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# Why the potential of earth necessarily zero?

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**Abstract**

The concept of potential is not very clear among the undergraduates they often make vague mistakes in using the concept of potential in electrostatic problems. One of the things that are taken as granted is that the potential of Earth is zero. Actually there is nothing as zero potential. Electric potential is rightly viewed when it is compared with height as in gravitational field. Just as for defining height we need a reference point from where we start measuring height for defining electric potential we need a reference point where the potential is zero. So why do we take the potential of Earth as zero? So, here in this paper I have addressed this question from a mathematical point of view. Where i have taken two spheres one charged (which is the smaller sphere) and one uncharged (which is the bigger one). Then I have assumed the bigger sphere as the earth where the radius of the earth is very large as compared to the radius of the sphere. And then came to a conclusion that indeed the potential of the earth is zero.

## 1 Introduction

Initially the conductor (A) had a charge $Q_a$ then it is connected to the other conductor (B) (neutral) . Now since the solution of the Laplace's Equation [1] is unique i.e. only a single potential which satisfies the appropriate boundary condition is valid. So now the point where the wire touches the left conductor will have the same potential as that of the conductor (A) and this is true for all point of the wire so the wire is also at the same potential as that of the conductor (A) and under the same reasoning conductor (B) will have the potential of (A). But now the initial potential of (A) has changed since some charges from the conductor (A) now flow to the conductor (B)

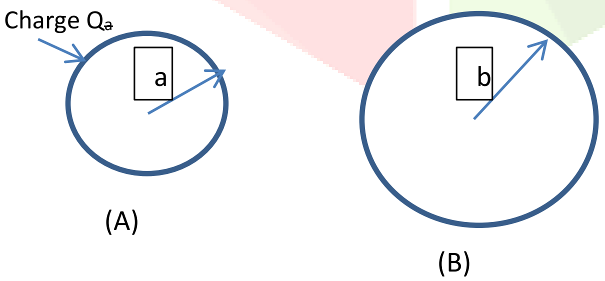


Figure 1: Showing two spheres on the left is sphere (A) which is charged and it bears a charge $Q_a$ and on the right is the sphere (B) which is uncharged

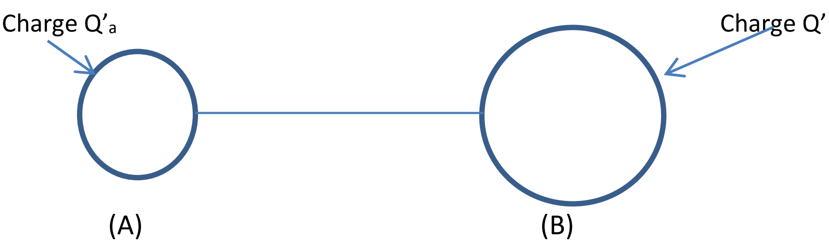


Figure 2: Wire connecting both the spheres

Let the amount of charge left in conductor (A) be $Q'_a$ and the amount of charge that went to (B) be Q'.

So $Q_a = Q'_a + Q'$———->(1)

Potential of (A) is same as that of (B) after wire connection,

So $Q'_a/(4\pi\varepsilon_0 a) = Q'/(4\pi\varepsilon_0 R)$

Or $Q'=(R/a)\,Q'_a$ ——————>(2)

From (1),

We get $Q'_a=Q_a-Q'$

Using that in equation (2),

$Q'=(R/a)\,(Q_a-Q')$

Or $Q'\,(1+(R/a)) =(R/a)Q_a$

$Q'=(R/(a+R))\,Q_a$

$Q'= (1/((a/R)+1))\,Q_a$

Now if we consider the second conductor as the earth whose radius is 6.3781×10^6 m and the conductor we used is of few centimetres so (a/R) is of the order 10^-8 so that (a/R) <<1 and can be neglected

which gives the remarkable result that :

$Q'=Q_a$

Which means that the entire charge in (A) has moved to the Earth so its neutral now using $V=Q'_a/(4\pi\varepsilon_0 a)$ where $Q'_a=0$ (which follows from (1) since $Q'=Q_a$) so (A) has a potential zero. Now again using the property of uniqueness of solution of Laplace equation as the wire is now connected to the earth it also has a potential zero

**2 Discussions**

Now the reader might be tempted to think that there is some charge that goes to the wire also but we can neglect that by considering the wire to be small in length or even we can forget about the wire and consider touching the conductors directly which doesn't change the actual result.

By using the boundary condition : that as we go far from the charged sphere the potential falls of by 1/r so sufficiently far away from the charge the potential basically tends to zero using that we get the exact potential of the charged conductor as $V=Q'_a/(4\pi\varepsilon_0 a)$.

**3 Conclusion**

The aim of the paper was to show that if we connect two spheres one a smaller one with a larger one and assuming the smaller sphere was initially charged we see that as we increase the radius of the larger sphere more charge goes into the bigger sphere from the smaller sphere. Using that simple model we get a remarkable result that why we take the potential of Earth to be zero.

References

[1] D J Griffiths. Introduction to Electrodynamics. In and others, editor, Introduction to Electrodynamics, pages 120–124. Pearson.