2018

AP® CollegeBoard

AP Physics C: Electricity and Magnetism

Sample Student Responses and Scoring Commentary

Inside:

Free Response Question 3

☑ Scoring Guideline

☑ Student Samples

☑ Scoring Commentary

© 2018 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board. Visit the College Board on the Web: www.collegeboard.org.

AP Central is the official online home for the AP Program: apcentral.collegeboard.org

AP® PHYSICS
2018 SCORING GUIDELINES

General Notes About 2018 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph-length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based Course and Exam Description* and the *AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but the use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 3

15 points total **Distribution of points**

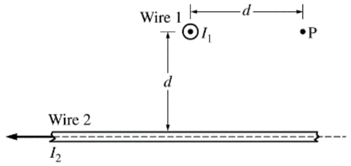
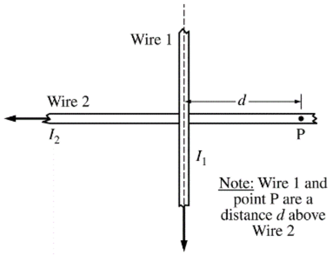


Figure 1. Side view



Note: Wire 1 and point P are a distance d above Wire 2

Figure 2. Top view

The figures above represent different views of two long, straight, horizontal wires, 1 and 2, carrying currents $I_1 = I$ and $I_2 = 2I$, respectively, in the directions shown. The wires are held in place. In Figure 1, the current in wire 1 is directed out of the page, and wire 1 is a distance d above wire 2. Point P is a horizontal distance d from wire 1 and a distance d directly above wire 2. Express your answers to parts (a) and (b) in terms of I, d, and physical constants, as appropriate.

(a) 2 points

Use Ampere's law to derive an expression for the magnitude of the magnetic field at point P due to wire 1.

For attempting to use Ampere's law to calculate the magnetic field at point *P*		1 point
$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$		
$B(2\pi d) = \mu_0 I$		
For a correct answer		1 point
$B = \frac{\mu_0 I}{2\pi d}$		

(b) 2 points

Derive an expression for the magnitude of the net magnetic field at point P.

For indicating $B_2 = 2B_1$		1 point
$B_1 = \frac{\mu_0 I}{2\pi d}$ & $B_2 = \frac{\mu_0 (2I)}{2\pi d} = \frac{\mu_0 I}{\pi d}$		
For an indication that the magnitude of the magnetic field is the vector sum of B_1 and B_2		1 point
$B_{net} = \sqrt{B_1^2 + B_2^2} = \sqrt{B^2 + B^2} = \sqrt{\left(\frac{\mu_0 I}{2\pi d}\right)^2 + \left(\frac{\mu_0 (2I)}{2\pi d}\right)^2} = \frac{\sqrt{5}\mu_0 I}{2\pi d}$		

Question 3 (continued)

Distribution of points

(c) 2 points

Calculate the numerical value of the angle to the horizontal for the direction of the net magnetic field at point P.

For correctly relating the angle to the individual magnetic fields		1 point
$\theta = \tan^{-1}\left(\frac{B_1}{B_2}\right)$		
For correctly substituting B_1 and B_2 into the equation		1 point
$\theta = \tan^{-1}\left(\frac{B_1}{B_2}\right) = \tan^{-1}\left(\frac{\left(\frac{\mu_0 I}{2\pi d}\right)}{\left(\frac{\mu_0 (2I)}{2\pi d}\right)}\right) == \tan^{-1}\left(\frac{1}{2}\right) = 26.6°$		

(d) 2 points

Wire 1 is now released. Which of the following best describes the initial motion of wire 1 due to the magnetic field of wire 2? Assume gravitational effects are negligible.

____ Wire 1 will not move.

____ Wire 1 will move upward as viewed in Figure 1.

____ Wire 1 will move downward as viewed in Figure 1.

____ Wire 1 will rotate clockwise as viewed in Figure 2.

____ Wire 1 will rotate counterclockwise as viewed in Figure 2.

Justify your answer.

