AP PHYSICS 2

Scoring Guidelines

Question 1: Experimental Design

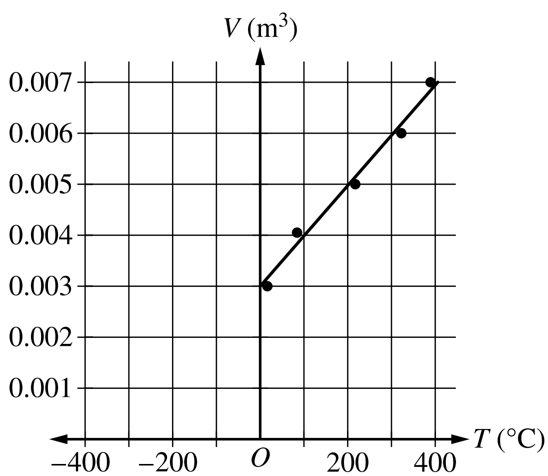
1. Students use a sample of gas to investigate the behavior of the pressure P of the gas at constant temperature T as the volume V changes. The gas is in a cylinder with a movable piston and volume markings. Pressure and temperature probes can be inserted into the cylinder. A hot water bath and a cold water bath are also available.

   (A) Describe a procedure that would allow the students to obtain data for the pressure P of the gas at constant temperature T as volume changes.

   (B) One student suggests that the temperature probe is not needed. Is the student correct? Briefly explain your answer.

   (C) Describe a method of analyzing the pressure and volume data that could be used to determine whether the gas is ideal. Explicitly indicate the results of the analysis that would indicate an ideal gas.

   The students are now given a sample of ideal gas in a similar container with a piston. They investigate the behavior of the temperature T of the gas at known constant pressure P as the volume V changes. Their graph of the data, including a best-fit line, is shown below.



   (D) Describe a method for using the graph to determine the number of moles of gas in the container.

   (E) From the graph, determine the students' experimental value for absolute zero temperature on the Celsius scale. Describe the method you used.

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Scoring Guidelines for Question 1: Experimental Design — 12 points

Learning Objectives: 7.A.3.2 7.A.3.2 7.A.3.3 7.A.3.3 7.A.3.1

(A)	Describe a procedure that would allow the students to obtain data for the pressure P of the gas at constant temperature T as volume changes. One point for using one of the baths to regulate the temperature.	**1 point** 4.2
	One point for using the piston to change the volume of the gas.	**1 point** 4.2
	One point for waiting for the temperature to reach equilibrium before measuring pressure	**1 point** 4.2
	One point for explicitly taking more than two measurements.	**1 point** 4.2
	Total for part (A)	**4 points**
(B)	One student suggests that the temperature probe is not needed. Is the student correct? Briefly explain your answer. One point for indicating that the student is incorrect with an acceptable explanation that addresses the need to know the gas temperature. Example of acceptable explanation (claim, evidence, and reasoning): • *The student is not correct* (claim). *As the pressure and volume change the temperature also changes* (evidence). *The gas temperature would need to be measured to verify that it has reached equilibrium with the water bath* (reasoning).	**1 point** 4.2
(C)	Describe a method of analyzing the pressure and volume data that could be used to determine whether the gas is ideal. One point for indicating an appropriate analysis method.	**1 point** 5.1
	One point for indicating the information from the analysis that would indicate an ideal gas. • Example 1: Graph pressure as a function of volume. If the gas is ideal the best fit to the data will be linear. • Example 2: For each pressure-volume data pair, multiply the pressure and the volume. If the values are reasonably the same, the gas is ideal.	**1 point** 5.1
	Total for part (C)	**2 points**
(D)	Describe a method for using the graph to determine the number of moles of gas in the container. One point for using the slope of the graph.	**1 point** 5.1
	One point for indicating that the slope equals $\frac{nR}{P}$.	**1 point** 5.1
	One point for noting that the fundamental constant R and the value at which P is held constant are known.	**1 point** 5.1
	Total for part (D)	**3 points**

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(E)	Determine the students' experimental value for absolute zero temperature on the Celsius scale. One point for indicating a value near 300° C (but not so precise as 273° C since the graph cannot be read that precisely).	**1 point** 6.4
	Describe the method you used. One point for describing the extrapolation of the line to zero volume to determine absolute zero.	**1 point** 6.4
	Total for part (E)	**2 points**
	Total for question 1	**12 points**

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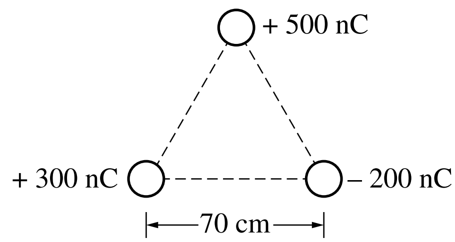
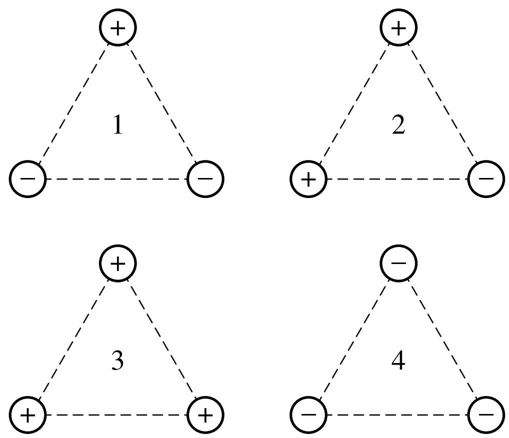
Question 2: Short Answer



2. Three small spheres, with net charges indicated above, are held fixed at the corners of an equilateral triangle with sides of length 70°cm.

