AP® Physics B
1999 Sample Student Responses

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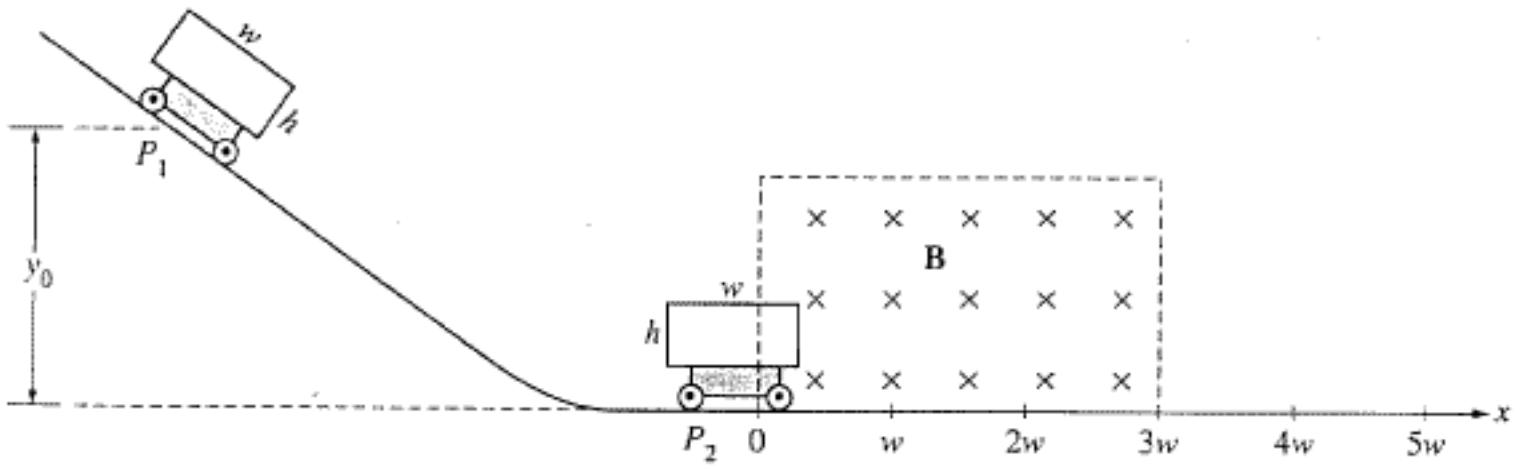

3. (15 points)

A rectangular conducting loop of width w, height h, and resistance R is mounted vertically on a nonconducting cart as shown above. The cart is placed on the inclined portion of a track and released from rest at position P_1 at a height y_0 above the horizontal portion of the track. It rolls with negligible friction down the incline and through a uniform magnetic field **B** in the region above the horizontal portion of the track. The conducting loop is in the plane of the page, and the magnetic field is directed into the page. The loop passes completely through the field with a negligible change in speed. Express your answers in terms of the given quantities and fundamental constants.

(a) Determine the speed of the cart when it reaches the horizontal portion of the track.

$PE_{at\ P_1} \xrightarrow{\text{converted to}} KE_{at\ P_2}$ $\quad -\Delta PE = \Delta KE$

$mgh = \frac{1}{2}mv^2$

$g \cdot y_0 = \frac{1}{2}v^2$ $\quad v = \sqrt{2gy_0}$

(b) Determine the following for the time at which the cart is at position P_2, with one-third of the loop in the magnetic field.

i. The magnitude of the emf induced in the conducting loop

$\Delta\Phi = B \cdot A \cos\theta$

$= B \cdot (h) \cdot (v \cdot \Delta t)$

$\mathcal{E} = \frac{\Delta\Phi}{\Delta t} = B \cdot h \cdot v = B \cdot h \cdot \sqrt{2gy_0}$

ii. The magnitude of the current induced in the conducting loop

$V = I \cdot R$

$I = \frac{V}{R} = \frac{B \cdot h \cdot \sqrt{2gy_0}}{R}$

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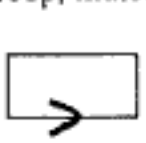
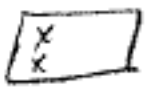
(c) On the following diagram of the conducting loop, indicate the direction of the current when it is at position P_2.