For stating there is no translational motion since the magnetic forces on the wire cancel		1 point
For stating there is a net torque which causes rotation		1 point
Example: In Figure 2, the top portion of wire 1 will be in a magnetic field into the page from wire 2 and, thus, will experience a force to the right. The bottom portion of wire 1 will be in a magnetic field out of the page from wire 2 and, thus, will experience a force to the left. So the net force will be zero, but there will be a net clockwise torque, so the wire will rotate clockwise.		

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 3 (continued)

Distribution of points

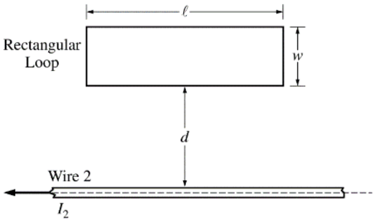


Figure 3. Side view

Wire 1 is now replaced by a conducting rectangular loop of length ℓ, width w, and resistance R. The loop is placed a distance d from wire 2, as shown. The loop, wire, and distance d are all in the plane of the page. The long side of the loop is parallel to the wire. The current I_2 for wire 2 is decreasing linearly as a function of time t according to the equation $I_2 = 2I_0(1 - kt)$, where k is a positive constant with units of s^{-1}.

(e) 1 point

Of the following, select the integration that will give an expression for the flux Φ as a function of time t.

____ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

__X__ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

For selecting $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$		1 point

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 3 (continued)

Distribution of points

(f) 3 points

Given that the flux through the rectangular loop as a function of time t is given by the equation $\Phi = \frac{\mu_0 I_0 \ell (1 - kt)}{\pi} \ln\left(\frac{d + w}{d}\right)$, derive an expression for the magnitude of the current, if any, induced in the loop. Express your answers in terms of I_0, d, r, R, w, k, ℓ, and physical constants, as appropriate.

For attempting to take the time derivative of the magnetic flux to calculate the emf		1 point
$\varepsilon = \left\lvert -\frac{d\Phi}{dt} \right\rvert = \frac{\mu_0 I_0 \ell}{\pi} \ln\left(\frac{d + w}{d}\right) \left\lvert \frac{d}{dt}[(1 - kt)] \right\rvert$		
$\varepsilon = \frac{\mu_0 I_0 k \ell}{\pi} \ln\left(\frac{d + w}{d}\right)$		
For dividing the emf by the resistance to calculate the current		1 point
$I = \frac{\varepsilon}{R} = \frac{\frac{\mu_0 I_0 k \ell}{\pi} \ln\left(\frac{d + w}{d}\right)}{R}$		
For a correct answer		1 point
$I = \frac{\mu_0 I_0 k \ell}{\pi R} \ln\left(\frac{d + w}{d}\right)$		

(g) 3 points

What is the direction of the current, if any, induced in the loop as seen in Figure 3?

____ Clockwise ____ Counterclockwise

____ Undefined because there is no current induced in the loop

Justify your answer.

For selecting "Clockwise" with an attempt at a relevant justification		1 point
For indicating that the flux inside the loop will decrease		1 point
For using Lenz's law to relate the decrease in the flux to the clockwise current		1 point
Example: Because the current in the wire is decreasing, the flux in the loop will decrease. According to Lenz's law, the induced current should create a magnetic field to oppose this decrease. Thus the induced magnetic field must be into the page, and the current in the loop must be clockwise.		

© 2018 The College Board.

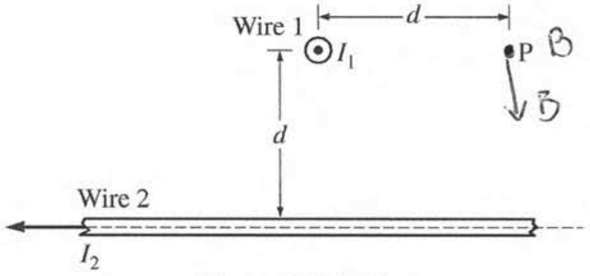
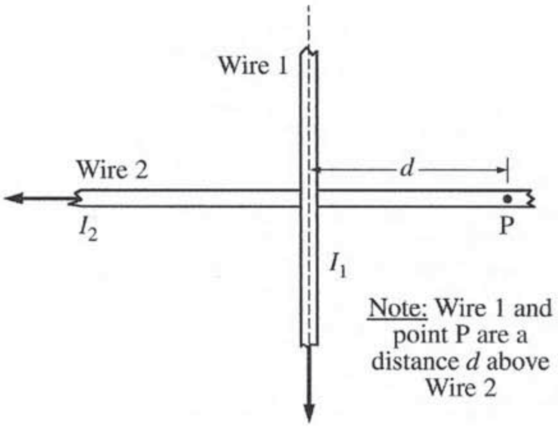


