General Notes About 2011 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 earned. 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 earn 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 earned. 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 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 earn 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 5

15 points total | **Distribution of points**

(a)

i. 3 points

For the correct identification of the magnetic force on the positively charged particles as they enter region 1 — 1 point

$F_B = qvB_1$, directed toward the bottom of the page

For the correct identification of the electric force on the positively charged particles as they enter region 1 — 1 point

$F_E = qE$, directed toward the top of the page

$F_{\text{net}} = \sum F = qE - qvB = ma$

For the particle to move at constant velocity, $a = 0$

For the correct application of Newton's laws to obtain the equation needed to relate the speed of the particles to the electric and magnetic field strengths — 1 point

$qE - qvB_1 = 0$

$v = E/B_1$

ii. 2 points

For selecting "It curves toward the bottom of the page." — 1 point

For an appropriate explanation — 1 point

Example: The electric force $F_E = qE$, directed upward, is the same for all speeds of the particle. However, the magnetic force $F_B = qvB_1$, directed downward, increases with increasing speed. Therefore if the speed of the particle is greater than that in part (a)i, then $F_B > F_E$. The resultant force on the particle as it enters region 1 is toward the bottom of the page, causing the particle to curve in that direction.

The justification point could be earned only if the correct answer was selected.

(b) 2 points

$F_B = qvB_2$

For correctly substituting $v = E/B_1$ from part (a)i — 1 point

$$F_B = \frac{qEB_2}{B_1}$$

For correctly indicating that the direction is up or toward the top of the page — 1 point

Question 5 (continued)

Distribution of points

(c) 2 points

For including in the description that the force is constant — 1 point
For including in the description that the direction changes — 1 point
Example: The magnitude $F_B = qvB_2$ does not change because the particle is in a constant magnetic field B_2 and the angle between the velocity and magnetic force remains constant at $90°$. But as the particle curves the direction of its velocity changes, and the direction of the magnetic force also changes because it remains perpendicular to the velocity vector.

(d) 2 points

For an appropriate description that includes a statement that the path is circular — 2 points
Example: When the particle is in region 2, it moves toward the top of the page in a circular arc.
An explanation saying only that the path curved upward earned only 1 point.
One earned point was deducted for any incorrect statement. For example, "circular, out of the page" earned only 1 point.

(e) 4 points

For indicating that the net force provides the centripetal acceleration — 1 point

$$F_{\text{net}} = \frac{mv^2}{R}$$

For indicating that the net force is due to the magnetic field — 1 point

$$F_{\text{net}} = qvB_2$$

$$qvB_2 = \frac{mv^2}{R}$$

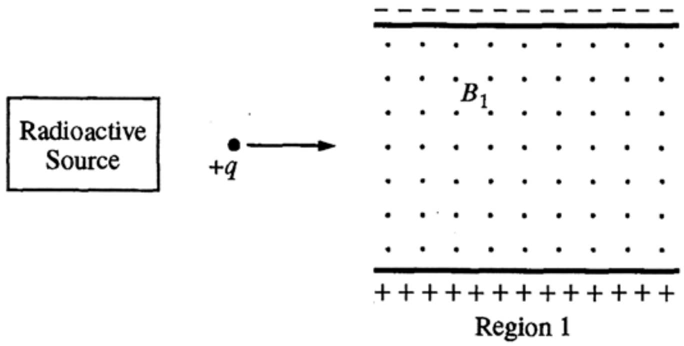
Substituting $v = \dfrac{E}{B_1}$, from part (a)i

$$qvB_2 = \frac{m}{R}\frac{E^2}{B_1^2}$$

For the correct answer — 1 point

$$\frac{q}{m} = \frac{E}{B_1 B_2 R}$$

For stating that R, a previously undefined quantity, is the radius of the circular arc in which the particle moves when in the magnetic field B_2 — 1 point



5. (15 points)

The diagram above illustrates a velocity selector, labeled region 1. It consists of two parallel conducting plates, with charges on the plates as indicated creating an electric field of magnitude E directed toward the top of the page. A uniform magnetic field of magnitude B_1 directed out of the page exists between the plates. The magnitude of the magnetic field can be adjusted so that only particles of a particular speed pass through the selector in a straight line. A radioactive source to the left of the selector emits charged particles, each having the same charge $+q$ and moving to the right in the plane of the page. The effect of gravity can be neglected throughout the problem.

