Electric potential

Potential in general

Potential is a scalar quantity expressing the ability of a certain physical field to act on material points, or charges located in it.

The value of the potential is relative, it refers to a specific location with a chosen zero potential (e.g. for electric field the ground is usually chosen as zero potential, for gravitational field the zero potential is at infinity , for thermodynamic potentials in the equilibrium state of the system).

Conservative physics field

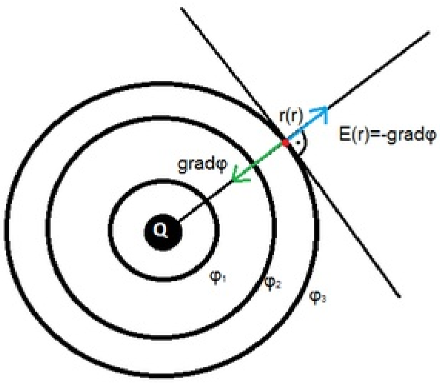
A conservative field is a physical field $E(x, y, z)$ of vector character of a certain force for which there is a scalar function - potential - satisfying the relation $\mathrm{d}\varphi = -\vec{E}(\vec{r}) \cdot \mathrm{d}\vec{r}$. (The scalar product, $\vec{r}$ is a position vector specifying a given location in space) Conversely, the magnitude of the physical field intensity can be determined using the gradient potential: $E(\vec{r}) = -\mathbf{grad}\varphi(\vec{r})$. A conservative physical field can therefore be characterized at each of its points by a scalar potential φ, which has a certain numerical value at each point. Thanks to the introduction of the potential, the vector field can be described by a scalar quantity.

Potential energy

Potential, or positional energy, is the energy that every body has in a potential field of a certain force.

The change in potential energy is defined as $\Delta E = E_2 - E_1$ where E_2 and E_1 are the potential energies associated with the original and resulting positions in the potential field . If this change took place along the direction of the potential gradient, the potential energy decreased and, according to the law of conservation of energy, the system did work $-W = \Delta E > 0$. If the position changed against the gradient direction, the potential energy increased and an external energy force of ΔE had to be supplied to the system.

The magnitude of the change in potential energy does not depend on the way the system got from the initial state to the final state, only on the value of the initial and resulting potential energy. It follows that the value of the resulting change in potential energy during a circular event is zero.



Electric field of a point charge:

Potential energy, like potential, is relative and refers to some chosen point with zero potential energy. It can therefore also take on positive and negative values.

Types of potentials

Depending on the type of potential field, we distinguish several types of potentials.

Electric potential

Electric potential is a scalar quantity describing the potential energy of a unit charge in a constant conservative electric field. It is defined as the amount of energy required to transfer a charge from a given point to a point of zero potential. The surface of the Earth is usually chosen as the point of zero potential.

Electric potential is denoted by φ, its unit is $[\varphi] = \mathrm{V}$.

The value of the electric potential can be calculated:

- $\varphi = \dfrac{W}{Q}$ where W is the work required to transfer the charge Q.
- In the field of a point charge Q, the relation $\varphi = k\dfrac{Q}{r}$ holds for the potential, where k is a constant dependent on the permittivity of the medium, Q the size of the charge inducing the electric field, and r the distance from it.
- The differential increase in electric potential can be calculated as $d\varphi = -\vec{E} \cdot \mathrm{d}\vec{r}$.

- The electric field intensity is the negative gradient of the electric potential $\vec{E} = -\mathbf{grad}\varphi$.

From a biophysical point of view, the electric potential is of fundamental importance as a component electrochemical potential of protons in the respiratory chain, or as a component of resting membrane potential and action potential.

Scalar magnetic potential

A static magnetic field, i.e. a field created by a non-moving permanent magnet, or a conductor with a constant current can be called a potential field and assigned a scalar potential. Its unit is $[\varphi] = \mathrm{A}$. Its size can be calculated:

- In the case of a conductor with a constant current $\varphi = I\frac{\Omega}{4\pi}$, kde I is the current flowing through the conductor and Ω the solid angle at which the conductor is seen from a given point.
- In the case of a permanent magnet, the magnetic potential is calculated as $\varphi = \frac{\vec{m}\cdot\vec{r}}{4\pi r^3}$ where {{#tag :math|\vec{m} }} is the magnetic moment vector, $\vec{r}$ is the position vector of a point in the magnetic field, and r distance from dipole.
- The differential increase in magnetic potential can be calculated as $\mathrm{d}\varphi = -\vec{H}\cdot\mathrm{d}\vec{r}$.
- The intensity of the magnetic field is the negative gradient of the scalar magnetic potential $\vec{H} = -\mathbf{grad.}\,\varphi$, respectively $\vec{B} = -\,mu\,\mathbf{grad}\varphi$, where μ represents the permeability of the environment.

A changing magnetic field is not conservative and is therefore described by a vector potential.

Gravitational Potential

Gravitational potential is a scalar quantity describing the potential energy of a body of unit mass in the gravitational field of other bodies. Since the range of the gravitational force is infinite, the point of zero potential is chosen at infinity, and therefore the value of the gravitational potential is negative.

The gravitational potential is denoted by ϕ, its unit is $[\phi] = \mathrm{J\,kg^{-1}}$, respectively $\mathrm{m^2\,s^{-2}}$. The size can be calculated:

- In the gravitational field of a mass point or spherical body by the relation $\phi = -\kappa\frac{M}{r}$, where κ is the gravitational constant, M is the mass of the body and r is the distance from it.
- In a homogeneous gravitational field by the relation $\phi = Kh$, where K is the magnitude of the gravitational field intensity vector (corresponding to the gravitational acceleration at a given location) of the earth and h height above the surface of the Earth.
- The differential increase in gravitational potential can be calculated as $\mathrm{d}\phi = -\vec{K}\cdot\mathrm{d}\vec{r}$.
- The intensity of the gravitational field is the negative gradient of the gravitational potential $\vec{K} = -\mathbf{grad}\phi$.

Thermodynamic potentials

Thermodynamic potentials are quantities with an energy dimension used mainly in thermodynamic and chemical calculations to establish the conditions of dynamic equilibrium of reactions. Individual potentials differ from each other in their natural variables, therefore each is suitable for calculations during reactions taking place in different conditions.

The name thermodynamic potentials is used as an analogy to the potentials of force fields, as they can be used to determine important quantities (state quantities, heat capacities,...) of given systems. They also have formally the same properties as potential energy.

- Depends only on location (space).
- There is their complete differential.
- The size of their change does not depend on the method, only on the initial and final state.
- In a circular event, their change is zero.
- In the equilibrium state, they reach their minimum.

Used thermodynamic potentials:

- Internal energy,
- enthalpy,
- Gibbs free energy,
- Helmholtz free energy.

Links

Related Articles

- Gradient
- Action and summation potentials
- Electrochemical Potential
- Chemical Potential

References

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