Figure 1. Side view



Note: Wire 1 and point P are a distance *d* above Wire 2

Figure 2. Top view

3. The figures above represent different views of two long, straight, horizontal wires, 1 and 2, carrying currents $I_1 = I$ and $I_2 = 2I$, respectively, in the directions shown. The wires are held in place. In Figure 1, the current in wire 1 is directed out of the page, and wire 1 is a distance *d* above wire 2. Point P is a horizontal distance *d* from wire 1 and a distance *d* directly above wire 2. Express your answers to parts (a) and (b) in terms of I, *d*, and physical constants, as appropriate.

(a) Use Ampere's law to derive an expression for the magnitude of the magnetic field at point P due to wire 1.

Amperes law

$B = \frac{\mu_0 I}{2\pi r}$ $\quad \vec{B} = \frac{\mu_0 I_1}{2\pi d} = \frac{\mu_0 I}{2\pi d}$

(b) Derive an expression for the magnitude of the net magnetic field at point P.

$\vec{B}_2 = \frac{\mu_0 I_2}{2\pi d}$ $\quad \vec{B}_1 = \frac{\mu_0 I_1}{2\pi d}$

$\vec{B}_{net} = \frac{\mu_0}{2\pi d}\sqrt{4I^2+I^2} = \frac{\mu_0 I}{2\pi d}\sqrt{5}$

$\Uparrow$

$\vec{B}_{net} = \sqrt{\vec{B}_1^2 + \vec{B}_2^2} = \sqrt{\frac{\mu_0^2 I_2^2}{4\pi^2 d^2} + \frac{\mu_0 I_1^2}{4\pi^2 d^2}} = \sqrt{\frac{\mu_0^2 (I_2^2 + I_1^2)}{4\pi^2 d^2}} = \frac{\mu_0}{2\pi d}\sqrt{I_2^2 + I_1^2}$

(c) Calculate the numerical value of the angle to the horizontal for the direction of the net magnetic field at point P.

$\tan\theta = \frac{\vec{B}_1}{\vec{B}_2} = \frac{\frac{\mu_0 I}{2\pi d}}{\frac{\mu_0 2I}{2\pi d}} = \frac{1}{2}$ $\quad \tan^{-1}(\frac{1}{2}) = \theta$

$\theta = 26.56°$

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

E Q3 A p2

(d) Wire 1 is now released. Which of the following best describes the initial motion of wire 1 due to the magnetic field of wire 2 ? Assume gravitational effects are negligible.

[✓ Wire 1 will not move.]

____ Wire 1 will move upward as viewed in Figure 1.

____ Wire 1 will move downward as viewed in Figure 1.

____ Wire 1 will rotate clockwise as viewed in Figure 2.

____ Wire 1 will rotate counterclockwise as viewed in Figure 2.

Justify your answer. According to the right hand rule, the magnetic field created by wire 2 will be into the page, which means $\vec{B}_2$ is parallel to wire 1. Since $\vec{F} = \vec{I}\ell\vec{B}$, the force will be zero as B & I are parallel.

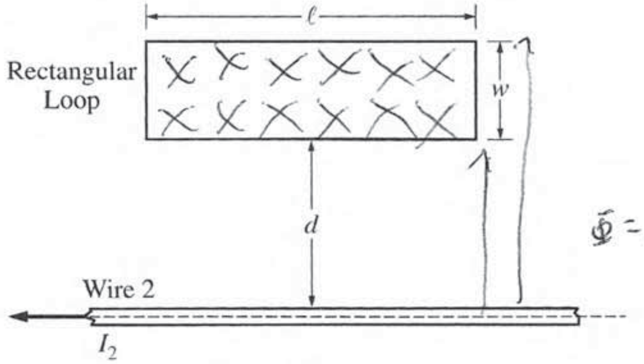


Figure 3. Side view

$\Phi = \int \vec{B} \cdot d\vec{A}$

$\frac{\mu_0 I_2}{2\pi r} \ell w$

$\frac{\mu_0 2 I_0 k}{2\pi r} \ell w$

Wire 1 is now replaced by a conducting rectangular loop of length ℓ, width w, and resistance R. The loop is placed a distance d from wire 2, as shown. The loop, wire, and distance d are all in the plane of the page. The long side of the loop is parallel to the wire. The current I_2 for wire 2 is decreasing linearly as a function of time t according to the equation $I_2 = 2I_0(1-kt)$, where k is a positive constant with units of s^{-1}.

