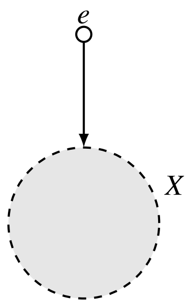
Student #: ___________________________ Student Name: __________________________________

AP PHYSICS C: MAGNETISM, PART 1

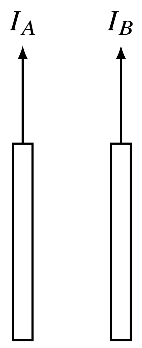
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

1. An electron is moving downward toward the bottom of the page when it passes through a region of magnetic field, as shown in the figure by the shaded area. The electron travels along a path that takes it through the spot marked X. The gravitational force on the electron is very small. What is the direction of the magnetic field?



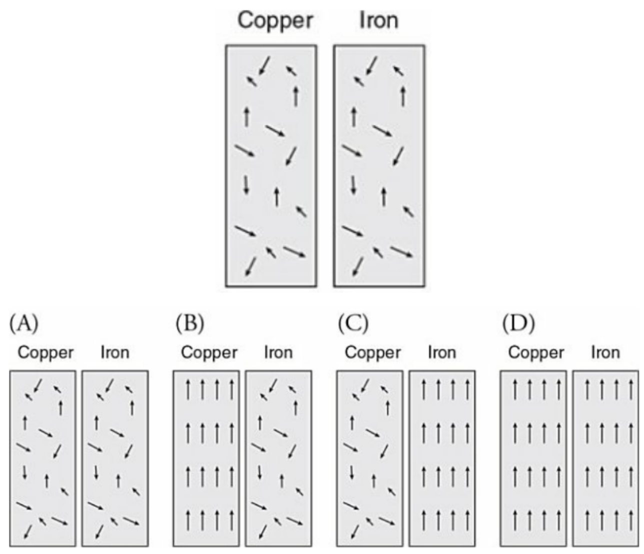
(A) Toward the bottom of the page
(B) Toward the top of the page
(C) Out of the page
(D) Into the page

2. Two long parallel wires carry currents (I_A and I_B), as shown in the figure. Current I_A in the left wire is twice that of current I_B in the right wire. The magnetic force on the right wire is F. What is the magnetic force on the left wire in terms of F?

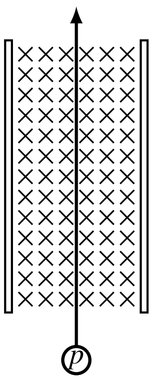


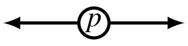
(A) F in the same direction
(B) F in the opposite direction
(C) $F/2$ in the same direction
(D) $F/2$ in the opposite direction

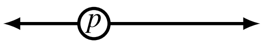
3. The figure below shows the microscopic dipoles inside two metal objects. Copper is diamagnetic. Iron is ferromagnetic. Which of the following best depicts the microscopic internal dipole position when the objects are placed in a strong, external magnetic field directed toward the top of the page?

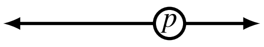


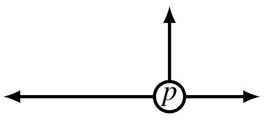
4. A magnetic field, directed into the page, is placed between two charged capacitor plates, as shown in the figure. The magnetic and electric fields are adjusted so a proton moving at a velocity of v will pass straight through the fields. The speed of the proton is doubled to $2v$. Which of the following force diagrams most accurately depicts the forces acting on the proton when traveling at $2v$?



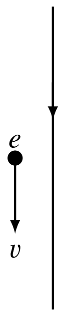
(A) 

(B) 

(C) 

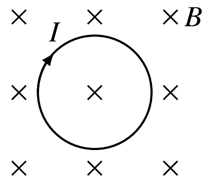
(D) 

5. Which of the following is true concerning the force on the current-carrying wire due to the electron?



(A) The force is directed toward the right.
(B) The force is directed toward the left.
(C) The force is directed into the page.
(D) There is no force on the current-carrying wire due to the electron.

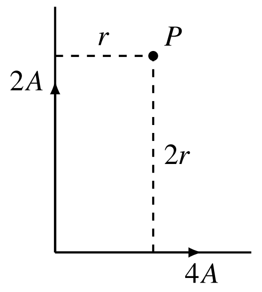
6. A loop of wire in the plane of the page carries a clockwise current I and is placed in a magnetic field that is directed into the page as shown. Which of the following will happen as a result of the wire loop being in the magnetic field?



(A) The wire loop will rotate clockwise.
(B) The wire loop will rotate counterclockwise.
(C) The wire loop will flip on a horizontal axis through its center.
(D) The wire loop will expand in size.
(E) The wire loop will contract in size.

