CollegeBoard
Advanced Placement Program

AP® Physics C: Electricity and Magnetism 2005 Scoring Guidelines

General Notes About 2005 AP Physics Scoring Guidelines

1. The solutions contain the most common method(s) of solving the free-response questions and the allocation of points for these solutions. 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 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 awarded.

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.

5. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. The exception is usually 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 1

15 points total | **Distribution of points**

(a)

(i) 2 points

For indicating that the electric field magnitude is greatest at point *C* — 1 point
For a correct justification — 1 point
For example: Field lines are drawn closer together where the field is greater.
Note: No credit was awarded for the justification if an incorrect point was chosen.

(ii) 2 points

For indicating that the electric potential is greatest at point *A* — 1 point
For a correct justification — 1 point
For example: The field along $y = 0.6$ m is toward the right. The field points in the direction of decreasing potential, so *A* must be at the highest potential.
Note: No credit was awarded for the justification if an incorrect point was chosen.

(b)

(i) 4 points

For indicating that the electron moves to the left, stated explicitly or implied — 1 point
For indicating that the speed increases — 1 point
For indicating that the acceleration is directed to the left, stated explicitly or implied — 1 point
For indicating that the magnitude of the acceleration decreases — 1 point
Example of a good answer: The force on an electron is opposite to the field, so it will move left. The field is weaker to the left so the acceleration will decrease. As long as there is a force on the electron, its speed will continue to increase to the left.

(ii) 3 points

For using conservation of energy with $U = qV$ — 1 point

$$\frac{1}{2}mv^2 = q\,\Delta V$$

$$v = \sqrt{2q\,\Delta V/m}$$

For correct substitution of values into either equation above — 1 point

$$v = \sqrt{2\left(1.6\times10^{-19}\text{ C}\right)(10\text{ V})\Big/\left(9.11\times10^{-31}\text{ kg}\right)}$$

For the correct answer — 1 point

$$v = 1.9\times10^{6}\text{ m/s}$$

Note: Substitution point was awarded if correct answer was indicated.

Question 1 (continued)

Distribution of points

(c) 2 points

$$E = -\frac{\Delta V}{r}$$

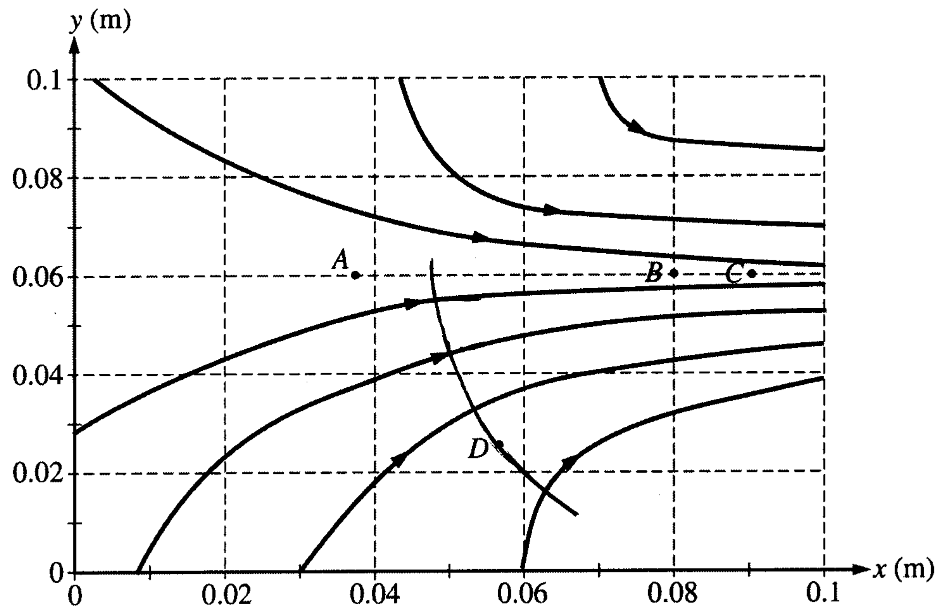
$$E = \frac{20\ \text{V}}{0.01\ \text{m}}$$

For the correct answer with correct units — 1 point

$E = 2000\ \text{V/m}\ \text{or}\ 2000\ \text{N/C}$

For the correct assumption that the field is close enough to uniform in this region to do a calculation as if it were — 1 point

(d) 2 points



For drawing a curved line concave up or concave right that passes through point D and at least three electric field lines — 1 point

