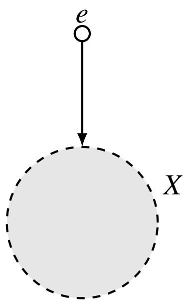
Student #: ____________________________ Student Name: ___________________________________

AP PHYSICS 2: MAGNETISM

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.

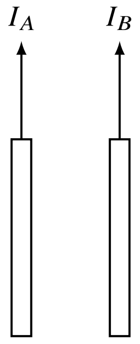
Note: To simplify calculations, you may use $g = 10\,\mathrm{m/s^2}$ in all problems.

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?

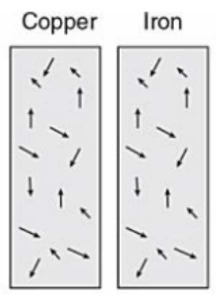


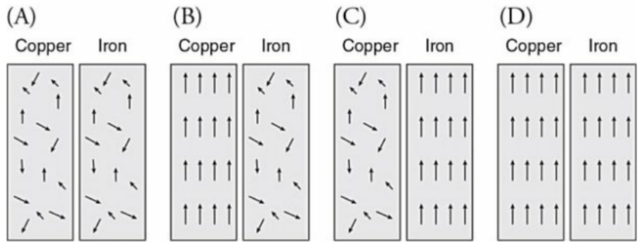
(A) F in the same direction
(B) F in the opposite direction
(C) $F/2$ in the same direction
(D) $F/2$ in the opposite direction

3. An iron magnet is broken in half at the midpoint between its north andsouth ends. What is the result?

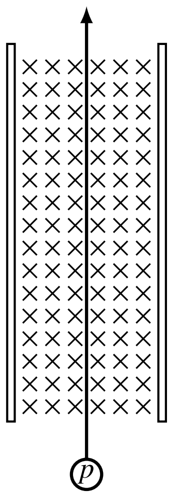
(A) A separate north pole and south pole, each with the same magnetic strength as the original magnet
(B) A separate north pole and south pole, each with half the magnetic strength of the original magnet
(C) Two separate north-south magnets, each with the same magnetic strength as the original magnet
(D) Two separate north-south magnets, each with half the magnetic strength of the original magnet

4. 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?

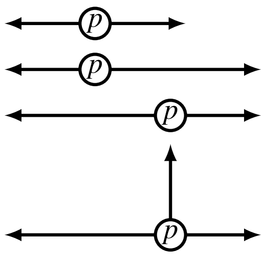




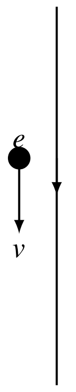
5. A magnetic field, directed into the page, is placed between two charged capacitor plates, as shown in the figure. The magnetic and electric fields are adjusted so a proton moving at a velocity of v will pass straight through the fields. The speed of the proton is doubled to $2v$. Which of the following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



(A)
(B)
(C)
(D)

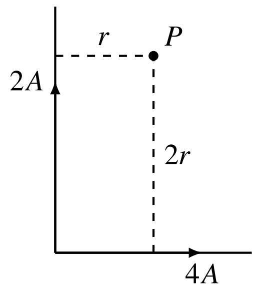


6. Which of the following is true concerning the force on the current-carrying wire due to the electron?



(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.

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) $\dfrac{\mu_0(6A)}{4\pi r}$

Questions 9–10 Two wires are parallel to each other, one carrying twice the current as the other. The two currents flow in the same direction.

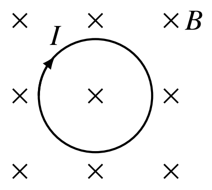
9. Which of the following is true of the forces the wires exert on each other?

(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.

10. The direction of the force between the wires is

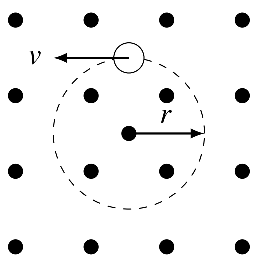
(A) repulsive
(B) attractive
(C) zero
(D) into the page
(E) out of the page

11. 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 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.



