

2016 SCORING GUIDELINES

Question 3

12 points total

Distribution
of points

- (a) 1 point
- For correctly labeling the magnitude of lines ($A = 60 \text{ V}$ and $B = 80 \text{ V}$, units not required) and for having the correct signs on each line (either explicit positive signs or no negative signs) 1 point
- (b)
- i. 2 points
- For indicating that Y has more charge than X with a correct explanation, such as the nearest potential of the same value is farther from Y 1 point
- For indicating X and Y must be the same sign with a correct explanation 1 point
- Examples:
- Field vectors are perpendicular to equipotentials, and the pattern of field vectors indicates that both must have the same sign.
 - There is no zero potential line between the spheres, so the potentials from the two charges do not cancel anywhere.
- ii. 1 point
- For a correct explanation that addresses the charge to mass ratio and distance relationship 1 point
- Example: Both spheres would gravitationally attract a third sphere just like two charges of the same sign would attract a third charge of the opposite sign because both forces are dependent on the distance and also dependent on the product of the charges or masses.
- (c) 2 points
- For a similarity that does not generally apply to all forces 1 point
- Example: The forces have the same dependence on the distance and are both functions of $1/r^2$.
- For a difference that does not generally apply to all forces 1 point
- Examples:
- The proton is the same sign as the spheres, so it is electrostatically repelled, but gravity is always attractive. Therefore, the directions of the forces are different.
- The forces are different in magnitude.

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Question 3 (continued)

Distribution
of points

- (d)
- i. 2 points
- The proton is repelled by both spheres, so it will move toward point A .
For some attempt to apply $\Delta U_E = q\Delta V$ using the given variables 1 point
- For using the correct variables and getting $\Delta U = q(V_A - V_B)$ (no credit for using numeric values of electric potential) 1 point
- ii. 2 points
- For using a correct expression for work 1 point
- $W = Fd$ or $-\Delta U_E = q\Delta V$
- For a correct expression for F or ΔV in terms of E_{avg} 1 point
- $F_{avg} = qE_{avg}$ or $\Delta V = E_{avg}d$
- $W = qE_{avg}d$ (full credit is awarded for just writing the correct expression)
- iii. 2 points
- For indicating that student 1 is correct and a correct discussion of why 1 point
- Example: Student 1 is correct. Because the system contains all the objects, the energy is transferred from one form to another within the system due to the law of conservation of energy.
- For indicating that student 2 is correct and a correct discussion of why 1 point
- Example: Student 2 is correct. Because the system is just the proton, there must be a force external to the system due to the electric field of the two spheres. That force does work on the proton which changes the kinetic energy of the proton.