AP Physics Study Guide   Chapters 20 21   Magnetism and Electromagnetic Induction

Name____________________

Circle the vector quantities below and underline the scalar quantities below

magnetic force   magnetic field   velocity of a charged particle   electric field

magnetic flux   induced emf

Write the equation that defines each quantity, **<u>INCLUDE UNITS FOR ALL QUANTITIES</u>**

magnetic force on current-carrying wire   magnetic force on moving charged particle

magnetic field created around current-carrying wire   magnetic flux through a closed loop

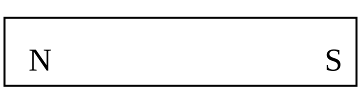
Faraday's Law of electromagnetic induction   emf induced in wire moving through B field

<u>Chapter 20</u>

The major difference between electric and magnetic field lines is that magnetic field lines are

closed ______________ while electric field lines are drawn from positive towards negative charge.

Draw the magnetic field line pattern for the bar magnet below. If the field lines pass through the magnet be sure to show these. Remember that field lines have direction – draw them as arrows.



Circle the correct answer

Magnetic field lines exit/enter the North pole and exit/enter the South pole of a permanent bar magnet

Write the magnetic force law between 2 like poles and between 2 unlike poles.

There are 3 right-hand rules that are used to specify the direction of magnetic fields and forces.
1st   Explain the right hand thumb rule for a straight wire carrying a current directed upwards towards the top of the page. Draw a diagram of the straight wire (as shown in Figure 20-8 in Giancoli) showing current and magnetic field lines as part of your explanation.

2nd A second right hand rule is a convenient alternative of the first one when the current-carrying wire is a circular loop or coil (solenoid) instead of a straight wire. Point the fingers of your right hand in the direction of the current around the coil with the thumb extended straight as with the first right hand rule. The thumb will point in the direction of the magnetic field produced by the current carrying loop.

3rd The third right hand rule specifies the direction of the magnetic force on a current-carrying wire when it is IN AN EXTERNAL MAGNETIC FIELD or when a charged particle is moving through a magnetic field. Mr. B recommends a RHR slightly different from the one shown in Giancoli. Hold your right hand out flat with the thumb forming a right angle with the fingers. The fingers represent the B field, the thumb represents either the current I in the wire or the velocity v of a moving <u>positive</u> charge. The magnetic force is a normal coming off the palm.
The magnetic force is a maximum when the wire or charged particle velocity vector form a _________ angle with magnetic field. The magnetic force is zero when the wire or charged particle velocity vector

are ______________ to the B field.
Draw Figure 20-13 from Giancoli below and practice the right hand rule. Label I, F and B in your drawing. Write the equation that specifies the force when the wire forms an angle θ with the B field.

There are two cases when the moving charge is not current in a wire but a charged particle q moving with velocity v through a magnetic field B at an angle θ. The right hand rule is used for POSITIVE charges. Explain what you must do with your right hand when an electron is moving through the magnetic field. Draw the diagram in Figure 20-14 for both types of charge and write the equation.

When a charged particle enters a magnetic field at a 90^o angle to the field that is large enough in size, what type of motion will result? Draw diagram 20-16 in Giancoli as part of your explanation. Include the equation that relates magnetic force to centripetal force.

The shape of the path changes when the charge enters the B field at an angle between 0 and 90^o. The

name of the shape of this path is a _____________.

Explain how an electric field E can be used to counterbalance the deflection of a charged particle by a magnetic field, including the equation that specifies this “crossed fields” situation.

You will need to be able to determine the potential difference V required to accelerate a charged particle q so that it has kinetic energy and speed prior to entering the magnetic field. Write this relationship (explained in chapter 17).

The magnetic field around a long, current-carrying straight wire forms _______________ with the wire at their _______________. Two wires carrying current in the SAME direction will ____________ each other, while two wires carrying current in the OPPOSITE direction will ______________ each other.

<u>Chapter 21</u>

Write a statement describing the electromagnetic induction process.