(a)

i. Derive the equation $v = E/B_1$ for the speed v of particles that move in a straight line through region 1.

$F_B = qvB_1 \sin\theta$, $\sin\theta = 1$. downward.

$F_E = qE$, upward

Particle move in a straight line if $F_B = F_E$.

$F_B = qvB_1 = F_E = qE$.

$vB_1 = E$.

$v = \frac{E}{B_1}$

ii. Some particles are emitted from the source with speeds greater than E/B_1. Which of the following describes the initial path of one of these particles immediately after entering region 1 ?

____ It curves toward the top of the page.

✓ It curves toward the bottom of the page.

____ It curves into the page.

____ It curves out of the page.

____ It moves in a straight line.

Explain your reasoning.

If $v > \frac{E}{B_1}$, then $F_B = qvB_1 > F_E = qE$, net force by the magnetic and electric field causes the positively charged particle to move downward.

$F_B - F_E > 0$, $F_B \downarrow$, $F_E \uparrow$, net $\downarrow$.

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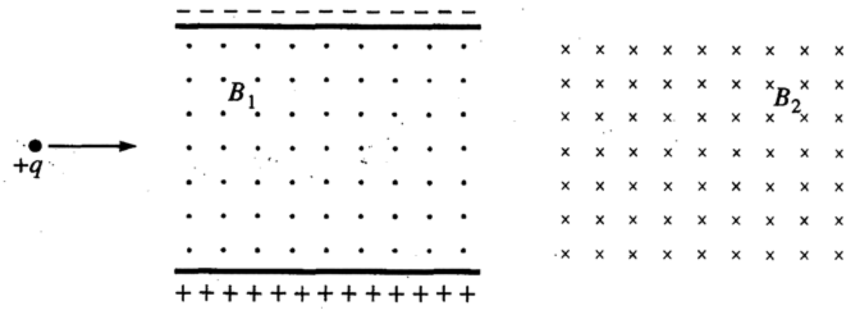
A constant magnetic field of magnitude B_2 directed into the page is now added in region 2 to the right of region 1, as represented in the figure below. Suppose a particle leaves the radioactive source, travels through region 1 in a straight line, and enters region 2. For each of the following, express algebraic answers in terms of E, B_1, B_2, q, and fundamental constants, as appropriate.



(b) Determine an expression for the initial magnetic force on the particle in region 2 and state its direction.

$F_{B2} = qvB_2 \sin\theta$, $\sin\theta = 1$.
$= q\left(\frac{E}{B_1}\right)B_2$.
$= qE\frac{B_2}{B_1}$
Direction : upward.

(c) Describe the changes, if any, in the magnitude and direction of the magnetic force as the particle moves in region 2.

The magnitude of the magnetic force remains constant, but the direction of the magnetic force changes in a counter-clockwise manner.

(d) Describe the path of the particle in region 2.

The particle travels in a counter-clockwise circular motion in region 2.

(e) Derive an expression for the charge-to-mass ratio q/m of the particle. Specifically note any quantities not previously defined that are included in your answer.

$F_{B2} = qE\frac{B_2}{B_1} = \frac{mv^2}{r}$

$\frac{q}{m} = \left(\frac{E}{B_1}\right)^2 \div \left(E\frac{B_2}{B_1}\right) \div r$.

$= \frac{E}{B_1 B_2 r}$

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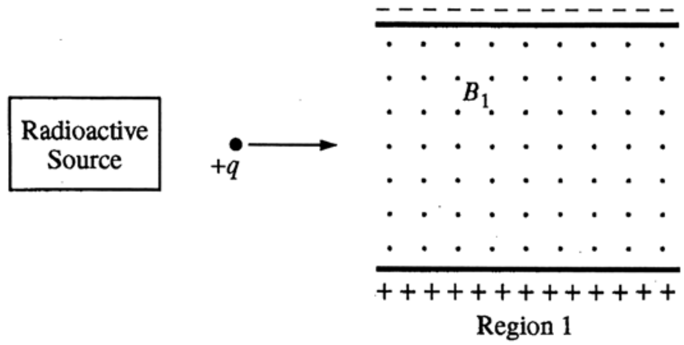

