AP® PHYSICS B
2010 SCORING GUIDELINES

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*.

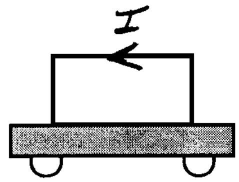
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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.

Question 6

10 points total — **Distribution of points**

(a) 3 points



For an unambiguous indication that the induced current in the loop is in the counterclockwise direction — 1 point

For a justification that includes <u>two</u> correct and relevant principles, such as the following: — 2 points

The flux is changing (or increasing into the page).
The induced current will oppose the change in flux.
A counterclockwise current will produce flux out of the page.
The magnetic forces on charges in the right-hand wire will drive a counterclockwise current.
Velocity is to the right, and $\mathbf{B}$ into the page, so $q\mathbf{v} \times \mathbf{B}$ points toward the top of the page.
The induced current must produce a magnetic drag force (opposite the motion).

A single relevant principle earns 1 point.

(b)

(i) 2 points

For writing relevant algebraic expressions for both the current and the emf somewhere in the part (b) answer space — 1 point

$I = \dfrac{\mathcal{E}}{R}$ and $\mathcal{E} = -\dfrac{\Delta\phi_m}{\Delta t}$ or $\mathcal{E} = B\ell v$

$I = B\ell v/R = (2.0\ \text{T})(0.10\ \text{m})(3.0\ \text{m/s})/4.0\ \Omega$

For the correct magnitude of the current — 1 point

$I = 0.15\ \text{A}$

(ii) 1 point

$F_B = BI\ell\sin\theta$, where $\theta = 90°$ because the field is perpendicular to the direction of the current.

For an unambiguous substitution of current and wire length consistent with part (i) and the correct magnetic field into a correct expression for force — 1 point

$F_B = (2.0\ \text{T})(0.15\ \text{A})(0.10\ \text{m})\sin 90°$

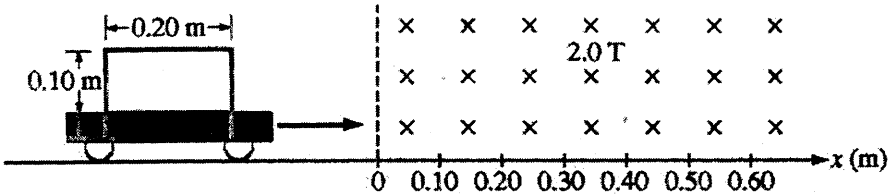
$F_B = 0.030\ \text{N}$

Units 1 point

For correct units in the answers to both parts (i) and (ii) — 1 point

Question 6 (continued)

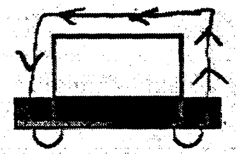
	Distribution of points
(c) 3 points	
For an unambiguous indication that the net force is zero	1 point
For stating that the current is zero	1 point
For either correctly explaining why the current is zero (such as "there is no change in magnetic flux" or "magnetic forces on charges in the two sides of the loop push the charges in opposite directions") or explaining how zero current results in zero magnetic force on the wire loop	1 point



6. (10 points)

The plastic cart shown in the figure above has mass 2.5 kg and moves with negligible friction on a horizontal surface. Attached to the cart is a rigid rectangular loop of wire that is 0.10 m by 0.20 m, has resistance 4.0 Ω, and has a mass that is negligible compared to the mass of the cart. The plane of the rectangular loop is parallel to the plane of the page. A uniform magnetic field of 2.0 T, perpendicular to and directed into the plane of the page, starts at $x = 0$, as shown above.

(a) On the figure below, indicate the direction of the induced current in the loop when its front edge is at $x = 0.12$ m.



Counterclockwise.

Justify your answer.

The magnetic flux is increasing directed into the page. Therefore, According to the Lenz's Law, the induced magnetic field must be directed out of the page. According to the right hand's rule, the thumb points the induced field and other fingers point induced current.

(b) When the front edge of the rectangular loop is at $x = 0.12$ m, its speed is 3.0 m/s. Calculate the following for that instant.

i. The magnitude of the induced current in the rectangular loop of wire

$$\mathcal{E} = Bvl = (2.0T)(3\ m/s)(0.10m) = 0.6\ V$$

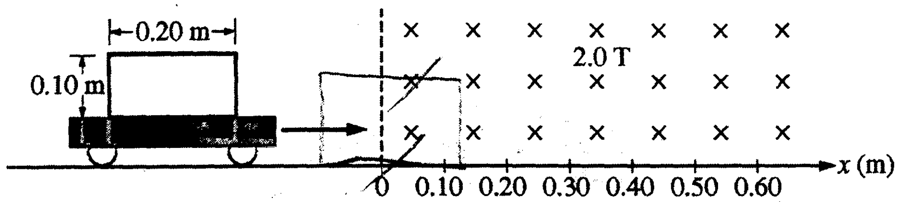
$$\therefore I = \frac{\mathcal{E}}{R} = \frac{0.6V}{4.0\Omega} = \boxed{0.15A}$$

ii. The magnitude of the net force on the loop

$$F_B = BIl = (2.0T)(0.15A)(0.10m) = \boxed{0.03N}$$

(c) At a later time, the cart and loop are completely inside the magnetic field. Determine the magnitude of the net force on the loop at that time. Justify your answer.

