AP® PHYSICS B
2008 SCORING GUIDELINES

General Notes About 2008 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. 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.

3. 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 contains the application of that equation to the problem but the student does not write the basic equation, 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 AP Physics 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 Course Description*.

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

5. 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.

AP® PHYSICS B
2008 SCORING GUIDELINES

Question 3

15 points total	**Distribution of points**
(a) 4 points	
For using Ohm's law to find the total resistance of the circuit $\mathcal{E}/I = R_{\text{total}}$ $16\text{ V}/4.0\text{ A} = 4.0\ \Omega$	1 point
For a correct expression for the total resistance that has the internal resistance of the power supply in series with the wire's resistance $R_{\text{internal}} + R_{\text{wire}} = R_{\text{total}}$ $0.50\ \Omega + R_{\text{wire}} = 4.0\ \Omega$ $R_{\text{wire}} = 3.5\ \Omega$	1 point
An alternate solution is to use a circuit equation to determine the voltage across the wire for the first point, and then Ohm's law to determine its resistance for the second point. $V_{\text{wire}} = V_{\text{term}} = \mathcal{E} - V_{\text{int}} = 16\text{ V} - (4.0\text{ A})(0.50\ \Omega) = 14\text{ V}$ $R_{\text{wire}} = V/I = 14\text{ V}/4.0\text{ A} = 3.5\ \Omega$	
Using the expression for the resistance of a wire in terms of its dimensions $R_{\text{wire}} = \rho L/A$ $L = R_{\text{wire}}A/\rho$	
For correct substitutions $L = (3.5\ \Omega)\left(3.5 \times 10^{-9}\text{ m}^2\right)/\left(1.7 \times 10^{-8}\ \Omega\bullet\text{m}\right)$	1 point
For a correct answer with correct units $L = 0.72\text{ m}$	1 point
<u>Note</u>: The last 2 points could be earned for showing understanding of $R = \rho L/A$ by using it with the appropriate values of ρ and A and some value of resistance.	
(b) 4 points	
The force on the magnet is upwards. Points are awarded for the justification as follows.	
For indicating that the right-hand rule should be used	1 point
For correctly identifying the direction of the magnetic field between the poles of the magnet as being to the right	1 point
For obtaining a downward force on the wire using the right-hand rule	1 point
Example for the above 3 points: The direction of the force on the wire is given by the right-hand rule. The current is into the page and the magnetic field is to the right. By the right-hand rule, the force on the wire is then downwards.	
For using Newton's 3rd Law	1 point
For example: The force on the wire is downwards, so the force on the magnet must be upwards.	
<u>Note</u>: A student who checks "downward" can receive 3 of 4 points if they correctly use the right-hand rule to show that the force on the wire is downward. Just checking the box "upward" without justification received no points.	

Question 3 (continued)

Distribution of points

(c) 3 points

For simplifying the formula given in the equation table for the force on a current-carrying wire (or stating that $\theta = 90°$) — 1 point