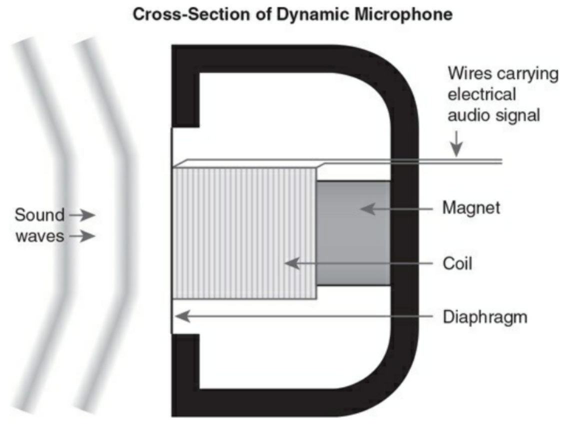
12. In terms of the other given quantities, the charge-to-mass ratio q/m of the particle is

(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 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?

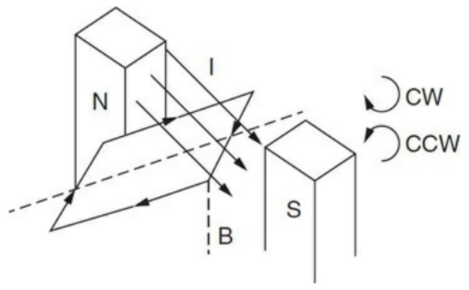


(A) The area of the coil changes.
(B) The magnitude of the magnetic field produced by the magnet changes.
(C) The angle between the plane of the coil and the magnetic field produced by the magnet change.
(D) The strength of the magnetic field in the plane of the coil changes.

15. 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.

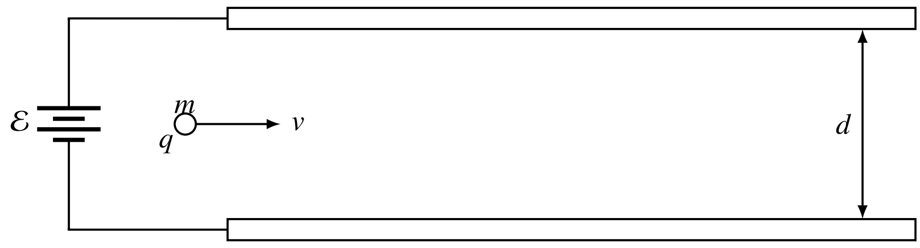
16. An electric motor consists of a current-carrying loop of wire mounted to an axle and turned at a slight angle in a magnetic field as shown. The wire loop will



(A) experience a torque and turn clockwise
(B) experience a torque and turn counterclockwise
(C) accelerate upward out of the magnetic field
(D) accelerate downward out of the magnetic field
(E) not experience a force or torque

AP PHYSICS 2: MAGNETISM
SECTION II
5 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. A positively charged particle (q) of mass m travels horizontally, with a velocity of v, through the center of two capacitor plates. The plates areseparated by a distance of d and connected to a battery of potential difference ($\mathcal{E}$), as shown in the figure.

   (a) Sketch the electric field between the plates.

   (b) Derive an algebraic expression for the electric field between the plates in terms of given quantities. Show all your work.

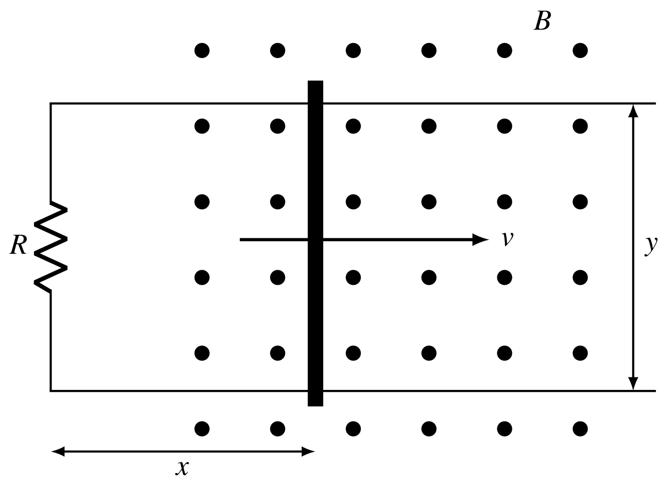
   (c) Describe the motion of the particle as it passes through the capacitor plates. What shape is the path? Which direction is the acceleration?

