General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this 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, e.g., 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 one 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 Exam 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 2

15 points total | **Distribution of points**

(a) 6 points

The solution starts with the expression for the force between point charges.

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

For having equal contributions to the force from each charge on the x axis (e.g., by including a factor of 2 in the calculation) — 1 point

For using the correct distance between charges — 1 point

$r^2 = y_A^2 + x_B^2$

For including only the y component of the forces, since the x components cancel (e.g., by including $\sin\theta$ in the equation, where θ is the angle between the x axis and the line connecting particle A and either of the other two particles) — 1 point

For correctly determining the angle θ from the geometry — 1 point

For example: $\theta = \tan^{-1}(y_A/x_B)$

These elements combine to yield the following expression.

$$F = 2\frac{kq_Aq_B}{y_A^2 + x_B^2}\sin\left[\tan^{-1}(y_A/x_B)\right]$$

$$F = 2\frac{\left(9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(0.20\times10^{-9}\ \text{C}\right)\left(0.30\times10^{-9}\ \text{C}\right)}{(0.030\ \text{m})^2 + (0.040\ \text{m})^2}\sin\left[\tan^{-1}\left(\frac{0.030\ \text{m}}{0.040\ \text{m}}\right)\right]$$

For the correct numerical answer — 1 point

$F = 2.59\times10^{-7}\ \text{N}$

For correctly indicating that the force is in the negative y direction — 1 point

(b) 2 points

For any indication that particle A will move toward the origin after release — 1 point

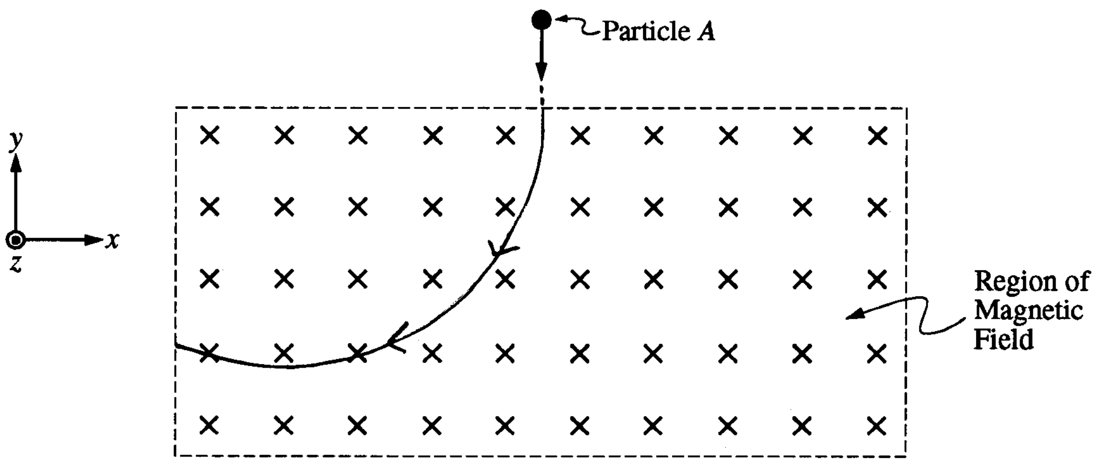
For any indication that the particle goes past the origin, then reverses direction — 1 point

For example: The particle oscillates between $y = \pm0.030\ \text{m}$

Question 2 (continued)

Distribution of points

(c) 2 points



For any path that (1) is an arc of a circle whose center lies on the line defining the side of the field where the particle enters and (2) goes completely through the field region — 1 point

For the path curving to the left — 1 point

(d) 2 points

For the correct expression for the force on a particle moving perpendicular to a magnetic field — 1 point

$F = qvB\sin\theta = qvB$

$F = \left(0.20 \times 10^{-9}\ \text{C}\right)(6000\ \text{m/s})(0.50\ \text{T})$

For the correct answer — 1 point

$F = \left(6.0 \times 10^{-7}\ \text{N}\right)$

(e) 3 points

For equating the expression for the electric and magnetic forces on the particle — 1 point