Questions 7–8

Two wires carry currents $2A$ and $4A$ in the directions shown. Point P is a distance r from the wire carrying $2A$, and a distance $2r$ from the wire carrying $4A$.



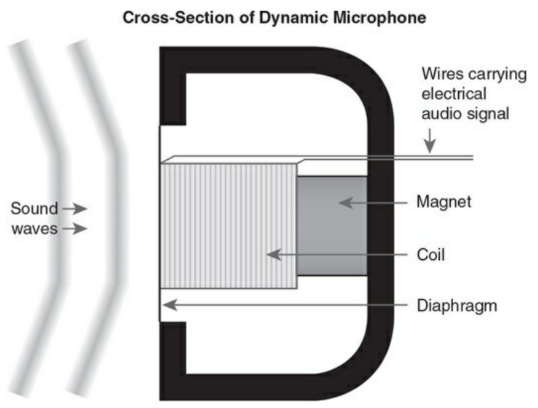
7. Which of the following statements is true?

   (A) The magnetic field produced at point P by the wire carrying $2A$ is greater than the magnetic field produced at point P by the wire carrying $4A$, but opposite in direction.
   (B) The magnetic field produced at point P by the wire carrying $2A$ is less than the magnetic field produced at point P by the wire carrying $4A$, and in the same direction.
   (C) The magnetic field produced at point P by the wire carrying $2A$ is equal to the magnetic field produced at point P by the wire carrying $4A$, but opposite in direction.
   (D) The magnetic field produced at point P by the wire carrying $2A$ is equal to the magnetic field produced at point P by the wire carrying $4A$, and in the same direction.
   (E) The magnetic field produced at point P by the wire carrying $2A$ is greater than the magnetic field produced at point P by the wire carrying $4A$, and in the same direction.

8. The magnitude of the resultant magnetic field at point P due to the current in the two wires is

   (A) zero
   (B) $\dfrac{\mu_0(2A)}{2\pi r}$
   (C) $\dfrac{\mu_0(2A)}{\pi r}$
   (D) $\dfrac{\mu_0(4A)}{2\pi r}$
   (E) $\dfrac{\mu_0(6A)}{4\pi r}$

9. A dynamic microphone contains a magnet and a coil of wire connected to a movable diaphragm, as shown in the figure. Sound waves directed at the diaphragm generate a current in the wires leading from the coil. Which of the following helps to explain why this occurs?



   (A) The area of the coil changes.
   (B) The magnitude of the magnetic field produced by the magnet changes.
   (C) The angle between the plane of the coil and the magnetic field produced by the magnet change.
   (D) The strength of the magnetic field in the plane of the coil changes.

Questions 10–11

Two wires are parallel to each other, one carrying twice the current as the other. The two currents flow in the same direction.

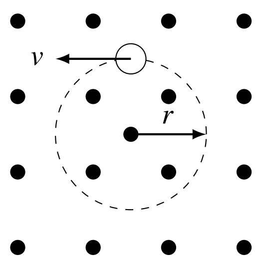
10. Which of the following is true of the forces the wires exert on each other?

    (A) The wire with the larger current exerts a greater force on the other wire.
    (B) The wire with the smaller current exerts a greater force on the other wire.
    (C) The wires exert equal and opposite forces on each other.
    (D) The wires exert equal forces on each other, but in the same direction.
    (E) The net force between the wires is zero.

11. The direction of the force between the wires is

    (A) repulsive
    (B) attractive
    (C) zero
    (D) into the page
    (E) out of the page

Questions 12–13 A negatively charged particle of mass m and charge q in a uniform magnetic field B travels in a circular path of radius r.



12. In terms of the other given quantities, the charge-to-mass ratio q/m of the particle is

    (A) $\dfrac{Bv}{r}$
    (B) $\dfrac{r}{Bv}$
    (C) $\dfrac{rv}{B}$
    (D) rvB
    (E) $\dfrac{v}{rB}$

