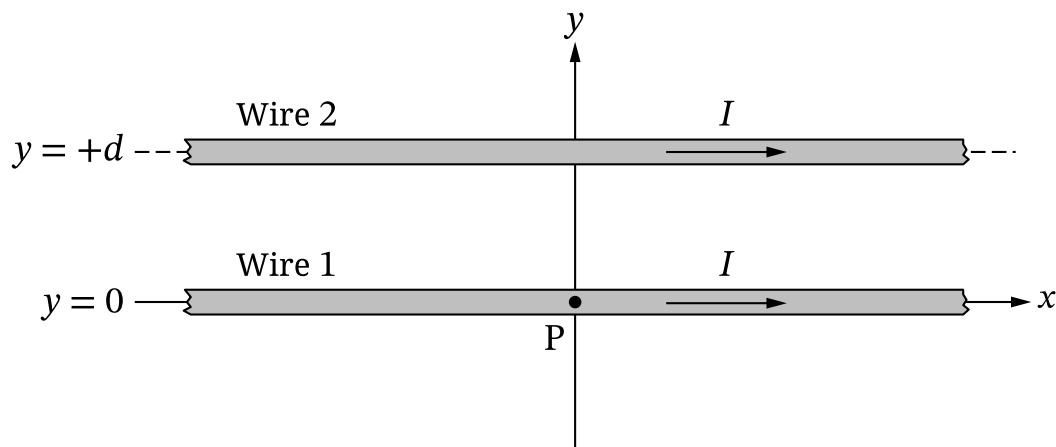


Question 1: Version J

1. Very long Wire 1 carries current I in the $+x$ -direction along the line $y = 0$. Very long Wire 2 carries current I in the $+x$ -direction along the line $y = +d$. Point P is located along Wire 1 at the origin, as shown in Figure 1. The diameters of the wires are small compared to the distance between the wires. Both wires are in the xy -plane.

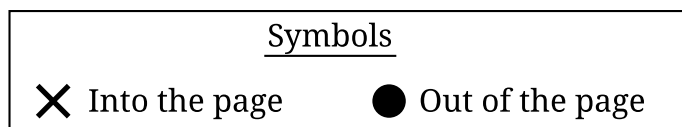
Figure 1

Note: Figure not drawn to scale.

A.

i. Complete the following tasks in figures 2 and 3. Use either arrows or the symbols shown in the box above the figures for your response.

- **Indicate** the direction of the magnetic field from Wire 2 at Point P in Figure 2.
- **Indicate** the direction of the magnetic force that is exerted on Wire 1 by Wire 2 in Figure 3.



Magnetic Field from
Wire 2 at Point P

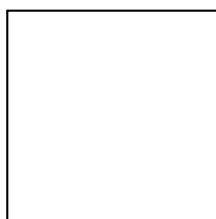


Figure 2

Magnetic Force on Wire 1
by Wire 2

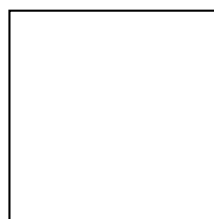


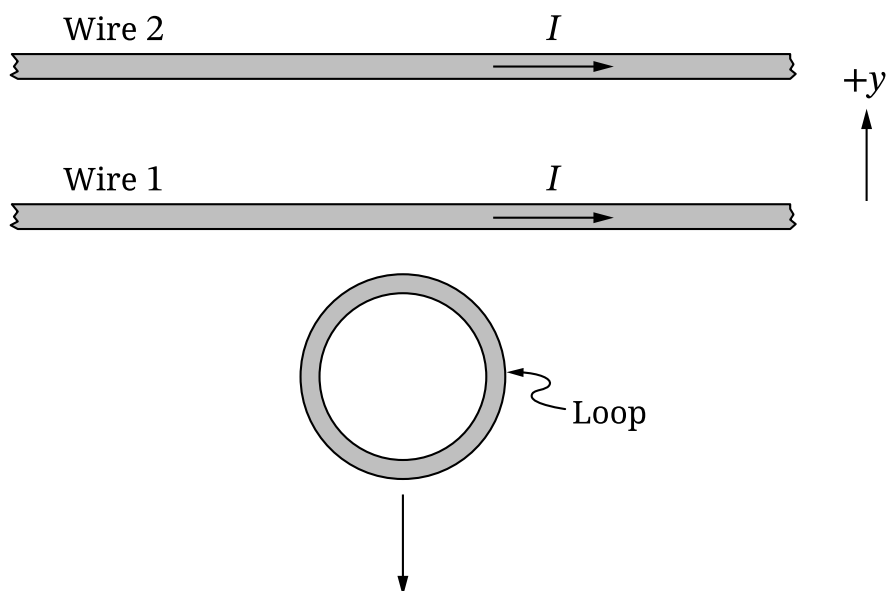
Figure 3

ii. Very long Wire 3 carrying current $2I$ in the $+x$ -direction is placed in the xy -plane along the line $y = y_3$. The net magnetic force exerted on Wire 1 by the currents in wires 2 and 3 is zero.

