PhyzGuide: FIELDS

a side-by-side comparison of gravitational and electric fields

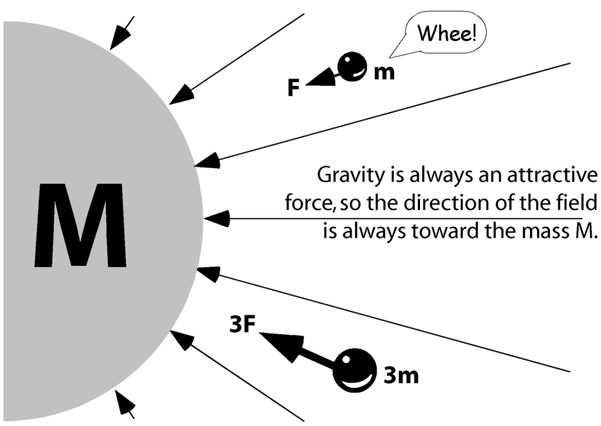
A **field** is a three-dimensional description of a certain region of space. A particular type of field provides a description of how that particular quantity varies throughout space. Fields do not consist of "field substance." They are not anything "material." They are means for describing a distortion in space. A field is a "tool" much like a vector is a tool. **Force fields** indicate how much force acts on any particle susceptible to that field. Since force is a vector quantity, a force field must represent the *direction* of force as well as the *quantity* of force.

GRAVITY

$$\boxed{\textbf{gravitational field} = \frac{\textbf{gravitational force}}{\textbf{mass}}}$$

I. field around a spherical mass

Gravitational force exists between any two objects with *mass*. If a small (test) mass *m* is placed in the vicinity of the large (field-creating) mass *M*, a gravitational force *F* will act on the test mass. If a test mass of 3*m* is placed in the same place, the gravitational force will be three times as great. The field concept allows a description of a point in space that specifies the quantity and direction of gravitational force per unit of mass.



Quantitatively, to calculate the field strength *g* (the amount of force per mass: *F*/*m*), we use our understanding of universal gravitation.

$$g = \frac{F}{m} = \frac{\frac{GMm}{R^2}}{m} = \frac{GM}{R^2} \qquad \boxed{g = \frac{GM}{R^2}}$$

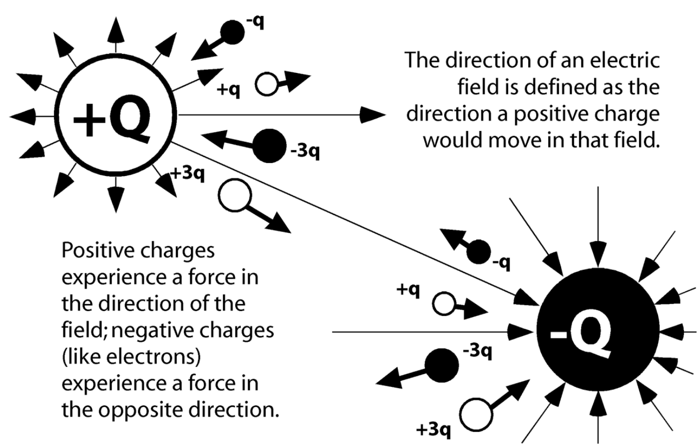
The field around a mass is proportional to the quantity of mass *M* and inversely proportional to the square of the distance *R* between the center of mass of *M* and the point in space where the field is being measured.

ELECTRICITY

$$\boxed{\textbf{electric field} = \frac{\textbf{electric force}}{\textbf{charge}}}$$

I. field around a spherical charge

Electric force exists between any two objects with *charge*. If a small (test) charge *q* is placed in the vicinity of the large (field-creating) charge *Q*, an electric force *F* will act on the test charge. If a test charge of 3*q* is placed in the same place, the electric force will be three times as great. The field concept allows a description of a point in space that specifies the quantity and direction of electric force per unit of charge.