(e) Of the following, select the integration that will give an expression for the flux Φ as a function of time t.

____ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

____ ~~$\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$~~

[✓ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$]

____ ~~$\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$~~

Question 3 continues on the next page.

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(f) Given that the flux through the rectangular loop as a function of time t is given by the equation $\Phi = \frac{\mu_0 I_0 \ell (1 - kt)}{\pi} \ln\left(\frac{d + w}{d}\right)$, derive an expression for the magnitude of the current, if any, induced in the loop. Express your answers in terms of I_0, d, r, R, w, k, ℓ, and physical constants, as appropriate.

$$I = \frac{\mathcal{E}}{R} \qquad \mathcal{E} = -\frac{d\Phi}{dt} = \boxed{\frac{\mu_0 I_0 \ell k}{\pi} \ln\left(\frac{d+w}{d}\right)}$$

$$I = \frac{\mu_0 I_0 \ell k}{\pi R} \ln\left(\frac{d+w}{d}\right)$$

(g) What is the direction of the current, if any, induced in the loop as seen in Figure 3 ?

✓ Clockwise ____ Counterclockwise

____ Undefined, because there is no current induced in the loop

Justify your answer.

According to the equation above, $\Phi = \frac{\mu_0 I_0 \ell (1-kt)}{\pi} \ln\left(\frac{d+w}{d}\right)$, as time goes on, Φ decreases. According to the right hand rule, wire 2 creates a $\vec{B}$ field into the page ⊗. This means that because the flux is decreasing and the area stays the same, $\vec{B}$ into the page must be decreasing. In order to oppose this change in flux, Lenz's law states thats a magnetic field will be created by an induced current. To compensate for the decrease in $\vec{B}$ into the page, the current must run clockwise to create a $\vec{B}$ into the page.

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

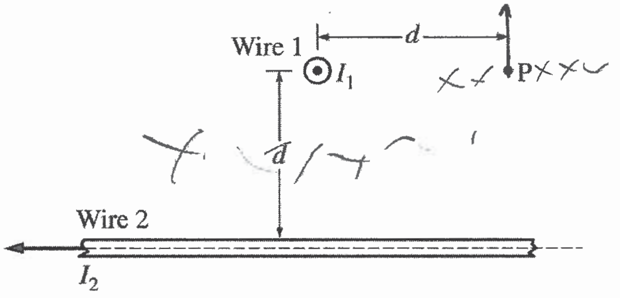
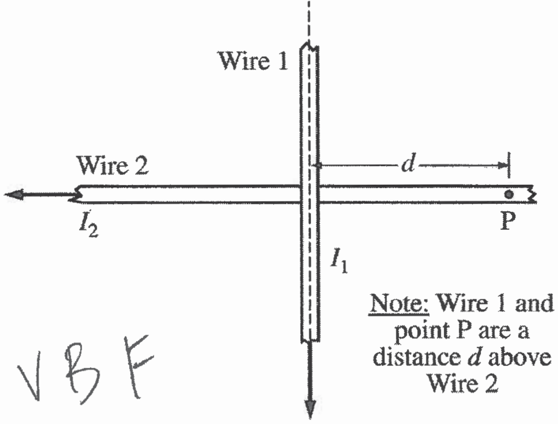


Figure 1. Side view

VBF



Note: Wire 1 and point P are a distance d above Wire 2

Figure 2. Top view

3. The figures above represent different views of two long, straight, horizontal wires, 1 and 2, carrying currents $I_1 = I$ and $I_2 = 2I$, respectively, in the directions shown. The wires are held in place. In Figure 1, the current in wire 1 is directed out of the page, and wire 1 is a distance d above wire 2. Point P is a horizontal distance d from wire 1 and a distance d directly above wire 2. Express your answers to parts (a) and (b) in terms of I, d, and physical constants, as appropriate.

