AP® PHYSICS B
2010 SCORING GUIDELINES (Form B)

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the 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 — for example, 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 Exams 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 $10\ \text{m/s}^2$ 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.

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Question 4

10 points total **Distribution of points**

(a) 2 points

For correctly determining the equivalent resistance of the two parallel resistors 1 point

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_2} = \frac{2}{R_2}$$

$$R_p = \frac{1}{2}R_2$$

For correctly determining the total equivalent resistance of the circuit 1 point

$$R_T = R_1 + R_1 + R_p$$

$$R_T = 2R_1 + \frac{1}{2}R_2$$

(b) 2 points

For a correct expression for the power in terms of emf and resistance 1 point

$$P = \mathcal{E}^2 / R_T$$

For correctly substituting the value of total resistance from part (a) 1 point

$$P = \mathcal{E}^2 \Big/ \left(2R_1 + \frac{1}{2}R_2\right)$$

(c) 3 points

For correctly indicating that the field is directed out of the plane of the page 1 point

For using the right-hand rule to determine the direction of the field at point *P* from each wire (into the page from the top wire, out of the page from the bottom wire) 1 point

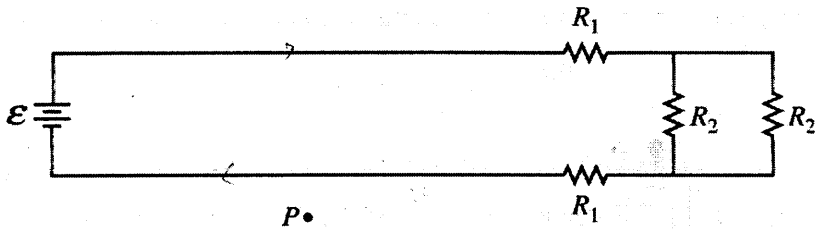
For indicating that the magnitude of the field at point *P* from the bottom wire is greater because it is closer to point *P* 1 point

(d) 3 points

For correctly indicating that the force is directed toward the bottom of the page 1 point

For indicating that the magnetic field at the bottom wire due to the top wire is directed into the page 1 point

For using the right-hand rule to determine the direction of the force on the bottom wire due to the magnetic field 1 point



4. (10 points)

In the circuit above, the battery of emf $\mathcal{E}$ is connected to two long, straight, parallel wires, which in turn are connected to four resistors with resistances given in the figure above. Assume that any other resistances in the circuit are negligible. Express all algebraic answers to the following parts in terms of the given quantities and fundamental constants.

(a) Derive an expression for the total resistance of the circuit.

Resistance of $2R_2$ in parallel $= R_{sub}$

$$\frac{1}{R_{sub}} = \frac{1}{R_2} + \frac{1}{R_2} = \frac{2}{R_2} \rightarrow R_{sub} = \frac{1}{2}R_2.$$

Total resistance $= R_1 + R_1 + \frac{R_2}{2} = 2R_1 + \frac{R_2}{2}$ //

(b) Derive an expression for the power dissipated in this circuit.

$$P = VI = \frac{V^2}{R} = \frac{\mathcal{E}^2}{\frac{4R_1+R_2}{2}} = \frac{2\mathcal{E}^2}{4R_1+R_2}.$$

Assume that any magnetic fields result only from the currents in the two long wires.

(c) What is the direction of the magnetic field, if any, at point P, which is in the plane of the page?

____ To the left ____ Toward the top of the page ✓ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ____ Into the plane of the page

____ None of the above, because the magnetic field is zero

Explain your reasoning.

Magnetic field due to upper wire is into the plane of the page.
Magnetic field due to lower wire is out of the plane of the page.
P is closer to the lower wire, hence magnetic field due to it is > magnetic field due to the upper wire.
Hence, B_p is out of the plane of the page.

(d) What is the direction of the force, if any, on the bottom wire due to the current in the top wire?

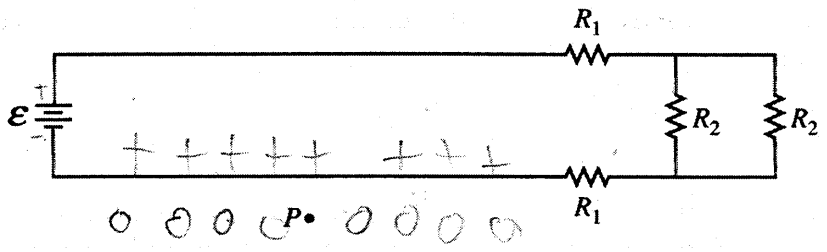
____ To the left ____ Toward the top of the page ____ Out of the plane of the page

____ To the right ✓ Toward the bottom of the page ____ Into the plane of the page

____ None of the above, because the force is zero

Explain your reasoning.

magnetic field caused by top wire to bottom wire is into the plane of the page. hence, by right-hand rule, F should point to the bottom of the page.