Explain how magnetic flux through a loop is formed. Include 3 things that can be changed to change the flux through a loop.

1)

2)

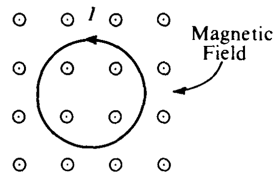
3)

Explain why the emf induced by a flux change through a loop can be either positive or negative.

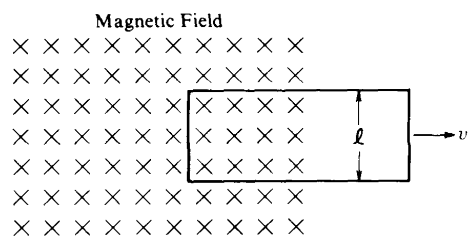
Write a full statement of Lenz's Law including how it applies to the direction of the current induced by the induced emf.

Read Example 21-5 in Giancoli. Draw the diagram in Figure 21-10 below. The direction of the induced current in the loop is ________________________ as it is pulled out of the magnetic field region.

No process is required for these multiple choice questions. Put answers on lines provided at right.



1. There is a counterclockwise current I in a circular loop of wire situated in an external magnetic field directed out of the page as shown above. The effect of the forces that act on this current is to make the loop
   (A) expand in size   (B) contract in size
   (C) rotate about an axis perpendicular to the page
   (D) rotate about an axis in the plane of the page   (E) accelerate into the page   1)________



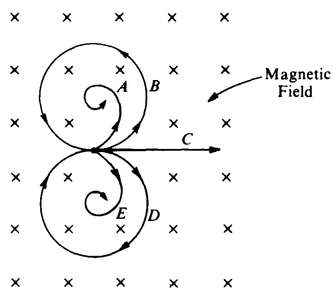
2. The figure above shows a rectangular loop of wire of width *l* and resistance R. One end of the loop is in a uniform magnetic field of strength B at right angles to the plane of the loop. The loop is pulled to the right at a constant speed v. What are the magnitude and direction of the induced current in the loop?

Magnitude	Direction
(A) BlvR	Clockwise
(B) BlvR	Counterclockwise
(C) Blv/R	Clockwise
(D) Blv/R	Counterclockwise
(E) 0	Undefined

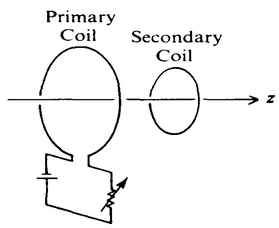
2)_______

3. A square loop of copper wire is initially placed perpendicular to the lines of a constant magnetic field of 5×10^{-3} tesla. The area enclosed by the loop is 0.2 square meter. The loop is then turned through an angle of 90° so that the plane of the loop is parallel to the field lines. The turn takes 0.1 second. The average emf induced in the loop during the turn is
   (A) 1.0×10^{-4} V   (B) 2.5×10^{-3} V   (C) 0.01 V   (D) 100 V   (E) 400 V

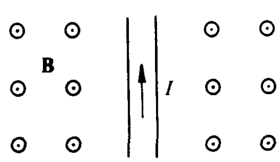
3)________



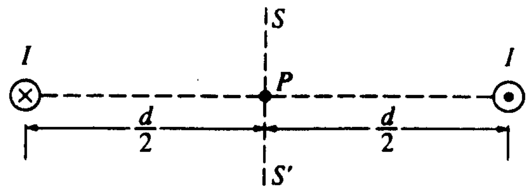
4. Which of the paths above represents the path of an electron traveling without any loss of energy through a uniform magnetic field directed into the page?
(A) A (B) B (C) C (D) D (E) E 4)_______



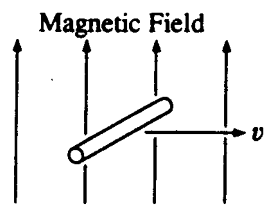
5. Two circular coils are situated perpendicular to the z-axis as shown above. There is a current in the primary coil. All of the following procedures will induce a current in the secondary coil EXCEPT
(A) rotating the secondary coil about the z-axis
(B) rotating the secondary coil about a diameter
(C) moving the secondary coil closer to the primary coil
(D) varying the current in the primary coil 5)_______
(E) decreasing the cross-sectional area of the secondary coil