   (d) What direction of magnetic field is needed to make the particle travel horizontally straight through the capacitor plates?

   (e) Derive an algebraic expression for the magnitude of the magnetic field needed to cause this straight, horizontal motion between the plates in terms of given quantities. Show all your work.

   (f) The crossed electric and magnetic fields are adjusted to cause positively charged particles with a velocity of vto travel straight. What happens to a particle traveling at $2v$? Will it travel straight, or will it curve? If it curves, indicate which way it will curve, and explain why. If it continues to travel straight, explain why.

   (g) The crossed electric and magnetic fields are tuned to cause positively charged particles with a velocity of vto travel straight. What happens to a negatively charged particle traveling at v? Will it travel straight, or will it curve? If it curves, indicate which way it will curve, and explain why. If is continues to travel straight, explain why.

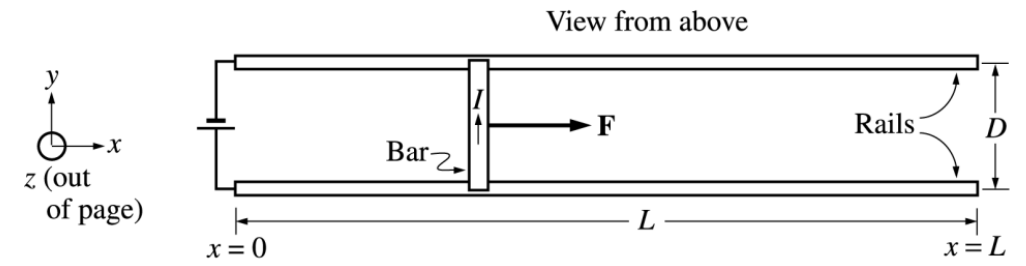


2. Two long parallel wires, separated by a distance of y, pass through a region of magnetic field (B). The two wires are connected by a resistor (R) and a metal bar, separated by a distance of x, to produce a circuit loop, as shown in the figure. The metal bar slides along the wires to the right at a velocity of v.

   (a) Calculate the induced emf (e) in the bar in terms of the given quantities.

   (b) Calculate the current in the circuit in terms of the given quantities.

   (c) What is the direction of the current in the resistor–upward or downward?



3. A rail gun is a device that propels a projectile using a magnetic force. A simplified diagram of this device is shown above. The projectile in the picture is a bar of mass M and length D, which has a constant current I flowing through it in the $+y$-direction, as shown. The space between the thin frictionless rails contains a uniform magnetic field $\mathbf{B}$, perpendicular to the plane of the page. The magnetic field and rails extend for a distance L. The magnetic field exerts a constant force $\mathbf{F}$ on the projectile, as shown.

   Express all algebraic answers to the following parts in terms of the magnitude F of the constant magnetic force, other quantities given above, and fundamental constants.

   (a) Determine the position x of the projectile as a function of time t while it is on the rail if the projectile starts from rest at $x = 0$ when $t = 0$.

   (b) Determine the speed of the projectile as it leaves the right-hand end of the track.

   (c) Determine the energy supplied to the projectile by the rail gun.

   (d) In what direction must the magnetic field $\mathbf{B}$ point in order to create the force $\mathbf{F}$? Explain your reasoning.

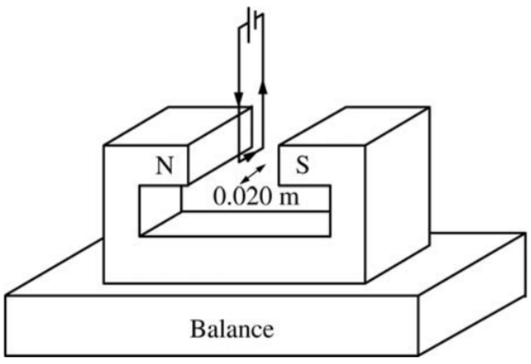
   (e) Calculate the speed of the bar when it reaches the end of the rail given the following values.

   $B = 5\,\mathrm{T}$ $\quad L = 10\,\mathrm{m}$ $\quad I = 200\,\mathrm{A}$ $\quad M = 0.5\,\mathrm{kg}$ $\quad D = 10\,\mathrm{cm}$

4. A rectangular wire loop is connected across a power supply with an internal resistance of $0.50\,\Omega$ and an emf of $16\,\text{V}$. The wire has resistivity $1.7 \times 10^{-8}\,\Omega \cdot \text{m}$ and cross-sectional area $3.5 \times 10^{-9}\,\text{m}^2$. When the power supply is turned on, the current in the wire is $4.0\,\text{A}$.

