A closed cylindrical Gaussian surface is placed in a region with an electric field as shown.

What can you say about the net electric flux through the closed cylindrical surface?

[1.] It is positive
[2.] It is negative
[3.] It is zero
Explanation:

The answer is 3. First approach: there is no charge inside of this cylinder (if there were, we would see field lines starting from it or ending on it). Therefore, by Gauss’ law, the net flux has to be zero. Alternative approach: note that any field line that enters the interior of the cylindrical surface also leaves it, hence the net flux is zero. If the net flux were not zero, field lines would have to end (or begin) inside of the volume.
Two point charges, one with charge $-Q$ and the other with charge $+2Q$ are enclosed by three Gaussian surfaces as shown below.

Through which of the Gaussian surfaces is the net electric flux largest?

[1.] A
[2.] B
[3.] C
[4.] All the same
[5.] No way to tell
Explanation:

The answer is 4. The net electric flux through a closed surface is equal to the enclosed charge; it doesn’t matter what the shape of the surface is.
An imaginary Gaussian surface encloses three charges as shown below.

If I introduce a fourth charge as shown below, what happens to the net flux through the Gaussian surface?

[1.] Increases
[2.] Decreases
[3.] Stays the same
Explanation:

The answer is 3. The net electric flux through a closed surface is equal to the enclosed charge; any external charges contribute zero to the net flux through the surface (any field lines due to the addition of these charges will enter and exit the surface, leaving a net flux of zero).
A charge $+Q$ is distributed on a sphere of radius $R_1$. Surrounding that sphere is a spherical shell of charge $-Q$, which sits between $r = R_1$ and $r = R_2$.

Which of the following plots best represents the electric field of the sphere + shell as a function of radius?
Explanation:

**The answer is 3.** If we draw a spherical Gaussian surface which encloses the sphere of charge and the spherical shell \( r > R_2 \), we know that this Gaussian surface encloses no net charge. This, along with spherical symmetry allows us to argue that the field outside \( r > R_2 \) must be zero.
A charge $Q$ is distributed uniformly on a thin, spherical shell of radius $R_o$.

Which of the following plots best represents the electric field of the shell as a function of radius?

1. 

2. 

3. 

4. 

Explanation:

**The answer is 2.** You can argue that by symmetry, the electric field is constant on any spherical surface you can imagine which is centered at \( r=0 \) (like the spherical shell). So, if I place this imaginary surface inside of the shell, I can argue that \( E \) is constant, therefore the left hand side of Gauss’ law is just \( EA \). But this surface \((r < R_o)\) encloses no charge. Therefore the field on the surface of any spherical shell whose radius is less than \( R_o \) has to be zero – and therefore the field inside the shell is zero. Outside of the shell, the same argument holds, but now I am enclosing charge \( Q \). So I can compute the field in this case and find it falls off like \( 1/r^2 \).
A charge $+Q$ is distributed on a sphere of radius $R_0$. Surrounding that sphere is a spherical shell of charge $-Q/2$, with radius $r = R_1$, as shown.

Which of the following plots best represents the electric field of the sphere + shell as a function of radius?
Explanation:

The answer is 4. In cases of spherical symmetry, in vacuum regions (where there are no charges) the electric field looks like that of a point charge (falls off like $1/r^2$, and is proportional to the charge enclosed by the Gaussian surface). So we know that outside of both spheres, there should be an electric field, as the net charge enclosed is not zero. But we also know that there should be a discontinuity in the field as we cross the thin sheet of charge at $R_1$. 
A charge $+2Q$ is distributed uniformly on a cylinder of radius $R_1$. Surrounding this cylinder, at radius $R_2$ is a cylindrical shell of charge $-Q$. Another cylindrical shell is located at $R_3$ and has charge $+Q$.

Which of the following plots best represents the electric field as a function of radius?
Explanation:

The answer is 2. In any case with cylindrical symmetry, the electric field in a region where there is no charge must fall off as $1/r$ and be proportional to the charge enclosed by the cylindrical Gaussian surface which has radius $r$. Also, note that an infinitely thin layer of charge results in a discontinuity in the electric field; so that the electric field should jump as you move from within a cylindrical shell to just outside of one.
A point charge, \( +Q \) sits at the center of a spherical shell made of conducting material (inner radius \( R_1 \), outer radius \( R_2 \)). The conducting shell is connected to ground (using a thin wire which doesn’t break any symmetry).

Which of the following plots best represents the electric field as a function of radius?

- [Image of graph 1]
- [Image of graph 2]
- [Image of graph 3]
- [Image of graph 4]
Explanation:

The answer is 2. If the shell were not grounded, it would polarize due to the presence of the positive charge in the center – negative charge would build up on the inner surface and an equal amount of positive charge would build up on the outer surface. However, when it is grounded, the positive surface charge on the outer surface is no longer there – these charges are trying to get as far away as possible from the positive charge in the center, and will travel down the wire to ground. Another way to think about it (and more correct physically) is that when the point charge is placed, electrons travel up the wire from ground and stop on the inner surface of the spherical shell (this is equivalent to positive charges leaving the shell and going to ground).
An electron starts at point “A” between two large charged plates (one charged positively and one charged negatively).

If I move the electron from point “A” to point “B”, how does the potential energy of the electron change?