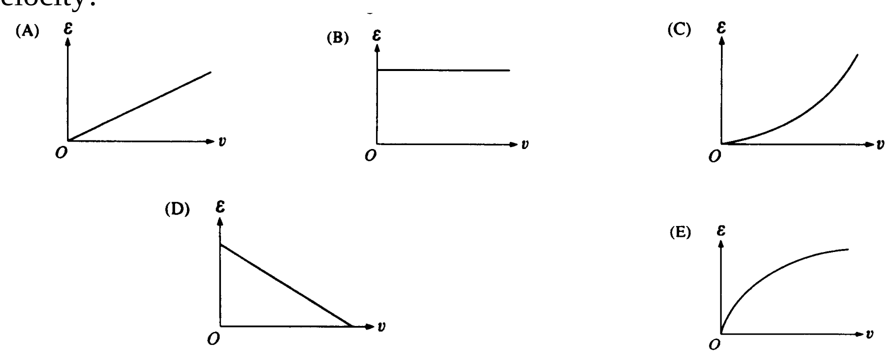
6. A wire in the plane of the page carries a current directed toward the top of the page as shown above. If the wire is located in a uniform magnetic field B directed out of the page, the force on the wire resulting from the magnetic field is
(A) directed into the page (B) directed out of the page (C) directed to the right
(D) directed to the left (E) zero
6)_______

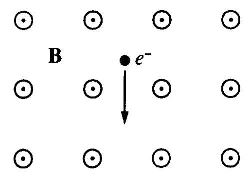


7. Two long, parallel wires are separated by a distance d, as shown above. One wire carries a steady current I into the plane of the page while the other wire carries a steady current I out of the page. At what points in the plane of the page and outside the wires, besides points at infinity, is the magnetic field due to the currents zero?
(A) Only at point P
(B) At all points on the line SS'
(C) At all points on the line connecting the two wires 7)______
(D) At all points on a circle of radius 2d centered on point P
(E) At no points

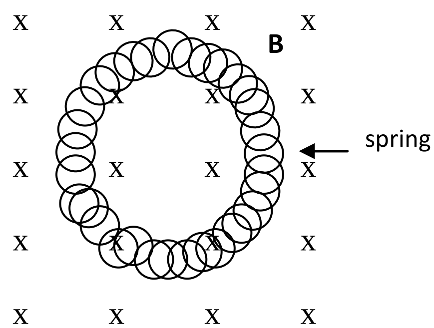


8. A wire of constant length is moving in a constant magnetic field, as shown above. The wire and the velocity vector are perpendicular to each other and are both perpendicular to the field. Which of the following graphs best represents the potential difference $\mathcal{E}$ between the ends of the wire as a function of velocity? 8)_______





9. An electron is in a uniform magnetic field **B** that is directed out of the plane of the page, as shown above. When the electron is moving in the plane of the page in the direction indicated by the arrow, the force on the electron is directed
   a. toward the right b. out of the page c. into the page 9)__________
   d. toward the top of the page e. toward the bottom of the page

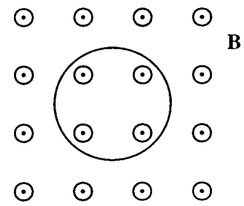


10. A metal spring has its ends attached so that if forms a circle. It is placed in a uniform magnetic field, as shown above. Which of the following will not cause a current to be induced in the spring?
   a. Changing the magnitude of the magnetic field
   b. Increasing the diameter of the circle by stretching the spring 10)__________
   c. Rotating the spring about a diameter
   d. Moving the spring parallel to the magnetic field
   e. Moving the spring in and out of the magnetic field

<u>Questions 11 – 12</u>
A magnetic field of 0.1T forces a proton beam of 1.5 mA to move in a circle of radius 0.1 m. The plane of the circle is perpendicular to the magnetic field.

