AP® PHYSICS B
2010 SCORING GUIDELINES (Form B)

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong — for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exams equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 3

15 points total — **Distribution of points**

(a) 2 points

Applying Newton's second law to one of the objects

$ma = T - kq^2/r^2 = 0$

For a correct expression for the tension T — 1 point

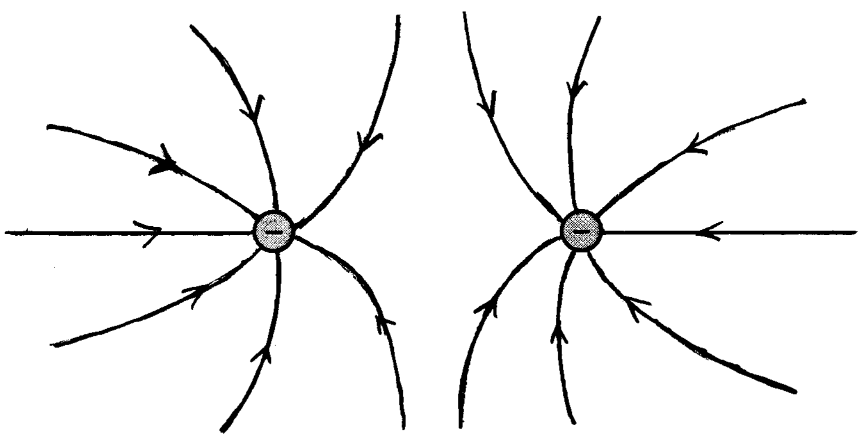
$T = kq^2/r^2$

$T = \left(9.0 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2\right)\left(-4.0 \times 10^{-9} \text{ C}\right)^2 / (0.020 \text{ m})^2$

For the correct answer, with units — 1 point

$T = 3.6 \times 10^{-4} \text{ N}$

(b) 4 points



For a full representation of the field in the vicinity of the objects	1 point
For field lines that begin or end on the objects	1 point
For having curved or bent field lines in the region between the objects that indicate an asymptotic approach to a vertical line midway between the objects	1 point
For showing the direction of the field as inward (toward the objects)	1 point

Question 3 (continued)

Distribution of points

(c) 3 points

The acceleration is caused by the electrostatic force, and initially that force has the same magnitude calculated in part (a).

$ma = kq^2/r = T$

For a correct force equation — 1 point

$ma = T$

$a = T/m$

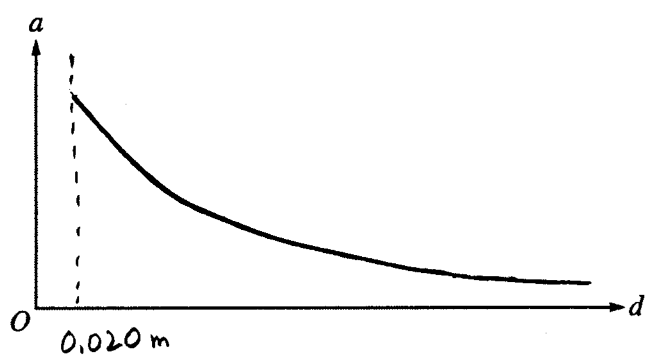
For correctly substituting the value of T from part (a), and mass m_1 — 1 point

$a_1 = \left(3.6 \times 10^{-4}\ \text{N}\right)/(0.030\ \text{kg}) = 1.2 \times 10^{-2}\ \text{m/s}^2$

For correctly substituting the value of T from part (a), and mass m_2 — 1 point

$a_1 = \left(3.6 \times 10^{-4}\ \text{N}\right)/(0.060\ \text{kg}) = 6.0 \times 10^{-3}\ \text{m/s}^2$

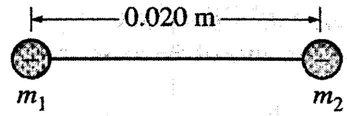
(d) 3 points



For beginning the graph at a value d that is clearly greater than zero — 1 point
For a concave upward curve — 1 point
For acceleration approaching zero as d approaches infinity — 1 point

(e) 3 points

For indicating that the speeds increase — 1 point
For indicating that as the objects move apart, their speeds increase at a slower rate (i.e., the acceleration decreases) — 1 point
For indicating that the speeds approach a constant value as d approaches infinity — 1 point



3. (15 points)

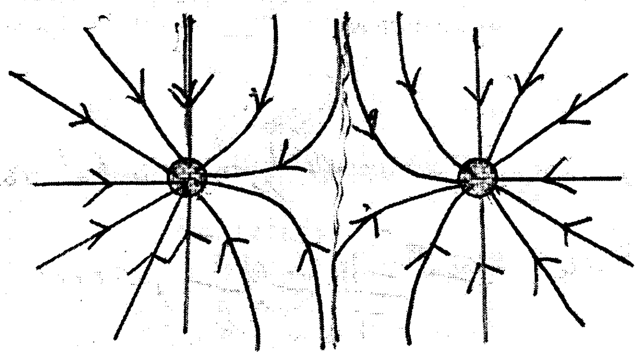
Two small objects, each with a charge of –4.0 nC, are held together by a 0.020 m length of insulating string as shown in the diagram above. The objects are initially at rest on a horizontal, nonconducting frictionless surface. The effect of gravity on each object due to the other is negligible.

