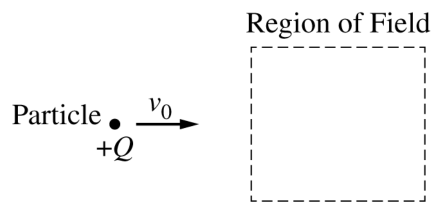
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

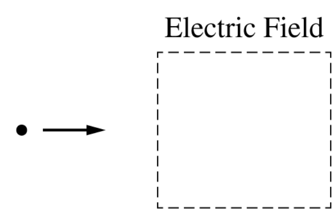


1. (10 points, suggested time 20 minutes)

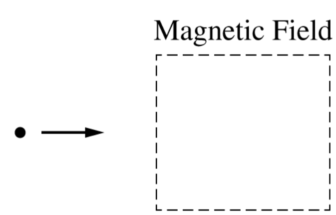
The figure above shows a particle with positive charge $+Q$ traveling with a constant speed v_0 to the right and in the plane of the page. The particle is approaching a region, shown by the dashed box, that contains a constant uniform field. The effects of gravity are negligible.

(a)

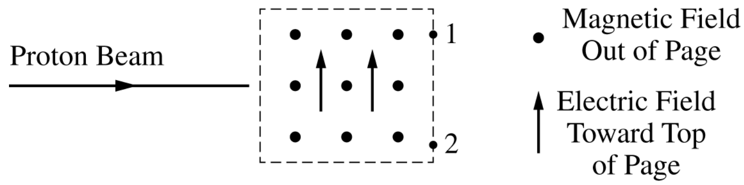
i. On the figure below, draw a possible path of the particle in the region if the region contains only an electric field directed toward the bottom of the page.



ii. On the figure below, draw a possible path of the particle in the region if the region contains only a magnetic field directed out of the page.



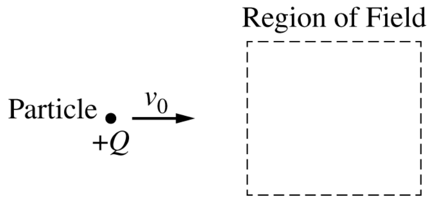
iii. For which of the previous situations is the motion more similar to that of a projectile in only a gravitational field near Earth's surface, and why?



(b) Another region of space contains an electric field directed toward the top of the page and a magnetic field directed out of the page. Both fields are constant and uniform. A horizontal beam of protons with a variety of speeds enters the region, as shown above. Protons exit the region at a variety of locations, including points 1 and 2 shown on the figure. In a coherent, paragraph-length response, explain why some protons exit the region at point 1 and others exit at point 2. Use physics principles to explain your reasoning.

Question 1

10 points

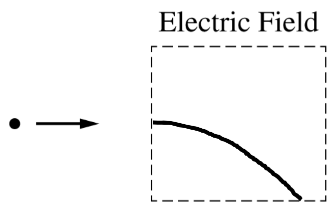


The figure above shows a particle with positive charge $+Q$ traveling with a constant speed v_0 to the right and in the plane of the page. The particle is approaching a region, shown by the dashed box, that contains a constant uniform field. The effects of gravity are negligible.

(a)

i. LO 2.C.1.1, SP 6.4
2 points

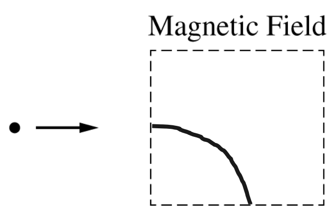
On the figure below, draw a possible path of the particle in the region if the region contains only an electric field directed toward the bottom of the page.



For a curved path that is initially horizontal and does not have a component of velocity toward the left		1 point
For a path that deflects toward the bottom of the page and reaches an edge of the region		1 point

ii. LO 3.C.3.1, SP 1.4
2 points

On the figure below, draw a possible path of the particle in the region if the region contains only a magnetic field directed out of the page.



For a curved path that is initially horizontal, is not more than a semicircle, and reaches an edge of the region		1 point
For a path that deflects toward the bottom of the page		1 point

Question 1 (continued)

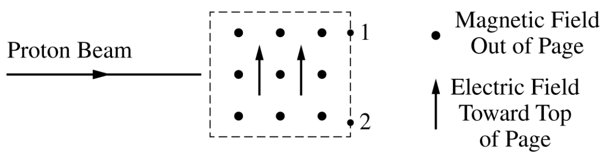
(a) (continued)

iii. LO 2.C.5.3, SP 1.1, 7.1
1 point

For which of the previous situations is the motion more similar to that of a projectile in only a gravitational field near Earth's surface, and why?

For indicating that the motion in the electric field is more similar to a projectile because the force or acceleration is always down or constant, or the shape is parabolic		1 point

(b) LO 2.D.1.1, SP 2.2; LO 3.A.3.4, SP 6.1, 6.4; LO 3.B.1.4, SP 6.4, 7.2; LO 3.B.2.1, SP 1.1, 1.4, 2.2
5 points



Another region of space contains an electric field directed toward the top of the page and a magnetic field directed out of the page. Both fields are constant and uniform. A horizontal beam of protons with a variety of speeds enters the region, as shown above. Protons exit the region at a variety of locations, including points 1 and 2 shown on the figure. In a coherent, paragraph-length response, explain why some protons exit the region at point 1 and others exit at point 2. Use physics principles to explain your reasoning.

For indicating that initially the electric and magnetic forces act in opposite directions		1 point
For indicating or implying that the magnetic force is affected by speed, but the electric force is not		1 point
For indicating that different paths occur as a result of the addition of forces		1 point
For indicating that slower protons exit higher than faster protons (i.e., slower protons exit at point 1 and faster protons exit at point 2)		1 point
For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response		1 point
Example: For a charged particle to travel through the region undeflected, the net force on it must be zero. This means that the upward electric force and the downward magnetic force must be equal and opposite to each other. This occurs for a particular speed. The electric force is independent of the particle's velocity, but the magnetic force will be larger for greater velocities and less for smaller velocities. If a particle is moving faster than the particular speed, it will experience a greater magnetic force and be deflected downward. If it is moving more slowly than the particular speed, it will be deflected upward.		

Question 1 (continued)

(b) (continued)

Claim: Slower protons exit higher than faster protons (i.e., slower protons exit at point 1 and faster protons exit at point 2). Evidence: The electric and magnetic forces act in opposite directions. The magnetic force is affected by speed, but the electric force is not. Reasoning: Different paths occur as a result of the addition of forces.		

Learning Objectives

LO 2.C.1.1: The student is able to predict the direction, and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation. [See Science Practices 6.4, 7.2]

LO 2.C.5.3: The student is able to represent the motion of an electrically-charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in Earth's gravitational field. [See Science Practices 1.1, 2.2, 7.1]

LO 2.D.1.1: The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. [See Science Practices 2.2]

LO 3.A.3.4: The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge. [See Science Practices 6.1, 6.4]

LO 3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [See Science Practices 6.4, 7.2]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]

LO 3.C.3.1: The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor. [See Science Practices 1.4]