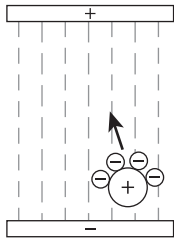


# Ponderomotive Forces

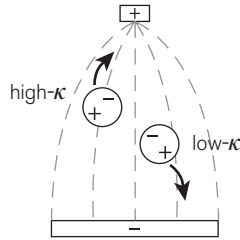
**Electromotive Forces** are electrical forces acting on charge to produce currents.

**Ponderomotive Forces** are electrical forces acting on matter to move or deform mass. Examples of ponderomotive forces include:

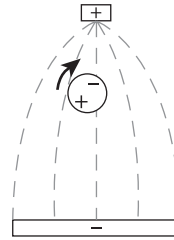
**Electrophoresis** A body at rest in an **E**-field acquires charge from the electrode with which it is in contact. It is repelled from the first electrode and attracted to the other. The field can be uniform or nonuniform, and the force experienced is proportional to the charge acquired.



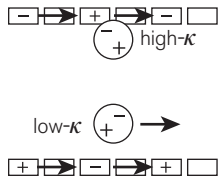
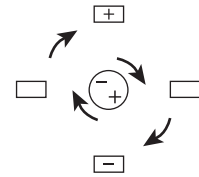
**Dielectrophoresis** A neutral, polarizable body in a strong, highly-divergent **E**-field will migrate toward the region of high intensity if its  $\kappa$  is significantly greater than that of the medium, or in the opposite direction if it is significantly lower. The force experienced is proportional to the cube of the body's diameter.



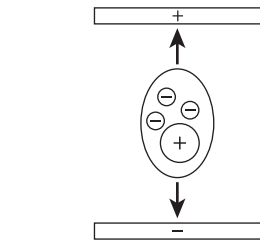
**Cellular spin resonance** A small, neutral, suspended particle may be spun in a nonuniform **E**-field. Prolonged spinning, as opposed to small torques that merely offset Brownian motion, begins only at a characteristic ac frequency.



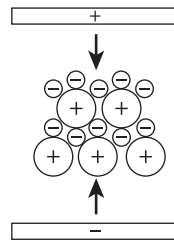
**Electrorotation** A neutral, polarizable body may also be spun in a rotating **E**-field established by appropriately phase-shifted ac electrodes. The frequency of rotation depends on the magnitude and sense of the field's phase angle and the dipole moment induced in the body.



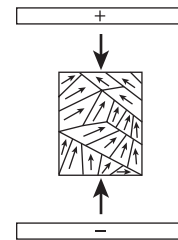
**Traveling wave dielectrophoresis** By appropriately adjusting the phase of the ac in a series electrodes, electrorotations and dielectrophoretic translations may be staged to guide an object along a predefined path. The high- $\kappa$  particle gets pegged on the electrodes, but the low- $\kappa$  particle continually seeks the region of lowest field intensity.



**Electrostriction** Any molecule in any medium will become polarized and stretch in an electric field. The field must be uniform, ac or dc; and the degree of elongation is proportional to the square of the field and dependent on the material's modulus of elasticity. The effect is minuscule except in the case of giant electrostriction materials.



**Piezoelectricity** A net dipole moment in a neutral **crystalline** lattice will be accentuated or diminished if the crystal is exposed to a change in **E**-field. The ionic bonds are maintained, but the distance between atoms expands or contracts in proportion to field strength. Conversely, mechanical strain also induces voltage.



The dipole moments in **ceramic** piezoelectrics are arranged in domains much like magnetic moments in ferromagnetic materials. Exposure to a change in **E**-field tends to align the domains, expanding or contracting the material by as much as 0.17%. Deformation is proportional to field strength.

Dielectrophoretic procedures implementing phased electrodes can produce macroscopic translations and rotations. These processes work when the time it takes to establish or neutralize a degree of polarization within the object lags sufficiently behind the rate of change of the **E**-field.

A substance's **relaxation time** measures how long it takes for 65% of an acquired charge to leak off an object. It usually takes about three times as long to lose 95% of the charge.

The **electric Reynold's number** indicates how well an object can travel under the influence of electrophoresis before losing its charge to the environment.

## Relaxation Times of Some Materials\*

air	none
metals	$\sim 10^{-18}$ sec
sea water	$10^{-10}$
distilled water	$10^{-6}$
typical oils	$10^{-9}$ - $10^3$
glass	$10^2$
Teflon	$10^5$
fused quartz	$10^6$
pure polyethylene	$10^{10}$

\*Note: Relaxation times vary greatly, depending on the purity of the material.

## Electric Reynold's Number

$$R_e \equiv \frac{\text{relaxation time}}{\text{transportation time}} = \frac{\epsilon/\sigma}{\ell/v} = \frac{\text{permittivity of medium/conductivity of medium}}{\text{plate separation/particle velocity}}$$

## If $R_e$ . Then the object

<1	does not translate
$\approx 1$	glides with constant velocity
>1	accelerates
$\gg 1$	likely shorts out the medium

**Source Material:** See references from the "Dielectrophoresis" article on page 8 of this issue.

The *Electric Spacecraft Journal* (ISSN 1067-7399) serves as an interactive platform addressed to those doing research and experiments in the areas of antigravity and electric and magnetic technologies useful for spacecraft propulsion. Its goals are to help individuals communicate and cooperate – both formally and informally – and to encourage individual research.