AP® PHYSICS B
2007 SCORING GUIDELINES

General Notes About 2007 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 and 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

10 points total | **Distribution of points**

(a) 1 point

For correctly indicating that the direction of the field is INTO the page or in the $-z$ direction. — 1 point

(b) 2 points

For stating that the (magnetic) force is perpendicular to the velocity, or the force is centripetal, or an equivalent concept. — 1 point

Note: The use of the phrase "centripetal force," without stating its source, earned no credit.

For stating that the (magnetic) force or field changes the direction of the velocity but not the speed, or an equivalent concept. — 1 point

(c) 4 points

For a correct expression indicating that the magnetic force provides the centripetal force — 1 point

$$\frac{m\upsilon^2}{R} = q\upsilon B$$

For a correct calculation of the radius of the trajectory — 1 point

$$R = \frac{x}{2} = \frac{1.75\text{ m}}{2} = 0.875\text{ m}$$

For correct substitutions into a correct expression — 1 point

$$\upsilon = \frac{qBR}{m} = \frac{2\left(1.60\times10^{-19}\text{ C}\right)(0.090\text{ T})(0.875\text{ m})}{1.45\times10^{-25}\text{ kg}}$$

For a correct answer with units — 1 point

$$\upsilon = 1.74\times10^{5}\text{ m/s}$$

(d) 3 points

For a correct expression indicating an equivalence of work and energy or electric potential energy and kinetic energy — 1 point

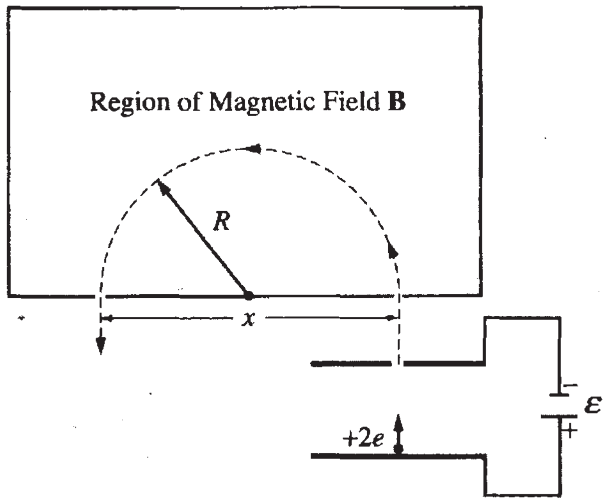
$$q\mathcal{E} = \frac{1}{2}m\upsilon^2$$

For correct substitutions into a correct expression — 1 point

$$\mathcal{E} = \frac{1}{2}\frac{m}{q}\upsilon^2 = \frac{1}{2}\frac{\left(1.45\times10^{-25}\text{ kg}\right)}{2\left(1.60\times10^{-19}\text{ C}\right)}\left(1.74\times10^{5}\text{ m/s}\right)^2$$

For a consistent answer with units — 1 point

$$\mathcal{E} = 6860\text{ V}$$



Top View

2. (10 points)

Your research director has assigned you to set up the laboratory's mass spectrometer so that it will separate strontium ions having a net charge of $+2e$ from a beam of mixed ions. The spectrometer above accelerates a beam of ions from rest through a potential difference $\mathcal{E}$, after which the beam enters a region containing a uniform magnetic field **B** of constant magnitude and perpendicular to the plane of the path of the ions. The ions leave the spectrometer at a distance x from the entrance point. You can manually change $\mathcal{E}$.

Numerical values for this experiment:

Strontium atomic number:	38
Strontium ion mass:	1.45×10^{-25} kg
Magnitude of B field:	0.090 T
Desired exit distance x:	1.75 m

(a) In what direction must **B** point to produce the trajectory of the ions shown?

into the page

(b) The ions travel at constant speed around the semicircular path. Explain why the speed remains constant.

Because the magnetic field exerts a force that is always perpendicular to the ion's velocity, it only changes the ion's direction and not its speed.

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(c) Calculate the speed of the ions with charge $+2e$ that exit at distance x.

$F = ma$

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

$2eB = \frac{mv}{\frac{x}{2}}$

$v = \frac{eBx}{m} = \frac{(1.6 \times 10^{-19}\ C)(0.090\ T)(1.75\ m)}{1.45 \times 10^{-25}\ kg}$

$= \boxed{1.74 \times 10^5\ m/s}$

(d) Calculate the accelerating voltage $\mathcal{E}$ needed for the ions with charge $+2e$ to attain the speed you calculated in part (c).

$W_e = KE$

$q\mathcal{E} = \frac{1}{2}mv^2$

$\mathcal{E} = \frac{mv^2}{2q} = \frac{mv^2}{4e} = \frac{(1.45 \times 10^{-25}\ kg)(1.74 \times 10^5\ m/s)^2}{4(1.6 \times 10^{-19}\ C)}$

$= \boxed{6,860\ V}$

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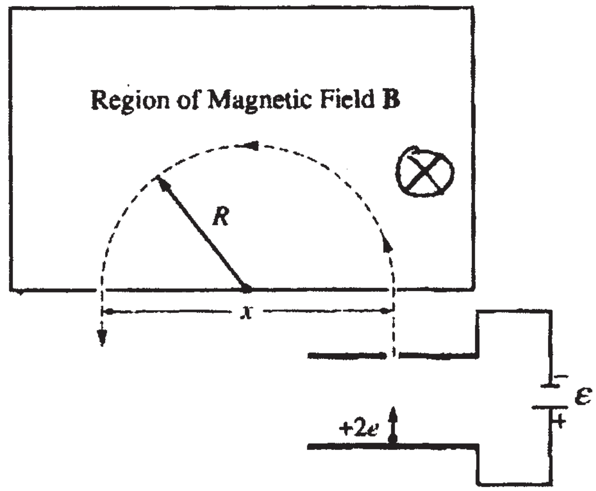

Top View

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Your research director has assigned you to set up the laboratory's mass spectrometer so that it will separate strontium ions having a net charge of $+2e$ from a beam of mixed ions. The spectrometer above accelerates a beam of ions from rest through a potential difference $\mathcal{E}$, after which the beam enters a region containing a uniform magnetic field **B** of constant magnitude and perpendicular to the plane of the path of the ions. The ions leave the spectrometer at a distance x from the entrance point. You can manually change $\mathcal{E}$.