5. (15 points)

The diagram above illustrates a velocity selector, labeled region 1. It consists of two parallel conducting plates, with charges on the plates as indicated creating an electric field of magnitude E directed toward the top of the page. A uniform magnetic field of magnitude B_1 directed out of the page exists between the plates. The magnitude of the magnetic field can be adjusted so that only particles of a particular speed pass through the selector in a straight line. A radioactive source to the left of the selector emits charged particles, each having the same charge $+q$ and moving to the right in the plane of the page. The effect of gravity can be neglected throughout the problem.

(a)

i. Derive the equation $v = E/B_1$ for the speed v of particles that move in a straight line through region 1.

$F_{B_1} = F_E$

$E = \frac{F}{q} \Rightarrow F_E = qE$

$F_{B_1} = qvB_1 \sin\theta$, $\theta = 90° \Rightarrow F_{B_1} = qvB_1$

$\not{q}E = \not{q}vB_1$

$E = vB_1$

$v = \frac{E}{B_1}$

ii. Some particles are emitted from the source with speeds greater than E/B_1. Which of the following describes the initial path of one of these particles immediately after entering region 1 ?

____ It curves toward the top of the page.
__✓__ It curves toward the bottom of the page.
____ It curves into the page.
____ It curves out of the page.
____ It moves in a straight line.

Explain your reasoning.

The force ~~of~~ on the particle by the magnetic field is downwards by the right hand rule. If velocity is greater than $\frac{E}{B_1}$, the magnetic force will be greater than the electric field force, causing the particle to move downwards.
thus they no longer cancel out,

GO ON TO THE NEXT PAGE.

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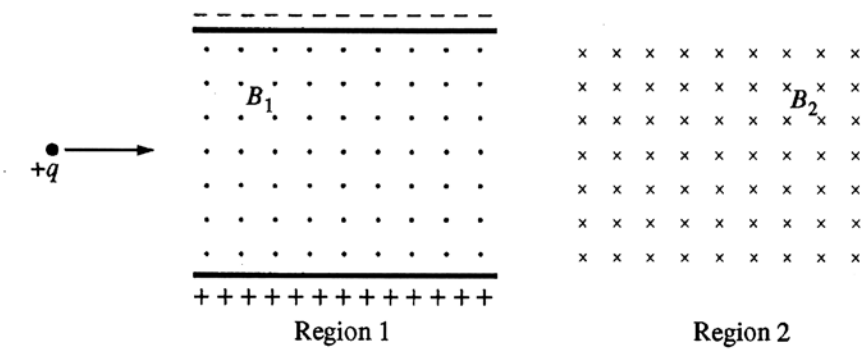

(b) Determine an expression for the initial magnetic force on the particle in region 2 and state its direction.

$F_B = qvB_2\sin\theta$.
$= (+q)\left(\frac{E}{B_1}\right)(B_2)\sin 90^\circ$
$= \frac{qEB_2}{B_1}$, to the top of the page.

(c) Describe the changes, if any, in the magnitude and direction of the magnetic force as the particle moves in region 2.

The magnitude of the ~~[illegible]~~ magnetic force remains constant but the direction would change to be perpendicular to the direction of the velocity.

(d) Describe the path of the particle in region 2.

The path will be a spiral inwards.

(e) Derive an expression for the charge-to-mass ratio q/m of the particle. Specifically note any quantities not previously defined that are included in your answer.

$F = ma = qE = qvB\sin\theta$

$\frac{q}{m} = \frac{a}{E}$, where a is the acceleration of the particle in the field.

$= \frac{a}{vB\sin\theta}$, where θ is the angle between the velocity and magnetic field
v is the velocity of the particle.