(a) Use Ampere's law to derive an expression for the magnitude of the magnetic field at point P due to wire 1.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

$$B = \frac{\mu_0 I_1}{2\pi d}$$

(b) Derive an expression for the magnitude of the net magnetic field at point P.

$$B_1 = \frac{\mu_0 I_1}{2\pi d} \quad B_2 = \frac{\mu_0 I_2}{2\pi d} \quad B_{total} = \sqrt{\left(\frac{\mu_0 I_1}{2\pi d}\right)^2 + \left(\frac{\mu_0 I_2}{2\pi d}\right)^2}$$

(c) Calculate the numerical value of the angle to the horizontal for the direction of the net magnetic field at point P.

$|B_1| = |B_2|$ so angle = 45°

Unauthorized copying or reuse of any part of this page is illegal.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(d) Wire 1 is now released. Which of the following best describes the initial motion of wire 1 due to the magnetic field of wire 2 ? Assume gravitational effects are negligible.

____ Wire 1 will not move.

____ Wire 1 will move upward as viewed in Figure 1.

____ Wire 1 will move downward as viewed in Figure 1.

✓ Wire 1 will rotate clockwise as viewed in Figure 2.

____ Wire 1 will rotate counterclockwise as viewed in Figure 2.

Justify your answer.

$F = BI\ell$

$F = \frac{\mu_0 I_1 I_2}{2\pi d}\ell$

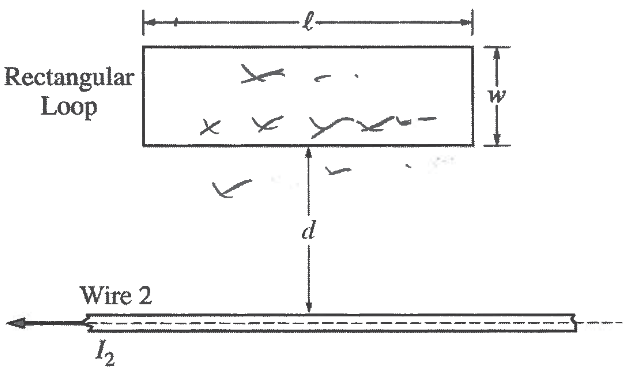


Figure 3. Side view

Wire 1 is now replaced by a conducting rectangular loop of length ℓ, width w, and resistance R. The loop is placed a distance d from wire 2, as shown. The loop, wire, and distance d are all in the plane of the page. The long side of the loop is parallel to the wire. The current I_2 for wire 2 is decreasing linearly as a function of time t according to the equation $I_2 = 2I_0(1 - kt)$, where k is a positive constant with units of s^{-1}.

(e) Of the following, select the integration that will give an expression for the flux Φ as a function of time t.

✓ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

____ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

$\frac{dB}{dt}$ A

Question 3 continues on the next page.

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(f) Given that the flux through the rectangular loop as a function of time t is given by the equation $\Phi = \frac{\mu_0 I_0 \ell (1 - kt)}{\pi} \ln\left(\frac{d + w}{d}\right)$, derive an expression for the magnitude of the current, if any, induced in the loop. Express your answers in terms of I_0, d, r, R, w, k, ℓ, and physical constants, as appropriate.

$$\phi = \frac{\mu_0 I_0 \ell(1-kt)}{\pi}\ln\left(\frac{d+w}{d}\right)$$

$$\mathcal{E} = \frac{d\Phi}{dt} = IR$$

$$\frac{d}{dt}\left(\frac{\mu_0 I_0 \ell}{\pi}(1-kt)\ln\left(\frac{d+w}{d}\right)\right) = IR$$

$$I = R\frac{\mu_0 I_0 \ell}{\pi}\ln\left(\frac{d+w}{d}\right)(-k)$$

(g) What is the direction of the current, if any, induced in the loop as seen in Figure 3 ?

[✓ Clockwise] ____ Counterclockwise

____ Undefined, because there is no current induced in the loop

Justify your answer.

