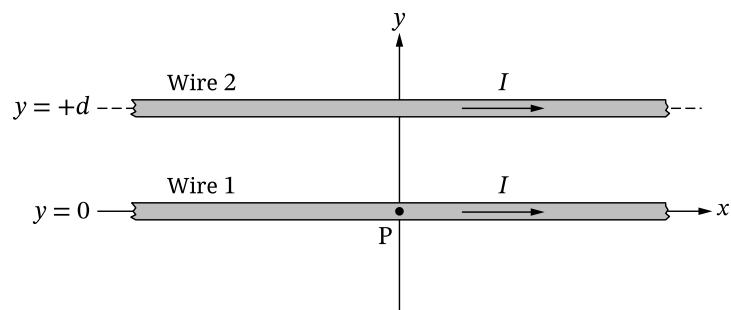


Question 1: Version J

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.

Symbols

✕ Into the page ● Out of the page

Magnetic Field from
Wire 2 at Point P



Figure 2

Magnetic Force on Wire 1
by Wire 2



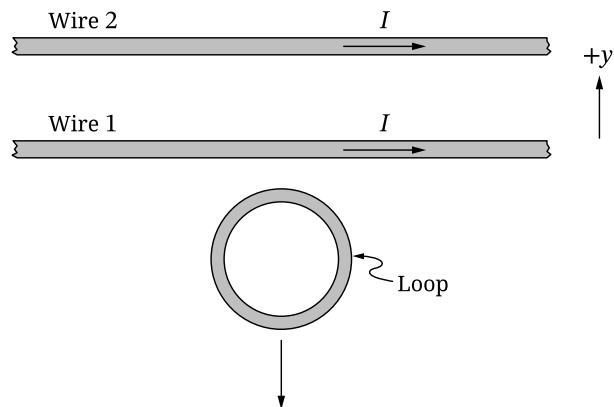
Figure 3

- 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 $\frac{K_2}{K_1}$.

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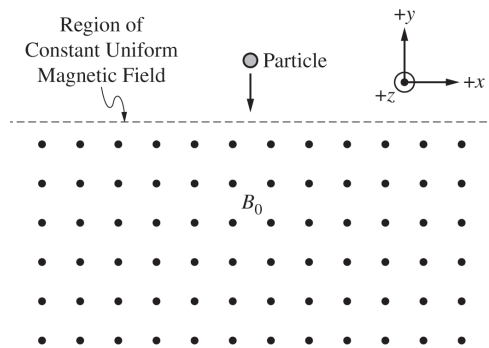
Continue your response to **QUESTION 4** on this page.

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.

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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.

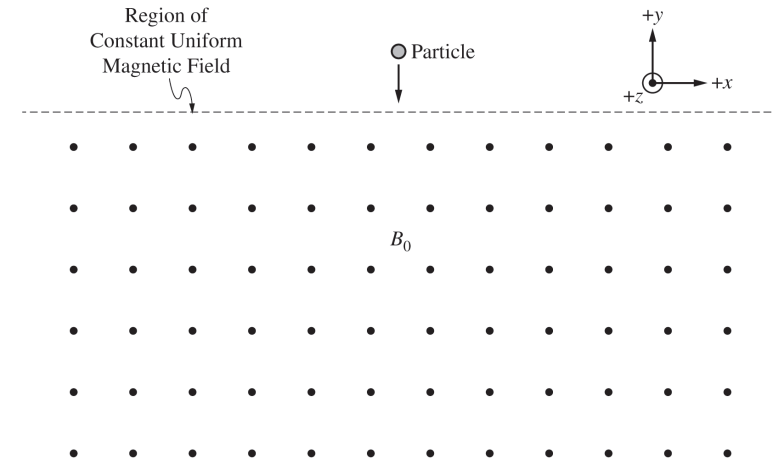


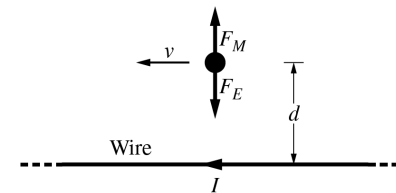
Figure 2

(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.

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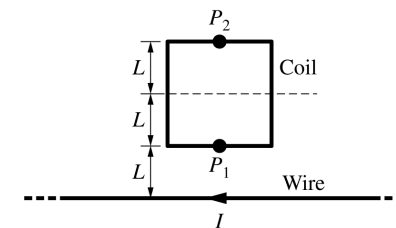
END OF EXAM



(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.



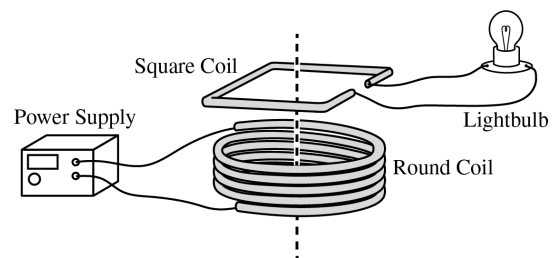
(b) The charged object is removed, and a square coil with side length $2L$ is placed near the long, straight wire, as shown above. The bottom of the coil is a distance L from the wire. The magnitude of the magnetic field due to the current in the wire is $3B_0$ at point P_1 and B_0 at point P_2 .

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.

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END OF EXAM