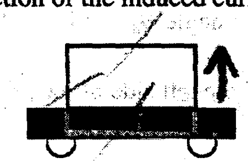
Zero. When the cart is completely inside, there is no change in flux anymore. Therefore $\mathcal{E} = 0$ and induced current is zero, and F_B is also zero.



6. (10 points)

The plastic cart shown in the figure above has mass 2.5 kg and moves with negligible friction on a horizontal surface. Attached to the cart is a rigid rectangular loop of wire that is 0.10 m by 0.20 m, has resistance 4.0 Ω, and has a mass that is negligible compared to the mass of the cart. The plane of the rectangular loop is parallel to the plane of the page. A uniform magnetic field of 2.0 T, perpendicular to and directed into the plane of the page, starts at $x = 0$, as shown above.

(a) On the figure below, indicate the direction of the induced current in the loop when its front edge is at $x = 0.12$ m.



Justify your answer.

Right Hand Rule

(b) When the front edge of the rectangular loop is at $x = 0.12$ m, its speed is 3.0 m/s. Calculate the following for that instant.

i. The magnitude of the induced current in the rectangular loop of wire

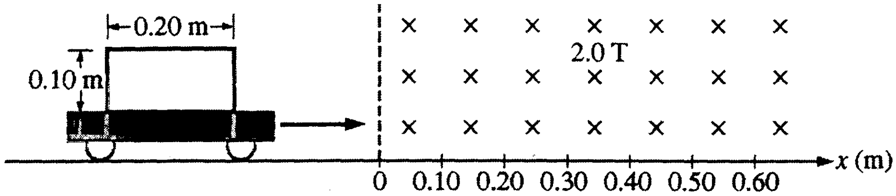
$\mathcal{E} = B\ell v$ $(2)(.1)(3)$ $\mathcal{E} = .6$ $V = IR$ $.6 = I(4)$ $I = \boxed{.15\text{ A}}$

ii. The magnitude of the net force on the loop

$F_B = BI\ell$ $(2)(.15)(.1)$ $F_B = \boxed{.03\text{ N}}$

(c) At a later time, the cart and loop are completely inside the magnetic field. Determine the magnitude of the net force on the loop at that time. Justify your answer.

$\boxed{0\text{ N}}$ All forces cancel out as opposite sides of rectangle have opposite forces



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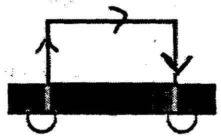
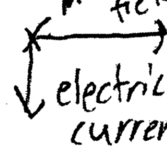
(a) On the figure below, indicate the direction of the induced current in the loop when its front edge is at $x = 0.12$ m.



Justify your answer.

Right-hand rule motion of cart



(b) When the front edge of the rectangular loop is at $x = 0.12$ m, its speed is 3.0 m/s. Calculate the following for that instant.

i. The magnitude of the induced current in the rectangular loop of wire

$0.12 m + 0.1 m = 0.22 m$

$\mathcal{E} = B \cdot l \cdot v$ $v = 3 \frac{m}{s}$ $B = 2.0T$

$\mathcal{E} = 2 \cdot 0.22 \cdot 3 = 1.32V$

$\frac{V}{R} = I$ $\frac{1.32V}{4.0\Omega} = \boxed{0.33 A}$

ii. The magnitude of the net force on the loop

$F_B = BIl \sin\theta$

$F_B = 2.0T \cdot 0.33A \cdot 0.22m \cdot \sin 90 = 0.1452 N$

(c) At a later time, the cart and loop are completely inside the magnetic field. Determine the magnitude of the net force on the loop at that time. Justify your answer.

$l = 0.2 + 0.1 + 0.1 = 0.4m$

$\mathcal{E} = B \cdot l \cdot v = 2.0T \cdot 0.4m \cdot 3.0\frac{m}{s} = 2.4V$

$\frac{V}{R} = I = \frac{2.4}{4} = 0.6A$

$F_B = BIl\sin\theta$

$F_B = 2.0T \cdot 0.6A \cdot 0.4m \cdot \sin 90$

$\boxed{F_B = 0.48N}$

GO ON TO THE NEXT PAGE.

Question 6

Overview

This question was designed to assess students' understanding of magnetic induction and magnetic force on currents.

Sample: B6-A
Score: 10

This full-credit response contains especially complete justifications.

Sample: B6-B
Score: 6

In part (a) the direction is correct, but there is no substantive justification, so only 1 point was earned. Part (b) received full credit, including the units point. In part (c) 1 point was earned for stating that $F = 0$, but the justification is insufficient.

Sample: B6-C
Score: 3

Part (a) earned no credit. In part (b)(i) both equations are explicitly listed, earning 1 point, but the wrong length is used so the current magnitude is incorrect. In part (b)(ii) the substitutions use the current found in part (b)(i) and consistently use the same incorrect length, earning 1 point. The units point for part (b) was also earned. Part (c) earned no credit.