13. The work done by the magnetic field after two full revolutions of the charge is

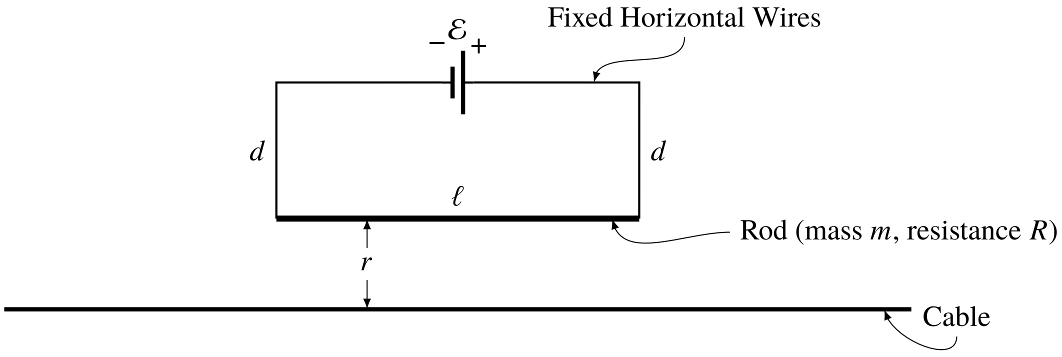
    (A) zero
    (B) $-qvB/rm$
    (C) qvm/Br
    (D) $-mBr/qv$
    (E) $-mqvBr$

14. A current is passed through an analog ammeter and the needle moves to indicate the current flowing through the circuit. Which of the following best explains how an analog ammeter works?

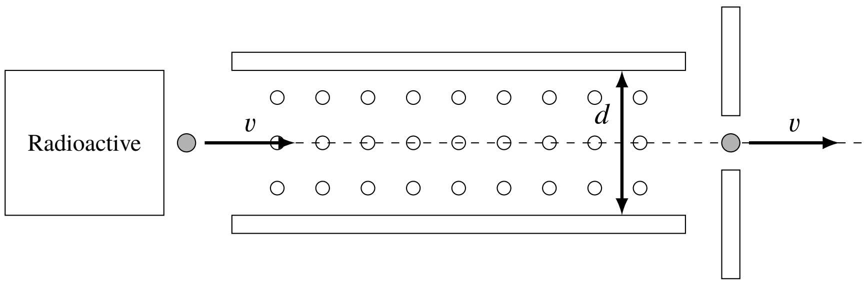
    (A) Current is passed through the needle placed in a magnetic field, and the needle is attracted to the high side of the scale.
    (B) The needle is a magnet, and is attracted to a magnet on the high side of the scale.
    (C) The needle gathers an electrostatic charge from the current, and is attracted to an electrostatic charge on the high side of the scale.
    (D) Current is passed through a spring coil of wire placed in a magnetic field, and the coil rotates, moving the needle proportionally to the current in the coil.
    (E) Current flows through the needle, making it heavier, and it falls to the high side of the scale.

AP PHYSICS C: MAGNETISM
SECTION II
8 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.



1. The circuit shown above consists of a battery of emf $\mathcal{E}$ in series with a rod of length ℓ, mass m, and resistance R. The rod is suspended by vertical connecting wires of length d, and the horizontal wires that connect to the battery are fixed. All these wires have negligible mass and resistance. The rod is a distance r above a conducting cable. The cable is very long and is located directly below and parallel to the rod. Earth's gravitational pull is toward the bottom of the page. Express all algebraic answers in terms of the given quantities and fundamental constants.
   (a) What is the magnitude and direction of the current I in the rod?
   (b) In which direction must there be a current in the cable to exert an upward force on the rod? Justify your answer.
   (c) With the proper current in the cable, the rod can be lifted up such that there is no tension in the connecting wires. Determine the minimum current I_c in the cable that satisfies this situation.



2. A lead box containing radioactive materials that emit both electrons and positrons is placed near an apparatus consisting of an evacuated capacitor that is filled with a magnetic field, as shown in the figure above. Electrons that enter along the center line of the capacitor plates travel straight through (undeflected) with a velocity of $v = 1.0 \times 10^7$ m/s and out the hole in the center of the apparatus on the right. The capacitor plates are separated by a distance of $d = 0.020$ m; each plate has an area of $A = 1.0 \times 10^{-4}$ m^2 and a potential difference of ΔV. A uniform magnetic field of $B = 0.030$ T is directed out of the page between the plates, as shown in the figure.

   (a) Explain why it is acceptable to neglect the effects of gravity on the electrons passing through the apparatus.

   (b) i. Explain why the electrons pass through the capacitor plates undeflected. Support your argument with an algebraic equation and an appropriately drawn force diagram.

   ii. Use your equation to calculate the potential difference (ΔV) between the capacitor plates.

   iii. Which capacitor plate has the highest potential? Justify your reasoning making reference to the electric field.

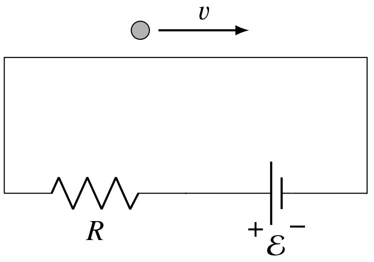
   iv. Calculate the magnitude of the energy that is stored in the capacitor.