Lenz's Law

original Strong flux into page

final weak flux into page

response restore flux into page,

So clockwise current

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

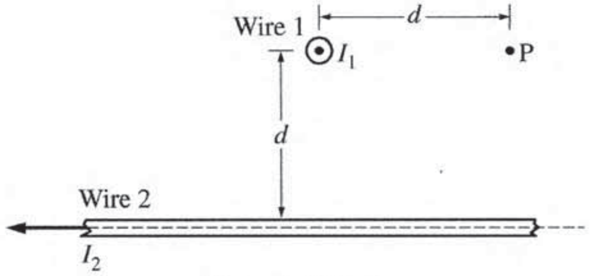
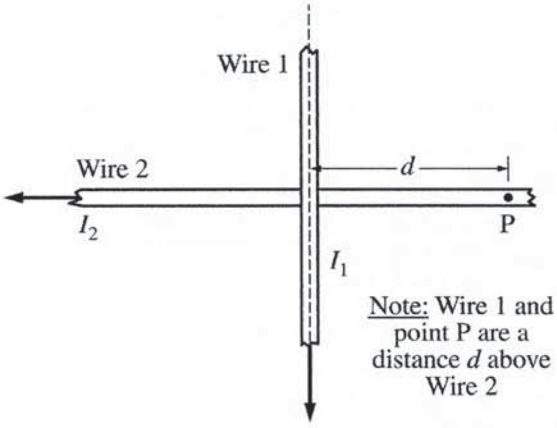


Figure 1. Side view



Note: Wire 1 and point P are a distance *d* above Wire 2

Figure 2. Top view

3. The figures above represent different views of two long, straight, horizontal wires, 1 and 2, carrying currents $I_1 = I$ and $I_2 = 2I$, respectively, in the directions shown. The wires are held in place. In Figure 1, the current in wire 1 is directed out of the page, and wire 1 is a distance *d* above wire 2. Point P is a horizontal distance *d* from wire 1 and a distance *d* directly above wire 2. Express your answers to parts (a) and (b) in terms of I, *d*, and physical constants, as appropriate.

(a) Use Ampere's law to derive an expression for the magnitude of the magnetic field at point P due to wire 1.

$\oint B\,dl = \mu_0 I$

$Bl = \mu_0 I$

$B 2\pi r = \mu_0 I$

$B 2\pi d = \mu_0 I$

$\boxed{B = \frac{\mu_0 I}{2\pi d}}$

(b) Derive an expression for the magnitude of the net magnetic field at point P.

$\oint B\,dl = \mu_0 I$

$\downarrow$

$Bl = \mu_0 I$

$B 2\pi d = \mu_0 2I$

$B = \frac{\mu_0 2I}{2\pi d}$

$\boxed{\sqrt{\left(\frac{\mu_0 I}{2\pi d}\right)^2 + \left(\frac{\mu_0 2I}{2\pi d}\right)^2}}$

(c) Calculate the numerical value of the angle to the horizontal for the direction of the net magnetic field at point P.

45°

Unauthorized copying or reuse of any part of this page is illegal.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(d) Wire 1 is now released. Which of the following best describes the initial motion of wire 1 due to the magnetic field of wire 2 ? Assume gravitational effects are negligible.

[✓] Wire 1 will not move.

____ Wire 1 will move upward as viewed in Figure 1.

____ Wire 1 will move downward as viewed in Figure 1.

____ Wire 1 will rotate clockwise as viewed in Figure 2.

____ Wire 1 will rotate counterclockwise as viewed in Figure 2.

Justify your answer.

The wire is not in motion and thus does not experience a magnetic force. It does not have a net flux going threw it