For drawing the curved line perpendicular to at least three field lines — 1 point

Question 2

15 points total | **Distribution of points**

(a) 3 points

The current through the inductor is zero immediately after the switch is closed $(I_L = 0)$.
Using Ohm's law
$V = IR$
For the correct substitution of the emf $\mathcal{E}$ for the voltage V — 1 point
For the correct substitution of the total resistance R_{tot} — 1 point
$R_{tot} = R_1 + R_2$
$\mathcal{E} = I_{init}(R_1 + R_2)$
For the correct answer — 1 point
$I_{init} = \mathcal{E}/(R_1 + R_2)$

(b) 3 points

For the correct application of the loop theorem to an appropriate loop of the circuit — 1 point
For example, using the right-hand loop containing L and R_2
$V_{R_2} + V_L = 0$
$V_{R_2} = R_2 I_{init}$
$V_L = -L\dfrac{dI}{dt}$
$R_2 I_{init} = L\dfrac{dI}{dt}$
This equation could also be obtained directly by recognizing that L and R_2 are in parallel and have the same voltage across them.
For the correct substitution of the current obtained in part (a) — 1 point
$$L\frac{dI}{dt} = R_2\frac{\mathcal{E}}{R_1 + R_2}$$
For the correct answer — 1 point
$$\frac{dI}{dt} = \frac{R_2\mathcal{E}}{(R_1 + R_2)L}$$

Question 2 (continued)

Distribution of points

(c) 2 points

After a long time the current is constant, so $V_L = 0$.

$V_L = V_{R_2} = 0$, so a constant current goes through resistor 1 and the inductor.

$V_{batt} = V_{R_1}$

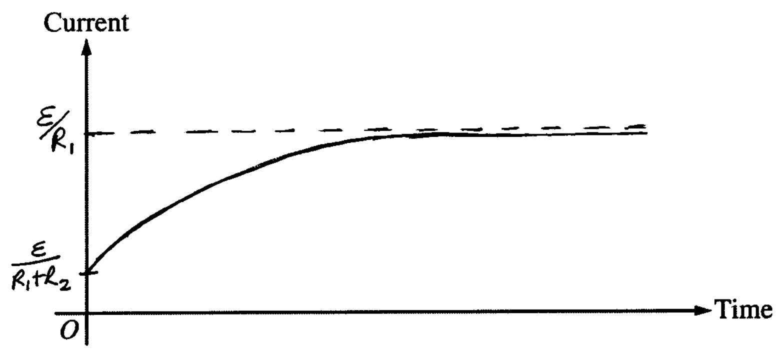
For the correct substitution of both voltage and resistance, using Ohm's law for V_{R_1} — 1 point

$\mathcal{E} = I_{batt}R_1$

For the correct answer — 1 point

$I_{batt} = \mathcal{E}/R_1$

(d) 4 points



For a graph that rises asymptotically — 1 point

This point must be earned in order to obtain any of the following points.

For starting the line above zero — 1 point

For starting the line at the lower limit determined in (a) — 1 point

For approaching the upper limit determined in part (c) — 1 point

(e) 3 points

The current calculated in part (c) that was going through the inductor now goes through only resistor 2.

For correct application of the loop theorem — 1 point

$I_{R_2} = I_L$, where I_L equals I_{batt} determined in (c)

For correct substitution of both currents, using Ohm's law for I_{R_2} with a resistance R_2 — 1 point