11. Of the following, which is the best estimate of the work done by the magnetic field on the protons during one complete orbit of the circle?
   a. 0 J b. 10^{-22} J c. 10^{-5} J d. 10^{2} J e. 10^{20} J 11)__________

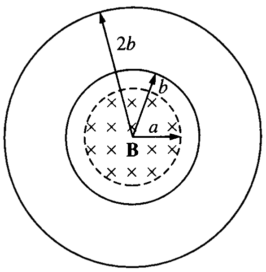
12. Of the following, which is the best estimate of the speed of a proton in the beam as it moves in the circle?
   a. 10^{-2} m/s b. 10^{3} m/s c. 10^{6} m/s d. 10^{8} m/s e. 10^{15} m/s 12)__________



13. A single circular loop of wire in the plane of the page is perpendicular to a uniform magnetic field **B** directed out of the page, as shown above. If the magnitude of the magnetic field is decreasing, then the induced current in the wire is

a. directed upward out of the paper
b. directed downward into the paper
c. clockwise around the loop
d. counterclockwise around the loop
e. zero (no current is induced)

13)_______



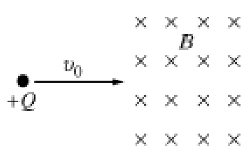
14. A uniform magnetic field **B** that is perpendicular to the plane of the page passes through two concentric loops, as shown above. The field is confined to a region of radius *a*, where $a < b$, and is changing at a constant rate. The induced emf in the wire loop of radius *b* is $\mathcal{E}$. What is the induced emf in the wire loop of radius *2b* ?

a. Zero b. $\mathcal{E}/2$ c. $\mathcal{E}$ d. 2 $\mathcal{E}$ e. 4 $\mathcal{E}$

14)________

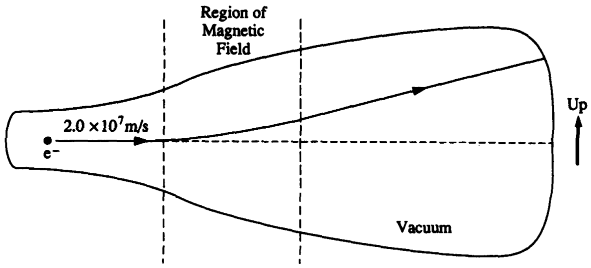
15)

15)___________



A particle of charge $+Q$ moving with speed v_0 enters a region of constant magnetic field B directed into the page, as shown above. The initial direction and magnitude of the acceleration of the particle as it enters the magnetic field is toward the

(A) bottom of the page and proportional to B
(B) bottom of the page and proportional to v_0
(C) top of the page and inversely proportional to v_0
(D) top of the page and inversely proportional to B
(E) top of the page and proportional to both B and v_0



Cross Section of Cathode Ray Tube

1) The figure above shows a cross section of a cathode ray tube. An electron in the tube initially moves horizontally in the plane of the cross section at a speed of 2.0×10^7 meters per second. The electron is deflected upward by a magnetic field that has a field strength of 6.0×10^{-4} tesla.

a. What is the direction of the magnetic field? a)____________

b. Determine the magnitude of the magnetic force acting on the electron. b)___________

c. Determine the radius of curvature of the path followed by the electron while it is in the magnetic field.

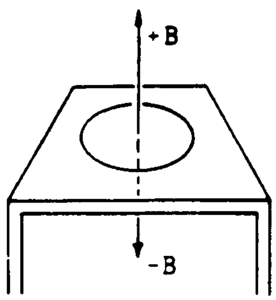
c)___________

An electric field is later established in the same region as the magnetic field such that the electron now passes through the magnetic and electric fields without deflection.