$F = ILB$

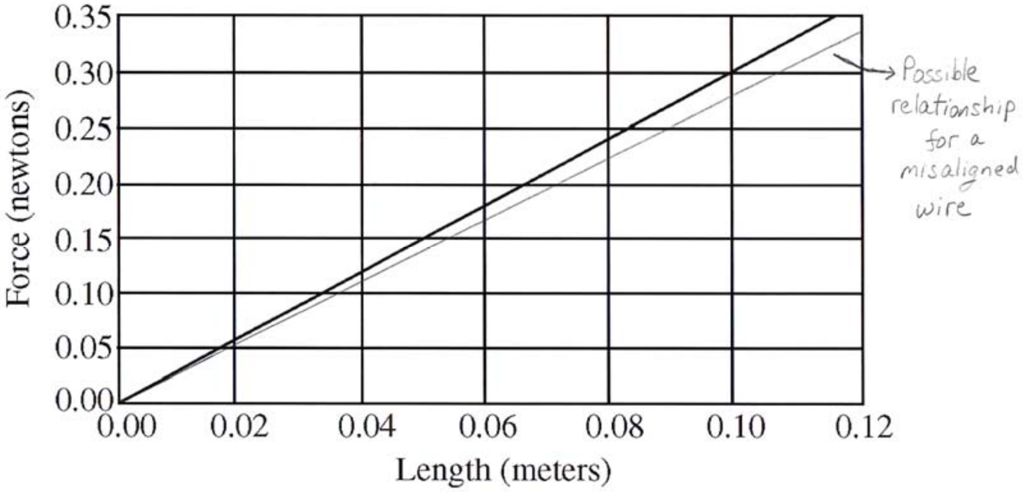
For correct substitutions — 1 point

$$B = \frac{F}{IL} = \frac{(0.060\text{ N})}{(4.0\text{ A})(0.020\text{ m})}$$

For a correct answer with correct units — 1 point

$B = 0.75\text{ T}$

(d) 3 points



For a straight-line relationship — 1 point

For a relationship that passes through the origin — 1 point

For a slope less than the original line but NOT zero — 1 point

(e) 1 point

For a plausible source of error that would produce the plotted results — 1 point

For example: The horizontal width of the wire approaches the width of the magnet. Near the edges of the magnet the strength of the magnetic field decreases. As the length of the wire increases, the magnetic field experienced by the ends of the wire decreases in strength, leading to a smaller magnetic force than expected.

3. (15 points)

A rectangular wire loop is connected across a power supply with an internal resistance of $0.50\ \Omega$ and an emf of 16 V. The wire has resistivity $1.7 \times 10^{-8}\ \Omega\text{•m}$ 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 A.

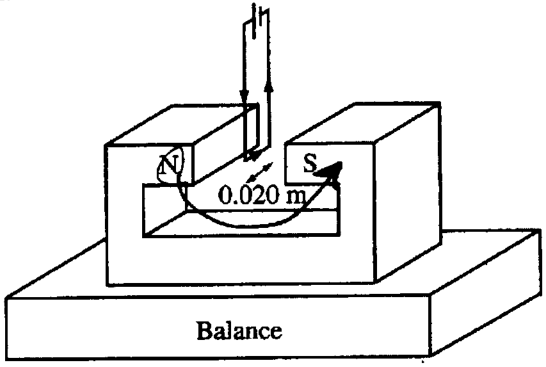
(a) Calculate the length of wire used to make the loop.

$V = IR_{eq}$ | $R_{eq} = .5 + R$ | $R = \frac{\rho l}{A} = \frac{1.7\times10^{-8} l}{3.5\times10^{-9}}$

$16 = 4R_{eq}$ | $4 = .5 + \boxed{3.5} \rightarrow 3.5 = \frac{34}{7} l$

$R_{eq} = \boxed{4}$ | $l = \boxed{.72m}$

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 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 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.

The B field flows from left to right and the current flows into the page. Using the left hand rule, the force on the wire is downward. The force on the magnet is upward

(c) The reading on the balance changed by 0.060 N when the power supply was turned on. Calculate the strength of the magnetic field.