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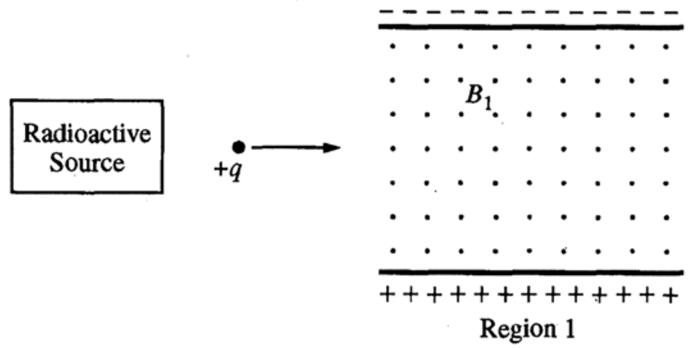

5. (15 points)

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(a)

i. Derive the equation $v = E/B_1$ for the speed v of particles that move in a straight line through region 1.

$F_B = F_E$

$Bqv = qE$

$v = E/B$

ii. Some particles are emitted from the source with speeds greater than E/B_1. Which of the following describes the initial path of one of these particles immediately after entering region 1 ?

____ It curves toward the top of the page. ____ It curves toward the bottom of the page.

____ It curves into the page. ____ It curves out of the page.

_✓_ It moves in a straight line.

Explain your reasoning.

With a speed higher than required to move the particle in a straight line, the particle will continue to move through the field in a straight line.

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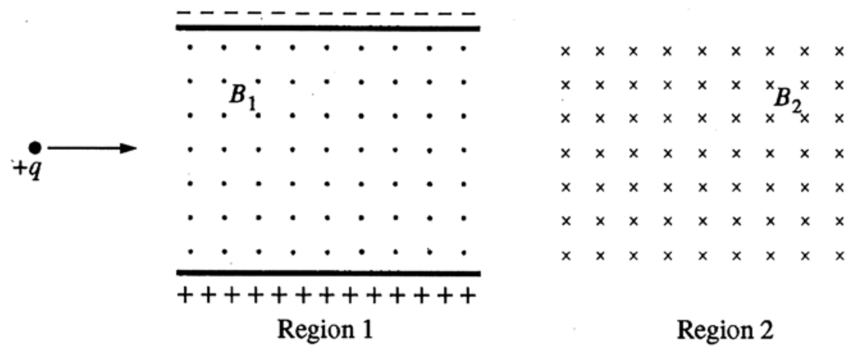
A constant magnetic field of magnitude B_2 directed into the page is now added in region 2 to the right of region 1, as represented in the figure below. Suppose a particle leaves the radioactive source, travels through region 1 in a straight line, and enters region 2. For each of the following, express algebraic answers in terms of E, B_1, B_2, q, and fundamental constants, as appropriate.



(b) Determine an expression for the initial magnetic force on the particle in region 2 and state its direction.

$F_B = Bqv$

The magnetic force on the particle will be down, towards the bottom of the page.

(c) Describe the changes, if any, in the magnitude and direction of the magnetic force as the particle moves in region 2.

The particle will display centripetal motion as it moves through region 2, but the magnitude will remain the same.

(d) Describe the path of the particle in region 2.

The particle starts initially in a straight line, then curves down towards the bottom of the page, then resumes that path of motion like a circle.

(e) Derive an expression for the charge-to-mass ratio q/m of the particle. Specifically note any quantities not previously defined that are included in your answer.

$\frac{mv^2}{r} = Bqv$

$q/m = \frac{v^3}{Br}$

- r is the radius of centripetal motion of the particle
- m is the mass

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Question 5

Sample: B5A
Score: 14

The response is well done and easy to follow. The only point not earned was because r is not defined in part (e).

Sample: B5B
Score: 8

The response earned full credit for parts (a) and (b). Part (c) earned the point for stating that the force is constant, but it does not correctly state the direction of the magnetic force. No credit was earned in part (d). Part (e) earned no credit, even though it states that the net force is due to a magnetic force, because the work does not specifically indicate which magnetic field to use.

Sample: B5C
Score: 6

Part (a) i received full credit. Because only region I has been introduced, it is acceptable not to include the subscript on the magnetic field magnitude. No credit was earned in parts (a) ii or (b). Part (c) earned 1 point for stating that the force is constant but not for giving the direction. Describing the motion is not an indication of the direction of the magnetic force. Part (d) received no credit. Part (e) received 1 point for defining r and 1 point for use of the centripetal force. Again, the point for the magnetic force was not earned because the work does not specifically indicate which magnetic field to use.