$qE = qvB$

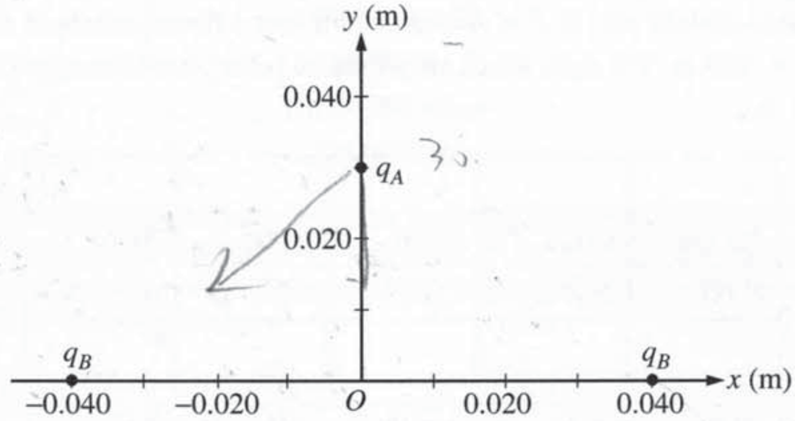
$E = vB$

$E = (6000\ \text{m/s})(0.50\ \text{T})$

For the correct numerical answer — 1 point

$E = 3000\ \text{N/C}$

For correctly indicating that the field is in the negative x direction — 1 point



2. (15 points)

Three particles are arranged on coordinate axes as shown above. Particle A has charge $q_A = -0.20$ nC, and is initially on the y-axis at $y = 0.030$ m. The other two particles each have charge $q_B = +0.30$ nC and are held fixed on the x-axis at $x = -0.040$ m and $x = +0.040$ m, respectively.

(a) Calculate the magnitude of the net electric force on particle A when it is at $y = 0.030$ m, and state its direction.

$F_N = 2F_{BA} \cdot \cos 53^\circ = 2\cos 53^\circ \cdot \frac{1}{4\pi\varepsilon_0} \frac{q_A q_B}{r^2}$

$= 2 \times 0.6 \times \frac{0.2nC \times 0.30nC}{4\pi \times 8.85 \times 10^{-12} \times (0.03^2 + 0.04^2)} N$

$= 0.259 \times 10^{-12} nN$

the direction: downward the y-axis

(b) Particle A is then released from rest. Qualitatively describe its motion over a long time.

it will go downwards to the point (0, -0.03) and then go upwards to the point (0, 0.03) and repeat the motion.

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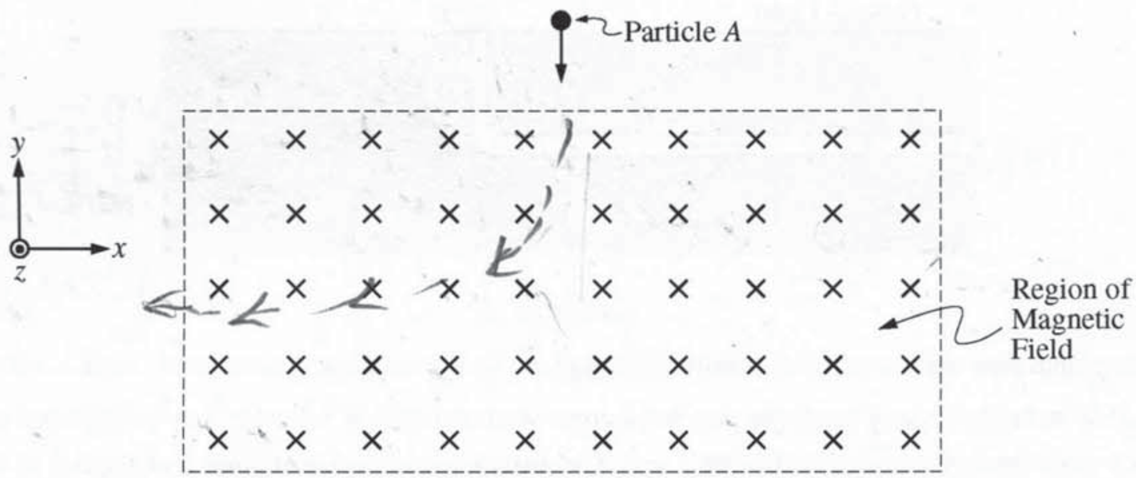
In another experiment, particle A of charge $q_A = -0.20$ nC is injected into a uniform magnetic field of strength 0.50 T directed into the page, as shown below, entering the field with speed 6000 m/s .