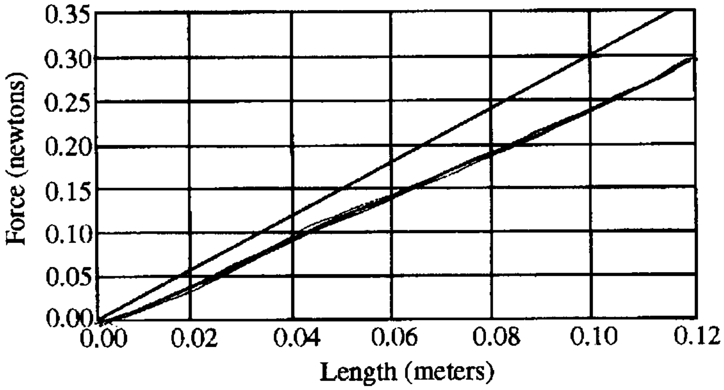
$F_B = BIl$

$.06 = B \cdot 4 \cdot .02$

$B = \boxed{.75T}$

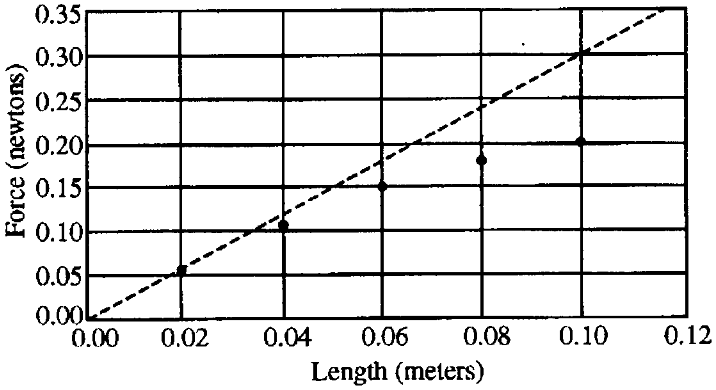
GO ON TO THE NEXT PAGE.

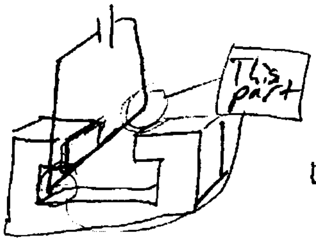
Suppose that various rectangular loops with the same total length of wire as found in part (a) were constructed such that the lengths of the horizontal segments of the wire loops varied between 0.02 m and 0.10 m. The horizontal segment of each loop was always centered between the poles, and the current 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.





The B field decreased on the ends of the loop ~~because it~~ Not as much force was produced on the sides because of this.

GO ON TO THE NEXT PAGE.

3. (15 points)

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

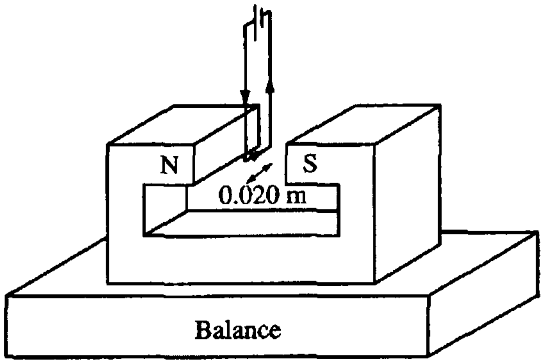
(a) Calculate the length of wire used to make the loop.

$$R = \frac{\rho l}{A} \qquad l = \frac{RA}{\rho} = \frac{(3.5)(3.5\times10^{-9})}{1.7\times10^{-8}} = .721\text{ m}$$

$$V = I(R+.5)$$

$$R = \frac{V}{I} - .5 = \frac{16}{4} - .5 = 3.5$$

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 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 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?

V Upward ____Downward

Justify your answer.

Right hand Rule

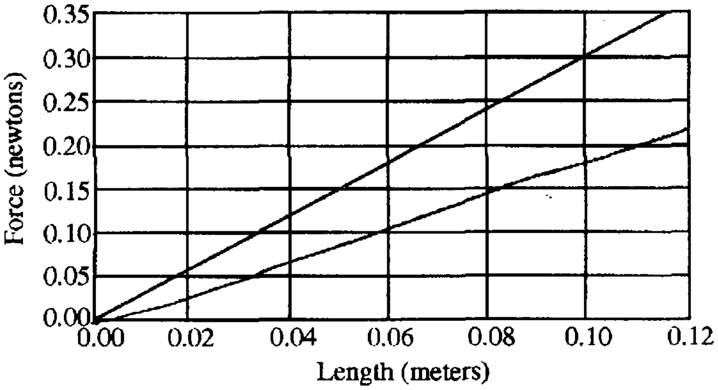
(c) The reading on the balance changed by 0.060 N when the power supply was turned on. Calculate the strength of the magnetic field.

$$F_B = B I l \cancel{\sin} \theta$$

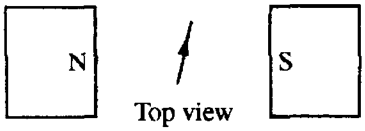
$$B = \frac{F_B}{Il} = \frac{.06}{4(.02)} = .75\text{T}$$

GO ON TO THE NEXT PAGE.