$V_{R_2}/R_2 = \mathcal{E}/R_1$

For a correct final answer — 1 point

$V_{R_2} = \mathcal{E}R_2/R_1$

Question 3

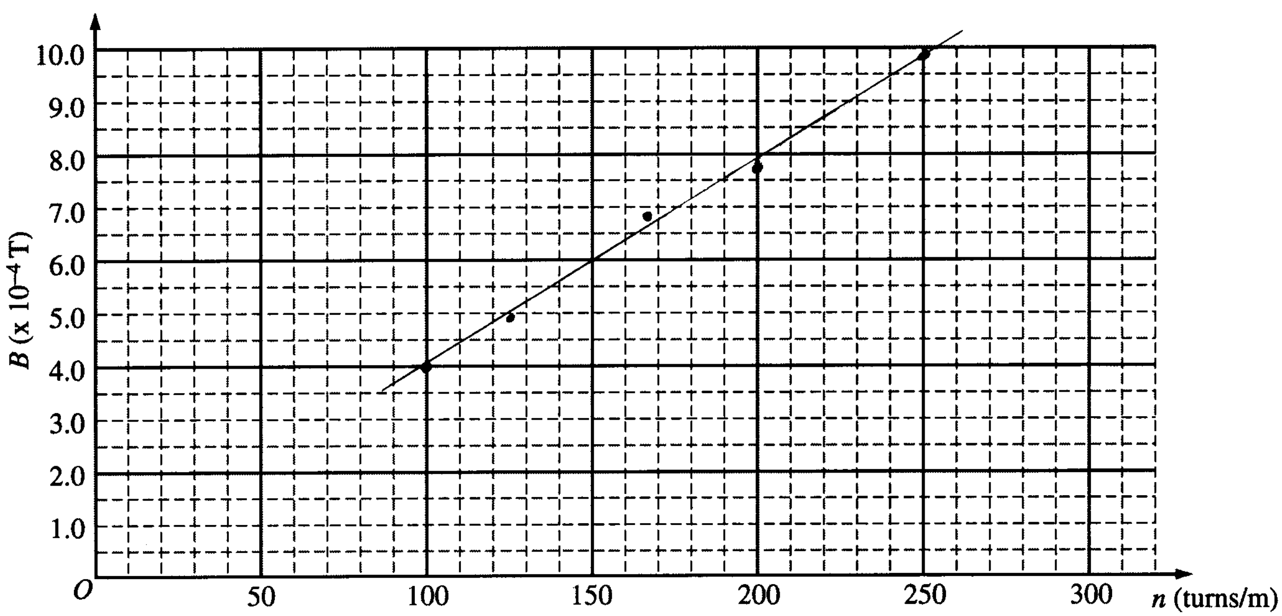
15 points total **Distribution of points**

(a) 5 points

Trial	Position of End Q (cm)	Measured Magnetic Field (T) (directed from P to Q)	n (turns/m)
1	40	9.70×10^{-4}	250
2	50	7.70×10^{-4}	200
3	60	6.80×10^{-4}	167
4	80	4.90×10^{-4}	125
5	100	4.00×10^{-4}	100

Dividing 100 turns by the length of the spring will yield the number of turns per meter.
For each correct value of n — 1 point each
Two points were deducted for using more than three significant figures.
Some students used $B = \mu_0 nI$ and the theoretical value $\mu_0 = 4\pi \times 10^{-7}\,(\text{T}\bullet\text{m})/\text{A}$ to solve for n. Since the question did not have any indication of using the data to obtain an experimental value for μ_0 until part (c), full credit for the question could be earned for this approach.

(b) 2 points



For correctly plotting the data from the chart — 1 point
For a best-fit straight line through the plotted data points, with points both above and below the line — 1 point

Question 3 (continued)

Distribution of points

(c) 6 points

$B_S = \mu_0 nI$

For correctly relating the slope of the graph to $\mu_0 I$ — 1 point

$\mu_0 I =$ slope of line $= \dfrac{\Delta B_S}{\Delta n}$

For correctly finding the slope — 1 point

For using at least one point from the graph in the calculation (i.e., not using two points from the chart that are not on the best-fit line) — 1 point

From the graph shown here

$$\frac{\Delta B_S}{\Delta n} = \frac{\left(9.5\times10^{-4} - 4.5\times10^{-4}\right)\ \text{T}}{(240-110)\ \text{turns/m}} = \frac{5.0\times10^{-4}\ \text{T}}{130\ \text{turns/m}}$$

For correctly substituting the obtained slope into the equation for μ_0 — 1 point

For correctly substituting the given value of I — 1 point

$$\mu_{0ex} = \frac{1}{3.0\ \text{A}}\ \frac{5.0\times10^{-4}\ \text{T}}{130\ \text{turns/m}}$$

$$\mu_{0ex} = 1.3\times10^{-6}\ (\text{T}\bullet\text{m})/\text{A}$$

For the correct units — 1 point

(d) 2 points

For a correct percent error formula — 1 point

percent error $= \left|\dfrac{\mu_0 - \mu_{0ex}}{\mu_0}\right|(100)$

For using the value of μ_{0ex} from part (c) — 1 point

percent error $= \left|\dfrac{4\pi\times10^{-7}\ (\text{T}\bullet\text{m})/\text{A} - 1.3\times10^{-6}\ (\text{T}\bullet\text{m})/\text{A}}{4\pi\times10^{-7}\ (\text{T}\bullet\text{m})/\text{A}}\right|(100)$

percent error $= |-0.035|(100)$

percent error $= 3.5\%$