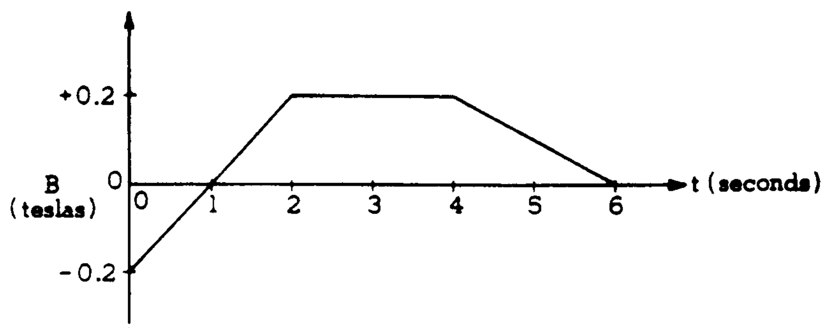
d. Determine the magnitude of the electric field.

d)____________

e. Draw and label the electric field vector E on the diagram on the previous page



2) A circular loop of wire of resistance 0.2 ohm encloses an area 0.3 square meter and lies flat on a wooden table as shown above. A magnetic field that varies with time t as shown below is perpendicular to the table. A positive value of B represents a field directed up from the surface of the table; a negative value represents a field directed into the tabletop.



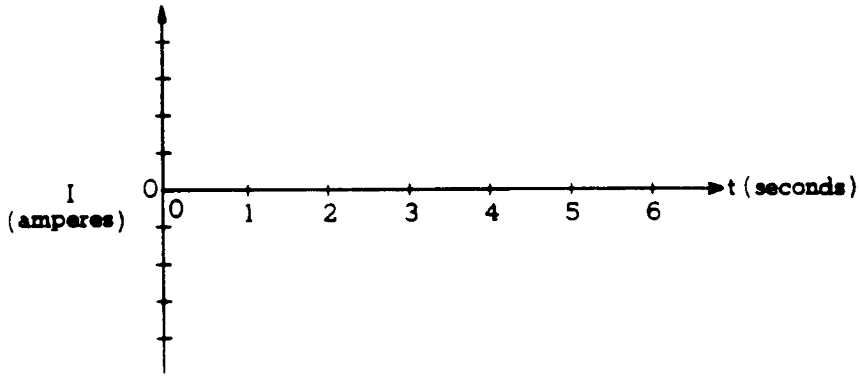
a. Calculate the value of the magnetic flux through the loop at time t = 3 seconds.

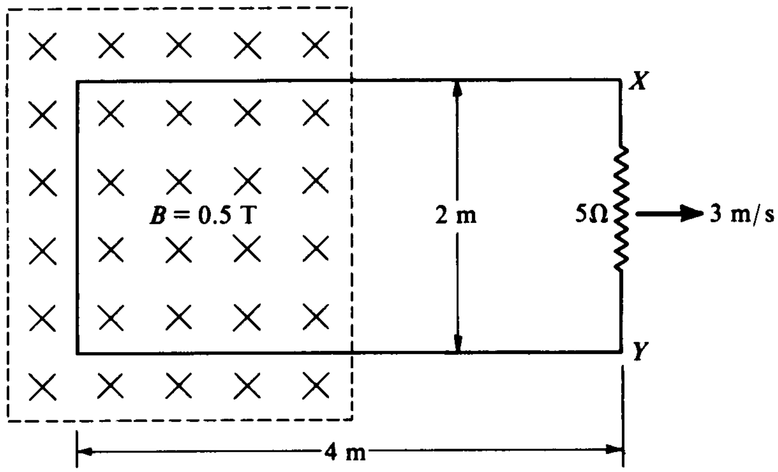
a)_____________

b. Calculate the magnitude of the emf induced in the loop during the time interval t = 0 to 2 seconds.

b)____________

c. On the axes below, graph the current I through the coil as a function of time t, and put appropriate numbers on the vertical scale. Use the convention that positive values of I represent counterclockwise current as viewed from above.





