# AP® Physics C: Electricity and Magnetism
# 2002 Scoring Guidelines



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# General Notes About
# 2002 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 approximate value $g = 10 \text{ m/s}^2$ for ease of calculation, but use of $9.8 \text{ m/s}^2$ 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, in calculations of mass differences in a nuclear reaction, rounding to too few digits can lose the accuracy required to determine a mass difference.

# AP® PHYSICS C: ELECTRICITY AND MAGNETISM
# 2002 SCORING GUIDELINES

## Question 1

**15 points total** **Distribution of points**

(a) 3 points

For a correct formula for the total charge 1 point

$q = \lambda \ell$

For the correct length of arc, i.e., one-third of the circumference of a circle 1 point

$\ell = \frac{1}{3}(2\pi r) = \frac{2\pi(0.10\text{ m})}{3} = 0.21\text{ m}$

For the correct answer with correct unit 1 point

$q = (1.5\times10^{-5}\ \text{C/m})(0.21\text{ m}) = 3.1\times10^{-6}\ \text{C}$

(b) 5 points

For either of the following formulas 1 point

$dE = \frac{k\ dq}{r^2}$ or $E = \frac{kq}{r^2}$

For an indication that $x$ components do not cancel. Acceptable is an arrow drawn to the right clearly shown on a diagram or use of horizontal component in equations. 1 point

$dE_x = \frac{k\lambda\cos\theta\ d\ell}{r^2}$

$dE_x = \frac{k\lambda\cos\theta\ r\ d\theta}{r^2}$

For a correct integration, without regard to limits (Several sets of limits are correct and give the correct answer.) For example: 1 point

$E_x = \int_{120°}^{240°} \frac{k\lambda\cos\theta\ d\theta}{r} = \frac{k\lambda\sin\theta}{r}\Big|_{120°}^{240°}$

$E = \frac{k\lambda}{r}\left(-\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{2}\right) = \frac{-\sqrt{3}\ k\lambda}{r}$

$|E| = \frac{\sqrt{3}\left(9\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.5\times10^{-5}\ \text{C/m}\right)}{0.10\text{ m}}$

For the correct numerical answer 1 point

$|E| = 2.3\times10^{6}\ \text{N/C}$ or $\text{V/m}$

For the correct direction 1 point

In the $+x$ direction, or to the right, or to the East

**Question 1 (cont'd.)**

**Distribution of points**

(c) 3 points

For a correct formula, either 1, 2, or 3 below — 1 point

1. $V = \dfrac{kq}{r}$ (recognizing that all the charge is the same distance from point $O$)

$$V = \frac{\left(9\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(3.1\times10^{-6}\ \text{C}\right)}{0.10\ \text{m}} = 2.8\times10^{5}\ \text{V}$$

2. $dV = \dfrac{k\ dq}{r}$

3. $V = k\int \dfrac{\lambda\ d\ell}{r}$

$$V = k\int \frac{\lambda\ d\ell}{r} = k\lambda \int_{2\pi/3}^{4\pi/3} \frac{r\ d\theta}{r}$$

$$= \left(9\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.5\times10^{5}\ \text{C/m}\right)\left(\frac{4\pi}{3} - \frac{2\pi}{3}\right) = 2.8\times10^{5}\ \text{V}$$

OR

$$V = k\int \frac{\lambda\ d\ell}{r} = \frac{k\lambda(2\pi r/3)}{r}$$

$$= \frac{\left(9\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.5\times10^{-5}\ \text{C/m}\right)2\pi}{3} = 2.8\times10^{5}\ \text{V}$$

For correct numeric answer for $V$ of $2.8\times10^{5}$ — 1 point

For correct unit of volts (or any equivalent) — 1 point

(d) 2 points

$$F = qE$$

$$F = \left(1.6\times10^{-19}\ \text{C}\right)\left(2.3\times10^{6}\ \text{N/C}\right)$$

For the correct numerical answer — 1 point

$$F = 3.7\times10^{-13}\ \text{N}$$

For the correct direction, such as in the $-x$ direction, or to the left, or to the West — 1 point

(e) 2 points

For the correct direction, such as the $+x$ direction, or to the right, or to the East — 1 point

For an additional correct description of the motion, such as the proton moves with decreasing acceleration, OR with its velocity approaching a constant value, OR with its velocity asymptotic to some value. — 1 point

Note: Velocity approaching zero is incorrect and "negative" acceleration is incorrect.