Quantitatively, to calculate the field strength *E* (the amount of force per charge: *F*/*q*), we use our understanding of Coulomb's Law.

$$E = \frac{F}{q} = \frac{\frac{kQq}{R^2}}{q} = \frac{kQ}{R^2} \qquad \boxed{E = \frac{kQ}{R^2}}$$

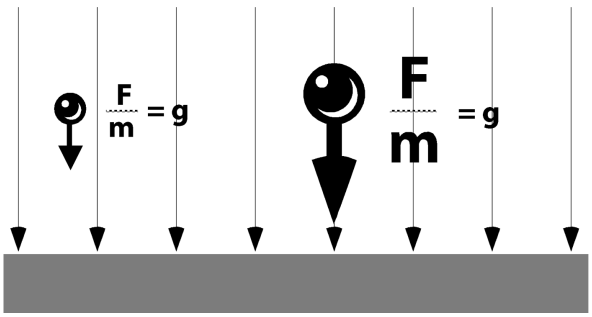
The field around a charge is proportional to the quantity of charge *Q* and inversely proportional to the square of the distance *R* between the center of charge of *Q* and the point in space where the field is being measured.

GRAVITY

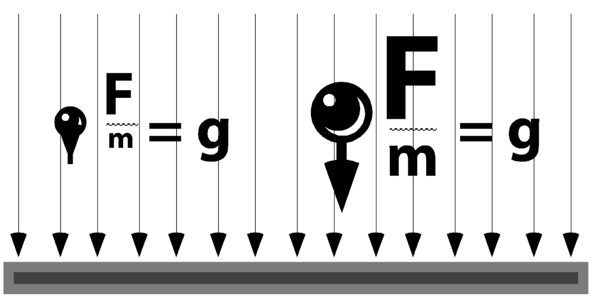
II. a UNIFORM gravitational field

such as one near the surface of the earth

If, instead of looking at a field-generating mass from a distance, we examine a small region of space in the vicinity of the mass, the field has a constant value (instead of having an inverse-square dependence). Again, a larger mass in this field experiences a greater force, but the ratio of force per mass (i.e. the field) is constant.



To double the force acting on a given particle, one would have to double the mass of the Earth without increasing the volume of the Earth. In other words, one would have to double the density of the Earth. Doubling the density of the Earth would thus double the strength of the gravitational field.



FIELD UNITS:
Since the *gravitational* field is a description of gravitational force per unit of mass, the units are units of force divided by units of mass. In the SI system, the unit of gravitational field strength is N/kg (newton per kilogram, which can be simplified to m/s^2).

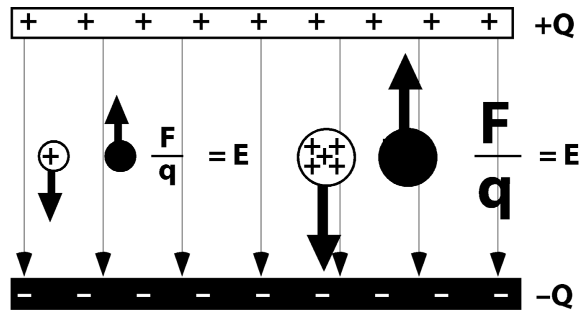
Since the *electric* field is a description of electric force per unit of charge, the units are units of force divided by units of charge. In the SI system, the unit of electric field strength is N/C (newton per coulomb).

ELECTRICITY

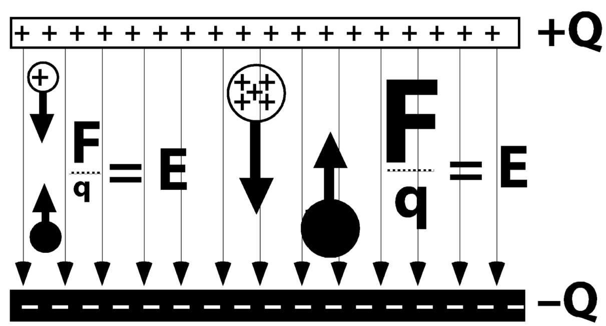
II. a UNIFORM electric field

such as one between parallel plates

If, instead of looking at a field-generating charge from a distance, we examine a small region of space in the vicinity of the charge, the field has a constant value (instead of having an inverse-square dependence). Again, a larger charge in this field experiences a greater force, but the ratio of force per charge (i.e. the field) is constant.



To double the force acting on a given particle, one would have to double the charge on the plates without increasing the area of the plates. In other words, one would have to double the charge density of the plates. Doubling the charge density of the plates would thus double the strength of the electric field.



“COOKIE SHEET” CALCULATIONS...
The electric field between two charged plates is

$$\boxed{E = 4\pi kQ/A}$$

where k is the electrostatic force constant $9 \times 10^9\ \mathrm{N{\cdot}m^2/C^2}$, Q is the charge on the surface on **one** plate (the positive one), and A is the surface area of **one** of the plates.

NOTICE that the field strength has no dependence on the distance from either plate: it’s uniform between the plates!