3) A wire loop, 2 meters by 4 meters, of negligible resistance is in the plane of the page with its left end in a uniform 0.5-tesla magnetic field directed into the page, as shown above. A 5-ohm resistor is connected between points X and Y. The field is zero outside the region enclosed by the dashed lines. The loop is being pulled to the right with a constant velocity of 3 meters per second. Make all determinations for the time that the left end of the loop is still in the field, and points X and Y are not in the field.

a. Determine the potential difference induced between points X and Y.

a)____________

b. On the figure above show the direction of the current induced in the resistor.

b)___________

c. Determine the force required to keep the loop moving at 3 meters per second.

c)____________

d. Determine the rate at which work must be done to keep the loop moving at 3 meters per second.

d)____________

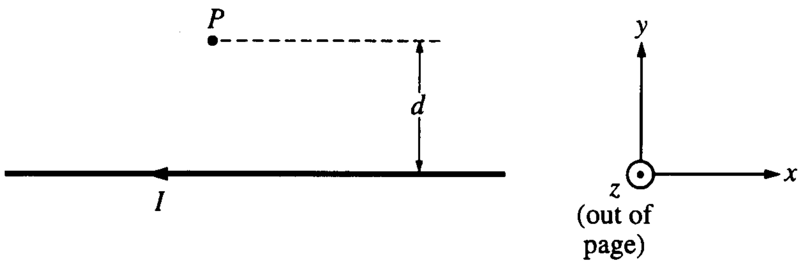


Figure 1

4) The long, straight wire shown in Figure 1 above is in the plane of the page and carries a current I. Point P is also in the plane of the page and is a perpendicular distance d from the wire. Gravitational effects are negligible.

a. With reference to the coordinate system in Figure 1, what is the direction of the magnetic field at point P due to the current in the wire?

a)________________

A particle of mass m and positive charge q is initially moving parallel to the wire with a speed v_0 when it is at point P, as shown in Figure 2 below.

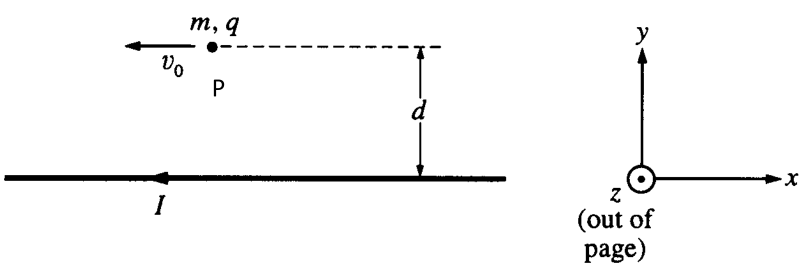


Figure 2

b. With reference to the coordinate system in Figure 2, what is the direction of the magnetic force acting on the particle at point P?

b)____________

c. Determine the magnitude of the magnetic force acting on the particle at point P in terms of the given quantities and fundamental constants.

c)________________

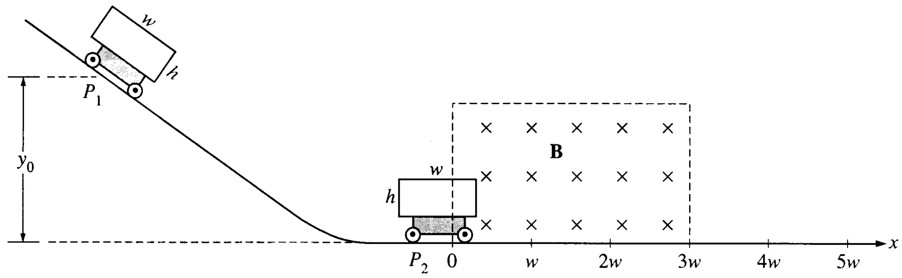
d. An electric field is applied that causes the net force on the particle to be zero at point P.

i. With reference to the coordinate system in Figure 2, what is the direction of the electric field at point P that could accomplish this?

i.)________________

ii. Determine the magnitude of the electric field in terms of the given quantities and fundamental constants.