## Question 2

**15 points total** **Distribution of points**

(a) 4 points

For using Ohm's law 1 point
$V = IR$
At $t = 0$ the capacitor contains no charge, so the total voltage drop occurs across the resistor.
$V_0 = I(0)R$ and $I(0) = \left(5.20 \times 10^{-3}\right) e^{-0/10}$ (where current is in amperes)

For correctly evaluating the exponential at $t = 0$ 1 point
$e^{-0/10} = 1$
$I(0) = 5.20 \times 10^{-3}$ A

For correctly substituting 50 kΩ for the resistance 1 point
$V_0 = \left(5.20 \times 10^{-3} \text{ A}\right)\left(50 \times 10^{3} \ \Omega\right)$

For the correct answer 1 point
$V_0 = 260$ V

(b) 3 points

For using the correct expression for capacitance 1 point
$C = q/V$
At $t = \infty$ the capacitor is fully charged, so the total voltage drop occurs across it. The given expression for the current can be integrated to determine the total charge $Q$ that is stored.
$I(t) = \dfrac{dq}{dt} = \left(5.20 \times 10^{-3}\right) e^{-t/10}$ (where current is in amperes)
$\displaystyle\int_0^Q dq = \left[\left(5.20 \times 10^{-3} \text{ A}\right)\int_0^\infty e^{-t/10}\, dt\right]$ (where charge is in coulombs)
$q\big|_0^Q = \left[-(10)\left(5.20 \times 10^{-3} \text{ A}\right) e^{-t/10}\Big|_0^\infty\right]$ (where charge is in coulombs)

For correctly evaluating the exponential at $t = \infty$ and $t = 0$ 1 point
$e^{-\infty/10} = 0$ and $e^{-0/10} = 1$
$Q = 5.20 \times 10^{-2}$ C
$C = Q/V_0 = \left(5.20 \times 10^{-2} \text{ C}\right)/(260 \text{ V})$

For the correct answer, including units 1 point
$C = 2.0 \times 10^{-4}$ F $= 200$ μF

**Question 2 (cont'd.)**

(b) continued

**Distribution of points**

*Alternate solution*

*Alternate points*

For recognizing that the equation for the current is of the form $I = I_0 e^{-t/\tau}$, and the correct relationship between the time constant $\tau$ and the values of the circuit elements. *1 point*

$\tau = RC = 10$ s

$C = \tau / R = (10 \text{ s}) / R$

For correctly substituting 50 kΩ for the resistance *1 point*

$C = (10 \text{ s}) / \left(50 \times 10^3 \, \Omega\right)$

For the correct answer, including units *1 point*

$C = 2.0 \times 10^{-4}$ F $= 200$ μF

(c) i. 2 points

For any reasonable answer 2 points

For example:

There is resistance in the connecting wires.

The power supply has an internal resistance.

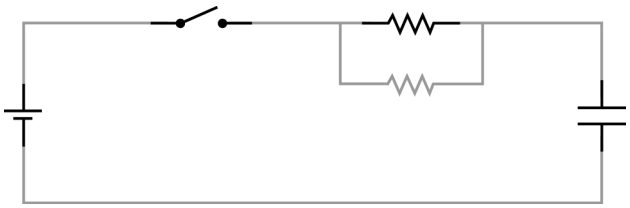
Since we have used a best fit to the actual data, values predicted from that fit have an inherent error.

(c) ii. 2 points

For indicating that the predicted value of the capacitance is too high or that the actual capacitance is lower 1 point

For any reasonable explanation based on the response to part (c) i. 1 point

(d) i. 2 points

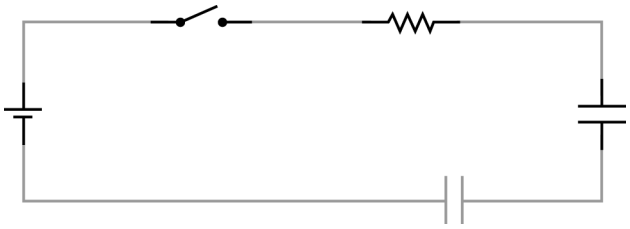


For placing an additional resistor in parallel with the original resistor, in a correctly completed circuit. 2 points

**Question 2 (cont'd.)**

**Distribution of points**

(d) ii. 2 points



For placing an additional capacitor in series with the original capacitor, in a correctly completed circuit. 2 points