   (a) Calculate the length of wire used to make the loop.

   The wire loop is then used in an experiment to measure the strength of the magnetic field between the poles of a magnet. The magnet is placed on a digital balance, and the wire loop is held fixed between the poles of the magnet, as shown below. The $0.020\,\text{m}$ long horizontal segment of the loop is midway between the poles and perpendicular to the direction of the magnetic field. The power supply in the loop is turned on, so that the $4.0\,\text{A}$ current is in the direction shown.



Note: Figure not drawn to scale.

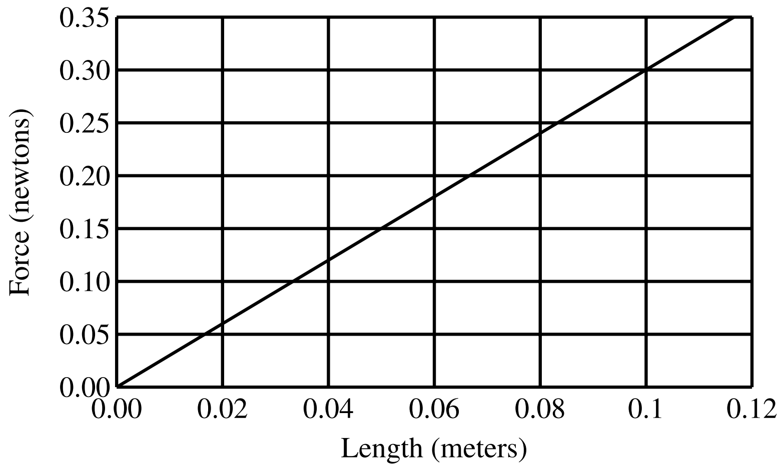
   (b) In which direction is the force on the magnet due to the current in the wire segment?

   _____ Upward   _____ Downward

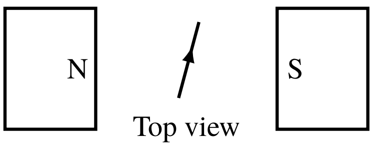
   Justify your answer.

   (c) The reading on the balance changed by $0.060\,\text{N}$ when the power supply was turned on. Calculate the strength of the magnetic field.

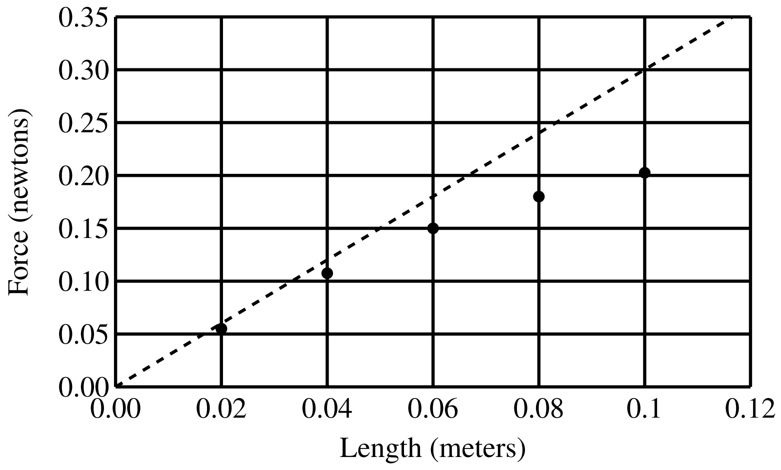
Suppose that various rectangular loops with the same total length of wire as found in part (a) were constructed such that the lengths of the horizontal segments of the wire loops varied between 0.02 m and 0.10 m. The horizontal segment of each loop was always centered between the poles, and the current in each loop was always 4.0 A. The following graph represents the theoretical relationship between the magnitude of the force on the magnet and the length of the wire.