Before



After

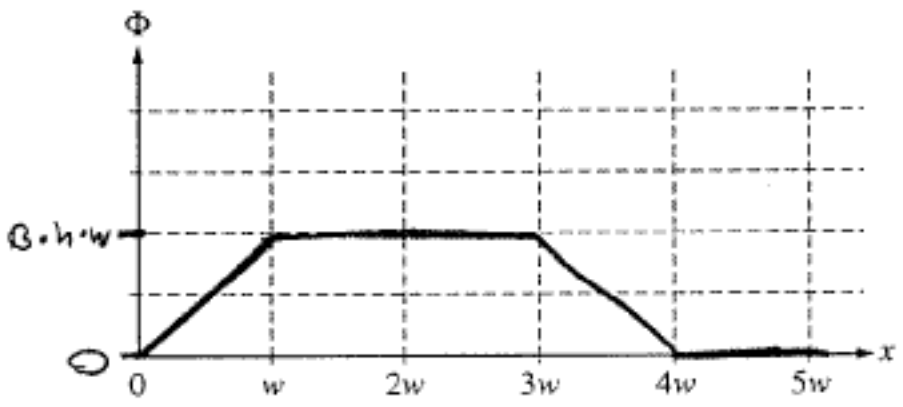
Right hand rule

(d) i. Using the axes below, sketch a graph of the magnitude of the magnetic flux Φ through the loop as a function of the horizontal distance x traveled by the cart, letting $x = 0$ be the position at which the front edge of the loop just enters the field. Label appropriate values on the vertical axis.