Derive an expression for y_3 in terms of d . Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

- B. Wire 3 is moved very far away from wires 1 and 2. A circular conducting loop in the xy -plane is initially held at rest below Wire 1. The loop is then moved at a constant speed in the $-y$ -direction, as shown in Figure 4.

Figure 4



Note: Figure not drawn to scale.

Indicate whether there is a clockwise induced current in the loop, a counterclockwise induced current in the loop, or no induced current in the loop.

_____ Clockwise

_____ Counterclockwise

_____ There is no induced current in the loop.

Justify your answer.

Begin your response to **QUESTION 4** on this page.

4. (10 points, suggested time 20 minutes)

Two particles, 1 and 2, have different mass and charge as described by the following.

- Particle 1 has mass M and negative charge $-Q$.
- Particle 2 has mass $\frac{M}{2}$ and positive charge $+2Q$.

In separate trials, a device is used to accelerate each particle in the $-y$ -direction from rest through a potential difference of absolute value $|\Delta V|$. The polarity of the potential difference can be adjusted so that a particle with either positive charge or negative charge can be accelerated in the $-y$ -direction by the device. Gravitational effects are negligible.

After moving through the potential difference, particles 1 and 2 exit the device with kinetic energies K_1 and K_2 , respectively.

(a) **Calculate** the ratio $\frac{K_2}{K_1}$.

GO ON TO THE NEXT PAGE.

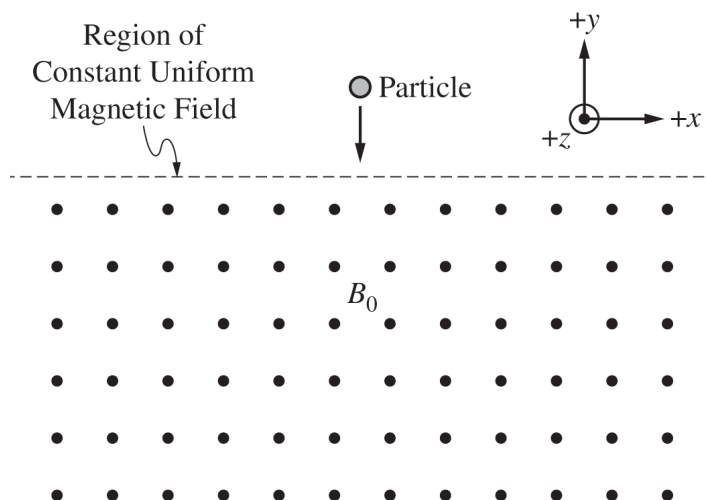
Continue your response to **QUESTION 4** on this page.

Figure 1

After exiting the device, the particles enter a large region of constant uniform magnetic field of magnitude B_0 that is directed in the $+z$ -direction (out of the page), as shown in Figure 1. Each particle is moving in the $-y$ -direction when entering the region, and each particle is moving in the $+y$ -direction when exiting the region.

(b)

i. **Determine** an expression for the speed of Particle 2 in the region. Express your answer in terms of M , K_2 , and physical constants, as appropriate.

ii. **Derive** an expression for the horizontal distance Δx between the locations where Particle 2 enters and leaves the region. Express your answer in terms of M , Q , K_2 , B_0 , and physical constants, as appropriate.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 4** on this page.

- (c) On the following diagram in Figure 2, **sketch** and clearly **label** the paths of both particles 1 and 2 in the region.

