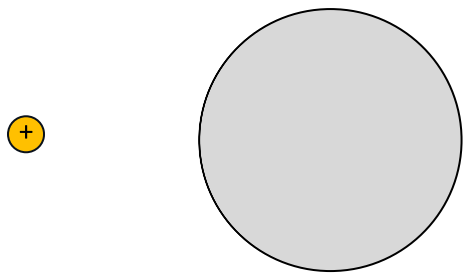
Teacher notes
Topic D

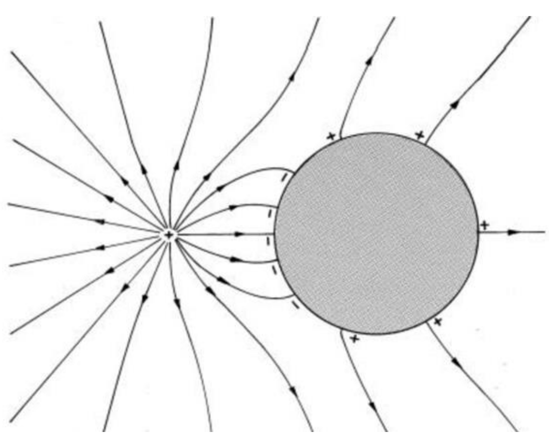
Electric force between point charge and neutral sphere

A point positive charge is placed near a neutral conducting sphere. Is there a force between the sphere and the point charge?



This question appeared in a past exam and caught most students off guard.

The naïve answer is that since $F = k\dfrac{Q_1Q_2}{r^2}$ and the charge on the sphere is zero, then $F = 0$. But this is not right. The sphere is conducting so it contains "free" electrons. The electric field created by the point charge will exert forces on these electrons making them move. The motion of the electrons will be towards the positive point charge, and they will accumulate on the left surface of the sphere. This means that the right surface of the sphere will be left with a surplus of positive charge. At all times the total charge on the sphere is zero. The motion of the electrons will stop when the electric field within the sphere is zero. In other words, the separation of charge in the sphere will create its own electric field, directed opposite to the field of the point charge so that the net field within the sphere is zero. This is expected from the general result that, in electrostatics (no motion of charge), the field within a conductor is zero. The field lines created by this arrangement make this pattern:

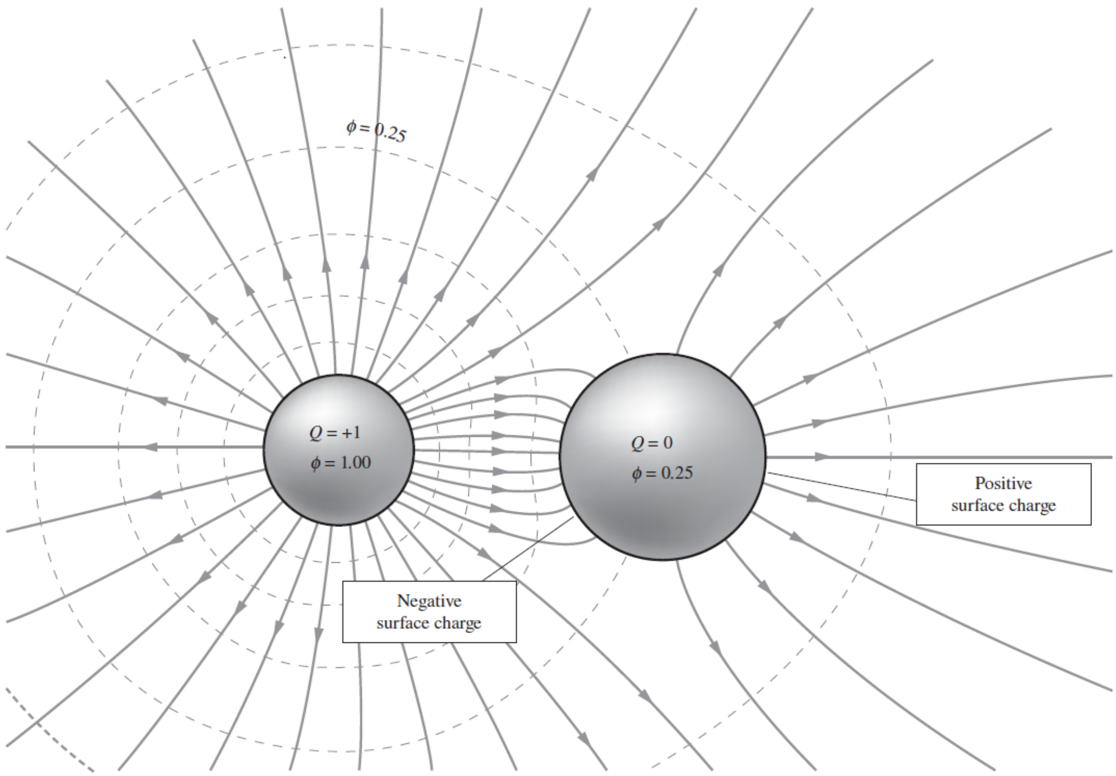


(From Haus, Hermann A. and Melcher James R., Electromagnetic fields and energy, Prentice-Hall, 1989.)

This shows that there is a force and that the force is attractive.

If the positive point charge is replaced by a negative point charge the figure above essentially stays the same with arrows reversed which means that the sphere has negative charge on its right surface and positive on the left surface. The force is **still attractive**.

A very nice diagram is the following from E. Purcell and D. Morin, Electricity and Magnetism, Cambridge University Press, 2013, which shows a positively charged sphere on the left and a neutral sphere on the right. The symbol ϕ stands for electric potential in arbitrary units. This shows equipotential lines as well.



Notice how the field lines are normal to the equipotential lines. The neutral sphere has zero net charge but non-zero electric potential. This means it would take work to bring a test charge from infinity to the surface of the neutral sphere.