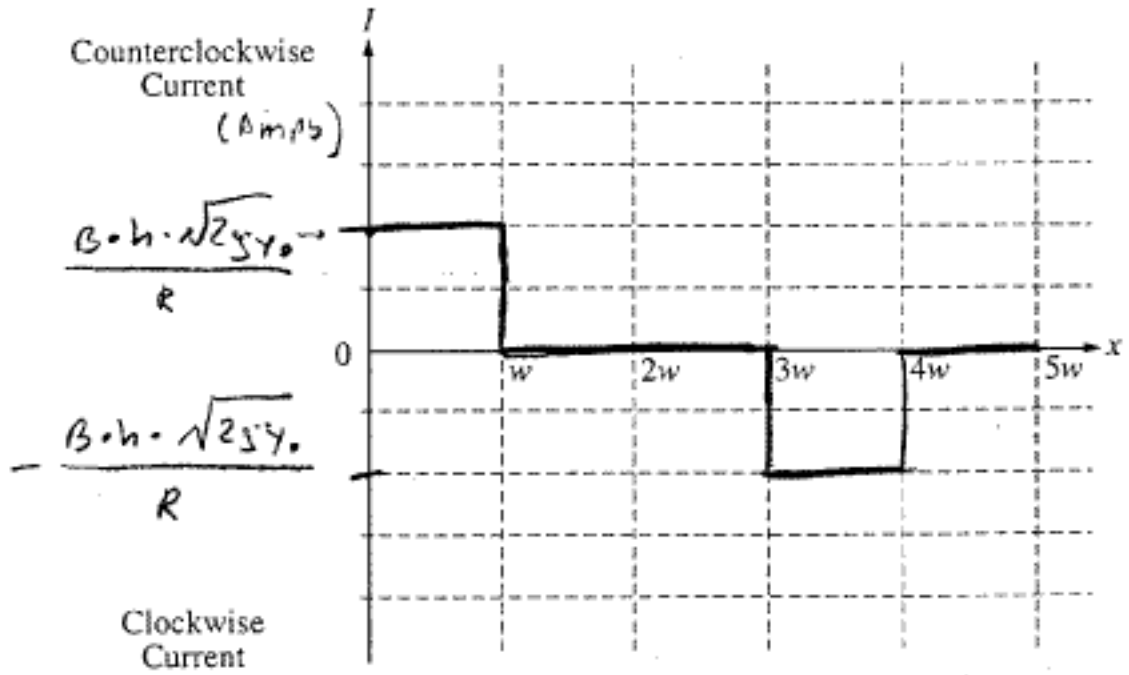
Φ at $x = w$

$\Phi = B \cdot A \cos\theta$

$= B \cdot h w$



ii. Using the axes below, sketch a graph of the current induced in the loop as a function of the horizontal distance x traveled by the cart, letting $x = 0$ be the position at which the front edge of the loop just enters the field. Let counterclockwise current be positive and label appropriate values on the vertical axis.



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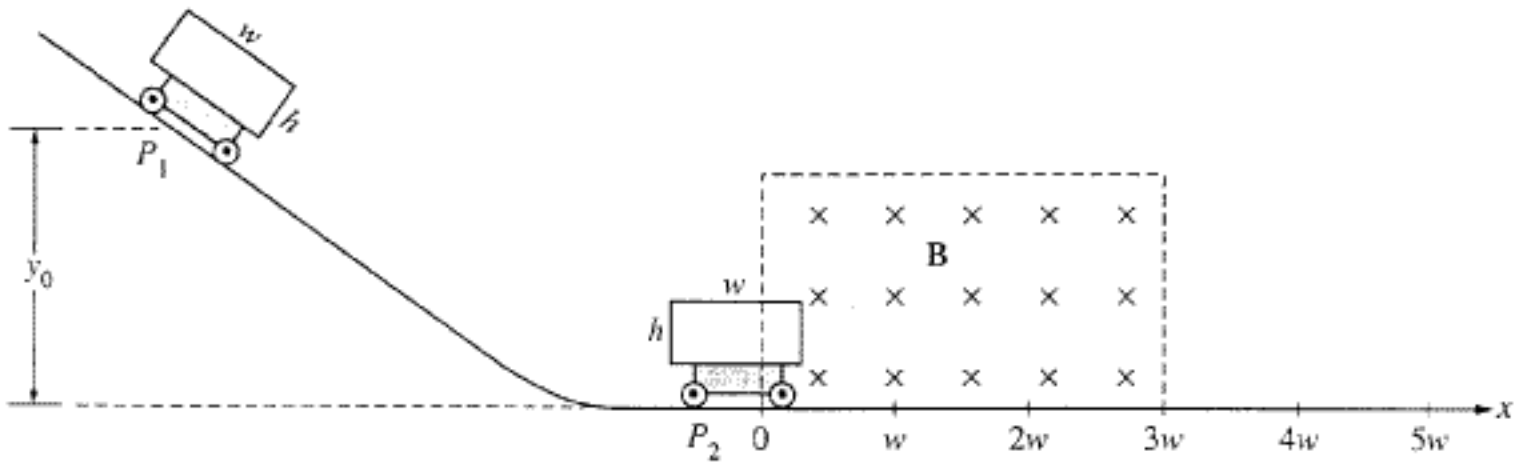

3. (15 points)

A rectangular conducting loop of width w, height h, and resistance R is mounted vertically on a nonconducting cart as shown above. The cart is placed on the inclined portion of a track and released from rest at position P_1 at a height y_0 above the horizontal portion of the track. It rolls with negligible friction down the incline and through a uniform magnetic field **B** in the region above the horizontal portion of the track. The conducting loop is in the plane of the page, and the magnetic field is directed into the page. The loop passes completely through the field with a negligible change in speed. Express your answers in terms of the given quantities and fundamental constants.

(a) Determine the speed of the cart when it reaches the horizontal portion of the track.