ii.)__________________



5) A rectangular conducting loop of width w, height h, and resistance R is mounted vertically on a nonconducting cart as shown above. The cart is placed on the inclined portion of a track and released from rest at position P_1 at a height y_0 above the horizontal portion of the track. It rolls with negligible friction down the incline and through a uniform magnetic field **B** in the region above the horizontal portion of the track. The conducting loop is in the plane of the page, and the magnetic field is directed into the page. The loop passes completely through the field with a negligible change in speed. Express your answers in terms of the given quantities and fundamental constants.

a. Determine the speed of the cart when it reaches the horizontal portion of the track.

a)__________________

b. Determine the following for the time at which the cart is at position P_2, with one-third of the loop in the magnetic field.

i. The magnitude of the emf induced in the conducting loop

i.)________________

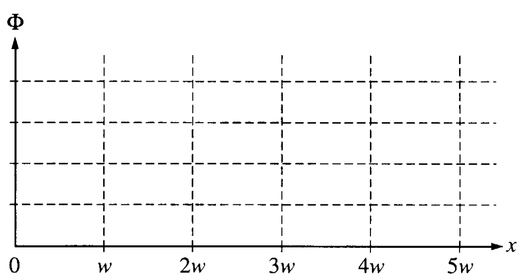
ii. The magnitude of the current induced in the conducting loop

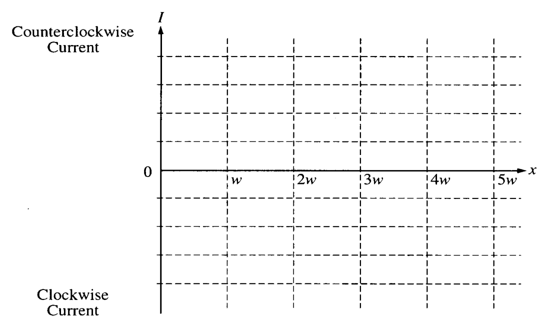
ii.)_______________

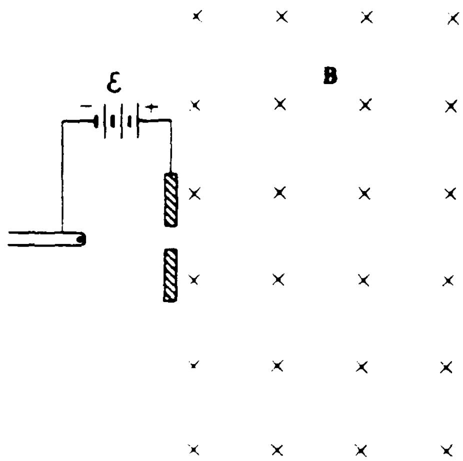
c. On the following diagram of the conducting loop, indicate the direction of the current when it is at Position P_2.

d. i. Using the axes below, sketch a graph of the magnitude of the magnetic flux ϕ through the loop as a function of the horizontal distance x traveled by the cart, letting x = 0 be the position at which the front edge of the loop just enters the field. Label appropriate values on the vertical axis.

ii. Using the axes below, sketch a graph of the current induced in the loop as a function of the horizontal distance x traveled by the cart, letting x = 0 be the position at which the front edge of the loop just enters the field. Let counterclockwise current be positive and label appropriate values on the vertical axis.







6) An electron from a hot filament in a cathode ray tube is accelerated through a potential difference ε. It then passes into a region of uniform magnetic field B, directed into the page as shown above. The mass of the electron is m and the charge has magnitude e.

a. Find the potential difference ε necessary to give the electron a speed v as it enters the magnetic field.

a)________________

b. On the diagram above, sketch the path of the electron in the magnetic field.

c. In terms of mass m, speed v, charge e, and field strength B, develop an expression for r, the radius of the circular path of the electron.