## Question 3

**15 points total** **Distribution of points**

(a) 5 points

$\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$

For a correct evaluation of the above expression 1 point

$\phi_m = BA\cos\theta$ or $\phi_m = BA\sin\delta$

For a correct determination of the area enclosed by the loop 1 point

$A = \pi r^2$ with $r = 0.10$ m

For a correct substitution of the angle 1 point

$\theta = 60°$ or $\delta = 30°$

For a correct substitution of the given equation for the magnetic field 1 point

$B = 4(1 - 0.2t)$ T

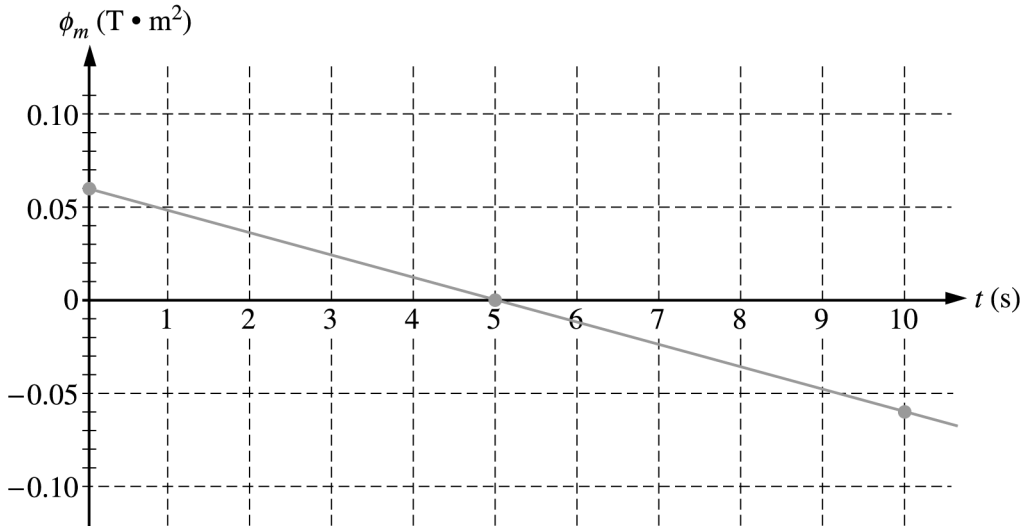
Making all the above substitutions

$\phi_m = [4(1 - 0.2t)\ \text{T}]\pi(0.10\ \text{m})^2 \cos 60°$

For a correct evaluation of the expression for the magnetic flux 1 point

$\phi_m = (0.063)(1 - 0.2t)\ \text{T} \cdot \text{m}^2$ or weber

(b) 2 points




For a correct $x$ or $y$ intercept (consistent with student's answer to part (a)) 1 point

For a correct shape (consistent with student's answer to part (a)) 1 point

For the correct expression for $\phi_m$, this means a straight line with the proper slope

**Question 3 (cont'd.)**

**Distribution of points**

(c) 2 points

$$\mathcal{E} = -\frac{d\phi_m}{dt}$$

For correctly substituting the expression for the flux obtained in part (a) — 1 point

$$\mathcal{E} = -\frac{d}{dt}(0.063)(1 - 0.2t)\ \text{T}$$

For correctly differentiating the above expression — 1 point

$$\mathcal{E} = -(0.063)(-0.2)\ \text{V} = 0.013\ \text{V}$$

*Alternate Solution* — *Alternate points*

For recognizing that $\mathcal{E}$ is the slope of the graph obtained in part (b) — *1 point*

$$\mathcal{E} = \frac{\Delta y}{\Delta x}$$

For correctly evaluating the slope using two points on the graph — *1 point*

$$\mathcal{E} = \frac{(0 - 0.063)\ \text{T} \cdot \text{m}^2}{(5 - 0)\ \text{s}} = 0.013\ \text{V}$$

(d) i. 1 point

$$I = \frac{V}{R}$$

For correct substitutions, using the value of the emf obtained in part (c) for $V$, and correctly calculating the answer — 1 point

$$I = \frac{0.013\ \text{V}}{50\ \Omega}$$

$$I = 2.6 \times 10^{-4}\ \text{A}$$

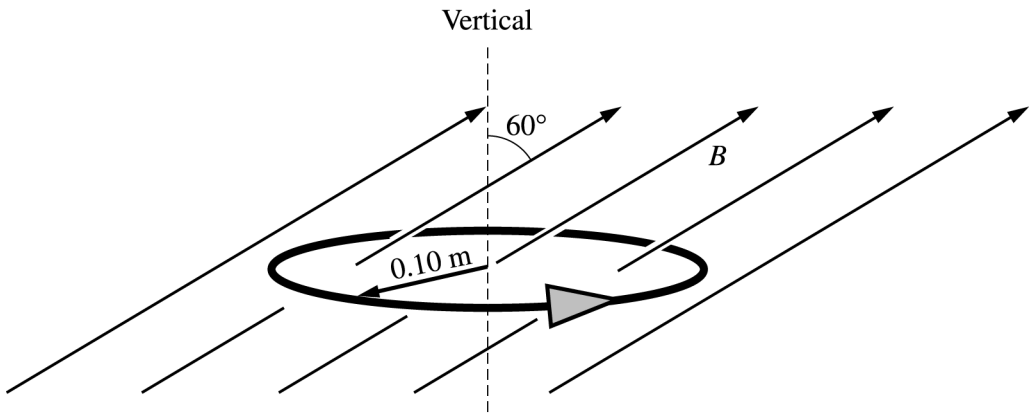
Units point

For correct units in the answers to parts (c) and (d) i. — 1 point

**Question 3 (cont'd.)**

**Distribution of points**

(d) ii. 1 point




For any indication of a counterclockwise current, as shown above 1 point

(e) 3 points

The energy dissipated can be determined from the power
$E = Pt$

For a correct expression for the energy 1 point
For example $E = \mathcal{E}It$

For correctly substituting values from previous parts 1 point
$E = (0.013\ \text{V})\left(2.6\times10^{-4}\ \text{A}\right)(4\ \text{s})$

For the correct answer, including units 1 point
$E = 1.3\times10^{-5}\ \text{J}$