Conservation of energy

$mgd = \frac{1}{2}mv^2 \quad v = \sqrt{2gd} = \boxed{\sqrt{2 \cdot g \cdot y_0}}$

(b) Determine the following for the time at which the cart is at position P_2, with one-third of the loop in the magnetic field.

i. The magnitude of the emf induced in the conducting loop

$\mathcal{E} = -\frac{\Delta\Phi}{\Delta T} = \frac{B\Delta A}{\Delta T}$

$\frac{A = h \cdot v}{\Delta T} \qquad \boxed{\mathcal{E} = hBv}$

ii. The magnitude of the current induced in the conducting loop

$V = IR$

$hBv = I \cdot R$

$\boxed{I = \frac{hBv}{R}}$

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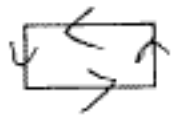
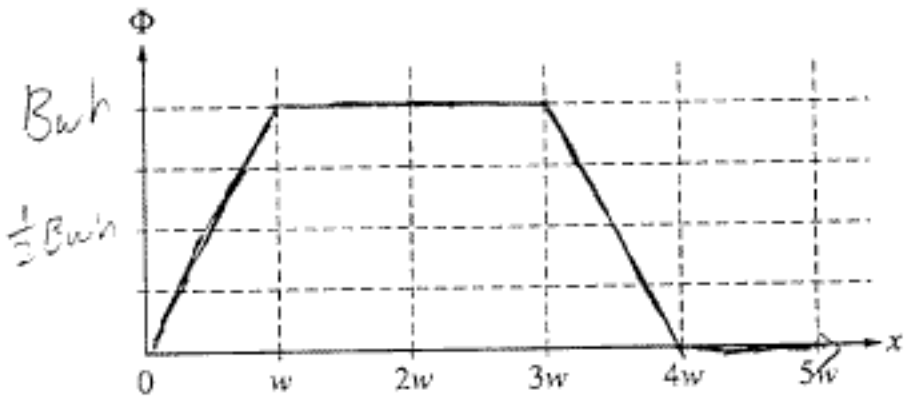
(c) On the following diagram of the conducting loop, indicate the direction of the current when it is at position P_2.



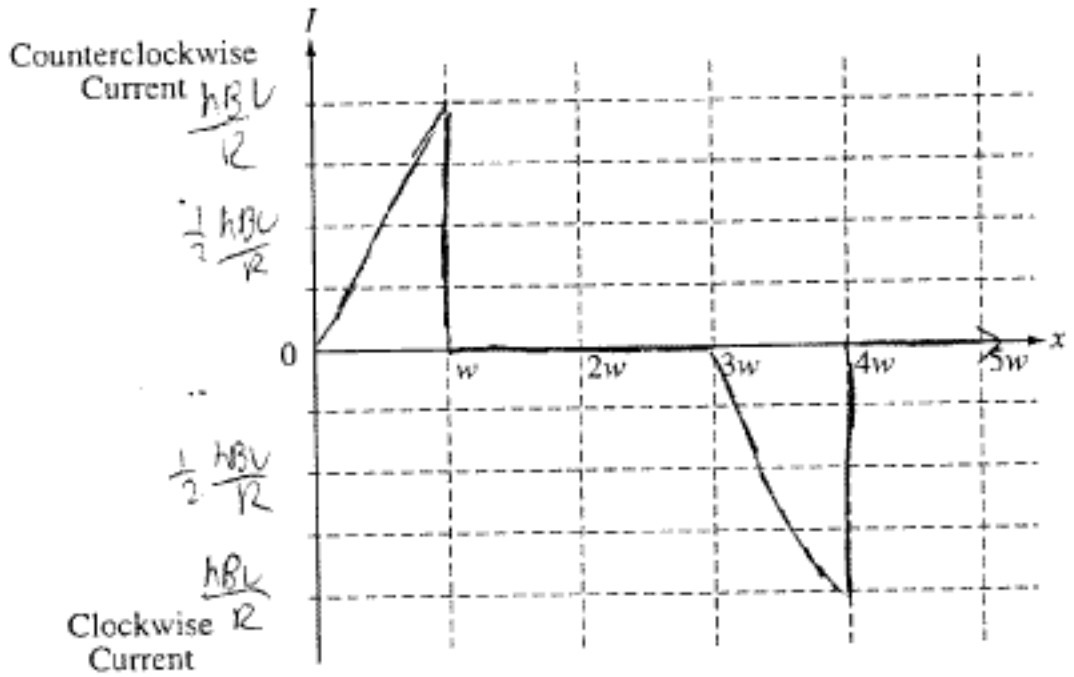
Lenz's law, induced field opposes the change, RHR

