Quiz 3: Solution

1. In a certain region of space, the electric potential is zero everywhere along the x axis. From this we can conclude that the x component of the electric field in this region is

- ■ zero
- □ in the x direction
- □ in the $-x$ direction.

> If the potential is constant along an axis (zero in this case), its derivative must be zero along that direction as well. Since $E_x = dV/dx$, the electric field must be zero.

2. In a certain region of space, the electric field is zero. From this we can conclude that the electric potential in this region is

- □ zero
- ■ constant
- □ positive
- □ negative.

> If the electric field is zero, then ∇V is zero as well (the derivatives of the potential are zero along the x, y, and z axes). If this is true, then the potential must be a constant, though not necessarily zero.

3. An electron initially at rest is accelerated through a potential difference of $1\,\text{V}$, and gains kinetic energy KE_e. A proton, also initially at rest, is accelerated through a potential difference of $-1\,\text{V}$, and gains kinetic energy KE_p. Which of the following must be true?

- □ $KE_e < KE_p$
- ■ $KE_e = KE_p$
- □ $KE_e > KE_p$
- □ not enough information

> Since both particles have the same magnitude of charge, $|q| = e$, and are accelerated through the same magnitude of potential difference $|\Delta V|$, they must have the same change in potential energy $|\Delta PE| = |e\Delta V|$. Conservation of energy dictates that they must also have the same kinetic energy.

4. Consider a collection of charges in a given region, and suppose all other charges are distant and have negligible effect. The electric potential is taken to be zero at infinity. If the electric potential at a given point in the region is zero, which of the following statements must be true? (Only one is *always* true.)

- □ The electric field is zero at that point.
- □ The electric potential energy is a minimum at that point.
- □ There is no net charge in the region.
- ■ Some charges in the region are positive and some are negative.
- □ The charges have the same sign and are symmetrically arranged around the given point.

Although the electric field and the electric potential depend on r it is not sufficient that the electric field is zero. The electric potential from each charge has to be summed up, and the potentials for each charge vary as $1/r$, while the electric field varies as $1/r^2$. Thus, the electric field is not guaranteed to be zero just because the potential is.

It is similarly not guaranteed that there is no net charge for the potential to be zero - the *vector* electric field can vanish (cancel) at a point while the *scalar* potential does not, but for this to be true there must be both positive and negative charges in the region. Consider problem 4 on quiz 1 as one example - with two opposite but unequal charges, we can easily find regions where E is zero and regions where V is zero, but they are *not* necessarily the same place, nor do we require no net charge, or a symmetric arrangement of charges of the same sign.

There is also no reason that the electrical potential energy is minimum - it could easily be *negative* somewhere else. It is also not necessary that there is no charge.

5. A spherical balloon contains a positively charged object at its center. As the balloon is inflated to a greater volume while the charged object remains at the center, does the electric potential at the surface of the balloon:

- ☐ increase
- ■ decrease
- ☐ remain the same

The amount of charge stays constant as the balloon is inflated. The electric potential is inversely proportional to the radius for a spherical distribution of charge, so the potential at the surface must decrease as the balloon increases in size.