AP® PHYSICS
2011 SCORING GUIDELINES

General Notes About 2011 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 earned. 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 earn credit. For example, if use of the equation expressing a particular concept is worth one 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 earned. 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 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 earn 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 2

15 points total | **Distribution of points**

(a)

i. 2 points

For correctly calculating the magnitude of the charge on the bottom plate of the capacitor and including correct units — 1 point

$V = Q/C$

$Q = CV$

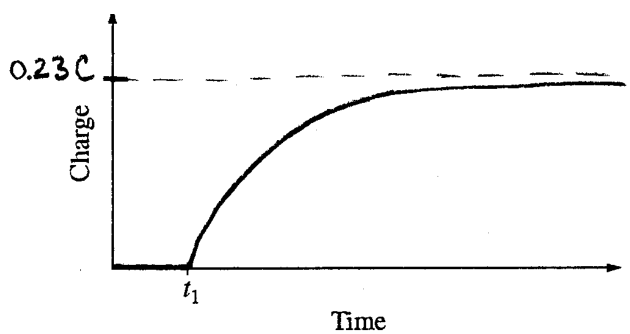
$Q = \left(25 \times 10^{-3}\ \text{F}\right)(9.0\ \text{V})$

$Q = 0.23\ \text{C}$

For correctly identifying the charge on the bottom plate as negative. — 1 point

With the polarity of the battery terminal attached to the bottom plate shown in the figure, the charge is negative.

ii. 3 points



For correctly indicating and labeling the asymptote, with either the value determined in part (a) or an equivalent algebraic expression — 1 point

For explicitly showing $Q = 0$ for $t < t_1$ — 1 point

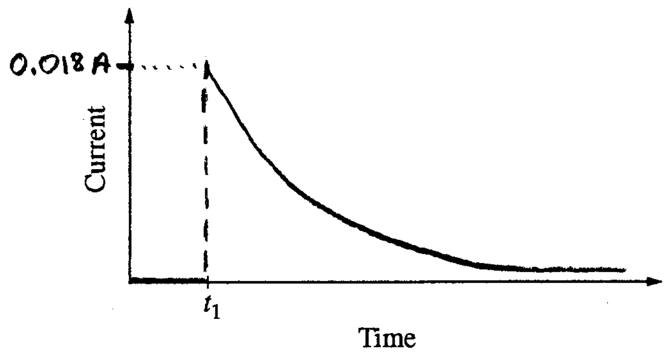
For correctly sketching the curve, starting at $t = t_1$ and asymptotically approaching the maximum charge — 1 point

Question 2 (continued)

Distribution of points

(a) (continued)

iii. 3 points



The maximum current occurs just after the switch is closed, when there is no charge on the capacitor.

$V = IR$

$I_{max} = V/R = 9.0\text{ V}/500\ \Omega = 0.018\text{ A}$

For correctly indicating and labeling the maximum current, with either the correct value or an equivalent algebraic expression — 1 point

For explicitly showing $I = 0$ for $t < t_1$ — 1 point

For correctly sketching the curve, starting at the maximum current at $t = t_1$ and asymptotically approaching zero — 1 point

(b)

i. 2 points

$$U_C = \frac{1}{2}QV = \frac{1}{2}Q\frac{Q}{C} = \frac{1}{2}\frac{Q^2}{C}$$

For substituting correct values into a correct expression — 1 point

For example, $U_C = \dfrac{1}{2}\dfrac{\left(105 \times 10^{-3}\text{ C}\right)^2}{\left(25 \times 10^{-3}\text{ F}\right)}$

For a consistent answer with correct units — 1 point

$U_C = 0.22\text{ J}$

Question 2 (continued)

Distribution of points

(b) (continued)

ii. 2 points

The maximum current occurs when there is no charge on the capacitor and all the energy is stored in the inductor.

$U_L = \frac{1}{2}LI^2$

The total energy is the energy that was stored in the capacitor at time t_2.

For a correct expression of energy conservation — 1 point

$\frac{1}{2}LI^2 = U_C$

$I = \sqrt{2U_C/L}$

Substituting the given value for L and the value of U_C determined in part (b) i

$I = \sqrt{2(0.22\ \text{J})/5.0\ \text{H}}$

For an answer with units consistent with previous work — 1 point

$I = 0.30\ \text{A}$

iii. 3 points

For a correct application of the loop rule — 1 point

$L\frac{dI}{dt} + \frac{Q}{C} = 0$

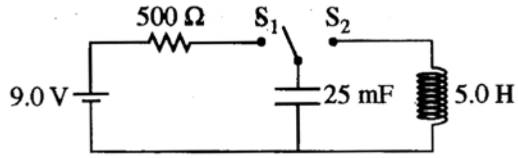
$\frac{dI}{dt} = -\frac{Q}{CL}$

$\frac{dI}{dt} = -\frac{(50 \times 10^{-3}\ \text{C})}{(25 \times 10^{-3}\ \text{F})(5.0\ \text{H})}$

For a correct numerical answer obtained from a correct procedure, with or without the negative sign — 1 point

For the correct units on a calculated answer — 1 point

$\frac{dI}{dt} = -0.40\ \text{A/s}$



E&M. 2.