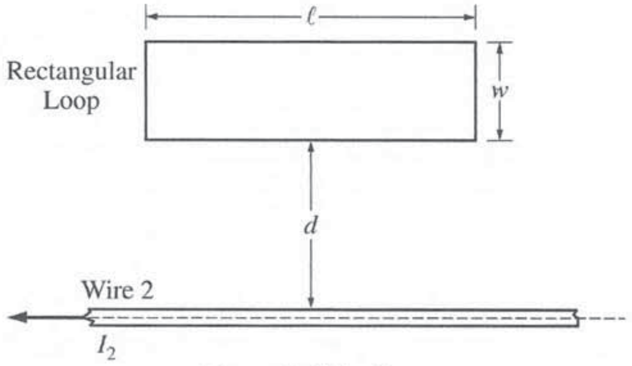


Figure 3. Side view

Wire 1 is now replaced by a conducting rectangular loop of length ℓ, width w, and resistance R. The loop is placed a distance d from wire 2, as shown. The loop, wire, and distance d are all in the plane of the page. The long side of the loop is parallel to the wire. The current I_2 for wire 2 is decreasing linearly as a function of time t according to the equation $I_2 = 2I_0(1 - kt)$, where k is a positive constant with units of s^{-1}.

(e) Of the following, select the integration that will give an expression for the flux Φ as a function of time t.

____ $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)\ell w}{2\pi} dr$

[✓] $\Phi = \int_{r=d}^{r=d+w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

____ $\Phi = \int_{r=d}^{r=w} \frac{\mu_0(2I_0)(1-kt)}{2\pi r} \ell dr$

Question 3 continues on the next page.

Unauthorized copying or reuse of any part of this page is illegal.

GO ON TO THE NEXT PAGE.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(f) Given that the flux through the rectangular loop as a function of time t is given by the equation $\Phi = \frac{\mu_0 I_0 \ell (1 - kt)}{\pi} \ln\left(\frac{d + w}{d}\right)$, derive an expression for the magnitude of the current, if any, induced in the loop. Express your answers in terms of I_0, d, r, R, w, k, ℓ, and physical constants, as appropriate.

$\boxed{5}$

(g) What is the direction of the current, if any, induced in the loop as seen in Figure 3 ?

____ Clockwise ____ Counterclockwise

X Undefined, because there is no current induced in the loop

Justify your answer.

There must be a current in the loop for their to be a force to go against.

Unauthorized copying or reuse of any part of this page is illegal.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS C: ELECTRICITY AND MAGNETISM
2018 SCORING COMMENTARY

Question 3

Overview

The responses to this question were expected to demonstrate the following:

- The ability to apply Ampere's law.
- An understanding of the superposition of magnetic fields.
- An understanding of magnetic forces and their effects on current-carrying wires placed in a nonuniform magnetic field.
- The ability to apply Faraday's law.
- The ability to apply Lenz's law.

Sample: E Q3 A
Score: 13

Parts (b), (c), (e), (f), and (g) earned full credit. Part (a) has a correct answer but does not show how Ampere's law is used, so 1 point was earned. Part (b) has the correct relationship between the two magnetic fields and has a correct vector sum, which earned 2 points. Part (c) has a correct substitution into an expression that correctly relates the angle to the fields, which earned 2 points. Part (d) has a correct explanation that the net force is equal to zero but has no mention of torques, so 1 point was earned. Part (e) has the correct selection, which earned 1 point. Part (f) shows the correct derivative of the flux, a correct use of Ohm's law, and a correct answer, which earned 3 points. Part (g) has a correct selection and correct explanations of flux and Lenz's law, which earned 3 points.

Sample: E Q3 B
Score: 7

Parts (a) correctly uses Ampere's law and has a correct answer, which earned full credit of 2 points. Part (b) correctly uses vector addition of the magnitudes of the fields but has an incorrect value for B_2, so 1 point was earned. Part (c) does not show a correct relation between the angle and the magnetic fields, so no points were earned. Part (d) has no discussion of the forces or the torques, which earned no points. Part (e) has an incorrect selection, which earned no points. Part (f) shows the derivative of the flux and uses Ohm's law but has an incorrect answer, so 2 points were earned. Part (g) has a correct selection and a correct explanation of the flux and Lenz's law, which earned 2 points.

Sample: E Q3 C
Score: 5

Parts (a) and (b) earned full credit of 4 points. In part (c) no substitution or expression relating the angle to the fields are indicated, so no points were earned. Part (d) has an insufficient justification, so no points were earned. Part (e) has a correct selection and earned 1 point. Part (f) does not show the derivative of the flux or the use Ohm's law, so no points were earned. Part (g) has no mention of flux or Lenz's law, so no points were earned.

© 2018 The College Board.
Visit the College Board on the Web: www.collegeboard.org.