4. (10 points)

In the circuit above, the battery of emf $\mathcal{E}$ is connected to two long, straight, parallel wires, which in turn are connected to four resistors with resistances given in the figure above. Assume that any other resistances in the circuit are negligible. Express all algebraic answers to the following parts in terms of the given quantities and fundamental constants.

(a) Derive an expression for the total resistance of the circuit.

$R_{tot} = 2R_1 + R_3$ $\quad \frac{1}{R_3} = \frac{1}{R_2} + \frac{1}{R_2}$

$R_{tot} = 2R_1 + \frac{R_2}{2}$

(b) Derive an expression for the power dissipated in this circuit.

$P = \frac{V^2}{R_{tot}}$ $\quad P = \frac{\mathcal{E}^2}{2R_1 + \frac{R_2}{2}}$

$P = IV$

$P = I^2R$

Assume that any magnetic fields result only from the currents in the two long wires.

(c) What is the direction of the magnetic field, if any, at point P, which is in the plane of the page?

____ To the left ____ Toward the top of the page ✓ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ____ Into the plane of the page

____ None of the above, because the magnetic field is zero

Explain your reasoning.

as the closest wire's current runs left, by the right-hand rule, the field at P is out, there is an opposite current on the parrallel wire, but since it is further away, and the field is therefore weaker, the closer field prevails.

GO ON TO THE NEXT PAGE.

(d) What is the direction of the force, if any, on the bottom wire due to the current in the top wire?

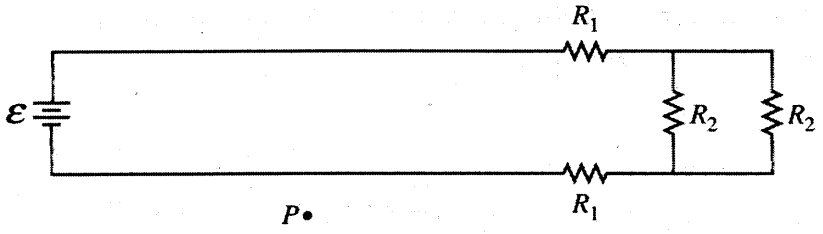
____ To the left ____ ✓ Toward the top of the page ____ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ____ Into the plane of the page

____ None of the above, because the force is zero

Explain your reasoning.

the current in the top wire is to the right, causing the field to come out of the page below it, the current in the bottom wire is to the left, causing it's field to go into the page above it. these opposite fields attract eachother, thus the force on the bottom wire is up.



4. (10 points)

In the circuit above, the battery of emf $\mathcal{E}$ is connected to two long, straight, parallel wires, which in turn are connected to four resistors with resistances given in the figure above. Assume that any other resistances in the circuit are negligible. Express all algebraic answers to the following parts in terms of the given quantities and fundamental constants.

(a) Derive an expression for the total resistance of the circuit.

$$\frac{1}{R_{22}} = \frac{1}{R_2} + \frac{1}{R_2} = \frac{2}{R_2}$$

$$R_{22} = \frac{R_2}{2}$$

$$R_{total} = R_1 + R_2/2 + R_1$$

(b) Derive an expression for the power dissipated in this circuit.

$$P = I\mathcal{E} \quad , \quad \mathcal{E} = IR_{total} \quad I = \frac{\mathcal{E}}{R_{total}}$$

$$P = \frac{\mathcal{E}^2}{R_{total}}$$

Assume that any magnetic fields result only from the currents in the two long wires.

(c) What is the direction of the magnetic field, if any, at point P, which is in the plane of the page?

____ To the left ____ Toward the top of the page ____ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ✓ Into the plane of the page

____ None of the above, because the magnetic field is zero

Explain your reasoning.

Using the right hand rule we get field to be clockwise around the wire. If it is clockwise then at point P the field's direction is into the page.

(d) What is the direction of the force, if any, on the bottom wire due to the current in the top wire?

____ To the left ____ Toward the top of the page ____ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ____ Into the plane of the page

✓ None of the above, because the force is zero

Explain your reasoning.

The force is zero because the direction of the current and therefore field is opposite whereas the current is the same.

AP® PHYSICS B
2010 SCORING COMMENTARY (Form B)

Question 4

Sample: B-4A
Score: 10

Full credit was awarded for this response in which the answers to all parts are correct and clearly developed.

Sample: B-4B
Score: 7

Parts (a), (b) and (c) are correct and earned full credit. In part (d) the direction of the fields produced by the top and bottom wires is incorrect and also inconsistent with the correct statements in part (c), and the physical mechanism ("fields attract") is confused, so no credit was earned.

Sample: B-4C
Score: 3

Part (a) is correct and earned full credit. The response in part (b) correctly states the expression for power in terms of emf and effective total resistance, but it does not substitute in the total resistance, so only 1 point was earned. Part (c) has an incorrect choice and statements that seem to confuse fields and currents in applying the right-hand rule, earning no credit. Part (d) also earned no credit for an incorrect choice and unclear statements.