A conservative force has the following properties

1. The work done by a conservative force on a particle moving between two points does not depend on the path taken by the particle.

2. The net work done by a conservative force on a particle moving around a closed path is zero.

3. There exists a scalar function, the potential energy \( U(x,y,z) \), so that the force at any point can be calculated from the negative gradient of the potential energy function.

4. The force at any point in space defines a vector field. The curl of this vector field is zero everywhere.

5. The force at any point in space defines a vector field. The divergence of this vector field is zero everywhere.

An electric potential \( V \) at a position \( r \) is related to the electric potential energy \( U \) of a test charge \( q \) at the position \( r \) through

\[
V = \frac{U}{q}.
\]

A good way to visualize a potential in two dimensions is to think of a landscape. For each point in the \( x-y \) plane, the height (\( z \)-coordinate) indicates the value of the potential energy \( V(x,y) \).

Which of the figures (a)-(d) represents a possible landscape for an electric dipole in two dimensions? (The colored lines in the figures are lines of constant potential.)

1. (a) 2. (b) 3. (c) 4. (d)

(a) (b) (c) (d)

The gravitational potential \( V \) at a position \( r \) is related to the gravitational potential energy \( U \) of a test mass \( m \) at the position \( r \) through

\[
V = \frac{U}{m}.
\]

Which of the figures (a)-(d) represents a possible landscape for the potential of two point masses in two dimensions?

1. (a) 2. (b) 3. (c) 4. (d)

1. (a) 2. (b) 3. (c) 4. (d)

The gravitational force is always attractive; bringing a mass closer to another one always lowers the potential energy.
If you know the potential energy of a particle everywhere in space, you can calculate the force from the negative gradient of the potential energy. In a landscape, the negative gradient points in the direction of the steepest decline. This is the direction in which a ball would roll if you released it from rest on a hill side. The steeper the hill, the larger the net force on the ball.

For the potential energy landscape of figure (a), where is the force the strongest?
1. Left of center, near the dark red lines.
2. Right of center, near the dark blue lines.
3. The force has the same magnitude throughout.
4. In the center, near the bright red lines.
5. Way to the left, outside the figure.

For the potential energy landscape of figure (a), where is the potential energy the highest?

For figure (a), where is the potential energy the lowest?

For figure (a), where is the force the weakest? (pick one of the previous answers)

The potential energy is an important concept in simulations because it allows us to calculate the force on each particle due to interactions with other particles, with walls, with external fields (electric, gravitational), etc.

Imagine you have three particles, 1, 2, and 3, each of mass $m$ and charge $q$, in the electric field of a parallel plate capacitor near the surface of the earth.

a) how many contributions are there to the potential energy of particle 1?

b) what are these contributions (names are fine, no need for equations)

1. Electric, due to the electric field of the capacitor
2. Electric, due to particle 2
3. Electric, due to particle 3
4. Gravitational, due to Earth
5. Gravitational, due to particle 2
6. Gravitational, due to particle 3
7. Intermolecular, due to plate (a)
8. Intermolecular, due to plate (b)

Van-der-Waals interactions are important only at very small distances ($10^{-9}$ m).