(a) Calculate the tension in the string.

$$T = F_{repulsion} = \frac{1}{4\pi\varepsilon_0} \times \frac{(-4.0\times10^{-9})^2}{(0.020)^2}$$

$$= 3.6\times10^{-4}\,N$$

(b) Illustrate the electric field by drawing electric field lines for the two objects on the following diagram.



The masses of the objects are $m_1 = 0.030$ kg and $m_2 = 0.060$ kg. The string is now cut.

(c) Calculate the magnitude of the initial acceleration of each object.

$$(m_1 \times a_{m_1}) = F_{repul} = (m_2 \times a_{m_2})$$

$$a_{m_1} = 3.6\times10^{-4}\,N / 0.030\,kg$$

~~$a_{m_1} = 0.12\,m/s^2$~~ $a_{m_1} = 0.012\,m/s^2$

$$a_{m_2} = 3.6\times10^{-4}\,N / 0.060\,kg$$ $a_{m_2} = 0.006\,m/s^2$

~~$a_{m_2} = 0.06\,m/s^2$~~

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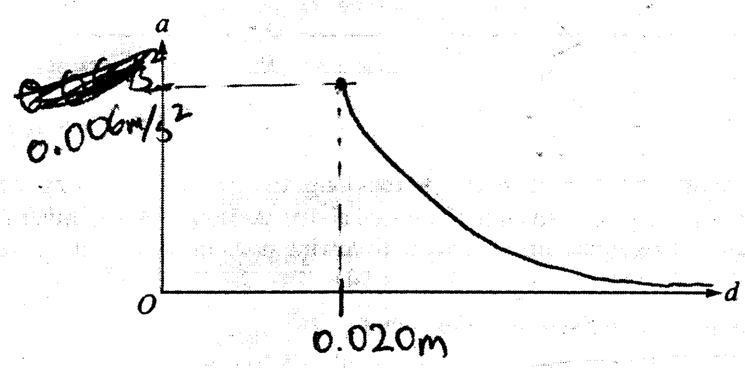
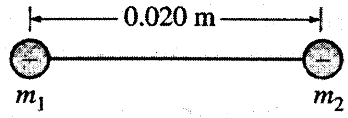
(d) On the axes below, qualitatively sketch a graph of the acceleration a of the object of mass m_2 versus the distance d between the objects after the string has been cut.



(e) Describe qualitatively what happens to the speeds of the objects as time increases, assuming that the objects remain on the horizontal, nonconducting frictionless surface.

The speeds will continue increasing but the rate of increase will tend to 0 as time increases. Eventually, both object's speeds will approach 2 different, finite limits, with the less massive object having a higher speed than the more massive one. Also, the speeds never decrease at any point in time.



3. (15 points)

Two small objects, each with a charge of –4.0 nC, are held together by a 0.020 m length of insulating string as shown in the diagram above. The objects are initially at rest on a horizontal, nonconducting frictionless surface. The effect of gravity on each object due to the other is negligible.

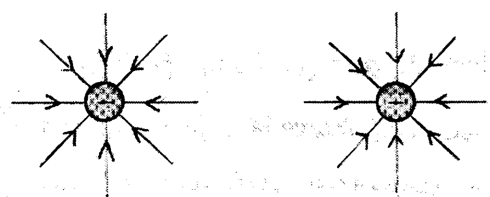
(a) Calculate the tension in the string.

Solution: $F_t = F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{(0.02m)^2}$

$= 9\times10^9 N \cdot m^2/C^2 \times \frac{(-4\times10^{-9})^2}{0.0004m^2}$

$= 0.00036 N$

(b) Illustrate the electric field by drawing electric field lines for the two objects on the following diagram.



The masses of the objects are $m_1 = 0.030$ kg and $m_2 = 0.060$ kg. The string is now cut.

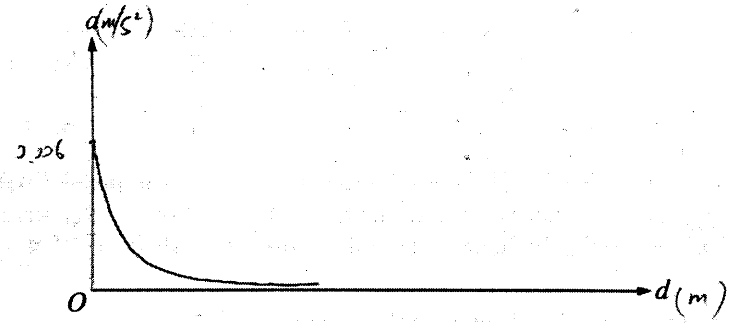
(c) Calculate the magnitude of the initial acceleration of each object.