(c) On the diagram above, sketch a complete path of particle A as it moves in the magnetic field.

(d) Calculate the magnitude of the force the magnetic field exerts on particle A as it enters the magnetic field.

$F = Bqv = 6000 \times 0.50 \times 0.2n\ N = 600nN$

(e) An electric field can be applied to keep particle A moving in a straight line through the magnetic field. Calculate the magnitude of this electric field and state its direction.

$F = BIv$

the direction: to the left.

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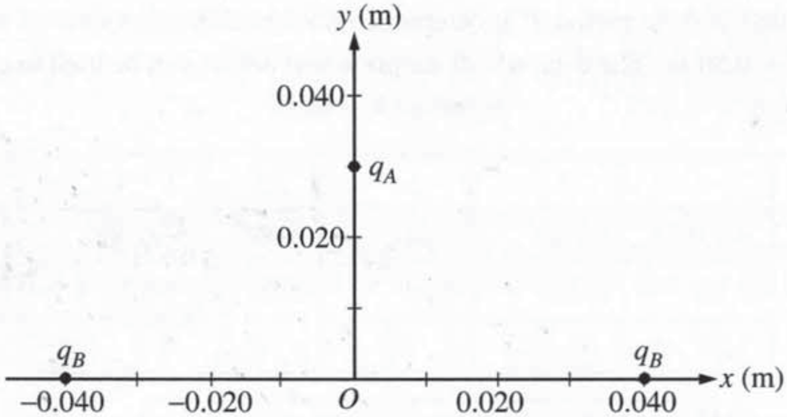

2. (15 points)

Three particles are arranged on coordinate axes as shown above. Particle *A* has charge $q_A = -0.20$ nC , and is initially on the *y*-axis at $y = 0.030$ m . The other two particles each have charge $q_B = +0.30$ nC and are held fixed on the *x*-axis at $x = -0.040$ m and $x = +0.040$ m , respectively.

(a) Calculate the magnitude of the net electric force on particle *A* when it is at $y = 0.030$ m , and state its direction.

$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = \frac{K q_A}{0} + \frac{K q_B}{\sqrt{0.040^2 + 0.03^2}^2} \times 2 = 0 + 2160 = \underline{2160\,N}$

x
~~[illegible]~~ → $-0.04m + 0.040m = 0$

y
$0.030m + 0.030m = 0.060m$

∴ ~~[illegible]~~ There is only a y direction so the direction is 90° towards the positive y-axis

(b) Particle *A* is then released from rest. Qualitatively describe its motion over a long time.

It would graduclly move up the positive y-axis and stop when the net force is 0.