(d) i. Using the axes below, sketch a graph of the magnitude of the magnetic flux Φ through the loop as a function of the horizontal distance x traveled by the cart, letting $x = 0$ be the position at which the front edge of the loop just enters the field. Label appropriate values on the vertical axis.

$\Phi = BA$



ii. Using the axes below, sketch a graph of the current induced in the loop as a function of the horizontal distance x traveled by the cart, letting $x = 0$ be the position at which the front edge of the loop just enters the field. Let counterclockwise current be positive and label appropriate values on the vertical axis.



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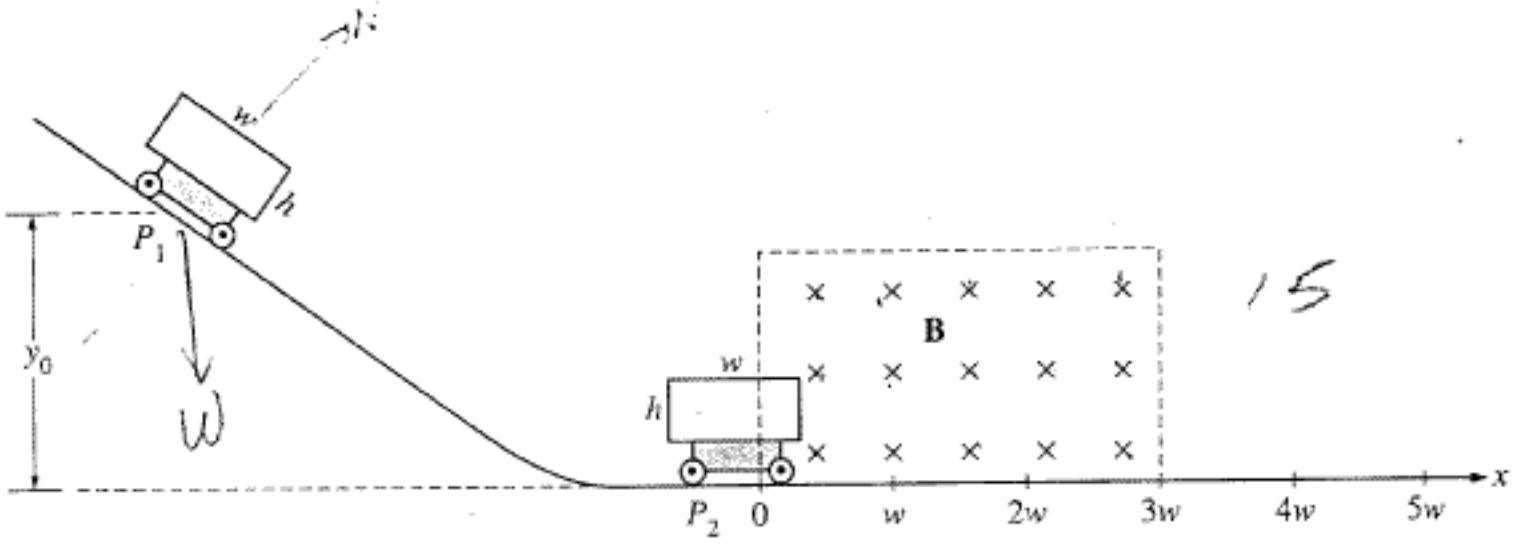

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(a) Determine the speed of the cart when it reaches the horizontal portion of the track.

