surface — *for a uniform line charge distribution, a cylindrical surface is selected as a gaussian surface. The electric-field vector is normal everywhere on the curved surface and tangential on both plane surfaces*.
f) Magnitude of the electric-field vector should be constant throughout each section of surface, allowing one to take it outside the integral — *for example, spherical surface with center at origin is, generally, chosen as gaussian surface for a spherical charge distribution of uniform density. Magnitude of electric field, being a function only of radial coördinate (distance from center of distribution), is constant over this surface*.

Examples were worked out for computing electric fields generated by *(i)* an infinite plane charge sheet, with constant surface-charge density and *(ii)* an infinite line charge, with constant line-charge density, with special emphasis to determine the form of electric-field vector. Similarities and differences of electricity and magnetism as well as electricity and gravitation were highlighted. An expression of Gauss' law for gravitation was presented and illustrated with computation of gravitational field inside and outside earth. In the context of Ampéré circuital law, line integral of magnetic flux density is to be computed along a closed curve. Criteria for choosing this curve, to most efficiently determine the magnetic field, were, also, mentioned.

*Keywords***:** Gauss' law, gaussian surface, strong Noether's theorem, Ampéré circuital law, space-time symmetries

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*Prof. Dr. Syed Arif Kamal (http://www.ngds-ku.org/kamal); PhD (Karachi); MA (Johns Hopkins, United States); MS (Indiana, Bloomington, United States); Professor, Department of Mathematics, University of Karachi, Karachi 75270, Pakistan; *Telephone***:** +92 21 9926 1300-15 ext. 2293