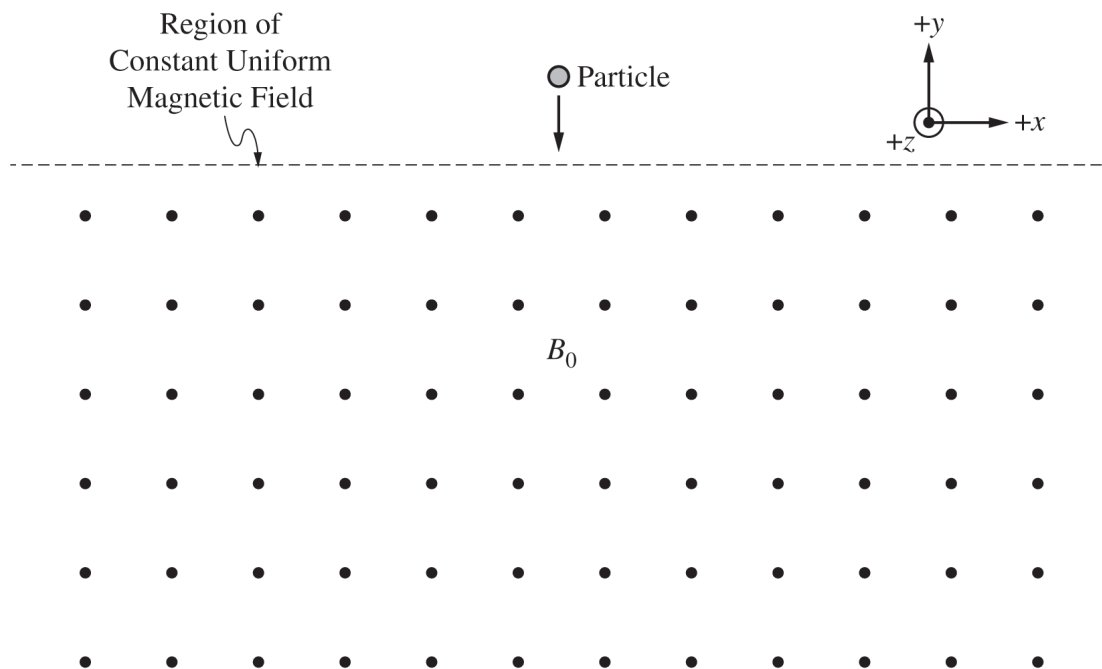


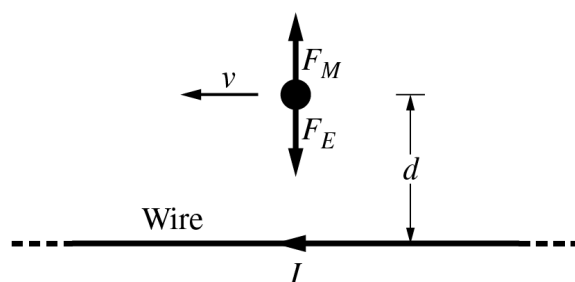
Figure 2

- (d) A uniform electric field is added to the region such that Particle 1 of negative charge $-Q$ travels with constant speed in a straight line through the region. **Determine** the direction of the electric field.

GO ON TO THE NEXT PAGE.

STOP

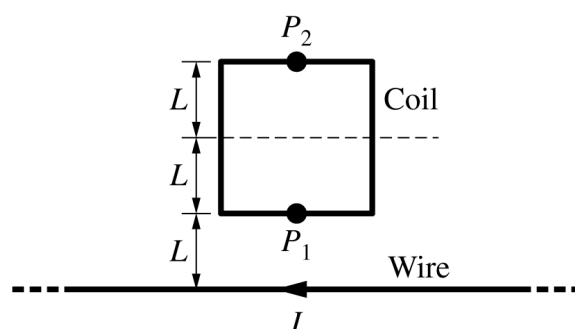
END OF EXAM



(10 points, suggested time 20 minutes)

At the instant shown above, a negatively charged object is moving to the left with constant velocity v near a long, straight wire that has a current I directed to the left. The region contains a uniform electric field of magnitude E , and the charged object is at a distance d from the wire. The figure shows the electric and magnetic forces, F_E and F_M , respectively, exerted on the charged object.

(a) Derive an expression for v in terms of E , d , I , and physical constants, as appropriate.



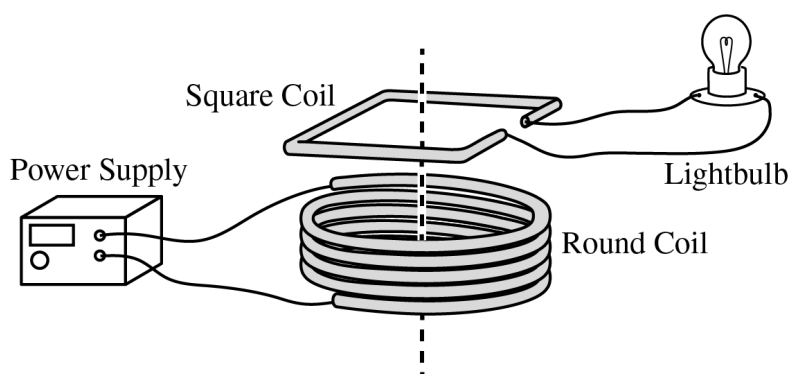
(b) The charged object is removed, and a square coil with side length $2L$ is placed near the long, straight wire, as shown above. The bottom of the coil is a distance L from the wire. The magnitude of the magnetic field due to the current in the wire is $3B_0$ at point P_1 and B_0 at point P_2 .

i. Write an "X" at a location on the figure where the magnitude of the magnetic field is $2B_0$. Briefly justify your reasoning.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 4** on this page.

- ii. Over a time interval of 2.0 s, the current in the wire is decreased. The initial magnetic flux through the coil is $5.0 \times 10^{-5} \text{ T} \cdot \text{m}^2$ and the final magnetic flux through the coil is $1.0 \times 10^{-5} \text{ T} \cdot \text{m}^2$. The coil has a total resistance of $10 \, \Omega$. Calculate the magnitude of the average current in the coil during the 2.0 s time interval.



The wire is removed and the square coil is positioned so that the coil is directly above and concentric with a round coil of wire connected to a power supply. A part of the square coil is removed and a lightbulb is connected to the coil, as shown above.

- (c) During a short time interval, the current in the power supply is constantly increasing. Use physics principles to explain why the lightbulb is lit during the entire time interval.

GO ON TO THE NEXT PAGE.

STOP

END OF EXAM