Calculation of the interaction between a 0V potential sphere and a point electric charge

2D Textbook Case Summary

Program	Dimension	Physics	Application	Work
Flux	2D - axi	Electric	Static	Electric

Analysis of the force induced by an empty sphere with a 0V potential on a point charge containing N elementary charges. This study underlines the electrostatic force existing between 2 elements.

Objective

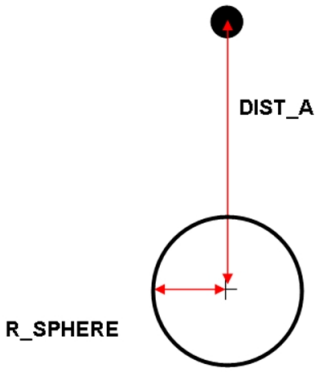
Exploitation of the value of the electrostatic force induced by the sphere on a point charge. The parameters which can vary are:

- The sphere radius (R_SPHERE)
- The distance (DIST_A) between the sphere centre and the punctual charge
- The number of elementary charges (N) contained in the point charge

Theoretical reminders

Analytical calculation of the attractive force induced by the sphere on the point charge:

$$F = \frac{1}{4 \times \pi \times \varepsilon_0} \times N^2 \times q^2 \times \frac{R\_SPHERE \times DIST\_A}{\left(DIST\_A^2 - R\_SPHERE^2\right)^2}$$

Illustration	Main characteristics
	• Point charge value: N x q, with q = 1.6 E-19 C and rated N = 20 • Rated distance (DIST_A) between the sphere centre and the point charge = 0.8 mm • Rated radius of the sphere: R_SPHERE = 0.3 mm • Relative permittivity of vacuum: ε_0 = 8.85 E-12 F/m

Results

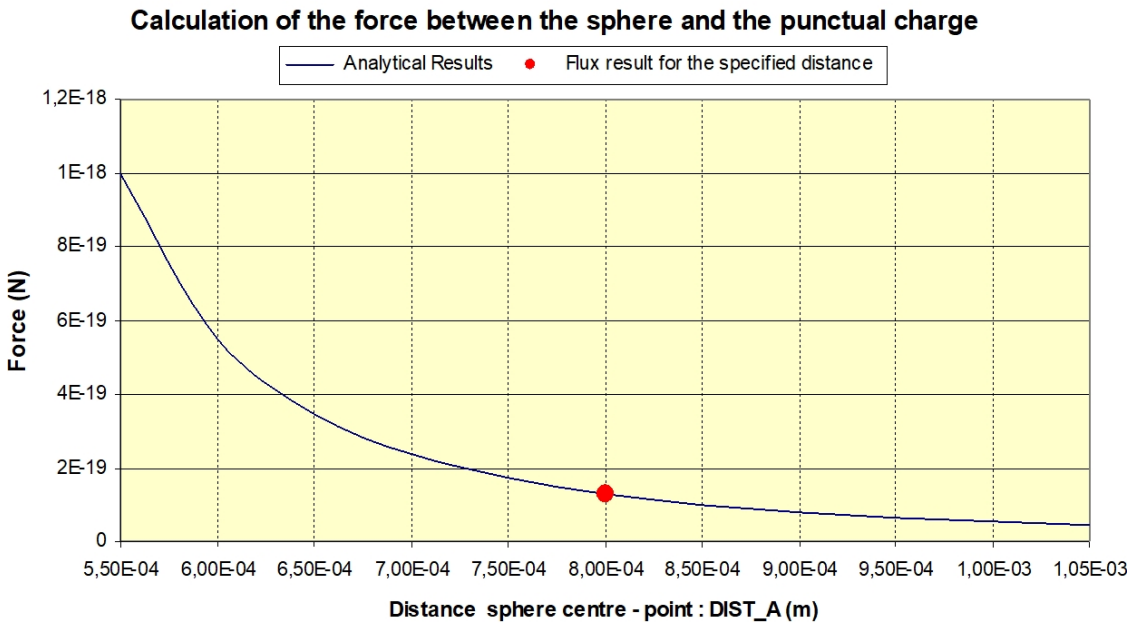


Figure 1: Force value in function of the distance DIST_A (other parameters are rated)

To go further:

- Replace the point region by a second sphere and vice-versa
- Study the distribution of the electric field
- Calculate the force between the 2 armatures of a capacity