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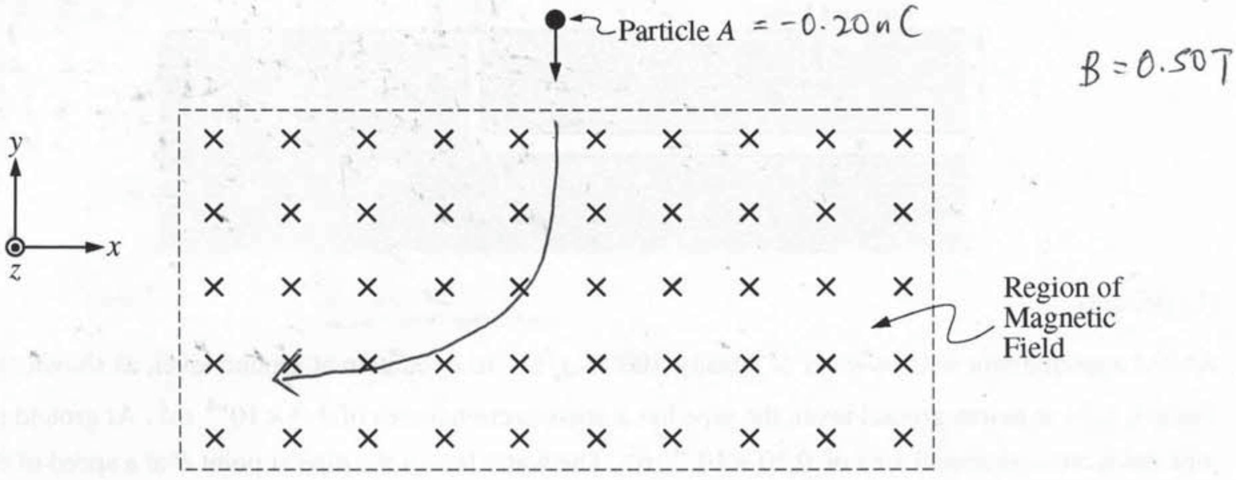

(c) On the diagram above, sketch a complete path of particle A as it moves in the magnetic field.

(d) Calculate the magnitude of the force the magnetic field exerts on particle A as it enters the magnetic field.

$F_B = qvB\sin\theta$, $q = -0.20 \times 10^{-9}$ C, $v = 6000$ m/s, $B = 0.50$T, $\theta = 90°$

$\therefore F_B = -0.20\times10^{-9}\text{C}\,(6000\,\text{m/s})(0.50\text{T})(\sin 90°)$

$= -6.0\times10^{-7}$ N

(e) An electric field can be applied to keep particle A moving in a straight line through the magnetic field. Calculate the magnitude of this electric field and state its direction.

$F_B = F_E$, $F_E = Eq$, $F_B = -6.0\times10^{-7}$ N

$\therefore Eq = 6.0\times10^{-7}$ N, $E = -6.0\times10^{-7}\text{N} / -0.20\times10^{-9}\text{C}$

$= 3000$ N/C

It is in the opposite direction of the magnetic field

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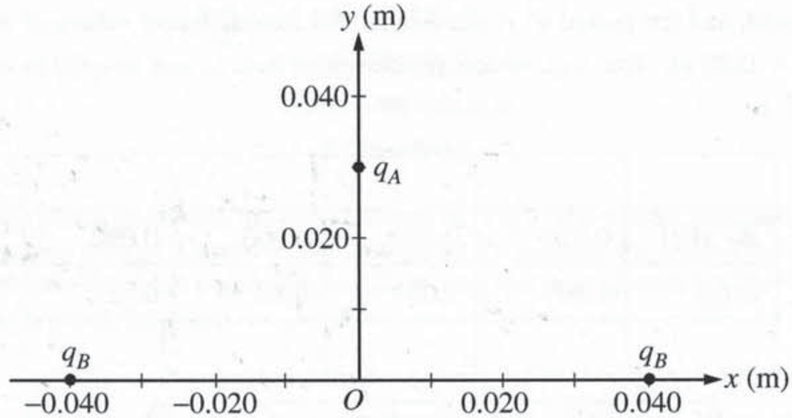

2. (15 points)

Three particles are arranged on coordinate axes as shown above. Particle *A* has charge $q_A = -0.20$ nC, and is initially on the *y*-axis at $y = 0.030$ m. The other two particles each have charge $q_B = +0.30$ nC and are held fixed on the *x*-axis at $x = -0.040$ m and $x = +0.040$ m, respectively.