   (A) Calculate the magnitude of the net electric force acting on the sphere with charge +500°nC at the top of the triangle due to the other two spheres.



Spheres with positive or negative charges of equal magnitude are now held fixed at the corners of four identical equilateral triangles, as shown above. Each triangle is isolated from all other charges.

   (B) For which of the triangles will the net electric field at the center of the triangle be zero?

   ___ 1 ___2 ___ 3 ___ 4

   Briefly describe the method you used to arrive at your answer.

   (C) Rank the electric potentials V_1, V_2, V_3, and V_4 at the center of the triangles.

   Briefly describe the method you used to arrive at your answer.

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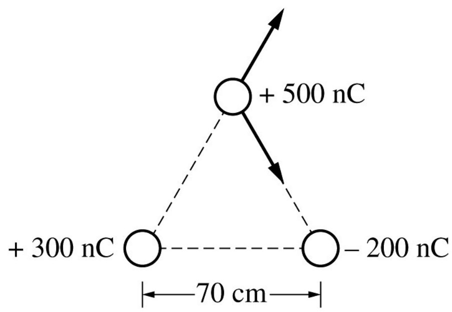
Scoring Guidelines for Question 2: Short Answer — 10 points

Learning Objectives: 3.C.2.3 2.C.2.4 2.E.2.1

(A) Calculate the magnitude of the net electric force acting on the sphere with charge +500°nC at the top of the triangle due to the other two spheres. **1 point** 2.2



As shown above, the vertical components of the forces subtract and the horizontal components add.

One point for correct substitutions for the magnitude of the force from each of the charges.

$$F = \frac{kq_1q_2}{r^2}$$

The magnitude for the positive charge is:

$$F = \frac{\left(9.0\times10^9 \frac{Nm^2}{C^2}\right)(500\times10^{-9}\text{ C})(300\times10^{-9}\text{ C})}{(0.7\text{ m})^2} = 2.8\times10^{-3}\text{ N}$$

The magnitude for the negative charge is:

$$F = \frac{\left(9.0\times10^9 \frac{Nm^2}{C^2}\right)(500\times10^{-9}\text{ C})(200\times10^{-9}\text{ C})}{(0.7\text{ m})^2} = 1.8\times10^{-3}\text{ N}$$

One point for evidence of taking components of the forces or adding the forces as vectors. **1 point** 2.2

One point for subtracting the vertical components and adding the horizontal components. **1 point** 2.2

The net vertical force is $(2.8-1.8)(\times10^{-3}\text{ N})\sin60^\circ = 8.6\times10^{-4}$ N.

The net horizontal force is $(2.8+1.8)(\times10^{-3}\text{ N})\cos60^\circ = 2.3\times10^{-3}$ N.

One point for adding the sum of the squares of the components to find the magnitude of the net force. **1 point** 2.2

$$F_{net} = \sqrt{(8.6\times10^{-4})^2 + (2.3\times10^{-3})^2}\text{ N} = 2.5\times10^{-3}\text{ N}$$

Total for part (A) — 4 points

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(B) For which of the triangles will the net electric field at the center of the triangle be zero? Briefly describe the method you used to arrive at your answer. **1 point** 1.4

One point for indicating triangles 3 and 4 with an attempt at a relevant description.

One point for treating the electric fields as vectors. **1 point** 1.4

One point for using the symmetry of the triangular arrangement. **1 point** 1.4

Example of an acceptable description:

- In triangles 3 and 4, the fields from each of the three spheres all point toward the center of the triangle or away from it. This is a symmetrical arrangement, so the net force is zero.

Total for part (B) 3 points

(C) Rank the electric potentials V_1, V_2, V_3, and V_4 a t the center of the triangles. **1 point** 6.4

Briefly describe the method you used to arrive at your answer.

One point for a correct ranking with an attempt at a relevant description.

$$V_3 > V_2 > V_1 > V_4$$

One point for treating the electric potentials as scalars. **1 point** 6.4

One point for indicating that positive charges produce a positive potential and negative charges produce a negative potential. **1 point** 6.4

Example of an acceptable description:

- *Potential is not a vector, so the potentials from each sphere simply add. Positive charges produce positive potential, and negative charges produce negative potential. The charges are equal, so all charges produce the same magnitude of potential at the center. V_3 is caused by a net of 3 positive charges, V_2 by 2 positives, V_1 by 2 negatives, and V_4 by 3 negatives.*

Total for part (C) 3 points

Total for question 2 10 points

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