Model in Flux

Domain

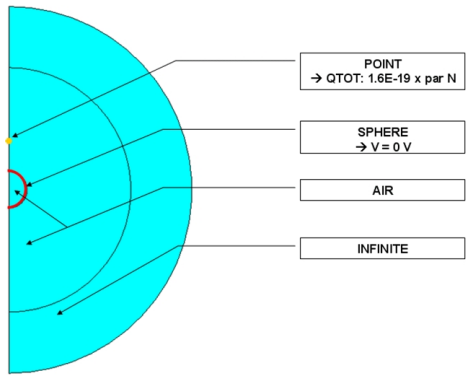
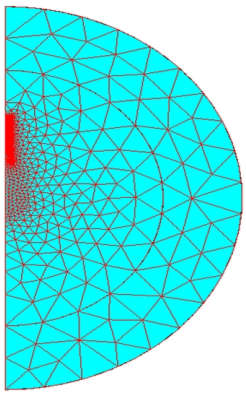
Dimension	2D	Depth	Axi
Length unit	mm	Angle unit	Degrees

« infinite » box		Disk
Dimensions	Rint : 2 mm	Rext : 3 mm

Symmetry	1 symmetry	symmetryYaxis_1 : No active physical symmetry

Physical application	Electrostatic
Property	Electric potential at infinite: 0 V

Geometry / Mesh

Full model in the FLUX environment	Mesh
	

Mesh	2nd order type	Number of nodes	3724

Entry parameters

Name	Type	Description	Rated value
R_SPHERE	Geometrical	Sphere radius	0.3 mm
DIST_A	Geometrical	Distance between the sphere centre and the point charge	0.8 mm
N	Physical	Number of elementary charges considered	1

Regions

NAME	AIR	INFINITE	POINT	SPHERE
Nature	Surface region	Surface region	Punctual	Line region
Type	Air or vacuum region	Air or vacuum region	Region with charge given by its total value	Stiff electric potential
Associated material	-	-	-	-
Mechanical set	-	-	-	-
Component associated circuit	-	-	-	-
Electrical characteristics	-	-	Qtot = N x 1.6 E-19 C	0 V
Current source	-	-	-	-
Thermal characteristics	-	-	-	-
Potential thermal source	-	-	-	-

Resolution parameters

Type of solver **Linear systems**	Automatically chosen	Parameters	Automatically defined

Type of solver **Non linear systems**	Newton Raphson	Precision	0.0001	Max. number of itérations	100
		Method of calculation of the relaxation coefficient		Authomatically specified method	

Resolution

Scenario	Name of parameter	Type of configuration	Variation method	Variation scale	Selection of the steps
REFERENCEVALUES	-	-	-	-	-

Annex

Theoretical reminders

Calculation of the force

General electrostatic equation: $\varepsilon \cdot \Delta V = -\rho$

Calculation of the attractive force exerted by the sphere on the point charge:

$$F = \frac{1}{4 \times \pi \times \varepsilon_0} \times N^2 \times q^2 \times \frac{R\_SPHERE \times DIST\_A}{\left(DIST\_A^2 - R\_SPHERE^2\right)^2}$$

Notation and symbols

Symbol	Description	Unit
F	Force exerted by the sphere on the point charge	N
ε_0	Absolute permittivity of vacuum $\varepsilon_0 \approx 8.85E^{-12}$	F/m
DIST_A	Distance between the sphere centre and the point charge	m
R_SPHERE	Sphere radius	m
N	Number of elementary charges constituting the point charge	
q	Elementary charge $q = 1.6E^{-19}$	C

Numerical applications

Calculation of the force F for a given point

Let's calculate the value of the attractive force exerted by the sphere on the point charge while the parameters are the following:

- Number of elementary charges constituting the point charge: N = 20
- Distance between the sphere centre and the point charge: DIST_A = 0.8 mm
- Rated radius of the sphere: R_SPHERE = 0.3 mm

$$F = \frac{1}{4 \times \pi \times \varepsilon_0} \times N^2 \times q^2 \times \frac{R\_SPHERE \times DIST\_A}{\left(DIST\_A^2 - R\_SPHERE^2\right)^2}$$

$$F = \frac{1}{4 \times \pi \times 8.85 \times 10^{-12}} \times 20^2 \times \left(1.6 \times 10^{-19}\right)^2 \times \frac{0.3 \times 0.8 \times 10^{-6}}{(0.8 - 0.3)^2 \times 10^{-6}}$$

$$F = 7.30 \times 10^{-20} N$$