   (c) A positron enters the apparatus along the same path as the electrons from part (b).

   i. Explain why the positron, traveling at the same speed as the electrons, will also travel straight through the device undeflected. Support your argument with an equation.

   ii. A second positron enters the apparatus at a speed of $2v$. Sketch the path of the positron through the capacitor plates on the figure.

   (d) An electron exits the apparatus at a velocity of $v = 1.0 \times 10^7$ m/s parallel to a long wire of a circuit, as shown in the figure. The distance between the electron and the wire is 1 mm.



   i. Calculate the potential difference-to-resistance ratio of the circuit such that the electron will experience a force F of 1.3×10^{-16} N.

   ii. Draw a force vector on the figure to show the direction of the force on the electron.

3. A section of a long conducting cylinder with inner radius a and outer radius b carries a current I_0 that has a uniform current density, as shown in the figure above.

   (a) Using Ampère's law, derive an expression for the magnitude of the magnetic field in the following regions as a function of the distance r from the central axis.

   i. $r < a$

   ii. $a < r < b$

   iii. $r = 2b$

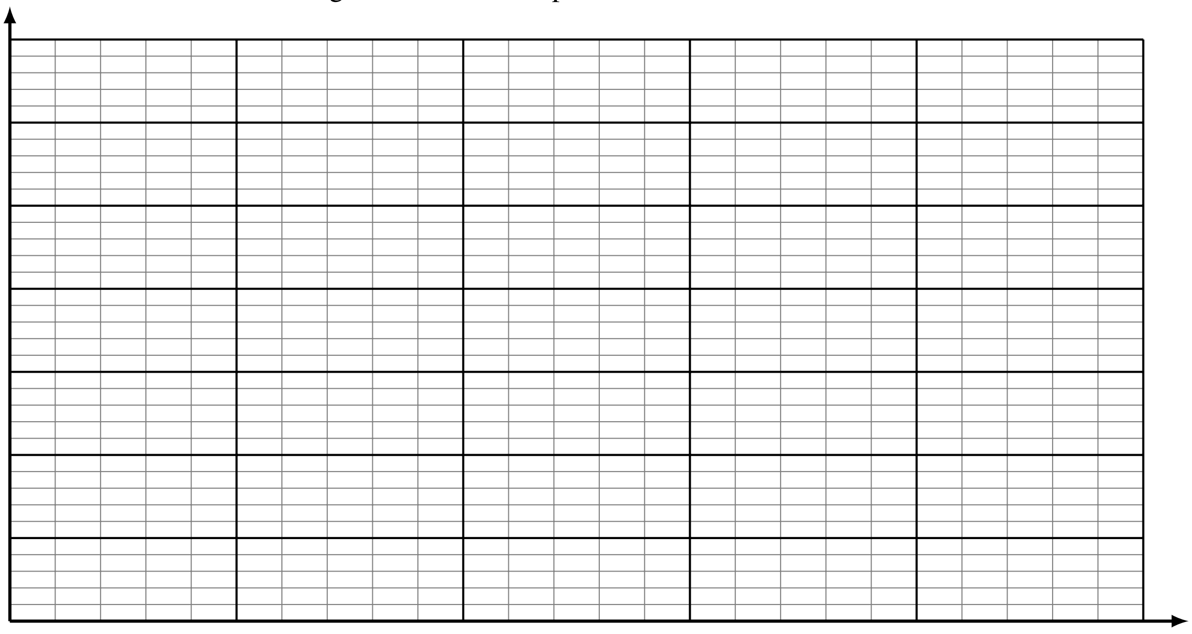
   (b) On the cross-sectional view in the diagram above, indicate the direction of the field at point P, which is at a distance $r = 2b$ from the axis of the cylinder.

   (c) An electron is at rest at point P. Describe any electromagnetic forces acting on the electron. Justify your answer.

Now consider a long, solid conducting cylinder of radius b carrying a current I_0. The magnitude of the magnetic field inside this cylinder as a function of r is given by $B = \mu_0 I_0 r / 2\pi b^2$. An experiment is conducted using a particular solid cylinder of radius 0.010 m carrying a current of 25 A. The magnetic field inside the cylinder is measured as a function of r, and the data is tabulated below.

Distance r (m)	0.002	0.004	0.006	0.008	0.010
Magnetic Field B (T)	1.2×10^{-4}	2.7×10^{-4}	3.6×10^{-4}	4.7×10^{-4}	6.4×10^{-4}

(d) i. On the graph below, plot the data points for the magnetic field B as a function of the distance r, and label the scale on both axes. Draw a straight line that best represents the data.



ii. Use the slope of your line to estimate a value of the permeability μ_0.