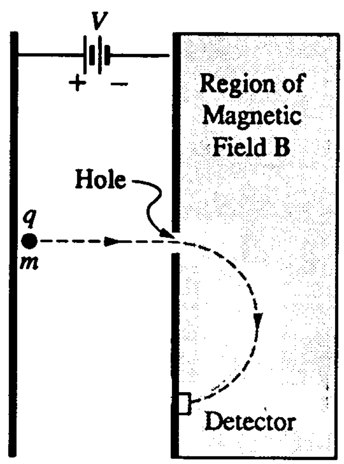
c)__________________

d. An electric field E is now established in the same region as the magnetic field, so that the electron passes through the region undeflected.

i. Determine the magnitude of E.

i)_________________

ii. Indicate the direction of E on the diagram above.



7) A particle of mass m and charge q is accelerated from rest in the plane of the page through a potential difference V between two parallel plates as shown above. The particle is injected through a hole in the right-hand plate into a region of space containing a uniform magnetic field of magnitude B oriented perpendicular to the plane of the page. The particle curves in a semicircular path and strikes a detector.

a. i. State whether the sign of the charge on the particle is positive or negative.

i.)_____________

ii. State whether the direction of the magnetic field is into the page or out of the page.

ii.)____________

b. Determine each of the following in terms of m, q, V, and B.

i. The speed of the charged particle as it enters the region of the magnetic field B

i.)__________________

ii. The force exerted on the charged particle by the magnetic field B

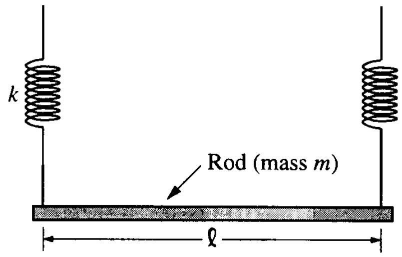
ii.)__________________

iii. The distance from the point of injection to the detector

iii.)__________________

iv. The work done by the magnetic field on the charged particle during the semicircular trip

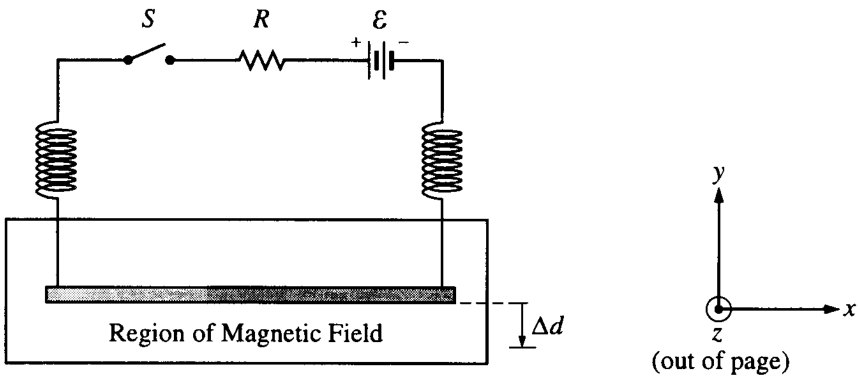
iv)_________________



8) A rigid rod of mass m and length ℓ is suspended from two identical springs of negligible mass as shown in the diagram above. The upper ends of the springs are fixed in place and the springs stretch a distance h under the weight of the suspended rod.

a. Determine the spring constant k of each spring in terms of the other given quantities and fundamental constants.

a)__________________



As shown above, the upper end of the springs are connected by a circuit branch containing a battery of emf, ε, and a switch S so that a complete circuit is formed with the metal rod and springs. The circuit has a total resistance R, represented by the resistor in the diagram. The rod is in a uniform magnetic field directed perpendicular to the page. The upper ends of the springs remain fixed in place and the switch S is closed. When the system comes to equilibrium, the rod is lowered an additional distance Δd.

b. What is the direction of the magnetic field relative to the coordinate axes shown on the right in the previous diagram?

b)_____________

c. Determine the magnitude of the magnetic field in terms of m, h, Δd, ε, R, ℓ and fundamental constants.

c)____________________

d. When the switch is suddenly opened, the rod oscillates. For these oscillations, determine the following quantities in terms of h, Δd, and fundamental constants:

i. The period i.)____________________

ii. The maximum speed of the rod ii.)____________________