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BLUEPRINT
Invisible Energy

# Additional Information

An electric field permeates the space surrounding an electrically charged object. In this demonstration, the charged object is the metallic sphere of the Van de Graaff generator. At a distance *r* from the centre of the generator, the field strength *E* is as follows:

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r} \qquad \text{(Equation 1)}$$

*E* is the electric field, *Q* is the total charge of the Van De Graaff sphere, $\varepsilon_0$ is the permittivity of free space (a constant) and $\hat{r}$ indicates the field's radial direction (positive if the field lines extend out of the sphere and negative if they point into it).

Note that because *r* is in the denominator of the equation, as the distance from the generator (*r*) increases, the strength of the field (*E*) will decrease.

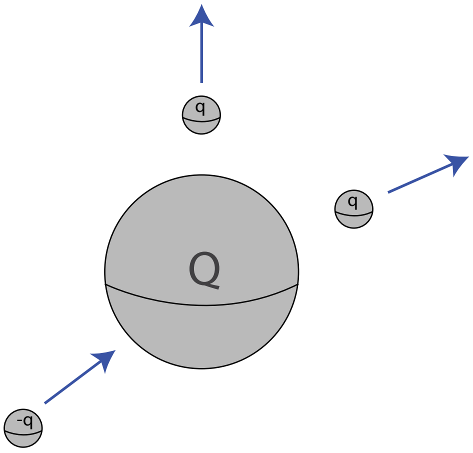

Figure 1

If a positively charged particle *q* is placed in the electric field, it will feel a force due to the field (**Figure 1**). If the field is positive it will exert a repulsive force on the particle and push it away, and vice versa. If a negatively charged particle -*q* is placed in a positive field, the field will exert an attractive force on the particle.

The force of an electric field on a charged particle *q* can be calculated by multiplying the value of the electric field (*E* from equation 1) by *q*. The force is given by the following equation:

$$\vec{F} = q\vec{E} \qquad \text{(Equation 2)}$$

For an attractive force, where *q* and *Q* have opposite charges, *F* is negative. For a repulsive force, *F* is positive.

Electric fields are visually represented by electric field lines. The lines point in the direction a positive charge would move if placed in the field (**Figure 2**).

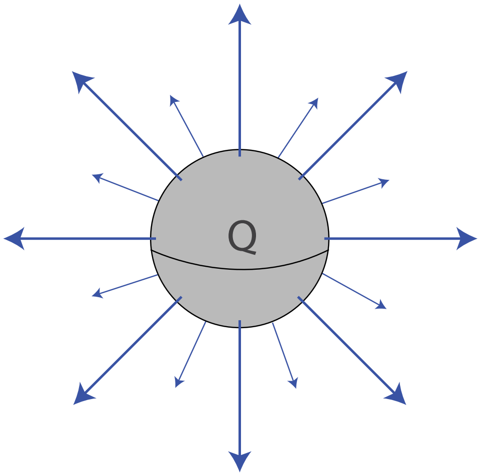

Figure 2

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# Invisible Energy - Additional Information

A related property is the electric potential of an electric field. The electric potential is the potential energy per unit charge of a static electric field. It is measured in volts. Like the electric field, electric potential decreases as the distance from the charged object increases (though to a lesser degree). The potential (*V*) is:

$$V = \frac{Q}{4\pi\varepsilon_0 r} \quad \text{(Equation 3)}$$

Electric potential differs from the electric field since it is a scalar quantity instead of a vector quantity. Electric potential does not have an associated direction. All equidistant points from a charged object, regardless of their direction, have the same electric potential value. Surfaces upon which all points share the same potential value are called equipotential surfaces (**Figure 3**).

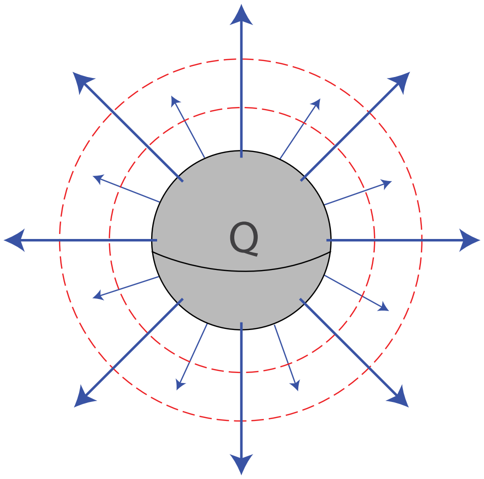

Figure 3

When the fluorescent tube is held radially to the Van de Graaff sphere, it intersects different equipotential surfaces (**Figure 4**). Therefore, the two ends of the tube are at different potential values. As a result, there is a potential difference (voltage) within the tube. This voltage difference illuminates the tube without the sphere touching the tube because the charges are still able to move to a lower equipotential surface.

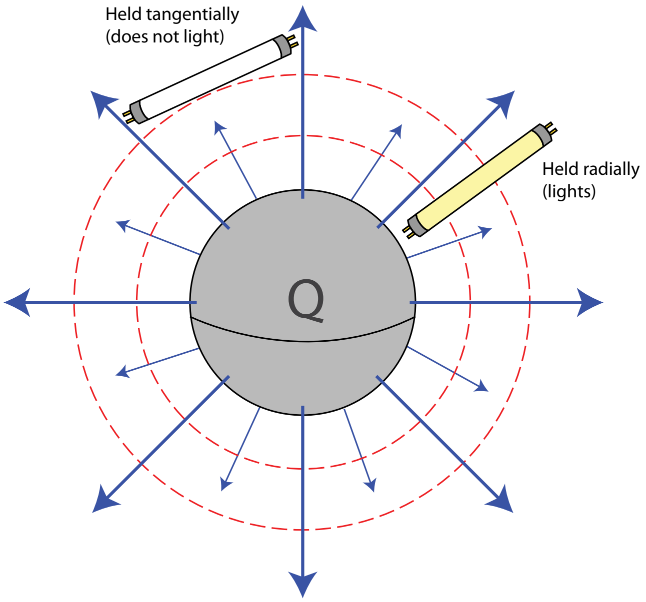

Figure 4

If the tube were held perfectly along an equipotential surface, it would not light. By definition, every point on the equipotential surface has the same electric potential. A tube held along an equipotential surface would experience no internal potential difference.

However, this result would only be possible if the tube were infinitely thin and perfectly curved along an equipotential line. Since the tube is linear and the equipotential lines are curved, there will always be at least a small potential difference within the tube. However, when held tangentially to the equipotential lines, this internal potential difference is minimized.