The circuit represented above contains a 9.0 V battery, a 25 mF capacitor, a 5.0 H inductor, a 500 Ω resistor, and a switch with two positions, S_1 and S_2. Initially the capacitor is uncharged and the switch is open.

(a) In experiment 1 the switch is closed to position S_1 at time t_1 and left there for a long time.

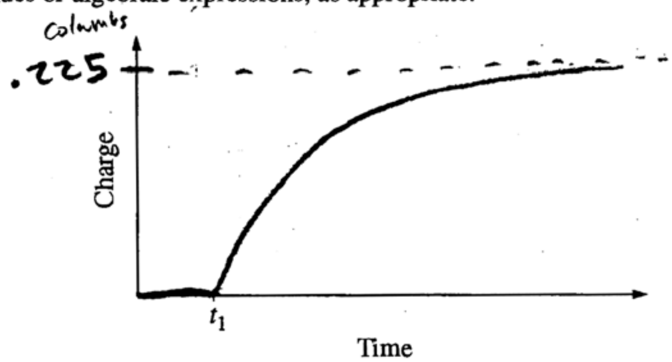
i. Calculate the value of the charge on the bottom plate of the capacitor a long time after the switch is closed.

Q = VC

.225 = 9 (25 mF)

Q = -.225 C (negative b/c this the bottom plate, which is attached to negative end of battery)

ii. On the axes below, sketch a graph of the magnitude of the charge on the bottom plate of the capacitor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

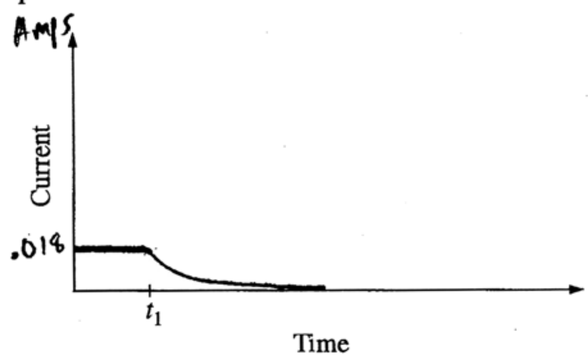


iii. On the axes below, sketch a graph of the current through the resistor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

V = IR

9 = I 500

I = .018



GO ON TO THE NEXT PAGE.

(b) In experiment 2 the capacitor is again uncharged when the switch is closed to position S_1 at time t_1. The switch is then moved to position S_2 at time t_2 when the magnitude of the charge on the capacitor plate is 105 mC, allowing electromagnetic oscillations in the LC circuit.

i. Calculate the energy stored in the capacitor at time t_2.

$U_c = \frac{1}{2}QV$ $Q = VC$

$105mC = V(25mF)$

$U_c = \frac{1}{2}(105mC)(4.2)$ $V = 4.2$

$U_c = .2205\ J$

ii. Calculate the maximum current that will be present during the oscillations.

$U_{c\,max} = U_{L\,max}$

$.2205\ J = \frac{1}{2}LI^2$

$.2205 = \frac{1}{2}(5)I^2$

$I = .297\ A$

iii. Calculate the time rate of change of the current when the charge on the capacitor plate is 50 mC.

$\mathcal{E} = -L\frac{dI}{dt}$ $Q = VC$

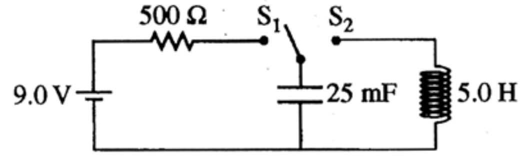
$Q = \mathcal{E}C$

$50mC = \mathcal{E}\ 25mF$

$2 = -5\left(\frac{dI}{dt}\right)$ $\mathcal{E} = 2V$

$\frac{dI}{dt} = -\frac{2}{5}$ Amps/sec

GO ON TO THE NEXT PAGE.



E&M. 2.

The circuit represented above contains a 9.0 V battery, a 25 mF capacitor, a 5.0 H inductor, a 500 Ω resistor, and a switch with two positions, S_1 and S_2. Initially the capacitor is uncharged and the switch is open.

(a) In experiment 1 the switch is closed to position S_1 at time t_1 and left there for a long time.

