Levitation of an Object with Static Electric Charge by use of the Earth's Electric Field

In this paper I present the theoretical calculation of net electrical charge required in order to levitate a material object with the Earth's electric field. I also discuss the practical uses of this effect in producing an elevation device.

Static Electrical Charging and Discharging

In the science of electronics we often refer to the "charging" of a conductor in a frivolous way, as we often refer to a capacitor plate as being "charged up" or "discharged". In these cases a potential difference is applied to the plates and the charges within the total conducting circuit will separate to opposite ends of the circuit. This arrangement actually charges nothing, because the total net charge of the circuit is still neutral. In this paper we wish to only use the term *charging* in the proper context of static electrical charging which is defined as imposing a *net electrical charge* upon an object. There are many means to charging an object such as charging by friction (triboelectric effect) and charging by induction but we do not wish to specify which exact means may be used. We will consider preparations where an object has a net static charge, *Q*, which may be acquired by a variety of different methods. We also use the term discharging which is spoken only in the context of static discharging of the *net electrical charge* of an object. Discharging may be performed by many different means such as conduction or grounding, but we do not specify which means to discharging an object should be used.

The Earth's Electric Field

The electric field of the Earth, *E*, is a variable quantity which for most of the Earth is directed radially inward to the surface of the Earth. This changes at the north and south poles, but for the majority of the Earth's surface it is pointed radially. The way to illustrate this field is to look at the fact that the Earth's surface is negatively charged and the ionosphere (upper atmosphere) is positively charged resulting in a potential difference between the two. This potential difference results in a radial electric field (going from positive to negative potential so it is pointed towards the Earth from above) which has a value of approximately 1.5×10^{2}V/m. This field reduces in strength as we get further away from the surface of the Earth.

Levitation

In order to levitate a conducting object with a net negative charge, we will consider the effect that the Earth's electric field, *E*, has on the object due to the Lorentz force exerted on the charge of the object. The Lorentz force, *F*, is expressed as,

$$F = QE$$

which is directed radially away from the Earth's surface due to the fact that the net charge of the object, Q, is negative. In order to levitate the object with the Earth's electric field this force must be equal to the force of gravity exerted on the object, F_g, (its weight). The force of gravity is calculated from the mass, m, and the acceleration due to gravity, g;

$$F_g = mg$$

Equating F and F_g we get,

$$F = F_g$$

$$QE = mg$$

So with this we have an expression for the net charge needed to levitate an object, Q_L;

$$Q_L = \frac{mg}{E}$$

This may be re-expressed with the substitution of density, ρ, and volume, Ω, as they may be related to the mass by the expression, $m=\rho\Omega$;

$$Q_L = \frac{\rho g}{E}\Omega$$

This expression may now be used to tabulate a list of "levitation charge" values which correspond to different types of material. In Table 1 we list the levitation charge, Q_L, along with the volume, Ω, weight and density, ρ, for several material samples. In Table 1 we assume that the Earth's electric field, E, is 150V/m and the acceleration due to gravity, g, is $10 m/s^2$. We also list the value of permittivity, ϵ, for the semiconducting materials which is an approximate value because of doping.

Table 1

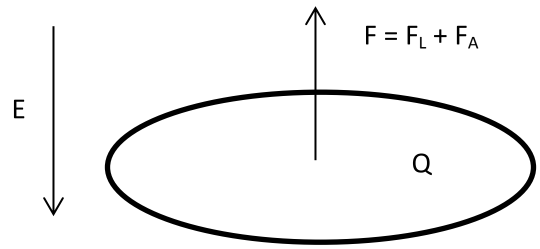
Material	Density ρ	Volume Ω	Weight	Levitation Charge Q_L	Permittivity
Doped Si	$2.3\times10^3 kg/m^3$	$10^{-3} m^3$	2.3kg	0.15C	$12\epsilon_o$
Doped Ge	$5.3\times10^3 kg/m^3$	$10^{-3} m^3$	5.3kg	0.35C	$16\epsilon_o$
Doped Graphite	$2.1\times10^3 kg/m^3$	$10^{-3} m^3$	2.1kg	0.14C	$11\epsilon_o$
Fe	$7.9\times10^3 kg/m^3$	$10^{-3} m^3$	7.9kg	0.53C	-
Cu	$9\times10^3 kg/m^3$	$10^{-3} m^3$	9kg	0.6C	-

Practical Application: Elevation

At this point we now consider the practical application of the effect, elevation. In order to increase the upward force on the charged object we simply need to increase the net charge, Q. When we consider the amount of static charge needed in order to get a lift force that will carry a reasonable load, we are talking about large amounts of net static charge that might be practically difficult to acquire when one performs the charging of the object.

To continue our analysis, we will calculate the upward force imparted by the object due to its motion. So we refer to the illustration in Figure 2 where a statically charged disc with net charge, *Q*, is being elevated by the Earth's electric field, *E*.

Figure 2



We must calculate the force which is additional to the weight of the object in order to give a value to the practical force which may be gained. The total Lorentz force on the object will be a sum of the levitating force/weight, F_L, and the additional force, F_A,

$$F = F_L + F_A$$

Due to the fact that the relationship between force and charge is linear it may be easier to state that the net charge of the object, *Q*, is a sum of the levitation charge, Q_L, and an additional charge, Q_A,

$$Q = Q_L + Q_A$$

so we have the following expression for F_A;

$$F_A = Q_A E$$

This is the practical force for the purposes of elevation that the object may be used for. This force is linearly related to the amount of additional charge, Q_A.

We should also consider the differences between a semi-conducting, conducting and insulating material because each will have advantages and disadvantages. An insulator would be easy to mechanically separate from a charging circuit without losing charge, but it would be difficult to charge the whole of an insulating object with a net charge because of the lack of movement of charges. If we use a conducting metallic material for our plate then we would have very mobile charges but the metal might be difficult to mechanically separate from a charging circuit without loss of charge. The best material might be a semiconductor with high permittivity.