(a) Calculate the magnitude of the net electric force on particle *A* when it is at $y = 0.030$ m, and state its direction.

$$F = k\frac{q_1 q_2}{r^2}$$

$$= 8.85\times10^{-12}\,C^2/N\cdot m^2 \times \frac{(-0.040\times10^{-9}\,C)(+0.040\times10^{-9}\,C)}{0.030^2}$$

$$= 1.573\times10^{-29}\,N$$

The net direction is zero because the opposite directions are cancelled.

(b) Particle *A* is then released from rest. Qualitatively describe its motion over a long time.

Particle A will move towards particle B which has a charge of +0.30nC because particle A has a negative charge so it'll move towards a particle with a positive charge.

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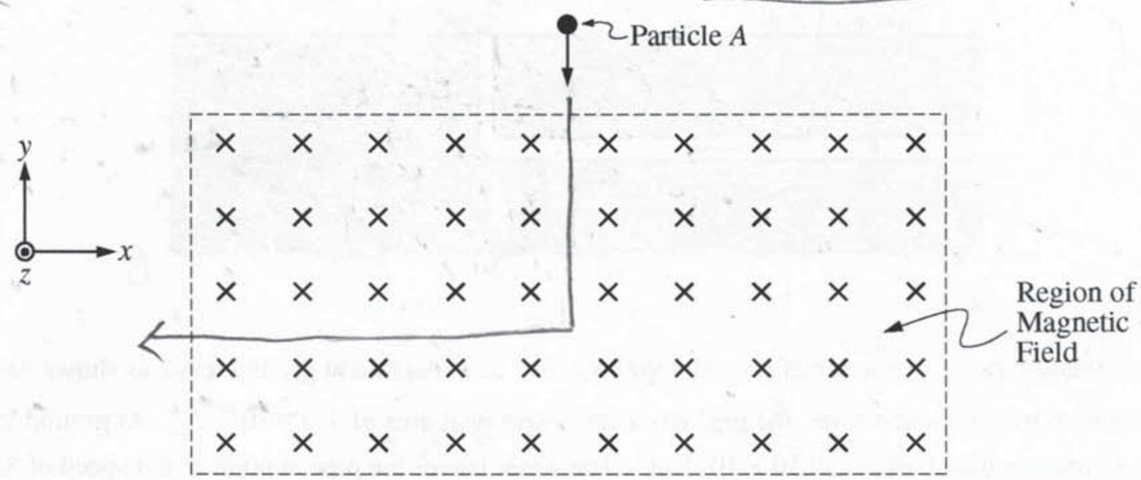
In another experiment, particle A of charge $q_A = -0.20$ nC is injected into a uniform magnetic field of strength 0.50 T directed into the page, as shown below, entering the field with speed 6000 m/s .



(c) On the diagram above, sketch a complete path of particle A as it moves in the magnetic field.

(d) Calculate the magnitude of the force the magnetic field exerts on particle A as it enters the magnetic field.

$F_B = qvB \sin\theta$

$= -0.20 \times 10^{-9}\ C \times 6000\ m/s \times 0.50\ T\ \sin(90^\circ)$

$= -6 \times 10^{-7}\ N$

$= 6 \times 10^{-7}\ N$

(e) An electric field can be applied to keep particle A moving in a straight line through the magnetic field. Calculate the magnitude of this electric field and state its direction.

$E = \frac{F}{q}$

$= \frac{-6 \times 10^{-7}\ N}{-0.20 \times 10^{-9}\ C}$

$= 3000$ right

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Question 2

Sample: B-2A
Score: 12

In part (a) 1 point was lost because the answer has an incorrect power of 10. The student has units of nN, which require a numerical answer of 2.59×10^2 . The next three parts earned 2 points each. Part (e) earned 1 point for the correct direction.

Sample: B-2B
Score: 8

Part (a) earned 2 points for using the correct distance between charges and multiplying the contribution from a positive charge by 2. Part (b) earned no points, while parts (c) and (d) both earned 2 points. Part (e) lost 1 point for an incorrect direction.

Sample: B-2C
Score: 4

The first three parts earned no points, but part (b) earned both points. Part (e) lost 1 point for an incorrect direction.