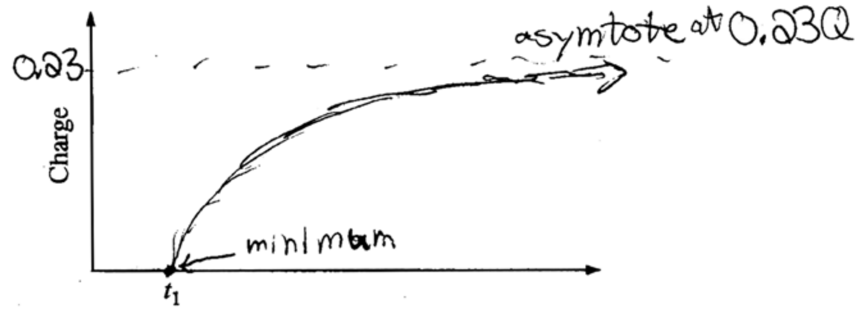
i. Calculate the value of the charge on the bottom plate of the capacitor a long time after the switch is closed.

$V = \frac{Q}{C}$

$9V = \frac{Q}{25 \cdot 10^{-3} F}$

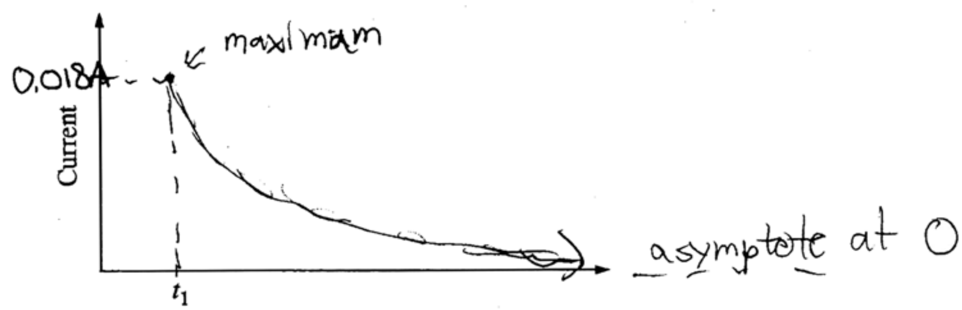
$Q = 9 \cdot 25 \cdot 10^{-3} = 0.23C$

ii. On the axes below, sketch a graph of the magnitude of the charge on the bottom plate of the capacitor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



iii. On the axes below, sketch a graph of the current through the resistor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

$i = \frac{V}{R} = \frac{9}{500}$



GO ON TO THE NEXT PAGE.

(b) In experiment 2 the capacitor is again uncharged when the switch is closed to position S_1 at time t_1. The switch is then moved to position S_2 at time t_2 when the magnitude of the charge on the capacitor plate is 105 mC, allowing electromagnetic oscillations in the LC circuit.

i. Calculate the energy stored in the capacitor at time t_2.

$U_c = \frac{1}{2} CV^2$

$V = \frac{q}{C}$ $U_c = \frac{1}{2}\frac{q^2}{C} = \frac{(105 \cdot 10^{-3})^2}{2(25 \cdot 10^{-3})} = 0.22 J$

ii. Calculate the maximum current that will be present during the oscillations.

$-L\frac{dI}{dt} + \frac{q}{C} = V$ $V = \frac{q}{c} = 4.2$

at maximum $\frac{dI}{dt} = 0$ so $\frac{q}{C} = V$.

$\frac{1}{2}LI^2 = 0.22 J$

$I = .30$

iii. Calculate the time rate of change of the current when the charge on the capacitor plate is 50 mC.

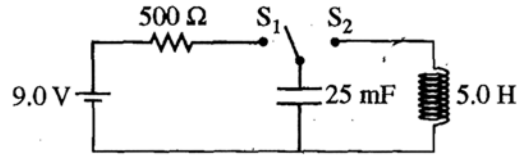
$-L\frac{dI}{dt} + \frac{q}{c} = 4.2$

$L = 5$
$q = 5 \cdot 10^{-2}$
$C = 2.5 \cdot 10^{-2}$

$\frac{dI}{dt} = \frac{4.2 - \frac{5 \cdot 10^{-2}}{2.5 \cdot 10^{-2}}}{-5}$

$\frac{dI}{dt} = -0.44 \frac{A}{s}$

GO ON TO THE NEXT PAGE.



E&M. 2.

The circuit represented above contains a 9.0 V battery, a 25 mF capacitor, a 5.0 H inductor, a 500 Ω resistor, and a switch with two positions, S_1 and S_2. Initially the capacitor is uncharged and the switch is open.

(a) In experiment 1 the switch is closed to position S_1 at time t_1 and left there for a long time.