$F_1 = ma_1$

$a_1 = \frac{F_1}{m_1} = \frac{0.00036N}{0.03kg} = 0.012 m/s^2$

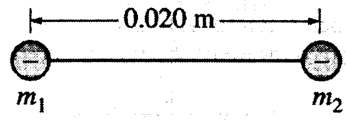
$a_2 = \frac{F_2}{m_2} = 0.006 m/s^2$

(d) On the axes below, qualitatively sketch a graph of the acceleration a of the object of mass m_2 versus the distance d between the objects after the string has been cut.



(e) Describe qualitatively what happens to the speeds of the objects as time increases, assuming that the objects remain on the horizontal, nonconducting frictionless surface.

the speed decrease, because the distance of two object is farther and farther, the force between them is also smaller and smaller



3. (15 points)

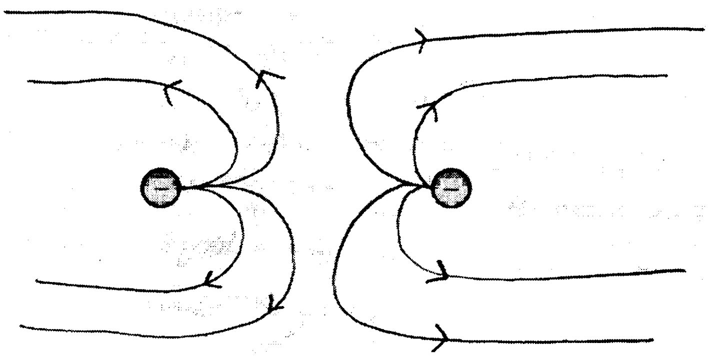
$Q = -4.0 \times 10^{-9}$

Two small objects, each with a charge of –4.0 nC, are held together by a 0.020 m length of insulating string as shown in the diagram above. The objects are initially at rest on a horizontal, nonconducting frictionless surface. The effect of gravity on each object due to the other is negligible.

(a) Calculate the tension in the string.

$$\text{Tension} = k(-4.0 \times 10^{-9})(0.02)$$
$$= 8 \times 10^{-11}\ \text{N}.$$

(b) Illustrate the electric field by drawing electric field lines for the two objects on the following diagram.

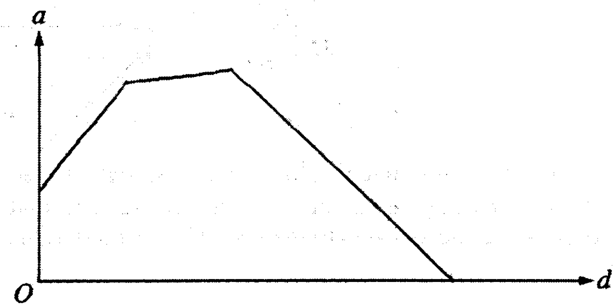


The masses of the objects are $m_1 = 0.030$ kg and $m_2 = 0.060$ kg. The string is now cut.

(c) Calculate the magnitude of the initial acceleration of each object.

$$F = ma$$
$$a_1 = \frac{F}{m_1} \Rightarrow \frac{8 \times 10^{-11}}{0.03} \Rightarrow 2.67 \times 10^{-9}\ \text{m/s}^2$$
$$a_2 = \frac{F}{m_2} = \frac{8 \times 10^{-11}}{0.06} \Rightarrow 1.33 \times 10^{-9}\ \text{m/s}.$$

(d) On the axes below, qualitatively sketch a graph of the acceleration a of the object of mass m_2 versus the distance d between the objects after the string has been cut.



(e) Describe qualitatively what happens to the speeds of the objects as time increases, assuming that the objects remain on the horizontal, nonconducting frictionless surface.

As time increases the speeds of the objects becomes constant. The acceleration becomes zero which means that there is constant velocity.

Question 3

Sample: B-3A
Score: 15

Correct work is shown in all parts, earning full credit. The drawing in part (b) even includes a dashed line to denote the asymptote.

Sample: B-3B
Score: 9

The work shown in part (a) is correct and earned full credit. Part (b) shows field lines in the immediate vicinity of the charged objects, with the direction correctly indicated, earning 2 points; the field farther from the objects is not shown, so the remaining 2 points were not earned. Part (c) earned full credit. The curve in part (d) has the qualitatively correct shape but is shown starting at $d = 0$ and so lost 1 point. A completely incorrect statement regarding speed is made in part (e), earning no credit.

Sample: B-3C
Score: 5

Part (a) earned no credit; the tension is calculated by multiplying the charge by the separation. One point was earned in part (b) for indicating that the field lines go to the charges. No other points were earned for part (b) as field lines are not represented over much of the region, the indicated field direction is incorrect, and there is no indication of an asymptotic approach midway between the charges. Part (c) earned full credit for correctly performing the calculations using a consistent substitution of the incorrect tension calculated in part (a). Part (d) earned no credit. Only one characteristic of the speeds — that they approach a constant value — is mentioned in part (e), so only 1 point was earned.