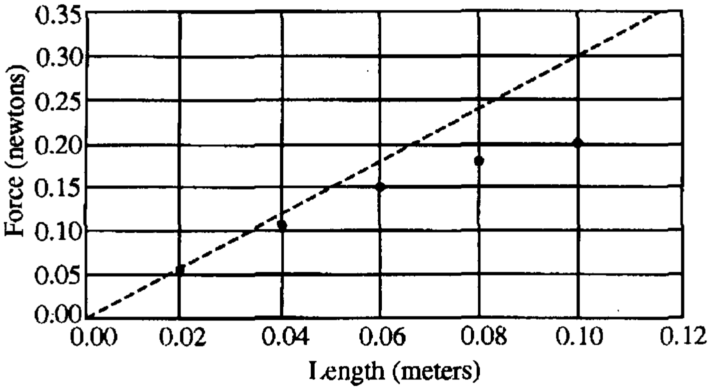
Suppose that various rectangular loops with the same total length of wire as found in part (a) were constructed such that the lengths of the horizontal segments of the wire loops varied between 0.02 m and 0.10 m. The horizontal segment of each loop was always centered between the poles, and the current 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.



Induced current lessens the force

3. (15 points)

A rectangular wire loop is connected across a power supply with an internal resistance of $0.50\ \Omega$ and an emf of 16 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 A.

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

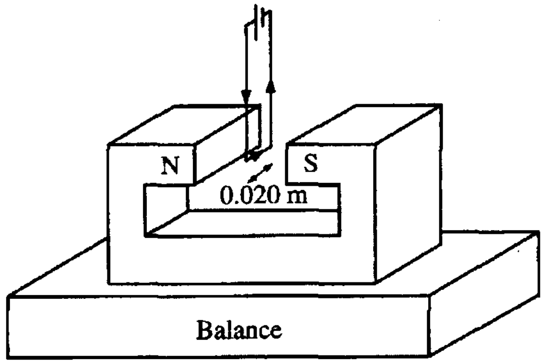
$R = 0.50\ \Omega$
$\mathcal{E} = 16\text{V}$
$\rho = 1.7 \times 10^{-8}\ \Omega\cdot\text{m}$
$A = 3.5 \times 10^{-9}\ \text{m}^2$
$I = 4.0\text{A}$
$\ell = ?$

$$R = \frac{\rho \ell}{A}$$

$$0.50 = \frac{(1.7 \times 10^{-8})\ell}{(3.5 \times 10^{-9})}$$

$\therefore \ell =$ $\boxed{.103\text{m is the length of the wire used to make the loop}}$

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 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 A current is in the direction shown.

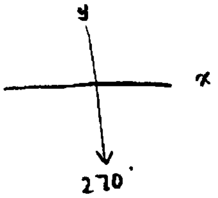


Note: Figure not drawn to scale.

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

____Upward ✓ Downward

Justify your answer.



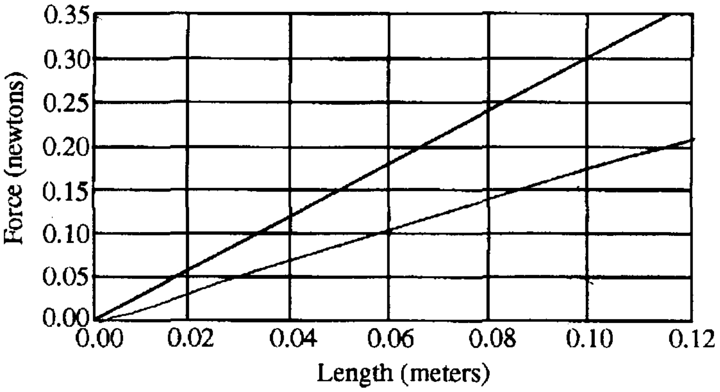
$F = BI\ell\sin\theta$
$= B\ (4.0)(.103)\sin 270^\circ$
$\therefore \ominus$ answer

(c) The reading on the balance changed by 0.060 N when the power supply was turned on. Calculate the strength of the magnetic field.