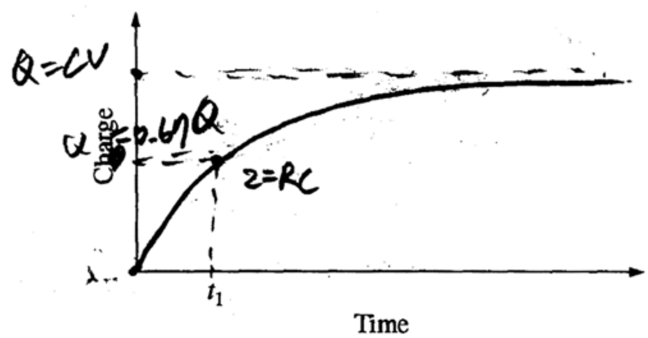
i. Calculate the value of the charge on the bottom plate of the capacitor a long time after the switch is closed.

$Q = CV$,

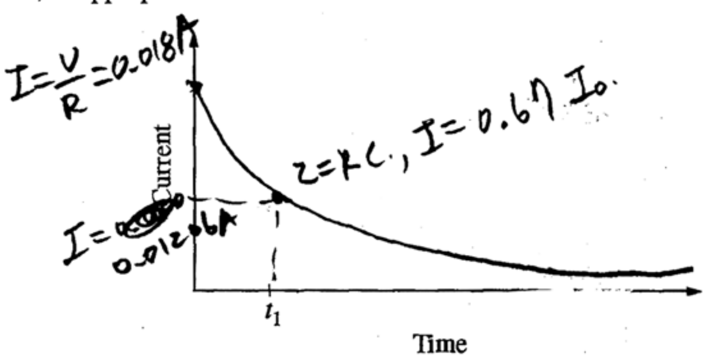
$Q = (25 \times 10^{-3}) \times (9.0)$

$= 2.025$ C.

ii. On the axes below, sketch a graph of the magnitude of the charge on the bottom plate of the capacitor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



iii. On the axes below, sketch a graph of the current through the resistor as a function of time. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



GO ON TO THE NEXT PAGE.

(b) In experiment 2 the capacitor is again uncharged when the switch is closed to position S_1 at time t_1. The switch is then moved to position S_2 at time t_2 when the magnitude of the charge on the capacitor plate is 105 mC, allowing electromagnetic oscillations in the LC circuit.

i. Calculate the energy stored in the capacitor at time t_2.

at time $t_e = t_2$, current is the initial current when S_1 is ~~closed~~ at t=0 :

$U = \frac{1}{2}LI^2$, $I = \frac{V}{R} = 0.018$ A)

$= \frac{1}{2}(5.0)(0.018)^2$

$= 8.1 \times 10^{-4}$ J.

ii. Calculate the maximum current that will be present during the oscillations.

Maximum current will be same as initial current when S_1 is closed at $t=0$

$V = IR$, $I = 0.018$A

iii. Calculate the time rate of change of the current when the charge on the capacitor plate is 50 mC.

$V_Q = L\frac{di}{dt}$

$V_Q = \frac{Q}{C} = \frac{(50 \times 10^{-3})}{(25 \times 10^{-3})} = 2$ V

$2 = L\frac{di}{dt}$, $\frac{di}{dt} = \frac{2}{5} = 0.4$ A/m

GO ON TO THE NEXT PAGE.

Question 2

Overview

This question assessed students' understanding of RC and LC circuits in two related hypothetical experiments where simple circuit analysis, conservation of energy and Kirchhoff's loop rule were used.

Sample: E2A
Score: 14

This response is well written and shows the work clearly and neatly. The only point the response did not earn is in part (a) iii, where the segment from zero to t_1 is incorrect.

Sample: E2B
Score: 9

In part (a) i the magnitude of the charge is correctly calculated but no negative sign is indicated, so only 1 point was earned. In parts (a) ii and (a) iii the zero values for $t < t_1$ are not explicitly indicated, so only 2 points were earned for each part. Part (b) i earned full credit. Part (b) ii is set up correctly using energy conservation and the numerical value obtained is correct, but no units are given; therefore only 1 point was earned. In part (b) iii a wrong equation is used, but the units are correct on the calculated answer, so 1 point was earned.

Sample: E2C
Score: 6

In part (a) i the charge is incorrectly calculated from the correct values and no negative sign is indicated, so no points were earned. In parts (a) ii and (a) iii the plots are incorrect for $t < t_1$, so only 2 points were earned for each part. Note the algebraic label of the asymptote in part (a) ii, which is acceptable. Part (b) i incorrectly uses the expression for the energy in an inductor and earned no credit. Ohm's law is incorrectly used in part (b) ii; thus no credit was earned. Part (b) iii is correct, but the units on the final answer are incorrect, so only 2 points were earned.