$PE = KE$

$mgh = \frac{1}{2}mv^2$

$\sqrt{2gy_0} = v$

(b) Determine the following for the time at which the cart is at position P_2, with one-third of the loop in the magnetic field.

i. The magnitude of the emf induced in the conducting loop

$\mathcal{E} = B\sqrt{2gy_0}\left(h + \frac{2}{3}w\right)$

$\mathcal{E} = Blv$

$l = h + 2\left(\frac{1}{3}w\right)$

ii. The magnitude of the current induced in the conducting loop

$V = IR$

$I = \frac{V}{R} = \frac{B\sqrt{2gy_0}\left(h + \frac{2}{3}w\right)}{R}$

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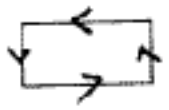
(c) On the following diagram of the conducting loop, indicate the direction of the current when it is at position P_2.



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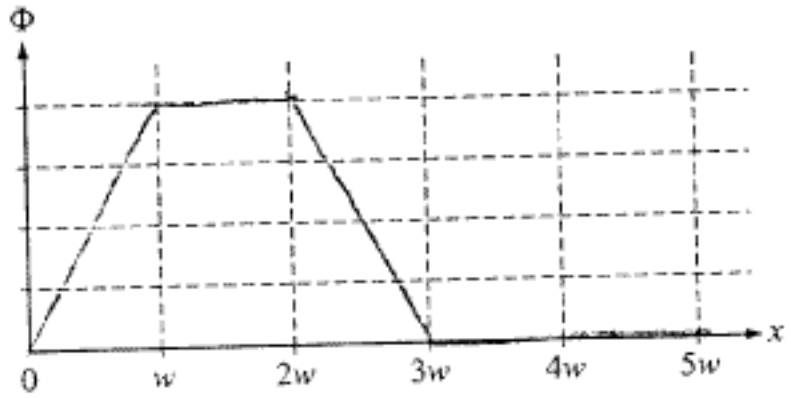
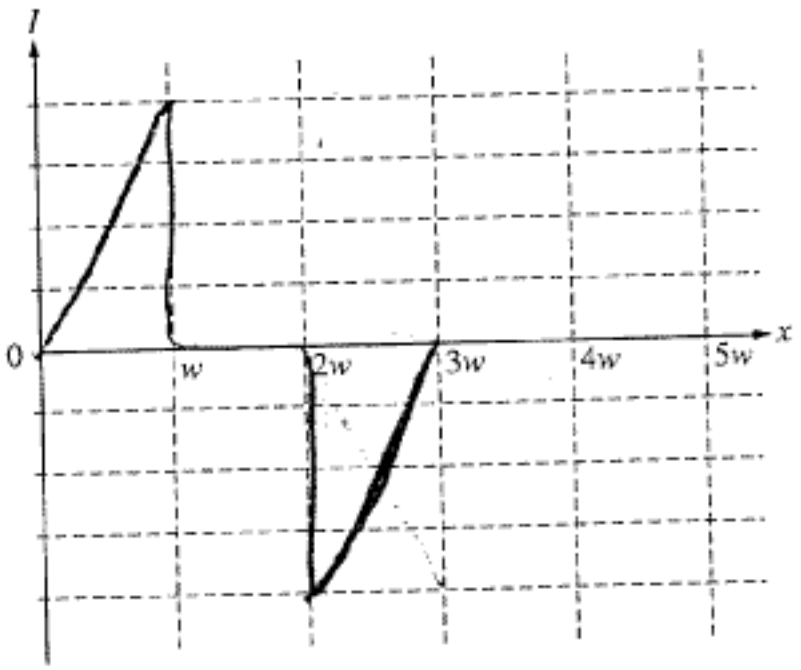


ii. Using the axes below, sketch a graph of the current induced in the loop as a function of the horizontal distance x traveled by the cart, letting $x = 0$ be the position at which the front edge of the loop just enters the field. Let counterclockwise current be positive and label appropriate values on the vertical axis.

Counterclockwise Current



Clockwise Current

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