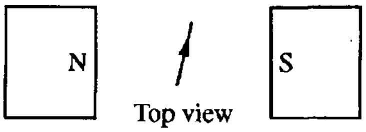
$F = BI\ell\sin\theta$
$0.060 = B(4.0)(0.103)(\sin 270^\circ)$
$0.14563106 = -B$
$\therefore B = \boxed{-0.146}$

GO ON TO THE NEXT PAGE.

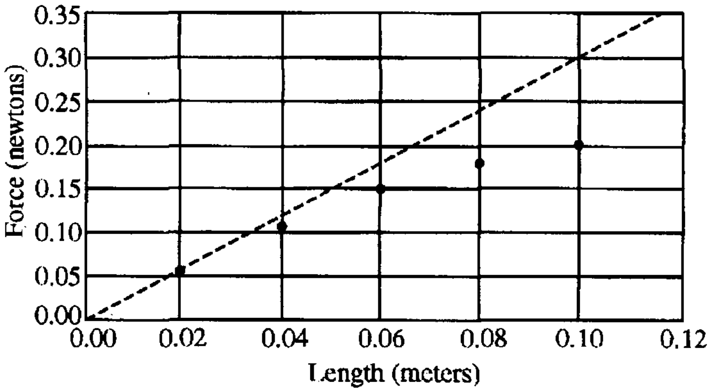
Suppose that various rectangular loops with the same total length of wire as found in part (a) were constructed such that the lengths of the horizontal segments of the wire loops varied between 0.02 m and 0.10 m. The horizontal segment of each loop was always centered between the poles, and the current 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.



The data found indicates a slower increase in the magnitude of the force on the magnet in comparison to the length of the wire. Likely, the strength of the magnetic field during the experiment was not strong enough therefore led to the data above

AP® PHYSICS B
2008 SCORING COMMENTARY

Question 3

Overview

Part (a) assessed student understanding of the relationships among resistance, resistivity, length, and area for a wire, in the context of a wire connected across a power supply. Concepts of series resistance and Ohm's law were also needed to answer the question. Part (b) assessed understanding of the force on a current-carrying wire in a magnetic field and the corresponding reaction force on the magnet. Understanding of magnetic field directions, application of an appropriate hand rule, and Newton's third law were needed to answer the question. Part (c) assessed application of the equation $F = BI\ell \sin\theta$. Part (d) assessed students' ability to explain how a change in the orientation of the wire loop would affect the experiment results. For part (e) students had to interpret experimental results and provide a rationale for experimental error.

Sample: B3A
Score: 15

Full credit was awarded for every part of the problem. Note that reference is made to the left-hand rule in the justification of part (b); this technique, sometimes referred to as Fleming's left-hand rule, is sometimes taught as an alternative to the right-hand rule and is entirely equivalent when used properly. The reason provided in part (e) is essentially the same as the example in the scoring guidelines.

Sample: B3B
Score: 11

The calculation in part (a) is correct, and full credit was awarded. While the right-hand rule is mentioned in part (b), earning 1 point, there is no mention of how it was used in the problem, so no additional points were given. Parts (c) and (d) are correct, and full credit was awarded for each. The reason provided in part (e) is not plausible, so no credit was given.

Sample: B3C
Score: 5

The internal resistance of the power supply is incorrectly used as the wire resistance, so 2 points were deducted for failure to use Ohm's law to determine the wire resistance. Two points were awarded in part (a), however, as understanding of the relationship between resistivity and resistance was shown, using appropriate values of resistivity and the cross-sectional area of the wire. No points were awarded for part (b), as the incorrect choice is made, and the justification is invalid. No points were awarded for part (c), since the incorrect angle is used, there is a substitution error for the length, and no units are given. Full credit was earned for part (d). The reason provided in part (e) is not plausible, so no credit was given.