Numerical values for this experiment:

Strontium atomic number:	38
Strontium ion mass:	1.45×10^{-25} kg
Magnitude of B field:	0.090 T
Desired exit distance x:	1.75 m

(a) In what direction must **B** point to produce the trajectory of the ions shown?

B must point into the page

(b) The ions travel at constant speed around the semicircular path. Explain why the speed remains constant.

The force from the magnetic field is centripetal. Therefore, there is no component of force acting in the direction (or opposite direction of) the electron. Since no force is acting on the electron's speed, it will not change (inertia)

GO ON TO THE NEXT PAGE.

(c) Calculate the speed of the ions with charge $+2e$ that exit at distance x.

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

$F = qvB$

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

$v = \frac{qBr}{m}$

$v = \frac{2(1.60\times10^{-19}C)(0.090T)\left(\frac{1.75m}{2}\right)}{1.45\times10^{-25}}$

$\boxed{v = 1.7\times10^{5}\frac{m}{s}}$

(d) Calculate the accelerating voltage $\mathcal{E}$ needed for the ions with charge $+2e$ to attain the speed you calculated in part (c).

$E_k = E_p$

$\frac{1}{2}mv^2 = \frac{1}{2}QV$

$\frac{mv^2}{Q} = V$

$\mathcal{E} = \frac{(1.45\times10^{-25}\,kg)(1.7\times10^{5}\frac{m}{s})^2}{2(1.6\times10^{-19}C)}$

$\boxed{\mathcal{E} = 1.4\times10^{4}\,V}$

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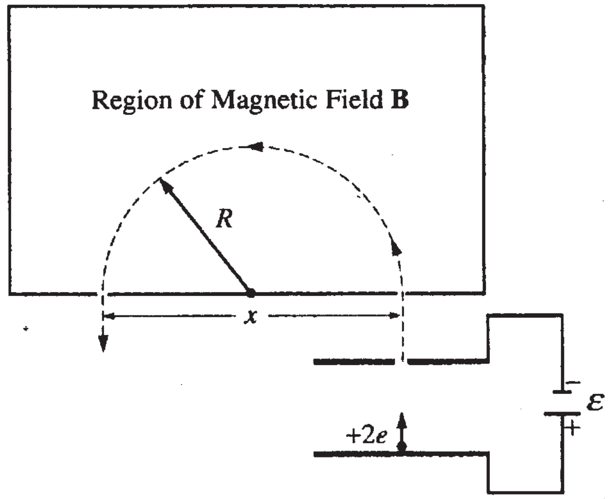

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Numerical values for this experiment:

Strontium atomic number:	38
Strontium ion mass:	1.45×10^{-25} kg
Magnitude of B field:	0.090 T
Desired exit distance x:	1.75 m

(a) In what direction must **B** point to produce the trajectory of the ions shown?

B points into the page

(b) The ions travel at constant speed around the semicircular path. Explain why the speed remains constant.

Because the equation $F = \frac{mv^2}{r}$ applies to circular motion, + the force applied to the particles, the mass of the particles, and the radius of the path all remain constant, v must also remain constant.

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(c) Calculate the speed of the ions with charge $+2e$ that exit at distance x.

$F_B = qvB\sin\theta$

$\frac{mv^2}{r} = qvB\sin\theta$

$\frac{mv}{r} = qB\sin\theta$

$\frac{(1.45 \times 10^{-25})(v)}{.875} = (2)(.09)\sin 90$

$(1.45 \times 10^{-25})(v) = .1575$

$v = 1.086 \times 10^{24}$

(d) Calculate the accelerating voltage $\mathcal{E}$ needed for the ions with charge $+2e$ to attain the speed you calculated in part (c).

$\mathcal{E} = B\ell v$

$= (.09)(1.75)(1.086 \times 10^{24})$

$= 1.711 \times 10^{23}$

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Question 2

Overview

This 10-point question was intended to assess students' understanding of the motion of charged particles in electric and magnetic fields. Ions of charge $+2e$ were accelerated by a potential difference $\mathcal{E}$ and then directed into a region containing a uniform magnetic field. The ions followed a semicircular path inside the magnetic field. Part (a) asked students to determine the direction of the magnetic field, and in part (b) they had to demonstrate a conceptual understanding of circular motion of the ions. In part (c) students were expected to calculate the velocity of the ions. In part (d) they were asked to determine the accelerating voltage of the ions.

Sample: 2A
Score: 10

This orderly response contains an explanation that is concise and to the point.

Sample: 2B
Score: 7

The first three parts earned full credit. No credit was earned for the last part, since an incorrect expression for the electrical potential energy is used.

Sample: 2C
Score: 3

Part (a) earned full credit, but part (b) earned nothing because the student shows no understanding that the net force is centripetal and does not differentiate between changing direction and changing speed. Part (c) contains a correct expression for force and uses the correct value for the radius but does not have the correct charge, so only 2 points were earned. In part (d) an expression for emf is used and nothing was earned.