[1.] It increases
[2.] It decreases
[3.] It stays the same
[4.] Not enough information to answer
Explanation:

The answer is 1. The electron wants to move toward the positive plate (if released from rest, it would go to the left). This means that the potential energy of the electron decreases toward the positive plate. So, if I move it toward the negative plate (from which it is being repelled), I increase the potential energy of the electron. Mathematically, the change in potential energy can be written:

$$\Delta U = U(B) - U(A) = -q \int_A^B \mathbf{E} \cdot d\mathbf{l}$$

Our path is along the electric field (from the positive plate, to the negative plate), so $\mathbf{E} \cdot d\mathbf{l}$ is positive. However, our charge is negative (electron), therefore the final sign of $\Delta U$ is positive.
An electron starts at point “A” between two large charged plates (one charged positively and one charged negatively).

If I move the electron from point “A” to point “B”, how does the electric potential at the location of the electron change?

[1.] It increases
[2.] It decreases
[3.] It stays the same
[4.] Not enough information to answer
Explanation:

The answer is 2. The electric potential is larger near positive charges than near negative charges; therefore the electric potential drops as I move from A to B (or the potential difference between A and B is negative). The electric potential is just the potential energy per unit charge – we already know (from the previous CT) that the potential energy of the electron increases as we move from A to B. Therefore, since $\Delta V = \Delta U/q$, the electric potential change is negative, or the potential decreases during the motion.
A proton (+Q) is fixed in the location shown. An electron is located at point A, but I wish to move it to point B. Which of the paths shown between point A and B should I take if I want to maximize the amount of work I have to do to move the electron?

5 = no difference
Explanation:

The answer is 5. The work required is the same as the change in potential energy. As the electric force is conservative, the value of the potential energy depends only on location, not how you get there. So all of the paths are equivalent. You can convince yourself of this by drawing the field lines and thinking about how the force on the electron varies along the different paths – in some cases you spend more time working against the electric force due to the proton, but this is balanced by spots where the electric force does the work for you. Also, note that if we move perpendicular to the electric field line, we don’t have to do any work – the electric force does not oppose (or assist) this motion.
Two point charges are separately brought close to a charge $+Q$. In case $A$, a charge of $+q$ is brought to within a distance $r$ of the charge $+Q$. In case $B$, a charge of $+2q$ is brought to within a distance $2r$ of the charge $+Q$.

What can you say about the electric potential at the location of the charge $+q$ in case $A$ compared to the electric potential at the location of the charge $+2q$ in case $B$?

[1.] Case $A$ it is greater than Case $B$

[2.] Case $A$ is smaller than Case $B$

[3.] The potential is the same in both cases

[4.] Not enough information to answer
Explanation:

The answer is 1. The value of the potential is independent of the charge which experiences the potential; it only depends on the charge which is producing the potential \((Q)\) and the distance from this charge. The charge \(+q\) is closer in case \(A\) than the charge \(+2q\) is in case \(B\); therefore the potential is greater in case \(A\).
Two point charges are separately brought close to a charge $+Q$. In case $A$, a charge of $+q$ is brought to within a distance $r$ of the charge $+Q$. In case $B$, a charge of $+2q$ is brought to within a distance $2r$ of the charge $+Q$.

What can you say about the potential energy of the charge $+q$ in case $A$ compared to the potential energy of the charge $+2q$ in case $B$ (relative to a position very far from the charge $+Q$)?

[1.] Case $A$ is greater than Case $B$
[2.] Case $A$ is smaller than Case $B$
[3.] The potential energy is the same in both cases
[4.] Not enough information to answer
Explanation:

The answer is 3. The potential energy depends on the electric potential (generated by charge $+Q$) and on the charge of the object whose potential energy you want to know. The potential is twice as small at the location of the charge $+2Q$, however the charge is twice as big. So the two have the same potential energy (relative to a point very far from all of the charges).
A positive charge $+q$ is a distance $r$ from a point charge $+Q$. If I add a second positive charge (also $+Q$) a distance $r$ on the other side of the charge $+q$, the force on $+q$ goes to zero. What happens to the potential energy of the charge $+q$ (relative to $\infty$)?

[1.] It becomes exactly zero
[2.] It increases
[3.] It decreases
[4.] It stays the same
[5.] Not enough information to answer
Explanation:

The correct answer is 2. The electric potential obeys the principle of superposition, so we can add the potential due to each $+Q$ charge, finding that the potential increases at the location of the charge $+q$, meaning that the potential energy of the charge also increases (relative to $\infty$). How can this be consistent with the fact that the force is zero?? It is perfectly consistent – you have to remember that the absolute value of the potential or potential energy at a certain spot is meaningless; all that matters is how the potential varies in the region you are in. The potential is flat near the center of the two charges, but if I move $+q$ up or down, it will go flying off, and when far away, will end up with more kinetic energy than if there was only one $+Q$ charge present.
A positive charge $+q$ is a distance $r$ from a point charge $+Q$. If I add a second negative charge (value $+Q$) a distance $r$ on the other side of the charge $+q$, the force on $+q$ increases. What happens to the potential energy of the charge $+q$ (relative to $\infty$)?

1. It becomes exactly zero
2. It increases
3. It decreases
4. It stays the same
5. Not enough information to answer
Explanation:

The correct answer is 1. The electric potential obeys the principle of superposition, so we can add the potential due to the $+Q$ and $-Q$ charges, finding that their potentials are equal but opposite at the location of the charge $+q$, making the potential there exactly zero. How can this be consistent with the fact that the force has increased?? Again, It is perfectly consistent – you have to remember that the absolute value of the potential or potential energy at a certain spot is meaningless; all that matters is how the potential varies in the region you are in. The particle will follow the path to lowest potential energy – in this case, that path will lead to the negative charge, not out to infinity as in the previous case.