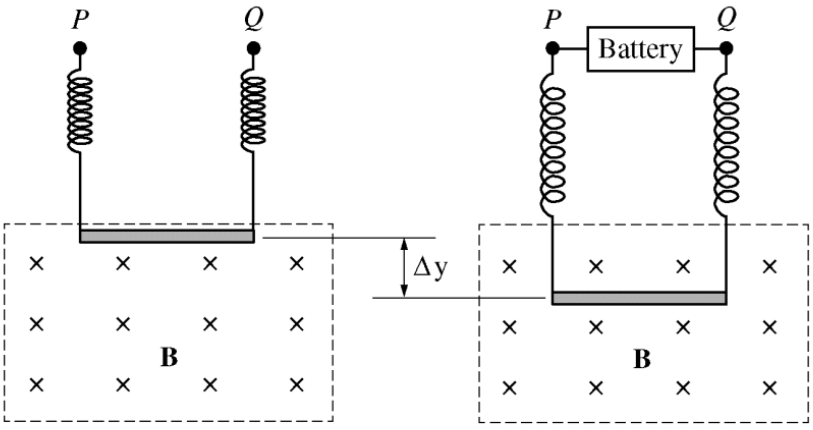


(d) On the graph above, sketch a possible relationship between the magnitude of the force on the magnet and the length of the wire segment if the wire segments were misaligned and placed at a constant nonperpendicular angle to the magnetic field, as shown below.



(e) Suppose the loops are correctly placed perpendicular to the field and the following data are obtained. Describe a likely cause of the discrepancy between the data and the theoretical relationship.





No Battery   Battery Connected

5. A conducting rod of mass m and length L hangs at rest from two identical conducting springs, each with spring constant k, as shown in the figure at left above. The upper ends of the springs are fixed at points P and Q, and the rod is in a uniform magnetic field $\mathbf{B}$ directed into the page. A battery is then connected between points P and Q, as shown in the figure at right above, resulting in a current I in the rod. The rod is displaced downward, eventually reaching a new equilibrium position with the springs stretched an additional distance Δy.

   (a) Which point, P or Q, is connected to the positive terminal of the battery?

   _______ P   _______ Q

   Justify your answer.

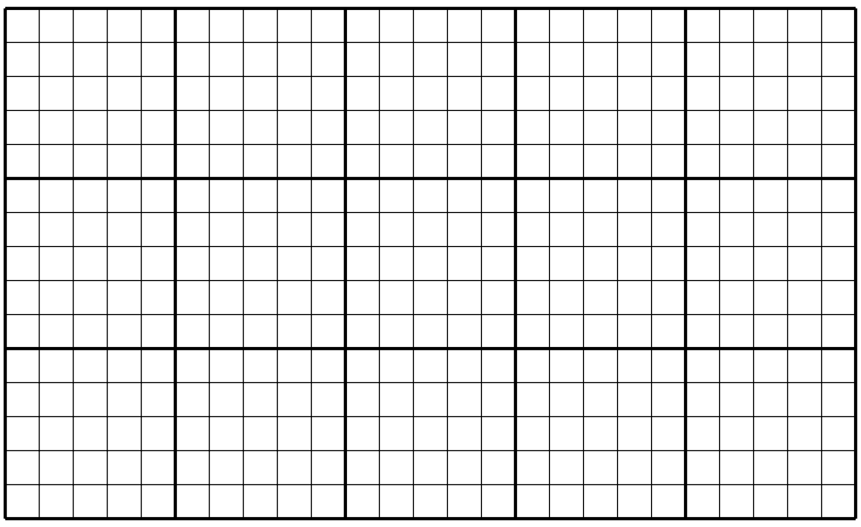
   (b) On the dot below that represents the rod, draw and label the forces (not components) that act on the rod in its new equilibrium position. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

   (c) Derive an expression for Δy in terms of k, m, L, I, the magnetic field strength B, and fundamental constants, as appropriate.

An experiment is conducted with batteries of different emf connected between points P and Q. The current I in the rod and the stretch of the springs Δy are measured and recorded in the table below.

I (amperes)	Δy (meters)
1.0	0.0028
2.0	0.0050
3.0	0.0084
4.0	0.0119
5.0	0.0140

(d) On the grid below, plot the data points for Δy as a function of I. Be sure to label your axes with variables, units, and scale. Draw a straight line that best represents the data.



(e) Using the straight line you drew in part (d), calculate the value B for the magnetic field if m is 0.019 kg, L is 0.35 m, and k is 25 N/m.